Universidade de Aveiro Departamento de Economia, Gestão, Engenharia Industrial e Turismo
2019

Ana Rita de Melo Pascoal Arromba

MELHORIA DOS FLUXOS DE INFORMAÇÃO NO PROCESSO DE PLANEAMENTO DA PRODUÇÃO: PROPOSTA DE UMA DASHBOARD SUPORTADA EM KPIs

IMPROVING INFORMATION FLOWS IN THE PRODUCTION PLANNING PROCESS: PROPOSAL OF A DASHBOARD BASED ON KPIs

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Relatório de Projeto apresentado à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia e Gestão Industrial, realizado sob a orientação científica da Prof. Doutora Ana Raquel Reis Couto Xambre, Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro, e coorientação da Prof. Doutora Leonor da Conceição Teixeira, Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro.

As melhores oportunidades surgem dos desafios mais difíceis.

Dedico este projeto a todos os que criam os desafios,
aos que os vivem diariamente comigo,
aos que me ajudam a ultrapassá-los,
e aos que me ensinam a abraçar as novas oportunidades.

o júri

presidente

Prof.ª Doutora Maria João Machado Pires da Rosa
Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro

Prof. Doutor Cristóvão Silva
Professor Auxiliar do Departamento de Engenharia Mecânica da Faculdade de Ciências e Tecnologia da Universidade de Coimbra

Prof.ª Doutora Ana Raquel Reis Couto Xambre
Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro

agradecimentos

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"Põe quanto és no mínimo que fazes". Ricardo Reis

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palavras-chave

Planeamento da Produção, Mapeamento de Processos, BPMN, Sistemas de Informação, Lean, Indústria 4.0

resumo

Hoje em dia a evolução tecnológica está a desencadear grandes mudanças no contexto das organizações, bem como no ambiente em que operam. Por sua vez, estas dinâmicas têm contribuído para que as organizações repensem a forma de trabalhar, observando-se uma necessidade contínua de melhorar os processos de maneira a ganhar eficiência e alcançar situações de vantagem competitiva.

Este relatório apresenta um estudo que foi conduzido numa multinacional dedicada à produção de componentes sanitários, mais especificamente no departamento de planeamento e controlo da produção, com foco na melhoria dos seus processos de informação.

O principal objetivo deste projeto consistiu na redução das ineficiências presentes nos fluxos de informação associados ao planeamento da produção, usando, para o efeito, ferramentas de mapeamento de processos, bem como técnicas de análise de desperdícios.

Enquanto o *BPMN 2.0* foi a linguagem escolhida para mapear os processos, identificar as fontes de dados e os fluxos de informação, as ferramentas *Lean* foram usadas para identificar as atividades de não valor acrescentado e, consequentemente, os desperdícios presentes naqueles processos. Por forma a fazer a prova de conceito utilizou-se a ferramenta *Microsoft Power BI*, vindo esta a constituir um Sistema de Informação orientado às necessidades da Indústria 4.0.

Como contributo prático deste projeto espera-se que esta solução, que integra pessoas, dados, fluxos e processos, venha a potenciar ganhos de eficiência nas tarefas diárias dos planeadores, nos processos de tomada de decisão e na identificação e eliminação de atividades de não valor acrescentado, melhorando, assim, o desempenho global do planeamento.

keywords

Production Planning, Process Mapping, BPMN, Information Systems, Lean, Industry 4.0

abstract

Technological evolution is currently triggering changes in companies' practices as well as in the environment they operate. This dynamic has led companies to rethink the way they work, trying to, continuously, improve their processes as a way of gaining efficiency and competitiveness.

This report presents a study developed in a sanitary systems multinational manufacturer, more specifically in its production planning and control department, with a focus on improving its information processes.

The main goal of this project was to reduce the existing inefficiencies associated to the production planning information flows, using, for that purpose, process mapping tools, as well as waste analyses techniques.

While BPMN 2.0 was the language chosen to map the processes, identify the data sources and information flows; Lean tools were used to identify non-value-added activities and, consequently, waste present in the processes. As proof of concept, Microsoft Power BI tool was used as a base for and Information System, guided by Industry 4.0 principles and needs.

The main practical contribution of this work should be that this solution, which integrates people, data, flows and processes, may contribute to efficiency gains in the daily tasks of the planners, in the decision-making processes and in the identification and elimination of non-value-added activities, improving the global planning performance.

Table of Contents

1. Introduction 1
1.1 Motivation and Background of the Work 1
1.2 Objectives and Methodology 2
1.3 Structure of the Report 4
2. State of the Art 5
2.1 Lean Information Management and BPMN 5
2.2 Industry 4.0 and Data Management 7
2.3 Information Systems and Business Intelligence 10
2.4 Production Planning and KPIs 13
2.5 Some Final Remarks 16
3. Organization and Problem Contextualization 17
3.1 Company Presentation 17
3.1.1 GROHE 17
3.1.2 GROHE in Portugal 18
3.1.3 Production Process 19
3.1.4 Products 20
3.2 Problem Contextualization 24
3.2.1 Data Sources Collection by the Company 24
3.2.2 GROHE’s Production Planning and Control: AS-IS Model 24
3.2.3 KPIs used by the company 32
3.3 Problem Description and Analysis 36
3.3.1 KPIs Issues 36
3.3.2 Planning Main Issues 37
3.3.3 Some Final Remarks 41
4. Proposed Solution: Process Analysis, Methodology and Solutions Developed 43
4.1 About Power BI 43
4.2 About Process Analysis and Methodology 44
4.3 Solutions Developed 47
4.3.1 Process Identification and Systems Requirements 47

4.3.2 Process Discovery 48
4.3.3 Process Analysis and Requirements Analysis 48
4.3.4 Process Re-design and Solution Design 48
4.3.5 Information System Development 49
a) The Scenario Before 50
b) The Scenario After 54
4.3.6 Information System Analysis 67
a) Practical Metrics 67
b) Dashboard Metrics 67
c) LIM Metrics 69
4.4 Decision-Making Support Files 72
4.4.1 Truck Expedition File 72
4.4.2 MRP Files 78
4.5 Some Final Remarks 82
5. Conclusions, Limitations and Future Work 83
5.1 Conclusions 83
5.2 Limitations and Future Work 85
Bibliographic References 87

List of Illustrations

Figure 1 - Business Intelligence published papers (Liu & Liang, 2018) 12
Figure 2 - Production Flow.. 20
Figure 3 - Products Categorization 21
Figure 4 - An Example of a Product Categorization... 21
Figure 5 - Grohe RED (GROHE Red, n.d.) 22
Figure 6 - Update KPIs Business Process Model.. 26
Figure 7 - Assembly Plan Business Process Model 27
Figure 8 - Pre-Process Plan Business Process Model 27
Figure 9 - PVD Plan Business Process Model.. 29
Figure 10 - Production Planning Business Process Model... 30
Figure 11 - Production planning in a pull logic 31
Figure 12 - KPIs used every morning 32
Figure 13 - BTS for PVD production plan 33
Figure 14 - Backlog information 34
Figure 15 - OTIF.. 35
Figure 16 - Availability information 35
Figure 17 - Ishikawa Diagram 38
Figure 18 - Hidden problems of production planning 39
Figure 19 - BPM Life Cycle (Dumas et al., 2018).. 44
Figure 20 - Ramingwong SD Life Cycle Perspective (Ramingwong, 2012) 45
Figure 21 - Waterfall Model (Royce, 1970) 46
Figure 22 - BPM Life Cycle with the SD Life Cycle (adapted)... 47
Figure 23 - Information about Backlogs 51
Figure 24 - Excess of information 51
Figure 25 - File used to perform production control.. 52
Figure 26 - Indicators control 52
Figure 27 - Graphic for the indicators control 53
Figure 28 - Data imported from the Excel file 54
Figure 29 - Initial Interface (KPIs) 55
Figure 30 - Refresh Button... 55
Figure 31 - Overview of the indicators 56
Figure 32 - Overview considering the drill-down 56
Figure 33 - Overview considering a year 57
Figure 34 - Overview considering a set of years 57
Figure 35 - Backlog overview.. 58
Figure 36 - Backlog in 2017.. 58
Figure 37 - OTIF overview... 59
Figure 38 - OTIF overview of the 20th of September 59
Figure 39 - SS overview.. 60
Figure 40 - SS overview considering 3 years 60
Figure 41 - Information about Backlog - excel file 61
Figure 42 - Initial Interface (Top 200)... 61
Figure 43 - Top 200 overview (backlog and transit).. 62
Figure 44 - Backlog overview.. 62

Figure 45 - Example of Backlog Analysis (Product 32843000) 63
Figure 46 - Example of Backlog Analysis (Product 32661001) 63
Figure 47 - In Transit overview 64
Figure 48 - Availability overview 64
Figure 49 - SS overview.. 65
Figure 50 - Example of SS Analysis (Stock > SS)... 66
Figure 51 - Example of SS Analysis (Stock < SS)... 66
Figure 52 - Dashboard Overview 68
Figure 53 - Other plants requirements... 73
Figure 54 - Stocks.. 74
Figure 55 - Queries and Connections 75
Figure 56 - Decision-making for the truck expedition.. 76
Figure 57 - MRP logic 78
Figure 58 - Example of MRP file 80
Figure 59 - Stocks and BOMs information.. 80
Figure 60 - Example of MRP file (subcomponents) 81

List of Tables

Table 1- Impacts on Information Flows (Before).. 69
Table 2 - Expected Improvements on Information Flows (After)................................... 70

List of Abbreviations

BI – Business Intelligence
BOM – Bill of Materials
BPM – Business Process Management
BPMN – Business Process Model and Notation
ERP – Enterprise Resource Planning
IS – Information System
I4.0 – Industry 4.0
KPI – Key Performance Indicator
LIM – Lean Information Management
LT – Lean Thinking
MRP – Material Requirements Planning
PVD – Physical Vapour Deposition
SD – System Development
SS – Safety Stock

1. Introduction

The present report aims to show the work developed at the production planning and control department of GROHE Portugal, *Componentes Sanitários, Lda*. This production plant, where the study was performed, is located in Albergaria-a-Velha, and is one of the five plants of the group.

1.1 Motivation and Background of the Work

The rapid pace at which technology has been evolving is notable and intrinsically present in our days. Technological evolution connected to a fresh new wave of innovation is triggering changes in companies' environments and in how they face the markets. However, with the exponential development that it has had, technology can also lead to unstable competitive environments (Hitt, Ireland, & Hoskisson, 2011). According to the same authors, a company is competitive if it can formulate and implement a strategy capable of adding value, considering its surroundings. Gröger, Hillmann, Hahn, Mitschang, & Westkämper (2013) also consider that, because the world is becoming more and more globalized, some companies may feel a constant and growing competition in a high volatile and unstable environment.

To succeed in such environments, companies must seek to improve their business processes to ease information flows, create value for the customers and achieve strategic results, connecting all its departments (Paim, Mansur Caulliraux, & Cardoso, 2008). Notwithstanding and as dynamic organisms, corporations need to be continuously adapting to new situations, aligning and shaping strategies to achieve competitive advantage.

In order to accomplish this philosophy, it is essential to understand that communication and information sharing are two vital factors for the prosperity of any supply chain. If they fail, so will the dynamic of the supply chain. Phenomenons like the Bullwhip Effect, that happen when the orders unpredictability increase as we move upstream in the supply chain, are a result of a lack of communication and information sharing, and it should be mitigated (X. Wang & Disney, 2016).

The technological progress may also influence the capacity and balance of the production lines, causing several consequences. Production environments are now more and more complex. Demand swings of some specific products, modifications in the machines used, fluctuations in learning and know-how of the employees and new products and raw materials may lead to disparities in the production lines, affecting the already defined strategy of the company (Oliveira, Da Paz, Da Silva, & Ferreira, 2017).

Moreover, the production planning and control is an area sensitive to the above-mentioned factors and recent years have shown an increasing complexity associated with the production plans. This has been happening because of different sales forecasts, changes in the delivery deadlines, smaller dimensions batches, products customization, a higher variety of orders or even absenteeism. By reducing the waste in physical and information flows, and by organizing the information in reports, it is possible to reduce the impact of these changes and make the processes more agile.

It is important to understand what can go wrong and what can be done to avoid problems and to enhance the implementation and achievement of a good strategy to gain competitive advantage. As such, the main goal of this project is to contribute to the development of features that can help to boost processes and allow the accomplishment of the goals of this specific company.

The present document characterises the work completed in a sanitary systems multinational corporation that focused on improving the global performance in the production planning and control department. In this department, the production plans are constantly being adjusted, consequently the production planners need a strict organization of information, namely regarding Key Performance Indicators (KPIs), to enable an efficient decision-making (Gelders & Van Wassenhove, 1981).

GROHE is a company that adheres to the technological evolution and, as proof of that, there are the increasingly modern and complex products that it produces. By all the reasons explained before, it is crucial to monitor the processes and to understand what can be improved. This is expected to be achieved by combining several languages and concepts, namely the Business Process Model and Notation 2.0 (BPMN 2.0), Business Intelligence (BI) tools, Lean Thinking (LT), Information Systems (IS) and Industry 4.0 (I4.0) principles. The foreseen result is an Information System that connects several aspects related with the processes, in a way that efficiency is achieved in the production planning daily tasks, in the decision-making and in the elimination of the non-value-added activities.

1.2 Objectives and Methodology

The main objective of the work is to improve the production planning process, through the reduction of the waste present in the information flows. To accomplish this, it is essential to map the processes, the relevant information flows, identifying the information sources and aligning these elements, so that the information is correct and suitable for the right people in the right time. The specific goals will be:

- Training and gaining knowledge of the sector to understand, not only the existing dynamic between the Production Planning and the Supply Chain Management, but also the interaction with other departments;
- Identification of the information sources and mapping information flows, eliminating waste in the processes associated with the development of the production plans or other relevant tasks for planning;
- Creation of an autonomous system that gathers, centralizes and shows the wanted information in near real time, specifically an interactive dashboard with an easy and intuitive updating to quickly view the status of several indicators;
- Definition and provision of new indicators depending on the current needs, leading to an improvement of customer service and the reduction of backlog.

A methodology must be followed throughout the project to achieve what was previously mentioned. The first stage, after the development of the bibliographic review to fulfil the theoretical background, is to **describe the current situation** of production planning and it encompasses the following steps:

- Observation of the planners' daily tasks, distinguishing the tasks that are associated with the production plans and, from the ones that are, what are the general and specific steps while developing the plan;
- Process mapping and analysis using BPMN 2.0 (AS-IS model);
- Identification of the main information flows;
- Identification of the main data sources;
- Identification of the main production planning problems;
- Characterization of the KPIs used throughout the planning.

The second step is the **description of the ideal future situation**, this is:

- Monitorization and uniformization of the data sources to simplify the process;
- Elimination of data redundancy;
- Selection of the most important KPIs, from the universe of indicators;
- Development of a history of KPIs that is easy and quick to examine;
- Introduction of new indicators, if those indicators are relevant to the situations that the planners must monitor;
- Improvement of the update of some of these indicators;
- Identification and improvement of the update of other files that support the planning;
- Comparison of the current and future situations to understand the impact on the results;
- Gathering of the important information to the conceptualization of the dashboard.

In the last phase, the objective is to **develop the visual tool of indicators** (dashboard), that will help to reduce visual waste. This order will be followed:

- Screening the pertinent data and files to be used;
- Joining the information in the same source;
- Set and develop the dashboard with the support of the software *Microsoft Power BI*;
- Understand the wanted visualization of the information;
- Perform tests to the proof-of-concept;
- Description of the types of waste that are being eliminated;
- Definition of metrics to evaluate the information system.

Following these steps, it is fundamental to get to know the dynamic of this company's processes, to describe them, to perform the data collection and to develop the dashboard. Therefore, the fulfilment of the methodology will determine the project's success. Moreover, this report is divided in several sections, according to the steps described in the methodology.

1.3 Structure of the Report

As mentioned, this work is structured in 5 chapters, defined in accordance to the methodology described previously.

In the present chapter, chapter 1, a brief background and introduction was presented to better understand the motivation of the report. Furthermore, the methodology and the objectives expected to be fulfilled are also exposed.

In chapter 2, a theoretical background with the most relevant concepts is presented. This background is fundamental to clearly perceive the contents that support the work developed.

In chapter 3, the focus is on the explanation of the practical case by describing the current situation of the company, the production planning and control department and its main difficulties.

In chapter 4, a process analysis will be performed, considering two different process life cycles. The before and after situations are presented, considering several different aspects. Finally, the solutions are proposed, as well as a critical analysis of the results obtained, and a general overview of the work developed.

In chapter 5, the main conclusions and limitations are described. This chapter also addresses some future work perspectives and suggestions.

2. State of the Art

In this section, the main concepts behind the development of this work are briefly presented. This state of the art is mainly focused on four big groups and how they interconnect to each other and are used in Production Planning and Control contexts. Those topics are: Lean Thinking, more focused on the Lean Information Management area; Business Process Modelling; Industry 4.0; Data Management, Information Systems and Business Intelligence.

2.1 Lean Information Management and BPMN

Business Process Model and Notation is one of the concepts that will support this work. Nevertheless, it is crucial to start from the beginning to understand the big picture. Business Processes are a set of related and coordinated activities that create value to customers, allowing a company to achieve certain strategic results (Dumas, La Rosa, Mendling, & Reijers, 2018); (Paim et al., 2008). If these processes are not correctly managed, they do not show their maximum value.

According to Chinosi & Trombetta (2012), Business Process Management (BPM) allows to improve agility and operational performance in a business process environment. It is an opportunity to simplify and optimize processes and operations (Arevalo, Escalona, Ramos, & Domínguez-Muñoz, 2016). Harmon (2007) states that Business Process Management increases the company's productivity and competitiveness while developing the business process architecture. It is crucial to identify the stages of the business process management life cycle: process identification, discovery, analysis, re-design, implementation and monitoring and control (Dumas et al., 2018). This cycle represents the framework to decompose and analyse specific processes.

Business Process Modelling arises as the representation of processes considering the "time period when manual or automated workflow descriptions are defined electronically" and it is performed to achieve process efficiency (Chinosi & Trombetta, 2012). Aguilar-Savén (2004) and Awadid (2017) state that business process modelling allows the analysis, identification and specification of business processes, being key to characterise the flows between internal and external environments of a company (Ouali, Mhiri, & Bouzguenda, 2016).

In order to apply these concepts, Chinosi & Trombetta (2012) give an overview about Business Process Model and Notation (BPMN) defining it as a graphical representation of the processes occurring in an organization and as the "leading standard in the frame of business processes and workflow modelling languages". Chinosi & Trombetta (2012) and Arevalo et al. (2016) agree that one of the weaknesses of BPMN are the poorly time rules. For example, Arevalo et al. (2016) already defined a time rule taxonomy found in some business processes and tried to apply it by using BPMN 2.0. Despite being a weak point of this language, it will not be a problem in this case, and it is possible to state that BPMN 2.0 is one of the powerful languages that will support this study and that joins the concepts exposed previously. According to Chinosi & Trombetta (2012), BPMN 2.0 is an easily readable and understandable modelling notation that shows the properties and execution information of a process.

However, the use of such language may require changes in an organizations' culture, since it is a platform that gives a different overview of the processes' architecture.

BPMN 2.0 will be used to do a study of the processes, in order to easier and graphically identify the existing problems. The aim is to reduce the impact of those problems or even eliminate them from the processes. To do so, a comprehension of the Lean philosophy concepts is required.

Lean Thinking (LT) is a concept that supports the reduction of waste and of the activities that do not offer any added value (non-value-added activities), using the same or a smaller amount of resources (Saleeshya, Raghuram, & Vamsi, 2012) and by means of continuous improvements and standardizations (Prinz, Kreggenfeld, & Kuhlenkötter, 2018). Lean is based in 5 main principles (Womack & Jones, 1997): specify value, identify value streams or flows, make the value flow, let the customer pull value and pursue perfection. Furthermore, it considers that there are 7 types of waste: Overproduction, Waiting, Transport, Extra Processing, Inventory, Motion and Defects (Hicks, 2007). Recently, the 8th waste was included, the Non-Utilized Talent. These types of waste will later be explained in an information flows context for the specific case of the company that is being analysed.

LT can be associated with several concepts, namely KPIs or Industry 4.0 (I4.0). An example can be seen in the case analysed by Ante, Facchini, Mossa, & Digiesi (2018). The authors describe a tree-like structure of KPIs to define the Performance Measurement System of a Lean Production System. The KPIs are identified and categorized in a multi-level hierarchy designed to give answers at strategic, tactical, and operational levels. In this case, the impact of the KPIs selection in supporting and evaluating the implementation of smart manufacturing projects in I4.0 is shown through measures like Intelligent Supermarkets and Digital *Heijunka* Boards.

Despite having its origins in production, Lean Thinking likewise gives contributions in information processes and flows like, for example, in inefficient information flows, being called, in this context, Lean Information Management (LIM). LIM is an approach that combines a set of principles from lean and information management and tries to improve the information flow reducing waste and non-value-added activities, driving up the information (Bevilacqua, Ciarapica, & Paciarotti, 2015) (Hicks, 2007) (Castle & Harvey, 2009) (Smith & Ibbitson, 2011). It helps to understand the information needs, eliminates data without value and helps to define value-added information flows. It intends to have the right information, in the right quantity, to be delivered at the right time, to the right people (Teixeira, Ferreira, & Santos, 2019).

The Lean Information Management has some principles to be considered. The information should only be created if it is useful to the decision makers (meaning that it adds value), it should only be sent to those who need it, it should be quickly processed, preferably in real-time, avoiding waiting on the part of the users and it should be provided by sources without duplication of data (Teixeira et al., 2019). In this specific case, the focus will be on improving the Lean Information Management in the production planning department.

2.2 Industry 4.0 and Data Management

Tortorella & Fettermann (2018), Leyh, Martin, & Schäffer (2017) and Sanders, Elangeswaran, & Wulfsberg (2016) state that Industry 4.0 characterizes the fourth stage of the industrial revolution. This concept appeared on the Hannover Fair in Germany and is associated with all mechanisms that promote connectivity between machines, smart production and systems, and integrated solutions. This notion focuses on the technology-driven vision of the combination of the physical world and the cyber world (Prinz et al., 2018). The fourth industrial revolution represents long run trends of technological change and economic development (Nuvolari, 2018).

The main features are the increased flexibility in manufacturing, the mass customization, an improved productivity and the better quality. I4.0 is associated with solutions such as cloud computing, Internet of Things (IoT), smart manufacturing, cloud-based services, cyber-physical systems, big data analysis, artificial intelligence, machine learning and information and communications technology (Zhong, Xu, Klotz, & Newman, 2017). To better comprehend the features related with I4.0, it is imperative to make a basic distinction between data, information and knowledge.

Data is defined as “a symbol, sign, or raw fact” (Mingers, 2006), while Information “equals data plus meaning” (Checkland & Scholes, 1990). Fast but right decisions are needed, so if the data is not well structured, it can create noise and block the decision-making process. Therefore, Stair & Reynolds (2010) consider that knowledge is the awareness and understanding of a set of information and of ways that information can be made useful to support a precise task or reach a specific decision.

In this context, the concepts of Information Quality and Information Management are also key. On the one hand, Kenett & Shmueli (2013) see Information Quality as the “potential of a dataset to achieve a specific goal using a given data analysis method”. On the other hand, Teixeira et al. (2019) define Information Management as “an activity where information is shared to support the decision-making process, being transversal to any organization, regardless of size or branch of activity”.

Combining these two perspectives, Oh & Pinsonneault (2007) and Peppard, Ward, & Daniel (2007) support that the value of information (as a part of information quality and management) is directly linked to the achievement of the organization’s goals, meaning that it helps to perform tasks more efficiently and effectively.

With the boom of I4.0 comes a huge and complex amount of data, the so-called Big Data. As expressed by Merendino et al. (2018), Big Data disrupts the senior management of organisations, pressuring directors to make decisions more rapidly and to shape their capabilities to address environmental changes. This type of data comes in large quantities, is unstructured, has no direct relationship and must be captured in high speed and analysed within a very short period of time to create value (Teixeira et al., 2019).

As these data sets are difficult to capture, store, analyse and visualize, it is required to have proper technologies integrated with flexible and agile information systems to manage them. These systems allow to share the information in real time in a coordinated supply chain and to provide it to different parts of the supply chain. This way, the information systems can adapt to the changing scenarios that characterize the industrial environments in I4.0 (Chaudhary, Hyde, & Rodger, 2017).

There is a specific example of a study where Data Management, Big Data and I4.0 were joined together. Miragliotta, Sianesi, Convertini, & Distante (2018) studied data productivity and define it considering three aspects, namely data availability, data quality and the performance of the decision-making. They built a model that considers technical and organizational factors that help companies to evaluate the data productivity and actions to improve it, reducing its waste. The model was tested in three companies and the results reflect the expectations of managers considering I4.0 and the potential regarding the exploitation of Big Data.

I4.0 is a concept that is easy to relate with other dimensions of production. Trstenjak & Cosic (2017) propose a theoretical solution that considers a software connected to several entities of a supply chain and uses advanced optimization algorithms to generate process plans, orders of operations and schedules automatically those operations' orders to the process plans.

The software establishes the link between smart products and an Enterprise Resource Planning (ERP) system. This smart product carries the knowledge used in manufacturing and allows to make optimal decisions using predictive analysis combined with a decision support system. This is an example of how I4.0 can help to achieve better results in the production planning.

There is also a relation between I4.0 and KPIs. For example, Brandl & Brandl (2018) showed that from the development of new integrated and flexible systems emerges the opportunity to create tools that boost the processes of a company. They state that smart manufacturing from I4.0 requires the collection of information from intelligent devices and use key performance indicators that consolidate the information and shows it in real-time, improving the processes' performance.

Lean Thinking can also be connected to Industry 4.0. Both represent two different practices that favour the operational excellence. However, they rely on different types of tools (Teixeira et al., 2019). It already exists a symbiosis between these two realities.

Lean Management has the goal to diminish lead times and is also related with the standardization of processes, the empowerment of the workers and the continuous improvement, in order to attain the highest quality at the lowest cost possible (Franke et al., 2018) (Mrugalska & Wyrwicka, 2017). In another perspective, Industry 4.0 supports that the data in real-time boosts the transparency and information quality and offers a variety of technologies that are capable to support lean principles (Franke et al., 2018). According to the authors Mrugalska & Wyrwicka (2017), Industry 4.0 is focused on the optimization of value chains due to autonomously controlled and dynamic production and covers the administrative powerful and flexible logistics and production systems.

Bearing in mind these two realities, there are several concepts that relate them: Lean 4.0, Lean Automation, Smart Lean Manufacturing and Lean Industry 4.0 (Franke et al., 2018). When talking about both concepts, it is important to consider that there is a need to spare some time to have a successful implementation.

These two philosophies help to reduce lead times, to walk in the way of success, to improve the quality of the processes and the profitability of the operations (Franke et al., 2018).They have similarities concerning the targets like the reduction of complexity, the increase of productivity and flexibility, the central pillars and the fact that they have lean principles as a common ground. Furthermore, both focus on avoiding waste, continuous improvement, customer value, value stream, pull, flow and perfection (Franke et al., 2018).

On the one hand, I4.0 benefits from Lean because it facilitates the application of Lean practices especially on the shop floor. This happens because the main concept of I4.0 is to increase productivity of a company with a complete elimination of activities that do not add value. With the help of Lean, I4.0 can generate a continuous data flow that is collected in real time but that has current, correct and consistent sets of data (Teixeira et al., 2019). Lean can be an enabler considering Industry 4.0, because it develops standardized, transparent, and reproducible processes that are fundamental for introducing I4.0. Besides that, by reducing the product and process complexity, Lean allows the efficient and economic use of I4.0 tools (Franke et al., 2018).

On the other hand, Lean benefits from I4.0 because Lean concepts applied to information flows can be an excellent basis for the preparation of industries wishing to adopt the phenomenon of I4.0. Moreover, the amount of data that is generated can also lead to I4.0 benefiting from Lean practices, on the definition of information flows and the selection of the relevant data, while eliminating the waste associated with the information management process (Teixeira et al., 2019). Industry 4.0 advances Lean management because lean processes can be stabilized and refined by applying I4.0 and it is also possible to improve the flexibility of modern lean production systems. (Franke et al., 2018)

2.3 Information Systems and Business Intelligence

Information systems (IS) are interrelated mechanisms working together to capture, monitor, process and display information, “supporting people, organizations or other software systems” (Vilcahuamán & Rivas, 2017).

Information systems also represent complementary networks of hardware and software that people and organizations use to find the information they seek without limit on its sources and “to support decision making, coordination, control, analysis, and visualization in an organization” (Vilcahuamán & Rivas, 2017) (Laudon & Laudon, 2012). It also offers a variety of opportunities for a company to automate and share its knowledge efficiently (Rahimi, Møller, & Hvam, 2016).

According to Blijleven, Koelemeijer, & Jaspers (2017), it is imperative that the design and functionalities of an information system are aligned with the intentions and behaviour of its users to facilitate the accomplishment of their tasks as efficiently as possible.

In this case, the information system will be developed following the system development life cycle considering the stages: systems and software requirements, requirements analysis and validation, solution design, coding and testing, operations and maintenance of the system (Ramingwong, 2012); (Casteren & Van Casteren, 2017).

The idea is to apply an information system to the production planning, which is an area that requires cooperation between multiple units of a company. It is also argued that a strategic advantage is achieved by making the right decisions. Therefore, there is a need for tools that quickly share information and support production planners in their decision-making.

Özdamar, Bozyel, & Birbil (1998) propose a Hierarchical Decision Support System for production planning that enables planners to use structured planning algorithms in an interactive way. The system was tested in a manufacturer of engines and it was a success. There is also a relation between information systems and how can they support business processes.

Bicevskis & Bicevska (2015) suggest an approach that uses business process diagrams to manage and visualize its execution directly. This provides handlers with “means to control process execution clicking on graphical diagrams that represent executable business processes”. The execution mechanism opens new ways to follow-upon the executed business processes. It is beneficial in terms of usability as the entire business process is visible to the users in a graphical form.

Such methods that improve business processes of a specific area of a company are the proof that the proper use of information systems “enables the institutions to access their information for better and effective decision-making” (Al-Emran, Mezhuyev, Kamaludin, & Shaalan, 2018) (Kebede, 2010). There are examples of tools that can have an information system on the background and bring significant changes in the processes architecture.

