Master Production Planning for the Glass Container Industry: Scenario Analysis

Filipe Fernandes Rocha

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Supervisor: Prof. Bernardo Almada Lobo

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Abstract

This work was drawn on the necessity to improve the long-term planning skills within a planning department, in a very complex environment where customer satisfaction is highly valuable. To understand what can be done today to deal the uncertainty in a longer rolling horizon is the focus of this dissertation.

The rising nervousness, due to the company's growth, both in capacity and marke share, has brought forth new difficulties and therefore challenged the *status quo* , and through this challenge, the need to reshape the processes within the the planning department. Firstly, the necessity of understanding the demand versus the real sales. This understanding entails, not only the quantitive deviations, but the qualititive reasons that can be extracted. This information also proves to be very important for investment purposes.

Secondly, with the growing network of customers and plants, the necessity of promptly and accurately have an overview of the firm's capacity resource is crucial to effectively do customer management. As such it is crucial, for the sales team, supported by the planning department, to have reliable and updated information about the available to promise resources, since the order promising process is a vital task in the customer service. Besides, by commiting with the customer with feasible due dates also increases customer satisfaction.

Finally, mathematically modelled tools are extremelly powerful to perform different what if analysis and construct a more robust view of the company. These tools, when properly used, companies are able to prepare themselves for a wider range of situations and, therefore, grab quicker the opportunities when they emerge and prevent damages from undesirable futures. However, to be properly used, these mathematically modelled tools, need to be accurate and its usability has to be smooth in order to perform many different analyses.

Resumo

Esta dissertação surge, num ambiente complexo de um departamento de planeamento de produção, onde a satisfação do cliente é da mais elevada importância e onde a necessidade do planeamento a longo prazo, tem mais do que nunca, um um contributo fundamental para a organização. O foco assenta ,ainda, na compreensão do que pode ser feito hoje e na melhor forma de lidar com a incerteza num horizonte mais alargado.

Numa altura de crescimento, tanto a nível de quota de mercado como de capacidade, a dificuldade inerente ao planeamento vem exigir uma redefinição do status quo relativos aos principais processos deste departamento.

Numa primeira fase é importante estudar a diferença entre a procura e as vendas reais que requerem, não só numa perspetiva quantitativa, mas também qualitativa. Fatores de elevada importância para fins de investimento.

Numa segunda fase, com o crescimento da rede de consumidores e de unidades produtivas, a necessidade de uma visão geral exata da capacidade de produção é fundamental para uma gestão eficiente do relacionamento com clientes. De facto, é crucial para a equipa de vendas ter informação fiável e actualizada sobre o que pode ser prometido aos clientes, de forma a garantir o compromisso de entrega em datas exequíveis e aumentar a satisfação geral do cliente.

Finalmente, ferramentas matemáticas poderosas que constroem diferentes cenários futuros preparam a empresa para vários possíveis desfechos, de forma a melhor aproveitar oportunidades ou evitar danos e prejuízos associados a futuros menos desejados. Contudo, estas ferramentas precisam de ser fiáveis e primar pela usabilidade para de facto criarem diferentes cenários.

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1 Introdution

The craftsmanship of glass dates back to 3,000 BC, when the first true glass was made in Syria, Mesopotamia and Ancient Egypt, but it was the Ancient Greeks and Romans who developed the European glass manufacturing tradition. This project was conducted in BA Glass, a glass manufacturer, more specifically a supplier of glass containers. Today there are around 160 glass factories across Europe, around 120 of which produce glass containers. This encompasses 20 corporate members, in which BA Glass, SA makes part of.

BA Glass started with only one plant with two furnaces, and grew steadily until the present, holding now twelve plants with a total of twenty-three furnaces. These plants are present all over Europe, which resulted from the growing strategy: to have plants in key locations, to allow BA to explore new markets and minimize the opposition when entering them.

Glass container manufacturers work in a business to business environment with clients spread around different areas such as wines (VM), champagnes (ES), beers (CE), soft drinks (RE), spirits (BE), food (AL), olive oils (AZ), pharmaceutical (IF) and others (OU). This is a very competitive market where clients look for high quality standards, low prices and short delivery windows. These characteristics and the constant quest for market share, make it very challenging to strive within this industry.

The competitive environment, together with the increasing capacity of BA has brought forth new challenges. Moreover, the internal processes within the company, more specifically, within the planning department have been strecthed to their limit and began to collapse. The conclusion is not that these processes were wrong to begin with, but that the *status quo* has changed and, therefore, the processes, that were once reliable in the previous environment, have to evolve with the current environmental change, otherwise the department will not be able to support the company's growth.

The growing network of both BA clients and its capacity has, therefore, delivered a urgent necessity to rethink the master production planning model, also refered as master production sechuling in the literature. In this study, not all the MPP process will be tackled. The focus will be on the perception of the long term planning should change and what critical requirements need to be approached, reorganized or developed.

The complexity of the environment has been growing at steep rate, very linked to BA sharp growth in the market and allied to its recurrent investments in short time-spans. Higher complexity, means that uncertainty in demand, supply and production also is higher. The uncertainty, or nervousness, is a natural characteristic of the market, meaning that it is not possible to be eliminated, hence to strive in this kind of circumstances the company must learn to deal with it. Moreover, uncertainty grows as more into the future one foresees.

A strong customer relationship management (CRM) also needs to be very strong in the aforestated characteristics. CRM oughts to always have reliable and updated information about the internal status – available to promise – of the company to properly manage the clients expectations and succeed in the order promising process with its clients.

While striking the mentioned problems, this dissertation will make use of the scenario analisys concepts and guidelines. Different what-if analysis lead to a comprehension of the system as whole, not the company itself, but the ecosystem which BA is a part of. Ergo, it reshapes the company, allowing it to be quicker when tackling new opportunities or mitigating problems caused by undesirable futures.

1.1 Company Background

The founders of BA Glass, Raul da Silva Barbosa and Domingos de Almeida, established the company in 1912, at the time called "Barbosa & Almeida". Since then many changes happened within the company, with successive innovations and growth.

As a glass container manufacturer, it has experienced a high growth, especially in the last 10 years, with the acquisition of others glass companies. The most recent ones were last year (2016) the Warta Glass in Germany with 1 plant and the Yioula Group with 4 plants that constitute the south-eastern Europe (SEE) group: 2 in Bulgaria, 1 in Romania and 1 in Greece (Figure 1). While the acquisition of the Yioula Group was last year, the integration of its plants was only finalized in the present year.

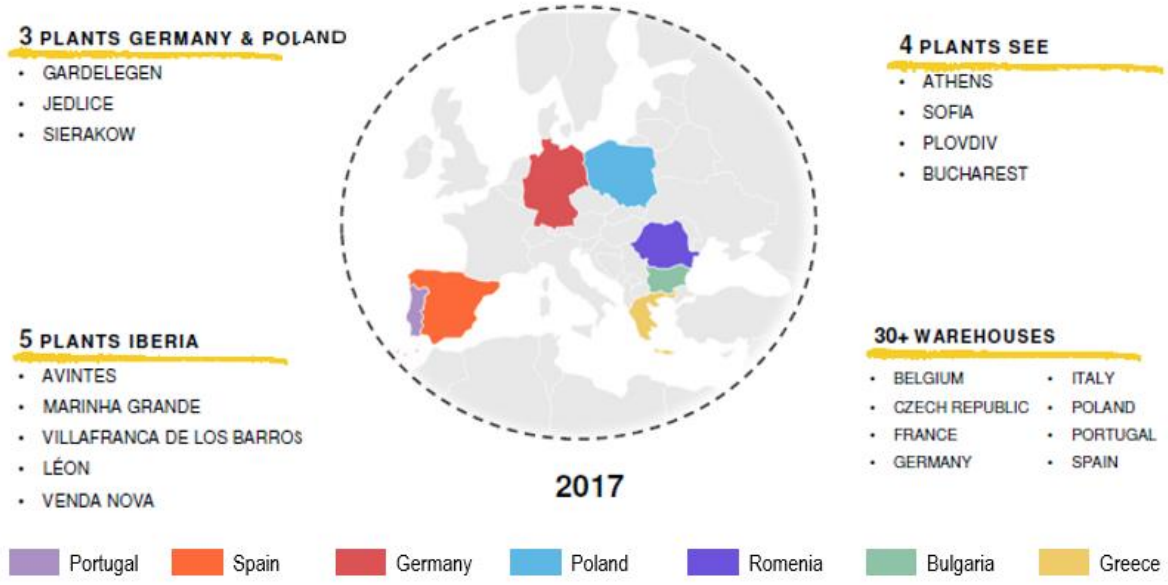

Figure 1. Plants of BA Glass Locations

BA Glass is the number 4 player within the global scenario, with clients scattered all over the world, being Europe the region with strongest presence (Figure 2). The mission of BA is to be the best within the greatest, and its current vision is to Wrap Dreams Beyond Packing, which means to go beyond supplying glass containers and understand better the end consumers, so that, together with the clients, create improvement opportunities that can benefit the whole supply chain.

Figure 2. Main Markets of BA Glass in 2016

1.2 Production Process

The production system follows the common production system used by most companies in this market. Each plant can have a set of furnaces that, individually receive and melt raw materials. The raw materials determine the quality and colour of the glass, meaning that each furnace can only produce one colour at a time. "Additionally, there are high sequence dependent setup times involved in colour changeovers (e.g., the colour changeover from cobalt blue to emerald green takes 120 h), clearly inducing colour long runs and, therefore, furnace colour's specialization" (Almada-Lobo, Oliveira et al. 2008). One of keys activities of the planning department is to understand how to schedule these colour campaigns: this encompasses finding the best timing as well finding the best furnace in which the colour campaign should occur.

In turn, each furnace can feed several lines, and each line can produce one type of product, whose colour is pre-determined by the colour that the furnace is currently melting. Besides this, there are several more restrictions that constrain what each line can produce, namely: the type of process through which the container is given the final form; the size of mould and the number of sections that a line has. A given product requires, therefore, some specific equipment and specialization. Requirements that are not economically viable to assure in every line for every product especially when one possesses a wide portfolio of products as BA does. There are three main processes, through which a material can be produced: Narrow-Neck (NN); Blow-Blow (BB) and Pressed-Blow(PB). Some lines can do more than one of these processes, however to change from one process to another requires a lot of personnel and generates a significant amount of glass waste. For this reason, it is also one BA planning department tasks, to schedule the process campaigns ensuring the minimum glass waste.

After leaving each line, the product can have a surface treatment or not, and then it follows through many levels of quality inspection, such as internal pressure, colour, size and others. Finally, it goes to palletization, where the product is palletized according to a set of rules previously agreed with the client. A more detailed explanation of the production process is present at (Almada-lobo, Klabjan et al. 2007).

This final area is called Cold Zone and the previous one Hot Zone. Note that the production planning is only constrained by the hot area. There is little freedom for varying output to match fluctuations in demand since furnaces and machine lines operate on a 24 h, seven days a week basis (Almada-Lobo, Oliveira et al. 2008).

1.3 Planning Department

In BA Glass, contrary to most of the companies, the planning department is a part of Market & Planning department, which aims to direct more attention into its customers, rather than its plants.

The goal of the Planning Department is to bridge the gap between the Sales Department and the Plants. By negotiating, with both groups, maintaining good communication between them and creating production schedules, the planners should make sure that the orders are delivered to customers on time according to sales plan. The planner should also make a realistic plan and consider the effect on the productivity rate of the plants. Such symbiosis may be difficult to achieve due to the high number of different articles produced by the company, which often must be delivered in the same time window however a have limited number of production lines.

The general process of creating production schedule based on customer needs is presented in Figure 3. The sales managers forecast sales after negotiations with customers. After, they launch the sales plan, or its update into the company's information system. For the planning department, this information becomes the production demand that is used for creating the production schedule, which means deciding when and on which production line the demanded articles should be produced. This initial plan is later subjected to negotiations with plant managers in order to create the final version. Finally, the plan is published and the plant realizes the production in accordance to the plan so that the products can be delivered to the customer.

Figure 3. Simple schematic illustrations of the workflow within the planning department

Another task of the planning department is to strictly control of the stocks, which can be Special or Free. The former refers to products that, for some reason, are suspected to have quality issues and, therefore, is blocked or put under quality control, so that it can be later rechecked and approved, if no quality issues are detected, or reused as raw materials. The free stock, as the name implies, is stock that is free for supplying BA customers.

1.4 Motivation for this dissertation

The increasing complexity in the environment of BA has not only driven the processes of the planning department to its limits but is also leading that the interaction between the plants, the

planning and the sales team through many discords and therefore damaged the BA as a whole – objectives are not being met; customer satisfaction is going down due to late deliveries and unreliable promises; plants performances are also falling behind expectations. This has been partly due dysfunctional objectives, on one side the sales team are pressured to sell more, while the capacity has reached its maximum. The pressure on the sales team to grab more market share and the pressure on the plants to produce those sales is creating a friction leading to the problems mentioned before mentioned. This work will focus on mapping some of the present processes and finding their shortcomings. A special attention will be given to the sales team and their processes since they are the department that puts all the others in motion. Some proposals will be presented to allow the sales team to have more reliable information and therefore start increasing the customer satisfaction and also to have a more deeper understanding of the markets, regarding a longer horizon.

The first question that arose when drawing BA's present conditions was "What is the real demand BA?", question which could not be answered. In the present information system, it is only possible to review what were the real sales and the forecasts for the next months. In an environment where the demand is lower than the capacity available (overcapacity), this is not so crucial, because, most of the times, the sales correspond to the actual demand. However, in the current environment (under capacity), it is critical to understand what is the unmet demand, be it lost sales or simply demand that the company decided not to accept. To have a deep understanding of the unmet demand is very important, for strategical reasons (whether to invest in more capacity or not) or for performance evaluations of the firm.

Another problem of the current status of BA was that the customer satisfaction was going down. This is a consequence of the inability of the sales team to provide the customers with feasible due dates about their requests, which in turn is repercussion of the lack of perception of the capacity in a long-term horizon. Due to this, there is a urgent need to increase the ability to see further in time and understand how the capacity of the future will be able to answer to today's needs, therefore this work also focused on improving the order promising process, which is one of the pillars responsible for high levels of customer satisfaction.

Additionally, BA has an engine optimizer, where given a forecast, transportation costs, stock holding costs among others, based on a set of constraints, gives the best combination of colour campaigns and resource allocation. Additional details will be given on chapter 5.1.2. This software has a very high potential for creating scenarios and calculating the optimal resource allocation and the corresponding costs. The potential is even higher, when the new plants have yet to be fully integrated. The integration of the new plants will bring opportunities to balance the resource capacity across BA furnaces. This can reduce the huge pressure that is currently present in the Iberia region. With the help of this optimizer, the analysis to do this capacity balancing and the identification of where the opportunities are to optimize the resource allocation will be easier. However, as a consequence of its low usability and the lack of time to dedicate to this type of analysis, has led to the disregard of this tool and its capabilities. Therefore, in this study it was also brought forth a deeper study, concerning the usability and type of analysis that this engine can perform, and how to integrate those analysis within the master production planning.

1.5 Methodology

The methodology followed in this research is divided in three main moments (Figure 4):

1. Long Term Planning (LTP) - Engine Optimizer
2. Understanding BA's demand
3. Capacity overview in the long term

The first moment was to understand the how LTP worked, through the creation of scenarios, not necessarily plausible or with utility, and understand its frailties as well its potential. In the first stage, it was identified the shortcomings of this engine. Secondly, solutions to the problems presented were proposed and implemented. Finally, some ad-hoc analysis were performed using LTP.

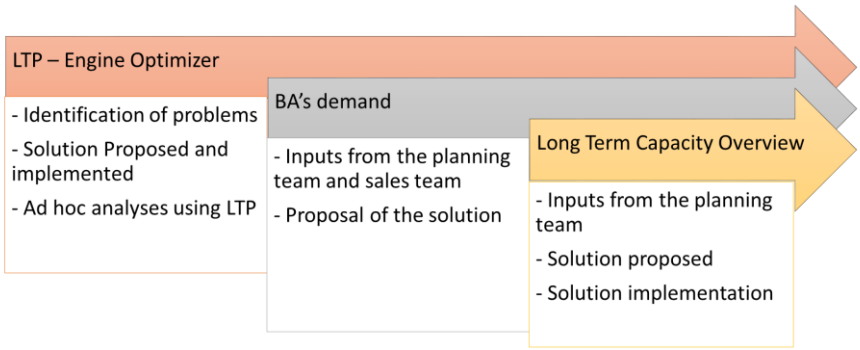

Figure 4. Activities scheduling in this study

The goal of the second moment was to understand BA's demand and the reason for its uncertainty, while registering this for later analysis and to create preventive measures. To reach this goal first stage was to understand with the planning team and with some inputs from the sales team what were the more urgent needs and what was necessary to tackle them. In the end, a solution was proposed and implemented. After the solution was implemented, the results were not as expected and a revision of the solution was performed and a new solution was implemented.

The last moment was drawn from the necessity of having the long-term perspective about BA's capacity. Firstly, a briefing with the planning team was done to understand the deepness and the structure of the result that should be presented. A solution was created and proposed and the implementation is still on-going, meaning that the proposed solution can still be reviewed.

1.6 Structure

The next chapter (chapter 2) is the literature review about master production planning (MPP) with special focus on the nervousness present in MPP and how it is related with the available to promise process. The goal was to learn about what are the consequences of these two concepts in the company's internal performance and customer satisfaction. In the link is made as to why this review is important for the study. In addition, this chapter also reviews the state of the art in what respects scenario planning as tool to do long term planning.

Chapter 3 focus on describing the current situation of BA Glass. First, it gives an overview of BA's main markets and their opportunities and threats. After, it is detailed the processes within the planning department: the main tasks and interactions with other departments. Lastly, it is described the main features of the LTP, namely how it works, what are the necessary inputs and the resulting outputs.

In the succeeding chapter 4 it is performed a process analysis within the planning department to understand the main difficulties and the more urgent needs. Moreover, in this chapter, the solutions to the problems are presented and explained how they can satisfy the necessities identified.

Next in chapter 5 is done a study about LTP, where the difficulties and problems with the optimizer are pointed out. After, the solutions to deal with the issues identified, are presented with its main results. A scenario was created and analysed using LTP, using the real information

from 2016, to understand how the outputs deviated from the reality and why. In the end, an *ad hoc* analysis for the next year was executed, to help understand what will be the future problems.

Finally, the conclusions (Chapter 6) draw a little summary of what has been done in this research and what were the results achieved. Additionally, it is presented a resume about what should be the future works.

2 Literature Review

2.1 Master Production Planning

A firm, to be able to meet customer requirements and maintain its competitiveness, must wisely acquire the means of production that include various resources and capacities. These acquisition decisions include spatial aspects as well as temporal aspects, which means that a firm must decide where to locate these production capacities by considering the time lag between capacity investment decisions, and production and transportation decisions after uncertain demands are realized. (Jakubovskis 2017)

Master production scheduling (MPS) is the process of developing plans for identifying which quantities of products should be manufactured during certain periods. MPS therefore drives operations in terms of what is assembled, manufactured, and bought (Vieira and Favaretto 2006). In companies that have at its core activity a manufacturing process, MPS is the basis for meeting delivery promises without inducing high inventory levels, as well as for resolving trade-offs between sales and manufacturing Jonsson and Kjellsdotter Ivert (2015). Moreover, MPS is a strong asset for the sales force to deal with customer expectation in what concerns the order promising process, which makes the method a vital link between customer order management and production . And, as Hsieh, Yuan et al. (2011) stated, customer expectation management is a strategic way to deliver a high quality service experience and enhance the service provider's competence.

Today there are many advanced software that provide this type of service – MPS – with sophisticated methods to improve the performance of companies. However, when accessing performance, it is important to differentiate the output from the effect of MPS. The output of MPS refers to the production plan indicating what to build and when (i.e.: plan feasibility), whereas the effect of MPS, if beneficial, refers to the improved performance of the plant and, in turn, the positive impact on profit and competitiveness (i.e., plant performance) (Jonsson and Kjellsdotter Ivert 2015). As many companies are prepared to invest or have already invested in standardised commercial off-the-shelf software, it is of necessity to evaluate how using sophisticated methods can affect performance (Jonsson and Kjellsdotter Ivert 2015).

2.1.1 Nervousness in MPS

It has been argued that planning becomes more difficult to conduct as environments become more complex (Günter,2005) and that this negatively impacts production plans and plant performance (Bozarth et al.,2009; de Snoo et al.,2011). According to Vieira and Favaretto (2006), with the rising complexity in terms of the number of products, resources, raw materials, setup times, restrictions incapacity, uncertainties in demand, supply and production, the more difficult it becomes to conduct MPS and generate feasible production plans.

An increased number of entities (e.g.: products, resources, and raw materials) increases the number of planning activities (Bozarth et al.,2009; Jacobs et al., 2011), whereas a high level of variability in production, demand, and supply makes it difficult to establish and adhere to an effective production plan (Wiers, 2009). Consequently, as the planning environment complexity increases, the need for the master production programme to be periodically adjusted according to demand also rises. Rescheduling is useful for several reasons, such as for planning raw material delivery and adjusting demand to resource capacity (Herrera, Belmokhtar-Berraf et al. 2015).

Therefore, a phenomenon known as nervousness generates instability in the MPS. Nervousness is defined as a characteristic in a master resource planning (MRP) system when minor changes in higher level records of the master production schedule (MPS) cause significant timing or

quantity changes in lower level schedules and orders (de Kok and Inderfurth 1997; Heisig and Fleischmann 2001). If not properly managed, this nervousness can compromise the ability to effectively integrate customer – manufacturer processes leading to higher total system costs (Sahin, Powell Robinson et al. 2008).

