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IMPROVEMENT OF FUNCTIONAL AND MANAGEMENT ASPECTS AT A WASTEWATER TREATMENT PLANT OF A BREWERY COMPANY

JOSÉ MIGUEL MARTINS DOS REIS COSTA
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Dissertation presented to ISEP – School of Engineering to fulfill the requirements necessary to obtain a Master's degree in Mechanical Engineering, carried out under the guidance of Francisco José Gomes da Silva, Professor at the ISEP's Mechanical Engineering Department.

2017/2018

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Mechanical Engineering Department

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KEYWORDS

Wastewater Treatment Plant; Maintenance; Sustainability; Key Performance Indicators

ABSTRACT

The project was conducted at the Maintenance Department of Super Bock Group (Former UNICER Bebidas), in the centre of Leça do Balio, and covers an overall improvement over the Wastewater Treatment Plant (WWTP) by implementing preventive maintenance in SAP-PM, cutting energy costs in equipment's and by implementing key performance indicator's (KPIs) in maintenance supervision.

The main objective of the project involved the implementation of preventive maintenance in all assets of the WWTP with support of the software Systems, Applications and Products in Data Processing (SAP) to have a more rigorous level on all maintenance activities, to cut the cost of electrical energy of assets by studying the energy schedule tariffs, creating some maintenance KPIs to know how the maintenance plan is doing and to check other situations and a general monitoring of the WWTP.

In the beginning, a background work is made to the topics that will be addressed in development. Then, all the steps for the decisions made and the development of each idea are explained. At the end, the results obtained show that the implementation of the preventive maintenance plan results to about 1100 assets, that the key performance indicators for maintenance supervision are an effective method for supervision and that the project of reducing electricity costs by studying energy tariffs can result in savings up to 20% of electricity costs.

PALAVRAS CHAVE

Estação de Tratamento de Águas Residuais; Manutenção; Sustentabilidade;

Indicadores Chave de Desempenho

RESUMO

O projecto foi realizado no Departamento de Manutenção da Super Bock Group (Ex-UNICER Bebidas), no centro de Leça do Balio, e abrange uma melhoria global da ETAR através da implementação de manutenção preventiva no SAP-PM, reduzindo custos de energia eléctrica de activos e na implementação de indicadores chave de desempenho na supervisão da manutenção.

Os principais objetivos do projeto envolveram a implementação de manutenção preventiva em todos os activos da ETAR com suporte do software Systems, Applications and Products in Data Processing (SAP) para ter um nível mais rigoroso em todas as atividades de manutenção, reduzir o custo de energia eléctrica dos equipamentos, estudando as tarifas sobre os diferentes horários de energia eléctrica, criar alguns indicadores chave de desempenho de manutenção para saber como o plano de manutenção está a ser realizado e para verificar outras situações e uma supervisão geral da ETAR.

No início é feita uma introdução científica aos tópicos que serão abordados no desenvolvimento. Depois, são explicados todos os passos para as decisões tomadas e o para o desenvolvimento de cada ideia. No final, são mostrados os resultados obtidos em que se demonstra que a implementação do plano de manutenção preventiva resulta para cerca de 1100 activos, que os indicadores chave de desempenho para supervisão de manutenção apresentam ser um método eficaz para o mesmo e que o projecto de redução de custos de energia eléctrica estudando as tarifas energéticas pode resultar numa poupança até cerca de 20% de custos de energia eléctrica.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

Abbreviation	Designation
AHRESP	Associação da Hotelaria, Restauração e Similares de Portugal
BC	Before Christ
CAD	Computer-aided Design
CIP	Cleaning In Place
CM	Corrective Maintenance
CMMS	Computerized Maintenance Management System
COD	Chemical Oxygen Demand
CUFP	Companhia União Fabril Portuense
eAM	Enterprise Asset Management
EU	European Union
FMEA	Failure Mode and Effect Analysis
HTC	Hydrothermal Carbonization
ICT	Information and Communications Technology
IFS	International Featured Standards
ISO	International Organizations for Standardization
KPI	Key Performance Indicator
LED	Light-emitting Diode
MTBF	Mean Time Between Failures
NH_3-N	Nitrogen-Ammonia
PDF	Portable Document Format
PID	Piping and Instrumentation Diagram
PLC	Power Line Communication
PM	Preventive Maintenance
PrM	Proactive Maintenance
RCM	Reliability Centred Maintenance
SAP	Systems, Applications and Products in Data Processing
SBG	Super Bock Group
SETIS	Strategic Energy Technologies Information System
SOP	Standard Operational Procedure
SS	Suspended Solids
SWOT	Strengths, Weakness, Opportunities, Threats
TN	Total Nitrogen
TPM	Total Productive Maintenance
TQM	Total Quality Maintenance
UN	United Nations
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

List of units

Unit	Designation
A	Ampere
°C	Celsius
D	Day
hl	Hectolitres
h	Hours
hl	Hectolitres
kg	Kilograms
kW	Kilowatt
l	Litres
Mj	Megajoules
ppm	Parts per million
V	Volt
W	Watt

List of symbols

Symbol	Designation
€	Euro

FIGURES INDEX

TABLES INDEX

INDEX

INTRODUCTION

1 INTRODUCTION

1.1 Contextualization

Since the early days of civilization, beer is one of the main beverages which was produced. Firstly, produced at home and then started to be more industrialized in monasteries, currently the brewing industry is a fair automatized and complex process system. As process systems become more complex, generally, more failures to assets will happen and will affect the performance of the company. To fight back asset failure, companies are devoted to maintenance. Maintenance had a huge evolution over the past 60 years as companies realized that with a good maintenance plan and management over facilities, they will increase production efficiency. Likewise, the overall revenue of a company will increase.

In a world with an increased awareness for sustainability, maintenance is a definitely factor to achieve such. But there are still other forms to increase the efficiency of companies, and investigators are always seeking ways to reach new ways to increase it.

This dissertation is a work that shows ways of improving the maintenance management process in aspects such as organization and supervision. It shows how a maintenance plan should be organized via software and follows every step of the creation. It also shows ways to supervise maintenance activities in by using key indicators. The dissertation also includes an improvement over the cost of energy by working with the electrical company schedule.

1.2 Main Objective

The main objective of the proposed work is to create to the hosting company a complete maintenance plan into a software for their wastewater treatment plant facility, leading to a more organized and detailed work for maintenance activities at the plant. It also was proposed to create a way to supervise the maintenance activities and to improve the energy cost of the plant.

So, the main objective aim is to:

- Analyse the wastewater treatment plant process;
- Create an ideal structure of the plant;
- Analyse, create and make necessary modifications to maintenance tasks;
- Find ways to organize general information of the plant;
- Create a way to supervise the maintenance activities at the plant, and
- Review and find new ways to decrease energy costs at the facility.

1.3 Methodology

The methodology used in this project was distributed in the following steps (Figure 1):

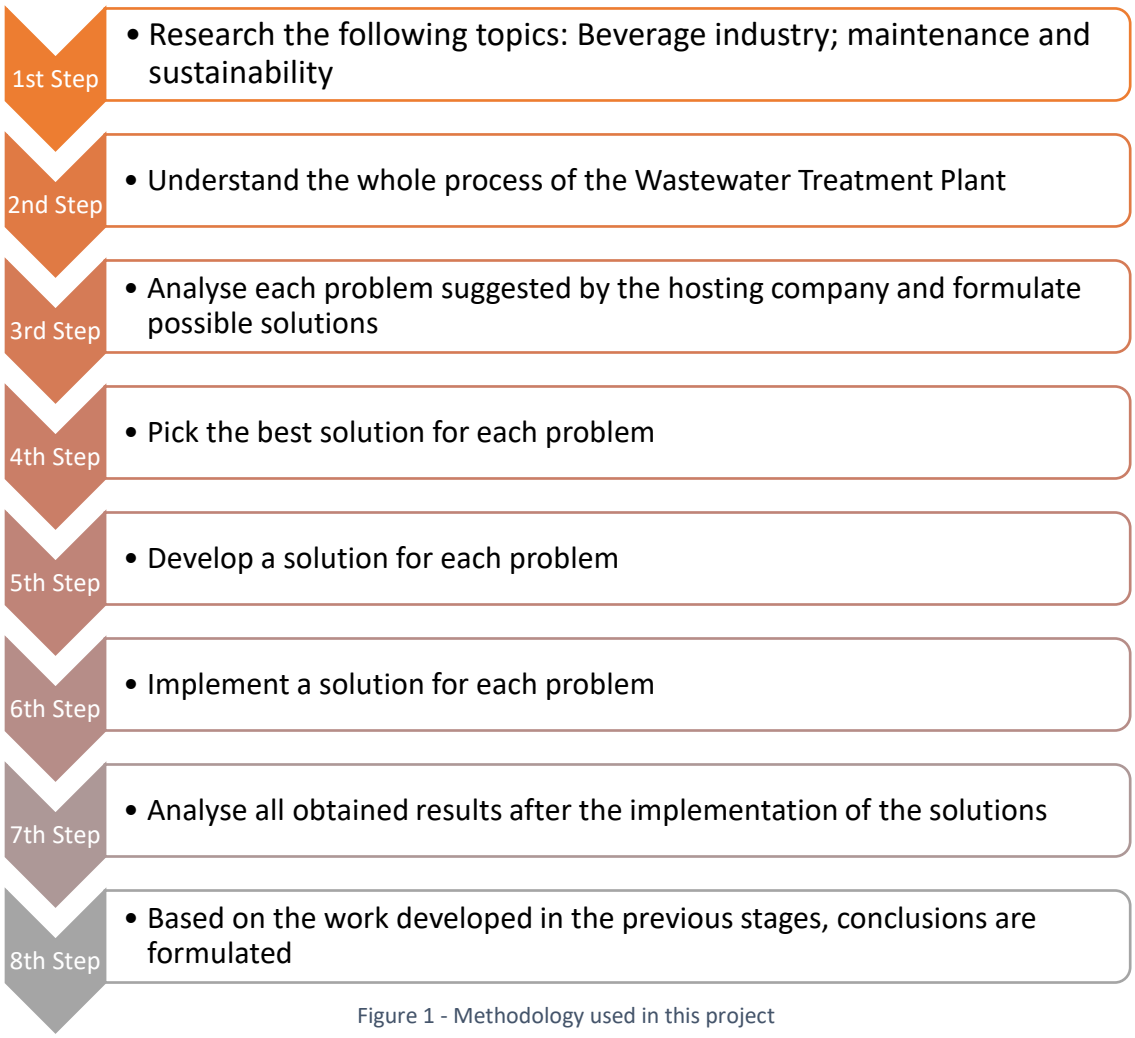

Figure 1 - Methodology used in this project

1.4 Dissertation Structure

This dissertation is divided into four major chapters

The first chapter is an introduction where is made a contextualization of the project and its main objectives. It also represents the methodology used, the structure of the dissertation and, finally, the hosting company where the work was conducted.

The second chapter is the background work which is divided into three topics: Beverage Industry, Maintenance and Sustainability. In each topic exists a small approach of their importance in today's society and other relevant information for this dissertation.

In the third chapter, the case study is demonstrated with a general explanation of all the solutions, how the chosen solutions were developed and implemented. In the final, it shows the results of each solution.

The fourth and final chapter, includes all the conclusions removed from the work and suggestions for future work.

1.5 Hosting Company

The development of this project occurred at Super Bock Group in their centre facility at Leça do Balio. It was a project of the Maintenance Department dedicated to the Wastewater Treatment Plant.

BACKGROUND WORK

2 BACKGROUND WORK

2.1 Beverage Industry

Beverages, or drinks, are used, mainly, to satisfy people's thirst, but they also have a great role on people's socialization way. It's believed that the beverage culture and development exist for than 8000 years, where wine has evidence of its production around 6000 BC (Before Christ) and beer production at 3000 BC [1]. Other drinks, such as tea, were, first, created as a medicinal drink.

The beverage industry consists of companies that market alcoholic and non-alcoholic drinks. A large array of beverages can be found in the market like beer, coffee, water and so on.

2.1.1 Importance of the sector in the worldwide economy

The beverage industry was 1.3 trillion dollars' worth in 2017 [2] and has an estimated value of 1.9 trillion dollars by 2021 [3], demonstrating constant increase of market over the years. It produces almost 2 x 10^{12} litres of fruit juices, carbonated and noncarbonated drinks per annum while 2 x 10^{11} litres of alcoholic drinks are produced. Tea beverage is about 37 billion dollars per year [4].

In all the different sectors that exist worldwide, such as housing, transport, clothing, food and beverages have the higher share when it comes to household consumption. People consume, on average, 38.6% on food and beverages of their total consumption (Figure 2).

All Sectors	Food and..	Others	Housing	Transport	Clothing ..	Energy	ICT	Health	Education	Personal ..	Financial ..	Water Uti..
9,756	3,767	1,134	1,035	898	698	522	514	498	398	136	94	62

Figure 2 - Worldwide human consumption [5]

Globally, the amount of litres produced are increasing year by year as figure 3 illustrates, mainly due to the fact that consumption is also increasing year by year. Also, the estimate global market share has the largest cut in Asia with 47.2% mainly because of its superior population. As for Europe, it has an estimate of 17.1% of the market share.