Business Intelligence (BI) is a concept that may sound new but was already referred in the past and has been evolving since then. Luhn (1958) used the concept to describe an automatic system that distributes information and supports decision-making process. Vitt, Luckevich, Misner, & Rosas Gallardo (2003) also referred to Business Intelligence as a complex concept that covers four stages: analysis, insight, action and performance measure. As the concept has been evolving, now it is considered to cover different phases: data warehouse, data acquisition, data mining, business analytics, and visualization (Turban, Aronson, & Liang, 2005).

More recently, Caseiro & Coelho (2018) stated that "Business Intelligence is attracting attention because there is an increase in information availability through electronic means of acquisition, processing and communication". Hence, Wanda & Stian (2015) say that this idea encompasses diverse "activities, processes and technologies for collecting, storing, analysing and disseminating information to improve decision making".

Vitt et al. (2003) state that Business Intelligence includes three basic perceptions: "making better and faster decision, converting data into information, and using a rational approach to management". According to Nasri (2012) and Dishman & Calof (2007), there are also several factors that oblige companies to improve their information use otherwise their survival may be compromised: political and social changes, increased global competition from new or more aggressive competition, growing uncertainty and rapid technological changes.

Caseiro & Coelho (2018) also studied BI but applied to startups. They consider that Business Intelligence can be used to acquire information and contribute to increase the availability of knowledge to managers. The results show that Business Intelligence capabilities have a positive impact on three important aspects, considering the start-ups dimension: network learning, innovativeness and performance.

In the perspective of Liu & Liang (2018), Business Intelligence provides great resources and powerful methodologies to perform data analytics and generate significant information to support business data-driven decision-making processes, as it is becoming an important area nowadays. This concept is transversal to several areas: "for instance, business applications are oriented toward profit making, while medical applications may focus more on accuracy or calculation efficiency" (Luhn, 1958).

Liu & Liang (2018) propose a comparison between Big Data and Business Intelligence trough an academic literature review and explore the development and research trends of both concepts. The authors discovered the most frequently used key words when talking about these concepts: "data mining, social media, information system, cloud computing, data warehouse and knowledge management".

The authors exposed that "the number of BI publications stayed relatively stable over the years" comparing it to Big Data. This happens because Big Data has a wider research coverage than Business Intelligence that only focuses on business applications. This study is summarized in Figure 1 (retrieved from the article of Liu & Liang (2018).

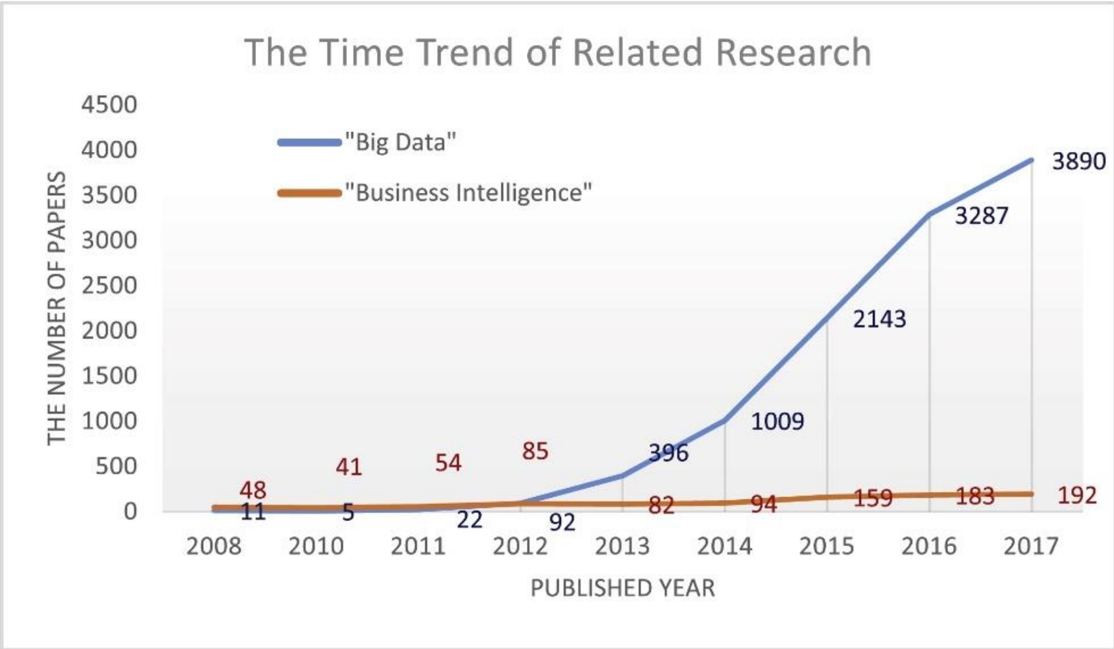

Figure 1 - Business Intelligence published papers (Liu & Liang, 2018)

As it can be seen, both Business Intelligence and Big Data are becoming relevant concepts nowadays, due to the increasing number of papers published. Hence, Business Intelligence is also a concept that may bring an important development to this work.

2.4 Production Planning and KPIs

Production Planning is a complex area that requires cooperation between multiple units of a company. Planning is the consequence of a hierarchy of decisions considering different issues and scenarios in the manufacturing environment (Özdamar et al., 1998). Production Planning and Control systems represent tools that can support enterprises in the planning and scheduling tasks, helping to allocate their resources according to a variety of production constrains, complexity and capacity, namely the number of shifts, materials availability, stocks, forecast, machines availability, amongst others (Riedel, Ellwein, & Elser, 2018). Both production planning and control are based on the scheduling of production orders. However, the planning of production precedes control.

Production control focuses on monitoring various inputs and targets in an efficient way. Whatever is planned needs to be controlled, that is why the production control considers the integration of several aspects used to achieve efficiency. It also considers the efforts that are needed to adhere to the production schedules and to issue all the necessary instructions to the staff for making the plans realistic. Production Control also needs to ensure that the goods are produced according to the prescribed standards and quality standards. It is also important because it ensures that the inputs are made available in the right quantity and at the proper time, assuring that the work progresses according to the production plans (Ventakesh, n.d.).

To gain a strategic advantage there is a need to take the right decisions. That is why it is essential to have tools that support production planners in the decision-making process. There are authors that already developed high-complex systems for doing this.

The study proposed by López-Ortega & Villar-Medina (2009) shows how to establish a connection between Industry 4.0 and the production planning. The authors developed a multi-agent system supported by a feed-forward artificial neural network that constructs and releases valid production orders.

The principles of the artificial intelligence combined with production planning allow to decompose the decision process, carried out by the human manager, into a series of tasks performed by software agents resulting in a new fully automated system. Thus, it helps to avoid the mistakes of the production planning managers, namely a wrong allocation of the used tools to a determined machine or a wrong allocation of the products with a specific design to the specific machines. This situation might occur due to fatigue, or the inability of a human-being to manage a larger number of combinations and complexity, causing mistakes.

To conclude, more accuracy and flexibility can be achieved by incorporating aspects of I4.0 in some processes, namely when generating a production order. This will help to reduce human made errors and improve the processes.

For example, one of the Lean methods is Heijunka, which aims to level the production to a constant rate. With the boost of Industry 4.0, a new concept raised, Heijunka 4.0 (Franke et al., 2018). As explained by the same author, “by solely producing the customer demand, waste in the form of overproduction is reduced. Some I4.0 tools contribute to improving Heijunka. Data analytics, for instance, enhances the forecast quality. Planning is stabilized by using data history in combination with a better understanding of customer needs through an in-depth analysis of the market”.

Applying Heijunka 4.0, which combines Lean an Industry 4.0, helps to reduce the effort for levelling the production scheduling. The planning is automated, and some adjustments can be simply integrated. It is also important to think about the impact that such tools can have on the meaning of the production planning in the future.

The production planning is also related with another areas, namely Lean Thinking. The authors Lanetzki & Kozara (2013) use a combination of simulators to help to optimize machine loading and the sequencing of the production orders, combining concepts and techniques like Critical Path, Kanban methodology, Pull Production and Just in Time (JIT) production.

The simulator automatically interacts with a set of parameters predetermined by the user and programs the resources to meet the requirements, thus reducing costs, time and maintaining the stocks at their lowest possible level. After each simulation, the system executes and identifies the most feasible situations in terms of deadline and cost effectiveness.

Özdamar et al. (1998) proposed a Hierarchical Decision Support System for production planning that enables planners to use structured planning algorithms in an interactive way. The system was tested in a company of manufacturing of engines, being a success.

As it can be seen, there are several ways of integrating the production planning with other concepts, in order to improve its performance. Despite that, it is important to emphasize the investments that are needed, not only in software, but also in qualified labour force. Other findings exist that allow to gain efficiency in the processes, namely in the production planning. For example, KPIs are a powerful tool in the Production Planning and Control context.

According to Meier, Lagemann, Morlock, & Rathmann (2013), Key Performance Indicators represent quantitative information in business environments and are crucial in planning and controlling, since they help to construct information, promoting transparency and supporting decision makers. The same authors defend that KPIs are "the basis for analyzing and improving processes, because they support planning in various areas, e.g. strategy and budget".

KPIs are a requirement to set and control several goals (even new ones), as well as their implementation, are the basis for decision-making to reach a desired performance and improvement and represent incentives, not only for the top management, but also for the employees. According to Weber (2005), KPIs allow managers to identify the progress in activities and allow the translation of a company's missions into concrete actions, evaluating how well the company is pursuing its objectives.

In this regard, the key performance indicators are a core of any performance measurement system. A performance measurement system consists in a set of procedures and indicators that precisely and constantly measure the performance of activities, processes and, consequently, of the whole organization, and is a vital aspect for the management of companies (Neely, Gregory, & Platts, 2005). This system should be able to provide data for monitoring both past and future performances and to strengthen the strategies to avoid introducing conflicting indicators. Nowadays, there are powerful business intelligence tools that support such systems.

Maté, Trujillo, & Mylopoulos (2017) state that business monitoring and control is a critical activity usually supported by a system that gives information about several KPIs. Therefore, it enables decision makers to identify problems and expose their sources, take corrective actions, but it is also a challenging action because of the large quantity and high speed of changes of data that needs to be processed.

Kibira, Morris, & Kumaraguru (2016) also state that “the continuous monitoring of metrics and indicators at different strategic, tactical, and operational levels in real-time will enable drilling-down to root causes of performance problems”.

There are several ways of controlling the most varied aspects. It is important to understand what to control and how to control it, focusing on doing that with the help of KPIs or other systems.

2.5 Some Final Remarks

Considering this study in an industrial context, the focus will be on the use of the powerful features of Business Process Management to represent the processes, the understanding of the principles of Lean Information Management to comprehend what sets of information are important and how to improve the information flows. This will also help to reduce the drawbacks of Big Data, one of the most important considerations of I4.0. After that, an Information System will be developed, bearing in mind the characteristics of Business Intelligence.

This approach will happen in the Production Planning department, where sets of KPIs are currently being used to monitor and control several aspects related with the planning activities.

To conclude, the idea behind the theoretical component of this study is to combine ideas from Lean Thinking, Business Process Management, Business Intelligence Tools, Data and Information Management, I4.0, and KPIs, applied to the Production Planning, to create an automatized information system and to sustain the practical part of the study.

The aim of this study will not be the development of production planning algorithms, as some authors did, but to improve, in general, the flows of information that are currently happening. In a future perspective, the goal will be to establish a connection between the Industry 4.0 automation of processes and the production planning so that the processes can be even more efficient.

Before implementing a new system, it is crucial to understand the existing current situation of the production planning and control department.

3. Organization and Problem Contextualization

Throughout this section, the company, the operations' logic and the environment and structure of the production planning and control will be presented. Since it has the complexity of a multinational enterprise, it is also important to understand the problems that are intended to be solved with this work, therefore there is also a problem background focus.

3.1 Company Presentation

3.1.1 GROHE

GROHE was founded by Friedrich Grohe in 1936 and is today one of the global references regarding technical-health products and systems. The range of products varies from faucets to bathroom or kitchen mixers, shower systems, thermostatics and sanitary systems. GROHE is the world's leading brand in sanitary fittings, whether they are bathroom solutions or kitchen faucets, and it is known for its design ethos (About GROHE, n.d.). "GROHE is today innovating the "digitalization of water", while leveraging technological synergies to roll out new product lines", according to the information from the LIXIL Annual Report of 2018 (LIXIL ANNUAL REPORT 2018, 2018).

This company is a very respected and well-known group from the metallurgical industry, leaving its mark in more than 150 countries. The headquarters are located in Düsseldorf, Germany, being the heart of technological development, engineering activities, innovation and design (About GROHE, n.d.). The group has a logistics centre that is responsible for the distribution and delivery to the final clients, being supported by 5 production plants:

- Hemer, Lahr and Porta Westfalica, in Germany, that manufacture sophisticated products in low amounts but at a high price;
- Albergaria, in Portugal, that manufactures high/medium complexity products, in moderate quantities and at an average range price;
- Klaeng, in Thailand, where the focus is the mass production only for low complexity parts, which corresponds to a lower price.

GROHE's supply chain is divided in production plants and in purchasing organizations situated in China and India. The objectives of these units are not only to ease the information flows and the processes from the supply chain, but also to increase the market share. Because the company is dispersed in several parts of the world, it can fulfil the market demands and the global challenges more easily, and it is also a way of expanding the business (About GROHE, n.d.).

In 2014, GROHE was acquired by the LIXIL Group Corporation, a Japanese manufacturer of building materials and housing equipment and solutions. This acquisition emerged from the expansion of this corporation in the water technology segment. As LIXIL is constituted by many individual product brands, its main goal is to increase its global production capacity and enhance the supply chain network to capture growing worldwide demand for water technology products.

According to the information from the LIXIL Annual Report of 2018, GROHE's plant in Albergaria is one of the 4 plants of the European group that contributes to establishing presence in strategic global markets. In total, LIXIL has 93 plants all around the world which gives the company the agility to serve individual markets, while enabling the collaboratively work worldwide (LIXIL ANNUAL REPORT 2018, 2018).

Despite this transition, GROHE continues to be an independent group, feeling only slight changes in the company's culture and values. For example, there are now 5 LIXIL values in which the firm focuses: "work with respect", "deliver on commitment", "embrace quality", "inspire passion" and "pursue growth" (About GROHE, n.d.).

In the fiscal year of 2017, from April 2017 to March 2018, the revenues of the group GROHE were almost 1,5 billion €, a result of the hard work of the 6.542 headcount employees, bearing in mind that 619 of them work in Albergaria (data from 31 March 2018).

In the Portuguese plant, the revenues were around 165 million €, being the production differentiation focused on sustainability, quality, technology and design. As an example of these 4 values, stand the ISO 9001 (Quality Management System), the ISO OHSAS 18001 (Health and Safety Management System) the ISO 14001 and the ISO 50001 (Environmental Management System). The company also has environmental concerns, namely, to measure the carbon footprint, energy efficiency and the recycling of scrap and waste plastic (About GROHE, n.d.) (LIXIL ANNUAL REPORT 2018, 2018).

3.1.2 GROHE in Portugal

GROHE Portugal, *Componentes Sanitários, Lda* began its activity in 1996, through a sales department in Porto. In 1997, the construction of what would become GROHE Portugal started, representing an investment of 35 million € for the group. Seven years later, in 2004, with the start of the production of thermostatic faucets, the industrial unit was expanded.

In 2013, GROHE Portugal was considered the best plant of the group and, in 2014, with LIXIL's acquisition, the Physical Vapor Deposition (PVD) coating started in this production unit. The PVD coating improves the hardness and wear resistance of the material and it is more environmental friendly than other conventional coating processes (Sivapragash, Kumaradhas, Vettivel, & Retnam, 2018). This coating process is expected to broaden the possibilities regarding the finishing of the faucets and to expand the market share of the firm.

According to data from the financial department, GROHE Portugal represents 25% of the total production of the brand, producing an average of almost 4.5 million pieces per year.

With regard to the structure, GROHE has a well-defined one. On the top of the hierarchy, there is the Chief Executive, followed by the Chief Financial Officer that, together, are responsible for managing, coordinating and monitoring the functional departments of the company, always communicating with each department's responsible person.

As mentioned before, this project was performed in Albergaria-a-Velha's production plant, more specifically in the Supply Chain Management department that encompasses three large areas: Production Planning and Control, Disposition and Transportation, and Warehouse.

3.1.3 Production Process

The production process covers different phases: foundry, machining, grinding/polishing, galvanic (these phases stand for the Pre-Process), PVD, assembly and shipment. As a result of these stages, there are different types of products (represented in orange in Figure 2):

- the bodies, that result from the Pre-Process and represent the principal components from the faucets;
- the colored parts, that are the output from the PVD process, a recent coating process;
- the finish goods, that represent the faucet assembled with all the components and that are the final product from the Assembly process.

Before starting the production, it is necessary to consider the production planning since this activity will define the course of the raw materials until they are transformed into faucets.

During the foundry, the solid raw material is melted in a furnace and, together with other components, constitutes a metallic alloy. This alloy is spilled into a mould and lies there until it is solidified. When it becomes solid, the piece is removed from the cast. The waste of raw material is reintegrated into the process, so that a reutilization is done. The parts then go to the machining where the main goal is to give functionality to the part. In this section, the parts are washed and then go to Computer Numerical Control (CNC) machines to be shaped.

The predominance of automation in this production section makes it only necessary to have people loading and unloading the machines. After being machined, the components go to the department of grinding and polishing where a surface treatment makes them glossy.

Some parts are treated in automatic machines, others are treated manually due to their physical complexity. The components then go to the galvanic or electroplating that encompasses 3 phases: loading, plating and unloading. Through a process of electrodeposition, the body is plated, first in nickel and then in chromium, so that the parts gain that silver and shiny aspect. As a result, there will be chromed bodies.

After this, the bodies can follow several paths, depending on the complexity, the wanted value added or the final destination: the parts go directly to the assembly; the parts go directly to the PVD; the parts go first to the Brushing and then go to the PVD; finally, the bodies that are not assembled internally are shipped and go to other plants of the group to support their production.

In the Brushing section, the parts are brushed to gain a metallic aspect and then go to the PVD specialized chambers. During the PVD, the chromed parts enter in the chambers and suffer a projection of zirconium and argon in a way that those elements are deposited in the faucet’s surface, giving it a specific decorative colour (black, bronze, golden). These faucets have higher monetary value due also to the complexity of the process. From here, the parts can be assembled or shipped, following the same logic mentioned before for the bodies.

One of the last steps is the assembly where all the components are joined and attached to form the faucet. The production lines are distributed according to streams or product families. Finally, a *Mizusumashi* or Logistic Train goes through all the production lines and collects the finished pallets, taking them to the warehouse so that they can be shipped afterwards.

In the warehouse, the processes are mainly of loading and unloading materials, as well as receiving outsourced materials. Throughout all the phases of the production process, there are several quality checkpoints, known as Firewalls, to assure that all the functionality and quality requirements of the faucets are fulfilled. To better understand what was previously described, Figure 2 summarizes the processes that transform the raw material in a faucet.

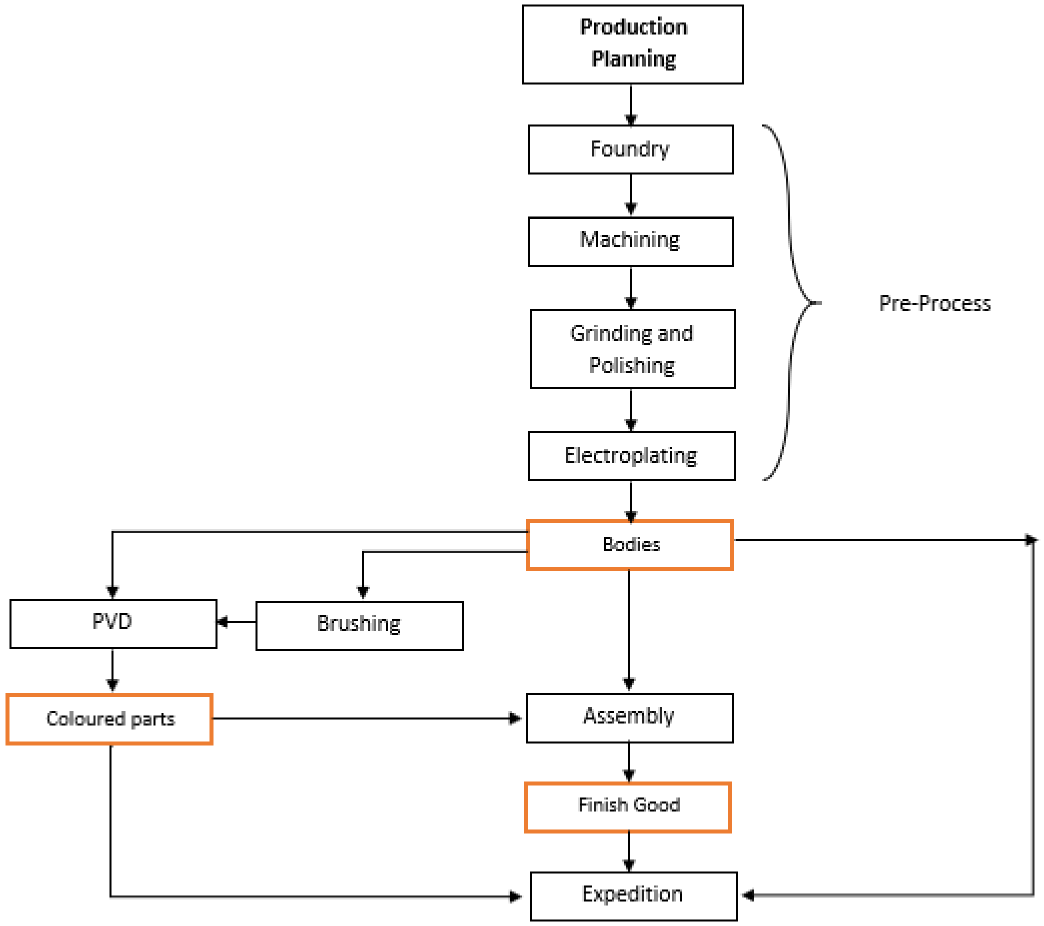

Figure 2 - Production Flow

3.1.4 Products

GROHE offers a widespread variety of products and there are plenty of aspects that make differentiates them. Products are generally known by their stock keeping unit (SKU), which represents a specific code assigned to a product. That identifying code gives information about the stream, the design and the supporting unit. The existing streams represent the product families: Alt/Costa, Basin/Bidet, Bath/Showers, Blue & Red, Concealed Valves, Kitchen, Thermostatics and Others.

There are also, depending on each stream, the supporting units that differentiate the product according to the respective function. For example, considering the stream Kitchen, it is possible to consider Accessories, Fittings or DIY (Do It Yourself). The products can also have different designs. Considering the stream Thermostatics, there are plenty of designs: *Clivia*, *Euphoria*, *Grohtherm 800*, *Grohtherm 1000*, *Grohtherm 1000 Cosmopolitan*, *Smart Control, Precision Joy, Precision Start,* and *Precision Trend New*. Figure 3 shows the products categorization (Design Trends 2018, n.d.).

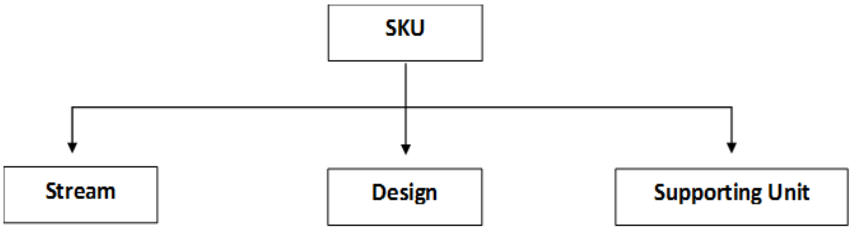

Figure 3 - Products Categorization

Figure 4 shows an illustrative example of the categorization for four different products categorizations, according to the mentioned features: design, supporting unit and stream.

Product	Design	Supporting Unit	Stream
40554645	GROHE Blue Professional	GROHE Kitchen Fittings	Kitchen
410812045	GROHE Blue Professional	GROHE Kitchen Fittings	Kitchen
27394002	New Tempesta Cosmop. System	GROHE Showers & Shower Systems	Bath/Showers
27922000	New Tempesta Cosmop. System	GROHE Showers & Shower Systems	Bath/Showers

Figure 4 - An Example of a Product Categorization

It is important to consider that not all SKUs have the same level of difficulty to be produced, because of the different streams, designs and supporting unit. Therefore, the complexity of the products influences the performance of the production and, consequently, the quality of the production plans. As such, it is also possible to distinguish three main complexity dimensions: Technological complexity, Raw Material complexity and Coating complexity.

- **Technological complexity**

In the range of products offered, some of them stand out due to their technological, technical and innovation level of complexity. Some examples are the GRT 1000 Cosmopolitan, Minta Touch, Grohe BLUE or Grohe RED.

The thermostatic GRT 1000 Cosmopolitan has a system that allows to adjust the water temperature in a matter of seconds. Minta Touch has a sensor that allows to have both functionality and hygiene in a touch. Grohe Blue has a carbon filter that allows to have potable water to drink in your home. Grohe RED contains a boiler in its system and warms up the water immediately when pressing one button.

Products like those have a big impact not only in the production, but also in the production planning, because they required more quality control tests, more experience when doing the faucet, but also more time invested. An example of a Grohe RED faucet is shown in Figure 5 (GROHE Red, n.d.).

Figure 5 - Grohe RED (GROHE Red, n.d.)

- **Raw materials complexity**

Changes in raw materials can also influence the production complexity and consequently the preparation of the production plans. For instance, in the Foundry, the raw material used is Material 1. Currently the company is starting to produce faucets with a new raw material, Material 2, that will lead to a cost reduction.

The goal is to replace all the Material 1 for the Material 2 along the production flow. When the planners are planning, they need to consider that the production plan must contain the two raw materials being used, both to spend the Material 1 and then to start incorporating Material 2. The production lines are now divided into two types, depending on the raw material that is going to be produced in that line. The concern of the planners is to set production orders for both versions, assuming a “phase in phase out” procedure.

- **Coating complexity**

Before being purchased by LIXIL, GROHE had a PVD production plant in Canada, with only one chamber. That plant was closed when LIXIL bought GROHE, because at the same time, LIXIL also bought American Standard Brands, meaning that it was not necessary to have two companies in the same country.

As a result, PVD coating started being done exclusively in Albergaria. The complexity increased exponentially, since the products started to be produced in nine different colours. The increase in demand and the requirements regarding the equipment and space needed for the process made the number of PVD chambers grow. PVD had and still has repercussions, not only in the production, but also in the assembly part and it was one of the reasons why the values of the backlog increased. The process is not 100% stable yet, because it is a brand-new process, so it is necessary to be constantly retracing and readjusting the production plans from this production group of the plant.

3.2 Problem Contextualization

3.2.1 Data Sources Collection by the Company

By following and observing the tasks performed by the planners, it was possible to track the data sources of the processes. Most of the data that integrates the plans comes from **SAP**, the enterprise resource planning (ERP) system of the firm, a management software used across the entire firm.

There are some interfaces that automatically and directly transfer the information that is on SAP to Microsoft Excel, the software used to work with the production plans. Those interfaces are called "Cubes" and were created by the IT team. Usually the information that comes in the "**Cubes**" is related to stock levels and productions for a specific period.

Apart from that data source, the planners also use the **internal Network** which is a group of local folders in the computer where the information is shared. One of those is dedicated to international projects, this is, a folder where the information is shared between all factories. A lot of the files, analysis and reports that exist inside this folder are created by the central planning team in Germany.

The plans are created using Microsoft Excel file., however, the files are different in terms of layout and presentation, depending from planner to planner. It is important to outline the experience and sensibility that are needed when planning, considering the different products and knowing what are the possible obstacles that will occur on the shop floor, and consequently in the decision-making process. After using that intermediate interface to treat the data and transform it into information, there are several ways of sharing the information.

The planners can change some parameters in SAP itself, but usually, the changes are mentioned in the Excel plans, uploaded in the same **Network** mentioned before, but this time in a different folder dedicated to the Supply Chain department.

The plans and other important files are uploaded to a platform called **SharePoint**, an Intranet that everyone from the Portuguese company as access to. SharePoint has a high usage rate by the Supply Chain department.

The information sources and flows will become clearer in the next section, by observing the models constructed regarding the processes of the production planning.

3.2.2 GROHE's Production Planning and Control: AS-IS Model

The Production Planning and Control is an important area of any company because it defines the course of manufacturing. To better understand the context, the problems and how to implement solutions in this specific area, the first step is to focus on how the planners update their plans. The production planning follows the same cycle whenever new data is needed: first the planners collect data and organize it in order to analyse it. After being analysed, the data gains some meaning, becoming information. This is the information that will support the decision-making of the planners. The cycle will start again, because the decision-making triggers the acquisition of new data.

In this case, there are three plans to be considered: Pre-Process, PVD and Assembly plans. Each plan has its own specificities and needs detailed information to be completed. To get all the information that is needed, it is important that the inefficiencies that are currently occurring can be minimized through a careful information management, otherwise a lot of time will continue to be wasted.

As it was described, BPMN 2.0 was the language chosen to represent the processes that generate the production plans. The approach that is going to be made is fundamental to prove how BPMN can be used to model business processes and find the points at which they can be improved.

The plans are built following a Pull logic, which, according to Womack & Jones (1997) represents a system of production from downstream to upstream activities where the products are "made-to-order". It means that the first plan to be made is the assembly plan (the last part of the production) and when finished, it supports the PVD and pre-process plans. All plans contain information about the parts that are missing, or the planned parts that they need to produce; what is the cause for the missing parts and when will the problem be solved. Additionally, the production that is missing is calculated and made visible in the planned quantities.

The plans have a timeframe of one week, meaning that they are weekly plans and at the end of each week the planners prepare the plan for the following one. During that following week, the plans need to be readjusted due to some changes that may occur, for example delayed components for production or absenteeism issues. Each plan has a responsible, except for the assembly plan that is divided in three parts allocated to three different planners, due to its complexity. The tasks are mostly the same, so Planner 1 is responsible for the Pre-Process plan, Planner 2 represents the Assembly planners and Planner 3 focuses on the PVD plan.

The production planning is based in a defined cycle: when performing the tasks, the planners make the data collection. When they start organizing and analysing it, the data gains a meaning and is transformed into information. That information supports the decision-making processes during the planners' tasks. After performing specific decisions, a necessity of searching for new data will then be triggered, making the cycle start again. In this case, the sequence starts with the planners getting data from SAP.

First, there are the inputs taken from the ERP, namely independent necessities or sales forecast, dependent necessities or clients orders, stocks and safety stocks. The data from the client's orders is stored and processed in SAP by the sales department. After that, the production planning department starts elaborating the plans and releasing the production orders.