The study of instability in production planning is a critical issue to generate a MPS. Steel (1975) and Mather (1977) identified the main causes for this nervousness: changes in customer orders, lead time, safety stocks and the demand forecast. In addition, Pujawan and Smart (2012) and Sahin, Narayanan, and Robinson (2013) concluded that the main reasons for nervousness are originated from the relationship between customers and suppliers, even proposing to tackle this problem from an external perspective instead of using the conventional approach, based on simulation and mathematical modelling of internal operations.(Herrera, Belmokhtar-Berraf et al. 2015). The necessity of reducing nervousness comes as it causes an increase of the global cost (Steel 1975), a reduction in the productivity (Hayes and Clark 1985) and an increase in the bullwhip effect (Vargas and Metters 2011). Thus, companies have to determine a trade-off considering production costs, quality of service and schedule instability (Blackburn, Kropp, and Millen 1986).

As mentioned before, a way to deal with the aforementioned variability is to use a rolling horizon to adjust the MPS to the demand forecast by minimising inventory costs with respect to delivery dates (Herrera, Belmokhtar-Berraf et al. 2015). However, some research has also focused in how to lower the nervousness within the company environment. Blackburn et al. (1986) examined five strategies for controlling rolling schedule nervousness finding that freezing the order schedule is the most effective mechanism for balancing the trade-offs between schedule cost and stability. Frozen intervals consist of fixing quantities within some planning period in which changes are forbidden for the next reschedules. The frozen-period strategy presents the best performance in a stochastic demand multi-level environment (Herrera, Belmokhtar-Berraf et al. 2015). However, freezing the MPS decreases the manufacturer's scheduling flexibility in the next planning iteration (Sahin, Powell Robinson et al. 2008).

Another way to control the nervousness is to integrate the whole supply chain to smoother its processes and make the flow of information quicker and clearer. The importance of information sharing, collaboration, and coordination in an effort to improve channel efficiency is well documented in the literature (Sahin and Robinson, 2002, 2005). However, it is not always practiced in industry where the tendency is for a manufacturer to optimize his production schedule and then release purchase orders one at a time to vendors. Unfortunately, in an attempt to minimize his costs, the manufacturer may export operational inefficiencies to upstream suppliers, resulting in sub-optimal system performance (Forrester, 1958; Lee et al., 1997). Berglund and Karltun (2007) and Carvalho et al. (2014) have also highlighted that the degree of proximity among employees is a factor that influences performance.

2.1.2 Available to promise

Today's global marketplace is characterized by high degree of unpredictability, resulting from economic, political, and social developments, as well as from rapidly changing customer demands, excessive product variety, and short product life cycles. One of the ways to address these challenges is to employ flexible production resources, or flexible capacities (Jakubovskis 2017). The unpredictability presents a demanding and difficult challenge for the sales teams to accurately and reliably provide feasible due dates customers' orders, a vital task in the customer relationship management, which is even more aggravated as the time horizon extends.

Making the order commitment decision promptly and accurately is important to the efficiency of supply network operations and tends to increase the level of customer satisfaction (Han et al., 1993; Helper and Sako, 1995; Larson, 1994; Larson and Kulchitsky, 2000; Miller and

Shamsie, 1996; Taylor, 1997; Walker and Poppo, 1991; Yan et al., 2000). Promptness is important for several reasons. A firm loses business if its order commitment decision takes longer than the customer can wait (Vaidyanathan and Devaraj, 2008). Promptness also avoids lost business by minimizing the number of times resources (capacity and raw materials) must be tentatively reserved. When a firm tentatively commits finished goods in response to a customer request, those goods are then unavailable to other requests unless the original request is cancelled.(Thammakoranonta, Radhakrishnan et al. 2008). Promptness in the order commitment decision also increases inventory turns in a supply network (Chopra and Meindl, 2001; Handfield, 1994; Morgan and Monczka, 1996; Shapiro et al., 1993; Wisner and Tan, 2000).

The OPP is defined as the set of activities carried out to analyse the extent to which it is possible to make a commitment with the client based on the order proposal received by the firm (Alarco´n et al., 2005a) and, therefore, to what extent it is possible to satisfy the client's requirements (Alemany et al., 2008).

During the OPP, when a new customer order request arrives, it is necessary to compute whether there are enough finished goods (FGs), materials and/or resources available to fulfil the new order on time. This availability check can include the calculation of the uncommitted quantity, either real or planned, of the items stocked at the customer order decoupling point, known as Available-To-Promise (ATP), which is based on the master production schedule. If there is not enough ATP to commit an order, or there is simply no stock of FGs and production is required, a calculation of the Capable-To-Promise (CTP) quantities is required. CTP represents the uncommitted available capacity, either real or planned, of those productive resources, work-in-progress, components and raw materials involved in the product fulfilment of a customer order. Furthermore, in SC contexts, it is necessary to check if there is enough uncommitted available capacity, either real or planned, of distribution resources (storage, transport and operations), which is known as Deliver-To-Promise (DTP) (Alemany, Lario et al. 2013).

A lot of authors (Alarcón, Alemany et al. (2009); Vollmann et al., 1995; Lambert and Cooper, 2000; Hegedus and Hopp, 2001; Rudberg and Wikner, 2003; Welker, 2003; Keskinocak and Tayur, 2004; Ball et al., 2004; Pibernik, 2005) considered that establishing delivery dates is a vital continuous function in a business firm, and that it has a clear impact on the service offered to the client. Promising over-long delivery dates generates unnecessarily long delivery times. Furthermore, if the dates are too close, the delivery dates generated are unrealistic and are not to be relied on, and may also be the cause of inefficient operations (Alarcón, Alemany et al. 2009). Order promising is a highly critical task with a clear impact on client service (Fleischmann and Meyr, 2003).

(Kilger and Schneeweiss, 2000) stated that the major goals pursued with the implementation of ATP models are (1) the improvement of on time delivery by generating reliable dates, (2) the reduction of the number of missed business opportunities by employing more effective methods for order promising and (3) an enhancement of revenue and profitability by increasing the average sales price.

Additionally, there are some industries that have to pay special attention to another detail – lack of homogeneity in the product (LHP) – which has to be supported by an order-promising system updated and reliable. The lack of homogeneity in the product (LHP) appears in productive processes which include raw materials that directly originate from nature and/or production processes with operations which confer heterogeneity to the characteristics of the outputs obtained, even when the inputs used are homogeneous.(Alemany, Lario et al. 2013). Poor LHP management may have very negative effects on supply chains' (SC) competitiveness: (1) LHP leads to fragmented stocks, which can rapidly become obsolete for products with a short life cycle as they cannot be accumulated to be used in the same order given their heterogeneity; (2) uncertainty in the homogeneous quantities available of end products or finished goods (FGs)

entails having to produce more than is necessary, thus increasing stocks; and (3) the customer service level may prove deficient, even with high stock volumes, if the order-promising system is not supplied with reliable information about the real and future homogeneous quantities available of a product (Alemany, Lario et al. 2013).

2.2 Scenario Planning

The future is not factual until it has become the past (Bell, 2003) or the "new present" (Hideg, 2006). In other words, until the it comes into realization, one cannot predict or foresee the future with perfect accuracy and precision. Nevertheless, it doesn´t mean that one cannot prepare for it, whether by using historical data or by making guesses through deduction or induction, it is possible to a certain point understand where the present conditions will lead. This is done in every day's lives of everyone. People continuously try to anticipate the future and act accordingly. Two processes are continually involved in constructing the present – our experiences of the past and our anticipation of possible futures Walton (2008).

The term scenario planning is nothing more than a methodical way to do the above-mentioned process as "the effort to anticipate and prepare for the future before it unfolds" (Fowles, 1978, p.52). Creating these future scenarios leads to better understanding of oneself and the environment, thus "the scenario itself becomes a reality, a thing that can be interpreted in various ways and that can influence choices and behaviour" Walton (2008). This stands true at someone's life, for a company or institution.

As stated before future scenarios can be constructed in two different ways: Techniques where usually one makes hard use of past data, including forecasting and entailing sophisticated quantitative techniques resulting in probability estimates; and on the other side of the spectrum where scenarios are created based on dialogue, creative thinking, brainstorming and intuition. The first techniques usually have as an output a single scenario, as in the last one the objective is to identify possible, plausible, and preferable futures, resulting in contingency and action plans (Walton 2008). When talked in a business perspective, scenario planning is a key factor in every company. To understand the company's strengths and weaknesses so it can prepare itself to grab the opportunities when they present themselves or to mitigate the problems and threats that appear along the way. By exercising foresight through scenarios, the companies can identify and prepare for probable, preferable, or undesirable futures, where some are to be aimed at, others are to be avoided and others will happen whatever the acting of the company does (Walton 2008).

When creating scenarios, it is important to have some criteria to help the people creating them understand if the work of constructing that scenario can be of any help on the role of the company in the future. I. Wilson (1998) proposes five underpinning criteria for constructing alternative scenarios.

- *Plausibility*: The selected scenarios must fall within the limits of what might conceivably happen.
- *Differentiation*: Each scenario constructed should be sufficiently different for it not to be construed as variations of a base case.
- *Consistency*: The logical reasoning contained in a scenario must not have any in-built inconsistency that would undermine its credibility.
- *Decision-making utility*: Each scenario should contribute sufficient insights into the future to bear on the decision focus selected.
- *Challenge*: The scenarios should challenge the organization's conventional wisdom about the future.

Among these five criteria, there are two of them of special importance. First, is plausibility, because creating a scenario that won't happen is time consuming and thus wasting resources.

Also, if the scenario is not plausible it also won't be credible, and so, it won't be a strong argument to lead the people and the organization when the moment of decision-making comes. Additionally, it also should have a decision-making utility, as if it doesn't, again it will be a waste of resources.

2.2.1 Advantages of scenario-based strategy making

It is important to emphasize what are the main advantages of scenario-based strategy making. van der Merwe (2008) explained the three main issues that give the upper hand in this model of strategy making:

a) The problems with prediction

b) The need for practical systems thinking

c) Strategy as a continuous learning process

Besides this three points, an additional one will presented that was mentioned in Burt and Chermack (2008).

d) Uncertainty in the contextual Environment

The problems with prediction

The most commonly used method for understanding what might happen in the future is to study what happened in the past (Bartlett & Ghoshal, 2002). But, while literature shows that this method produces great results when properly used, there are also events that show that the past is not able to always help us predict the future. Disruptive events are hardly caught by historical data. These can be events that never occurred before, or seldom occur. The importance of these events is that, a great number of times, put the companies to test and can even dictate its survival. This kind of events are especially common when an organization is starting or growing, and new challenges appear every day that the company has never faced before.

When companies observe the future solely based on what happened in the past, their view of the future becomes limited to a narrow band of variability (Schwartz, 1991). In most companies, the power to the strategy making is located on the top leadership, so it is important that the top managers are able and open to debate other risks and opportunities not told by historical data. The "blessing" of these managers on these scenarios also changes the nature of conversation, within the organization, from revealing the risk to concealing the risk, thus preventing people from seeing emerging forces and discontinuities outside the "official future" (Figure 5) van der Merwe (2008).

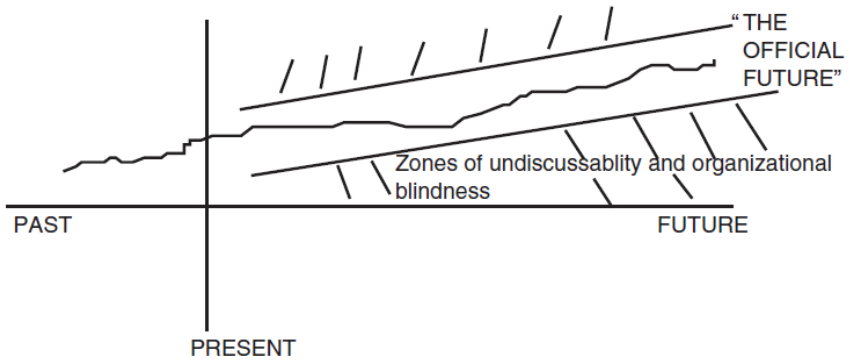

Figure 5. Predictions, Scenarios, and the Dangers of the Official Future (Source: van der Merwe (2008))

The need for practical systems thinking

Systems thinking is the label for a worldview that focuses on interconnections ad causal relationships rather than on snapshots and independent parts (Kuhn, 1970). This means that one should not only look the events that happen around us, but rather understand what were the behaviours that led to those events and which patterns are identifiable. A systems worldview, together with tools and techniques to make structure visible, is important for building quality scenarios (Davidson, 1983).

To understand better the structure of the environment, its driving forces and causal relationships will allow companies to better understand itself and the context they are in and therefore take decisions that will better prepare them for the future, making them more robust. This does not only apply when creating scenarios but also after creating them, to better understand what went wrong or good. This perspective forms the foundation of building an organization capable of detecting error, learning, and self-correcting errors, as it pursues its goals and strategies also known as a learning organization (Argyris, 1999; Senge, 1992)

The iceberg analogy (Kauffman, 1980) is a useful way to picture what stated before and is represented in Figure 6, where deeper we go in the iceberg the more substantial learning is, and scenarios create a forum in which decision makers can explore the structural level of various forces facing the organization.

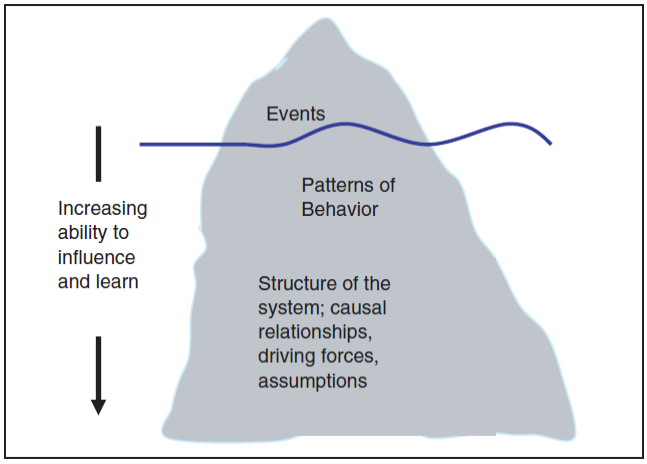

Figure 6. Systems Thinking – The Iceberg Analogy. (Source: van der Merwe (2008))

Strategy as Fit

Describing strategy as process of fit presents the ongoing process of detecting deviation from good fit and correcting for such deviation (van der Merwe 2008). This theory suggests that each organization should fit within its environment and if so happens it will prosper otherwise it will falter, or, in some cases fail. Porter (1998) called this first order fit. Supporting this we have the second order fit (Figure 7) which are the key strategy enabling processes that will guide the company in to maintaining a good fit within the surrounding environment.

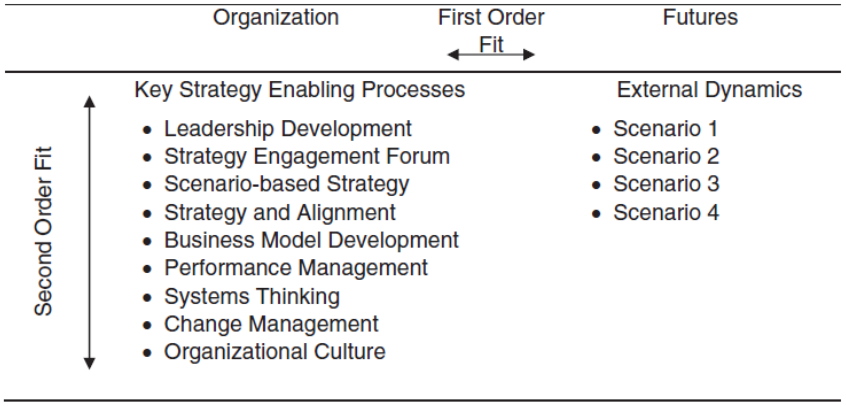

Figure 7. Strategy as Fit (Source: (van der Merwe 2008))

What should be remarked is that among others scenario-based strategy is present in the key strategy enabling processes, which means that it is a key tool for a company to prosper. Since it allows a company to react fast to changes in the environment, where hesitation and delays can sometimes be fatal because it no longer fits within the environment.

Uncertainty in the Contextual Environment

When dealing with uncertainty it is possible to identify three types of perceived uncertainty identified by Milliken (1987):

a) State – When people do not understand how the environment is changing.

b) Effect – Not understanding how the changes in the environment will influence the company.

c) Response Uncertainty – Not understanding what are the response options and/or inability to understand the likely consequence of a certain response choice.

To recognize the aforementioned uncertainty, explore it and gain insights about its links to the strategic development of the organization is what is at the core of scenario planning (Burt, 2003).

2.2.2 Multidirectional temporal analysis in Scenario Planning

What is most commonly done in companies, in scenario planning, is that the scenarios created are only meant for analysing the future. They take the present conditions of the company from there see where they should do in case *Scenario* X happens. Although it is relatively easy to understand why this is the most common case and see its purpose, Deal, Pan et al. (2017) state that there are some shortcomings in this approach.

A planning system that focus only on future forecasts lose several important opportunities: to learn from the past, to create scenarios that envision major shifts from current established structures, and an ability to understand how to attain future goals or outcomes effectively (Deal, Pan et al. 2017). What Deal, Pan et al. (2017) suggest is that besides forecasting, companies also should: a) Recast from a point in time in the past to the current condition; b) Pastcast from the current condition to a point in time in the past and c) backcast from a point in time in the future back to the current condition (Figure 8).

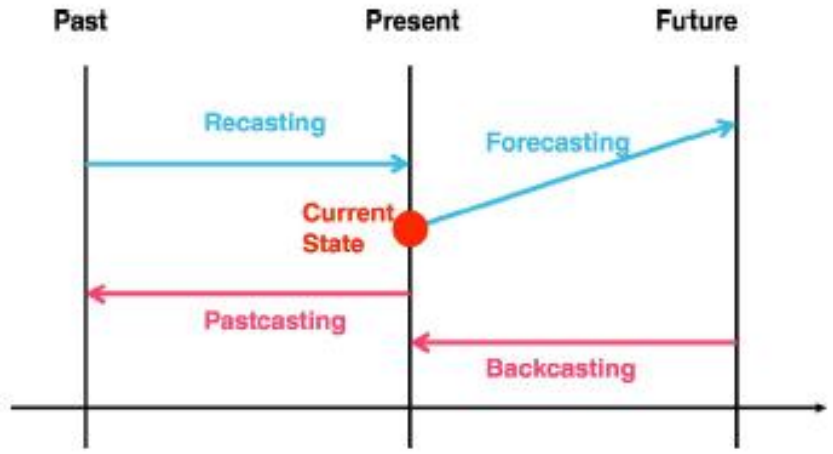

Figure 8. Multi-Directional Analysis using forecasting, backcasting, recasting, and pastcasting to and from the present or current condition. This multidirectional analysis is useful for constructing and understanding robust planning scenarios.Multi-Directional Analysis using forecasting, backcasting, recasting, and pastcasting.

This multi-point analysis in time can prove more reliable information in what respects the understanding the links between the past, present and future. Besides that, it puts the company in a self-learning process constantly evolving and adjusting its strategy to best fit its environment. These examinations can help planners to catch an important causal relationship that they failed to catch. The ability to make these types of examinations along multiple directions in timeline will also lead to more robust and reliable forecasts (Deal, Pan et al. 2017).

The terminology used will be the same adopted in Deal, Pan et al. (2017):

i. Forecasting. Currently the most common approach in scenario planning. A typical forecast starts from a (near) current condition and projects to a future state—this usually refers to the land-use changes that might occur over some specified period.

ii. Backcasting. The reverse version of forecasting – the model starts from a future state and draws a developmental path back to the current condition. This is useful for plotting a path that responds to "how do we get there" questions.

iii. Recasting. Basically, recasting is a reconstruction of the present. It uses forecasting techniques that start from a condition set in the past and project to the current state, usually for comparison purposes (from a projected current state to the actual state). This type of analysis is useful for calibration purposes and understanding a previously unforeseen condition that emerges in the present state.

iv. Pastcasting. This analysis starts from a current time point (again, not necessarily the current state; it may often be a virtual, more preferred 'current' state) and draws a developmental path back to a previous point in time. This approach is useful for understanding the processes that took place (or should have taken place) in order to arrive at the current or virtual state.

A more detailed explanation of the mentioned temporal directional analysis methods follows.

Backcasting from the future

Backcasting is the process of starting an analysis from a future state and considering the path required to achieve this state and has been found to be an extremely useful process, especially in the sustainable development realm (Vergragt and Quist, 2011). Backcasting from a point in the future "enables planners to step outside the haze of current realities and trends to test ideas and to re-examine assumptions" (Deal, Pan et al. 2017). Figure 9 is a schematic illustration of this process.

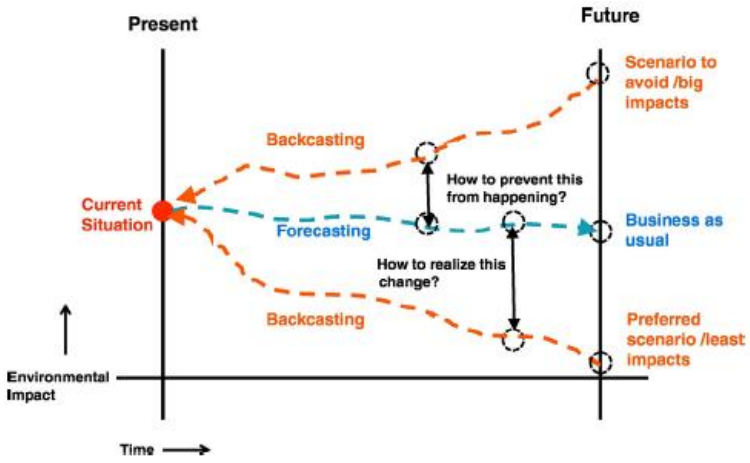

Figure 9. Forecasting and Backcasting (Source: Deal, Pan et al. (2017))

As present in Figure 9 the future scenarios from where backcasting is done does not have to be necessarily preferred futures. On the contrary, it can also start from least favourable situations and try to understand what can be done to prevent or mitigate those unwanted situations. Additionally, backcasting can be used as an argument for considering different goals and "highlight potential problems in reaching the goals, and help create strategies to overcome the identified problems"(Deal, Pan et al. 2017). Finally, backcasting can promote systems thinking and inform potential risky outcomes.