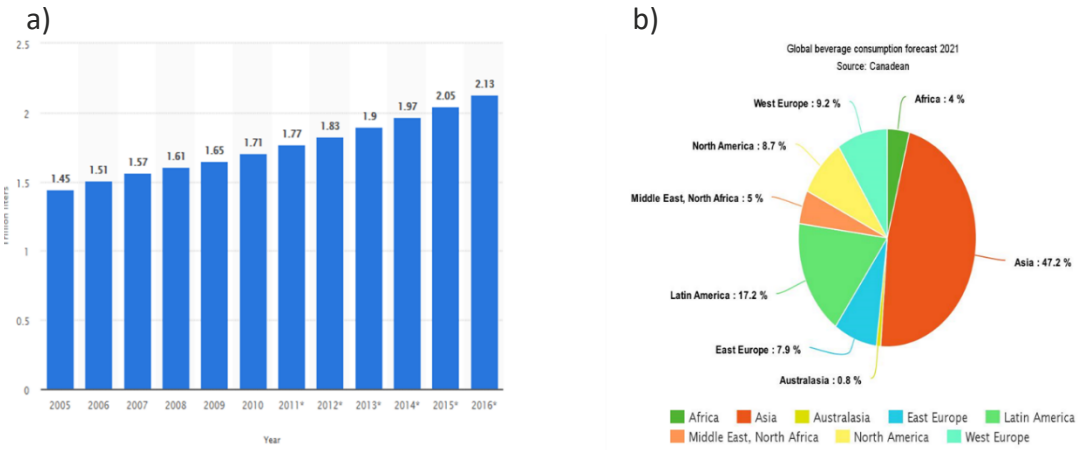

Figure 3 – a) - Produced litres in the beverage production [6], b) - Consumption share by regions [7]

2.1.2 Importance of the sector in the national economy (Portugal)

In 2015, the beverage industry in Portugal was represented by 1094 companies which corresponded to 0.3% of the total companies in Portugal, 1% of the total business volume and 0.5% of the number of people in service.

It is known that Portugal is one of the greatest world wine producers, and such, most of the beverages producers produce wine (Figure 4). But, the turnover is not directly proportional with the number of companies, giving wine about half of the total turnover, and soft drinks and beer nearly 25%. This is because most of the wine producers are a micro-enterprise, which generally generate a lower turnover. In fact, big companies, which only represent about 1% of the total beverage companies, create 50% of the total turnover (Figure 5).

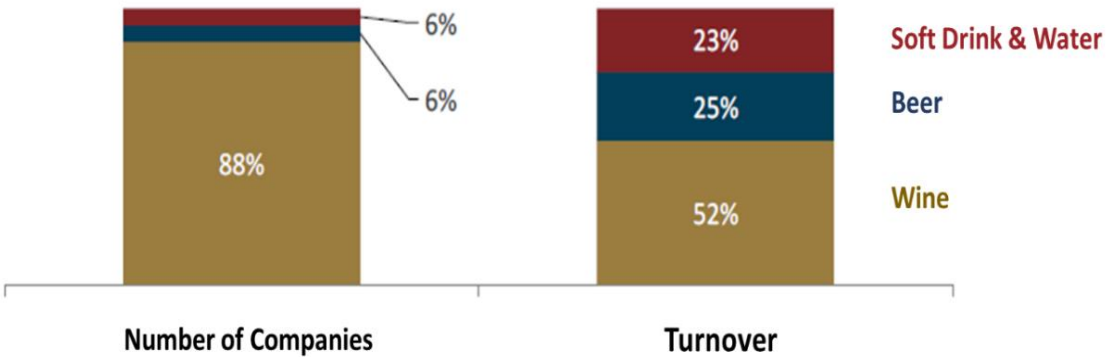

Figure 4 - Share and turnover of different types of beverage companies in Portugal [8]

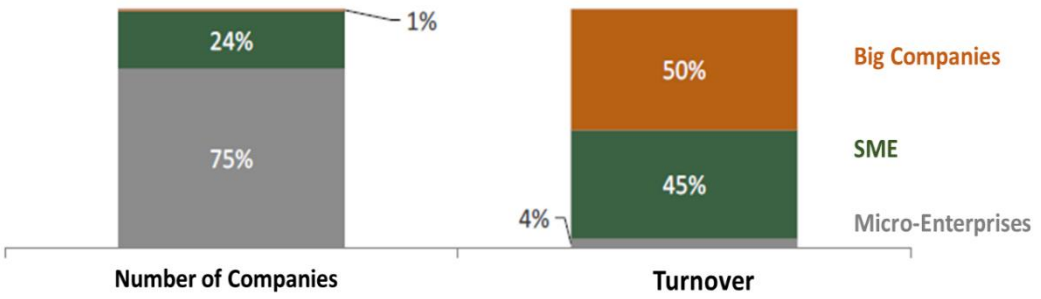

Figure 5 - Share and turnover of the beverage sector by types of companies [8]

The distribution of the companies doesn't concentrate in the main centres of the country as usually happens with other industries. Beverage industry in Portugal exists in almost every region (Figure 6). This is caused by the wine production whose production is in regional lands were the large fields of grapes grow (to become wine).

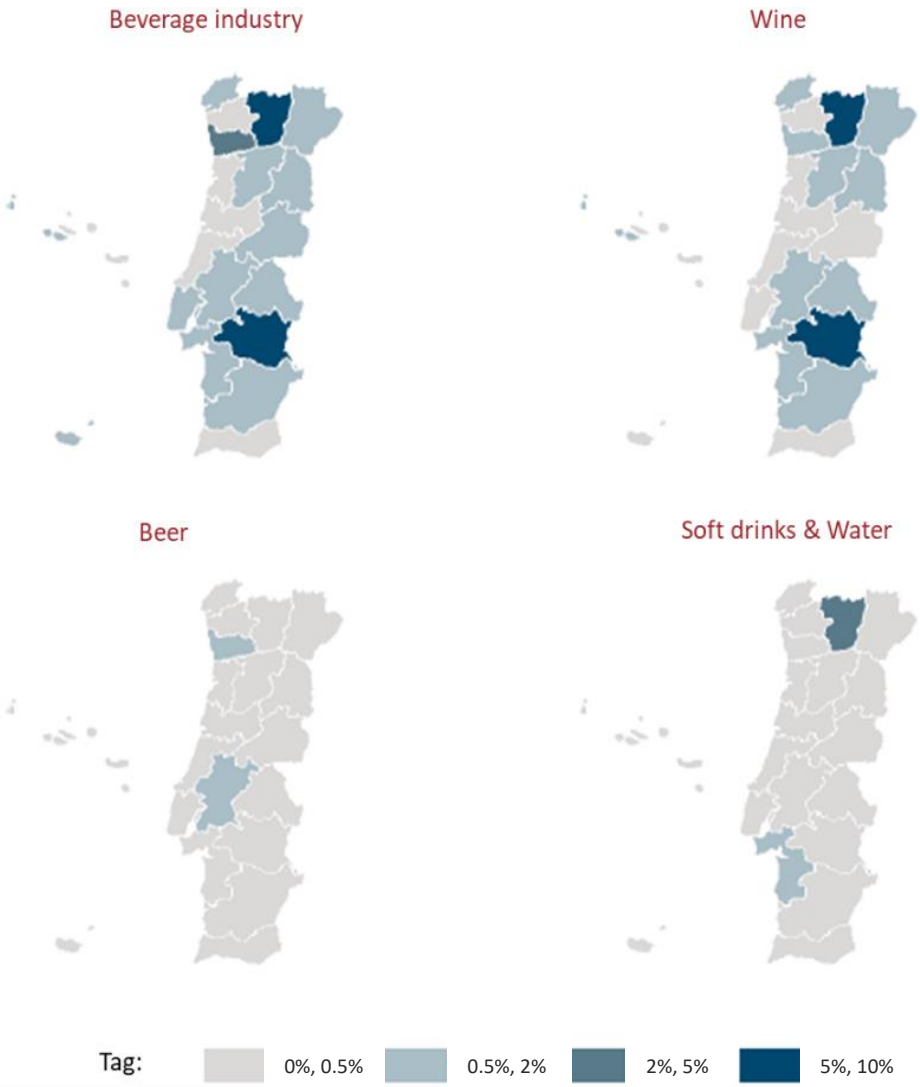

Figure 6 - Distribution of the beverage sector in Portugal [9]

As for beer, the production happens at the centres of the country, including Porto. As far as exporting goods is concerned, the beverage industry represents values above the average of the total industries, here the number of companies surpasses the triple and the turnover is almost double. As within the beverage industry, wine companies tend to sell more beyond the border, while beer producers come shorter. As for the turnover, soft drinks and water producers generate a higher turnover when selling off border than wine and beer producers (Figure 7).

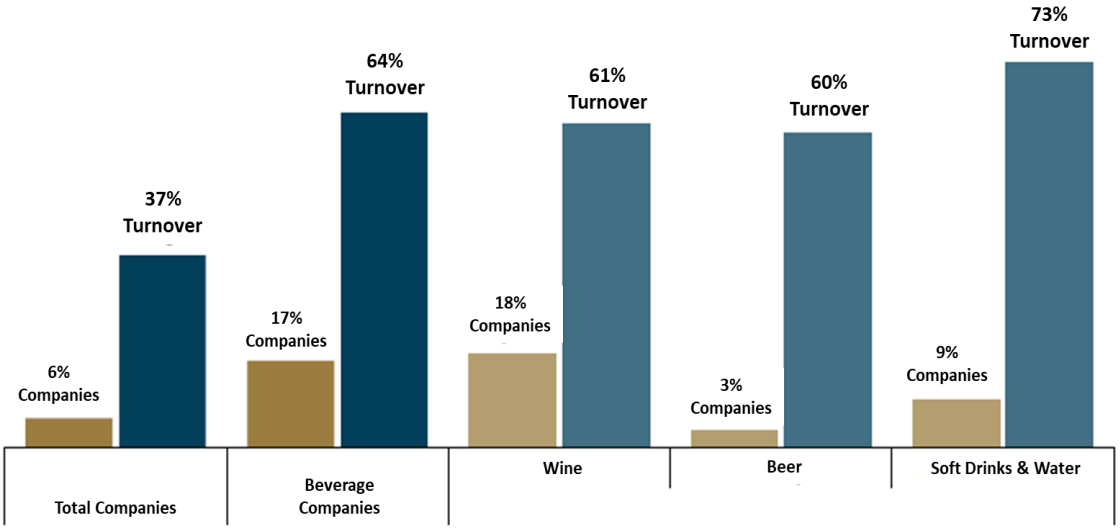

Figure 7 - Exportation weight of the beverage industry in Portugal compared to all industry [9]

From the beginning of the 2015 to the end of 2017 the catering and drinking business almost had a 100000 increase of people working in the sector, showing the impact of tourism in the country [10]. With the constant rise of tourism in Portugal and the relevance of the country outside, the beverage industry has an advantage and can continue to grow its market.

2.1.3 Types of beverages

Beverages can be divided into two major groups, non-alcoholic drinks and alcoholic drinks. They are distinguished by the presence of ethanol. If a drink has more than 0.5% of ethanol on its constitution, it is considered an alcoholic drink, otherwise, it is non-alcoholic.

There is a wide range of non-alcoholic drinks. They can be (Figure 8):

- Water;
- Tea;
- Soft/Carbonated Drinks;
- Coffee, and
- Juice.

Water is the most common liquid on earth and it's the main drink that people use to hydrate. Tea is one of most important drinks worldwide having a lot of variations such as black tea or green tea. Around two-thirds of the world population drink tea in the morning. Soft drink, such as coke and soda, is a drink that typically contains carbonated water, sweetener, and a

natural or artificial flavouring. Coffee is also a very drank drink in the world which can be prepared in various different ways. Juice is prepared by mechanically squeezing or macerating fruit or vegetables without the application of heat or solvents [4].

Figure 8 - Non-alcoholic drinks [8 - 11]

As for alcoholic drinks, they can be (Figure 9):

- Wine;
- Beer, and
- Spirits;

Wine is most commonly made of grapes. In production, yeast is added for fermentation, transforming the natural sugars of the grapes to ethanol. Wine is aged before consumption for periods depending on variety. Beer is the most important alcoholic beverage produced worldwide and is produced by the saccharification of a source of starch followed by extraction of the sugars and their fermentation. Spirits are usually achieved by the distillation of a fermented source. Sources are numerous such as cereals, berries or even potatoes [4].

Figure 9 - Alcoholic drinks [12 – 14]

In the United States of America, the type of non-alcoholic drink that has the biggest market share are Carbonated/Soft drinks, while alcoholic drinks it is Beer with the highest market share (Figure 10).