Second, some considerations are also critical, namely the bodies availability, the materials availability, the quantity of parts that make a pallet, an average of the pieces from a specific product that are produced in each shift and the production capacity that must be respected, especially when releasing the production orders.

Third, it is also important to consider the relevant information from the Top Management that is mainly available in the internal network of the company. Since it is a multinational company, there is a dependency between this department and the Central Production Planning and Control. This board is responsible for providing every morning a file called "KPI Central Planning" to identify the production priorities for that day.

This file is a guideline to fulfil the strategic goals of the company, to align the strategy of the five production plants and to establish indicators that allow to monitor different situations that are important in each moment. Thus, as it contains an enormous diversity of data from all the plants of the group, it becomes necessary to shape the file and put it into a specific template, otherwise it will only create entropy. Planner 2 performs several steps to alter the file (see Figure 6) and after it is finished, it is provided to the other planners.

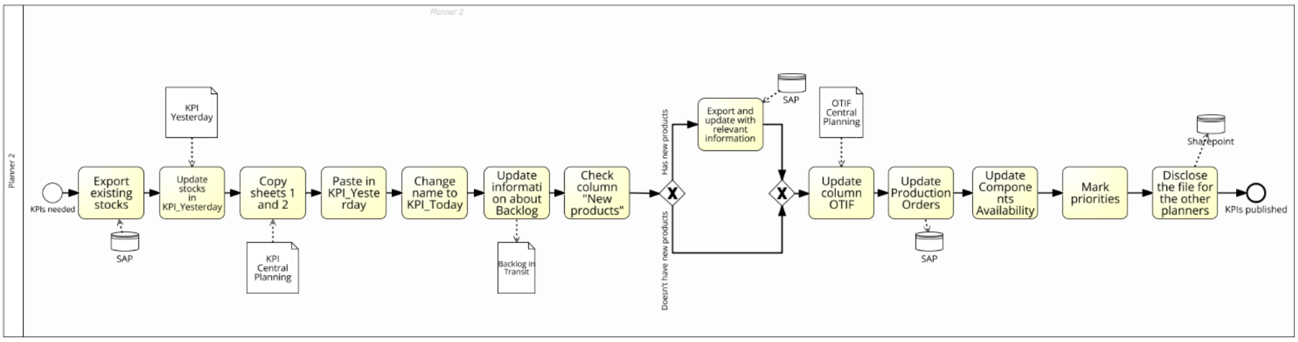

Figure 6 - Update KPIs Business Process Model

The above-mentioned file plays an important role since it has all the information about the products, their description, the supporting unit, the design, the stocks, the sales, the required safety stocks, the COGM (Cost of Goods Manufactured, or cost of producing that product), the availability of materials and descriptions about the types of backlog, for instance the backlog in transit (products that are on their way to the client).

Additionally, there are also some performance indicators like OTIF (on time in full, a delivery indicator), ageing orders (orders that have serious delays) and spare parts (for products that are already sold but have a broken piece that needs to be replaced). In another sheet, there are also the production orders, the released orders, what is missing and blocking the production, why is it missing, and when will the situation be solved. All planners fill in the file, depending on the products for which they are responsible. These performance measures are established based on defined targets that the company must follow to guarantee the control of production and the desired performance. A better description of these indicators is done in section 3.2.3.

Once the KPIs are ready, the assembly planners can start building and checking their plans, making readjustments if needed (see Figure 7).

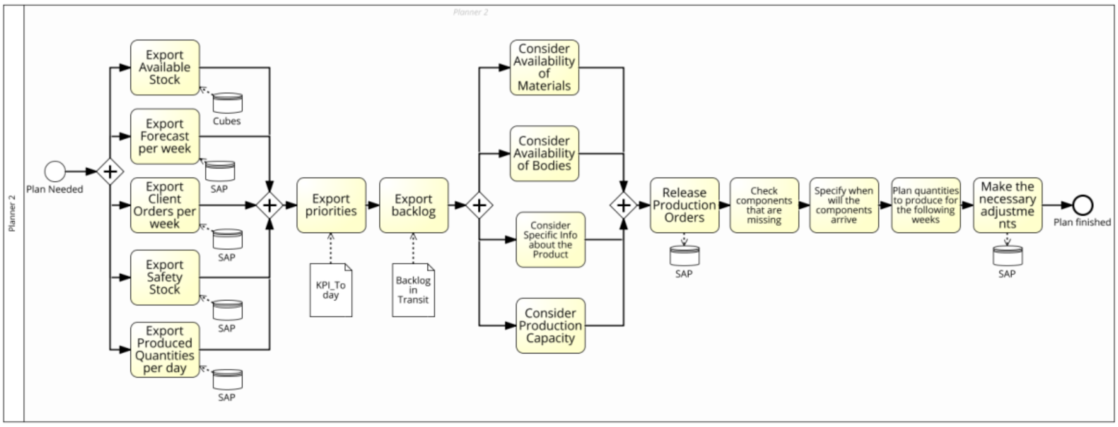

Figure 7 - Assembly Plan Business Process Model

The plans represent a guideline for the production and identify the amounts that need to be produced. What is planned arrives to the production in Production Orders (POs) that are released by the planners through SAP. The POs represent the “green light” to start producing. In case it is needed, the planners can make the necessary adjustments via SAP and then the plans are ready to be delivered to be fulfilled in the production. The same logic is followed for the Pre-Process and PVD plans, however they have slight differences that can be observe in Figure 8 (Pre-Process) and Figure 9 (PVD).

After finishing the assembly plan, Planner 1 has conditions to start the pre-process plan (Figure 8). The planner defines the quantity of bodies that are needed for the rest of the production, bearing in mind that the production flow itself has a certain course and consequently requires a certain lead time. This means that the planner must place orders in time to fulfil the finish good demand internally. In case the internal capacity is not enough, some materials are outsourced.

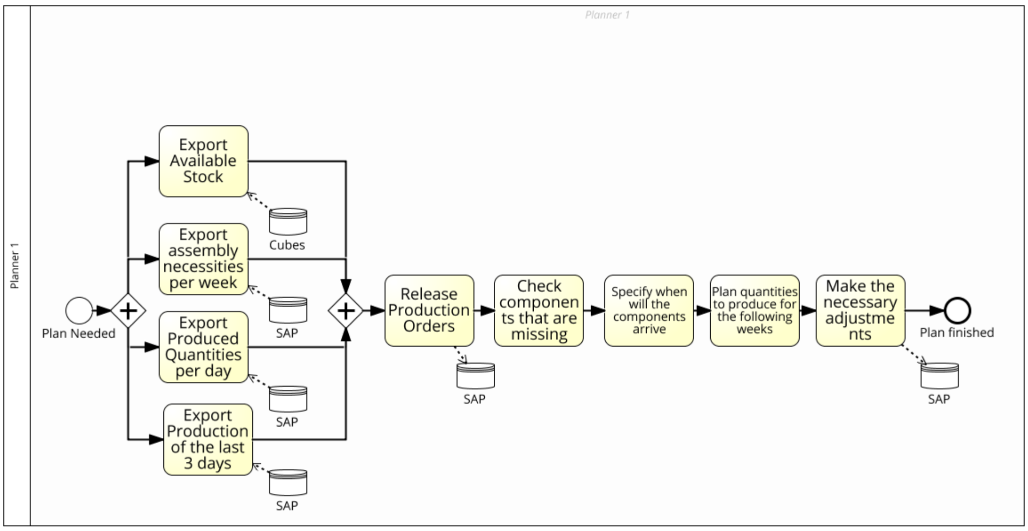

Figure 8 - Pre-Process Plan Business Process Model

Moreover, there is also an internal waste of bodies, meaning that there is a percentage of scrap that needs to be considered in the plan. For example, if the request is for day X, the planner knows that it needs to start producing the bodies for that product 4 weeks before the day X and if the assembly needs 400 pieces, there must be a safety margin for that value (scrap rate).

As the Pre-Process deals with the raw materials that are transformed to become the finish goods, the KPIs are not fundamental for this planner, neither the products that are in transit. By using some formulas, the data is allocated to the related week of the plan in an Excel file, defining the necessities according to each production section (foundry, machining, etc.).

From this, secondary inputs needed for the assembly plans are generated. First, there is an internal availability of bodies that must be considered. If by any reason the pre-process fails, there will be delays in the assembly. As the demand is not stable, there is a part of the production that is outsourced. In specific products, there is also an availability of components that are outsourced and that is another secondary input for the assembly plan.

Considering now the PVD plan, Planner 5 needs a specific list that identifies the pieces to be produced. That list is checked in another document called "Priorities" that has 4 types of priorities.

The priority list considers four levels from 1 to 4, being Priority 1 the higher priority and more critical than Priority 4. *Prio 1* considers the most critical situations that the planning team needs to control: Ageing Orders (orders with a considerable delay), some particular special manufacturing orders (SMOs) and other important events (for instance, the participation in ISH 2019[1], which led to a special manufacturing for that trade fair). *Prio 2* considers the special manufacturing orders (SMOs) in general, *Prio 3* considers the backlogs (or delayed orders) and, finally, *Prio 4* considers the orders that are in risk of becoming backlogged. It is important to have information about the required quantities per week and for the following weeks, defined in accordance to what the client orders are. There is also the need to have information about the availability of chromed bodies to use in the PVD section.

The assembly plan complements the PVD plan as well. Despite having the same logic as the pre-process plan, the PVD plan also needs, as an input, the P2P (plant-to-plant) orders, which are the necessities from the other plants of the group, since the PVD production only happens in Portugal. As it can be seen, this is one of the most complex parts of productions, since it has different inputs and several scenarios to be considered (explained in Figure 9).

[1] ISH 2019 is the "world's leading trade fair for the responsible use of water and energy in buildings" (ISH 2019, n.d.).

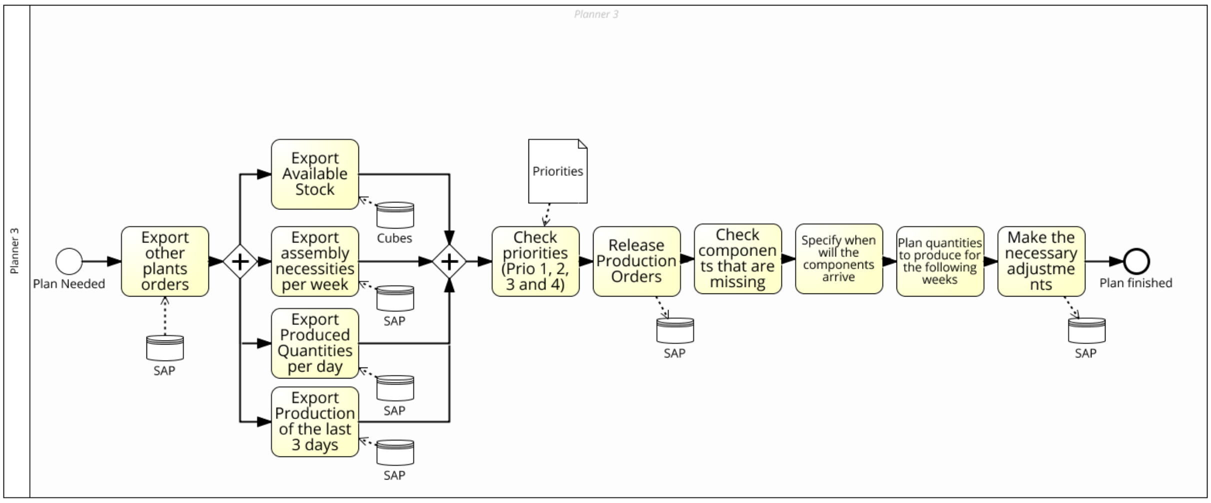

Figure 9 - PVD Plan Business Process Model

As it can be seen, when the plans are ready, the information from all the assembly plans are grouped into one file called Weekly Production Plan (WPP). After that, the pre-process planner gathers the information from the WPP file plus the information from the PVD and Pre-Process plans and joins it in a file called Balance Sheet. The Balance Sheet transforms the planned quantities according to the SKU in quantities per bodies, identifying the bodies that need to be produced so that the pre-process plan can fulfil the needs of the other plans.

It is important to have in mind that the plans are an orientation for the production, but they can suffer alterations. Many times, because of the lack of workforce, some delays in the deliveries of raw materials or for other reasons, it is not possible to strictly follow what the planners define.

Consequently, every week there is a meeting called “Alignment” with the responsible parties of the production planning, the pre-process and the assembly. In that meeting, they use the Balance Sheet and compare what is planned and what is being produced, as well as analyse what are the problems happening and how to solve them.

They start analysing the production from the top to the bottom. As the meeting includes each department’s responsible, the result is a final plan more adequate to the reality, called “Alignment Sheet”, since this new plan considers the problems that are occurring. After that meeting, the planners readjust their plans and share them in the company’s internal network.

The whole process required for updating the plans, which happens every week, is shown in Figure 10.

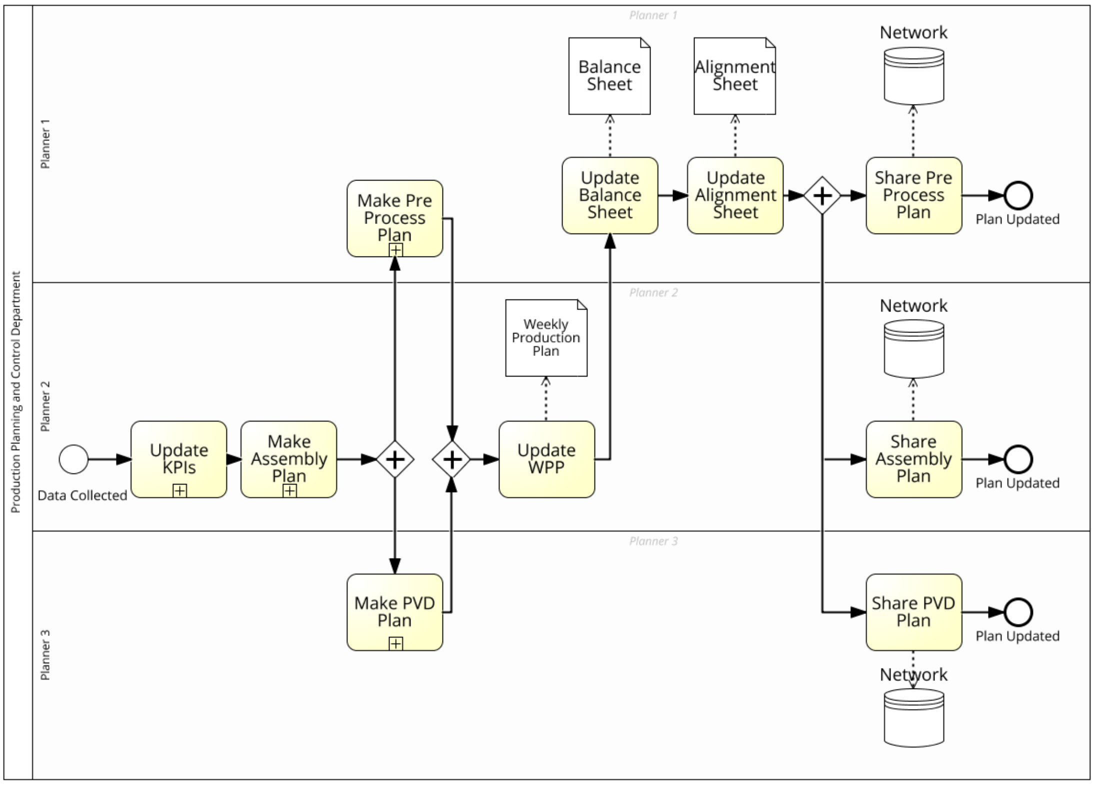

Figure 10 - Production Planning Business Process Model

The production planning logic, according to the mentioned plans and all the specific features, is explained in the scheme presented in Figure 11:

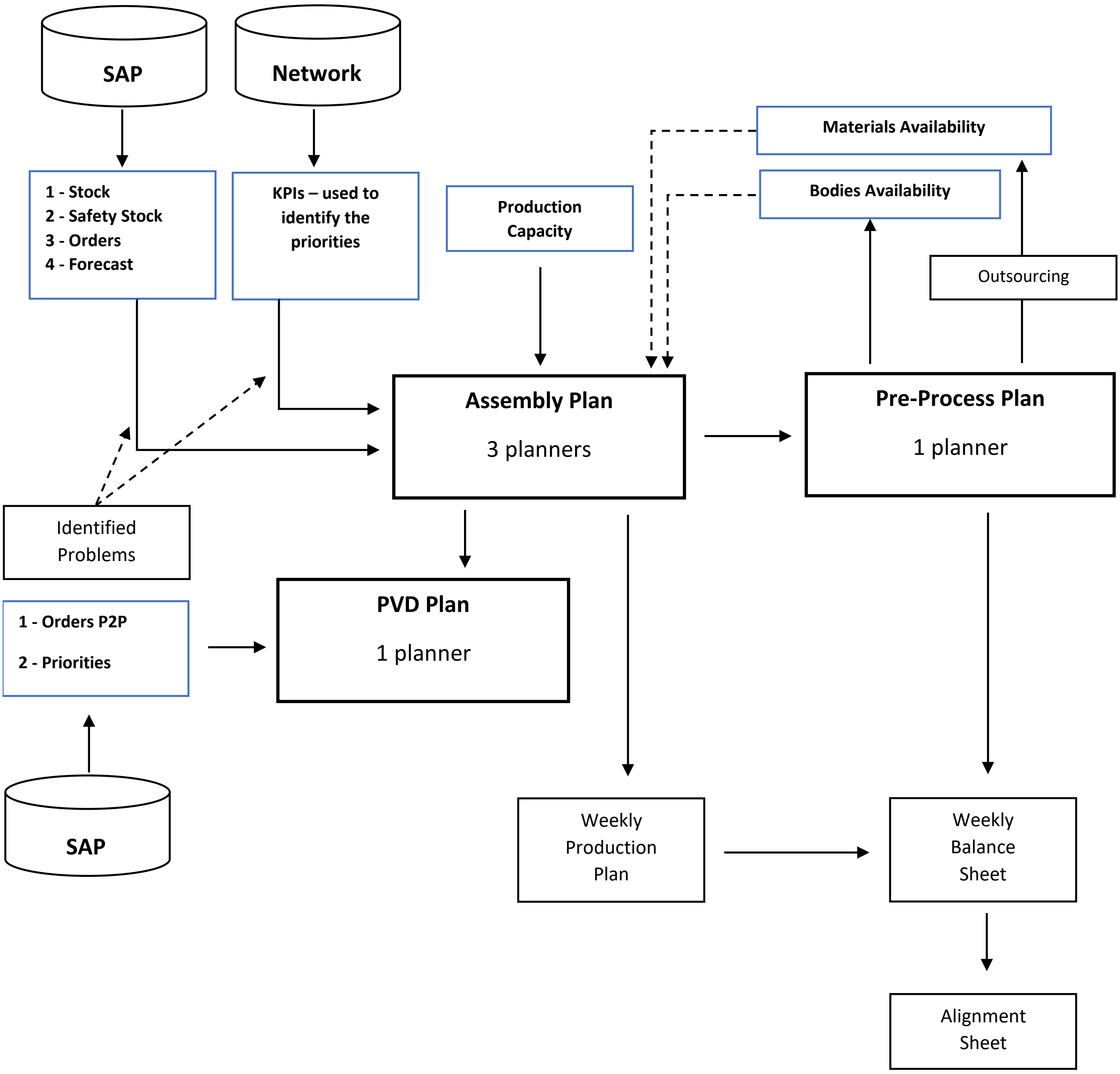

Figure 11 - Production planning in a pull logic

3.2.3 KPIs used by the company

The accurate definition of performance measures for a specific process plays a fundamental role in nowadays' companies. This happens because such measures aggregate a wide range of information that helps to have a general vision of the evolution of the company.

KPIs are used because there is a necessity of having control at a strategic level. They started being developed by the Central Production Planning and Control. Because of their high importance, the KPIs are the same meaning that they don't often create new ones or eliminate old ones; the ones they use evolve and, by doing so, are refreshed every day.

The KPIs file is prepared and sent by the central planning in Germany, containing a diversity of data that creates noise and entropy impairing to understanding of the production priorities for the Portuguese plant. This may interfere with the Information Quality, mentioned in the literature, since it will block the potential of this set of data to achieve the goal of having specific information about a product or a family of products. It will also affect the Data Productivity, not in a data availability sense, but in a data quality way, as well as the performance of the decision-making. The noise resultant from the excess of data creates a necessity of working and shaping the file, putting it in a specific template for the Portuguese plant.

One of the main challenges from this work is to improve the way this file is updated. Usually the planner takes a long time to update the file. This happens because there are a lot of steps that needs to be performed, as it could be seen in Figure 6. Figure 12 shows a part of the file used every morning to define the strategy of the production planning. It should be noted that, for confidentiality reasons, the data showed in all the figures of this chapter, as well as the next one, have been altered.

Date	Plant	AVIndicat or	MRPTyp	Status	Product	Design	Supporting Unit	Stock	Safety Stock	Availab	Achievement	BL	<30	30-80	>80	100
10/1	0201	PD	XC	2	40554xyz	GROHE	GROHE Kitchen Fit	2	0	-627	0 %	1	1	0	0	0
10/1	0201	PD	XC	2	41081xyz	GROHE	GROHE Kitchen Fit	1 039	0	-337	0 %	1	1	0	0	0
10/1	0201	D9	AC	2	27394xyz	New Ten	GROHE Showers &	1 084	3 723	-3 890	0 %	1	1	0	0	0
10/1	0201	D9	AC	1	27922xyz	New Ten	GROHE Showers &	476	2 634	-1 324	0 %	1	1	0	0	0
10/1	0201	D9	BC	2	26075xyz	Euphoria	GROHE Showers &	26	0	-198	0 %	1	1	0	0	0
10/1	0201	CX	AC	3	31347xyz	GROHE	GROHE Kitchen Fit	12	0	-126	0 %	1	1	0	0	0
10/1	0201	D9	AC	2	27939xyz	Rainsho	GROHE Showers &	9	75	-164	0 %	1	1	0	0	0
10/1	0201	D9	BC	2	26075xyz	Euphoria	GROHE Showers &	19	0	-183	0 %	1	1	0	0	0
10/1	0204	C1	AC	1	39117xyz	Solido O	GROHE DIY Sanita	24	0	-828	0 %	1	1	0	0	0
10/1	0201	C1	AC	2	31455xyz	GROHE	GROHE Kitchen Fit	34	0	-146	0 %	1	1	0	0	0
10/1	0201	D9	AC	2	27922xyz	New Ten	GROHE Showers &	1 163	5 019	-860	0 %	1	1	0	0	0
10/1	0201	CX	AC	3	31302xyz	GROHE	GROHE Kitchen Fit	4	0	-125	0 %	1	1	0	0	0
10/1	0203	PD	AC	1	38723xyz	Uniset	GROHE Sanitary S	7 031	8 437	-1 771	0 %	1	1	0	0	0
10/1	0201	D9	AC	2	27615xyz	Euphoria	GROHE Showers &	129	2 138	-646	0 %	1	1	0	0	0

Figure 12 - KPIs used every morning

BTS **(Build-to-Schedule)**

Build-to-Schedule is an indicator used to control the pace and performance of the production. Almost every planner uses this indicator on its plan, even if it is not explicitly mentioned. It compares the planned production with the real production and shows the result as a percentage. To calculate the BTS, the formula is:

$$BTS\ (\%) = \frac{Produced\ Quantities}{Planned\ Quantities}\ x\ 100$$

To understand the Build-to-Schedule indicator, an example is given regarding the PVD production plan (Figure 13). In this case, the total production is 13773 pieces, that divided by the production plan of 27227 pieces, represents 51% of BTS. This means that half of the plan was produced.

Plano Peças / cor

	Prio 1 ISH	Prio 1 Ageing	Prio 1	Prio 2	Prio 3	Prio 4	Grand Total
Hard Graphit A0	0	678	30	40	163	2 734	3 645
Brushed Hard Graphit AL	500	1 597	605	200	346	1 534	4 782
Polished Nickel BE	0	234	44	0	324	598	1 200
Warm Sunset DA	199	1 515	740	0	508	1 828	4 790
Supersteel DC	326	282	489	192	765	1 568	3 622
Brushed Warm Sunset DL	0	429	515	0	104	1 264	2 312
Brushed Nickel EN	0	280	215	0	0	623	1 118
Cool Sunrise GL	0	782	72	128	200	958	2 140
Brushed Cool Sunrise GN	0	1 021	1 283	188	536	590	3 618
	1 025	**6 818**	**3 993**	**748**	**2 946**	**11 697**	**27 227**

BTS 51%

Produção Total / cor

	Prio 1 ISH	Prio 1 Ageing	Prio 1	Prio 2	Prio 3	Prio 4	Grand Total
Hard Graphit A0	0	225	0	0	99	828	1 152
Brushed Hard Graphit AL	239	1 093	0	79	232	1 211	2 854
Polished Nickel BE	0	173	1	0	316	515	1 005
Warm Sunset DA	105	793	347	0	416	1 525	3 186
Supersteel DC	320	14	478	89	712	1 008	2 621
Brushed Warm Sunset DL	0	230	362	0	70	463	1 125
Brushed Nickel EN	0	28	80	0	0	13	121
Cool Sunrise GL	0	100	0	0	0	0	100
Brushed Cool Sunrise GN	0	753	371	3	333	149	1 609
	664	**3 409**	**1 639**	**171**	**2 178**	**5 712**	**13 773**

Figure 13 - BTS for PVD production plan

Backlog **(and Backlog in Transit)**

As defined by Peters (2015), backlog "gives a picture of resources and whether if we are capable of accomplishing work with in-house staff, overtime, staff additions, or outsourcing to contract maintenance providers" (What is the difference between order and backlog?, n.d.). In other words, backlog is a set of orders that were not yet delivered to the client.

Backlog in transit is already on the way to the customer, but it has not been delivered yet. To control this type of backlog, there is a file that is updated together with the KPIs and gives precisely this information.

There are two important distinctions to be done: if it was possible to deliver the order within the agreed span, it was a *backlog*. However, if the promised delivery date has passed and the order is still in plant, then it becomes a *backorder*. Figure 14 shows the Backlog Information.

Product	Design	Supporting Unit	Stock	Safety Stock	BL	<30	30-80	>80	100	Backlog pcs <=today	VS Backlog pcs prev day	Changes Backlog
40554xyz	GROHE	GROHE Kitchen Fit	2	0	1	1	0	0	0	-42	-32	increased
41081xyz	GROHE	GROHE Kitchen Fit	1 039	0	1	1	0	0	0	-22	-337	reduced
27394xyz	New Ten	GROHE Showers &	1 084	3 723	1	1	0	0	0	-259	-756	reduced
27922xyz	New Ten	GROHE Showers &	476	2 634	1	1	0	0	0	-88	-149	reduced
26075xyz	Euphoria	GROHE Showers &	26	0	1	1	0	0	0	-13	-8	increased
31347xyz	GROHE	GROHE Kitchen Fit	12	0	1	1	0	0	0	-8	-5	increased
27939xyz	Rainsho	GROHE Showers &	9	75	1	1	0	0	0	-11	32	reduced
26075xyz	Euphoria	GROHE Showers &	19	0	1	1	0	0	0	-12	-4	increased
39117xyz	Solido O	GROHE DIY Sanita	24	0	1	1	0	0	0	-55	0	increased
31455xyz	GROHE	GROHE Kitchen Fit	34	0	1	1	0	0	0	-10	-18	reduced
27922xyz	New Ten	GROHE Showers &	1 163	5 019	1	1	0	0	0	-57	150	reduced
31302xyz	GROHE	GROHE Kitchen Fit	4	0	1	1	0	0	0	-8	-7	increased
38723xyz	Uniset	GROHE Sanitary S	7 031	8 437	1	1	0	0	0	-118	-1 771	reduced
27615xyz	Euphoria	GROHE Showers &	129	2 138	1	1	0	0	0	-43	-102	reduced
14919xyz	Sensia A	GROHE Spare Par	6	128	1	1	0	0	0	-10	-5	increased
27968xyz	Rainsho	GROHE Showers &	129	224	1	1	0	0	0	-23	-7	increased

Figure 14 - Backlog information

***OTIF* (on time in full)**

On Time in Full is a KPI divided into 2 parts: deliver on time, in which organizations define a delivery time which they should be able to reach (not too soon, not too late); deliver in full, which means that the customer gets exactly the amount that was ordered. This indicator shows if the client is receiving everything it asked for and within the estimated time, representing the performance of the delivery (OTIF, n.d.).

In this case, there are two types of OTIF: against lead-time/stock and against confirmation. They work with OTIF against confirmation, which means that the client receives the totality of what it ordered, but it is not receiving as fast as he would like to. This is an indicator that is made available by the central planning as a separate part of the KPIs and is calculated accordingly to the following expression:

$$OTIF\ (\%) = \%orders\ delivery\ on\ time\ x\ \%orders\ delivery\ in\ full$$

To understand the OTIF indicator, an example is given regarding the Portuguese plant performance (Figure 15).

	Valor SS > 100% (K€)	Valor em falta para SS (K€)	Backlog (K€)	Backlog S/Trânsito (K€)	OTIF	Objectivo OTIF
03-01-2013	62	175	41	41	18,6%	18,0%
04-01-2013	59	179	44	40	18,5%	18,0%
07-01-2013	55	186	46	42	16,9%	18,0%
08-01-2013	49	196	50	41	17,6%	18,0%
09-01-2013	47	202	52	30	13,9%	18,0%
10-01-2013	41	217	55	27	16,0%	18,0%
11-01-2013	40	212	51	24	13,9%	18,0%
14-01-2013	42	198	41	20	15,3%	18,0%
15-01-2013	41	201	41	18	16,1%	18,0%
16-01-2013	43	189	34	16	16,7%	18,0%
17-01-2013	43	182	31	15	13,7%	18,0%
18-01-2013	40	193	40	19	17,9%	18,0%

Figure 15 - OTIF

Availability

It represents the availability of materials for the future weeks (it can also have the future backlog and when is the expected end of backlog). This indicator appears indirectly in the production plans and allows the planners to have a picture of when will the materials be out of backlog and what is going to be the production for the following weeks. If the cell is orange and negative, it means that it is a backlog. If it is orange but positive, it has a high probability of becoming a backlog. To better understand the description, Figure 16 shows the materials' availability according to the current week and for the following weeks, according to the production plan for those materials.