Pastcasting and Recasting to the past

These types of processes are very useful for ground truthing and calibrating the modelled outcomes. Moreover, understand emerging properties in a system and how these properties might implicate future conditions. Figure 10 represents a schematic illustration of these kind of analysis.

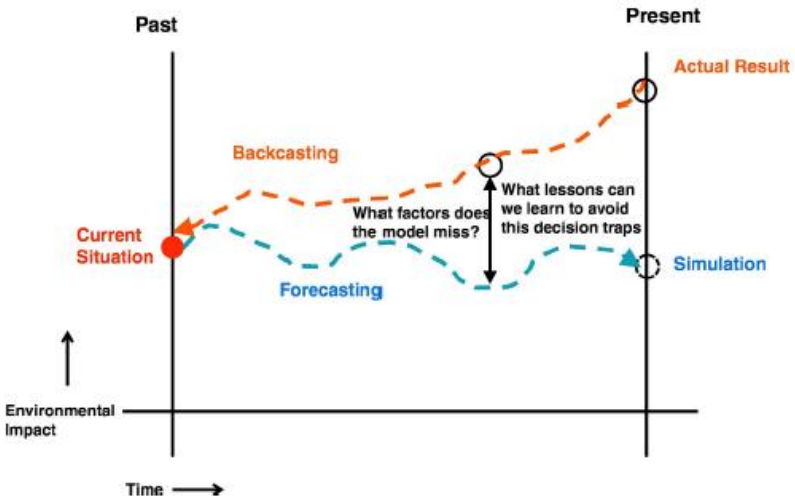

Figure 10. Pastcasting and Recasting (Source: Deal, Pan et al. (2017))

These techniques can help planners understand what they failed to see in previous planning exercises, including specific conditions that may not have been included in the initial planning analysis. A final remark about this technique is that research teams have natural disincentive to conduct post mortem analysis because it is a frank analysis of past failures. Thus, it is important to make the process positive and blame free with no penalizing decisions on future projects (Collier et al., 1996).

3 BA Glass - Present Conditions

3.1 Market positioning

At the end of each year, all the departments in BA create a budget, where they specific what will be their expenses/revenues throughout the next year. The sales department is no exception, and consequently at the end of the year of 2016, a budget for 2017 (B17) was created, where it is specified what will be the sales in each month, to whom, and from where will it be supplied. The B17 is not a strict document to follow, from where the company should never diverge, but to serve as a guideline and everyone understand what should be their objective and focus.

The main countries of activity are Portugal, Spain, France, Germany, Poland, Italy, Greece and Romania. These amount to 70% of BA sales in 2017 and when compared with 2016 most countries remain the same with slightly increases, except for Italy and the countries in the south-eastern region, in which sales have increased significantly (Figure 11). The explanation for these exceptions is that they are a consequence of the recent acquisition of BA, the Yioula Group, with plants in Greece, Romania and Bulgaria therefore allowing the penetration in those markets to be bigger, and made Italy a much more profitable and interesting market.

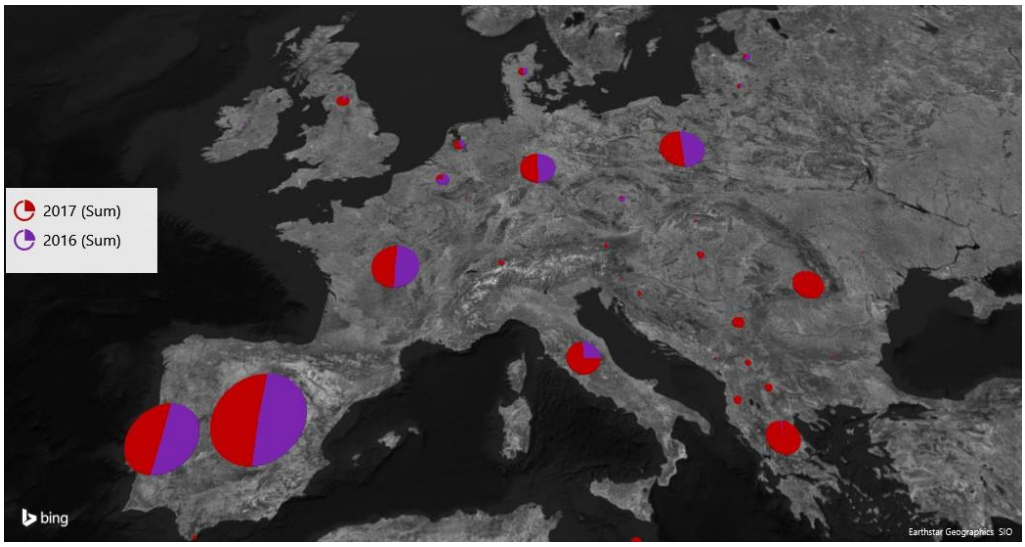

Figure 11. Sales of 2017 versus Sales of 2016 (Real Sales up until May 2017 the rest of the months until the end of 2017 are either forecasted)

The distribution of the segments per country is displayed in Figure 12. Food is the dominant segment in most countries, thus being the biggest one in BA. On the other hand, is also the one with less innovation. The food segment products are mostly produced in Flint colour, with very standardized sizes and shapes, therefore it is harder to create a difference for BA's target customers other than being cost competitive while keeping high standards in quality.

The wine segment is mostly present in the Iberian Peninsula and France in BA sales, however there is another big market that wasn't profitable for BA until the recent acquisitions – Italy, the biggest producer of wine. Wine is a very competitive segment; thus, the prices are very low, being the segment with the worst margins. Also in France – one of BA's biggest market – the consumption has been decreasing because the price of wine to the end consumers is very high, which then damages the whole supply chain and consequently BA sales. These facts make it a segment where the loyalty of customers is extremely valuable, and the efficiency of producing these products is critical.

Relatively to the beer segment it is possible to observe, that, prior to the acquisition of the south-eastern group, the only countries of significance that had a high rate of consumption were Portugal, Spain and Germany with some potential. However, after that, there are some

countries with some significance like Romania, Bulgaria and Greece. The countries on this area are still feeling the damages from the past wars where they were dominated by the Soviet Union and became communist states, so there is a lot of potential to grow in beer consumption in these countries. According to Yakovlev and Guessford (2013), "holding everything else constant, we find that as states become more liberal over time, they experience higher consumption of beer and spirits per capita". The consumption of beer in central Europe – Germany, Netherlands, Belgium, etc - is also very high, however the most common packaging present in these countries is the beer can or returnable bottles, making them difficult markets to enter. Beer relates to a strong seasonality, like the summer, football events, among others.

The spirit market is very characteristic of the south-eastern Europe, as they are famously known. BA's highest market is Poland, mainly due to the existence of plants there. This market is very complicated and difficult to handle, because, while this is the most innovative segment, spirits producers change their bottles almost every year, the final price to the consumer is very low, which means that the price of the bottle itself cannot be very high.

The soft drinks market includes every non-alcoholic drink – from water to every kind of juice gasified or not. However, in this segment, the main type of containers aren´t glass. In 2016, glass packaging in soft drinks only represented 17%. Nevertheless, it is a market with a high potential, especially if the tendency in the packaging inverts to glass containers.

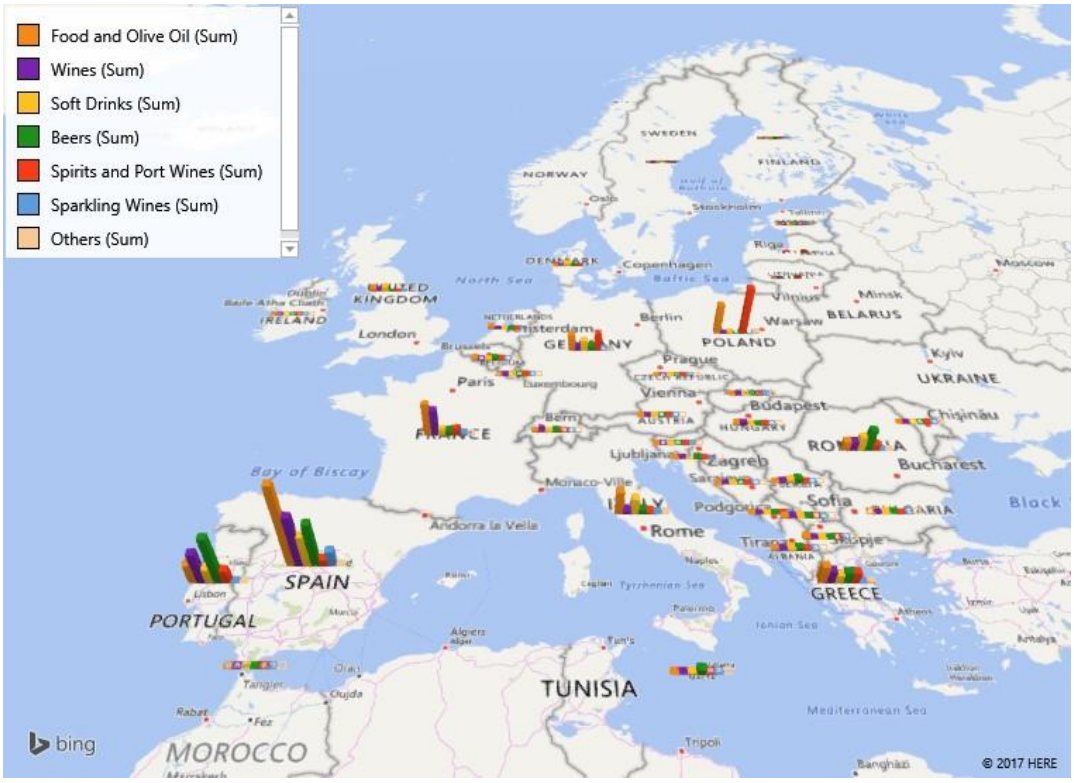

Figure 12. Illustration of 2017 sales per segment in each country of Europe (Real Sales up until May 2017 the rest of the months until the end of 2017 are either forecasted or already contracted)

As remarked before it is important to keep track of the sales perfomance compared to what is the guideline (B17), but also with previous years, to grasp how BA is growing. Figure 13 depicts, in the upper chart, the main deviations per country and in the lower chart the deviations per segment. For instance, although the Spanish market decreased when compared to B17, it has undergone a significant growth when compared with the year of 2016. It is

important to remark that it is not only important to read these deviations but is even more crucial to understand what were the causes of each deviation.

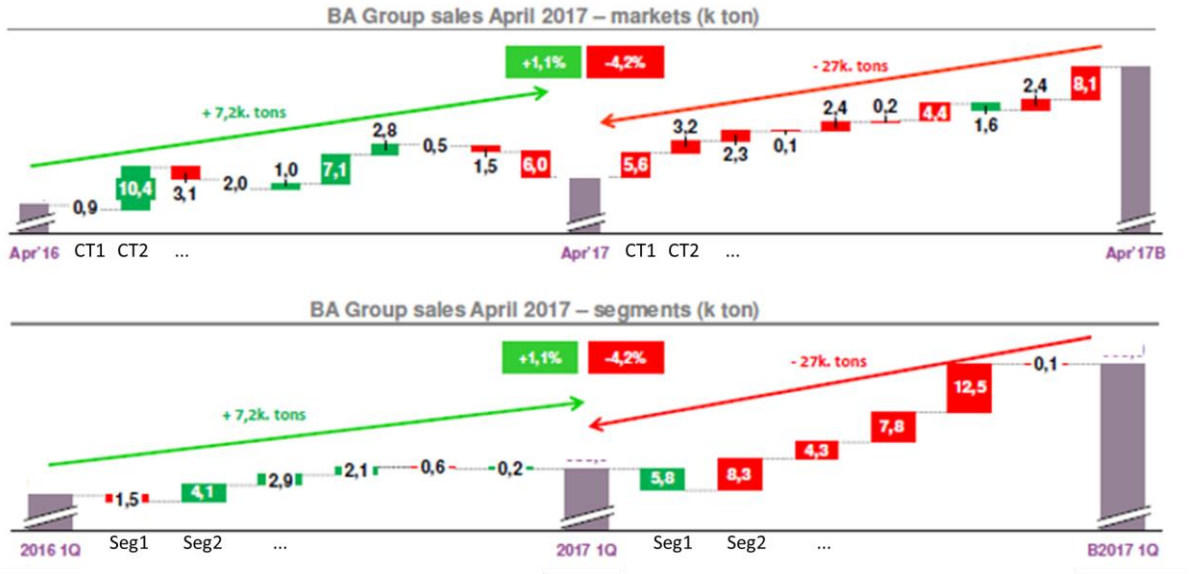

Figure 13. Sales of BA by country/segment (Real 16 vs Real 17 vs B17)

To the date (April 2017) where it was studied, these deviations were happening due to the product mix being sold. More precisely, productions of low quantities of small clients were still being kept. This created a snowball effect: by doing these small productions, it created many setups, leading to the loss of glass and preventing the longer productions from being done, which usually entail better yields and furnace pulls.

3.2 Master Production Planning in BA

Within BA's Enterprise Resource Planning (ERP) software – SAP – there is manufacturing resource planning module (MRP) that aids the master production planning process. Very briefly, this module allows planning to see the historic of productions and sales, as well as the forecasted demand and planned productions. The main tool of the planning department is the sales plan. As can be seen in Figure 14 the sales plan contains the vital information, such as the demand per month, the clients and its initial stock. SAP's MRP module has a colour scheme to help understand the status of each product. The colour scheme reads as follows:

- Red: Final stock at the end of the month is negative, which means there will be no stock to fulfil the demand (stockout)
- Green: Production scheduled and on time to fulfil the demand of the period.
- Orange: Production already finished.
- Yellow: Production is too yearly. There is enough initial stock to cover the demand in the period where the production is present.

Additionally, the mentioned figure, shows the sales plan for a given final product, that is divided in different finished goods. The first eleven characters – 9999Z111VBA – represent the final product, which is the container itself. The remaining two characters, represent the packaging scheme in which the final product will be delivered to the client. Packaging scheme, is the way the final product is palletized, such as: the height, number of bottles per pallet, material of pallet, among others.

Pref Line	Material	Description	Real Sales	Pending Sales	Prod.Line	Data Type	Jun 2017	Jul 2017	Aug 2017	Sep 2017	Oct 2017	Nov 2017	Dec 2017	Total
VFE1	9999Z111VBA01	Product X – Palletization A	66	0	100% VFE1	Stock I	198	132	704	504	204	46-	296-	0
						PV	66	280	200	300	250	250	0	1.346
						Produção	0	851	0	0	0	0	0	851
						Stock F	132	704	504	204	46-	296-	296-	0
	9999Z111VBA2	Product X – Palletization B	17	111	72 % VFE1	Stock I	17	252	837	568	981	720	401	0
						PV	388	843	269	370	261	319	184	2.634
						Produção	623	1.427	0	784	0	0	0	2.834
						Stock F	252	837	568	981	720	401	217	0

Figure 14. ERP information about the sales plan for a specific product

The sales plan should be updated every time a person from the sales team has new information about a product. Moreover, the sales person should also warn the planning department of any significant changes in the sales plan. The planner uses the information in the sales plan to develop the productions plans to deliver to the plant managers, specifying what to produce, where, and when.

Today, there are 5 planners, plus a team leader. Each planner is responsible for one or more plants as specified in Table 1. The allocation of the planners is based on the location of the plant and the colour it produces. Summarizing: there are 3 planners in Iberia, 2 responsible for the flint colour and lighter variations of it and 1 for other colours; 1 planner for Poland and 1 planner for Germany.

Table 1. Planners distribution in BA Glass

Planners	Plants	Locations	Colours
One	AV; VF	Avintes; VillaFranca	Amber; Dark Amber; Green; Emerald Green; UV Green
Two	VN; MG; LE	Venda Nova; Marinha Grande; León	Flint; Light Blue; Georgia Green
One	JE; SI	Jedlice; Sieraków	Flint
One	GA	Germany	Flint
One	SO; BU; AT; PV	Sofia; Plovdiv; Bucharest; Athens	Flint

To conclude, the short-term planning is very demanding and the long-term planning even more so. In terms of planning, anything that goes beyond 3 months is still very poorly developed. But the need for it is crucial, especially as a support to the sales team to manage the client's expectation.

Out Of Stock Analysis

Besides the creation of the budget, the monthly tasks performed by the planning department are what is presently done in terms of a long-term perspective, despite the long-term view encompasses only a 3 months horizon. The monthly tasks will be described next and are presented schematically in Figure 15.

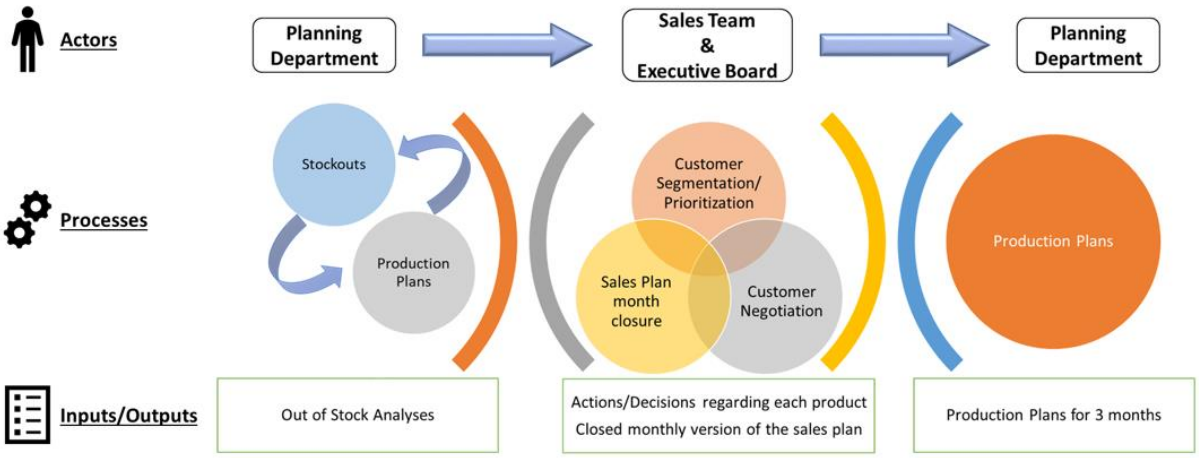

Figure 15. Monthly tasks done by the planning department

At the start of every month the planning department does an Out of Stock (OOS) analysis. This process consists of iteratively analyse what will be in OOS in a 3 months' time span and creating a production plan for the same period. The result is a document with the products that the planning is not able to produce and, consequently, the stockout will occur in the future. This report helps understand what are the main issues with the resources and capacity within each plant.

This report, is thereafter sent to the sales team and to the executive border where they redefine the customer's priorities and take preventive measures. Thereupon, a feedback is given back to the planning for each product in OOS, mainly, with one of the two actions:

- The sales plan of product *X* shall be eliminated, therefore also eliminating the OOS.
- Product *X* must be produced. To allow this, the production of product *Y* can be delayed/removed, therefore liberating capacity/resources to produce product *X*.

While there are other feedbacks, these are the most recurrent ones, and they fall on the category of client segmentation and prioritization. After the planning receives the feedback, it should redo the plan for the 3 months taking in to account the changes.

It also should be remarked that at the same time, a monthly version of the sales plan is saved. The goal is, at the beginning of each month, save a version of what were the real sales until the starting month and what is planned for the following months. This allows the planning department to review what were the forecasted sales, at the beginning of the a given month, versus what is in the real version of sales plan in a given day. (e.g.: compare what was forecasted at the beginning of May and what were the real sales at the of that month.)

Closing a production plan

At the beginning of each week, a plan is closed and is published to each plant, where the following week is closed and there is a proposal version for the next 4/5 weeks.

For a week to be closed, means that the final quantities to be produced and the order of each finished product are established and cannot be changed. Each planner, negotiates with both the plant and the sales team and its job is to define the best quantities in the best order, so that it can reach the customer until the due date while taking in to account restrictions from the plants such as job changes, furnace pull and yields.

The following weeks are a proposal from planning to the plant, so that the plant can analyse them and check if they have all the resources necessary to produce the proposed products (e.g.: moulds). The general tasks of this process have already been presented in Figure 3.

3.3 Long Term Planning Optimizer

The concept of long-term planning never came into play due to under capacity environment, consequently any process related to it was still very poorly developed. Additional to this fact, when the plants were all concentrated in Iberia, even in terms of transportation costs, producing at a given plant was, most of the times, irrelevant, since plants were so close to each other. So, the need to invest in a different kind of planning never arose neither from the capacity and resource allocation perspective neither from the transportation view.

Nowadays, this is not the case. Figure 1 shows how the plants of BA are now scattered around Europe. The most important thing about this is to have a perception of the effort needed to understand which plants should be supplying each market. Not only the transportation costs vary in these regions, but also the production costs fluctuate significantly. Which means that to answer to the previous question is not only a matter of transport optimization, but to analyse the whole demand and cost spectrum,

The growth of BA has not only been through the acquisition of competitors, but also through frequent investments in their already existing plants. Investments which allow BA not only to expand their capacity in their furnaces but also to make their plants more flexible (ability to produce a wider range of products) and more efficient. Again, the same question applies: with the larger network of plants, where should they focus these investments and, what type of investments should they do?