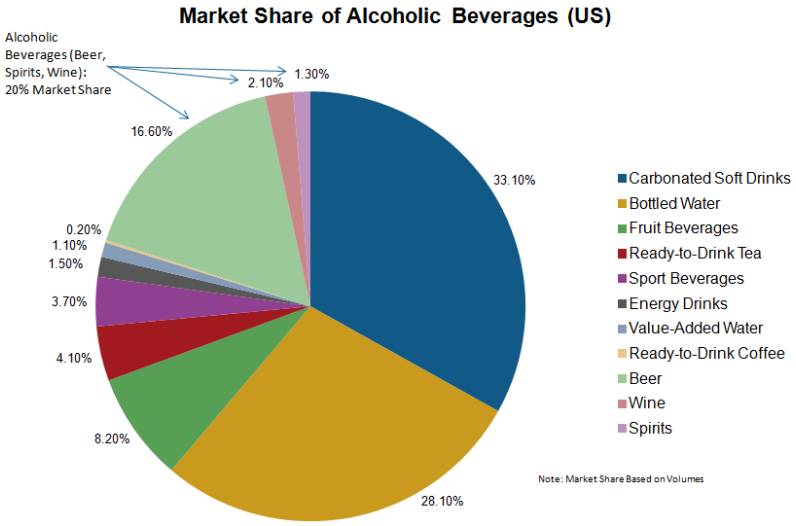

Figure 10 - United States of America consumption share of the different types of beverages [15]

These are some of the types of beverages around the world, but not all. Within the beverages mentioned above, there are thousands of types. For example, beer as almost 45 different types like Stout or Bock [16].

2.1.4 Beer manufacturing process

According to the *Reinheitsgebot* (Figure 11), or the Bavarian Purity Law of Germany, implemented by William IV, Duke of Bavaria, beer is defined as a fermented alcoholic beverage made of malted cereals, water, hops and yeast [17].

Figure 11 - The *Reinheitsgebot* [17]

Today, beer can be more than that, some companies use additional substances such as enzymes or antifoaming agents. Barley is the main cereal used in beer production but, other companies use cereals such as rice, wheat or corn.

The conversion of cereals into beer is not a direct process. The cereals used in beer production do not contain sufficient quantities of fermentable sugars. These cereals must first undergo modification during the malting and mashing steps to yield carbohydrates that yeast can convert during the fermentation step into ethyl alcohol and carbon dioxide. Finishing steps include the filtering, pasteurization and packaging as shown on figure 12 [18].

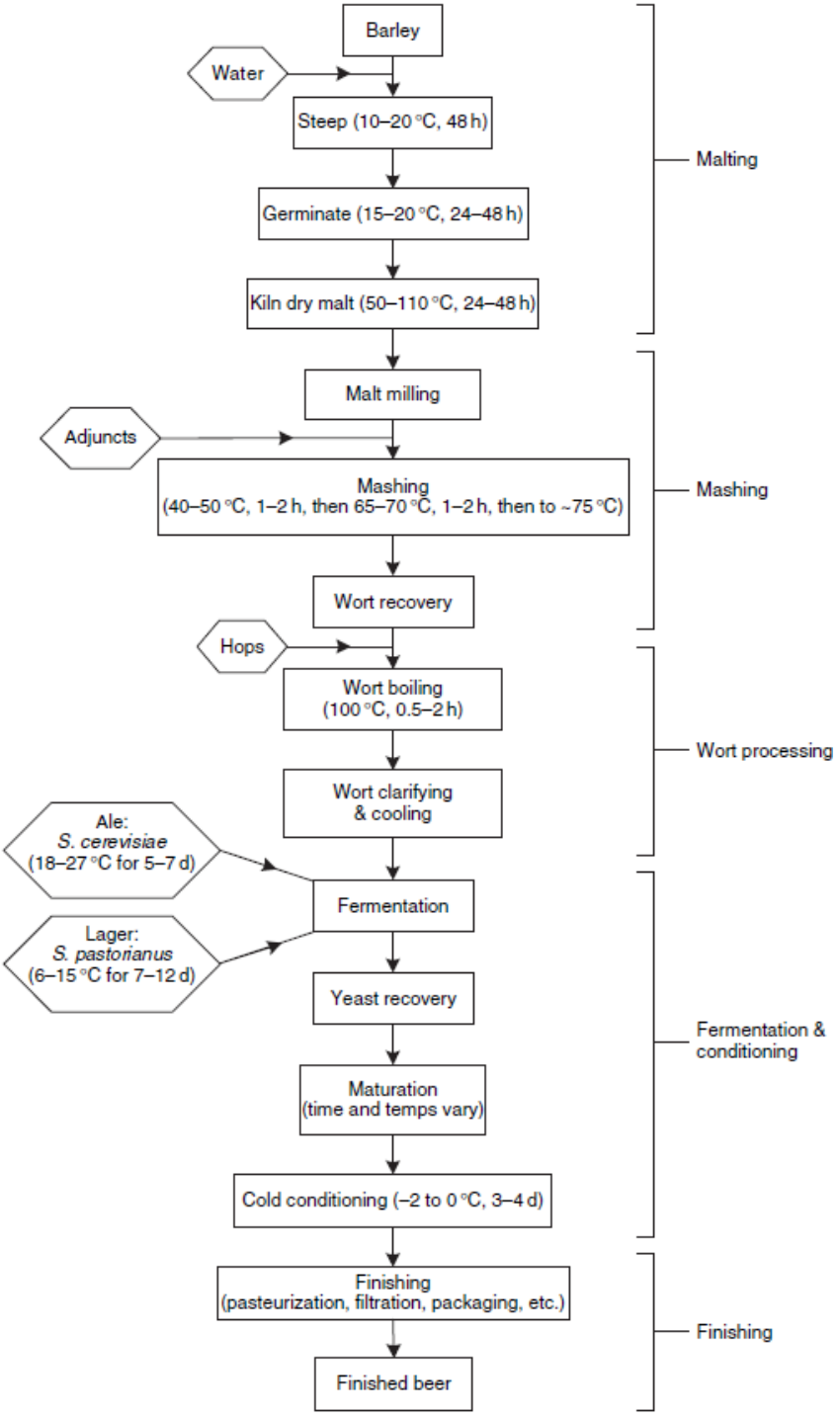

Figure 12 - Beer production processes [18]

So, the main steps to produce beer are [18]:

- Malting – is to produce an ample supply of enzymes that degrade starch, proteins and other components of grain. This transforms the mixture of water and cereal into malt;
- Mashing – Hydrolyses unfermentable carbohydrates and proteins into soluble fermentable materials by the enzymes present in the malt. This process transforms malt into wort;
- Wort Processing – In this stage, wort is boiled, mainly to kill all present microorganisms, evaporate water, to enhance oil extraction and to enhance colour development. It also adds hops into the mix to improve flavour and aroma. At the end, wort is separated from the spent hops (clarification) and cooled rapidly;
- Fermentation – wort is inoculated with yeast which will transform fermentable sugars into alcohol and also produce carbon dioxide and some additional flavour constituents;
- Maturation and Conditioning – Allows the beer to develop its final flavour, colour and body characteristics, and
- Finishing – To finish the final product, beer is usually pasteurized and filtrated to increase its shelf life and, eventually, packed in the form of bottles, cans or barrels.

Each of these steps are necessary to the process of beer manufacturing. They are responsible for companies to produce a high-quality beer.

2.1.5 Sustainability in beer production

The quest for sustainability and combat of climate change as major driving forces new developments in the food and beverage industry focus on multiple possibilities of introducing energy efficiency and the use of renewable resources [19]. For industry, the main ways to reduce greenhouse gases will embrace:

- Increased efficiency in energy conversion with an emphasis on cogeneration;
- Process intensification and heat integration;
- Zero-energy design for production halls and heat integration;
- A shift in energy resources from fossil to renewable, and
- The use of industrial waste heat for general heating purposes outside the company.

Sustainability resides on three main pillars; Environmental, Economic and Social. By trying to reduce greenhouse gases (Environmental Pilar), indirectly, companies can reduce their overall costs (Economic Pilar) and having a cleaner image towards society (Social Pilar). So, some actions can link all pillars at the same time.

The brewing industry is a large consumer in the world, mainly in resources such as water, energy and cereals such as barley. Basic eco-strategies for breweries include improving insulation and implementing heat recovery measures [20]. For breweries much effort has been done lately in research and plant development to reduce the energy demand of the processes, visible through a large number of papers and publications. Typical energy demand figures, such as 24-54 Mj/hl beer for wort boiling, can be found in literature for different processes [19].

Annex 1 shows all different quantities of various resources spent in different stages of the process per month at the brewer Sai Gon Beer in Vietnam. This example is unique to this brewer because breweries have different sizes, but the proportions do not vary so much. As illustrated, it is seen that the main resources spent are:

- Water;
- Energy for chilling purposes, and
- Steam.

While water and energy for chilling normally come from the water and electrical company, on the other hand, steam is generated in the brewery at the boilers. Boilers burn fossil fuel (being natural gas the most used), to turn water into steam. This steam is then used to heat up necessary parts of the process such as brewing or pasteurization. This might sound contradictory with the reduction of greenhouse gases; however, the boilers can use biogas which is a source that is generated by treating wastewater. So, the creation of steam becomes more sustainable by using resources that are created in processes that involve the company, in this case, the treatment of wastewaters.

When it comes to resources such as cereals, spent grains which are generated by the process of mashing, the rendering malt and cereal grain content soluble in water. Instead of dumping these grains, they can be sold as livestock feed with an average profit close to 5 €/ton [22] (Strategy A) (Figure 13).

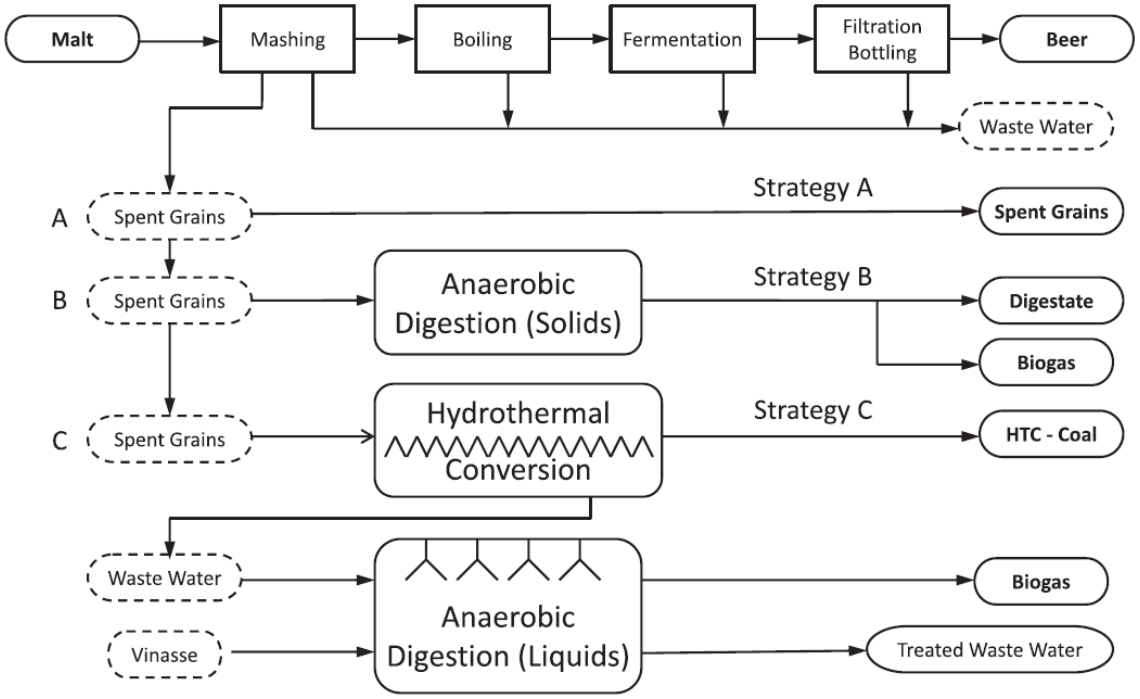

Figure 13 - Different strategies to manage spent grains (Adapted from [23])

But, it isn't the only strategy. Figure 13 shows other strategies that can benefit with spent grains. Spent grains can be sent to an anaerobic digestor in the form of solid and are transformed in Biogas and Digestate (Strategy B). Small anaerobic digestors are already available and are being used on high strength brewery streams [23]. Spent grains can also be

used in industrial incineration systems. They can also undergo low temperature conversion at 350 – 500 °C to generate bio-oil and bio-char [24] or may be subject to hydrothermal carbonization (HTC) to produce bio-char with chemical characteristics similar to lignite for on-site use (Strategy C) [25].

As for water, the annual brewing industry production exceeded 2.13 billion hectolitres by 2016. Water management and waste disposal have become a significant cost factor and an important aspect in the running of a brewery operation. Every brewery tries to keep waste disposal costs low whereas the legislation imposed for waste disposal by authorities becomes more stringent [26].

Water that is used in the processes becomes wastewater which contains high level of organic matter, diatomaceous earth (Kieselguhr), spent grains, waste labels or even bottles. Kieselguhr is used as a filter-aid in a conventional dead-end filtration and is very difficult of dispose and to treat and is a very high pollutant. Waste labels, although may not cause an impact as Kieselguhr and may sound minimal, on average, a weight of 282 kg/1000 hl of produced beer has been calculated. Their waste should be avoided or, at least, limited since they are not simple papers, but wet-strength paper impregnated with caustic solution [22].

Nowadays, Kieselguhr should become less used for beer clarification. Literature reports three trends:

- The reduction of Kieselguhr consumption;
- The replacement of Kieselguhr by regenerable filter-aids, and
- Development of Kieselguhr-free processes (membrane filtration).

As for organic matter, wastewater treatment plants are currently used, with preference for biological alternatives of treatment.

To sum up, managing all resources of a brewery requires effort due to the amount of them. Brewers are very concerned that the techniques they use are the best in terms of product quality and cost effectiveness. Energy consumption, water consumption, wastewater and solid-liquid separation constitute real economic opportunities for improvements for brewing companies become more sustainable.