Product	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9
40554xyz	-109	-345	-521	-621	-797	55	59	59
41081xyz	-96	-205	-373	-549	-709	0	0	0
27394xyz	-5 850	-4 409	-4 721	-3 555	-2 583	-1 583	60	-1 831
27922xyz	-1 534	-929	-700	-417	-256	27	280	242
26075xyz	-331	-318	-187	-85	-36	-37	-39	-42
31347xyz	-130	-136	-137	-93	-77	11	1	10
27939xyz	-169	-285	-246	-176	-114	-100	-13	57
26075xyz	-546	-454	-355	-262	-117	-70	30	30
39117xyz	-832	-424	-753	-287	5	-103	-111	2

Figure 16 - Availability information

3.3 Problem Description and Analysis

3.3.1 KPIs Issues

As said before, the KPIs are a measure that highly supports the production planning and control. It allows to identify and track several critical situations and to solve them before they become problems. But this file sometimes does not identify all the critical situations. Some circumstances may occur where a lack of control or information unfortunately happens.

While structuring and following this project, it was important to understand what were the previous problems that the team had identified as related with a lack of information or indicators. Unfortunately, there were two situations in which that happened, and the team had to develop two new indicators to solve the problem: it was the case of the Ageing Orders and the Spare Parts.

Ageing Orders are orders that have a delivery delay of 1 month, 3 months or 6 months, meaning that a client is waiting more than it should for the delivery.

In the middle of 2018, the German leadership started sending reports that showed that some deliveries from Albergaria had high delays. For that reason, they started tracking the situation and the planners from Albergaria created this KPI that is updated daily and that allows to understand how many components are needed to fulfil the ageing orders. Ageing Orders are one of the foremost states to be solved. The objective of the planning team is to monitor the status quo of these situations and to solve then as fast as possible.

Spare Parts are needed when a customer complains because it has a damaged part in its faucet. Strategically, this issue is crucial because in terms of labour force, it is the same as a normal faucet, however in terms of output it is almost insignificant.

Also, in the middle of 2018, the central board started sending reports related with Spare Parts, because there wasn't any type of control related with that. Spare parts are currently another concern of the planning team, since they must check every day if they have released enough production orders for those parts.

These two KPIs are a result of the increase need for control that was talked throughout this work, especially of having control over strategic situations.

There is also another situation to be considered that, although it cannot be called a KPI, represents a situation that needs to be strictly controlled. There is a list of the most sold SKUs, that is called ***Top 200***, and it is valid for the whole GROHE group. From those 200 SKUs, there are 43 that are produced in Albergaria and, in those cases, there cannot exist backlog, the safety stocks need to be always fulfilled. The top management is therefore constantly creating tools to control this situation.

3.3.2 Planning Main Issues

After observing the processes that the planners must follow to conclude the respective plans, several problems were identified, at numerous levels and that are related with a few tasks. The problems were all discussed and approved by the planners and two types of problems were identified: the ones that can be solved and the ones that are hard to solve during this work, because of their complexity or because they require a higher investment. Consequently, a distinction was done between Type 1 and Type 2 problems.

The type 1 problems are solvable, considering that there is no need for investment or other additional effort from the company. These problems are related with the information and to make it more explicit. On the other hand, the type 2 problems are complex problems, that do not depend only of the production and planning department, making them harder to solve. These problems are related with the proceedings of the processes. However, they were also identified during this project but, for all practical purposes, only type 1 problems will be handled.

Type 1 problems

- High quantity of support files – to construct the plan, they need information from file A, B, C. There are flows of information that are happening at the same time which causes a dispersion of data;
- Excess of manual work – some proceedings could be more automated;
- Redundancy of data – some files have the same information shown in a different way;
- Excess of information that creates a necessity of selecting and filtering – complexity to obtain the wanted information that requires a lot of effort when analysing the files;
- Unappealing visualisation of the files – some of them have a lot of data, others have the essential data but not presented in the most user-friendly way;
- Information is not condensed in the same place – increases the probability of errors.

Type 2 problems

- Sometimes the information is not real, that reduces the credibility of the information that is used in the plans – for example, deviations of stock in terms of quantity and location;
- A lot of oscillations of the central planning that result in additional effort to develop the local planning – poor stability, the process is the same, but the goals are always changing;
- The turnover in the shop floor is high, so it is difficult to constantly adjust the plan to the production capacity (poor stability, again);
- Communication failures with the central planning – the forecast review is done every month, which influences the consistency of the plan in the long term;
- Sometimes there is no availability of the material which influences the fulfilment of the planning tasks, and that can cause some pressures that should not exist. This can lead to errors because they may have to do a lot of things at the same time;
- Heavy files or slow computers.

In the process of identifying the main problems felt in the production planning, it was considered that the number of files that are shared in SharePoint was too high, and that would cause entropy. However, when the planners were confronted about that, they stated that it "eases the access of everyone to everything".

Although each of the planners has its own functions, it doesn't exist a lot of specificity in the tasks. Therefore, the planners are a backup of each other. If one is missing, there is always someone that knows how to do their tasks.

To expose the problems in a clearer way, an Ishikawa Diagram was used (see Figure 17). This diagram shows the "systematic relationship between a result or an effect and its possible causes. It is an effective tool to systematically generate ideas about causes for problems and to present these in a structured form" (Magar & Shinde, 2014). The Ishikawa will be useful to perform an analysis to the problems felt while updating the production plans, and to identify possible points of improvement, which is one of the mail goals of this work. The main causes of the poor quality of the decision making and, consequently, of the not so good performance of the production planning were identified in an easier and faster way.

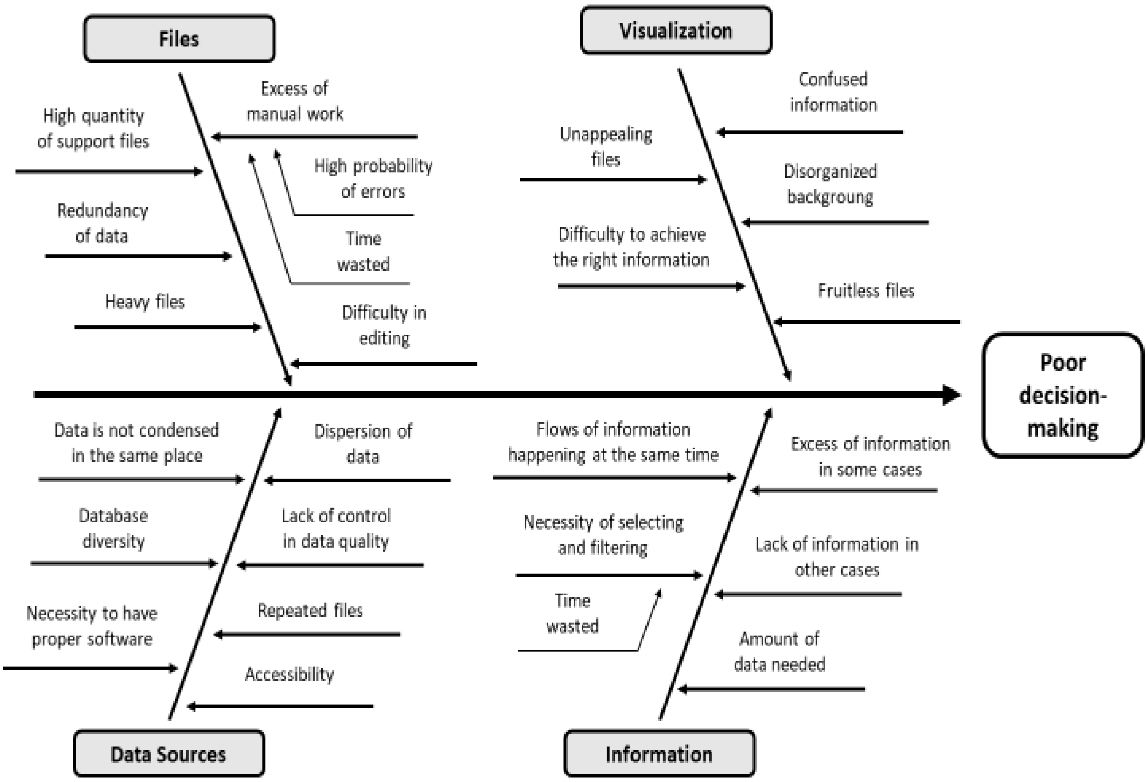

Figure 17 - Ishikawa Diagram

As it can be perceived at this point, there are four main possible causes that may lead to the poor decision-making in the production planning: the data sources, the information itself, the files and the visualization. In the diagram, it is also possible to see that each of the causes has several secondary causes.

Figure 18 summarises the relation between the plans' preparation and the hidden problems that most affect the planners when preparing the plans. To have an efficient decision-making, there are several factors that may get in the way and to better understand the factors that block the desired efficiency, an example will be given.

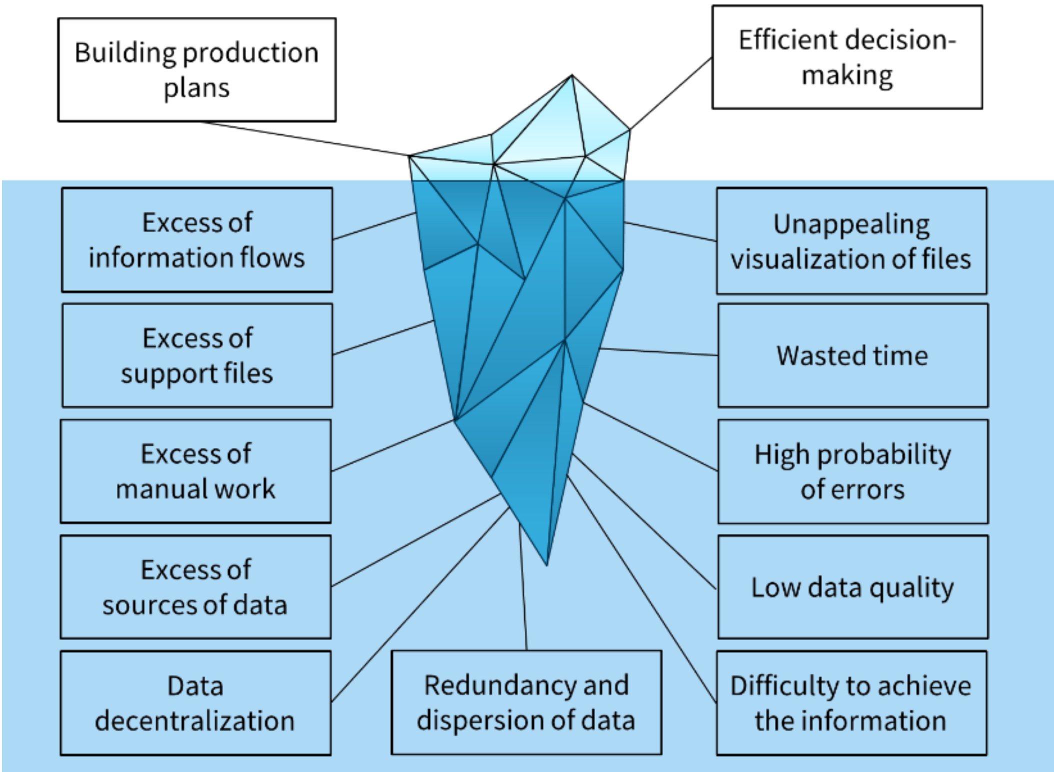

Figure 18 - Hidden problems of production planning

For example, when analysing Figure 6 – Update KPIs Business Process Model, one of the hidden problems is the unappealing visualization of files. It happens because this planner works on the KPI file, in Excel, with information for all the products produced in Albergaria, which means working with thousands of products. This includes analysing stocks, backlogs, OTIF or other types of data/indicators without having any graphical information about them, but mainly numbers. The same situation happens in the production plans.

This poor visualization is mainly seen when performing the activities "Export existing stocks", "Update information about Backlog", and "Update column OTIF". As it is not appealing it leads to more hidden problems, for example the difficulty to obtain the information, because it is hard to get to the wanted one since the file is heavy and has data for thousands of products. It may also lead to errors or to waste of time, as it can be seen in Figure 6, because there is a sequence of steps that needs to be followed to update the KPI file.

If the planner makes an error, which is not that uncommon due to the high quantity of information, it will have to perform the steps from the beginning. The unappealing visualization of files and indicators also implies effort to get to the wanted information, considering the confusing and disorganized environment.

There is another problem associated with this, which is the excess of manual tasks that the planner does, also observed in the sequence of stages to update the KPIs (Figure 6). For example, it can be seen in the activity “Mark priorities” where the planner analyses a set of specific products one-by-one. In this case, there is a possible improvement if that sequence is more automated. Another example can be seen in Figures 7, 8 and 9. There is a common activity in the plans, which is “Check components that are missing”. Knowing what are the components that are missing is not an automated task and requires several one-by-one manual verifications of the components.

The excess of support files is another hidden inefficiency of the process of updating and building the plans. To construct the plan, the planner needs information from different files, meaning that a lot of information flows will also happen. In some cases, the information that is shared is the same, leading to the redundancy of data. The high quantity of support files reduces significantly the Data Productivity, especially in what concerns the data quality. It means that some files have the same data but shown in a different way. For example, in the Assembly Plan Business Process Model (Figure 7), it is possible to see that the planners “Export the Available Stock” of their products from SAP. When they use the KPI file, they only “Export the priorities”, but the stock information is already there, and they do not export it to the plans. This is also one of the consequences of the high number of data sources and information flows that exist.

The planners retrieve data from different sources and analyze it to decide what is going to be produced. Figure 7 shows the different data sources: Cubes, SAP, KPIs and Backlog in Transit. As the information is not condensed in the same place, it not only increases the possibility of making mistakes, but shows a data decentralization. This may lead to poor data quality because, in some cases, the data may be unstructured, causing entropy to the processes. The presented explanation reflects only a part of the daily struggles of the planners and is not an ideal situation, since most of the times the planners are wasting valuable time that could be allocated to another task.

Considering the aspects of the Lean Information Management, it is possible to conclude that most of its principles (Teixeira et al., 2019) are not being correctly followed:

- the information should only be created if it is useful to the decision makers – in some cases there is redundancy of data, contradicting this principle;
- it should only be sent to those who need – as most of the information is shared in SharePoint, only the ones who need the data search for it, not being a problem in this case;
- it should be quickly processed, if possible, in real-time, avoiding waiting on the part of the users – the planners need to use the KPI file to start working on their plans, so the “in real-time” may not be ensured;
- and it should be provided by sources without duplication of data – as there are several data sources, this principle may be disregarded.

3.3.3 Some Final Remarks

According to what was presented in the previous sections, the set of existing indicators was defined regarding a future perspective. Nevertheless, after a careful analysis, it was possible to see that the measures used are essential for the production planning operations. This means that more indicators will only bring entropy but will not bring the wanted value-added, which is not the goal for this project. Therefore, there are no significant alterations to the set of KPIs that are used by the company. The KPIs that are going to integrate the dashboard are the same that were presented before.

For the future of the production planning, the ideal scenario is one where there is a higher performance and efficiency in updating the files to obtain the wanted information associated with a fast visualization of that information. It is expected that this change is achieved by reducing the time spent in a specific task by reducing the movements that are needed, or even the effort put to achieve a certain information.

To reach the future ideal situation, it is crucial to perform a process analysis in order to develop more accurate solutions.

4. Proposed Solution: Process Analysis, Methodology and Solutions Developed

In this section and according to what was exposed in the previous chapter, after performing a detailed analysis to the current situation of the production planning, several problems were identified, as well as opportunities of improvement. Hence, it is fundamental to present a proposal that may alter the current situation, not establishing barriers to the planners, and that can contribute to the development of the output quality of the Supply Chain.

The steps and techniques used to achieve the solution will be explained in this section. The before and after situations will be explained in order to measure and comprehend the changes proposed. With this solution. it is expected that the results are automatically communicated and felt in the different areas of the company. The solutions developed will mainly focus on 2 aspects:

- **Development of a Dashboard Application Using Microsoft Power BI** to have a faster and more appealing visualization of files and to improve the agility and efficiency of the decisions made.

- **Development of Decision-Making Support Files** to reduce different types of waste in the processes and in the information flows.

4.1 About Power BI

Power BI is a "business analytics service that delivers insights to enable fast, informed decisions". It is used to connect several sources of data, gather and transform the data itself, in order to display it in dashboards in clean visuals. Those visuals help to explore and analyse a determined set of data, considering that it is exposed in interactive dashboards and reports. This is mainly a data management tool.

Nowadays, data that is transformed into information represents power, however, there are also drawbacks from the huge sets of data that the companies currently need to manage. In an era of concepts such as Big Data, the treatment and the access to the right information is essential to gain competitive advantage. Business intelligence tools are vital to retrieve the best output from processes and are now gaining more relevance and importance. As it was an already-known tool amongst the supply chain team, Microsoft Power BI, a business intelligence software, was chosen to build the final solution.

Power BI will be the tool used to implement the Information System solution that mitigates the several problems exposed in this industrial context. As it was explained in chapter 2, an information system should capture, monitor, process and display information in order to support the planners. To develop the system and to understand the inputs needed to have a successful performance, two cycles, described below, were used.

4.2 About Process Analysis and Methodology

To better understand the inputs for this business analytics tool, the Business Process Management (BPM) life cycle will be presented Dumas et al. (2018). This cycle has different phases that explain how the processes' shaping and improvement works. In each of the stages, diverse tools were used to fulfil the necessary requirements. According to this cycle, a process crosses several stages: Identification, Discovery, Analysis, Re-Design, Implementation and Monitoring and Control. Although the cycle has the referred stages, the TO-BE model, the Implementation and the Monitoring and Control will not be considered in this project. The cycle is illustrated in Figure 19.

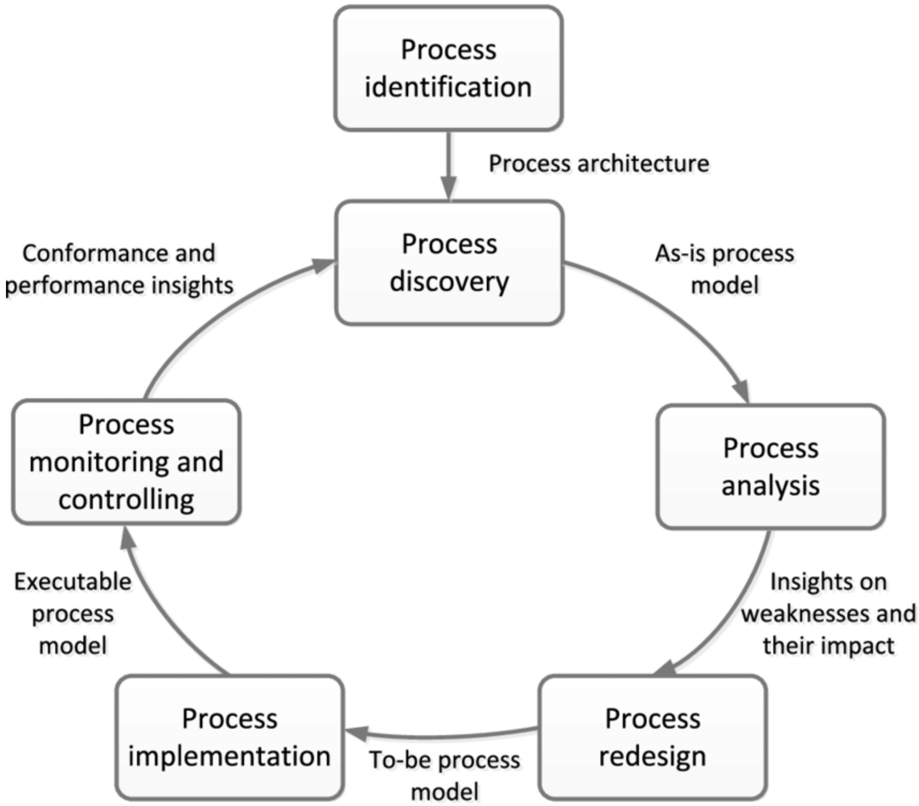

Figure 19 - BPM Life Cycle (Dumas et al., 2018)

Afterwards, the structure of the information system developed was built bearing in mind the System Development (SD) life cycle. The stages of the SD were defined considering the perspective of two different authors. Therefore, several stages will be considered: the systems and software requirements, specified by the requirements analysis and validation, solution design, coding and testing, operations and maintenance of the system (Ramingwong, 2012); (Casteren & Van Casteren, 2017).

On the one hand, Ramingwong (2012) postulates a perspective more dedicated to the Requirements specification, taking into account the Requirements elucidation, the Requirements analysis and negotiation, the Requirements Documentation and the Requirements validation (Figure 20).

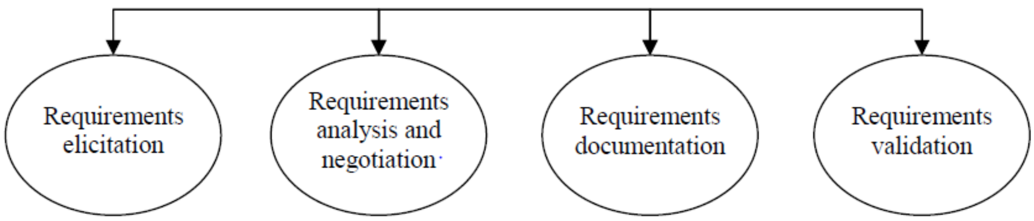

Figure 20 - Ramingwong SD Life Cycle Perspective (Ramingwong, 2012)

On the other hand, in Casteren & Van Casteren (2017) perspective, the System Development is considered as a Waterfall Model. According to (Royce, 1970), the Waterfall Model is a sequence of phases that have an iterative relationship between them and “form a software development sequence”. Therefore, it comprehends several stages: Systems Requirements, Software Requirements, Analysis, Program Design, Coding, Testing and Operations (Figure 21). In this case, as Power BI is an already powerful tool, the Program Design, Coding and Testing will not be necessary. To substitute those stages, a prototype will be defined.

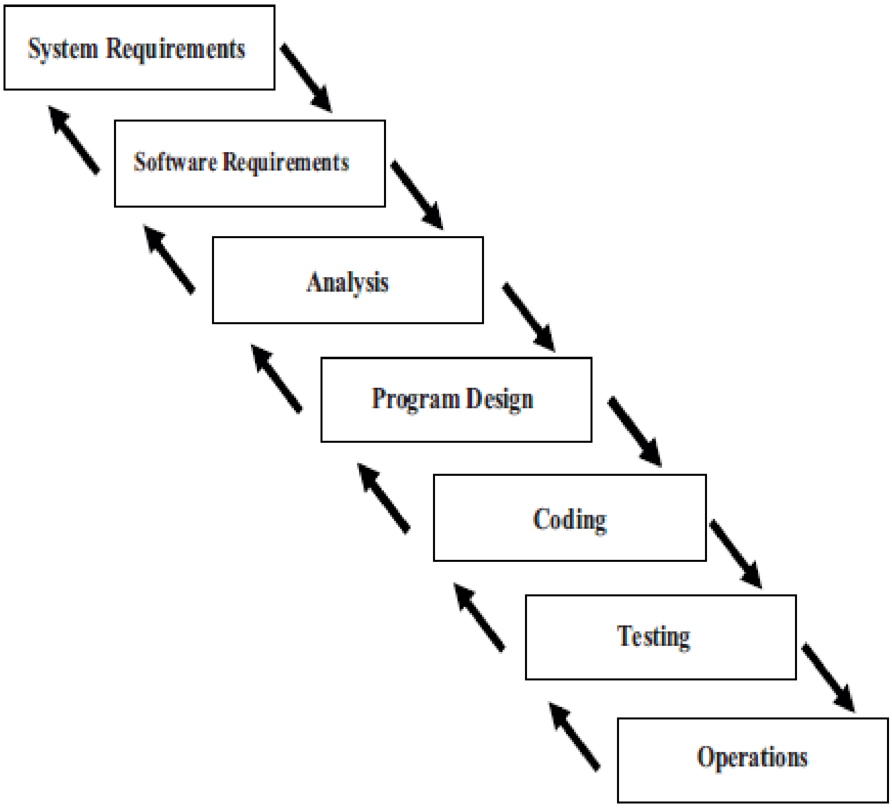

Figure 21 - Waterfall Model (Royce, 1970)

The solution will arise from the combination of the Business Process Management Life Cycle and the System Development Life Cycle.

In the Process Identification and Discovery stages, the System and Software Requirements will also be explored, considering the information gathered about the processes that need to be improved. The problems and the possible improvements are identified, as well as a plausible solution. This requires the definition of a strategy that considers the limitations of the processes, the possible barriers and gains, representing the solution planning phase.

In the Process Analysis, the Requirements are analysed and validated, meaning that the solution is studied to conclude if it is viable or not. BPMN 2.0 is the bridge between the two cycles since it exposes the processes already mapped. If the requirements are not well validated, everything is going to be inadequate after this stage.

The correct and detailed requirements collection and specification is critical in this phase. It is important to emphasise the importance of the Requirements Engineering as the driving force of the SD life cycle that influences the quality of the final system (Serna M., Bachiller S., & Serna A., 2017). It needs to clearly translate the planners' needs and be user-oriented, being also a feasible solution to the company.

In the Process Re-design, it is important to develop a prototype to test the feasibility of Power BI. The coding and testing will not be necessary because the software itself is already autonomous in that aspect. In this phase, it is important to understand what the timing, storage, inputs or outputs are needed for the system.

Figure 22 summarizes the complementary stages of both cycles represented by the same colour. The following explanation will describe each of the referred steps, applied to the specific case of GROHE's Production Planning activities.

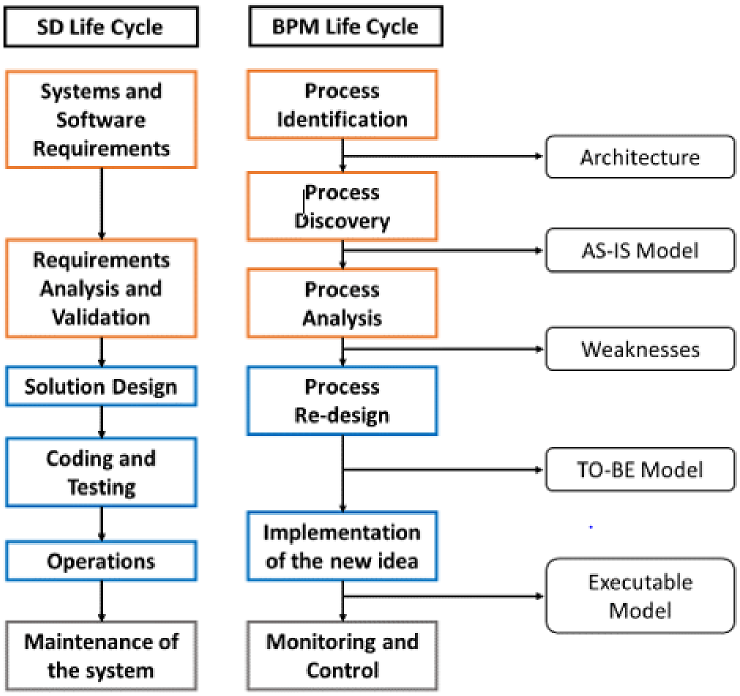

Figure 22 - BPM Life Cycle with the SD Life Cycle (adapted)

4.3 Solutions Developed

4.3.1 Process Identification and Systems Requirements

First, it was important to gather information about the processes, identifying what were the ones that needed to be improved, how to manage them and how to establish priorities, resulting in an architecture of the processes.

In this case, the top management established that the KPIs, that were supporting the production planning, needed to be developed and improved, as well as the information flow quality. To do so, it was important to track the processes' streams that include the KPIs and the production plans making. To clarify and identify the processes, the planners' daily tasks were observed and, while doing that, the boundaries of the processes were established.

This happens because the planners also perform secondary tasks that are not directly related with the production planning but are also important for the success of the planning, like defining what products are going to be shipped in the truck's expeditions from the warehouse.

4.3.2 Process Discovery

The information needed was collected using 3 different techniques: observation, documental analysis and informal interviews. Then, it was organized while doing the process mapping through an AS-IS Model, using the language BPMN 2.0. This instrument was important to map and identify the data sources, the information flows, the people involved and the connection between these elements. Simultaneously, the requirements for the software were being defined.

First, all planners' tasks were observed. This procedure was crucial to distinguish the ones associated with the production plans and, from the ones that were, what were the general and the specific steps and what was the level of data processing and treatment.

Second, as there is a considerable number of files, a documental analysis allowed to understand the importance of the files. Some doubts emerged and there was the necessity to debate some topics. Through informal interviews with the planners, it was easier to discuss the problems and what could be improved. Everything was organized in BPMN 2.0 diagrams, allowing the display of information sources, flows, tasks, files and people involved (as already shown in chapter 3).

4.3.3 Process Analysis and Requirements Analysis

After the Process Discovery, it was possible to identify the main problems of the production planning and divide them into smaller problems with the help of an Ishikawa Diagram (chapter 3). It was then easier to identify the main sources of waste and non-value-added activities so as to implement measures to reduce them. A specific diagram for the production planning was developed, also presented in chapter 3.

Apart from the problems identified, the BPMN 2.0 diagrams were essential to recognize the flows in the production planning processes and what needed to be improved. In this context, it was vital to perform an analysis based on requirements engineering, to discover the purpose of the system under development. Therefore, with the help of BPMN 2.0, it was possible to identify the critical business processes to accomplish the planning goals and the requirements specification and conditions related to the development of the system. This allowed to understand what software to use, why and when to use it. Therefore, a tool that allowed to have dynamic, adaptive and iterative activities was needed, and, in this context, Microsoft Power BI emerged.

4.3.4 Process Re-design and Solution Design

After identifying the problems, a process performance improvement is expected. Hence, the solution will mainly rely on the information system that collects data automatically and favours the visualization of data, as the most important requirements. To do so, Microsoft Power BI was chosen, since it is a system that supports the decision-making, the control, analysis and coordination of the organization.

This solution is also related with a performance measurement system explained in chapter 2, since it will be constantly measuring the performance of specific processes and activities.

This system should also be able to "provide data for monitoring the past and the future performance and to strengthen the strategies to avoid introducing conflicting indicators" (Microsoft Power BI, n.d.), as referred in the State of the Art. Also, to achieve a better performance, the planners' opinion and feedback about the selected software is needed.

In order to understand the feasibility of the solution, an analysis of the Lean minimization of waste, or *Muda*, was made. *Muda* elimination is one of the hardest challenges faced today (Arunagiri & Gnanavelbabu, 2014). A comparison between the initial situation, considering the 8 types of Muda, and the results from the implementation of the proposed actions, considering the same types of *Muda*, will be presented.

4.3.5 Information System Development

Whenever there is waste there is also an opportunity for improvement. In this case, the improvement will be the creation of an autonomous information system that streamlines the process, gathers, centralizes and quickly shows the wanted information in near real time. These systems combines technology, people and data to support business requirements (Shelly & Rosenblatt, 2012).