To help give an answer to this an optimizer was bought to help the planning department. This optimizer (LTP) can provide BA with relevant and required data used to take decisions in the production planning of the group of plants, such as:

- Launching annual planning to obtain colour and process campaigns
- Launching what-if analysis to make better decisions
- Obtaining reports about colour campaigns, furnace and line production, production costs and production and stock analysis.

In short, the optimizer is a problem solver which employs the input data to model the problem at hand and find an optimal solution to it. By creating a set of mathematically defined rules, called constraints, and given a defined objective to be reached, finds the values of the variables which satisfy all the constraints while finding an optimal resolution, if any, for that objective.

What will be explained next is a more detailed information about what are the constraints that LTP takes in to account, what is the objective function, and what parameters can be manipulated.

The constraints can be divided in to four categories:

- Furnace Constraints
- Line Configuration Constraints
- Line Production Constraints
- Distributions Constraints

The furnace constraints mainly control the capacity of the furnace, the colour that each furnace can melt, define colour campaigns, closures (sometimes the furnaces must be closed for maintenance) and other operational constraints.

The line configuration constraints give respect to the configurations that a line has. Such as the initial line configuration, other possible configurations it can take and number of configuration setups.

Line production constraints establish requirements regarding duration of configuration campaigns and compatibility among melted colours configurations to be used during colour campaigns.

Distribution constraints deal with the distribution of all products generated by the previous constraint families. The supplying amount to each region, from which plant, and the resulting stocks are taken in to account.

In a very concise way, the optimizer receives the inputs regarding demand information, production constraints and specifications, transportation details for twelve periods and outputs the production data of each furnace/line (What did it produce? When? To where?), as well the respective costs and performances. In Table 2 the files needed for LTP are displayed with a little explanation of what each file should contain. There are 22 files to be submitted with a specific structure and format.

There are some important aspects to retain about the inputs. First is how the definition of families of products can be made. The large number of materials in BA, makes it too complex for the optimizer to find an optimal solution when considering a long-term perspective. In short families are created based on the colour, type of process, size of the mould and the segment. For example, family AMNNPQCE represents all products with the amber colour (AM), that are produce through the narrow-neck process (NN), using small moulds (PQ) and of the beer segment (CE).

Furthermore, the same concept is applied to the region of demand. The regions in SAP, is based on a two-digit postal code, as shown in APPENDIX B Figure 37. While, in LTP, these regions are transformed into clusters as show in APPENDIX B Figure 38. So, from ninety-eight different regions in France in SAP, LTP considers only four: France north-west; France north-east; France south-west and France South-east.

There wouldn’t be any decision-making utility of having all these materials and regions were disaggregated, on the other hand by clustering them, can deliver a more reliable understanding of what will happen in the future. This flexibility and robustness of the optimizer is essential for creating many types of scenarios and retrieving various types of insights. Together with the fact that it is possible to choose the several levels of aggregation or disaggregation and the possibility to choose what each period represents (e.g.: 1 period can represent one week, one month or one year), makes LTP a powerful tool that can provide powerful knowledge about the future and the past.

Table 2. Necessary input files for LTP

File Name	Contents
Colour	Definition of the existing colours and its RGB code
Period	Definition how much days each period has
Process	Definition of the existing types of processes
Moldsize	Definition of the different mould sizes.
Family	Definition of each family in terms of processes, mould sizes, colour, segment, weight, average sales price, holding cost, backlog and lost sales cost, stock deviation costs, minimum and maximum stock to have.
Furnace	Definition of the furnaces and plants, nominal capacity, and maximum capacity
Furnacecolorcampaign	Definition of colour campaigns that the user wants to impose.

Furnaceinitialcolor	Definition of what colours can each furnace melt and at which cost.
Furnaceclosure	Definition of closures that a furnace can have where the user specifies the period and the number of days
Forecast	Definition of the demand of each family, to which region and in which period.
Line	Definition of the existing lines belonging to each furnace
Linefamily	Definition of which families can each line produce, in what configuration with what performance.
Lineinitialconfiguration	Definition of the initial lines configurations at the beginning of the first period
Lineclosure	Definition of closures that a furnace can have where the user specifies the period and the number of days
Region	Definition of the existing regions for supplying purposes
Transportationcost	Definition of the transportation cost form each plant to each region
Colorchange	Definition of setup times between changes of colours.
Gobtypechange	Definition of setup times between changes of gob types.
Processchange	Definition of setup times between changes of processes.
Sectionchange	Definition of setup times between changes of sections.
Initialstock	Definition of the initial stock for each family.
Initialbacklog	Definition of the initial backlog sales for each family

Upon completion, the optimization engine generates automatically a complete report of the scenario. The report is split into several Microsoft Excel worksheets, covering in detail the following sections:

1. **Colour campaign:** In this section, the assignation of colour campaigns per furnace and period is displayed, creating a temporal graph of colour campaigns and their transitions and closures throughout periods.
2. **Furnace and line production:** A separate table is generated for each furnace. Inside each of them, the different lines attached are shown, displaying the number of days the different families are produced by them in each period. Details such as the colour produced and process used, as well as the length of the period, is shown in the table to help understanding. Furthermore, the furnace pull in each period is also displayed above, in terms of percentage and actual tons.
3. **Cost analysis:** The cost analysis table plots the periods with the different sources of cost for BA, them being the Holding cost, Supply expenses, Colour setup and process setup costs, production costs, backlog and lost sales. Additionally, the Final stock and Total amount is also provided.
4. **Production and Stock analysis:** The following analysis provides the user with information regarding the initial stock, demand, production and final stock of every family in each period.
5. **Production detail:** Similarly, the production detail shows for each line information such as the families produced in a period, number of days in production (for that configuration campaign), tons generated and cost associated.

6. **Supply detail:** The supply detail presents the quantity (in tons) of the different product families sent from the different factories to their destination regions. Each factory-region shipment of a given family in a detail both the tons shipped and its associated cost.
7. **Stock detail:** Stock detail, similarly to the supply detail, shows the tons and cost associated of holding a specific family in a factory for a given period.
8. **Backlog detail:** The backlog details shows which families have not been able to be supplied to a specific region in each period, specifying the tons missing and the associated cost.
9. **Lost sales detail:** Similarly, to the backlog detail, the lost sales detail displays the product families which have not been able to be fulfilled for a specific region in a period. Once again, both the tons and associated cost are shown.

4 Long-Term Planning

4.1.1 Processes analysis and Problems

It was mentioned in the Chapter 2.1.1 that the nervousness present in the business environment is directly connected to the complexity of the same. Also, if not properly managed, it can significantly increase the overall costs and reduce a company's efficiency and productiveness. BA's environment complexity has been steadily increasing. It owns 12 plants across Europe, managing 23 different furnaces with 75 lines, of which many are unique within BA. Moreover, its portfolio of products, ranges up to more than 4 thousand different finish goods and above 18 thousand final products, with new products being launched almost every month. These figures indicate LHP problem mentioned in Chapter 2.1.2. These products are scattered over more than 2 thousand clients, being that each client can have different holdings (e.g.: The client Heineken can be Heineken Spain or Heineken Brazil. While each one belongs to the same older, the relationship with either of them is different).

By doing a pareto analysis to BA sales, it was found that its result does not exhibit the common result of the pareto curve (Figure 16), where 80% of the revenues should be supported by 20% of the customers. Furthermore, BA is exclusive in some products, which means that no competitor of BA is capable of supplying these materials, adding more responsibility in the supplying process.

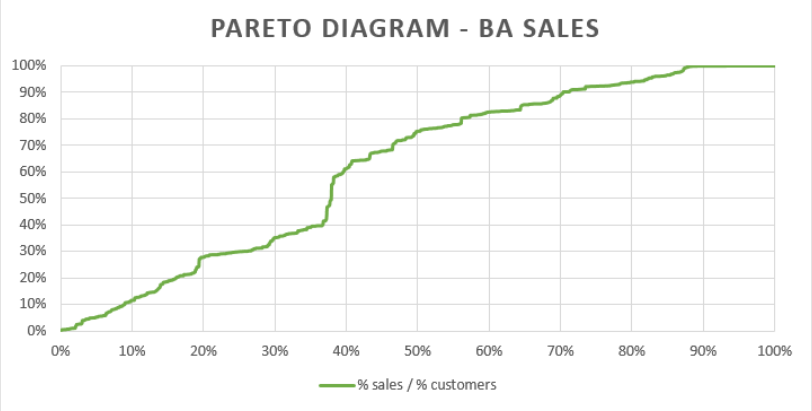

Figure 16. Pareto Analysis of BA Sales

It should also be mentioned, that while there is a safety stock considered for some products, whether due to its high demand or due to the intrinsic value of the customer, in the present moment the company is not working with safety stocks. While BA should work, as a rule, with 90 days of stock, meaning that every time a production was scheduled, it should cover 3 months of demand, the stocks levels are currently around 50 days of stock. The rule before mentioned, was created so that the planning department is able to be more flexible in the scheduling and, therefore, take more into account the KPI's of the plants and be able to produce to safety stock. But the growth and ambition of BA to sell more, and to different customers, has led to a reduction of these days of stock. Creating a chain of reaction, where it is not possible to produce to stock, hence productions have to be more frequent leading to smaller quantities produced each time, damaging the KPI's of the plant.

1. Sales Plan Changes

The ecosystem described above results in an everyday changing sales plan. Every day the sales plan is updated with information from the sales team, sometimes with information regarding the following weeks demand; other times regarding information of products which already have

scheduled production, requiring the planning team to do a rescheduling of the product, which inherently will affect other planned productions since each furnace cannot stop producing.

This fact is a double-edge sword for the planning, because if the sales team updates the sales plan every time they have new information, the planning team will be overwhelmed with the amount of information received and will be very difficult to manage these changes and understand what are the ones that require the highest priority. On the other, if the sales team doesn't update the information, the planning department can be scheduling productions in wrong quantities and/or in the wrong period, consequently having to spend more time for rescheduling the productions or in worst scenario do a bad scheduling.

2. Demand Vs Sales

There is no historic demand recorded for BA. Only the real sales are recorded in the sales plan. This is a critical issue, especially in an under-capacity environment, to understand what is the amount of demand that BA is currently not supplying and if any of the demand that is not being supplied is of interest, thence replacing existing customers. This is very useful to apply quantitative methods and grasp trends and do better forecasts. Besides, it can be an important tool to gain qualitative market insights. Finally, this methods and insights can prove to be very meaningful to understand the potential of the unmet demand and support, quantitatively and qualitatively, new investment decisions concerning the increase of capacity.

3. Long-term perspective

The reduction in days stock and the extremely fast changing sales plan has the planning department completely focused on the short-term planning, by means of constantly scheduling and rescheduling productions which is very time consuming. The oversight in the long-term planning creates big shortcomings, with a special relevance in the customer relationship management. By not having an overview of the resource availability in the future creates big gaps for the customer management expectation.

In chapter 2.1.2 it was referenced how it was important, in order promising process, to establish feasible delivery dates and quantities, and how promising unrealistic dates can damage the relationship with the clients and/or the company's performance. This lack of knowledge has originated many unfeasible dates from the sales team, resulting in one of the following situations:

- Not compliant with customer requests (out of stock)
- Late deliveries
- Renegotiation with the customer

All the above, reduce the customer service and as consequence customer satisfaction. Moreover, situations arise and to not damage a relationship with a given customer, other customers are harmed, being the damage to the customer satisfaction even greater. The unfeasible dates also difficult the job of the planning department, since the team is fighting for an objective that, from the start is either impossible to reach (if the promised date is too soon) or not in to account when planning the following weeks (if the promised date is too late). Therefore, the need for a constant overview of the resource availability is needed to be able to do an efficient order promising process. This includes, not only what is available to promise (ATP), but also how much can BA deliver, capable to promise (CTP) and when, deliver to promise (DTP).

4.1.2 Monthly Deviations Report

The deep understanding of customers and the markets which is a part of are crucial to prepare a company in robust way. On one hand, by hypothesising desirable scenarios and understand

how to harvest the possible upcoming opportunities and, on the other hand, by creating the scenarios with conceivable threats and protect the company from those.

Besides, to be able to meet the five underpinning criteria, when creating scenarios (chapter 2.2.1) it is critical to possess the knowledge referenced above. From those, plausibility, consistency and decision-making utility should be remarked, since these will be most benefited from obtaining good market and customer insights. Scenarios that consistently meet these criteria are mainly created and reached out through the sales people and marketing department, since their proximity to the market/customers is greater than any other department. Nonetheless, every hypothesis should be analysed thoroughly.

Not only the scenarios created through market insights should be kept in mind. These typically provide the company with a perspective of the opportunities and threats concerning the markets, but do not consider the reality inside BA. Meaning, the scenarios created should also account for possible changes in BA, like investments, closures, acquisitions, innovations and everything else that can significantly affect the way BA performs today.

Still the monthly deviations report focuses above all on the market insights, since it has been found that this was the most difficult information to capture. The monthly deviations report objective is: Every month, the sales team, should receive their main deviations when compared to the budget and to the beginning of the month, and have them comment why those deviations are happening.

There are different goals to these reports:

1. Give the sales team leaders an overview of their markets.
2. Give each sales person an overview of their performance
3. To collect important customer/markets insights
4. Understand what is the potential demand

Besides the points mentioned above, this allows to have more reliable, instead of the recasting from the past, at the end of a long period, like Deal, Pan et al. (2017) proposed (chapter 2.2.2), to understand what lessons can be learned, in this study is proposed to make small reports in smaller time windows so everything is recorded more accurately.

To implement this tool there were some cares to take into consideration. First and foremost is to always present this reports as a positive process and blame free with no penalizing decisions on future projects as stated by (Collier et al., 1996). Otherwise, when answering to these reports the answers can be influenced in such a way that the deviations and shortcomings that happen will never be on their responsibility, which means that the information provided will not be correct. So, the first phase was to be clear and transparent with everyone in the sales team about the reports, and to explain the end objective of this process.

Before explaining what was the next step it is necessary to explain how exactly the sales team is divided hierarchically. In short, there are the Key Account Managers (KAM's) who are responsible managing each segment. Then, there is a region responsible (e.g.: the person responsible for the Iberian region), who in turn has a team of sales people working in that region.

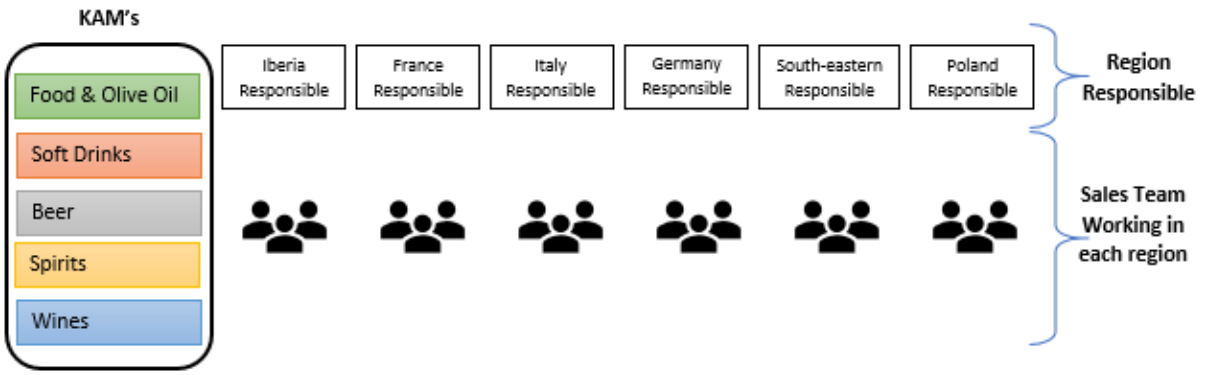

Figure 17. Sales Team hierarchically organization

Secondly is to have a tool where it is possible to analyse in a systemically way deviations through several layers of conditions and between different moments of the sales plan. Besides, both the requested information and outputs and feedback should be different for all the organization layers

As such the tool created, in the initial page, it allows to create three types of more general reports (Figure 18):

- By Sales Responsible;
- By Country;
- By Segment;

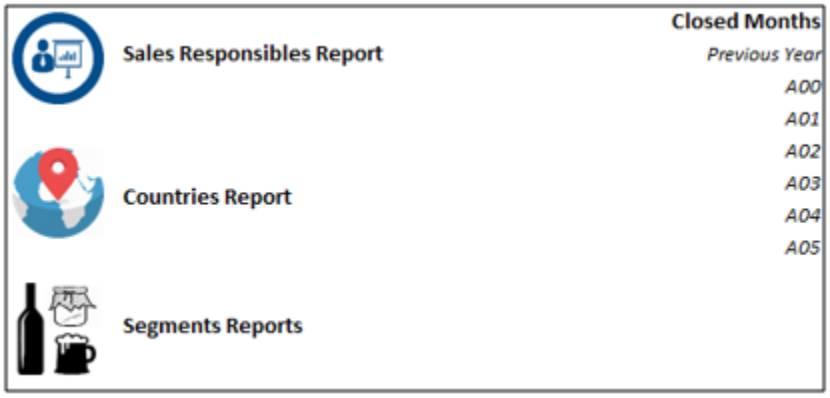

Figure 18. Report Creation Tool - Initial Page

The sales responsible report gives two types of output, one where it is possible to have an overview of the deviations per sales responsible in each semester of the year (APPENDIX A Figure 30). Additionally, it is possible to see in a more detailed version, for each sales responsible, what are the main deviations per month and as well the deviations of the clients for which they are responsible (APPENDIX A Figure 31).

The countries and segment report follow the same concept, first there is an overview per country (APPENDIX A Figure 33) and per segment (APPENDIX A Figure 35), followed by a more detailed report of deviations, respectively (APPENDIX A Figure 34 and APPENDIX A Figure 36).

Besides the initial page, there is other another page – the Custom Report page – that allows the creation of more specific reports. As seen in the example in Figure 19, in the Custom Report page it is possible to make several types of filters and analysis. In the upper part, it is possible to choose the different moments of sales plan for comparison. As a rule, the budget is always

one them. For the others, it is possible to choose from the previous year to any of the versions of the closed sales plan. The result of this kind of report is seen in APPENDIX A Figure 32.

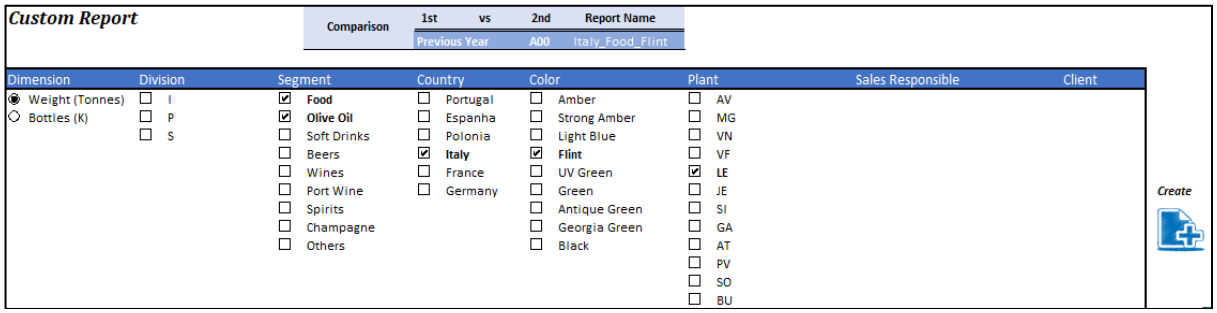

Figure 19. Custom Report page

The third and final care to be taken in to account in this process was not to send the reports to every sales person and ask for a reason. What should be applied is the following:

- Send the segments report to the KAM's;
- Send the countries report to the regions responsible;
- Send the individual sales responsible reports to each one of them;
- And the overview of the sales responsible to each one of the team leaders/ regions responsible.

This type of information is what is required and was mentioned in chapter 2.2.1 The need for practical systems thinking, which in this case means to see beyond the deviation itself, but to understand the causes and consequences of it. To understand the true underlying causes of an event will dictate if the consequent action/interpretation will be appropriate and successful or not.

4.1.3 Capacity overview

It has already been remarked across this study how the customer management expectation is a crucial task (Chapters 2.1.2 and 4.1.1). To be able to do that, they need to know two things: if BA will be able to supply in a near future and if not, then when will it be able to supply. The answer to the second question has been a critically issue, especially with the shifting environment that BA has been going through. To be able to answer this question with reliable and updated information is a vital to negotiate with the clients, properly manage their expectations and avoid their turn away.

To help mitigate this problem a tool was developed to give an overview of the line's capacity in a span of a one year, or more. Four keys pieces of information are fundamental for this analysis.