2.2 Maintenance

2.2.1 Maintenance relevance

In the early stages of industry, maintenance was seen as something not important. Companies didn’t care about having a strategy over its assets, it was like a necessary evil. Over the last decennia, industrial maintenance has evolved from a non-issue into a strategic concern [27] (Figure 14).

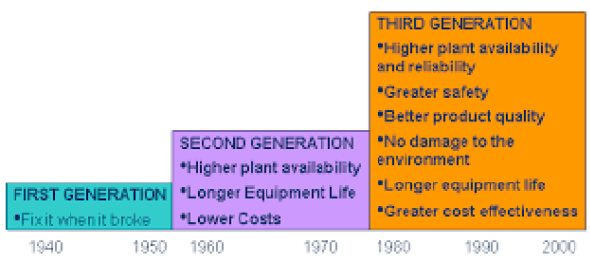

Figure 14 - Maintenance over time

Maintenance can be defined as the combination of all technical, associated administrative and managerial actions during the life cycle of an asset intended to retain in, or restore it to, a state in which it can perform its required function [28]. Management personnel often consider plant maintenance an expense, yet a more positive approach is to view maintenance work as a profit centre [29].

As time went by, companies sought to be ahead of competition by producing more in a shorter period and with less resources. To enable these serious needs, physical assets take a central role. However, installations have become highly automated and technologically very complex and, consequently, maintenance management had to become more complex having to cope with higher technical and business expectations [27].

Maintenance evolved over the time, whereas the first generation, companies would only take action on an equipment in case of failure. Second generation, companies noticed that each failure of an equipment would overwhelm them with huge loss of production and started to implement strategies to anticipate future failures. By the third generation, with the increase automatization of companies, the introduction of just-in-time and the low levels of stock, failures would become more critic, and maintenance would evolve to one of the main activities on companies and, eventually, lead to an organized system and to its constant development on ways to improve it.

The grand objective of maintenance is to optimize the total asset life cycle. Maintenance function needs to cope with multiple forces and requirements within and outside the walls of the organization (Figure 15) [27].

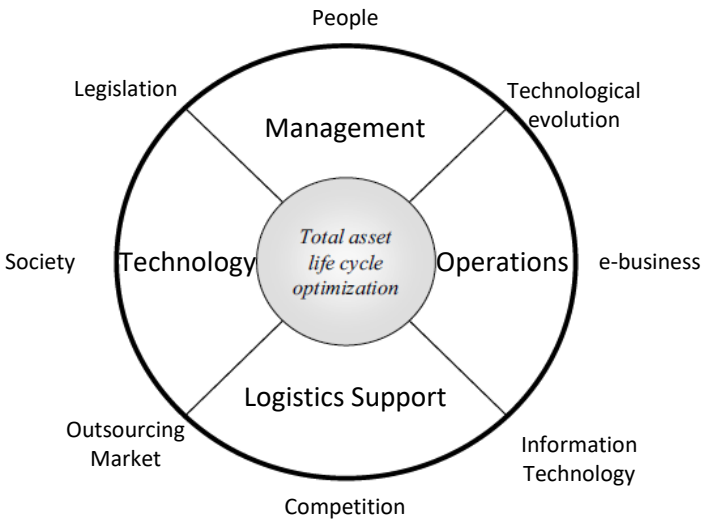

Figure 15 - Maintenance in context [27]

Several stakeholders can be involved on an asset and only depend under it (Figure 16) [30].

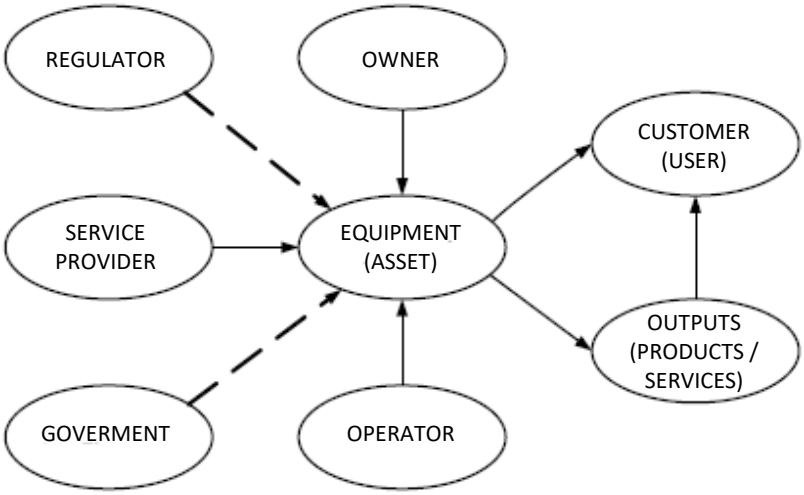

Figure 16 - Stakeholder for maintenance of an asset [30]

To ensure the main maintenance objective, diverse management actions must be defined and mastered, such as:

- Planning;
- Execution;
- Cost control;
- Materials management, and
- Personnel management.

Giving this contextualization, it is clear that maintenance management is a highly complex task.

2.2.2 Types of maintenance

Maintenance has different types of action, policies and concepts. As far as actions, maintenance follows according to figure 17. Companies should follow not one of these examples, but an adequate combination of them all, considering total costs.

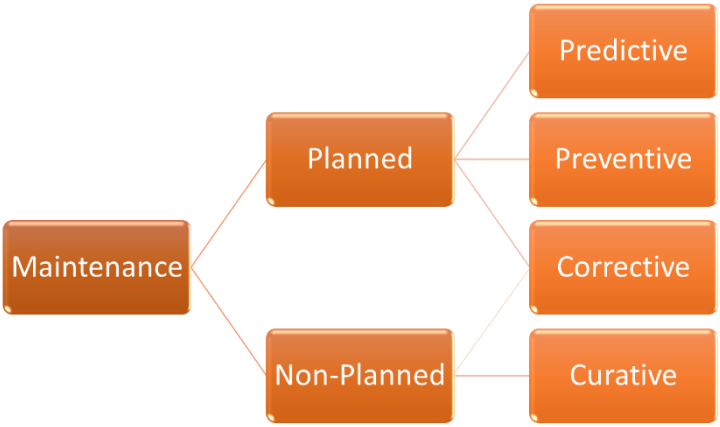

Figure 17 - Different types of maintenance (Author's work)

Definitions of the types of maintenance mentioned on figure 17 can be viewed in table 1.

Table 1 - Examples of different types of maintenance

	Definition	
Type of maintenance	According to EN 13306 [28]	Other authors
Preventive maintenance	Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item	Is the process of performing specific inspections, tests, measurements, adjustments or part replacements, specifically aimed at preventing failures before they happen
Predictive maintenance	Condition based maintenance carried out following a forecast derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item	The focus of predictive maintenance should be on investigating and purchasing technology that solves or mitigates chronic equipment problems that exist such as vibration analysis for rotating equipment or thermography analysis for electrical equipment [32]. A well-defined predictive maintenance will provide a clear indication if further action is currently needed or not [29].
Corrective maintenance	Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function	Non-planned executed only after a malfunction of an asset or planned to repair assets before they start working or with implement an improvement to the asset [33]. Corrective actions are difficult to predict as equipment failure behaviour is stochastic and breakdowns are unforeseen [27].
Immediate corrective maintenance	Corrective maintenance that is carried out without delay after a fault has been detected to	Similar to corrective maintenance, it will consist of replacing a failed system,

	avoid consequences	unacceptable	subsystem or component to ensure that full, fault-free, operating condition is restored [31] but, due to urgency of the repair or unavailability of the maintenance team, it is not possible to diagnose the failure at full and actions to improve the asset are not done.

2.2.3 New maintenance approaches

As mentioned before, maintenance is in constant evolution. Companies are always developing new methods or philosophies to have a more effective way for maintenance management and to increase machine performance (Figure 18).

In current papers, some general new philosophies and strategies approaches can be found such as:

- Reliability Centred Maintenance (RCM);
- Total Productive Maintenance (TPM), and
- Self-Maintenance.

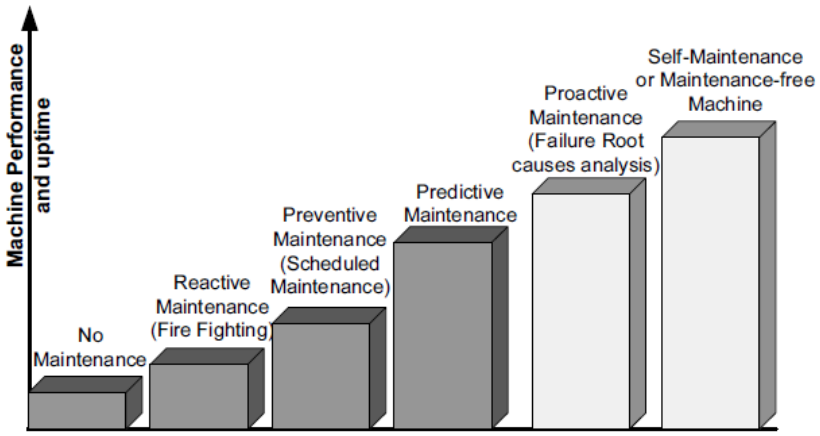

Figure 18 - The development of maintenance technologies [34]

RCM is basically found to be the most efficient strategy in comparison with the existing supervision of maintenance strategies [35]. This is achieved by realizing resources inherent reliability by logically incorporating the maintenance strategies like corrective, preventive and proactive maintenance [36]. It develops a cost-effective method to intentionally manage the maintenance procedures from a reliability point of view [37]. There are five basic steps of the RCM process:

1. Selection of a system and subsystem;
2. Identification of critical component, which has a considerable influence on system reliability;
3. Construction of a Failure Mode and Effect Analysis (FMEA);
4. Selecting the optimal maintenance strategy, and
5. Cost analysis.

The RCM tools require data to be effective. For this reason, the RCM process is used after the organization has progressed to the point that ensures complete and accurate data asset [32].

TPM is designed to maximize equipment effectiveness (improving overall efficiency) by establishing a comprehensive productive-maintenance system covering the entire life of the equipment, spanning all equipment-related fields (planning, use, maintenance, etc.) and, with the participation of all employees from top management to shop-floor workers, to promote productive maintenance through motivation management or voluntary small-group activities [38]. In short, TPM goal is to improve productivity and quality along with increased employee morale and job satisfaction [39].

It lies on 8 major pillars as figured in Figure 19. With a total employee participation and using methods such as 5S, by applying it to these major pillars, companies can achieve an overall improvement, idealistically with zero defects, breakdowns, accidents and waste.

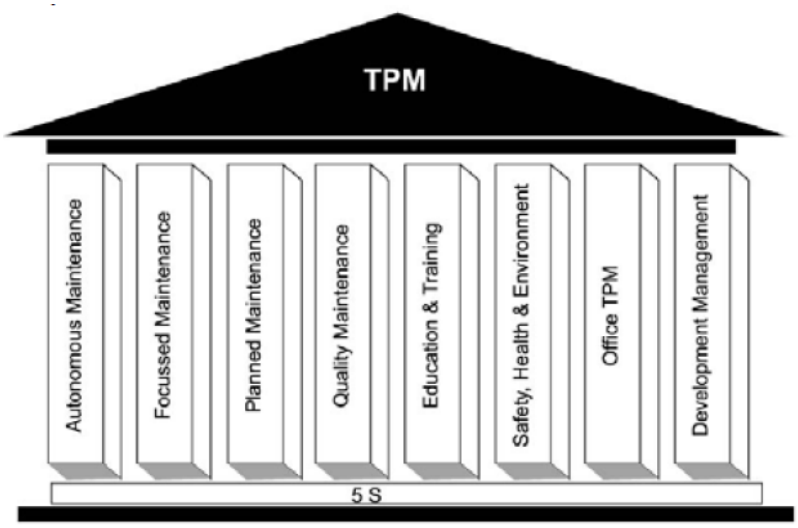

Figure 19 - Pillars of TPM [40]

TPM is similar to Total Quality Management (TQM), but, instead of companies focusing on their products, they focus on their assets. TPM can use all of the tools and techniques for implementing, sustaining and improving the total quality effort [32].

Self-Maintenance is a new design and system methodology and it is expected to the machines to be able to monitor, diagnose and repair themselves in order to increase their uptime. The way to fulfil the self-maintenance function is by adding intelligence to the machine, making it clever enough for functional maintenance so that the machine can monitor and diagnose itself, and it can still maintain its functionality for a while if any kind of failure or degradation occurs [34].
The capabilities required for a self-maintenance machine are defined, according to Labib [41], as:

- Monitoring capability;
- Fault judging capability;
- Diagnosing capability;
- Repair planning capability;
- Repair executing capability, and
- Self-learning and improvement.

Efforts towards realizing self-maintenance have been mainly in the form of intelligent adaptive control, where investigation of control was achieved using fuzzy logic control. Such controller must be able to cater for sensor degradation and this leads to self-learning and improvement capabilities [34].

2.2.4 Maintenance costs

The motivation for developing advance maintenance strategies is essentially to reduce the maintenance costs while maintaining safety. Researchers proposed many cost models to facilitate the comparison of maintenance strategies. All these cost analysis and comparison share one thing in common. The maintenance strategy is independent from unit cost (e.g., the setup cost, the corrective maintenance cost, the predictive maintenance cost, etc.) and the interaction between strategy and unit has not been considered, which in fact might affect the maintenance strategy in some situations [42].