The solution was developed and supported using a business intelligence tool: Microsoft Power BI, that allows to import and connect to different data sources by using queries. Its powerful features help to create customized dashboards that show various types of information, through a user-friendly interaction (Microsoft Power BI, n.d.).

The software improves the data visualization and centralization, helping the planners in their daily tasks, especially when consulting specific information, and bringing efficiency to the processes. Visualization is the key for quickly accessing and processing data to transform it into information. Moreover, the access to data is instantaneous, since the dashboard is easy and fast to update. It also gives the possibility to select only the wanted information, while having access to it in nearly real time.

These business intelligence instruments are excellent to perform data management and analysis, as they permit to build an historical-based analysis and overview of the indicators. It is a tool used to support the information creation and provision, as said in the literature.

Depending on what the user wants to view, it is possible to click in the displayed graphics that will expand and drill-down, for example, to the wanted year, month, day or to a specific value. Additionally, almost anyone can have access to the dashboards, if an authorization and a link are shared, making it possible to spread information in a general way.

This software has a Data Model on its background, meaning that by using the function Power Query, it is possible to refresh the files automatically following the same principles of the feature *Get and Transform* from Microsoft Excel. It centralizes the information, reducing the excess of flows that happen, the probability of errors caused by human intervention and the time for treating and analysing data.

The idea is to incorporate small changes so that the data can be handled automatically. It is expected that the system brings efficiency to the daily management and the decision component of the production planning, also fulfilling the principles of the Lean Information Management: information is useful to the decision makers, it is only invoked by the ones who need it, is quickly processed and doesn't have duplicated sources of data.

Since the most relevant information is exposed on the file KPIs sent by the Central Planning, that will be the basis to provide the system with data. The idea is to have a main menu that can lead the user to several points of information (daily, weekly or monthly analysis of the indicators for example). It should be possible for the user to see several charts, depending on the wanted options. It should also have information about the target for each indicator and a recorded past regarding that same indicator, to help understand how the company is evolving. To better understand the two scenarios, namely before and after the proposed system, a brief explanation will be made.

a) The Scenario Before

In section 3.2.2, the steps to update the KPIs file were explained. As it can be seen in Figure 18, this file (that contains the most important information for the planners) has the data presented basically in numbers and letters, for almost 15.000 different products. The complexity increases every time a new product is developed, which happens frequently. There are no graphics that represent the huge amount of information to be considered. This file represents a database of the materials produced along the supply chain, as well as the relevant information about those components.

Despite having these characteristics, it is true that the good performance and results of the production planning of the Portuguese plant are due to the fact that the team bases its approaches and strategies on the mentioned file. They know where to focus and what are the situations that need to be controlled. Nevertheless, a lot of time is wasted when updating the file and it is hard to extract the wanted information in a direct and fast way.

Considering the three components of the data productivity, in this case, the data availability is not the problem, but the data quality and the performance of the decision-making could be better. It can be said that the data productivity in general can be improved. If, for example, a planner wants to know what is the product that has the highest value of backlog, it has to filter the data since it does not have the answer instantly. Also, it has an unappealing visualization of that information, as it can be seen in Figure 23.

Once more it should be referred that the data included in the figures was modified, due to confidentiality issues.

Product	BL	<30	30-80	>80	100	Backlog pcs <=today	Changes Orders	Changes Backlog	Changes<30	Cluster prev day	Expected end of backlog	BL Reason	BL Comment
40554xyz	1	1	0	0	0	-42		increased		<30%	CW 7		
41081xyz	1	1	0	0	0	-22		reduced		>80	CW 7		
27394xyz	1	1	0	0	0	-259	increased	reduced		<30%	CW 8	Procurement	MRP Planer
27922xyz	1	1	0	0	0	-88	increased	reduced		<30%	CW 7	NN	Solved
26075xyz	1	1	0	0	0	-13	reduced	increased		<30%	CW 12	colours	MRP Planer
31347xyz	1	1	0	0	0	-8	increased	increased		<30%	CW 7		
27939xyz	1	1	0	0	0	-11	reduced	reduced		<30%	CW 9	Procurement	MRP Planer
26075xyz	1	1	0	0	0	-12	increased	increased		<30%	CW 8	colors supplie	MRP Planer
39117xyz	1	1	0	0	0	-55	increased	increased		<30%	CW 6		
31455xyz	1	1	0	0	0	-10	increased	reduced		<30%	CW 5		
27922xyz	1	1	0	0	0	-57	increased	reduced		<30%	CW 5	Capacity	MRP Planer
31302xyz	1	1	0	0	0	-8	increased	increased		<30%	CW 5		
38723xyz	1	1	0	0	0	-118	increased	reduced		<30%	CW 4		
27615xyz	1	1	0	0	0	-43	increased	reduced		<30%	CW 7	Capacity	MRP Planer

Figure 23 - Information about Backlogs

Another thing that happens with this file is that, when it is sent from the German Central planning, there is information that the planners don't use, don't know what it means, but also don't erase from the file. Hence, as the information is not being fully used, it has waste associated. The idea would be to eliminate this excessive data that is not adding value for the planning. In the case of Figure 24, for example, the planners know what the Transit Total pieces is, as well as the Transit Total Value. This information is useful for the "Backlog in Transit". However, they don't know what the Transit pieces BW and Transit BW Value represent.

BW_Prod plan pcs	BW_Prod plan Value	Transit Total pcs	Transit Total Value	Transit pcs BW	Transit BW Value
346	149 784,27	0	0,00	0	0,00
209	99 097,35	0	0,00	0	0,00
896	34 218,78	896	34 218,78	84	3 208,01
96	7 484,77	896	69 857,89	32	2 494,92
0	0,00	0	0,00	0	0,00
0	0,00	0	0,00	0	0,00
0	0,00	0	0,00	0	0,00
0	0,00	0	0,00	0	0,00
0	0,00	0	0,00	0	0,00
0	0,00	0	0,00	0	0,00
22	1 757,53	166	13 261,37	22	1 757,53
16	8 674,97	0	0,00	0	0,00
0	0,00	78	2 711,58	0	0,00
28	2 615,28	266	24 845,20	28	2 615,28
50	17 664,01	460	162 508,89	50	17 664,01
0	0,00	0	0,00	0	0,00
0	0,00	0	0,00	0	0,00
72	3 745,49	354	18 415,33	72	3 745,49
0	0,00	0	0,00	0	0,00

Figure 24 - Excess of information

To improve the information quality, a dashboard was developed. This dashboard was based on an Excel file that uses data from the KPIs to construct an historic overview of three indicators: Safety Stocks status, OTIF status and Backlog status of the Portuguese plant.

This file is manually updated every day and helps to perform analysis of the situations of the three indicators. This tool is mainly used to perform a production control and to monitor the performance of the Portuguese plant (Figure 25).

	Valor SS > 100% (K€)	Valor em falta para SS (K€)	Backlog (K€)	Backlog S/Trânsito (K€)	OTIF	Objectivo OTIF
03-01-2013	62	175	41	41	18,6%	18,0%
04-01-2013	59	179	44	40	18,5%	18,0%
07-01-2013	55	186	46	42	16,9%	18,0%
08-01-2013	49	196	50	41	17,6%	18,0%
09-01-2013	47	202	52	30	13,9%	18,0%
10-01-2013	41	217	55	27	16,0%	18,0%
11-01-2013	40	212	51	24	13,9%	18,0%
14-01-2013	42	198	41	20	15,3%	18,0%
15-01-2013	41	201	41	18	16,1%	18,0%
16-01-2013	43	189	34	16	16,7%	18,0%
17-01-2013	43	182	31	15	13,7%	18,0%
18-01-2013	40	193	40	19	17,9%	18,0%
21-01-2013	40	179	33	18	15,6%	18,0%
22-01-2013	31	188	40	15	18,0%	18,0%
23-01-2013	35	171	34	12	17,9%	18,0%
24-01-2013	34	163	29	9	16,1%	18,0%
25-01-2013	32	160	25	9	17,2%	18,0%
28-01-2013	28	144	21	7	18,6%	18,0%
29-01-2013	27	150	21	8	15,4%	18,0%
30-01-2013	29	143	17	8	19,2%	18,0%
31-01-2013	28	168	19	8	18,7%	18,0%
01-02-2013	30	176	22	9	18,2%	18,0%
04-02-2013	32	180	25	10	18,7%	18,0%
05-02-2013	38	174	22	10	18,6%	18,0%
06-02-2013	37	173	22	8	18,7%	18,0%
07-02-2013	38	165	20	8	17,0%	18,0%
08-02-2013	40	148	17	8	19,3%	18,0%
11-02-2013	45	134	16	10	19,5%	18,0%
13-02-2013	50	138	18	13	17,3%	18,0%
14-02-2013	54	137	19	13	18,0%	18,0%
15-02-2013	52	153	24	15	18,6%	18,0%
18-02-2013	53	155	26	14	18,5%	18,0%
19-02-2013	66	145	26	15	18,1%	18,0%
20-02-2013	65	140	23	15	18,8%	18,0%
21-02-2013	62	133	22	16	19,0%	18,0%

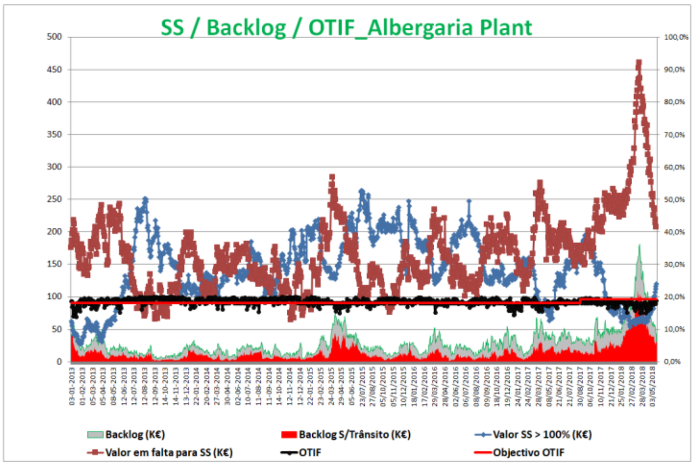

Figure 25 - File used to perform production control

As it can be seen, the file has several data from each of the indicators since 2013. On the one hand, in the way it is used, it does not even show the indicators and, therefore, it is not easy to perceive what is the general evolution of both SS; Backlog and OTIF (Figure 26).

	Valor SS > 100% (K€)	Valor em falta para SS (K€)	Backlog (K€)	Backlog S/Trânsito (K€)	OTIF	Objectivo OTIF
03-01-2013	62	175	41	41	18,6%	18,0%
04-01-2013	59	179	44	40	18,5%	18,0%
07-01-2013	55	186	46	42	16,9%	18,0%
08-01-2013	49	196	50	41	17,6%	18,0%
09-01-2013	47	202	52	30	13,9%	18,0%
10-01-2013	41	217	55	27	16,0%	18,0%
11-01-2013	40	212	51	24	13,9%	18,0%
14-01-2013	42	198	41	20	15,3%	18,0%
15-01-2013	41	201	41	18	16,1%	18,0%
16-01-2013	43	189	34	16	16,7%	18,0%
17-01-2013	43	182	31	15	13,7%	18,0%
18-01-2013	40	193	40	19	17,9%	18,0%
21-01-2013	40	179	33	18	15,6%	18,0%
22-01-2013	31	188	40	15	18,0%	18,0%
23-01-2013	35	171	34	12	17,9%	18,0%

Figure 26 - Indicators control

On the other hand, a graphic is also displayed in this tool, however, it represents all the indicators in the same background. For that reason, it is also confusing to understand what is happening to the indicators in an individual way and to clearly understand what is happening in each case (Figure 27).

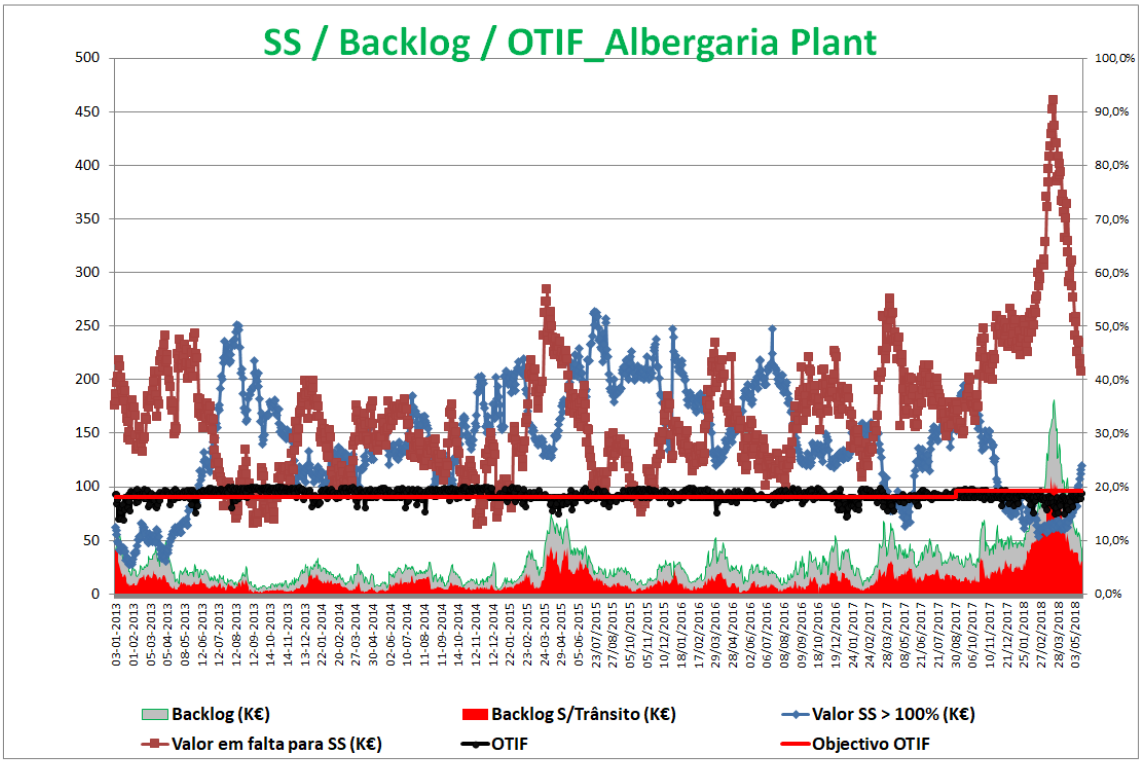

Figure 27 - Graphic for the indicators control

In the production planning, the large amount of data and variety of information sources and flows make the processes complex. Also, the display and storage formats currently used are not the most efficient to comprehend the production performance.

There is a loss in the visual information flows, and it is hard to establish the connection between the indicators. The panorama and status of each of the indicators could also be displayed in another format that was simpler. With this type of format, there is a redundancy in the resources used, since there is a person that manually has to perform this analysis. There is also an additional effort to understand the information, as perceived by Figure 26 and Figure 27.

With a technological integrated system, it is easier to improve the information flows and to better perform this type of analysis. Therefore, that solution should have several simple and organized dashboards, easy to consult and comprehend and that contain only the relevant information for each indicator, displaying it to the right users, in the right time and in the right order of importance. In terms of the process itself, no great changes occurred, however, some types of waste were mitigated with the implementation of some other tools (decision-making support files).

b) The Scenario After

Before implementing the system, two prototypes were developed to show the potentiality of the features of this business intelligence tool and to perform the proof of concept. Prototype 1 considers the information that comes from the KPIs file and is used in the Excel file that considers the evolution of Backlog, Safety Stock and OTIF. Prototype 2 considers the information that comes from the KPIs file and is used to control the situation of TOP 200, the most recent situation that needs to be controlled. Since it is one of the most important inputs for the production plans, the KPIs file used in the production planning is the basis for this prototype.

Considering Prototype 1, this is the information from the Excel file already in the Power BI (Figure 28). Although it looks the same, it will be exhibited in another way.

Date	SS > 100% (K€)	Missing to SS (K€)	Backlog (K€)	Backlog w/Transit (K€)	OTIF (%)	OTIF Target (%)
25 de julho de 2016	209	118	18	6	18,00%	18,00%
27 de julho de 2016	200	131	16	5	18,00%	18,00%
2 de agosto de 2016	193	124	15	5	18,00%	18,00%
5 de agosto de 2016	204	107	9	2	18,00%	18,00%
8 de agosto de 2016	194	121	12	4	18,00%	18,00%
12 de agosto de 2016	197	99	10	5	18,00%	18,00%
18 de agosto de 2016	182	120	13	6	18,00%	18,00%
23 de agosto de 2016	170	131	19	8	18,00%	18,00%
24 de agosto de 2016	171	126	16	6	18,00%	18,00%
31 de agosto de 2016	146	175	30	12	18,00%	18,00%
2 de setembro de 2016	139	155	18	5	18,00%	18,00%
6 de setembro de 2016	132	161	22	9	18,00%	18,00%
14 de setembro de 2016	124	172	25	7	18,00%	18,00%
22 de setembro de 2016	131	168	18	7	18,00%	18,00%
17 de outubro de 2016	136	182	28	9	18,00%	18,00%
24 de outubro de 2016	139	152	18	5	18,00%	18,00%

Figure 28 - Data imported from the Excel file

First, an history of the three KPIs (Backlog, OTIF and Safety Stock) from 2013 to the present was built into the referred Excel file. The data was imported to the software and that file was connected to Power BI. Several different graphics were select for each of the KPIs in order to do a comparison between the present and the past. Once the software is open, the interface that will be displayed can be seen in Figure 29.

It is possible to navigate through several pages, namely a general one, where there is an historic overview of the status of Backlog, Safety stock and OTIF, and three more pages, each dedicated to one of the indicators, with data from 2013 to 2019. The big advantage of this tool is that the navigation is easy and intuitive, since the user can always return to the initial page by clicking in the arrow that is on the left lower corner.

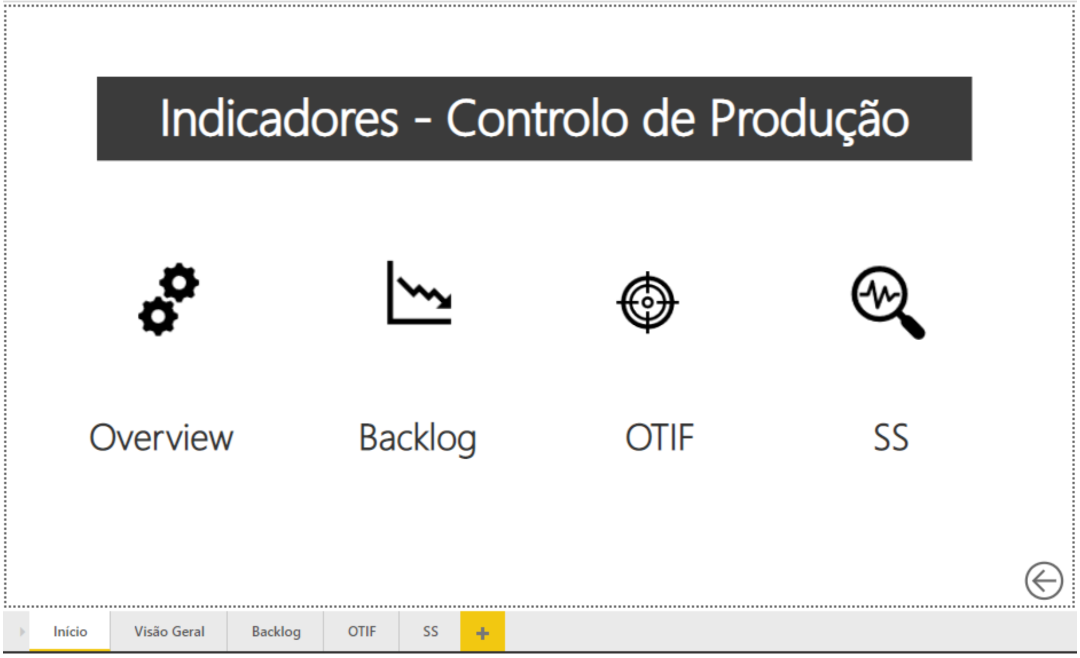

Figure 29 - Initial Interface (KPIs)

Every time that there is new data about the indicators (every morning when the Central Planning updates it), the user just needs to press the button “Refresh” and the data from the Excel file will automatically be loaded with the new data, to the Power BI software (Figure 30). In a few seconds, the new data will be seen in the displayed graphics. It is important to consider that, before this dashboard, the planner responsible for updating this file spent almost 45 minutes every morning to update the file to get this information.

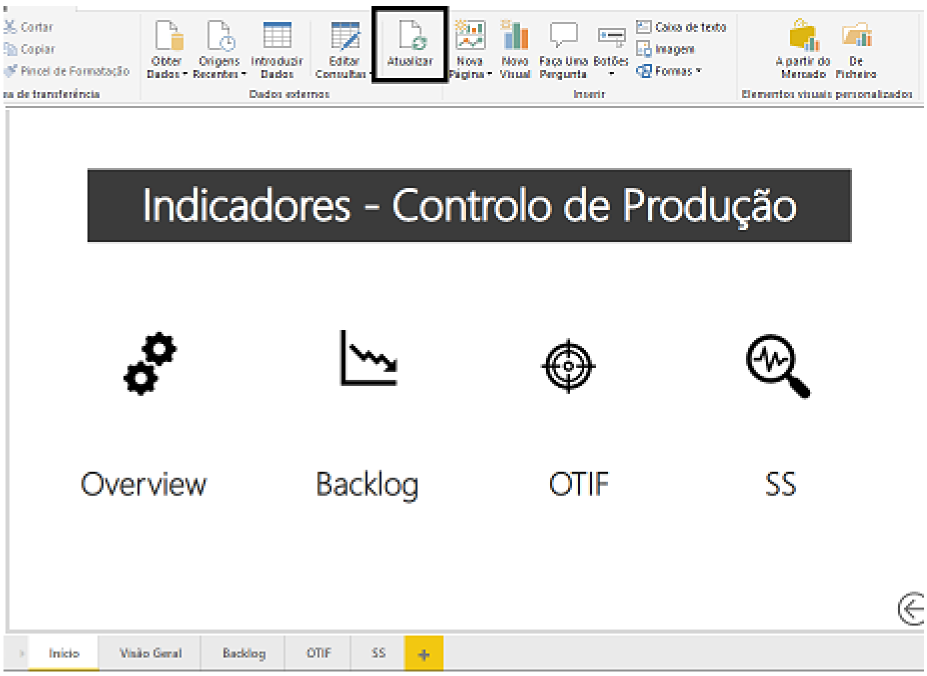

Figure 30 - Refresh Button

As it is important to constantly analyse data in the production planning and control, this file is useful to see “the big picture” and to quickly review the state of progress to the mentioned indicators. When the user clicks in “Overview”, this the screen displayed will be one in Figure 31.

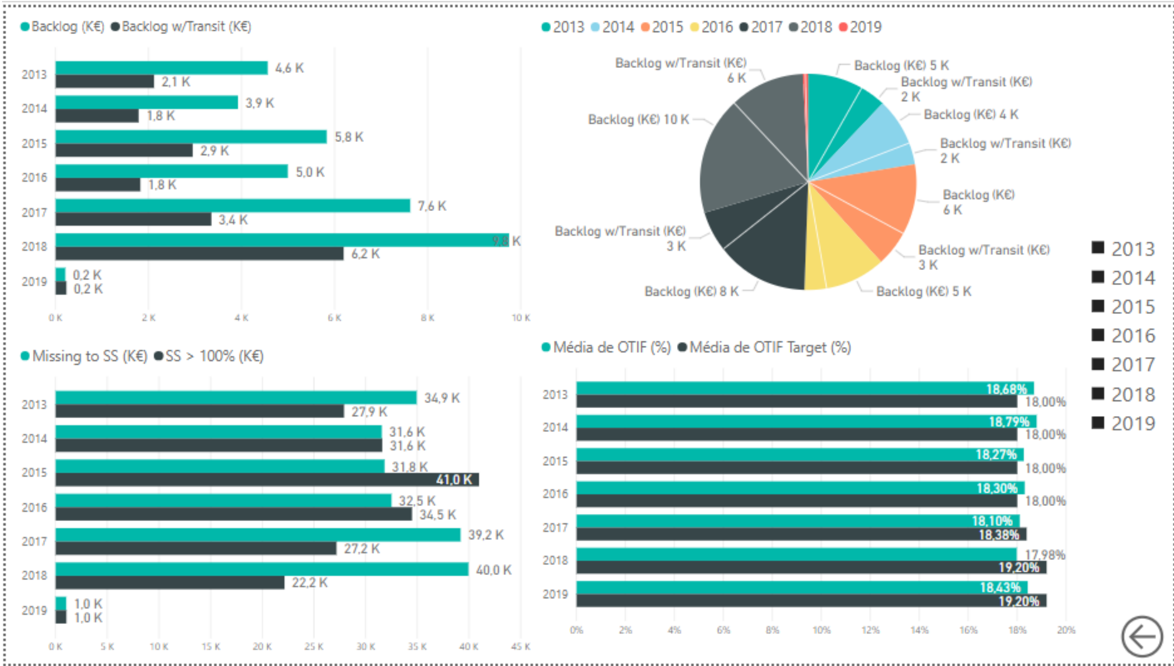

Figure 31 - Overview of the indicators

Another advantage of this tool, comparing to the file used before, is the fact that it is an interactive dashboard, and since it compiles data from 2013 to 2019, the user can drill-down the data or select only data from 2013, from 2013 and 2014, etc (Figure 32, 33 and 34).

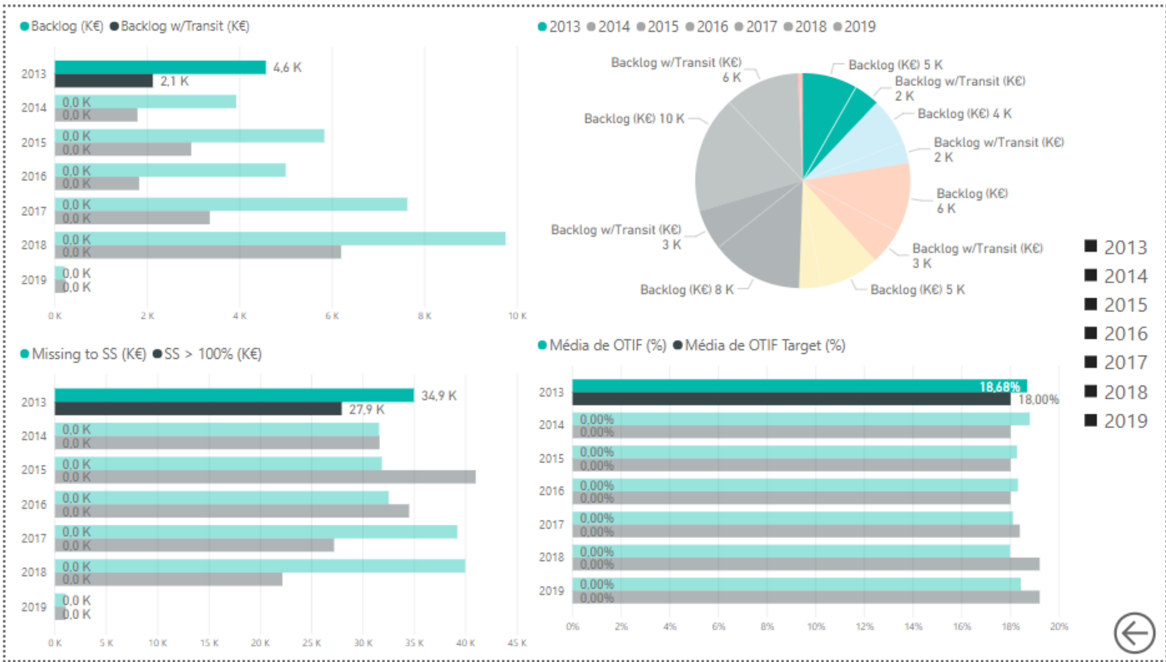

Figure 32 - Overview considering the drill-down

As the user can visualize the data almost instantly, depending on what it wants to see, the displayed graphics can show the data for the wanted year, month or day or for a set of years.