1. First, is the sales plan, of the next year, mainly the product, division where it shall be produced (Iberia; Central Europe Division; South-Eastern Europe), date, and quantity.
2. Secondly, a table containing the preferential line, in each division, for every product. Every product must have a preferential line where it should be produced. This preferential line is chosen based on where it is predicted it will have better yield, which in turn is intimately connected to the specialization of each plant/line. The preferential line, is given by PLA, every time a product is created and can be updated at any time.
3. Lastly, a table with the average yield and production rate by minute of each line, product and colour. This table is updated every day by SAP by the values of what was produced in that day. With this information, it is possible to calculate the number of units produced per day as shown in (Equation 1). Since the dimension of the production

rate is units/minute, it is necessary to multiply for 1440 – the number of minutes per day. The product yield based on the average of historic productions.

$$\boldsymbol{Number\ units}\left[\frac{\boldsymbol{units}}{\boldsymbol{day}}\right] = \boldsymbol{yield} * \boldsymbol{production\ rate}\left[\frac{\boldsymbol{units}}{\boldsymbol{minute}}\right] * 1440\ [\boldsymbol{minutes}] \quad (\mathbf{1})$$

4. The fourth key piece of information is the initial stock in each line in days. This is calculated by consulting from what was produced in that line, how much tonnes are in stock, dividing by the total tonnes produced since the beginning of the year and multiplying by the number of days since the beginning of the year (Equation 2). This way we are calculating, on average how many days of our production goes to stock.

$$\boldsymbol{Init\ Stock}\ [\boldsymbol{days}] = \frac{\boldsymbol{Current\ Stock}\ [\boldsymbol{Tonnes}]}{\boldsymbol{Accum.production\ SBOE}\ [\boldsymbol{Tonnes}]} * \ \boldsymbol{days\ SBOE}\ [\boldsymbol{days}] \ (\mathbf{2})$$

After this information is prepared, the objective is to calculate for each month, the number of days needed to produce everything present in the sales plan. The pseudo algorithm behind this tool is presented in Figure 20. The algorithm calculates for each product how many days are necessary to produce the sales plan in the given month and in the preferential line. All the days are then summed up to every line. If there is no yield for the combination product, colour, line, then the average yield for the combination product, line is assumed. If there is also no yield found for this combination, then the average yield for that product returned.

In what respects the appearance, there is a small sample presented in Figure 21 for the plant of Avintes. The objective is, for the user, to immediately see which are the lines that are overloaded and which aren't. This is done by the blue bars that fill each month and the symbols which represent if the line is overloaded or not. Additionally, there are some icons to draw attention to the users.

```
Algorithm 1: Capacity Overview
Input:
        sp (i, j, k) ←Sales plan (units) of each product i, in period j, to be produced in division k
        cl (i) ← colour of product i
        pl (i, k) ←Preferential Lines for every product i in division k
        y (i, c, z) ←Historical yields of product i of colour c in line z
        r (i, c, z) ←Historical production rate (units/minute) of product i of colour c in line z
        is (z) ←Initial Stock in line z (tonnes)
        prod(z) ← Accumulated production (tonnes)  since the beginning of the year
Output:
        Is_d (z) ←Initial Stock in line z in days
        dn (z, j) ← Days needed for line z in period j
For each product i
    For each period j
        For each division k
                prefline ← pl (i, k)
                colour ← cl(i)
                yield ← y (i, colour, prefline)
                rate ← r (i, colour, prefline)
            If yield is nothing or rate is nothing then
                    yield ← for all c Average { y (i, c, prefline) }
                    rate ← for all c Average { r (i, c, prefline) }
                If yield is nothing or rate is nothing then
                        yield ← for all c, z Average { y (i, c, z) }
                        rate ← for all c, z Average { r (i, c, z) }
                End if
            End if
        dn (prefline, j) ← dn (prefline, j) + sp (i, j, k) / yield * rate * 1440
        Next k
    Next j
Next i
For each line z
        is_d(z) ← [ is(z) / prod(z) ]*DateDiff( datetoday(); Date(1;1;CurrentYear() )
Next z
```

Figure 20. Algorithm for capacity Overview

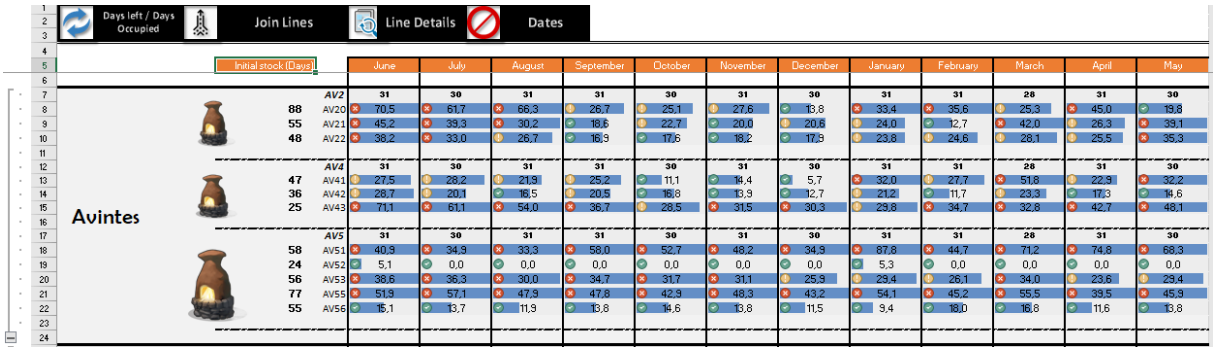

Figure 21. Capacity overview for the plant of Avintes

This tool has other features to potentialize its usability, which will be enumerated and explained next:

1. Change the appearance: Instead of reporting how much days that would be needed to produce the sales plan. Show, how many days are left free after producing the sales plan.
2. Join lines. Some lines are identic, since they have the same possible configurations and specialization, so instead of considering each line separately, it joins the occupation of both lines and, instead of considering the number of days of that month it considers the double.
3. Change available days. When there are furnace closures or colour campaigns, the available days in those times shall not be considered, so this feature allows the user to restrict the number of days available in a given month for a certain furnace.
4. Line Details. Choose a line and a month and give all the details about the products about the products that are being produced in that month. Moreover, it gives the user the ability to change the preferential lines of the products or any other characteristic or even eliminate that product from the sales plan in that given month or for every month and see what will happen to the line.

5 Long Term Planning Optimizer

5.1.1 LTP Difficulties and Problems

The files that were mentioned in chapter 3.3 can be generated automatically through BA's E.R.P – SAP. Through some inputs (period in analysis, furnace closures, colour campaigns, line/process compatibility, …), the rest of the data is created automatically.

Data Accuracy

However, this is not done without error and problems. First and foremost, is that some information in SAP is not correct or is not all in the same format. This leads to many type of errors: Materials not allocated to any family; Family demand not accurate (sum of the demand of all the materials considered in the family does not equal de family demand); Demand without information about its location and others. Consequently, the quality of the inputs for each scenario will be deteriorated due to these problems.

Usability

Some difficulties were also found regarding the usability of the ERP. Some errors result from the programming routine that is used in SAP to generate the information and, as consequence, there is information that comes with defects and, each time that the data is generated, these errors repeat itself, meaning they must be revised every time.

Finally, another thing that is problematic is that the forecast it gets is not modifiable at the product level or market level. For example, to cancel all the demand in a given country, to study the impact in the other markets. To this the user first needs to retrieve the intended materials that the user wants to change. Additionally, the user needs to retrieve the destination region in SAP and period for each product. Then, it necessary to make the correspondence between the products with the respective families and the regions from SAP with the regions of LTP. Finally, in the forecast file retrieved from SAP that will be used as an input for LTP, it has to sum or subtract the correspondent demand. Figure 22 shows the process flow that was explained.

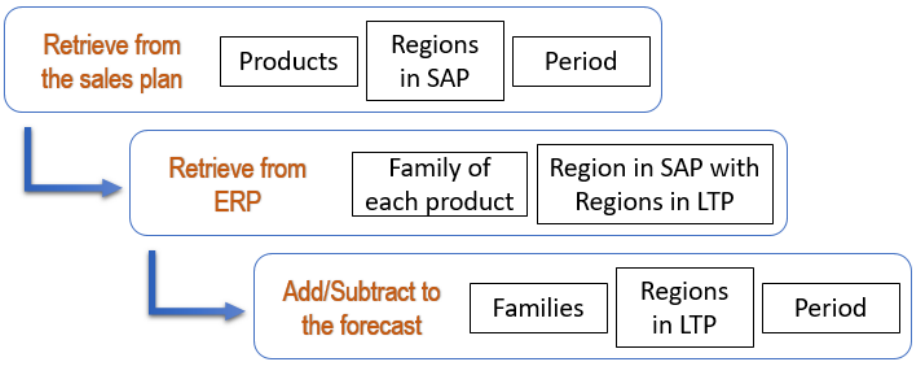

Figure 22. Process flow to change the demand at item/market level

LTP – Engine Optimizer Usability problems

In the previous section, some troubles in the usability of SAP and its accuracy were point out. The problems described next are going to focus on the usability of LTP. Even though LTP is very robust and flexible in what concerns the variety of scenarios that one can create, the same cannot be said about the versality about its outputs and interaction with the user.

To run each scenario created, there is a web-based front-end for users to access the system as it is shown in Figure 23. Here you can check the status of each execution and download it or

delete it. Additionally, you can submit a new one. There is “Validate File” button where you can validate your files and check if they have the correct structure. However, if there are inconsistencies in the files (e.g.: Furnace A can only produce flint colour and you impose a colour campaign of Amber in the same furnace) it is not recognized here and every time you try to run it gives the status failed, without saying which is the error. Since there are 23 different files to be submitted, it is hard and time consuming to find the error(s).

In addition, the files that you submitted in each execution aren’t available after submitting. This is very relevant, because it is important to know which were the conditions of each execution to understand the output analysis. Another downside, is that it doesn’t give the information of how much time it took to find the optimal solution. This is an important information, that can be used to evaluate how the optimizer performs with different levels of complexity.

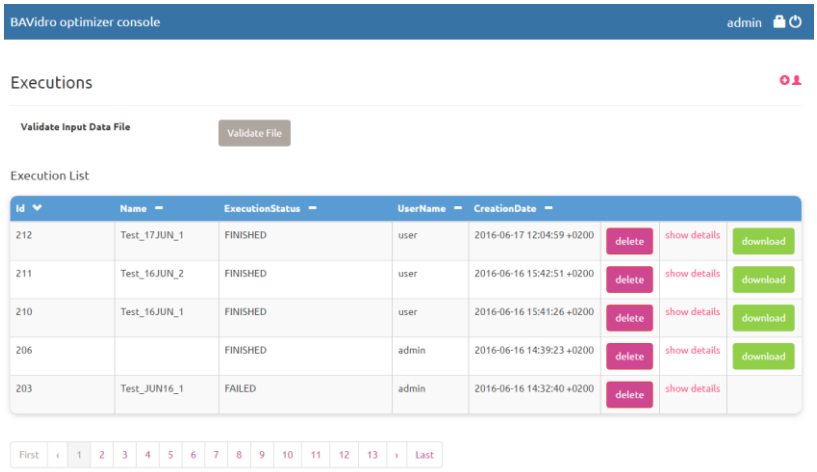

Figure 23. Web-Based Front-End of LTP

Furthermore, the output of the executions format isn’t very appropriate to do the meaningful analysis. While it contains the information and data, sometimes it is not very clear how one can extract that information and what kind of insights it is possible to take from the output.

5.1.2 Engine Optimizer - LTP

Accuracy improvement

To improve the accuracy and usability of the input files, the approached of creating the data through SAP was abandoned. Instead, it was taken the approach of manually creating these files and only retrieving from the ERP the raw information, such as the sales plan. This way, it is possible to create a customized and more robust way to creating the necessary files.

While designing this approach, it was also kept in mind the usability and friendliness of the interface. Figure 24 shows the first screen of interaction. From this screen, it is possible to interact with every file necessary to provide LTP. Besides this, in the interactions with these files, some minor automatisms were used to facilitate the input of data. As an example, Figure 25 shows the period input file for LTP, where, instead of filling each period individually, the user only needs to put the initial date and the type of time span that it is considering (e.g.: M-Month), and the periods are filled automatically.

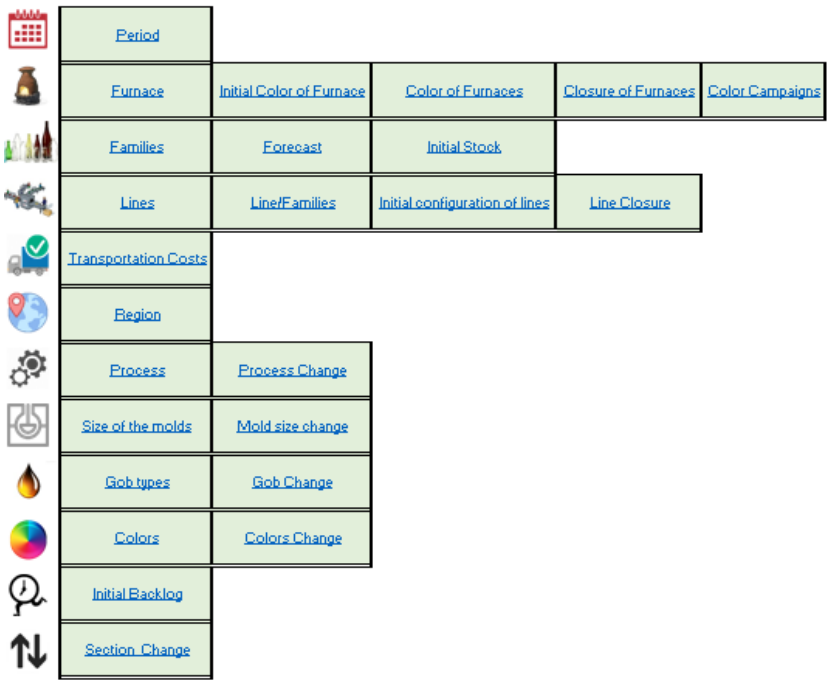

Figure 24. Interface for dealing with the files necessary for the input of LTP

Starting Date	01/01/2017
Ending Date	01/12/2017
Type	M

Year	Month	Period	Number of days	Type	Date Beggining	Date Finish
2017	1	1	31	M	01.01.2017	31.01.2017
2017	2	2	28	M	01.02.2017	28.02.2017
2017	3	3	31	M	01.03.2017	31.03.2017
2017	4	4	30	M	01.04.2017	30.04.2017
2017	5	5	31	M	01.05.2017	31.05.2017
2017	6	6	30	M	01.06.2017	30.06.2017
2017	7	7	31	M	01.07.2017	31.07.2017
2017	8	8	31	M	01.08.2017	31.08.2017
2017	9	9	30	M	01.09.2017	30.09.2017
2017	10	10	31	M	01.10.2017	31.10.2017
2017	11	11	30	M	01.11.2017	30.11.2017
2017	12	12	31	M	01.12.2017	31.12.2017
2018	1	13	31	M	01.01.2018	31.01.2018
2018	2	14	28	M	01.02.2018	28.02.2018

Figure 25. Period Input for LTP

This new approach, while initially was more time consuming, because of the work correcting the errors that come from SAP, in the end it proved to be beneficial, since the accuracy of forecast improved significantly. For instance, concerning the forecasts deviations, for one of the scenarios created the improvement was of 3.9 percental points, representing almost 68 thousand tonnes, depicted in Table 3.

Table 3. Improvement in the forecast in one of the scenarios

Values in tonnes

Real	Before	After	
1 725 130	1 633 072	1 701 008	67 936
Deviation vs Real	5,3%	1,4%	3,9%

Finally, it was created a programming routine to check on the coherence between the files and report if any inconsistency was found. This small routine, saves time by methodically searching every file and reporting the errors found APPENDIX B Figure 40.

Output usability improvement

It was also mentioned on chapter 4.1.2 that one of the problems of LTP was the output generated by it. The output is complete in terms of information. However, it was needed to create a way of systematically analysing the data generated by the engine. As such, it was developed a systematic way to analyse the output generated by LTP. The files generated have already been presented in chapter 3.3. The files presented here were created by extracting information from LTP's output and they consist in two types of information: tables and charts.

The first file presented is a table report called LTP Pull Analysis, where, for each furnace, the main key performance indicators (KPIs) are presented, namely the Utilization Rate and the Pack to Melt. APPENDIX B Table 5 shows a sample for the furnaces of Avintes Plant.

In addition, it was created a report generator using the programming language visual basic for applications (VBA) in Microsoft Excel. The report generator appearance is presented in Figure 41, and its objective is to allow the user to quickly create different types of reports and be able to do a quick drill-down through the different layers. The reported generated is different depending whether the user selects processes, segments or colours. A sample for each one of the reports is shown in APPENDIX B Table 6, Table 7 and Table 8 respectively. From each one of these table reports it is possible to generate a chart report as shown in Figure 42, which is based on the APPENDIX B Table 6.

2016 Analysis – Engine Accuracy Tests

An analysis was performed to understand what was the current accuracy of LTP. The goal of this analysis was to understand the reliability of the engine in what concerns its outputs. To accomplish this the information of 2016 was retrieved and used as an input for the optimizer: the real data about the colour campaigns that were done, the real sales and the initial stock of 2016. Next, it was analysed what were the biggest differences in terms of production and transportation costs. The period in analysis is a year, where each period represents one month (e.g.: 1 – January; 2 – February; …)

In APPENDIX B Table 9 is displayed the results of the production analysis is present. From this table, it possible to see that the overall different is around one percental point. Since the period in analysis is one year, this difference is not considered very significant, since the inputs, as mentioned before, are also not perfectly accurate. Moreover, due to the material clustering some sensitivity is lost about how much plants can produce of each family.

However, if it the differences per plant are observed, it is possible to see that the plants with the biggest deviation are the polish plants – Jedlice (JE) and Sierakrów (SI) – who have twenty-eight and ten percental points of difference, respectively. This difference is mainly because LTP is an optimizer, it has chosen to produce more in Jedlice and Sierakrów, and relieve some demand in the Iberian plants, mainly in the food segment in Jedlice (Figure 26) and in the Spirits and Soft drinks segment in Sierakrów (Figure 27).

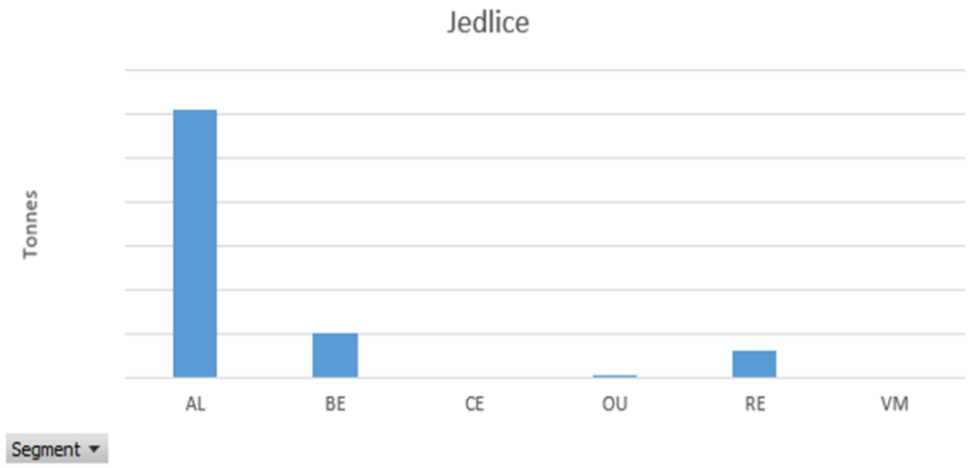

Figure 26. LTP Jedlice total production per segment

Figure 27. LTP Sierakrów total production per segment

APPENDIX B Table 10 is present the comparison between the real transportation costs of 2016 and the LTP transportation costs. The overall difference in the transportation costs is around twenty-one percent. The region with the biggest deviation, as it was to be expected, was the rest of the world (REST), mainly due to the clustering process, since everything outside the red line in APPENDIX B Figure 39 is considered as REST and there is a single transportation cost from each plant to the rest of the world. This reduces the accuracy of the transportation costs significantly.

To conclude, the reliability of LTP results is high in terms of productions. The same cannot be said about the transportation costs. Therefore, it is important to maintain the cost relativization costs from each plant to each region (e.g.: The transportation cost of supplying one tonne from the plant of Avintes to the Netherlands is three times higher than supplying from the plant of Jedlice).

5.1.3 The future - Ad Hoc Analysis

With the objective of understanding what BA can expect of the following year it was made an ad hoc scenario analysis, through LTP, in beginning of May of the current year, with a time horizon of twelve months.

The first insight gained from this analysis is about the food segment. The food segment, consists mainly of either big or small jars. They are mainly produced through the pressed-blow process and in the flint colour. Figure 28 represents the big jars that were produced – through pressed-blow process - and supplied in the LTP simulation, complementing with information about the stock levels. Figure 29 gives the same information about the small jars. From comparison of

both, it is possible to conclude that our levels of stock in the big jars will be decreasing throughout the year, while the small jars remain steady only increasing in the final periods. After a more thoroughly study it led to the conclusion that the capacity to produce big jars is lower than the small jars, even if the demand for both is similar.