Maintenance costs are significant to the total operating costs in the industry sector. But what many companies don’t realise is that many of the maintenance costs are hidden (Indirect costs) and are significantly higher than the traditional ones (Direct costs). Figure 20 shows the “Iceberg Model” where it examples direct and indirect maintenance costs.

Reducing these hidden costs requires a shift from the traditional reactive (Corrective) approach to a proactive reliability-based approach. For such to happen, key factors must be put in place including to form the basis of maintenance management [43]:

- A clear strategy;
- Policies to support the strategy;
- Procedures and processes to enable implementation of the strategy and policy;

- Tools to support this implementation, and
- A well-established Maintenance Business Process with checks and balances.

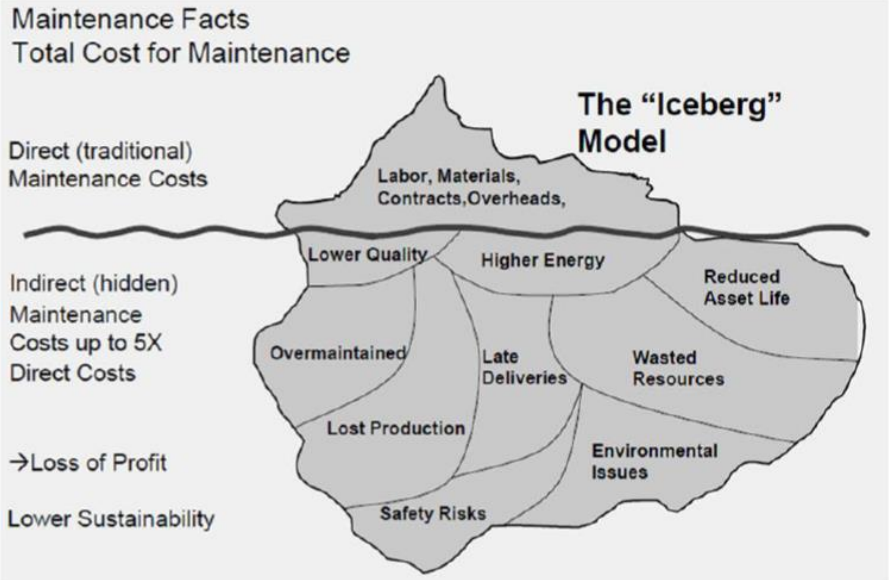

Figure 20 - The "Iceberg" model of maintenance costs [43]

Whenever a failure occurs, the costs associated to the equipment returning to its operating state result not just the restoring of the equipment (Direct costs) but also indirect costs from the penalties incurred. So, total costs are direct and indirect ones. These costs can be lowered through greater proactive maintenance, but this implies their increased costs (Figure 21) [44].

Since the corrective maintenance (CM) are uncertain, the optimal proactive maintenance (PrM) effort is based on minimizing the expected total cost. This requires the company to first define the kind of PrM policy that would be employed and then to optimally select the parameters of the policy so as to minimize total cost [44].

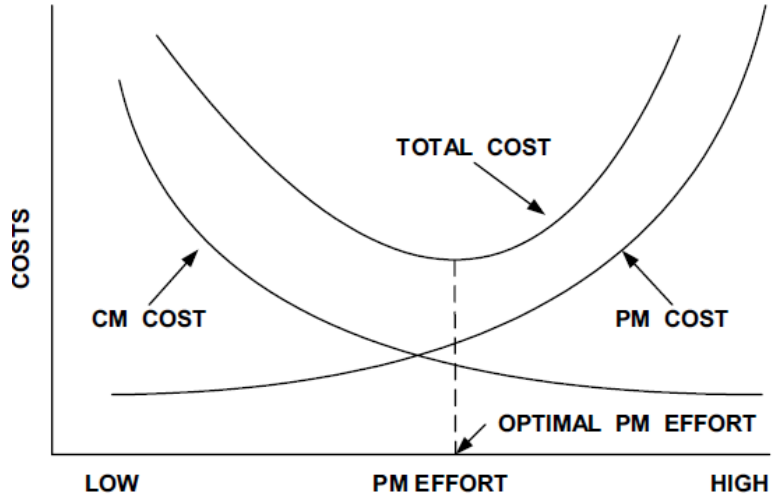

Figure 21 - An approach of costs by combining corrective and prevenive maintenance [44]

2.2.5 Software suitable for maintenance tasks

As maintenance management becomes more complex and as companies become more aware of its impact on profitability, managing the process becomes almost impossible without a computer-based support.

Computerized maintenance management system (CMMS) is a software package that maintains a computer database of information about an organization's maintenance operations [45]. This information is intended to [46]:

- Help maintenance workers do their jobs more effectively;
- To help management make informed decisions;
- Verify regulatory compliance, and
- Allows for record keeping, to track completed and assigned tasks in a timely and cost-effective manner.

A CMMS should not be misunderstood by a maintenance strategy, it is just a tool to support a strategy. This belief that the CMMS will change maintenance in an organization from a reactive to a proactive approach is quite common and often results in poor usage of available modules of such systems [43]. According to Wienker [43], the main reason for dropouts are due to:

- Attempting to implement a new maintenance management strategy and the associated processes and tools such as a CMMS to an organization that is not “ready”;
- Believing that the CMMS is the strategy rather than one of the tools to facilitate effective implementation of maintenance management;
- Inadequate IT infrastructure such as poor network capacity;
- Failure to sell the benefits of CMMS to senior management;
- Failure to understand the need for a well-designed “change management” process, and
- Inadequate resources to carry out the implementation.

Enterprise Asset Management (eAM) are also another type of software that can also handle maintenance management and represent in current software’s minimal difference between CMMS’s.

To sum up, for complex process of maintenance management, mainly present in big enterprises, it is necessary to have powerful tools to support the day-to-day workflow in an effective manner, whether it uses a CMMS or a eAM, to generate information that identifies key maintenance issues that impact on the hidden costs and to improve overall business performance [43].

With a very well-planned project to install a software maintenance management, by addressing the main reasons of poor implementation, companies will have a chance to achieve a high success rate of implementation.

2.3 Sustainability

2.3.1 Main principles

For the past two centuries, worldwide population add a growth of nearly 6 billion people (Figure 22). With this high increase, Earth has become unsustainable. The impact of humans' conflicts with Earth's regeneration process due to humans' current patterns of consumption and production has caused an increased awareness of the environmental impacts of human activities.

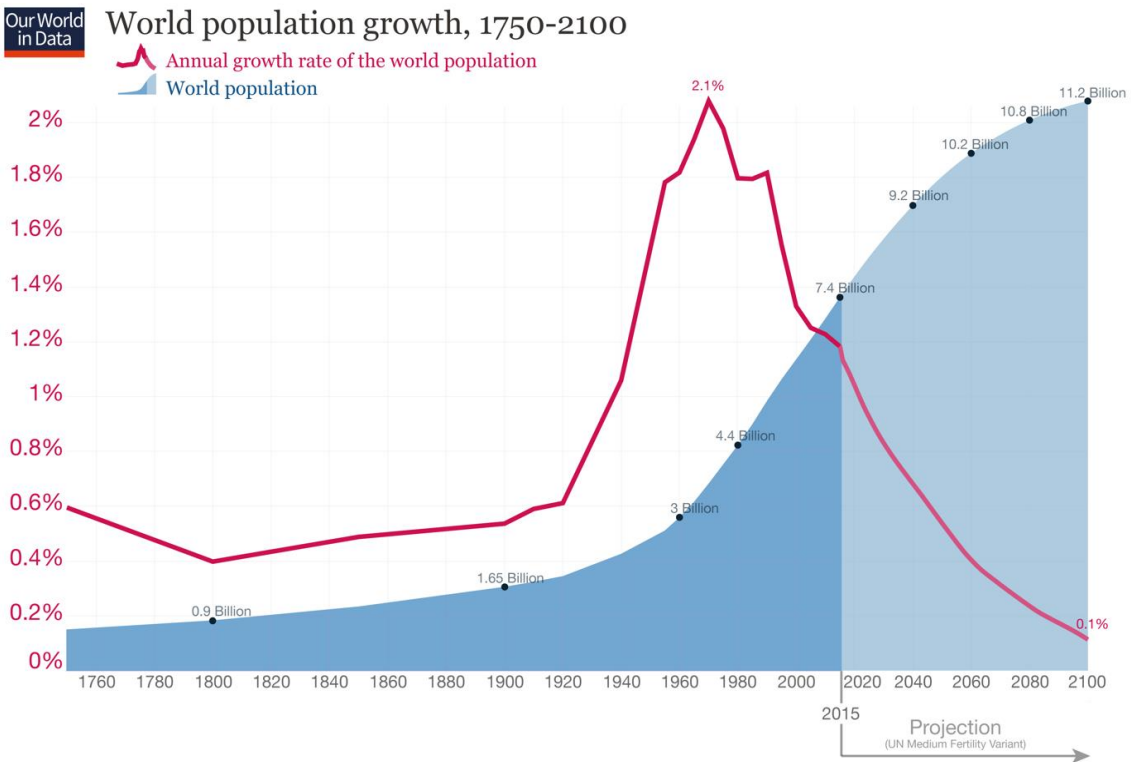

Figure 22 – World population over the years [47]

The industry sector is responsible for the production of consumption goods. With the increasing pressure from customers and markets, for economic and political reasons, sustainability is a paradigm that affects many sectors. It is a relative consensus that to deal with sustainability is a necessary challenge imposed to all society's sectors, considering the environmental degradation and its social consequences that affect even the economic dimension [48].

Sustainability lies in three main pillars:

- Economic;
- Environmental, and
- Social.

Companies must have the ability to be profitable and manage their risk, to be supported by their community (stakeholders) and by focusing on reducing their carbon footprint. These all combined will grant the achievement of sustainability.

In order to be sustainable, companies generally create sustainability principles to follow. Principles are a popular way of expressing commitment to certain ideals. They offer a starting point for both individuals and organizations of all kinds for addressing sustainability [49].

For example, United Nations (UN) principles focus on the ones figured in figure 23, such as no poverty, zero hunger and so on. These 17 principles are adapted to UN mission.

Figure 23 - UN sustainability principles [50]

As for industry, sustainability principles are frameworks for making smarter decisions about growth management and responsibilities within specific industry sectors [49]. They are premised on the idea that each industry has:

- Operational practices;
- Resource consumption;
- Waste management;
- Safety technologies, and
- Environmental impact patters.

As an example, Lipor, a company responsible for managing, treating and valorising urban residues in Oporto city in Portugal, has the following principles [51].

- Assume the sustainability challenge;
- Stake on prevention of residues;
- Maintain good relations with their stakeholders;

- Face residues as resources;
- Follow their residue management hierarchy according to European Union (EU);
- Be an auto-sufficient organization, and
- Follow the principles of the Polluter – Payer and the Producer Responsibility.

These are the sustainability principles chosen by Lipor that they think will help them achieve an economic, social and environmental success in order to be a sustainable company.

2.3.2 Standards and certifications

With the current market situation, to be competitive companies need to stand out among others. It is essential that the products, systems or services of a company have to be in conformity with regulations and applicable standards in order to take part in global supply chains and other business. In the last two decades, standards have come to function as key tool in governing conduct in more and more areas. They can be defined as specifications and/or criteria for manufacture, use and/or attributes of a product, process or service. They represent norms by which people, objects and actions can be judged and compared, and which provide a common language to evaluators, to the evaluated and their audiences [52].

Certification standards exist when companies are looking for a supplier. If the supplier has a number of certifications that interest the client, it can assure the quality of product or services the client is seeking for. As a result, suppliers will increase their chances of doing more deals and clients will feel safer when choosing these suppliers. It also motivates companies to improve to achieve the approval of a certification.

There are a ton of different certifications such as for:

- Environmental and Sustainability;
- Global Organic and Sustainable Food;
- Global Fair Trade and Social Certifications, and
- Quality and Safety.

These are just some types of certifications and on figure 24 there are some agents responsible for these certifications. For example, the International Organizations for Standardization (ISO) 14000 is a family of standards that provide tools for companies and organizations of all kinds to manage their environmental responsibilities [53].

Figure 24 - Organizations responsible for sustainability certifications [54]

As for quality and safety standards on food production a more practical example can be referenced. Recently, at Super Bock Group (SBG) facilities, changes were made so that SBG could achieve the certification of the International Featured Standards (IFS). They are mainly responsible to certify safety and quality standards at the food and beverage sector. In the end, SBG, now as certified by IFS, could supply to more clients, mainly in Switzerland where some clients would demand a IFS certification.

So, as a main advantage, certification standards are acknowledged for their potential to transcend nation-state boundaries and thus influence international supply chains to adhere to principles of sustainability, and thus function “as a mechanism in countries with poor abilities to enforce policy” [55].

2.3.3 Sustainability and manufacturing parameters

Increased awareness of society over sustainability has resulted in attention to sustainable manufacturing. Although an attractive goal to most, executives face difficulties in implementing sustainable manufacturing due to the necessity of balancing social, economic and environmental [55].