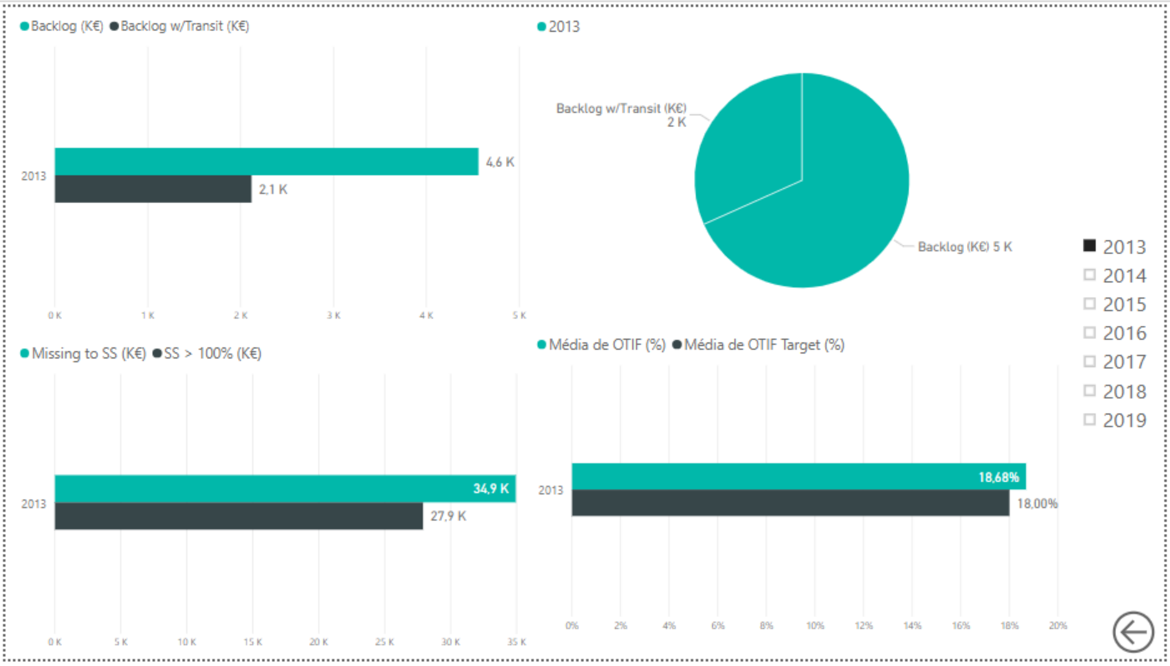

Figure 33 - Overview considering a year

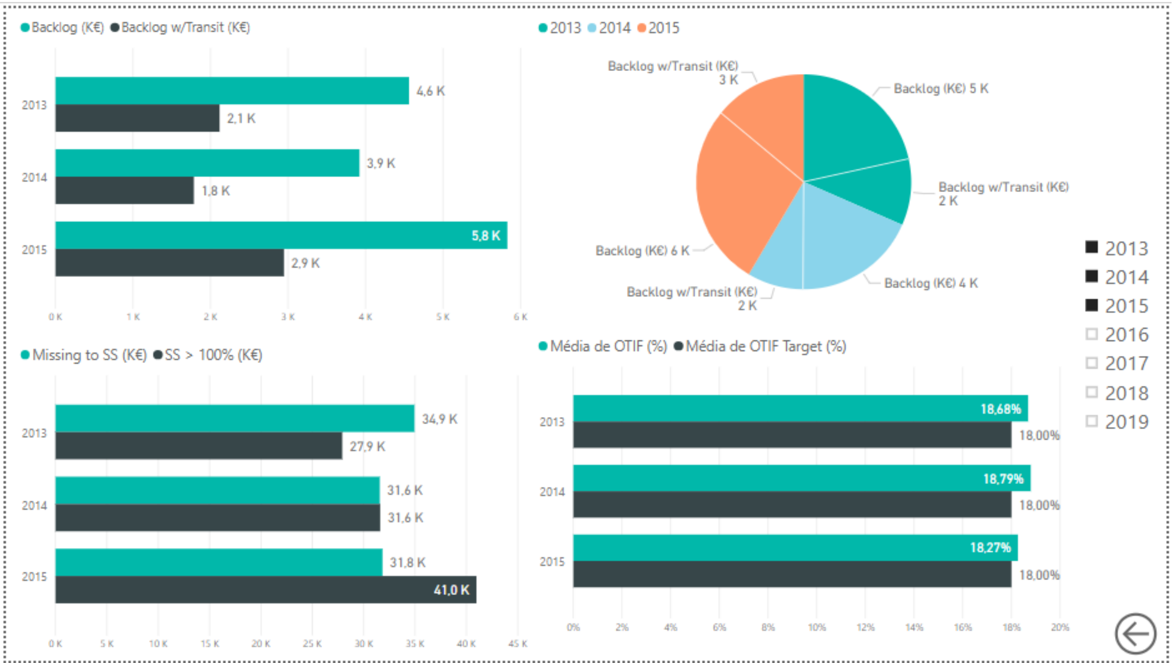

Figure 34 - Overview considering a set of years

This may serve as a starting point for more detailed and comprehensive analysis, as it can be seen in the figures bellow (Figures 35, 36, 37, 38, 39 and 40). On the right it is possible to consult several measures for each indicator: the mean, the minimum or the maximum values.

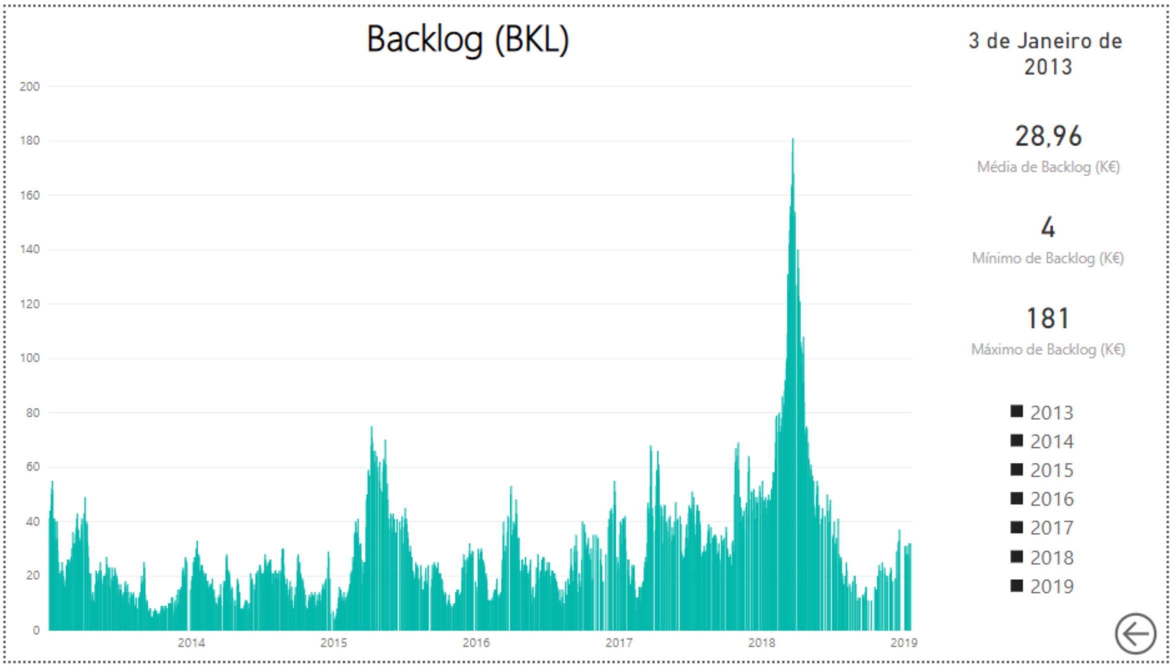

Figure 35 - Backlog overview

It is also possible to observe the detailed values in a specific year (Figure 36).

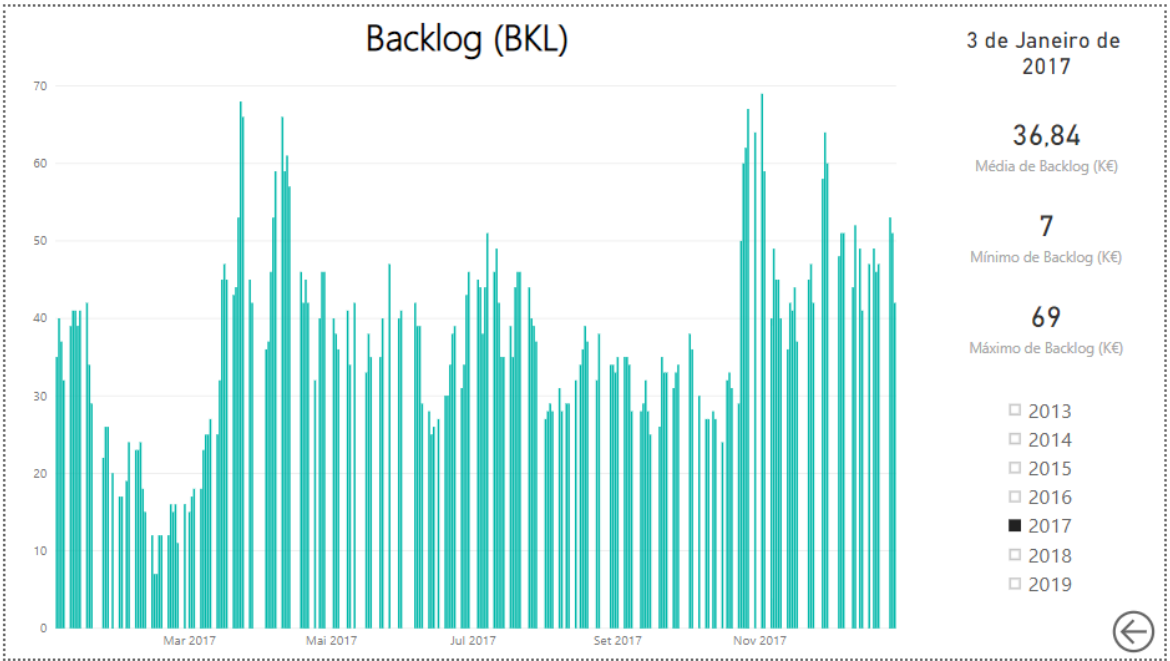

Figure 36 - Backlog in 2017

The same scenario can be obtained for the OTIF (Figure 37).

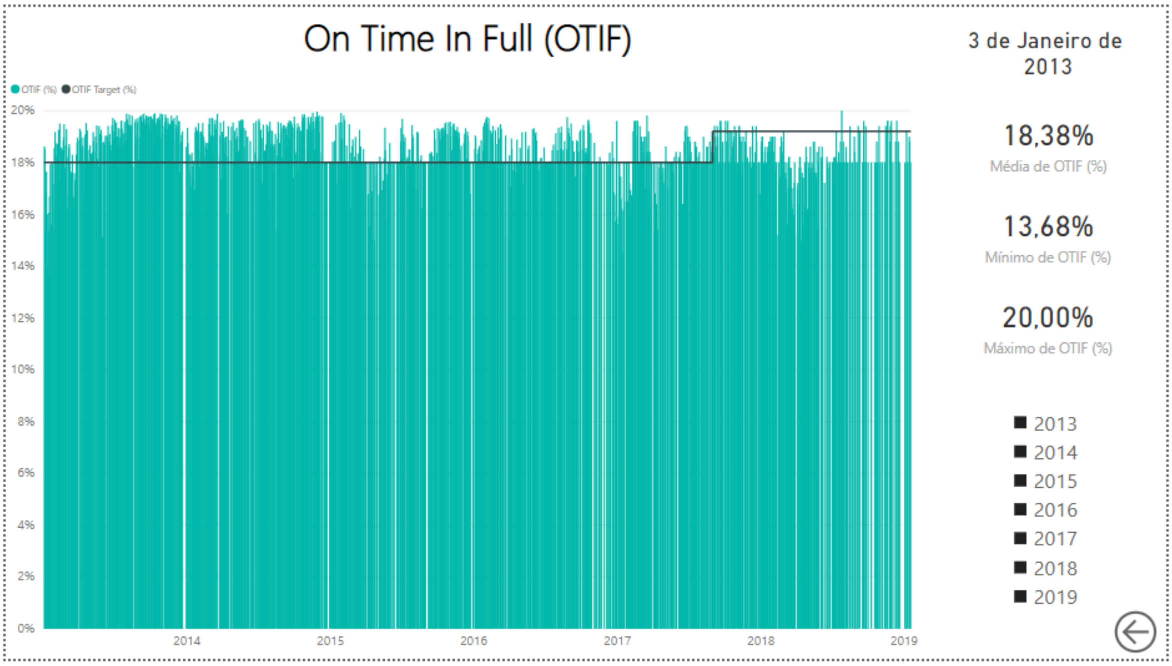

Figure 37 - OTIF overview

This software also allows to see the specific information regarding one selected day (in this case the 26th of September of 2018 (Figure 38).

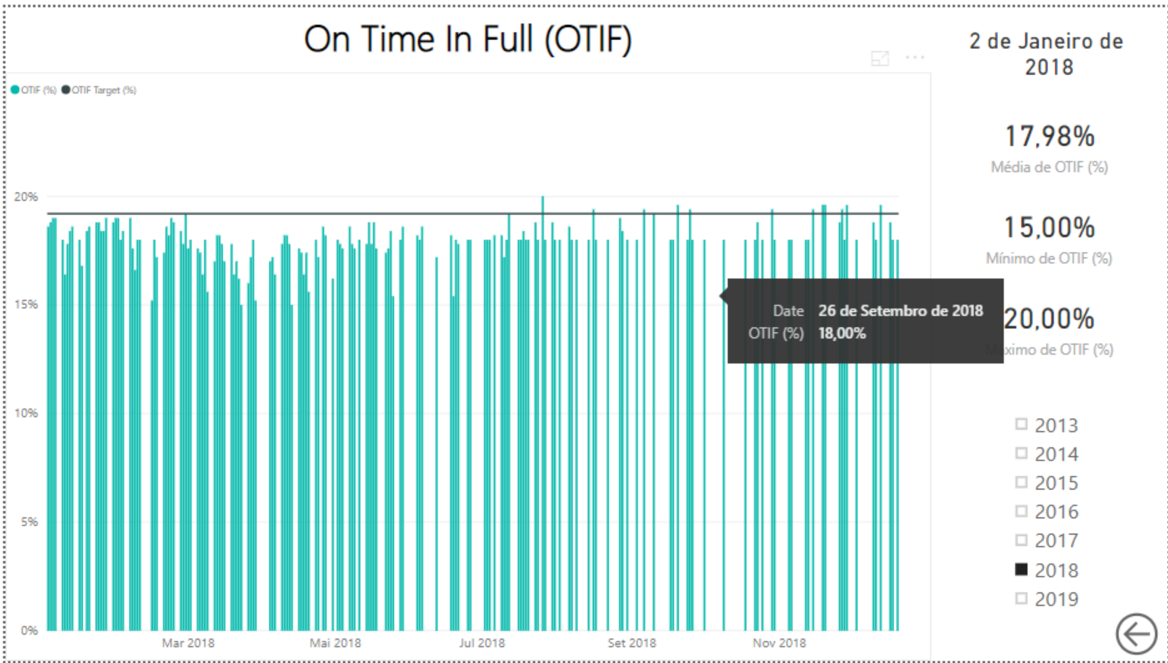

Figure 38 - OTIF overview of the 20th of September

Finally, an analysis to the safety stock status can also be done (Figure 39).

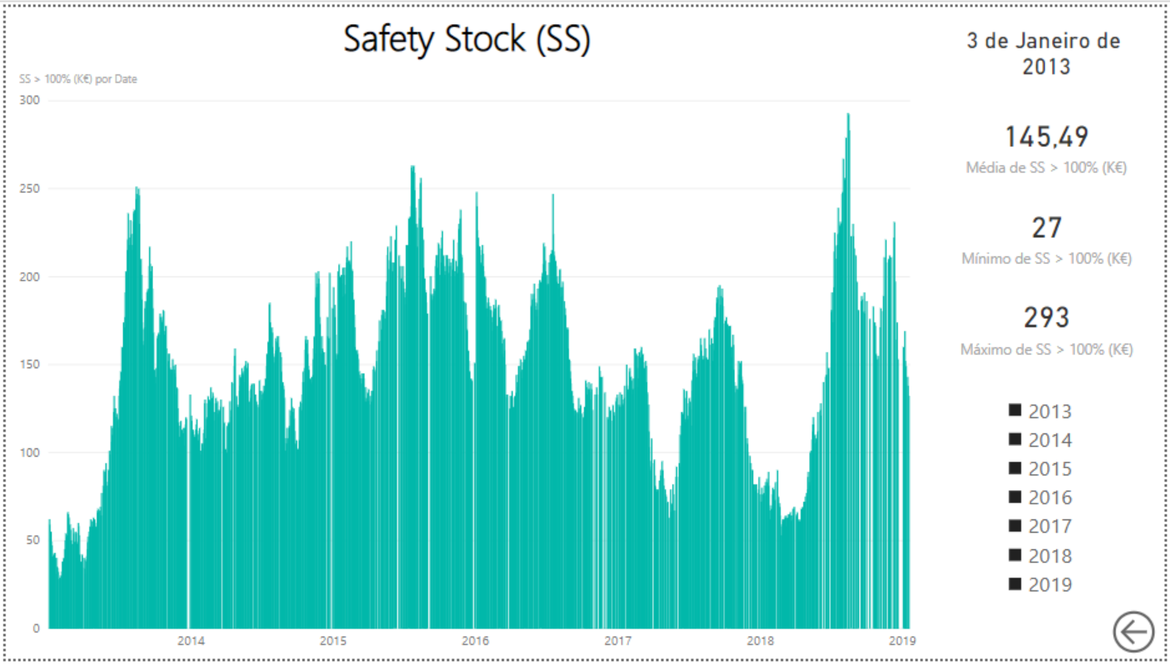

Figure 39 - SS overview

And finally, a scenario for 2016, 2017 and 2018 can also be seen (Figure 40).

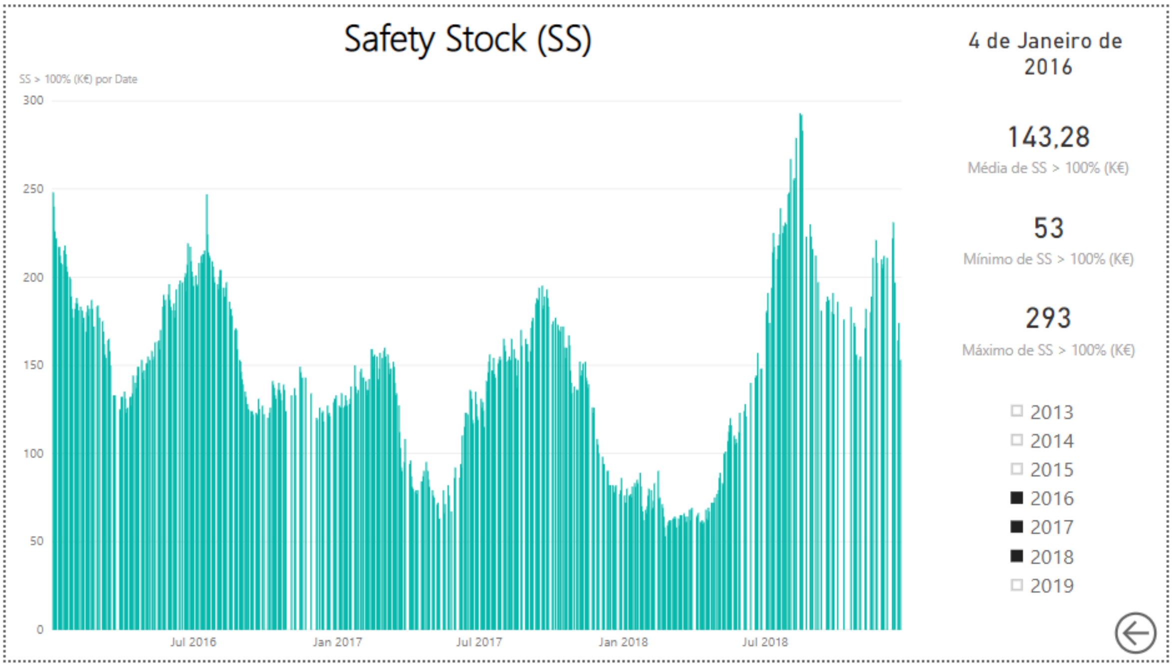

Figure 40 - SS overview considering 3 years

As for Prototype 2, it considers the Top 200 case. As it is becoming a strategic situation that needs to be strictly controlled, the planners have been feeling a necessity of verifying the status of the products that integrate the Top 200. One of the fundamental information that the planners need to check for those products are the ones that are in backlog, so that they can apply tools or methods as the ones that are going to be explained in Example 2, in section 4.2.

In order to check what Top 200 products are in backlog, the planner that usually updates the KPI file had to do that, then shape the file into a specific format used in the plant. After that, it had to choose in the column "Top 200" the ones that contain a "x" and finally analyse the situation of the products one by one. Since the file is heavy, because it contains information about all the SKUs of all the factories, it is not always easy to work with it (Figure 41).

Top200	ME	DIY	BL50	Vendor	Launch	HDE	AVIndicator	MRPTyp	Status	Product	Supporting Unit
			x				PD	XC	2	40554xyz	GROHE Kitchen Fittings
			x				PD	XC	2	41081xyz	GROHE Kitchen Fittings
x			x				D9	AC	2	27394xyz	GROHE Showers & Shower Systems
x			x				D9	AC	1	27922xyz	GROHE Showers & Shower Systems
							D9	BC	2	26075xyz	GROHE Showers & Shower Systems
x							CX	AC	3	31347xyz	GROHE Kitchen Fittings
							D9	AC	2	27939xyz	GROHE Showers & Shower Systems
							D9	BC	2	26075xyz	GROHE Showers & Shower Systems
		x					C1	AC	1	39117xyz	GROHE DIY Sanitary Systems
x			x				C1	AC	2	31455xyz	GROHE Kitchen Fittings
x							D9	AC	2	27922xyz	GROHE Showers & Shower Systems
							CX	AC	3	31302xyz	GROHE Kitchen Fittings
x	y		x				PD	AC	1	38723xyz	GROHE Sanitary Systems
x			x				D9	AC	2	27615xyz	GROHE Showers & Shower Systems

Figure 41 - Information about Backlog - excel file

The big difference between the Excel file and this dashboard is that the information is exposed in an easier way, compared to Figure 41. It is similar to Prototype 1, since the planner also has an initial page where it can select the wanted KPI for the Top 200 (Figure 42).

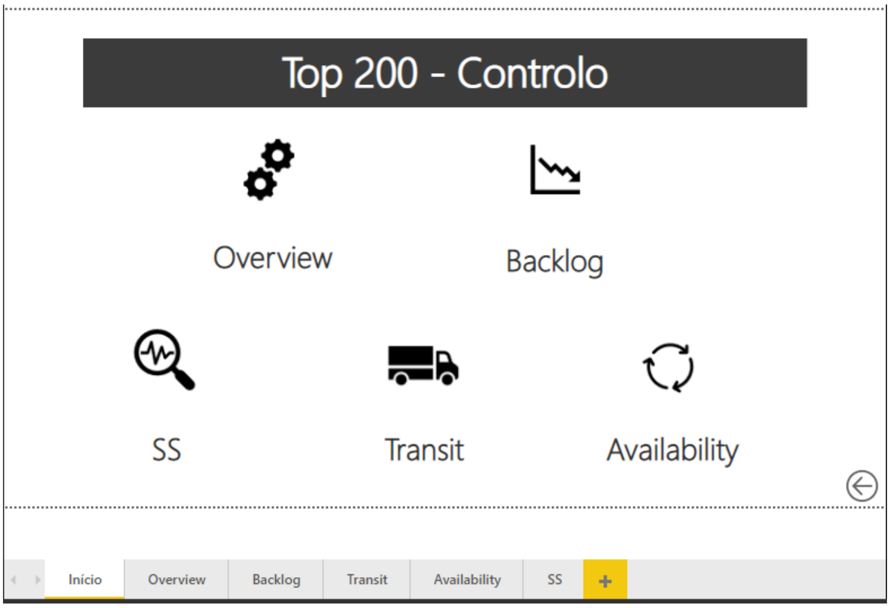

Figure 42 - Initial Interface (Top 200)

In the Overview page, there is a general scenario regarding the 43 SKUs, from Albergaria, that are a part of the Top 200 and considering the backlog and the pieces that are in transit (Figure 43).

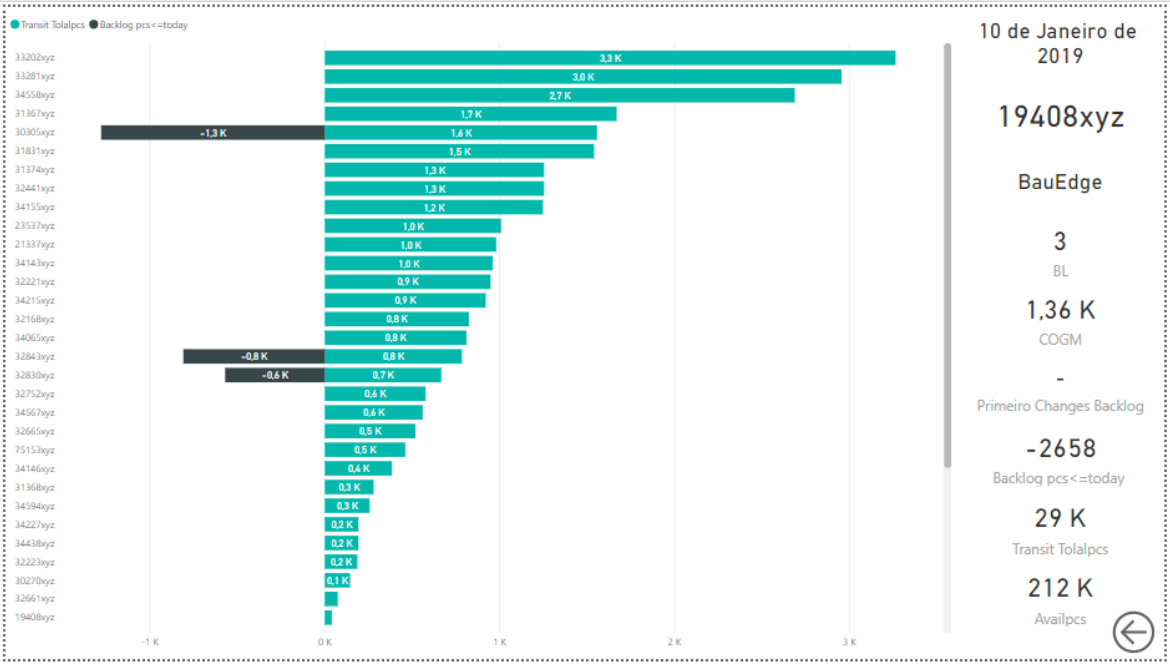

Figure 43 - Top 200 overview (backlog and transit)

It is possible to analyse just the backlog status if the user selects the page “Backlog”. For example, if the planner wants to know what the products with the highest values of backlog are, it just needs to press the Refresh button and it will immediately see what is in the figure 44.

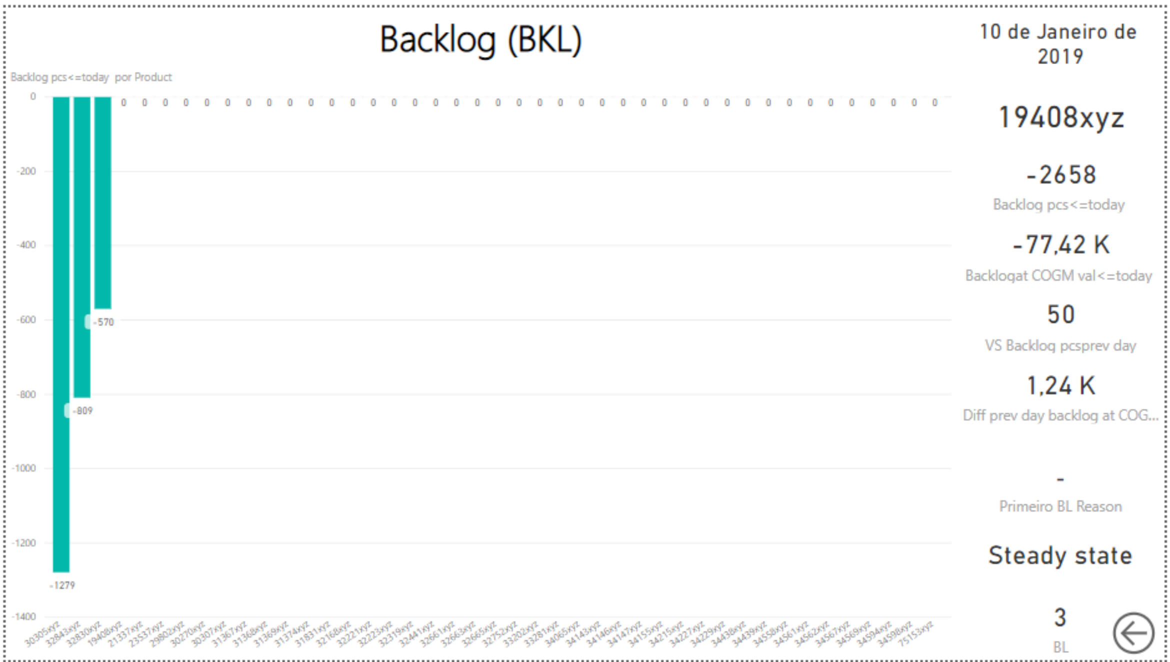

Figure 44 - Backlog overview

As it can be seen, the planner quickly identifies that there are 5 products in Backlog. On the right column, the planner can analyse the information about each one of those materials – SKU, number of pieces in backlog, the value (€) of backlog, a comparison between the situation of the previous day, what is the backlog reason and what is the product Life Cycle. This information is exposed both in Figure 45 and Figure 46.

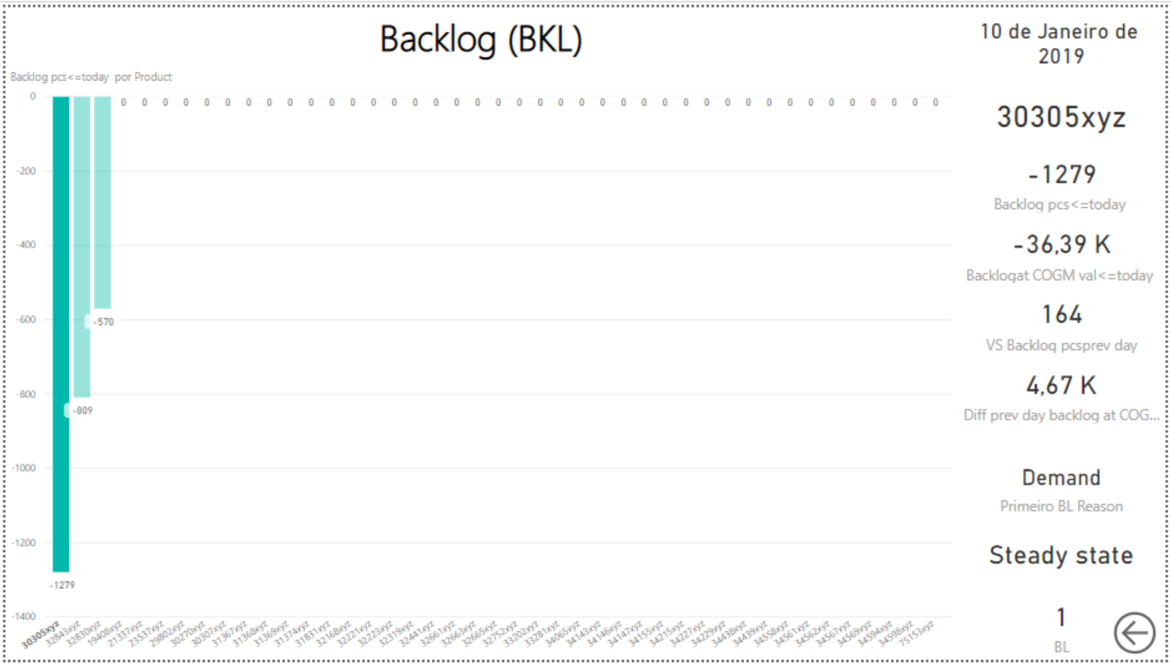

Figure 45 - Example of Backlog Analysis (Product 32843000)

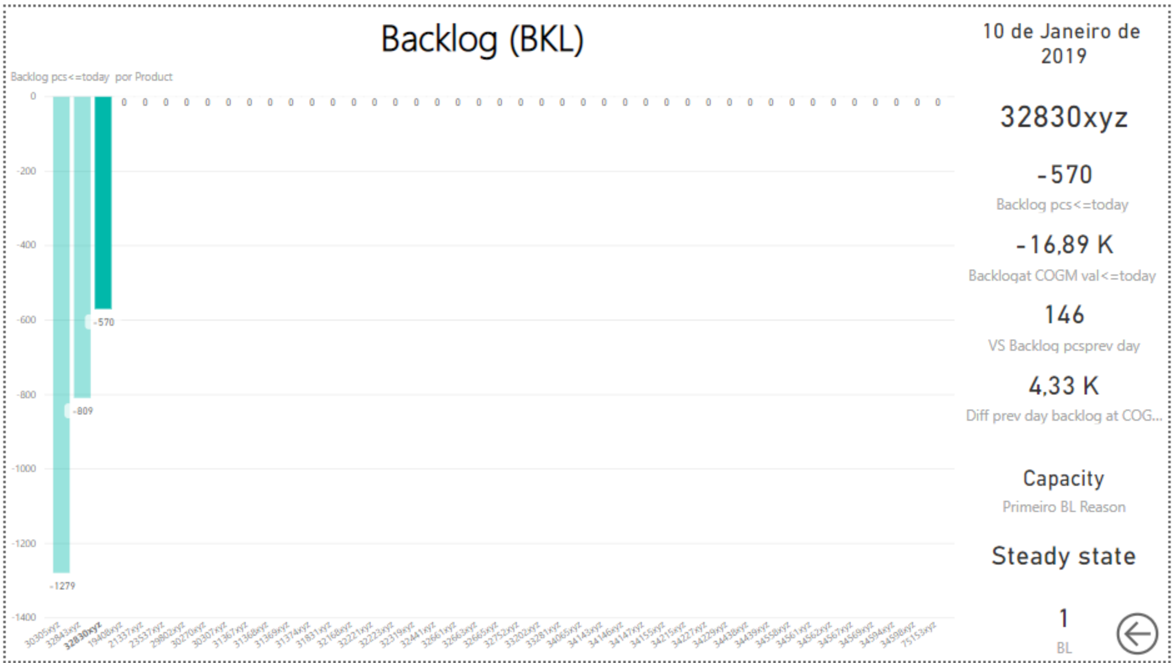

Figure 46 - Example of Backlog Analysis (Product 32661001)

Other types of analysis can be done for these products, in terms of the materials that are In Transit to other factories, their SS status and the availability for the future. The situation of the products that are in transit is shown in Figure 47. The dashboard indicates, for the selected product, the SKU, the number of pieces that are in transit, the value (€) in transit, if the material is in backlog or not and other information that define the category of the product.