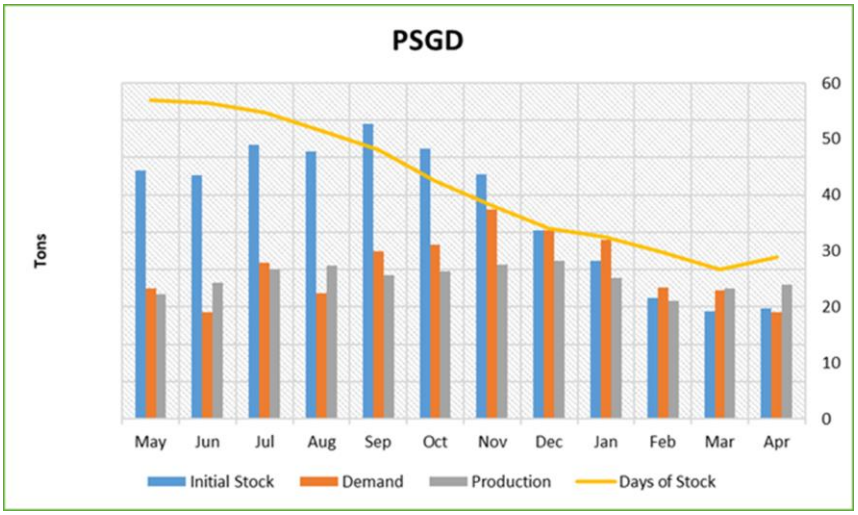

Figure 28. Big Jars produced through the pressed-blow process information

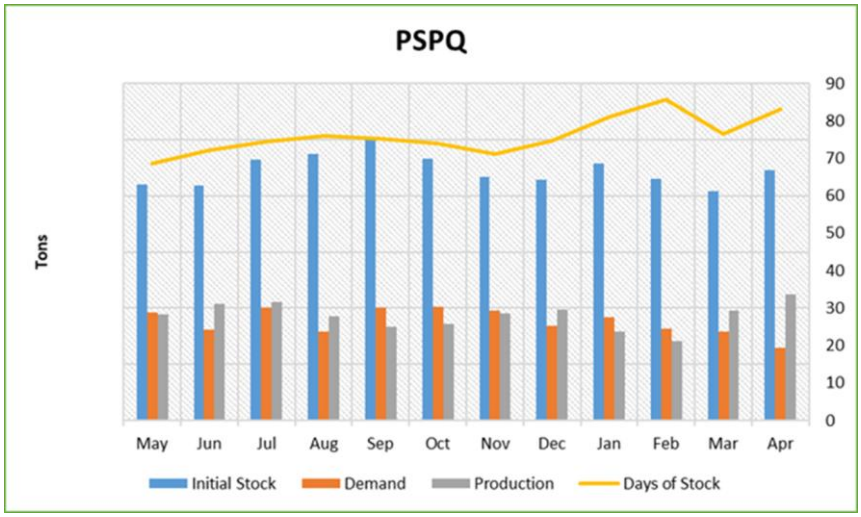

Figure 29. Small jars produced through the pressed-blow process information

The second insight is relatively to the beer segment. Currently, BA has two furnaces dedicated to produce beers, whose colour is mainly amber. As it is possible to observe from Table 4 their utilization rate is already above their nominal capacity. While each furnace has a maximum capacity, which is exceeds the nominal capacity, the optimal condition is to be working slightly above to its nominal capacity. This means that these two furnaces are very close to their limit, while on the other hand there is an expected increase in the beer segment as mentioned in chapter 3.1, with the acquisition of the new plants that also allowed the entrance in new market, namely in beer. This proves that in a near future, there will be a necessity to increase the beer capacity, which consequently, will bring the question as to where it should this new capacity be invested.

Table 4. LTP Pull analysis of furnaces AV2 and VFD, who produce mainly beers.

LTP Pull Analysis		Period												
		1	2	3	4	5	6	7	8	9	10	11	12	
AV2	Color Campaigns	AM	AM	AM	AM-AS	AM	AM	AM	AM	AM-AS	AM	AM	AM	Total
	Nominal capacity													
	Melted glass													
	Utilization Rate	118,1%	118,0%	118,1%	118,0%	118,3%	118,1%	118,1%	118,1%	117,9%	118,2%	118,1%	118,0%	118,1%
	Packed Prod.													
	Pack to melt	90,7%	90,8%	90,6%	88,7%	88,6%	90,7%	90,7%	90,7%	88,7%	88,5%	90,5%	90,4%	90,0%
VFD	Color Campaigns	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	Total
	Nominal capacity													
	Melted glass													
	Utilization Rate	103,8%	98,8%	95,6%	98,7%	103,7%	99,5%	104,5%	100,2%	99,9%	99,9%	100,6%	95,6%	100,1%
	Packed Prod.													
	Pack to melt	90,4%	90,7%	90,9%	90,7%	90,4%	90,6%	90,4%	90,6%	90,6%	90,6%	90,6%	90,9%	90,6%

6 Conclusions

The objective of this researched was to improve the master production planning regarding the long-term horizon, while understanding the benefits from its implementation. On the process of this study, it was defined the objective to

With the increasing complexity in the environment, the tasks inside the planning department started being reviewed and the *status quo* challenged. The need for this long-term view started to be clearer as time progressed, as new requirements started emerging. The reason for these new challenges are the aftermath of BA rapid grow, without reviewing the initial processes. This has led to their rupture and consequent shortcomings that started damaging important KPI's across the company such as the customer satisfaction.

Along with the growth of BA, the uncertainty in the environment also rose unexpectedly, making the planning decisions harder to make and therefore creating delays and unreliable information across the different departments. The markets in which BA is present are very different and behave in very different ways: from the food segment with the same products for years to the spirits segment that reinvents itself almost every year. Moreover, with wide a portfolio of resources, where each furnace, and even line, is unique, also adds up to the difficulty of planning department.

One of the main problems found in the planning department was the lack of knowledge about the current demand of BA, it was very scarce, since all that remained recorded was the actual sales of BA. However, the deep understanding about BA's demand is crucial to make investment decisions and correctly approach new opportunities. Therefore, the monthly deviations reported was proposed, where different reports are sent to different persons of the sales team, so that in the end is possible to capture a bigger picture of the unmet demand that was present in a sales plan. This will not only allow to grasp information about the demand, but also provide with interesting market insights more qualitatively.

Another urgent need that arose as consequence of the decline in the customer satisfaction, was the to improve the order promising process. The sales team of BA needed, to have an updated and reliable source of information regarding the resource capacity in BA. This is essential information for the sales team, since it's the tool that they mainly use in negotiations with customers and, likewise, use to manage customers' expectations. The improvement in the horizon, for which the planning team had the knowledge about the current available capacity of each plant/line, was, therefore, a key aspect in dealing with the customer management. As an answer to this urgent need, the Capacity Overview tool was developed. This tool, has allowed the planning team to understand the usage of their lines accordingly to the current sales plan. Moreover, it allowed them to do simple what if analysis, through simple changes, so that they were able to quickly answer the incoming requests from the sales team.

Finally, this project took as an objective to understand the potentialities and make use of the engine optimizer (LTP) bought by BA. First, a usability and accuracy test was done to this software. Some problems point out, such as the fact that it doesn't show the time of each execution, could not be resolved since it's a closed platform only managed by the service provider. However, in terms of usability some progresses were made to improve it and make the software a more viable and constant tool in the planning department. This was done by creating an error handling tool, that replaced the process of manually having to find inconsistencies among twenty-two files. Also by creating more appealing and user-friendly interfaces to deal with the input files.

In what respects the accuracy, the tool still has work that needs to be done, especially on tuning the transportation costs. Also, it is important to create a maintenance process of these costs, where they are reviewed and updated if needed. Additionally, a process to systematically

analyse the output files and extract meaningful information from it was developed, this is time saving and allows a deeper analysis of the information provided by LTP.

To conclude, an ad hoc analysis was done, through LTP, with the current information, to understand what are or will be the main problems that BA will face. From this scenario, resulted some insights about the food segment and the beer segment. The capacity for the food segment is unbalanced: higher capacity to produce small jars, with the demand for small and big jars is similar. The other insight is that the production for the beer segment is reaching its maximum capacity and its demand is about to grow due to the entrance in new markets, therefore, this segment will need a bigger resource allocation, one that can be provided by the recent acquisitions.

Future works

In the end of the research some solutions were presented and implement. This is not, however, enough to improve the long-term planning in BA. It is necessary to draw a bigger picture and specify the tasks, actors and results to in each moment. Furthermore, it is necessary to define the schedule of these tasks and they should be frequent enough, so that the company can successfully realign its objectives more frequently, instead of pursuing objectives that were defined, for example, half a year ago, and are currently unachievable or, on the other side of the spectrum, little ambitious.

In what respects the monthly deviations report, the report created is just the first step to create a more automatic and accurate process to capture the unmet demand. The next step is to start typifying the feedback given by the sales team. A deviation in sales plan can occur for several reasons, that range from, a wrong forecast done by the sales team to a stockout due to lack of capacity. In between, there can be such reasons as the client turned away because he found a better price or the promised dates are too late, among others that are yet to come in to fruition. Through a typifying process, it shall be possible to make the report feedback much quicker and the analysis more reliable. Finally, these reports should be integrated in the information systems of the company, to facilitate its use and, to implement this, the tool created and information retrieved from it can likely be used as a prototype.

Even so, there is a problem that will be necessary to tackle, that is the sales team not making the proper use of this tool mentioned above. The threat to this tool is that the sales team can start using it to give false reports about the reasons for the deviations. For example, the sales responsible of Italy, always update the sales plan with sales forecasts bigger than those expected, causing consistent deviations when compared with the real sales, which in turn will be explained as lack of capacity to supply that market. This action, can wrongfully lead to an interpretation that there is a high potential of unmet demand in Italy and, consequently, increase the resource allocation to that location. This would allow the sales responsible to be more comfortable when negotiating with the customer, since the availability of resources would be higher. Therefore, the conclusions from these reports have to be deeply analysed before leading to an action.

Concerning the Capacity Overview tool, there is still room to improve, especially if complemented with a customer segmentation. If BA applies a customer segmentation model, dividing them in several categories, when allocating the products to each line, it shall be done so, while taking into consideration to which customer(s) that product is for. This will allow, in the end the user of this tool will be able to say which clients will be out of stock in the future. This would save time to the sales team, that every time, have to look to all products and the correspondent clients and understand from there which are the most import customers. Besides, it would shorten the response time, every time a new request comes to understand if and when BA is able to supply it. As an example, line one, which is the only line that produces the product requested, is already fully booked for December by ten clients, five of which have priority one

and the other five have priority two. If a client, with a priority two, requests the given product for December, it is possible to answer without further ado that it will be not possible. On the other hand, if the client has priority one the situation will be analysed and probably the one of the priority two clients will be postponed for another month.

Regarding LTP, in this work, the conclusion that this tool has a high potential is irrefutable, nonetheless it still needs more refining in what concerns its accuracy and usability. All the solutions proposed to improve the usage of this optimizer, should now be implemented and integrated in the information systems and smooth the creation of inputs. Besides, information for scenarios should be available at every moment, such as the present condition or the conditions regarding the last twelve months. Moreover, a deeper study should be done in what concerns the family and region clustering. Ideally, the clustering should vary in terms of size to find the best cluster size that maximizes the decision-making utility. Furthermore, different levels of clustering can result in different insights about the scenario in analysis.

Finally, it is necessary to blend all this tools in global process that is the long-term planning, by defining the schedule of this activity as well its main tasks and actors, explaining how the results will articulate with the planning decisions in the present. A special remark to the LTP, by reason of its versality. LTP can help planning make a lot of different analysis, the first being the *post hoc analysis* to understand what went wrong in the past. Secondly, is analysis as preventive measure for the future to grasp the best way and timing to strike the opportunities and to reduce the threats. Lastly, are the *ad hoc* analysis, also showed here in this dissertation, which allow to do a specific analysis to individual situations. The biggest potential for this optimizer in the near future is to do intensive runs, with several scenarios for the optimization of resource allocation, when all the four new plants recently acquired by BA are completely integrated in the information systems. The need to redesign the plants supplying network has been growing steadily and this tool can help significantly.

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APPENDIX A: Monthly Deviations Report

Sales Responsible		2016	Z00	B17	Diff
TMS	1st Sem	24 866	26 899	24 594	2 306
	2nd Sem	19 664	23 558	21 069	2 489
SVR	1st Sem	69 910	82 417	71 199	11 218
	2nd Sem	43 141	55 192	41 159	14 033
SMA	1st Sem	761	2 227	3 359	1 132
	2nd Sem	664	3 055	4 211	1 156
RV	1st Sem	40 005	39 568	41 416	1 848
	2nd Sem	42 236	39 328	35 705	3 623
RAB	1st Sem	67 016	65 107	71 203	6 097
	2nd Sem	62 919	64 032	88 213	-24 181
PCO	1st Sem	58 712	41 100	59 754	-18 653
	2nd Sem	34 728	27 500	37 366	-9 866
NPG	1st Sem	21 308	32 749	29 658	3 091
	2nd Sem	26 616	27 441	29 022	1 581
MVK	1st Sem	33 467	39 383	40 152	-768
	2nd Sem	29 114	38 319	39 421	1 102
MMM	1st Sem	15 452	0	0	0
	2nd Sem	18 997	0	0	0
MM	1st Sem	299 077	310 422	298 277	12 145
	2nd Sem	309 570	268 023	291 576	-23 553
MAL	1st Sem	6 806	140 527	170 942	-30 416
	2nd Sem	5 194	150 214	160 349	-10 135
JPM	1st Sem	55 325	55 350	59 100	-3 750
	2nd Sem	58 774	62 352	58 675	3 678

Figure 30. Overview of the semester deviations per sales Responsible

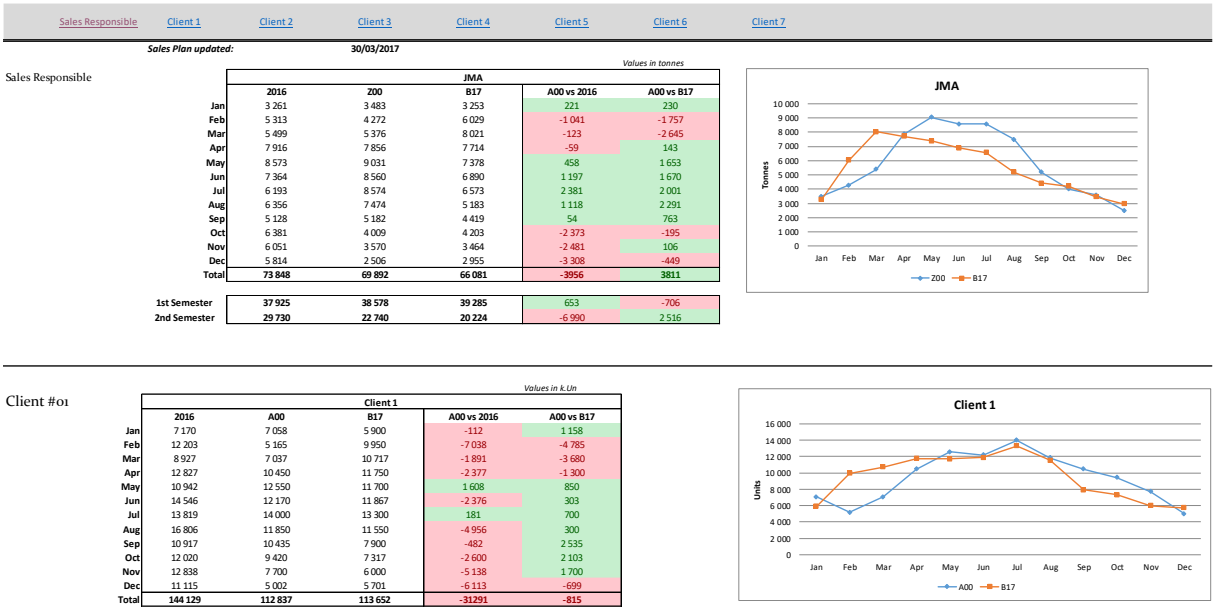

Figure 31. Deviations per month of a sales responsible and the deviations of its top 10 clients

Beers_Iberia					
	Previous Year	A00	B17	vs Previous Y	A00 vs B17
Jan	40 444	39 043	45 861	-1 402	-6 819
Feb	41 805	35 734	38 549	-6 071	-2 815
Mar	49 480	57 917	53 046	8 437	4 871
Apr	47 920	47 675	47 390	-245	284
May	47 924	50 843	47 424	2 919	3 418
Jun	69 545	70 413	64 045	868	6 369
Jul	56 050	69 173	59 592	13 123	9 581
Aug	60 684	57 217	58 181	-3 466	-964
Sep	64 730	43 087	56 852	-21 643	-13 766
Oct	47 873	41 406	39 798	-6 467	1 608
Nov	48 106	36 699	38 604	-11 407	-1 905
Dec	45 119	30 762	45 574	-14 356	-14 811
Total	619 681	579 969	594 917	-39711	-14948

Semester Deviation					
	2016	Z00	B17	Z00 vs 2016	Z00 vs B17
1st Semester	297 118	301 624	296 315	4 506	5 309
2nd Semester	322 562	278 345	298 602	-44 217	-20 256

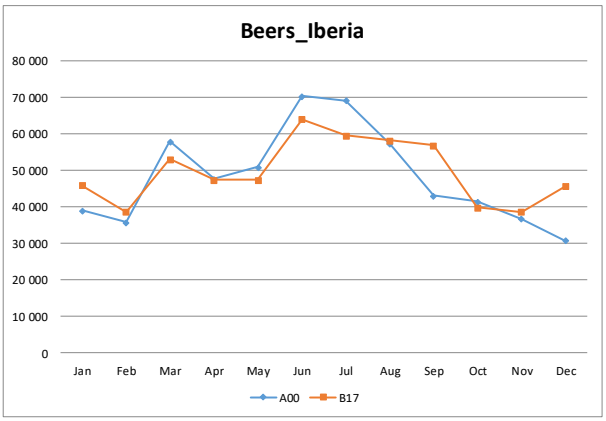

Figure 32. Result of a custom report - Segment of Beers in Iberia

Country		2016	Real 2017	Budget 2017	Diff
Portugal	1st Sem	317 784	318 202	318 410	-208
	2nd Sem	343 007	318 739	329 088	-10 349
Espanha	1st Sem	571 556	612 238	595 890	16 348
	2nd Sem	557 350	561 566	516 824	44 742
Polonia	1st Sem	193 089	188 531	186 632	1 899
	2nd Sem	220 003	221 804	213 530	8 274
Italy	1st Sem	42 120	50 850	43 885	6 965
	2nd Sem	44 324	44 084	52 546	-8 462
France	1st Sem	192 705	202 621	209 954	-7 333
	2nd Sem	181 300	176 128	205 338	-29 210
Germany	1st Sem	128 996	124 480	136 887	-12 407
	2nd Sem	123 941	126 764	162 246	-35 482

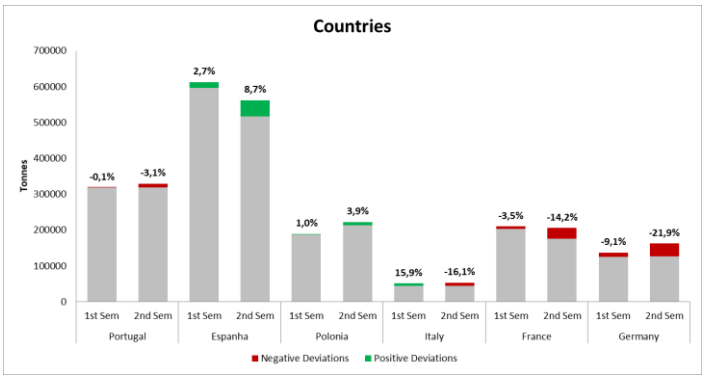

Figure 33. Overview per country of the semester deviations

France					
	2016	Z00	B17	Z00 vs 2016	Z00 vs B17
Jan	27 060	36 820	27 887	9 760	8 933
Feb	30 810	27 222	31 893	-3 588	-4 671
Mar	33 240	32 151	32 443	-1 088	-292
Apr	33 534	30 758	39 943	-2 776	-9 184
May	31 396	35 495	35 413	4 100	82
Jun	36 665	40 174	42 376	3 509	-2 202
Jul	29 810	38 423	40 735	8 613	-2 312
Aug	32 407	32 299	36 369	-108	-4 070
Sep	32 140	28 942	34 259	-3 198	-5 317
Oct	26 946	26 096	34 338	-850	-8 242
Nov	30 324	28 420	31 387	-1 904	-2 967
Dec	29 673	21 947	28 249	-7 726	-6 301
Total	374 005	378 749	415 292	1,3%	-8,8%

Semester Deviation					
	2016	Z00	B17	Z00 vs 2016	Z00 vs B17
1st Semester	192 705	202 621	209 954	9 916	-7 333
2nd Semester	181 300	176 128	205 338	-5 172	-29 210

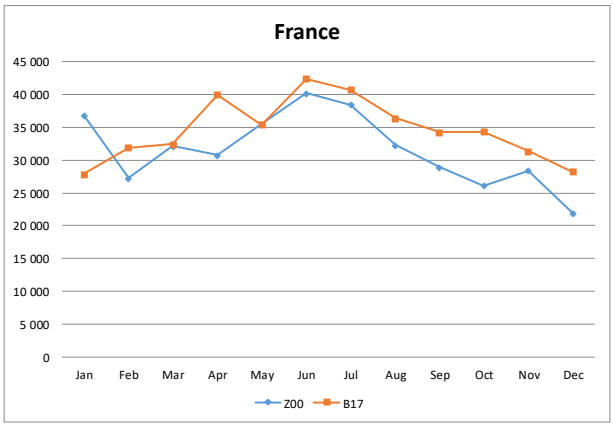

Figure 34. Deviations per month in France

Segment		2016	Real 2017	Budget 2017	Diff
Food and Olive Oil	1st Sem	495 431	523 805	498 547	25 258
	2nd Sem	527 519	527 342	549 485	-22 144
Beers	1st Sem	313 481	315 720	316 504	-784
	2nd Sem	331 371	284 519	321 099	-36 580
Wines	1st Sem	277 714	288 760	286 701	2 059
	2nd Sem	269 471	281 349	256 851	24 498
Soft Drinks	1st Sem	186 744	200 207	196 944	3 264
	2nd Sem	174 627	179 652	163 958	15 694
Spirits and Port Wine	1st Sem	237 894	249 723	256 799	-7 077
	2nd Sem	285 716	280 751	283 996	-3 245
Champagne	1st Sem	72 465	68 845	76 937	-8 092
	2nd Sem	27 207	24 728	31 709	-6 982
Others	1st Sem	3 602	3 620	4 463	-842
	2nd Sem	7 623	8 091	8 782	-690