The quest for a new method of manufacturing system demand modern systems that can meet the societal needs and industrial problems. It is important to highlight that such a manufacturing system must be flexible, novel and sustainable. The modern manufacturing techniques and processes do not only focus on meeting the societal needs and technical

challenges but also more on the sustainability of the process because it will be a colossal waste if a process sustainability is in question [56].

Sustainable manufacturing is defined as the creation of manufactured products through economic-sound processes that minimise negative environmental impacts while conserving energy and natural resources [57]. It ensures that all economic, environmental, and social cost and benefits of set out activity are considered because a sustainable society includes a healthy environment, social equity and strong economy [58]. Figure 25 shows the role of a manufacturing system in a sustainable system.

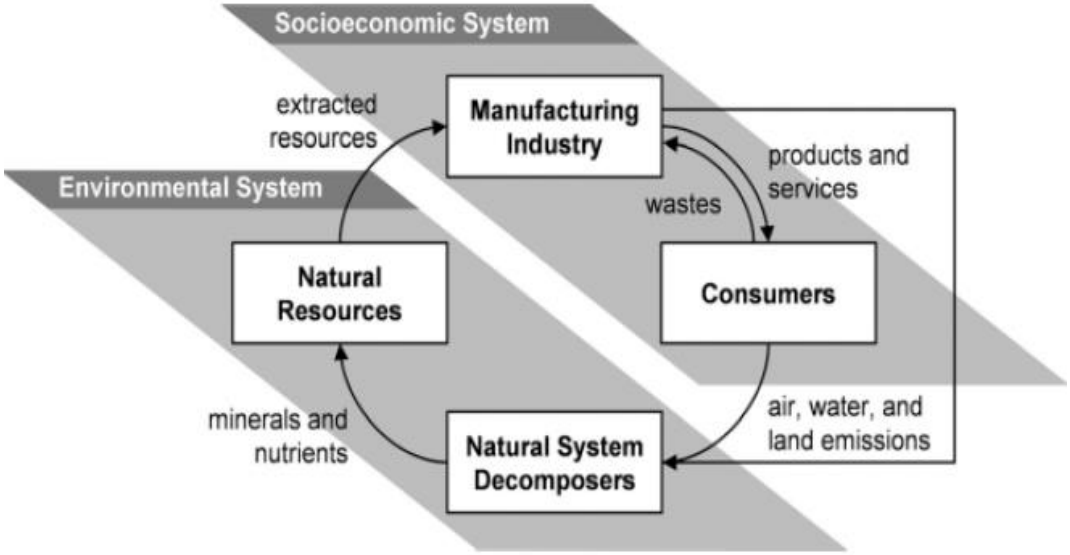

Figure 25 - Manufacturing systems in a sustainable system [56]

According to Moldavska and Martinsen [59], sustainable manufacturing can be represented as in figure 26 which represents three basic parameters to define sustainable manufacturing.

These parameters are only a few of the total parameters. There are more such as:

- Reduce noise pollution from all processes;
- Improve safety of technologies;
- Increase functionality of the product, and
- Increase stakeholder engagement.

Moldavska and Martinsen [59] studied that exist around 76 parameters currently and will continue to grow over time. They will help and define what companies should do in order to reach a sustainable state.

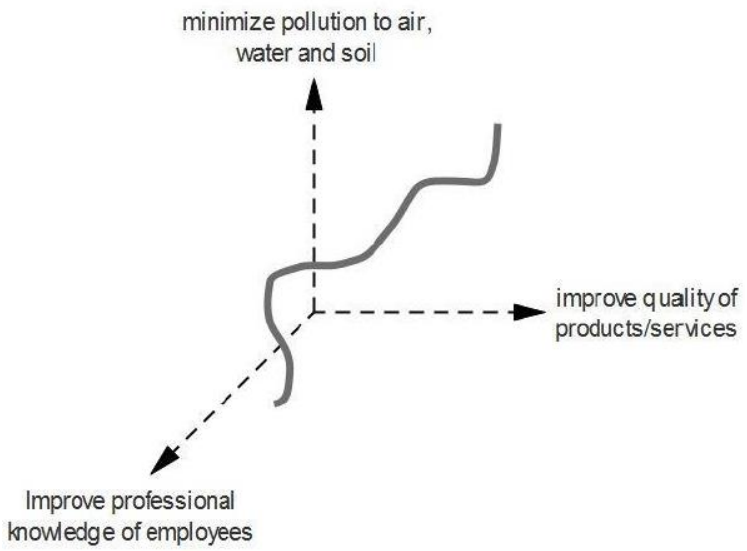

Figure 26 – Graphical representation of sustainable manufacturing with three criteria [59]

2.3.4 Key Performance Indicators

The measurement of performance allows identifying performance gaps between current and desired performance [60]. With companies always seeking on how to be more competitive with today's market, Key Performance Indicators (KPI) are no exception to achieve such. KPIs are tools designed to allow stakeholders to measure the progress of a business towards its goals [61]. Various industries use them, such as nuclear industry [62], the financial sector [63] and health care [64].

KPIs can control a lot of factors that companies find interesting and crucial for their daily basis. While, for example, in the food industry, investigators found interesting to add a multivariate key performance indicator to evaluate their process energy efficiency [65], others opt to use KPIs that are already defined which adjust to their needs.

Maintenance KPIs are one of them. Maintenance has a lot of KPIs which help by supporting overall management and utilizing assets in a competitive manner in all types of industry, such as breweries, transportation or even hospitals. The indicators must reach out the intended objectives, measuring their performance, over time, so organizations can organize themselves [66].

According to the BS EN 15341:2007 [67], maintenance KPIs should be used to:

- Measure the status;
- Compare (internal and external benchmarks);
- Diagnose (analysis of strengths and weaknesses);
- Identify objectives and define targets to be reached;
- Plan improvement actions, and
- Continuously measure changes over time.

Companies are encouraged to use maintenance KPIs when performance is not satisfactory. To reach the objectives, such as [67]:

- Measure the status;
- Evaluate the performance;
- Compare performance;
- Identify strengths and weaknesses;
- Control progress and changes over time;
- Set objectives;
- Plan strategies and actions;
- Share the results in order to inform and motivate people;
- On a periodic basis, to prepare and follow-up a budget, and during asset performance, and
- On a spot basis, for instance within the framework of specific audits, studies and benchmarking.

Maintenance KPIs are divided into the following groups: Economic Indicators (Where maintenance costs are being spent), Technical Indicators (How maintenance operations are being done) and Organizational Indicators (How maintenance is being organizes), with each one having a unique objective. A variety of indicators exist in each group and each of them have a respective equation. Some examples can be seen in annex 2 for each group

Although many indicators have been defined, there is still no agreement on all possible indicators. Some of them need to be adjusted or even defined to their specific industry. Some authors [68] [69], have created KPIs based on their needs and functions of the problem. Fortunately, the trend of companies becoming more sustainable and competitive lead to a strong investigation on new KPIs for different sectors of industry.

DISSERTATION DEVELOPMENT

3 DISSERTATION DEVELOPMENT

3.1 The company

Founded in 1890, CUFP or *Companhia União Fabril Portuense* was to become one of the biggest companies in Portugal. Its logo is shown in Figure 27. Super Bock Group, former *Unicer Bebidas* or CUFP, is the biggest beverage producer in Portugal, mainly in the business of beer, bottled mineral water and carbonated water, as can be seen in Figure 28 through the different brands owned by the group. It also produces sodas, ciders, malt, wine and has small tourism business with the management of Vidago Palace and the Pedras Salgadas Spa & Nature Park.

Figure 27 - Super Bock Group logo

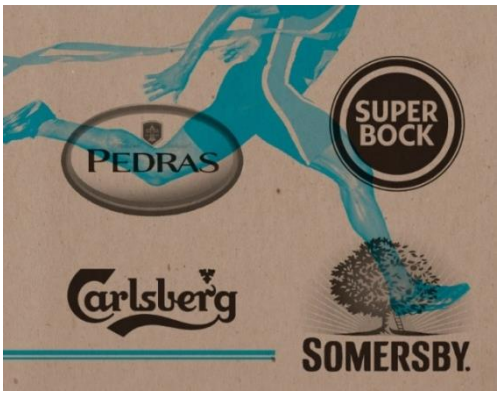

Figure 28 - SBG different activities across the country [70]

Currently, SBG is held 56% by Viacer Group, which is formed by two Portuguese groups, Violas (71.5%) and Arsopi (28.5%), and 44% by Carlsberg group, the biggest beverage producer in Denmark.

SBG motto is "*Paixão Local, Ambição Global*", which stands for local passion, global ambition. It translates the company's mission of its care and focus to the national market but at the same time the wish to become a greater company outside its frontlines.

Figure 29 shows all the placements the company has in Portugal, being the main one in yellow where *Leça do Balio* plant is located: it produces beer, barrelled and bottled. It also shows where the rest of the products are made and where the main sale and logistic points are at.

As stated, the company also sells across the world and not just nationally. In Figure 30, it can be seen where SBG sells its products all around the world, reaching every continent and over 40 countries.

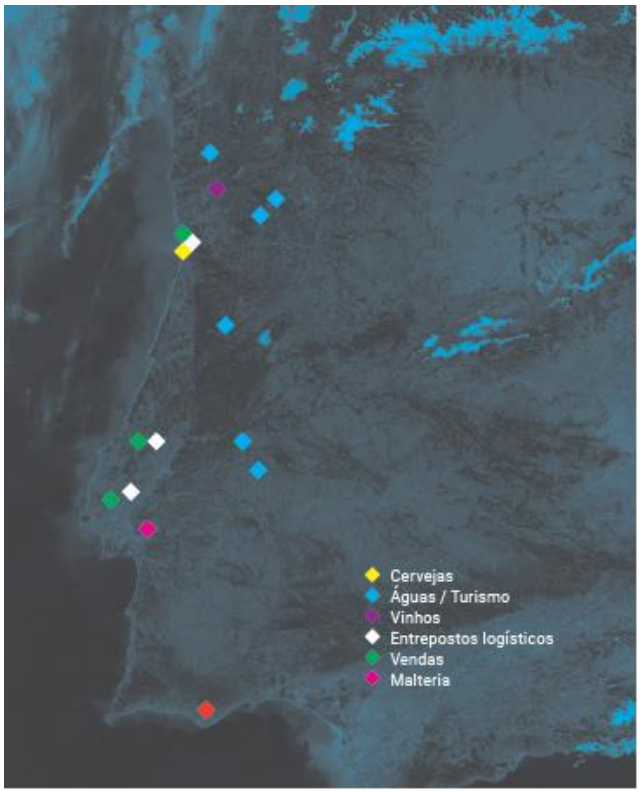

Figure 29 - Examples of some of Super Bock's main products [70]

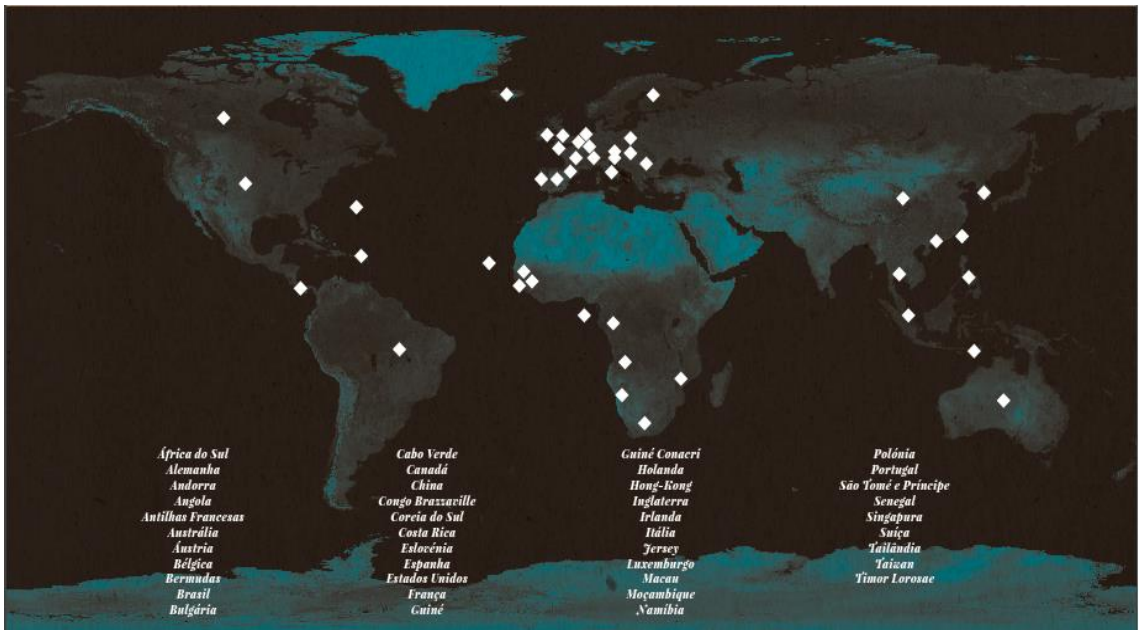

Figure 30 - All the countries where SBG sells its products [70]

In terms of market, SBG is leader, nationally, in almost all of its products, mainly, beer, cider and carbonated water (Figure 31).