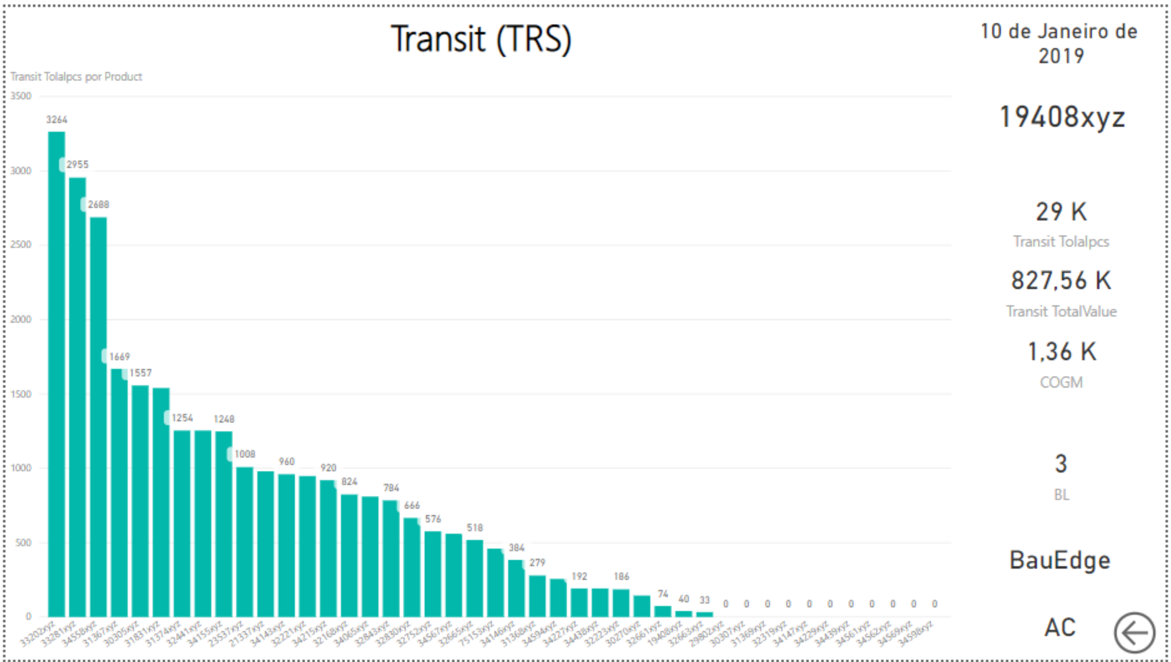

Figure 47 - In Transit overview

In Figure 48, the availability situation is displayed, meaning that the selected product is the one that has more stock available, and therefore, it is not in backlog.

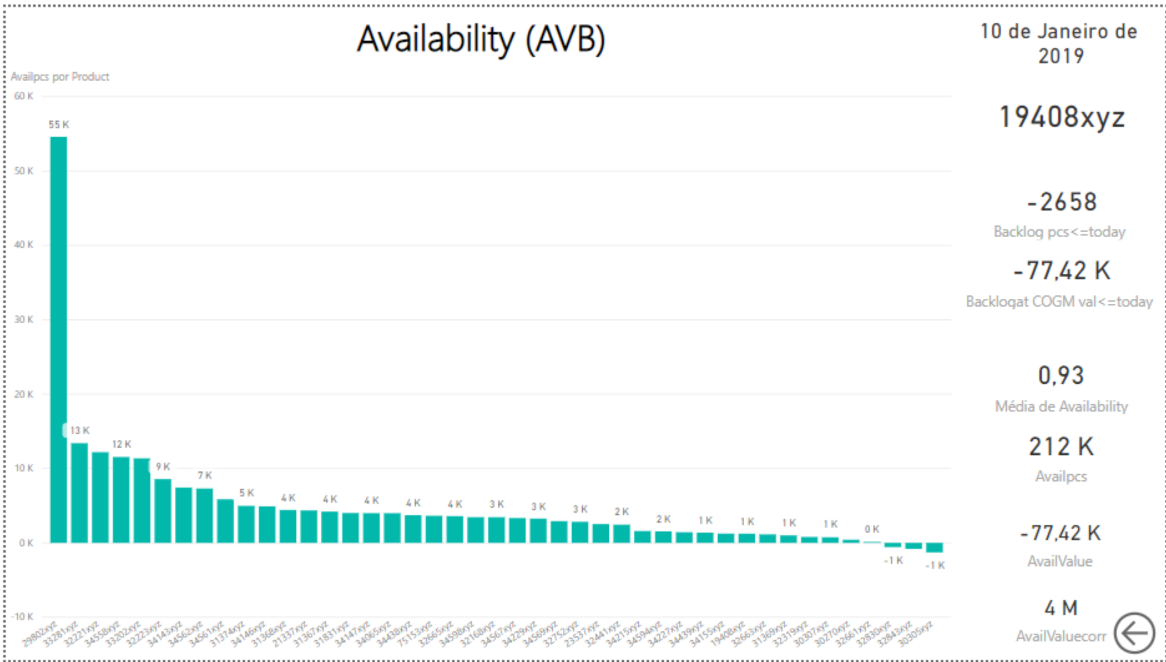

Figure 48 - Availability overview

Finally, considering now the Safety Stock panorama, there are several overviews that can be done. In this case (Figure 49), it is possible to have a general impression about the Safety Stock Coverage situation of the Top 200 SKUs. From this dashboard, the user can see several data: the SS pieces, the stock pieces, the SS value and the stock value.

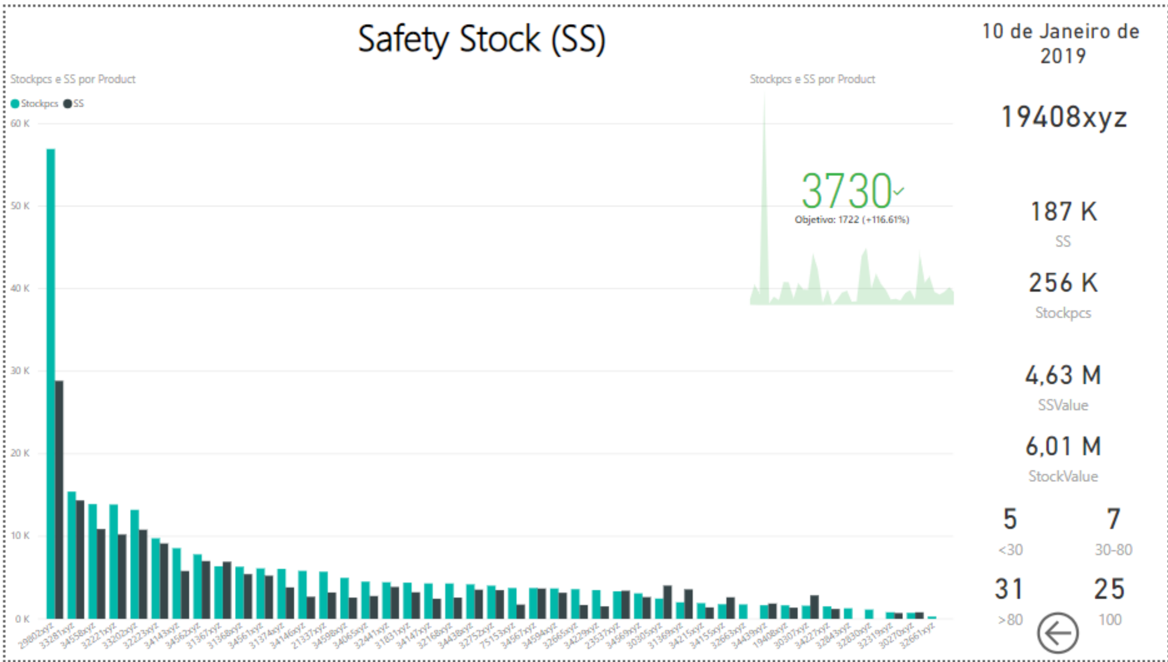

Figure 49 - SS overview

A KPI was also developed in order to quickly see the panorama for these materials. This means that, on the one hand, if the product has a stock higher than the SS, the KPI will be green. On the other hand, if the product has a stock that is lesser than the SS, the KPI will appear in a red colour. In this manner it is easier for the planners to identify the critical situations.

It is also possible to check that, from the 43 SKUs of the Top 200 produced in Albergaria, 8 have less than 30% of their SS value, 6 have a SS value between 30% and 80%, 29 have more than 80% of the SS value and 17 have their SS value fully covered (100%). In this type of analysis, there is always a comparison between what is the current situation (the blue bars) and the objective (the black bars).

From here, the user has a general panorama of all the SKUs. The main goal of the Top 200 is that all SKUs have the safety stock levels covered, which means that the planners need to identify situations where the KPI indicates that there is less stock then the required safety stock. With this tool, it is easier, not only for the planners, but for all the production team, to signal where are the critical situations. It is also easier to draw an action plan and to mitigate the SKUs that need to be produced, helping also with the main difficulties felt in the shop floor and by the production team.

The user can perform a more detailed examination by clicking in the wanted SKU. For example, in Figure 50, there is a situation of a product that has the SS fully covered, this is, the stock is higher than the SS. In this case, the KPI will appear green, since it is an OK situation.

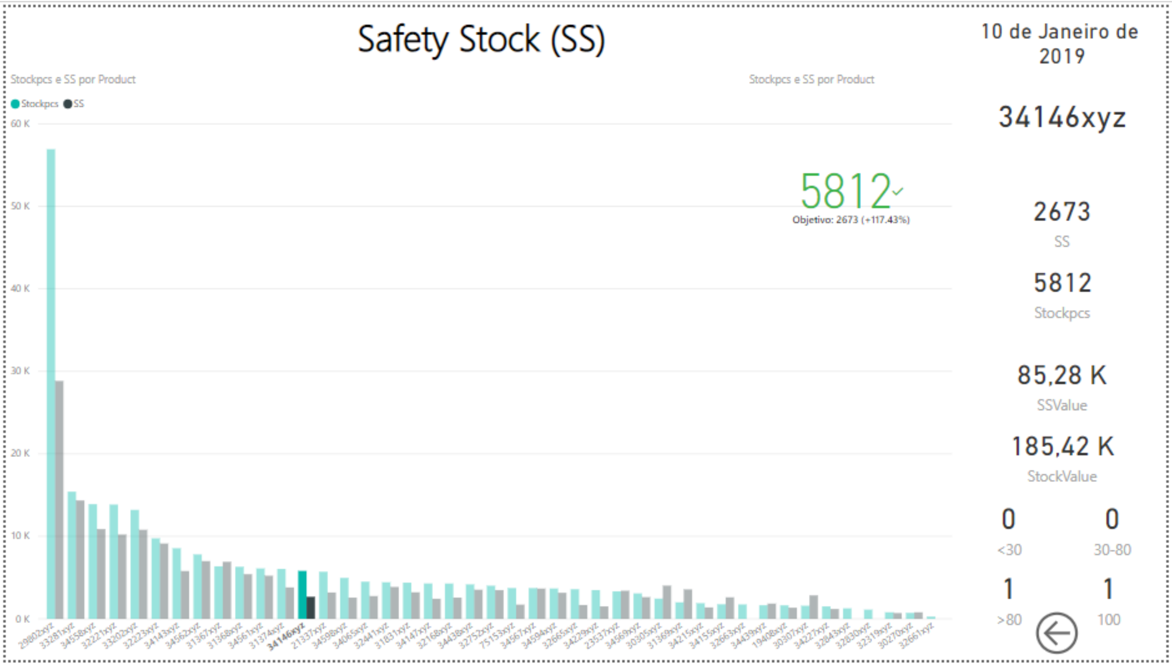

Figure 50 - Example of SS Analysis (Stock > SS)

In Figure 51, the product should have more stock to fulfil the SS needed. As it can be seen, the KPI in this case is red and indicates the number of pieces needed to fulfil the SS required. It indicates a not OK situation were the planners need to define an action plan, in order to produce the products that are lacking and thus reduce the backlog.

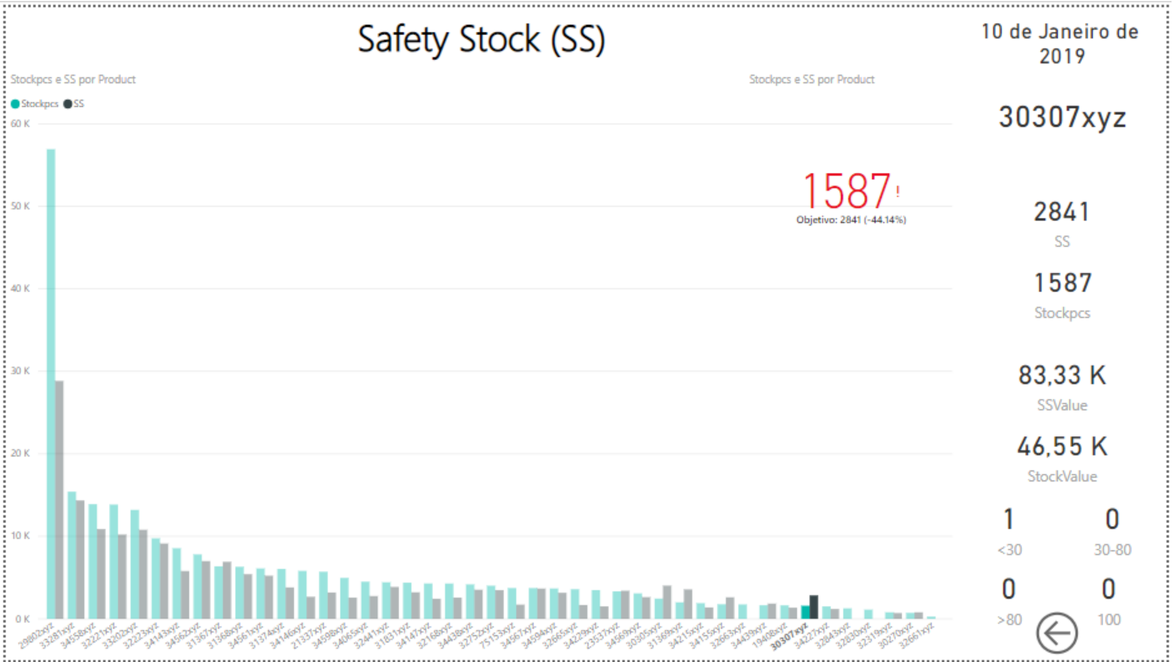

Figure 51 - Example of SS Analysis (Stock < SS)

4.3.6 Information System Analysis

The two prototypes were developed to test the Power BI tool in the production planning context, consequently it is now important to analyse its performance. The information system will be assessed considering several metrics in different aspects.

a) Practical Metrics

First, considering the practical aspects, the performance of the system is evaluated according to 2 metrics:

1. **KPI Coverage**, to perceive if the KPIs exposed are the same or if there are new ones;
2. **Response Time**, to see if the tool is reducing the time the planners spend when accessing the data.

It can be argued that, in terms of KPI Coverage, it is the same as it was before implementing the process modelling and the dashboard. After discussing with the team, it was thought that no new indicators were needed for the production planning, therefore no new indicators were developed. As it could be seen with the Top 200 and the Spare Parts, new indicators emerged when there is a necessity to strictly control something in a specific task. This situation did not, however, emerged.

In terms of response time, it is possible to see an improvement in the time spent to identify the critical situations of the KPIs. This is important for the planning, since it helps to identify in a fast and direct way what are the urgent situations, what is missing, and give the planners the opportunity to perform a close monitoring of those situations.

b) Dashboard Metrics

Second, looking at the dashboard metrics and according to (Gröger et al., 2013), the architecture and performance of a dashboard is based on three considerations, namely:

1. **Presentation** that has the following characteristics:
   - easy-to-use and intuitive user interface;
   - personalized content composition;
   - flexible mobile access.
2. **Data Analytics and Result Distribution** that consider:
   - metrics calculation data mining-based pattern detection;
   - storing and sharing of free form knowledge;
   - audio- and video-based communication.
3. **Data Provisioning** that contemplates:
   - holistic data warehouse with operational and process data;
   - near-real-time provisioning of data.

In this case, regarding **Presentation**, it can be said that this dashboard has an easy and intuitive user interface, since the users can directly interact with it by clicking, which results in the displaying and possible analyses of the wanted data. It is not difficult to learn how to work with this platform. As it can be seen in Figure 52, this dashboard has several features and options that allow to build different graphics, according to a specific set of information.

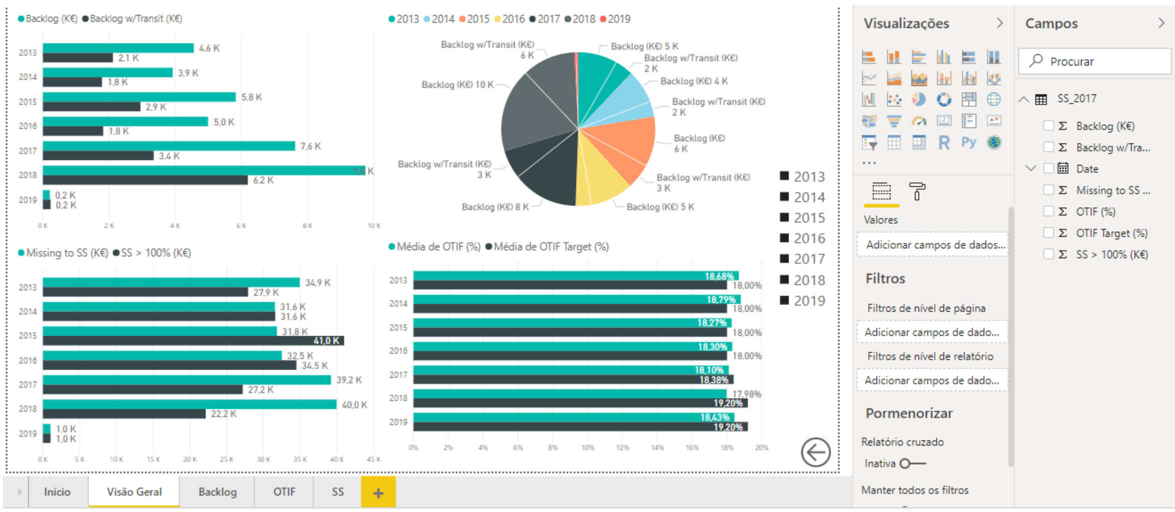

Figure 52 - Dashboard Overview

The dashboard is also self-explanatory. For that reason, it allows to have a personalized content composition, since the users construct the substance and the dashboard itself. In addition, it also considers the different tasks that the planners perform. The flexible mobile access was not one of the main aspects considered here, nevertheless any computer that has this software installed will display the same graphics. The overall performance considering the Presentation is good.

In terms of **Data Analytics** and **Result Distribution** it is possible to consider the metrics calculation and data mining-based pattern detection that require a statistical and analytical processing capacity. Another feature is the possibility of storing and sharing free form knowledge, this is, unstructured data. Finally, an audio and video-based communication for process communication is also required.

This category may not be one of the strengths from this dashboard. Despite having the capacity to process the data in an analytical way, that is why it has the possibility of selecting the different graphics with the same data, the video-based communication for example may be a weak point of this dashboard. This happens because the 3 criteria defined by Gröger et al. (2013) are used in an example of "a mobile dashboard for shop floor workers providing information on process context, process performance, process knowledge and process communication", which is not exactly the same case as the one that is being considered in this industrial example.

Now looking at the **Data Provisioning**, several aspects can be measured. It can be said that this dashboard displays the information in a near-real-time situation, this is, the "data changes in the source systems have to be immediately propagated" (Gröger et al., 2013).

This requirement is fulfilled, because whenever the planning team makes changes to the KPIs file, those changes will automatically be loaded to the dashboard. Nevertheless, it takes less effort for the planners to have access to the wanted information.

Additionally, the dashboard should contemplate the holistic data warehouse with operational and process data, this is, to integrate process manufacturing data by having information from ERP systems, as a core requirement. In this case, the information is not directly exported from SAP, but it is indirectly. Therefore, stating that the dashboard is connected to the ERP system of the company and exports information from it is correct. Thus, the performance of the dashboard in terms of Data Provisioning is satisfactory.

c) LIM Metrics

Third, considering a Lean Information Management overview and the types of waste that are being reduced, the performance of the system considers the **Impacts on the Information Flows**. As explained in the Literature Review, the main concern when talking about LIM is to improve the information flow reducing waste and non-value-added activities. To do so, it is fundamental to identify the sources of waste of the information flows.

Therefore, the 8 main types of waste will be combined, considering a Lean Thinking approach, with its impact and improvements on the information flows. To do so, Table 1 and Table 2 relate and make an analysis between the 8 types of waste and the before (Table 1) and the after (Table 2) situations, as well as the results and improvements that were a consequence from the information system implemented.

Table 1- Impacts on Information Flows (Before)

Type of Waste	Impact on Information Flows
Defects	The excess of data sources sometimes makes the information created not reliable
Overproduction	The excess of non-value added data creates an excess of non-value added information flows
Waiting	Planners have to wait for the right information because resources are not easily available
Non-utilized Talent	Planners do not innovate or create new ways of efficiently sharing information
Transportation	Excess of steps to achieve the right information and excess of movement of the non-value added one
Inventory	Excess of files that provide the same data that causes redundancy on the information created
Motion	Decentralization of data that creates dispersion as it is not well organized
Extra work	As the files are confuse, there is a necessity of creating new information to achieve another

Table 2 - Expected Improvements on Information Flows (After)

Type of Waste	Impact on Information Flows
Defects	There is a common data source, improving data quality, productivity and reducing errors
Overproduction	The easy access to Power BI and its information leads to less but more efficient information flows
Waiting	Better visualization of data leads to faster and better decision-making
Non-utilized Talent	Planners can think about different ways of displaying the same information in the same platform
Transportation	The data is centered in the same software, reducing the steps to achieve the right information
Inventory	The standardization of the dashboard reduces the number of files with redundant data
Motion	The data is structured and organized in the same place, reducing the unecessary movements
Extra work	Interactive and user-friendly dashboard that substantially reduces the effort of the planners

When comparing the two tables and applying Lean to the information flows, several changes are seen. With the use of Power BI, the 8 types of waste suffer different types of transformation. Considering the waste Inventory, it went from a situation where the "Excess of files that provide the same data causes redundancy on the information created" to a situation where "The standardization of the dashboard reduces the number of files with redundant data".

In general, improvements were made in the information flows considering those 8 aspects. It is possible to say that there was an improvement in data quality and data productivity, since the data is more structured, organized and accessible now. There is a rational management of the file that is associated with the production control, the KPI file, as well as a decrease in the human resources that are needed to perform the data collection, treatment and analysis.

As stated by H. Wang, Gong, & Wang (2017), one of the conditions to have a more efficient decision-making is to have better information flows, that is why it is fundamental to improve them.

The results also point out an improvement with regard to quality of the information flows throughout the production planning. As the information is concentrated in the same place and it is more transparent with the use of the dashboard, it is easier for the planners to understand what is happening. For example, by using this tool, the planner can quickly see what backlogs exist without needing to perform all the steps needed to shape the KPI file to the specific Portuguese template.

Moreover, the planner can also establish in a faster way an action plan to solve the backlogs or the problems associated with it, in a way that the information is transversal not only to the production plans, but also to the planners.

There are also visible visual improvements, because the information is now displayed in the format of graphics, when previously the information was mostly shown in tables. The fact that the data is more transparent with the use of these dashboards boosts the information flows performance and reveals efficiency not only to the production planning processes, but to the production itself.

To conclude, it can be said that this dashboard helps to understand the information needs and define value-added information flows, guaranteeing the right information, in the right quantity, to be delivered at the right time, to the right people.

4.4 Decision-Making Support Files

Also related with the solutions implemented for the problems that are currently being felt in the production planning are the *decision-making support files*. The main goal of the creation, development and improvement of such files is to save time to the planners when they are executing parallel tasks related with the planning. Therefore, it is possible to streamline processes and to make improved decisions, gaining efficiency with the same inputs and embracing the Lean philosophy of reducing waste in the processes.

In this context, two examples will be explained. On the one hand, Example 1 will be the Truck Expedition File done as a supporting task to the warehouse and, on the other hand, Example 2 will be the MRP Files.

The fact that this part of the solution was the first to be developed allowed an easier learning and understanding of Microsoft Power BI. Since Power BI has a feature that requires the use of queries and one of the decision-making files was done using queries in Microsoft Excel, this work was fundamental to understand how to use Power BI and how it works.

4.4.1 Truck Expedition File

The example that is going to be explained is not completely related with the planning tasks, however, the task is done by a production planner and has a high importance in establishing a direct relation with the warehouse. It is fundamental for helping the warehouse activities, namely the truck expeditions to the other plants of the group.

As it was explained before, the Portuguese plant is the only one from GROHE group that manufactures PVD products. Therefore, a significant proportion of what is produced has to be sent to the other factories.

What is happening is that the planner that executes this activity usually spends too much time doing it (usually a whole afternoon, several times a week). The decision itself is not complex, but there is a lot of data to be examined. The planner needs to export a considerable amount of information from SAP to an Excel file. From here a list of products, that need to be carefully analyzed almost in a one-by-one case, is generated. In the end, the planner sends a list to the warehouse of what can be shipped to a specific plant.

The planner needs to know, from SAP, the internal requirements for a specific product and the requirements from other plants. Associated with the requirements from other plants there is the indication of the SKU, the quantity needed, the expected delivery date and the purchase order associated, so that the shipment can be valid. This data is exported to an Excel file.

After that, the planner analyses if the products are in stock or not, also considering information retrieved from SAP. In case the product is available, it is necessary to understand if there are any internal requirements. This means that if a product is needed in Albergaria and in another plant simultaneously, so the planner has to decide, depending on the case, if the product is going to be sent or not. It can also happen that a part of the stock is sent, and the other part stays in the plant for the internal requirements. If a product does not have internal requirements and it has stock, it is easier to decide.

As it can be seen, there are a lot of decisions to be made in this process. Therefore, it is not easy to automatize these tasks, but it possible to simplify the whole process if the information that the planner needs to check is consolidated in the same place.

The first step is to export from SAP all the useful information: total requirements for the following 4 weeks, requirements for other plants for the following 4 weeks and stocks for the products that are being required. Some products also have a safety stock that needs to be considered. Note that the internal requirements are the total requirements minus the expedition requirements.

In order to automatize the Truck Expedition process, an Excel file that is easily updated was created, bearing in mind the features from the functions *Get and Transform* and *Queries* in Excel. This file allows for a faster decision-making in the procedure of deciding what is shipped. The file is divided into two parts: "Base" and "Envio". The file is divided in two, otherwise it would become too "heavy" and its use would become unworkable.

In the file "Base", all the data from SAP is downloaded and condensed in the same place in order to provide a correct decision making. To update the file, it is necessary to refresh the queries created for all the information mentioned above. To better understand, see the figures bellow (Figure 53).

Material	QtdPendent	SaídaMerc	Origem	Cen.
01050xyz1	20000	31/12/2018	4505973495	0202
01050xyz1	20000	16/01/2019	4505979874	0202
01050xyz1	20000	29/01/2019	4505979878	0202
01161xyz1	700	28/12/2018	4505959867	0301
01281xyz1	1000	14/01/2019	4505975477	0202
01383xyz1	500	02/01/2019	4505979880	0202
01969xyz2	35	25/01/2019	4505969470	0301
02210xyz1	704	23/01/2019	4505929717	0202
02271xyz1	5	28/12/2018	4505963118	0290
02323xyz1	30	27/12/2018	4506006584	0202
02511xyz1	10000	28/12/2018	4505946929	0202
02511xyz1	10000	03/01/2019	4505979886	0202
02511xyz1	10000	31/01/2019	4506001918	0202
02625xyz3	16	14/01/2019	4505946930	0202
02693xyz2	35	27/12/2018	4505946932	0202
02693xyz2	35	24/01/2019	4506001920	0202
02693xyz4	25	31/01/2019	4505946934	0202
02693xyz5	130	17/01/2019	4505963251	0202
02693xyz5	30	24/01/2019	4506001922	0202
02693xyz6	36	28/01/2019	4505985444	0202
02693xyz6	37	31/01/2019	4506001923	0202
02693xyz7	35	24/01/2019	4506001924	0202

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Figure 53 - Other plants requirements

In this specific case the requirements from other factories are shown and the table contains the following information:

- “Material” represents the product that is going to be sent;
- “QtdPendente” represents the quantity that is going to be sent;
- “SaídaMerc” represents the expected delivery date;
- “Origem” represents the purchase order;
- “Cent.” Represents the receiving plant.