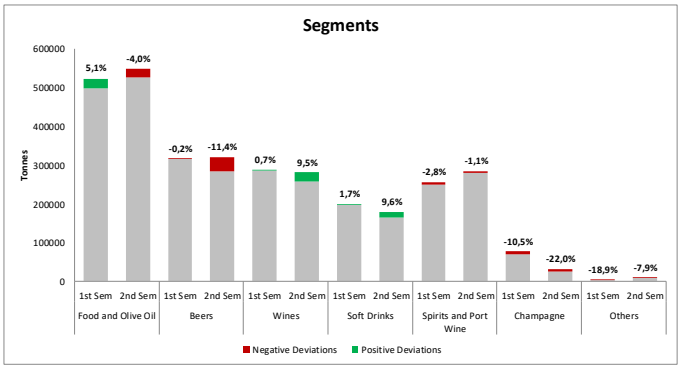

Figure 35. Overview per country of the segment deviations

Soft Drinks	2016	Real 2017	Budget 2017	Real 2017 vs 2016	Real 2017 vs Budget 2017
Jan	21 295	21 400	22 310	49	-427
Feb	23 860	24 254	30 124	185	-2 756
Mar	30 122	31 394	33 969	597	-1 209
Apr	37 796	34 787	37 330	-1 412	-1 194
May	36 605	42 028	37 065	2 546	2 330
Jun	37 067	46 344	36 146	4 356	4 788
Jul	35 768	43 163	36 617	3 472	3 073
Aug	31 844	39 867	31 815	3 767	3 780
Sep	25 193	30 706	27 965	2 588	1 287
Oct	31 944	28 439	27 059	-1 645	648
Nov	25 472	21 090	22 120	-2 057	-484
Dec	24 406	16 387	18 382	-3 765	-937
Total	169 658	178 338	169 438	8 680	8 900

Semester Deviation	2016	Real 2017	Budget 2017	Real 2017 vs 2016	Real 2017 vs Budget 2017
1st Semester	87 673	93 994	92 462	6 321	1 532
2nd Semester	81 985	84 344	76 976	2 359	7 368

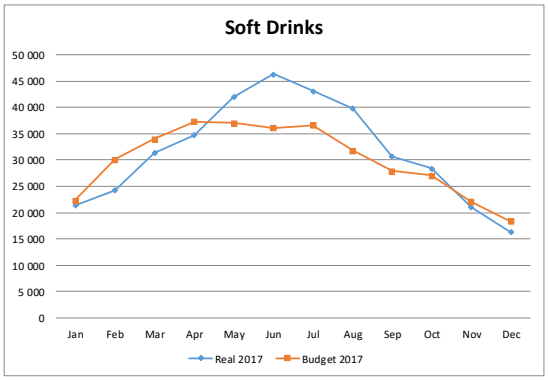

Figure 36. Deviations per month in Soft Drinks

APPENDIX B: LTP – Engine Optimizer

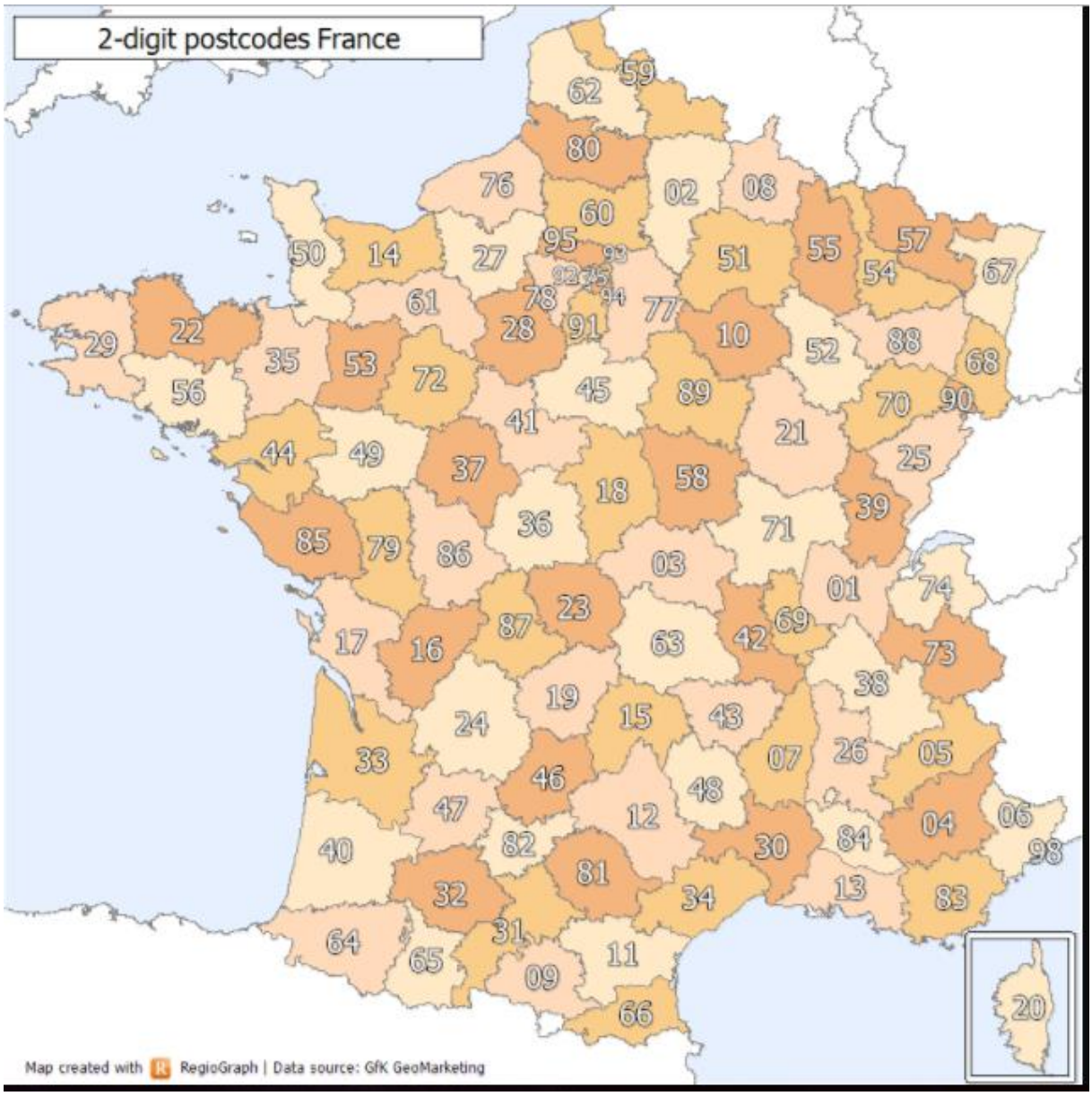

Figure 37. Two-digit postal code for France

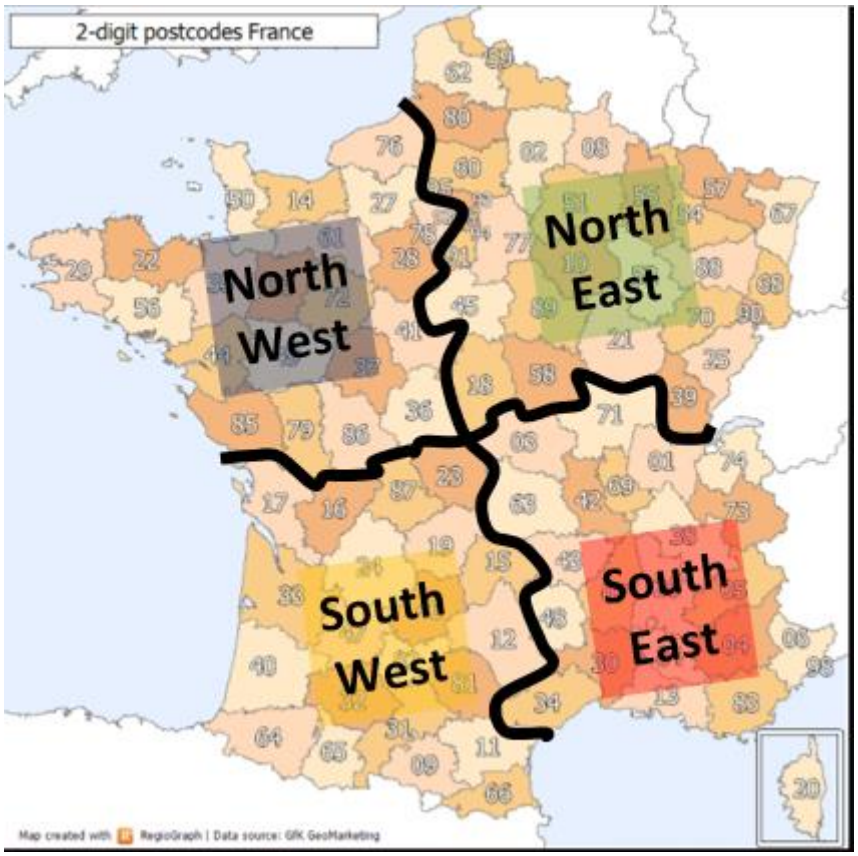

Figure 38. Region division of France in LTP

Figure 39. Regions considered in LTP. Every country outside the red line is considered as rest of the world (REST)

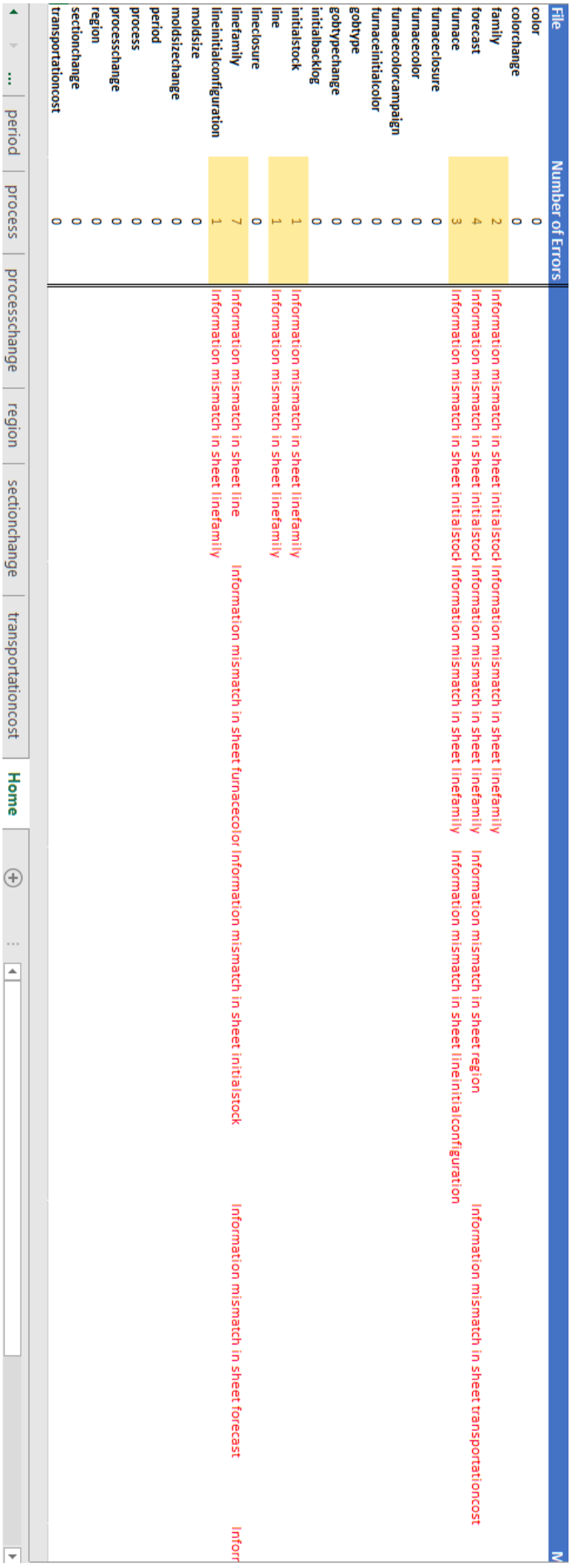

Figure 40. Result of an error check routine

Table 5. LTP Pull Analysis of the Avintes Plant

LTP Pull Analysis		Period												
		1	2	3	4	5	6	7	8	9	10	11	12	
AV2	Color Campaigns	AM	AM	AM	AM-AS	AM	AM	AM	AM	AM-AS	AM	AM	AM	Total
	Nominal capacity													
	Melted glass													
	Utilization Rate	118,1%	118,0%	118,1%	118,0%	118,3%	118,1%	118,1%	118,1%	117,9%	118,2%	118,1%	118,0%	118,1%
	Packed Prod.													
	Pack to melt	90,7%	90,8%	90,6%	88,7%	88,6%	90,7%	90,7%	90,7%	88,7%	88,5%	90,5%	90,4%	90,0%
AV4	Color Campaigns	VR	VR	VR	VR	VR	VR	VR	VR	VR	VR	VR	VR	Total
	Nominal capacity													
	Melted glass													
	Utilization Rate	88,7%	88,7%	89,9%	94,8%	89,8%	88,8%	88,7%	88,8%	88,8%	88,7%	88,8%	88,7%	89,4%
	Packed Prod.													
	Pack to melt	90,0%	90,1%	89,9%	90,0%	90,3%	90,3%	90,5%	89,8%	90,3%	90,4%	89,8%	89,5%	90,1%
AV5	Color Campaigns	UV	UV	UV	UV	UV	UV	UV	UV	UV	UV	UV	UV	Total
	Nominal capacity													
	Melted glass													
	Utilization Rate	102,3%	102,2%	102,3%	102,2%	102,2%	102,2%	102,2%	102,2%	102,2%	102,2%	102,2%	102,3%	102,2%
	Packed Prod.													
	Pack to melt	90,3%	91,6%	90,7%	88,0%	89,5%	90,6%	90,5%	89,8%	90,4%	90,1%	90,4%	89,4%	90,1%

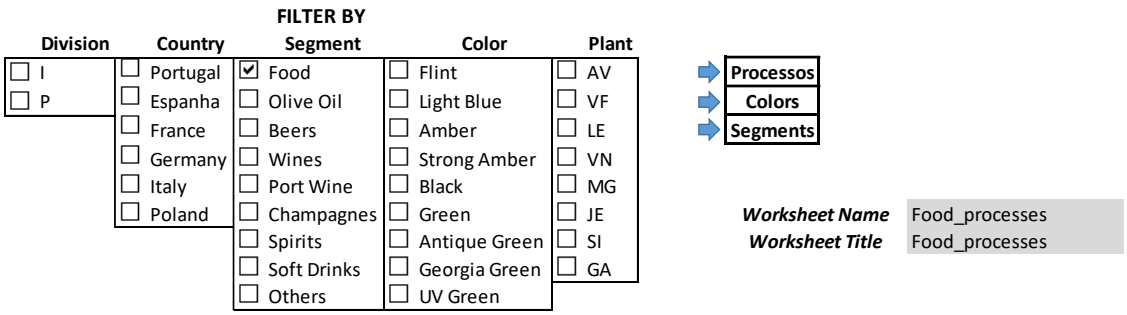

Figure 41. Generating customized reports for different layers of analysis

Table 6. Generating a report in terms of processes and sizes of the families for the food segment

		Period											
		1	2	3	4	5	6	7	8	9	10	11	12
PSGD	Initial stock	182499	178699	200918	196319	216263	198375	179315	138254	115918	88455	79207	80751
	Demand	95637	78001	114421	92344	123171	127543	153863	138381	131177	96176	93977	77974
	Production	91837	100220	109822	112287	105283	108483	112802	116045	103715	86928	95521	98745
	Final stock	178699	200918	196319	216263	198375	179315	138254	115918	88455	79207	80751	101522
	Dias de stock	**57**	**56**	**55**	**52**	**48**	**43**	**38**	**34**	**32**	**30**	**27**	**29**
PSPQ	Initial stock	230247,8	228590,8	253813,7	259887,7	274323,7	255351,2	237753,1	234849,3	250356,9	235948,1	223842	244228,2
	Demand	104998,7	88087,26	109590,5	87096,87	109813,5	111295,4	107568,7	92396,25	100923,8	89687,43	87077,1	71079,38
	Production	103341,7	113310,1	115664,5	101532,8	90841	93697,34	104664,9	107903,8	86514,96	77581,39	107463,2	123154,9
	Final stock	228590,8	253813,7	259887,7	274323,7	255351,2	237753,1	234849,3	250356,9	235948,1	223842	244228,2	296303,7
	Dias de stock	**68**	**72**	**75**	**76**	**75**	**74**	**71**	**75**	**81**	**86**	**77**	**83**
SSGD	Initial stock	4197	4197	3988	1603	1920	1791	1663	1482	785	530	411	766
	Demand	0	208	2386	711	129	129	181	697	947	999	947	674
	Production	0	0	0	1028	0	0	0	0	692	880	1302	2647
	Final stock	4197	3988	1603	1920	1791	1663	1482	785	530	411	766	2739
	Dias de stock	**146**	**114**	**111**	**149**	**394**	**160**	**82**	**50**	**24**	**18**	**23**	**78**
SSPQ	Initial stock	2718	2657	1906	3268	2852	1659	1211	509	5761	5203	4646	3903
	Demand	809	751	1158	416	1193	625	701	547	558	558	743	523
	Production	748	0	2521	0	0	177	0	5799	0	0	0	0
	Final stock	2657	1906	3268	2852	1659	1211	509	5761	5203	4646	3903	3379
	Dias de stock	**90**	**103**	**62**	**132**	**102**	**80**	**60**	**28**	**279**	**257**	**201**	**169**
Total	**Total Sum of Initial stock**	**419661**	**414143**	**460626**	**461078**	**495359**	**457177**	**419942**	**375095**	**372821**	**330137**	**308106**	**329648**
	Total Sum of Demand	**201446**	**167047**	**227556**	**180568**	**234306**	**239592**	**262314**	**232021**	**233606**	**187420**	**182744**	**150251**
	Total Sum of Production	**195927**	**213531**	**228008**	**214849**	**196124**	**202357**	**217467**	**229748**	**190922**	**165389**	**204286**	**224546**
	Total Sum of Final stock	**414143**	**460626**	**461078**	**495359**	**457177**	**419942**	**375095**	**372821**	**330137**	**308106**	**329648**	**403944**
	Dias de stock	**63**	**65**	**65**	**63**	**61**	**56**	**52**	**52**	**56**	**57**	**52**	**57**