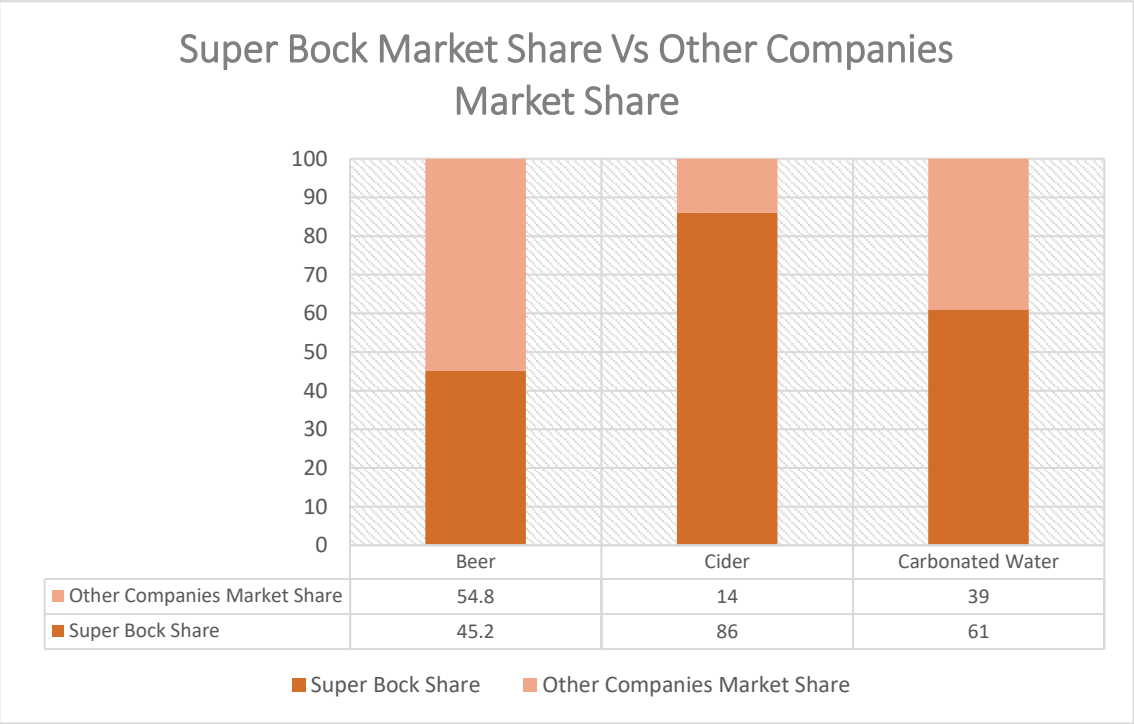

Figure 31 - SBG national market share of some products facing the rest of other companies (Author's work)

In terms of people, in 2016, SBG had 1243 collaborators which 70% of male against 30% of women. As for group of age, 10.5% of the collaborators have less than 30 years old, 70.9% of collaborators are between 30 to 50 years old and 18.6% collaborators are more than 50 years old [70].

With over 24 different brands, 1200 collaborators and an average profit of 50 million euros per year (Annex 3), SBG is a national leader in the beverage industry by overcoming its competitors and for being a sustainable organization.

As far as the foreign market is concerned, SBG has been increasing its market share, mainly in countries like the United States of America, Angola, Saudi Arabia with its non-alcoholic beer Moussy and, specially, China by selling Super Bock Gold, a beer crafted only for the Asian market.

3.1.1 Super Bock's Wastewater Treatment Plant

In the main centre of SBG, where the author has worked at, in Leça do Balio, the main product is beer. The brewery industry has an intense energy and use of water process (Figure 32). A large amount of this water is discharged to the drains. The main water use areas of a typical brewery are brewhouse, cellars, packaging and general water use. Water use attributed to these areas includes all water used in the product, vessel washing, general washing and cleaning in place (CIP); which are of considerable importance both in terms of water intake and effluent produced [71].

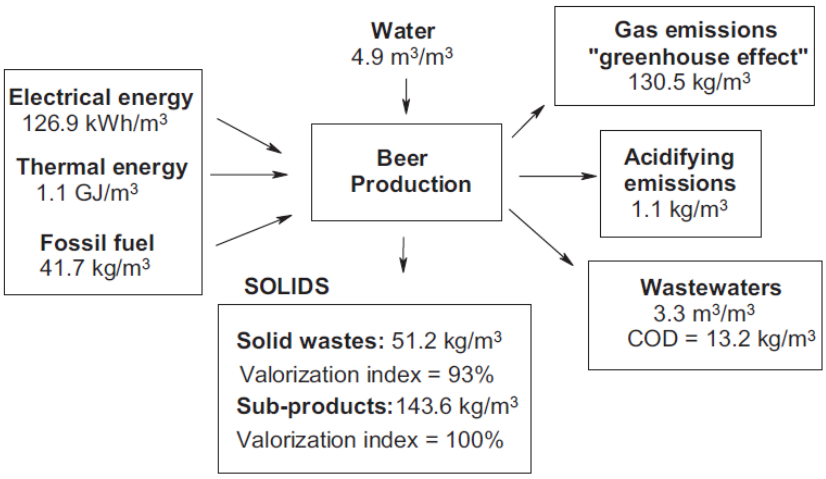

Figure 32 – Quantities of different resources and waste used or generated to produce beer at SBG at Leça do Balio in 2005 [72]

With so much use of water, breweries processes create a lot of wastewater. In fact, it has been estimated that approximately 3-10 l of waste effluent are generated per litre of beer produced [72]. It also produces a fair amount of solid waste but the difference between solid wastes and wastewaters is that solid waste can be reused and valorised.

At Super Bock, wastewater comes from:

- Industrial process wastewater;
- Sanitary wastewater from toilets and the kitchen, and
- Rain water.

Sanitary wastewater and rain water have little flow and organic material compared with industrial process wastewater. Usually, industrial process wastewater has a large amount of organic material, usually measured in chemical oxygen demand (COD), Nitrogen and Phosphorus and lots of solids like beer bottles, spent grains, product labels and Kieselguhr (Table 2).

Table 2 - Common characteristics of brewery wastewater [72]

Characteristics	Amount
pH	6.5 ± 0.4
COD (mg/L)	1250 ± 100
NH_3–N (mg/L)	16 ± 5
TN (mg/L)	24 ± 3
SS (mg/L)	500 ± 50
Heavy metal	Very low
Water to beer ratio	4–10 hL water/hL beer
Wastewater to beer ratio	1.3–1.8 hL/hL less than water to beer ratio

In 1998, Unicer opened its wastewater treatment plant. As the process generates lots of wastewater effluent, the plant treats it at the minimum cost and in the safest way, in order to meet strict discharge regulations that are set by government bodies to protect the ecosystem. Not meeting discharge regulations can end up as a fine or even shutting down the factory.

SBG WWTP is divided into three major parts (Figure 33):

- Pre-Treatment – Responsible for removing large solids, spent grains and kieselguhr;
- Anaerobic Treatment – Responsible for treating organic material, and
- Aerobic Treatment – Responsible for treating levels of nitrogen, phosphorus and organic matter

Figure 33 - Clockwise: Aerobic Treatment; Anaerobic Treatment; Pre-Treatment; Overview of the WWTP

The final concentrations of each compound reach to a level that is accepted by the government entities. For example, the final concentration of effluent of COD to the river Leça is less than 150 ppm. As a matter of fact, in 2008, this same reactor removed 82% of COD [73].

The diagram constructed below (Figure 34) represents each process of the WWTP for a better understanding.

One of the many good things about this WWTP is the production on Biogas. The anaerobic reactor is constantly producing biogas which is then used, mixed with in line gas, into the boilers.

Also, sludge produced in the process of the WWTP is dried up and is sold to local farms for fertilizing land.

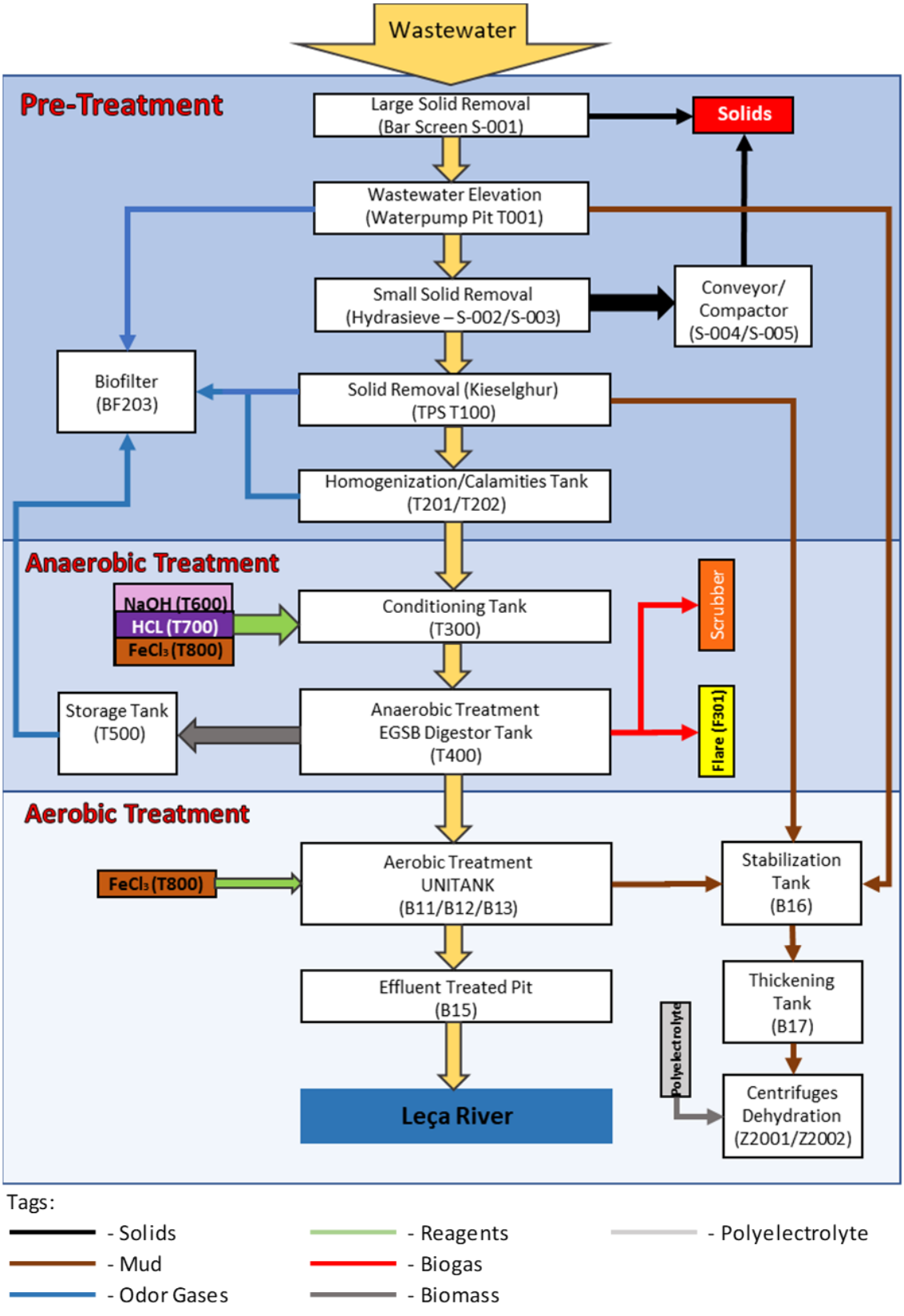

Figure 34 - WWTP processes

3.2 Problems' Characterization

3.2.1 Preventive Maintenance

Like most WWTP, SBG one has a lot of equipment, over 60 to be precise. All of this equipment need to have a maintenance to perform well. If not, what can occur?

Figure 35 leads to three paths, where an asset will consume more energy and/or will reduce the overall process efficiency and/or will create a hazardous situation. While energy consumption is an important part to manage, process efficiency and hazardous situations are more critic.

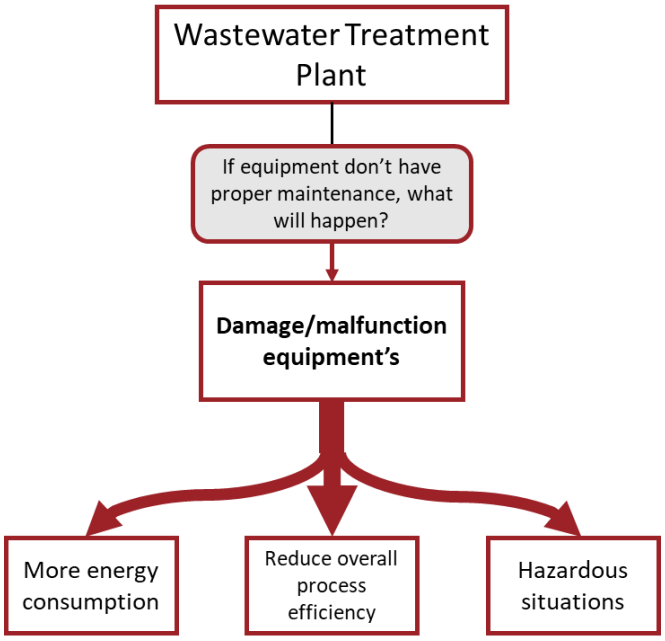

Figure 35 . Different paths if maintenance on the WWTP is not proper

If the WWTP process efficiency isn't sufficient to meet discharge regulations, SBG is forced to shut down production, making it top priority. It's an extreme case but it can occur if critical equipment is not functioning properly. But having a preventive maintenance plan leads to another problem, how can it be supervised?