The stock information is also available in another Excel sheet (Figure 54)

Material	Tp.	Dep.	Estoque total
02693xyz2	001	P001	154
02693xyz3	001	P001	64
02693xyz4	0V0	P001	86
02693xyz4	001	P001	36
02693xyz5	0V0	P001	19
02693xyz6	001	P001	59
02693xyz7	001	P001	22
08239xyz2	004	P001	5
08239xyz2	001	P001	4
08239xyz3	001	P001	11
08239xyz4	0V0	P001	1
08239xyz4	001	P001	5

Material	001	0V0	902	004	Total
0211xyz1	0	0	0	0	0
01050xyz1	0	0	0	0	0
01281xyz1	0	0	0	0	0
01383xyz1	0	0	0	0	0
01945xyz1	0	0	0	0	0
01969xyz2	0	0	0	0	0
01971xyz2	0	0	0	0	0
02210xyz1	0	0	0	0	0
02511xyz1	0	0	0	0	0
02693xyz2	154	0	0	0	154
02693xyz3	64	0	0	0	64
02693xyz4	36	86	0	0	122

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Figure 54 - Stocks

In this specific case there are stocks for the required products and the table contains the following information:

- “Material” represents the product that is being analyzed;
- “Tp.” Represents the stocks location;
- “Dep.” Represents the stock availability (if it is a P001 it is available, otherwise it is blocked);
- “Estoque total” represents the stock quantity.

The white table is only used to organize the information. A product can have stock in different locations. That table joins that information in the same place.

This data is automatically update whenever the planner presses the button to refresh the query that gives this information. That update can be made in a side bar available in Excel that contains information about “Queries and Connections”, presented in the figure bellow (Figure 55).

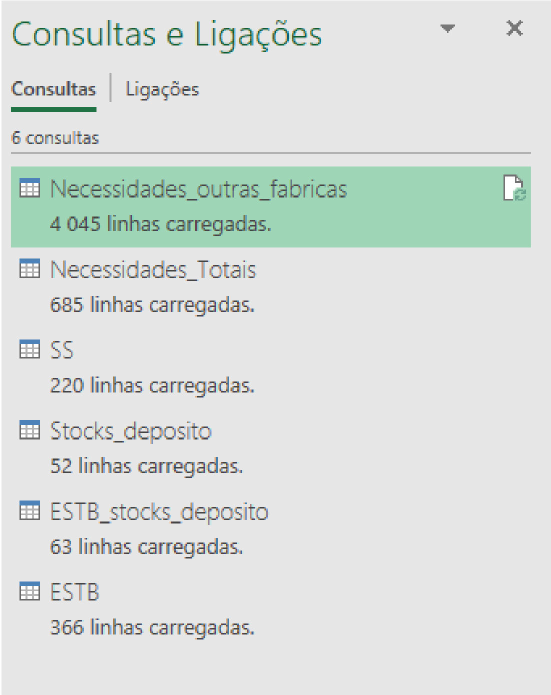

Figure 55 - Queries and Connections

In the file "Envio", with the help of queries, the main data from the ERP is collected into the same Excel file. This information is crossed, and the planner understands, according to a set of formulas, the materials' availability to be sent.

This file displays several columns regarding different information based on the file "Base": PO (Purchase Order), Date (Estimated Delivery Date), Material, To Send, Total Req (Requirements), Alb Req (Albergaria Requirements or the Internal Requirements), Stock, SS or Safety Stock, Available, and PO Quantity.

To facilitate the decision-making process, two columns were created: the column "Suggestion" and the column "Status". The "Status" considers if the material has stock or not, if it has stock, it displays the message "Stock available", if the contrary is true it will display the message "No stock". The column "Suggestion" considers the materials' availability and this means that if a material does not have stock, the column "Suggestion" will automatically show the message "Stop".

If the material has stock, two things can happen: (i) the stock is available, but the Internal Requirements are higher than the Other Plants Requirements and, in this case, the column "Available" will show a negative and the message displayed will be "Stop"; (ii) the stock available is enough to fulfill total or partially the Other Plants Requirements and, in that case, the message that will appear is "Possible to send".

Basically, there are only 3 possible scenarios for this tool:

- Stop + No Stock;
- Stop + Stock Available;
- Possible to Send + Stock Available.

Figure 56 shows an example of the tool described.

PO	Date	Material	To send	Total Req	Alb Req	Stock	SS	Available	PO Qty	Suggestion	Status	Bin	Rede	Zona EM	Arm Ext
91639117	14/11/2018	01351xyz1	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639120	14/11/2018	01351xyz2	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639121	14/11/2018	01351xyz3	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639122	14/11/2018	01351xyz4	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639118	14/11/2018	01351xyz5	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91620957	14/11/2018	01351xyz6	0	29	0	0	0	0	29	Stop	No stock	0	0	0	0
91639116	14/11/2018	01351xyz7	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639115	14/11/2018	01351xyz8	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639123	14/11/2018	01351xyz9	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639414	21/11/2018	01532xyz1	0	26	0	0	0	0	26	Stop	No stock	0	0	0	0
91639125	14/11/2018	01532xyz2	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639416	21/11/2018	01532xyz3	0	25	0	0	0	0	25	Stop	No stock	0	0	0	0
91646991	23/11/2018	01532xyz4	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91639124	14/11/2018	01532xyz5	0	30	0	0	0	0	30	Stop	No stock	0	0	0	0
91474813	20/09/2018	01532xyz6	84	482	70	154	0	84	154	Possible to send	Stock available	154	0	0	0
91585439	31/10/2018	01532xyz7	84	482	70	154	0	84	213	Possible to send	Stock available	154	0	0	0
91639402	21/11/2018	01532xyz8	25	482	70	154	0	84	25	Possible to send	Stock available	154	0	0	0
91704769	14/12/2018	01532xyz9	20	482	70	154	0	84	20	Possible to send	Stock available	154	0	0	0
91693698	11/12/2018	02693xyz1	40	511	24	64	0	40	400	Possible to send	Stock available	64	0	0	0
91704784	14/12/2018	02693xyz2	37	511	24	64	0	40	37	Possible to send	Stock available	64	0	0	0
91704741	14/12/2018	02693xyz3	40	511	24	64	0	40	50	Possible to send	Stock available	64	0	0	0
91693661	11/12/2018	02693xyz4	92	200	30	122	0	92	170	Possible to send	Stock available	36	86	0	0
91515772	05/10/2018	02693xyz5	0	632	280	19	0	-261	92	Stop	Stock available	0	19	0	0
91628359	16/11/2018	02693xyz6	0	632	280	19	0	-261	60	Stop	Stock available	0	19	0	0
91693677	11/12/2018	02693xyz7	0	632	280	19	0	-261	200	Stop	Stock available	0	19	0	0
91560479	23/10/2018	02693xyz8	0	489	70	59	0	-11	389	Stop	Stock available	59	0	0	0
91704788	14/12/2018	02693xyz9	0	489	70	59	0	-11	30	Stop	Stock available	59	0	0	0

Figure 56 - Decision-making for the truck expedition

The idea is that the planner filters the column “Suggestion” by *Possible to Send*, so that it does not have to waste time searching for and analyzing materials that do not have stock. This will facilitate the planner’s tasks and considerably reduce the time spent doing this activity. Depending on the stocks and the quantities that need to be sent, the planner specifies the number of pieces to be sent in the column “To send”.

Since this decision is complex, because it has a lot of inputs and restrictions to be considered and balanced (especially in the Internal Requirements vs Other Plants Requirements situations), this process is not fully automatized and still requires the planner to make a specific decision. In some particular cases, if the decision is too hard, the planner may have to consult SAP to analyze that particular case.

After all the materials are checked, the planner sends this same excel file with information about the PO (Purchase Order), Date (Estimated Delivery Date), Material and To Send to the warehouse. After that, the warehouse workers follow this list and just have to pick the materials in the specified location, load the trucks and send them to their destination.

The stock location is also specified in this file, so that when the planner sends it to the warehouse, they spend less time searching for the materials that they have to send. That information is shown in columns Bin, Rede, Zona EM and Arm Ext, which represent different warehouse locations.

Despite being a simple tool, this file is an example of how the automation of some processes and files can be in accordance with the Lean philosophy of reducing waste and can also be an advantage not only for one department of a company but reducing inefficiencies throughout the supply chain.

The biggest difference between the method used by the planner to work with the file and the new file that was created is the way the data is handled and the number of manual tasks that were reduced. Before this tool, every product had to be checked on the ERP system (SAP) to get an overview of the status of that item and decide whether it could be sent or not.

The planner needed to check, for every product individually, if it had internal requirements, other plants requirements, the stocks, the availability of stocks that could be send, the stocks location and the Pos quantities. It was a lot if verifications and validations that the planner needed to do manually. Not only it was an exhaustive analysis, but also the planner used to spend an average of three hours building the file to send to the warehouse.

With this new tool, despite not being completely automatized and not deciding for the planner, after getting all the necessary inputs from SAP, it gives a suggestion that reduces the effort of the planner to get the same output. This way, two experiences were done to validate the efficiency and the effectiveness of the file and the time needed to obtain the same result were an average of 45 minutes. Having the same output with less effort is the basis of the Lean philosophy and automatizing the process is the main goal of Industry 4.0. Therefore, it is possible to say that this tool helps to combine ideas from Lean and I4.0 to develop a process, which was one of the goals of this work.

4.4.2 MRP Files

The example that is going to be explained is related with the planners' tasks, but it was something not automatized before and that now allows to gain efficiency in the planning tasks.

This case characterizes files that are similar to a Material Requirements Planning (MRP), this is, a system that is a "common mean of developing production plans in discrete parts manufacturing" (Milne, Mahapatra, & Wang, 2015). According to H. Wang et al. (2017), MRP is a planning technique that organizes the production planning and "schedules the release of work based on demand".

The main goal of this system is to decompose a product on its components, considering the bill of materials (BOM) that specifies the nature of the components. To determine the inputs needed to the production system and to define a plan for the raw materials (RM), that in this case are the components, a MRP logic is needed, based on the bill of materials and process recipes for each finish good (FG) (Graves, 2011).

The logic that is used is expressed in Figure 57.

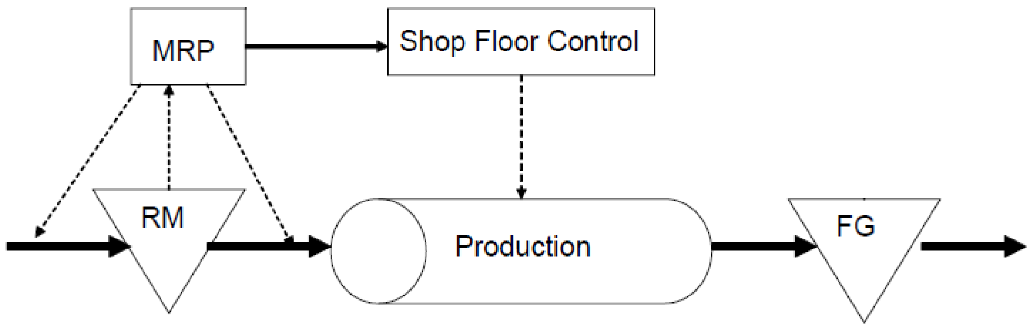

Figure 57 - MRP logic

In this case, the idea is to create a file that follows this logic and that allows to control the steps that are described in Figure 57. The file should have information about the finish good and the components needed to produce it, according to the BOM.

Such files characterize sporadic situations that are highly important in a specific moment and that demand a strictly and constant control and follow-up. This refers, for example, to strategic situations where there was a delay in production and a determined finish good needs to be urgently produced.

The MRP files have mainly two goals:

- Identify the components that are missing;
- Identify the minimum final product quantity that can be produced.

This tool helps to respond to certain problems by quickly identifying were the problems are and what is the action plan to solve them. In the production planning case, it allows to understand, for a specific case, what can be produced according to the existing stock from the components that incorporate the finish good.

The case that is going to be presented describes finish goods that are in backlog and that have some components that are missing. Every finish good has several components that usually are assembled to form the faucet. The planners go from the finish good to the components by accessing to the Bill of Materials (BOM) of the finish good. It represents a document that specify all the components that constitute the finish good.

Each of the components has a specific stock and a specific quantity. The quantity means the parts that are required for the finish good, for example, a faucet may need two buttons that are the same component, so the quantity will be two. By planning and producing these components, the finish goods can be assembled and shipped to the clients. These situations are called "Quick Wins".

To facilitate the planners' actions and to give transparency on knowing where to act, the MRP files were created. They are mainly used to act on the Quick Wins and to solve backlog situations, because most of the times a finish good is not being assembled, is because of one component that is missing. Such files specify what is the component that is being the "bottleneck" of that final product and what can be done to produce the missing item.

Figure 58 represents one of the files created to identify the Quick Wins, what is missing and the quantity to be produced.

The column "Material PA" has the final product codes, the column "Material CO" has the components. The column "Quantidade" refers to the quantity, the column "BKLG" mentions the quantity that is in backlog. The column "Fornecedor" contains the supply information that is going to be explained later. The column "Stock Total" represents the total stock that exists for the component, while the column "Stock/Quant" is the total stock divided by the quantity needed. If a final product needs 2 parts of the component and the total stock of that component is 100 pieces, the stock to be considered is only 50 pieces. The column "Sort" is used to perform a calculation that is going to be explained later. The column "Menor" has the minimum quantity of the columns "Stock/Quant" and "Sort". Finally, the column "A Fazer" indicates the minimum stock of the components that compose a finish good, this is, the quantity that is possible to produce of that finish good. If one of the stocks from the components is 0, it will not be possible to produce the finish good, but the planners will know the item that is causing that backlog.

Such tools are essential to understand what components need to be planned and produced for the future and, in other words, where are the problems and what needs to be done to mitigate determined problems.

As it can be seen in Figure 58, there is a list of materials that are currently in backlog.

Material PA	Material CO	Quantidade	BKLG	Fornecedor	StockTotal	Stock/Quant	Sort	Menor	A Fazer
27074xyz0	65294xyz1	1	111	E	0	0	0	0	0
27074xyz0	65294xyz2	1	111	FZ7	0	0			
27074xyz0	65298xyz2	1	111	FZ7	363	363		363	
27226xyz0	401309xyz2	1	312	FZ7	370	370		370	4
27226xyz0	15873xyz4	1	312	E	160	160	222,5	222,5	
27226xyz0	401044xyz2	2	312	FZ7	125	32,5			
27226xyz0	401041xyz2	1	312	FZ7	385	385		385	
27226xyz0	401417xyz3	1	312	FZ7	212	212		212	
27226xyz0	401420xyz2	1	312	FZ7	129	129		129	
27226xyz0	401423xyz2	1	312	FZ7	504	504		504	
27226xyz0	401051xyz2	1	312	FZ7	4	4		4	
27226xyz0	27221xyz3	1	312	E	281	281	307	307	
27226xyz0	64931xyz2	1	312	FZ7	26	26			
27226xyz0	64792xyz2	1	312	FZ7	505	505			
27226xyz0	28388xyz2	1	312	F	650	650		650	

Figure 58 - Example of MRP file

The backlog information comes from the KPI file and the stocks and quantities information (that are related with the Bill of Materials of the products) comes from queries taken from SAP. Figure 59 shows the data that is directly exported from the ERP system to Microsoft Excel.

Menor	A Fazer
0	0
363	
370	4
222,5	
385	
212	
129	
504	
4	
307	
650	

Stocks	Material	Estoque Total
	15873xyz4	160
	27221xyz3	281
	28388xyz2	650
	401041xyz2	385
	401044xyz2	125
	401051xyz2	4
	401309xyz2	370
	401417xyz3	212
	401420xyz2	129
	401423xyz2	504
	64792xyz2	505
	64931xyz2	26
	65294xyz1	0
	65294xyz2	0
	65298xyz2	363

BOM	Material PA	Material CO	Quantidade
	27074xyz0	65294xyz1	1,000
	27074xyz0	65294xyz2	1,000
	27074xyz0	65298xyz2	1,000
	27226xyz0	401309xyz2	1,000
	27226xyz0	15873xyz4	1,000
	27226xyz0	401044xyz2	2,000
	27226xyz0	401041xyz2	1,000
	27226xyz0	401417xyz3	1,000
	27226xyz0	401420xyz2	1,000
	27226xyz0	401423xyz2	1,000
	27226xyz0	401051xyz2	1,000
	27226xyz0	27221xyz3	1,000
	27226xyz0	64931xyz2	1,000
	27226xyz0	64792xyz2	1,000
	27226xyz0	28388xyz2	1,000

Figure 59 - Stocks and BOMs information

As it can be seen, for the finish good 27226xyz0, it is possible to produce 4 faucets with the existing stocks. In this case, the bottleneck is the 401051xyz2. This is useful for the planner to understand that it needs to plan more pieces of 401051xyz2 and to balance the stocks to boost the production of this finish good.

There are cases in which the calculation is not so linear, depending on the supply information. The supply information is used to understand the "subcomponents" that are needed to produce a component.

For example, in Figure 60, the minimum quantity possible to produce of 27226xyz0 should be 26 pieces. However, according to the supply information (E and FZ7 codes), to produce 27221xyz3 it is needed 1 part of 64931xyz2 and 1 part of 64972xyz2. As the minimum quantity of these two components is 26 pieces, it is possible to produce 26 pieces of 27221xyz3. As the existing stock of 27221xyz3 is already 281, the total quantity that is possible to produce of 27226xyz0 is the sum of the possible to produce and the stock, this is, the 26 pieces plus the 281 pieces, which corresponds to the 307 pieces. This calculation is done in the column “Sort” and these groups are identified in a grey color.

27226xyz0	27221xyz3	1	312	E	281	281	307	307
27226xyz0	64931xyz2	1	312	FZ7	26	26		
27226xyz0	64792xyz2	1	312	FZ7	505	505		

Figure 60 - Example of MRP file (subcomponents)

This tool represents and automatic way of simplifying the planners’ tasks: after the information is exported from SAP, the tool automatically distributes the stocks according to the corresponding finish goods and calculates the minimum quantity that can be produced, considering those stocks.

Most of the times what would happen was that there was a lack of tools that would support the planners in the production control, especially for situations regarding backlogs, that can become critical in some cases. Due to the complexity that is felt when planning the PVD components, since we are talking about thousands of different products, those situations where identified by reports developed by the other plants of the group. In those reports, the main concern were the serious situations of delays in fulfilling the customers’ orders, and that needed to be quickly solved.

In these cases, the planners would have to see all the components of the finish good, with the help of the BOMs, to identify what was causing the backlog, which would mean the need to check the components one-by-one. For some finish goods, the list of components is not that short, and this is why it is crucial to gain efficiency throughout the processes and, especially, in the planning. Every decision that is taken by the production planners will influence directly the course of production and indirectly other departments.

Consequently, this is a tool that helps to quickly identify where the problems are, where to act and what has to be done to solve the problems. The MRP file helps to better follow the critical cases or the ones that will soon become critical, preventing that they become even more serious. Such files are an important support for the planners, because they help to reduce the existing waste in the planners’ tasks, helping to gain efficiency in the production control.

4.5 Some Final Remarks

As a final overview, the examples explained in section 4.4, namely Truck expedition files and MRP files, contribute to a process improvement, in a different way from Power BI, explained in section 4.3. This is one of the goals of the work developed, to understand the architecture of processes and how can they be improved.

There is also a possibility to establish an articulation between solution 1 (Power BI) and solution 2 (Truck Expedition and MRP files). If the planners can quickly identify the materials that are in backlog by looking at the Power BI tool, they can also quickly use those materials to construct an MRP tool and to understand where they need to act to solve the backlogs. This is useful in order to avoid blocking the planning of specific materials due to a lack of materials. This is also an easier way of reducing the impacts that the backlog may have on customers satisfaction.

The expected results of combining the two solutions are basically to streamline the decision making of the planners. Even with the I4.0 boom, the automatization and improvements of processes, the Lean philosophy features, there will always be a need to make decisions. Those decisions will be better if there are favorable conditions to make them, which is one of the main goals of this work. It was proven that the development of some tools can boost the efficiency of the decision making.

It is also expected that the visualization of data becomes better, as well as the centralization of data, and that can be assured with the help of Power BI. With this, the manual tasks performed by the planners, the dispersion and inefficient information flows can also be reduced. In a nutshell, with the presented solutions, it is possible to integrate, join and connect people, processes, products and data.

5. Conclusions, Limitations and Future Work

In this final chapter, the major goal is the drawing of conclusions. It is fundamental to sum up the project and to understand the main contributions not only for the success of the solutions developed but also for the company.

5.1 Conclusions

The work developed in *GROHE Portugal, Componentes Sanitários, Lda* and described throughout this document, intends not only to improve the decision-making and the performance of the processes of the production planning department, but also to reduce waste in the information flows, in the planners' tasks and in the gathering and processing of data. To support this project, an integration of different areas was performed, focusing on Business Process Modelling, Lean Thinking, Industry 4.0 and Information Systems concepts. It is important to recall that, by reducing the waste in information flows and by organizing the information in reports, it is possible to reduce the impact of several changes in the productive environment of the factory and make the processes more agile.

On the one hand, Business Process Modelling Notation is a graphical notation that depicts the steps in a business process, and represents comprehensive solutions whenever talking about processes' improvement. It helps to understand the processes but also the people, the flows, the tasks and the files involved in the fulfilment of a goal. As it describes the processes in a graphical way, it is the starting point to identify problems, especially with respect to understanding the existing inefficiencies in information flows, the points that require development, as well as the requirements needed to get from the problem to a desired solution.

Before implementing solutions, a careful and proper analysis of the processes had to be done, fundamental to help understand where to act. In this case, the focus was the update of the KPIs that are the basis of the production plans, as well as the information sources and the storage and working formats of the data used in the KPIs. By acting in the beginning of the process, it is expected that the results are felt in the global performance of the process.

BPMN 2.0 facilitated this exploratory work, as it establishes the connection between processes and the systems used. This notation was also fundamental to understand the boundaries of the planning processes, which is something that was not graphically documented before. BPMN 2.0 was used to establish the bridge between the BPM life cycle and the SD life cycle. From the BPM life cycle resulted the identification of the critical steps of the KPIs update, and from the SD life cycle the definition of the requirements for the new system. Hence, it was possible to detail and identify the necessary data for each part of the process. Moreover, this work presents a practical case of how BPMN can be used to model business processes and to find the points at which they can be improved.

It is crucial to state that all solutions proposed had in mind a proper analysis of the proceedings used in the production planning department. With the help of BPMN 2.0, it was possible to map the processes and to get to know the elements, the mechanisms, the daily routines and the difficulties involved in the planning and control of production.

On the other hand, Microsoft Power BI was a dashboard used to improve several points that together have a direct impact on the efficiency of the decisions performed by the planners, particularly in the updating and handling of information.

Since it is a “data and analytics reporting tool that helps organizations bring together disparate data sets into reporting dashboards” (Microsoft Power BI, n.d.), it also helps to improve the information flows by concentrating sets of data in the same dashboard. For the specific case of the indicators used to control the production and the performance of the planning (Backlog, OTIF, Safety Stock), and in order to improve the information flows, there was a need to reshape the display of some indicators, as it was seen with the use of the tool.

Power BI provided a solution for reducing the manual tasks performed by the planners, particularly in the updating of the KPIs. Before, the planners would have to perform a set of steps to update the file that would guide the priorities of the production planning. Now, this information is available with just a click. This was achieved because Power BI is an information system that centralizes the data and automatizes its use.

To develop a new system, the requirements defined need to be verified so as to test its feasibility. One of the main challenges was precisely to perceive and integrate the sources of relevant data, to have the information available on the same platform. Therefore, this system represents a connection between several areas used to solve the problems presented: Lean Thinking, to improve the information flows’ quality; Industry 4.0, to understand the powerful features of automatization mirrored in Microsoft Power BI; and Information Systems, to have a robust support to the production planning process.

To test if the prototypes are allowing to gain efficiency, several metrics were thought about. The Practical Metrics served as performance measures for the KPIs in 2 different aspects: the Coverage and the Response Timing. The Dashboard Metrics were used to test the performance of the dashboard itself, considering the Presentation, the Data Analytics and Result Distribution and the Data Provisioning. The Lean Information Management Metrics were defined to analyze the before and after situation, considering the dashboard and the 8 types of waste identified in the Lean Thinking philosophy. Considering a future work perspective, it would be useful to measure in a quantitative way these metrics, this is, for example, measuring the time the planner is saving by using the new software as a support for the planning process.

The two prototypes were developed to complete the proof of concept. To test if they are robust and efficient, the prototypes can be used to rectify the necessity of shaping the indicators to the desired format for the Albergaria plant, concerning the KPIs file. Solutions like the one proposed with the use of Power BI are important to leverage the importance of Industry 4.0 and to start thinking about new ways of integrating the processes along the organization.

On another level, the Decision-Making Support Files were also brought to this work, as they represent another solution to mitigate one of the problems identified: the excess of manual tasks. The main goal is to improve the efficiency of the tasks related with the planning.

The Truck Expedition file was created to change the way the data is handled, this is, to ease the decision when talking about getting an overview of the status of the products and decide whether they could be shipped or not. Another important topic about the Truck Expedition file is the fact that is has the same pillars and background of Microsoft Power BI. Working with Power Query in Microsoft Excel facilitated the understanding of how Microsoft Power BI works.

The MRP file was developed to identify the components that are missing and the minimum final product quantity that can be produce. Therefore, with the help of this tools, it is possible to streamline processes and to improve the decisions, embracing the Lean Thinking philosophy.

Considering that the main goals of this work were: (i) the identification of data sources and the mapping of information flows with the elimination of waste in the processes associated with the production plans creation; (ii) the creation of an autonomous system that gathers, centralizes and shows the wanted information in real time, namely an interactive dashboard with an easy and intuitive updating to quickly view the status of several indicators; and (iii) the definition and provision of new indicators depending on the current needs, leading to an improvement of the customer service and the reduction of backlog; it can be said that in general this work fulfilled the defined goals. However, “there is always room for improvement”, so it is important to understand the limitations of this document and also the suggestions for future work.

5.2 Limitations and Future Work

Throughout this work, several inefficiencies and problems were exposed. The problems identified in the production planning were described in the Ishikawa Diagram shown in section 3.2.5. Regardless of the problems referred, the process accomplishes its purpose, being effective but not efficient. This makes it hard to change the architecture of the process and to change them in a practical way. Therefore, for a future work suggestion, the problems identified could be broken down to the production processes. Every decision made in the planning will have an impact on the production itself. Therefore, to test the feasibility of the solutions proposed, a monitoring of the decisions from the planners to the production processes could be done.

One of the goals of this work was also the introduction of new indicators, if those indicators were relevant to the situations that the planners must monitor. However, no new indicators were defined, therefore it is one of the limitations of this work. This was not done because there was no necessity to create new indicators. Consequently, a suggestion for future work is the monitoring of the existing ones, exactly to understand when there is a need to create new ones and what will they measure. This creation must be a result of a discussion between the planning team that should agree on the new indicators, just like with the cases of Top 200 and the Spare Parts.

BPMN 2.0 facilitated this exploratory work because it helped to decompose the processes in the corresponding activities. Therefore, it allowed to understand where a process can be automatized, thus serving as a basis for a future work related with the automatization of processes. As the automatization of processes and Industry 4.0 have a variety of features and are still growing concepts, namely in the information flows field, there is still a long path to go through considering this perspective.

In another perspective, at the current moment, it is not possible to think about further steps of both BPM and SD life cycles. Hence, another suggestion for the future work is to continue to develop those stages, considering the BPMN 2.0 and the BPM life cycle, this is, a possible To-Be Model, the implementation of the new system and a monitoring and control to check the conformity and fulfilment of the changes.

As Power BI provides visibility and transparency of the information flows, considering the Lean and Information Management philosophy, is makes it easier to understand if everyone from the team is “on the same page”. Thus, this tool should be used by all the planners. In this case, Power BI was only tested in the shaping of the KPIs file.

What if every planner uses Power BI to control their part of the planning? This is, the Finish Good planners use Power BI to understand the Backlogs and the Safety Stocks that need to be monitored considering the Finish Good products only, and so on.

Therefore, a more detailed feasibility analysis should be done, considering technical and economic aspects, to make sure it is the right solution for the manufacturing company. This will depend on the business strategy and focus of the top management. Not only a feasibility analysis is important, if the system is implemented, it is also important to keep performing more feasibility analysis. The quality of information flows gets naturally deteriorated and, bearing that in mind, for future work it is suggested that this system is monitored and maintained, also considering that the external environment of the company is changing, as well as customer requirements and the planners’ focus.

One of the limitations of this work considering Power BI is that the features of the tool can be even more explored and worked on, in order to have a more efficient dashboard.

Another suggestion is the integration of this information system with other systems and the possibility to show the Power BI outputs in the shop floor. For this, the IT support is needed, and the shop floor also needs to be appropriately equipped, in order to have the nearly real time and automatic characteristics of the visualization of data provided by Power BI.

It is also important to consider that the results exposed with the information system and dashboard presented, as well as the corresponding interfaces, can be the starting point for a standardization and integration of the several information systems that already exist in the firm, despite those systems having several different purposes. To confirm the accuracy of the tools developed, and as another suggestion for future work, the metrics developed could be quantified to measure the results. This is not easy to implement, since some of them can be subjective.

In a nutshell, BPMN 2.0 allowed to identify the amount of waste of the processes, reflected in an excess of time wasted, manual tasks performed and in the generation of information. Therefore, and considering the theoretical background of this work, it is important to constantly monitor and if necessary, to reshape the IT structure. The processes also need to be reviewed to guarantee that they are being improved, bearing in mind the Lean Thinking philosophy. This proper analysis can also boost the future adaptation to an Industry 4.0 perspective, with the automatization of processes, and can also bring even more efficient solutions.

To conclude, improving a process in a company is not easy, no matter if it is in the Production Planning, in the Shop floor, or in another department. It changes the way people perform certain tasks and change sometimes is seen as something to avoid, making it hard to implement. It is recommended that the solution developed should not be too complex or something that the planners will not use. In addition, it is important that everyone is involved in the significant changes right from the start, also in order to avoid the resistance to change. If this new system is seen and showed as a way of improving and having better results, changes like the one proposed in this exploratory study can be successful.

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