Table 7. Generating a report for each segment

		1	2	3	4	5	6	7	8	9	10	11	12
CE	Sum of Initial stock	31 948	42 610	49 423	42 360	40 721	40 292	30 882	21 451	17 173	20 954	23 355	29 973
	Sum of Demand	18 532	17 130	27 496	22 690	26 088	33 071	33 363	24 917	19 252	19 849	17 503	14 866
	Sum of Production	29 194	23 943	20 433	21 051	25 660	23 660	23 932	20 638	23 033	22 250	24 121	22 216
	Sum of Final stock	42 610	49 423	42 360	40 721	40 292	30 882	21 451	17 173	20 954	23 355	29 973	37 322
	Days of stock	**46**	**57**	**58**	**47**	**40**	**40**	**36**	**30**	**27**	**36**	**41**	**53**
RE	Sum of Initial stock	35 775	42 092	46 997	53 465	55 185	48 172	44 611	45 836	44 281	43 404	44 052	45 075
	Sum of Demand	10 013	11 017	14 445	16 058	20 447	22 176	20 114	18 486	13 939	12 875	9 587	7 345
	Sum of Production	18 274	15 922	20 913	17 778	13 434	18 615	21 339	16 931	13 062	13 524	10 610	9 309
	Sum of Final stock	42 092	46 997	53 465	55 185	48 172	44 611	45 836	44 281	43 404	44 052	45 075	47 040
	Dias de stock	**91**	**91**	**83**	**82**	**79**	**71**	**76**	**91**	**109**	**131**	**147**	**143**
BE	Sum of Initial stock	44 704	43 948	39 277	38 053	38 115	40 017	36 894	36 265	39 114	34 780	33 862	35 517
	Sum of Demand	17 156	14 589	19 807	16 359	19 097	18 985	18 006	18 020	19 586	20 744	21 814	18 819
	Sum of Production	16 399	9 918	18 583	16 421	20 999	15 862	17 377	20 869	15 252	19 826	23 469	20 128
	Sum of Final stock	43 948	39 277	38 053	38 115	40 017	36 894	36 265	39 114	34 780	33 862	35 517	36 827
	Dias de stock	**78**	**78**	**64**	**63**	**61**	**65**	**60**	**56**	**57**	**51**	**53**	**63**
VM	Sum of Initial stock	45 577	42 064	42 188	39 198	44 825	39 961	34 919	29 650	31 983	35 564	38 023	37 982
	Sum of Demand	23 291	19 319	22 144	18 218	24 459	26 373	27 385	19 119	22 660	21 905	21 544	17 392
	Sum of Production	21 551	19 443	19 154	23 845	19 595	21 331	22 115	21 452	26 241	24 364	21 503	29 654
	Sum of Final stock	42 064	42 188	39 198	44 825	39 961	34 919	29 650	31 983	35 564	38 023	37 982	50 244
	Days of stock	**63**	**63**	**59**	**51**	**52**	**49**	**45**	**42**	**44**	**53**	**55**	**57**
VP	Sum of Initial stock	6 952	7 686	6 625	5 383	5 524	6 314	4 298	3 169	6 424	5 844	5 950	5 844
	Sum of Demand	1 614	1 518	1 878	1 451	1 925	2 258	2 498	1 318	2 852	2 321	2 320	1 804
	Sum of Production	2 348	458	636	1 591	2 716	241	1 369	4 573	2 271	2 427	2 214	2 915
	Sum of Final stock	7 686	6 625	5 383	5 524	6 314	4 298	3 169	6 424	5 844	5 950	5 844	6 955
	Dias de stock	**125**	**143**	**114**	**86**	**74**	**94**	**58**	**44**	**77**	**82**	**93**	**107**
AZ	Sum of Initial stock	10 134	10 774	11 960	11 675	12 055	11 402	9 167	7 756	6 932	5 999	4 458	4 208
	Sum of Demand	3 037	2 562	2 819	2 306	4 101	4 679	4 420	3 266	3 680	4 356	3 106	2 008
	Sum of Production	3 677	3 748	2 534	2 686	3 449	2 444	3 009	2 442	2 747	2 816	2 857	3 232
	Sum of Final stock	10 774	11 960	11 675	12 055	11 402	9 167	7 756	6 932	5 999	4 458	4 208	5 432
	Days of stock	**108**	**126**	**117**	**95**	**82**	**83**	**73**	**62**	**56**	**57**	**49**	**50**
ES	Sum of Initial stock	15 538	10 173	9 024	8 132	5 164	4 215	6 538	5 658	6 299	8 111	12 918	15 089
	Sum of Demand	9 347	6 192	6 317	4 624	2 826	2 607	2 324	220	1 270	2 507	3 138	2 151
	Sum of Production	3 982	5 043	5 424	1 656	1 876	4 931	1 443	861	3 081	7 315	5 308	1 205
	Sum of Final stock	10 173	9 024	8 132	5 164	4 215	6 538	5 658	6 299	8 111	12 918	15 089	14 142
	Days of stock	**64**	**53**	**59**	**73**	**60**	**74**	**154**	**127**	**82**	**94**	**79**	**77**
AL	Sum of Initial stock	76 619	75 612	84 098	84 181	90 440	83 469	76 671	68 483	68 068	60 274	56 252	60 185
	Sum of Demand	36 779	30 499	41 546	32 967	42 778	43 743	47 892	42 361	42 650	34 218	33 364	27 432
	Sum of Production	35 771	38 985	41 628	39 226	35 807	36 945	39 704	41 946	34 857	30 196	37 297	40 996
	Sum of Final stock	75 612	84 098	84 181	90 440	83 469	76 671	68 483	68 068	60 274	56 252	60 185	73 750
	Days of stock	**63**	**65**	**65**	**63**	**61**	**56**	**52**	**52**	**56**	**57**	**52**	**57**
OU	Sum of Initial stock	1 108	1 531	1 438	1 242	2 246	1 895	2 059	1 484	1 239	2 468	2 826	2 272
	Sum of Demand	362	183	226	216	351	286	659	582	772	909	554	263
	Sum of Production	785	91	30	1 220	0	451	83	337	2 001	1 267	0	25
	Sum of Final stock	1 531	1 438	1 242	2 246	1 895	2 059	1 484	1 239	2 468	2 826	2 272	2 034
	Days of stock	**129**	**220**	**163**	**131**	**156**	**112**	**92**	**59**	**50**	**129**	**216**	**253**
Total	Total Sum of Initial stock	**268 355**	**276 490**	**291 031**	**283 689**	**294 274**	**275 738**	**246 040**	**219 750**	**221 513**	**217 398**	**221 697**	**236 144**
	Total Sum of Demand	**120 130**	**103 009**	**136 677**	**114 888**	**142 072**	**154 178**	**156 660**	**128 288**	**126 661**	**119 685**	**112 932**	**92 080**
	Total Sum of Production	**131 983**	**117 550**	**129 335**	**125 473**	**123 536**	**124 480**	**130 371**	**130 051**	**122 545**	**123 984**	**127 379**	**129 681**
	Total Sum of Final stock	**276 490**	**291 031**	**283 689**	**294 274**	**275 738**	**246 040**	**219 750**	**221 513**	**217 398**	**221 697**	**236 144**	**273 746**
	Days of stock	**67**	**70**	**67**	**62**	**58**	**57**	**54**	**53**	**55**	**60**	**97**	**231**

Table 8. Generating a report for each color

		1	2	3	4	5	6	7	8	9	10	11	12
AM	Sum of Initial stock	23 899	30 223	34 108	31 932	29 757	28 185	19 103	11 377	9 923	10 984	13 286	17 984
	Sum of Demand	13 761	13 777	21 376	19 126	21 470	28 069	27 884	21 140	16 312	17 165	14 387	13 022
	Sum of Production	20 085	17 662	19 200	16 950	19 898	18 987	20 159	19 686	17 373	19 467	19 084	19 175
	Sum of Final stock	30 223	34 108	31 932	29 757	28 185	19 103	11 377	9 923	10 984	13 286	17 984	24 136
	Days of stock	**44**	**50**	**50**	**42**	**35**	**33**	**26**	**19**	**19**	**22**	**29**	**40**
AS	Sum of Initial stock	1 559	905	714	436	1 906	1 527	1 075	854	765	1 991	1 726	1 381
	Sum of Demand	654	191	278	307	379	452	221	89	242	264	346	328
	Sum of Production	0	0	0	1 777	0	0	0	0	1 468	0	0	0
	Sum of Final stock	905	714	436	1 906	1 527	1 075	854	765	1 991	1 726	1 381	1 053
	Dias de stock	**125**	**105**	**67**	**34**	**163**	**180**	**175**	**129**	**81**	**191**	**117**	**106**
BA	Sum of Initial stock	6 043	5 072	4 289	6 095	8 089	6 505	5 054	7 234	5 760	4 669	3 869	3 109
	Sum of Demand	970	783	815	1 560	1 583	1 678	1 554	1 474	1 091	800	760	567
	Sum of Production	0	0	2 621	3 554	0	226	3 733	0	0	0	0	0
	Sum of Final stock	5 072	4 289	6 095	8 089	6 505	5 054	7 234	5 760	4 669	3 869	3 109	2 542
	Dias de stock	**212**	**145**	**98**	**114**	**151**	**124**	**110**	**193**	**196**	**198**	**152**	**121**
BR	Sum of Initial stock	178 619	181 454	193 121	188 923	197 671	185 708	173 762	159 498	160 567	156 282	159 585	171 027
	Sum of Demand	72 965	64 236	84 588	68 555	88 932	91 339	94 014	82 630	81 563	73 998	71 042	57 913
	Sum of Production	79 518	75 903	80 390	77 303	76 969	79 393	79 750	83 699	77 278	77 301	82 484	84 098
	Sum of Final stock	181 454	193 121	188 923	197 671	185 708	173 762	159 498	160 567	156 282	159 585	171 027	197 212
	Days of stock	**72**	**75**	**72**	**68**	**65**	**62**	**61**	**60**	**64**	**69**	**71**	**79**
PR	Sum of Initial stock	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of Demand	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of Production	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of Final stock	0	0	0	0	0	0	0	0	0	0	0	0
	Dias de stock	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
UV	Sum of Initial stock	23 839	18 851	20 420	21 649	19 459	18 654	16 479	14 840	17 052	20 468	27 212	25 175
	Sum of Demand	15 503	10 902	14 134	12 094	11 211	12 364	12 159	8 230	11 370	11 833	12 208	9 904
	Sum of Production	10 516	12 471	15 362	9 905	10 406	10 189	10 520	10 442	14 785	18 578	10 171	10 398
	Sum of Final stock	18 851	20 420	21 649	19 459	18 654	16 479	14 840	17 052	20 468	27 212	25 175	25 669
	Days of stock	**53**	**46**	**49**	**55**	**49**	**51**	**47**	**42**	**43**	**54**	**65**	**62**
VB	Sum of Initial stock	22 741	22 978	21 206	19 210	22 415	21 781	19 422	16 947	18 945	13 664	5 194	5 656
	Sum of Demand	10 792	8 472	8 372	7 277	11 489	12 874	13 331	8 908	11 261	11 767	10 034	7 288
	Sum of Production	11 030	6 699	6 375	10 482	10 856	10 514	10 856	10 906	5 981	3 297	10 496	10 717
	Sum of Final stock	22 978	21 206	19 210	22 415	21 781	19 422	16 947	18 945	13 664	5 194	5 656	9 085
	Days of stock	**74**	**86**	**70**	**55**	**54**	**56**	**52**	**48**	**52**	**42**	**17**	**19**
VG	Sum of Initial stock	610	5 986	5 876	5 409	4 398	3 704	2 870	2 048	1 343	1 191	1 063	858
	Sum of Demand	136	110	467	1 011	694	834	822	705	642	128	205	60
	Sum of Production	5 512	0	0	0	0	0	0	0	490	0	0	0
	Sum of Final stock	5 986	5 876	5 409	4 398	3 704	2 870	2 048	1 343	1 191	1 063	858	798
	Dias de stock	**77**	**339**	**243**	**192**	**168**	**141**	**119**	**125**	**124**	**273**	**238**	**252**
VR	Sum of Initial stock	11 046	11 021	11 296	10 036	10 580	9 673	8 276	6 952	7 158	8 149	9 761	10 954
	Sum of Demand	5 347	4 539	6 648	4 959	6 314	6 568	6 676	5 112	4 180	3 731	3 949	2 998
	Sum of Production	5 322	4 815	5 387	5 503	5 407	5 171	5 353	5 318	5 171	5 343	5 143	5 293
	Sum of Final stock	11 021	11 296	10 036	10 580	9 673	8 276	6 952	7 158	8 149	9 761	10 954	13 250
	Days of stock	**60**	**61**	**57**	**51**	**49**	**47**	**47**	**48**	**54**	**69**	**71**	**77**
Total	Total Sum of Initial stock	**268 355**	**276 490**	**291 031**	**283 689**	**294 274**	**275 738**	**246 040**	**219 750**	**221 513**	**217 398**	**221 697**	**236 144**
	Total Sum of Demand	**120 130**	**103 009**	**136 677**	**114 888**	**142 072**	**154 178**	**156 660**	**128 288**	**126 661**	**119 685**	**112 932**	**92 080**
	Total Sum of Production	**131 983**	**117 550**	**129 335**	**125 473**	**123 536**	**124 480**	**130 371**	**130 051**	**122 545**	**123 984**	**127 379**	**129 681**
	Total Sum of Final stock	**276 490**	**291 031**	**283 689**	**294 274**	**275 738**	**246 040**	**219 750**	**221 513**	**217 398**	**221 697**	**236 144**	**273 746**
	Days of stock	**67**	**70**	**67**	**62**	**58**	**57**	**54**	**53**	**55**	**60**	**61**	**67**

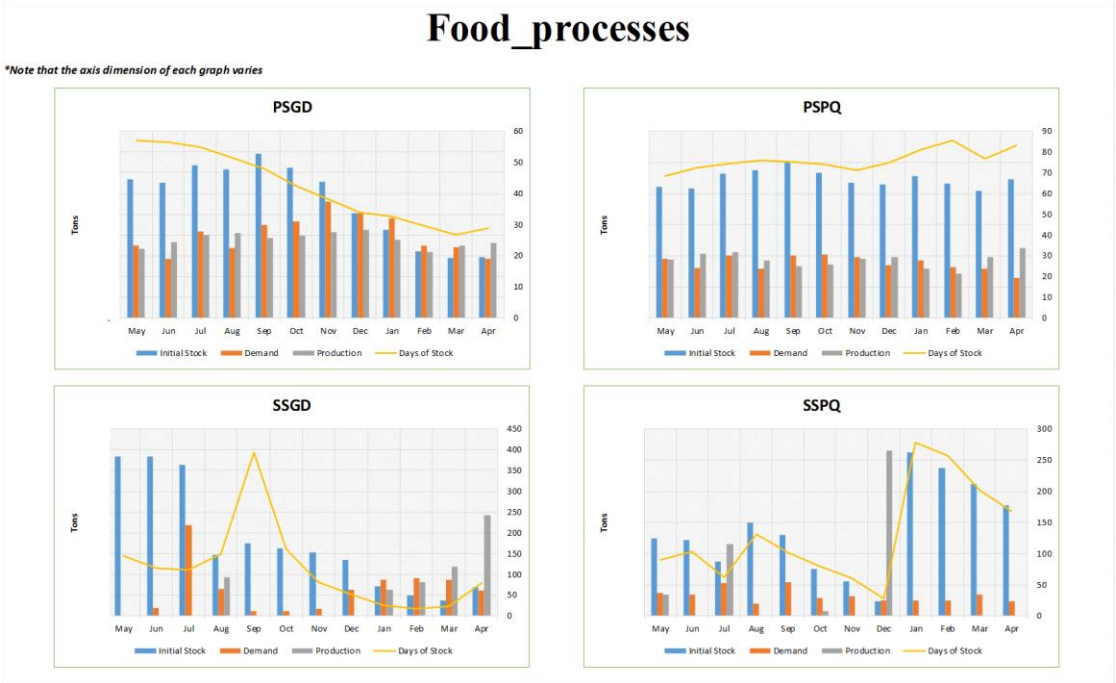

Figure 42. Chart report based on the report present in APPENDIX B Table 6

Table 9. Productions of each plant in real 2016 versus the LTP - percental deviation.

% Deviation	Periods												
Plants	1	2	3	4	5	6	7	8	9	10	11	12	Total
AV	-6%	-8%	-4%	-10%	-6%	-4%	-6%	-1%	-11%	-5%	-6%	-4%	-6%
GA	24%	20%	24%	19%	22%	27%	23%	19%	-2%	8%	-2%	-8%	1%
JE	-3%	-1%	0%	-5%	-2%	-5%	-4%	-2%	46%	87%	51%	9%	28%
LE	4%	-4%	-7%	-5%	-5%	-1%	-4%	-6%	-3%	-6%	-6%	-10%	-4%
MG	11%	14%	12%	18%	11%	9%	6%	10%	-6%	-8%	-4%	-4%	-4%
SI	6%	-2%	-2%	-4%	-3%	-2%	-9%	-11%	4%	5%	10%	9%	10%
VF	11%	24%	13%	9%	2%	10%	9%	5%	4%	4%	9%	6%	-4%
VN	6%	3%	2%	0%	1%	3%	0%	0%	0%	2%	2%	-1%	1%
Total													

Table 10. Transportation Costs (in euros) to each LTP region in real 2016 versus the LTP and its percental deviation.

Region	Period 1	2	3	4	5	6	7	8	9	10	11	12	Total
R1	2 600	596	4 127		3 200				2 350	2 900	552	3 200	19 525
R2	327 536	249 064	304 370	286 181	184 553	399 357	254 120	485 674	448 066	365 929	330 846	322 556	3 958 252
R3	70 884	100 636	90 933	105 871	121 339	109 225	75 565	45 224	80 832	45 342	32 723	48 431	927 005
R4	6 600	2 350	10 866	5 625	6 900	6 108	4 128	21 001	9 669	12 994	12 537		98 779
R5	14 789	11 815	19 440	7 269	13 286	33 315	19 123	12 308	13 216	11 793	13 178	10 132	179 665
R6	69 931	117 611	107 656	140 935	112 773	117 925	173 892	271 428	191 778	196 393	191 022	246 958	1 938 302
R7	66 420	52 629	67 388	64 257	62 887	74 750	60 101	61 917	25 830	53 320	41 000	41 190	671 689
R8	1 211 100	1 473 974	1 462 155	1 389 536	1 410 335	1 526 511	1 256 098	1 310 951	1 349 766	1 236 818	1 612 780	1 176 879	16 416 904
R9	880 439	908 465	1 017 451	1 054 544	856 816	1 039 720	921 441	1 042 590	1 029 200	930 715	1 009 935	970 469	11 661 785
R10	12 630	7 825	1 595	56 100	12 065	3 700	32 390		29 715	24 310	32 914	20 250	233 494
R11	186 086	156 147	212 654	233 661	296 229	385 747	324 281	232 691	319 882	230 380	247 599	169 828	2 995 185
R12	10 659	8 838	6 667	7 587	7 392	16 147	5 728	5 292	10 639	9 796	16 533	7 955	113 234
R13	32 679	38 863	40 569	50 331	43 066	46 560	56 160	46 583	70 978	39 763	51 051	35 301	551 903
R14	11 287	14 971	34 403	10 609	19 972	43 520	36 469	33 355	38 271	46 398	32 189	28 222	349 666
R15	260 721	332 230	322 035	307 966	260 046	279 702	227 823	236 283	240 666	271 029	305 570	252 050	3 296 121
REST	930 774	735 976	900 577	866 798	780 597	887 050	763 675	788 602	810 340	652 163	627 803	567 738	9 312 094
R16		13 050	13 050	16 762	17 400	9 125	1 240	5 590	4 825		5 800	6 034	92 875
R17	727					1 457	4 260						6 445
Total	4 095 862	4 225 042	4 615 938	4 604 031	4 208 855	4 979 919	4 216 496	4 599 488	4 676 024	4 130 043	4 564 032	3 907 193	**52 822 922**

Region	Period 1	2	3	4	5	6	7	8	9	10	11	12	Total
R1	2 990	662	4 581	-	3 680	-	-	-	2 491	3 219	618	3 456	21 697
R2	363 565	256 536	325 676	297 628	193 780	415 331	274 450	509 957	470 470	402 522	347 389	358 037	4 215 341
R3	75 137	113 719	100 935	111 164	131 046	117 963	80 099	51 555	88 107	48 062	35 996	52 306	1 006 089
R4	8 118	2 820	11 410	6 413	7 866	6 780	5 160	24 361	11 313	14 034	15 295	-	113 569
R5	16 268	13 115	21 578	8 141	14 216	35 980	21 418	13 170	14 670	13 208	14 496	10 943	197 204
R6	81 120	134 077	124 881	160 666	128 561	132 076	206 932	325 713	218 627	221 924	219 675	279 063	2 233 314
R7	71 069	55 787	72 779	67 470	67 918	80 730	62 505	62 536	26 605	54 920	41 410	41 602	705 330
R8	1 404 875	1 577 152	1 476 776	1 417 327	1 438 542	1 557 041	1 281 220	1 337 170	1 390 259	1 335 764	1 677 291	1 247 492	17 140 910
R9	1 100 548	1 253 682	1 241 291	1 275 998	1 148 133	1 382 827	1 243 945	1 386 644	1 389 420	1 163 394	1 373 512	1 213 086	15 172 481
R10	14 019	9 234	1 930	71 808	13 754	4 699	39 192	-	35 658	27 957	36 534	25 110	279 894
R11	204 695	179 569	236 046	259 363	337 701	439 752	369 680	267 595	367 865	255 722	277 310	195 302	3 390 600
R12	13 537	10 782	8 601	9 332	9 536	20 991	6 931	6 721	13 405	12 245	20 005	9 784	141 871
R13	36 928	41 583	46 655	55 364	46 511	49 353	61 214	49 844	80 205	45 727	56 667	40 596	610 646
R14	12 077	15 720	36 467	10 927	22 768	44 825	36 834	38 025	43 247	50 109	37 018	31 044	379 061
R15	284 185	365 453	354 239	348 002	273 048	296 484	241 493	262 274	257 512	292 712	339 183	277 255	3 591 840
REST	1 452 008	1 037 727	1 431 918	1 360 873	1 163 090	1 410 409	1 214 243	1 253 877	1 239 821	1 023 895	916 593	857 284	14 361 738
R16	-	15 921	15 791	20 449	21 576	11 680	1 587	6 708	5 982	-	6 960	7 723	114 378
R17	851	-	-	-	-	1 749	4 942	-	-	-	-	-	7 542
Total	5 141 991	5 083 538	5 511 553	5 480 926	5 021 726	6 008 672	5 151 845	5 596 150	5 655 656	4 965 414	5 415 951	4 650 083	**63 683 505**

Region	Period 1	2	3	4	5	6	7	8	9	10	11	12	Total
R1	15%	11%	11%		15%				6%	11%	12%	8%	11%
R2	11%	3%	7%	4%	5%	4%	8%	5%	5%	10%	5%	11%	7%
R3	6%	13%	11%	5%	8%	8%	6%	14%	9%	6%	10%	8%	9%
R4	23%	20%	5%	14%	14%	11%	25%	16%	17%	8%	22%		16%
R5	10%	11%	11%	12%	7%	8%	12%	7%	11%	12%	10%	8%	10%
R6	16%	14%	16%	14%	14%	12%	19%	20%	14%	13%	15%	13%	15%
R7	7%	6%	8%	5%	8%	8%	4%	1%	3%	3%	1%	1%	5%
R8	16%	7%	1%	2%	2%	2%	2%	2%	3%	8%	4%	6%	5%
R9	25%	38%	22%	21%	34%	33%	35%	33%	35%	25%	36%	25%	30%
R10	11%	18%	21%	28%	14%	27%	21%		20%	15%	11%	24%	19%
R11	10%	15%	11%	11%	14%	14%	14%	15%	15%	11%	12%	15%	13%
R12	27%	22%	29%	23%	29%	30%	21%	27%	26%	25%	21%	23%	25%
R13	13%	7%	15%	10%	8%	6%	9%	7%	13%	15%	11%	15%	11%
R14	7%	5%	6%	3%	14%	3%	1%	14%	13%	8%	15%	10%	8%
R15	9%	10%	10%	13%	5%	6%	6%	11%	7%	8%	11%	10%	9%
REST	56%	41%	59%	57%	49%	59%	59%	59%	53%	57%	46%	51%	54%
R16		22%	21%	22%	24%	28%	28%	20%	24%		20%	28%	24%
R17	17%					20%	16%						18%
Total	26%	20%	19%	19%	19%	21%	22%	22%	21%	20%	19%	19%	**21%**