3.2.1.1 Supervising maintenance

The WWTP is not managed by SBG, it has another company managing it, which is Veolia Group, the current responsible for managing the WWTP and, since it's not by Super Bock's collaborators, it's more difficult to keep a record of the maintenance plan activities.

Weekly meetings are always done but they don't give a real sense and results of the plan and their objective is mostly to discuss process and laboratory data of the effluent, and without any kind of supervision, the situation can become the same in Veolia as the prior company.

By not giving the maintenance plan any following, situations like early described can occur, which will cause major damage to SBG, economically, socially and environmentally.

3.2.2 Reducing energy cost

Energy efficiency is an important part of today's organizations. SBG at Leça do Balio is a major brewery and the brewing process is energy intensive, especially in the refrigeration process, the brewhouse, bottling hall and the wastewater treatment plant. The need to reduce energy is constantly on focus and there's always new ideas in development for such need.

It is known from literature and managing experience that in a conventional WWTP about 25 – 40% of operational cost is ascribable to electrical energy consumption [74], being the aeration part, the most consuming (around 55-75% of total). Super Bock's WWTP is no exception, the aeration process is the biggest consumer due to its equipment, mainly the surface aerators and the decanter centrifuges because these machines have very big electrical engines that are constantly working. They are responsible for an average of 60000€ per year of energy cost or 2% of the yearly energy cost of SBG at Leça do Balio (Figure 37). It may not sound much, but

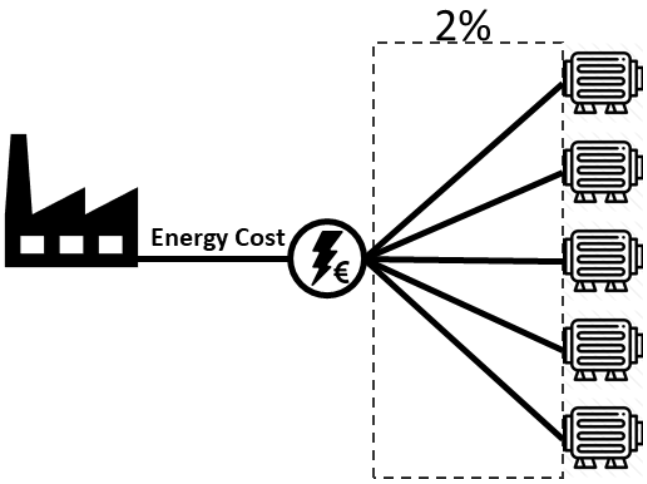

Figure 36 - The five electrical engines of the centrifuges and surface aerators are responsible, annualy, for 2% of the total energy cost at SBG

it's just a part of the process of the WWTP and SBG is a beverage producer, not a WWTP.

So, it's with greatest concern that solutions to reduce this electrical energy costs or consumption must be implemented to reduce the total costs of SBG's Leça do Balio plant.

3.3 Brainstorming

3.3.1 Group Selection

For the problems mentioned above, ideas to work out with were conceded not only by the author but also the responsible for the WWTP in Super Bock's side; a SBG colleague who is an expert in SAP PM and all of the WWTP team from Veolia Group.

3.3.2 Ideas

To put it simple, the group worked together to find solutions to the problems mentioned above, which are:

- Implement a preventive maintenance plan on SAP;
- How to supervise the preventive maintenance plan? and
- How to reduce electrical energy cost?

3.3.2.1 Implement a preventive maintenance plan

For the first problem, the idea was simple, to follow SBG practices.

Super Bock runs all its preventive maintenance tasks by SAP which is a business management software, it can manage sales, logistic, human resources or even maintenance. The module of SAP maintenance is known as SAP PM, PM for preventive maintenance, and it's what is usually called a CMMS, short for Computerized Maintenance Management System. As companies become bigger, maintenance management becomes complex which requires a combination of technical and economic expertise. Managing this process effectively without computer-based support is almost impossible and that is where a well implemented CMMS is one of the key tools that is essential to underpin proactive maintenance management [43].

SAP PM isn´t a new thing in SBG, but the WWTP was lacking it. By implementing, it will be much easier to keep track on preventive maintenance activities as SAP keeps a record of all of them and will help the WWTP team organize themselves since preventive orders will come automatically.

So, in order to start implementing it, the structure of the WWTP must be made into SAP, which involves all the equipment, instrumentation, accessories and even localizations. This is the first part of the problem, to figure out how to organize the structure of the WWTP, gathering any possible information of each asset and introducing it in SAP. Without it, it's impossible to attach a maintenance plan to an equipment that doesn't exist in SAP. When the structure is finalized, it is now possible to advance to the implementation of the maintenance plan, but, in order to do so, a discussion with both parts (Veolia and SBG) must be made to supply preventive maintenance tasks for each asset and their frequency. Only when this is done, it can all be transferred to SAP. This is the second part of the problem.

The final part of the problem lies in the fact that when all the work in SAP is finished, comes the training of the WWTP team to work with SAP PM. This is a crucial part for the SAP maintenance plan to work well which is often ignored by companies. The persons who are going to work directly with SAP PM, need to know where to view the preventive maintenance plan, the tasks for each asset, where to view the PM orders, how to print them, how to confirm them and many more. Annex 4 gives a good visual explanation.

With a good study of the WWTP structure, creating tasks and frequencies for each asset and giving a good formation to each member of the team, will be sufficient to a properly working

preventive maintenance plan on SAP. It will improve maintenance management and allow all preventive maintenance data to be recorded on the system.

3.3.2.2 How to supervise the preventive maintenance plan?

The maintenance plan can come out very organized and structured, but if the WWTP team doesn't carry it out as it should be, then all the work made so far will be in vain. Therefore, supervising is also a priority.

Weekly meetings are always done but they don't give a real sense and results of the plan and their objective is mostly to discuss process and laboratory data of the effluent. With SAP PM it's possible to view if the plan is being followed or not, but constructing the plan takes a lot of time. Also, SAP PM isn't very user friendly and it can get quite difficult to supervise (Figure 38).

So, while the plan was in construction, a strategy for supervising must be done and the answer was in KPIs, Key Performance Indicators.

KPIs are tools to help measure how something is being done towards its goal or just for monitoring purposes. They can be used in the process, for example, the amount of beer produced by the amount of water used, or it can be used in maintenance, like the cost of maintenance materials by the total maintenance cost. KPIs can be implemented in various scenarios.

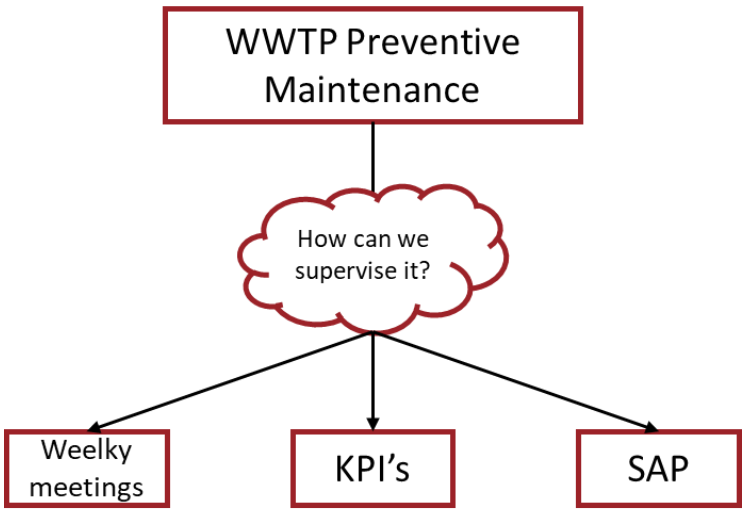

Figure 37 - Possible ways to supervise preventive maintenance

The WWTP has already used such indicators for its process, like measuring the entry COD in the process versus the final COD that goes to the river. But for maintenance, there was no KPIs implemented.

The main interest of SBG was not economic nor technical indicators but more of organizational indicators. It is key to SBG to know how well the preventive maintenance plan is being carried out as planned. If not, the problems of non-fulfilment of maintenance tasks may lead to problems as explained in figure 38.

Thus, it was studied what kind of KPIs would make sense for this purpose in order to answer the following questions: Is the plan being executed? What is failing? Is it done on schedule?

This is what KPIs are going to answer and will lead to a more rapid solution for issues and will help supervise the WWTP in a more effective way.

3.3.2.3 How to reduce electrical energy cost?

For the final problem, when dealing with reducing electrical energy costs it comes to mind several solutions that have to do with energy efficiency or energy conservation.

Energy efficiency should not be confused with energy conservation. While energy efficiency is defined as “doing more with the same or less energy input or better still, improving the ratio of energy outputs to energy inputs” since of energy conservation is defined as “an attempt to reduce the amount of energy used for domestic and industrial purposes. So, in general terms, energy efficiency is achieved through the application of technology, such as insulation upgrades, LED (light-emitting Diode) bulbs, and so forth. Energy conservation is achieved through behavioural changes, such as turning off lights when not needed, using appliances differently and so forth [75].

The focus is in the main surface aerators and centrifuge decanters, 5 machines to be exact. Like said before, energy efficiency is supported by technological application. In this case, this type of equipment has nothing or too little to implement. One could be switching these old assets to newer ones, but since these are still working properly and the new ones would cost very much, it’s out of question. Also, conserving energy is difficult to put because this equipment is always in need of use. But, there are still solutions, whether is not energy efficiency or energy conservation to reduce energy cost and this is what the group studied about.

At houses, normally they have a contract with the electrical company which involves two tariffs of electricity cost, the night tariff, being the cheaper, and the daily tariff, being the more expensive one. SBG has a similar situation, but instead of two different tariffs it has four different tariffs, the Peak, Half-Peak, Normal Off-Peak and Super Off-Peak, in which the first is the most expensive one and the last the cheapest one (Figure 39).

Hence, it can be defined when this equipment will work at the period with the lowest cost. But there are some drawbacks with this method. The surface aerators follow a very strict matrix when each one them will work. Therefore, this method can’t be implemented. But the centrifuge decanters can, they don’t follow any matrix or time period. Then, it can be studied when it is the best period to put the centrifuge decanters to work with the least amount of energy costs.

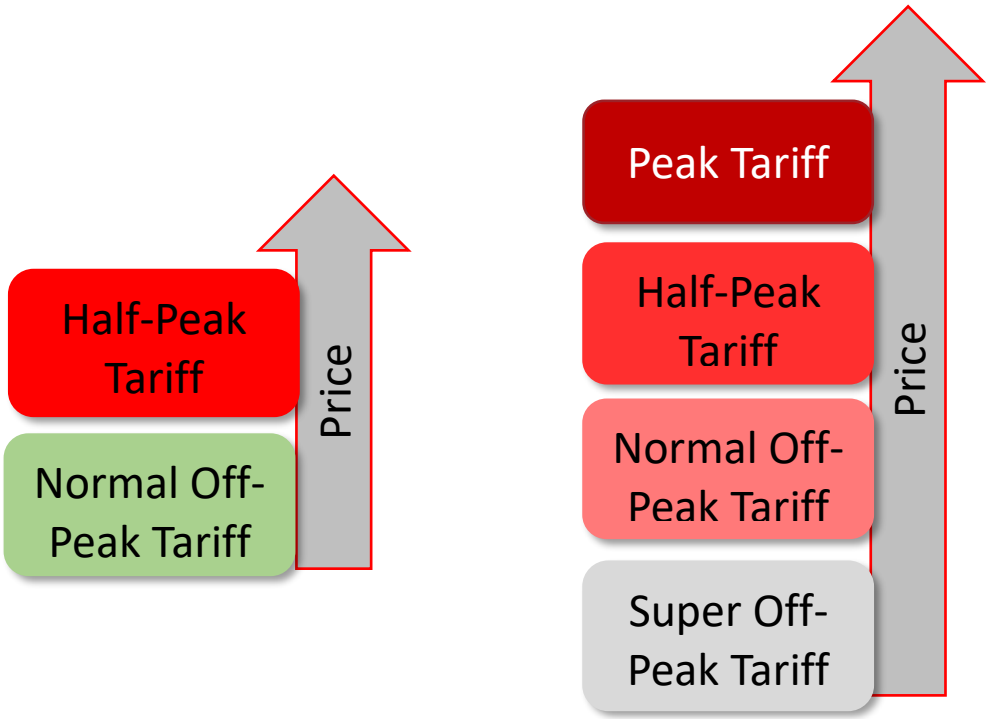

Figure 38 - Commonly used energy shift vs. SBG Tariff (Author's work)

3.3.3 Ideas Structuration

To sum up the former chapter, it has:

Table 3 - Ideas associated with the problems

Problem 1: Implementing a preventive maintenance plan	Idea 1: Maintenance the plan on a CMMS
Problem 2: How to supervise a maintenance plan?	Idea 2: KPIs to supervise maintenance Idea 3: CMMS to supervise maintenance
Problem 3: How to reduce electrical energy cost?	Idea 4: Switching old assets to newer ones/new technology Idea 5: Use the cheapest electrical energy tariff

As for the first three ideas, they all have a main goal: to improve maintenance efficiency and organizations on the WWTP. As for the last two ideas, they only focus on reducing the amount of money spent on the energy, in a sustainable matter (Figure 40).

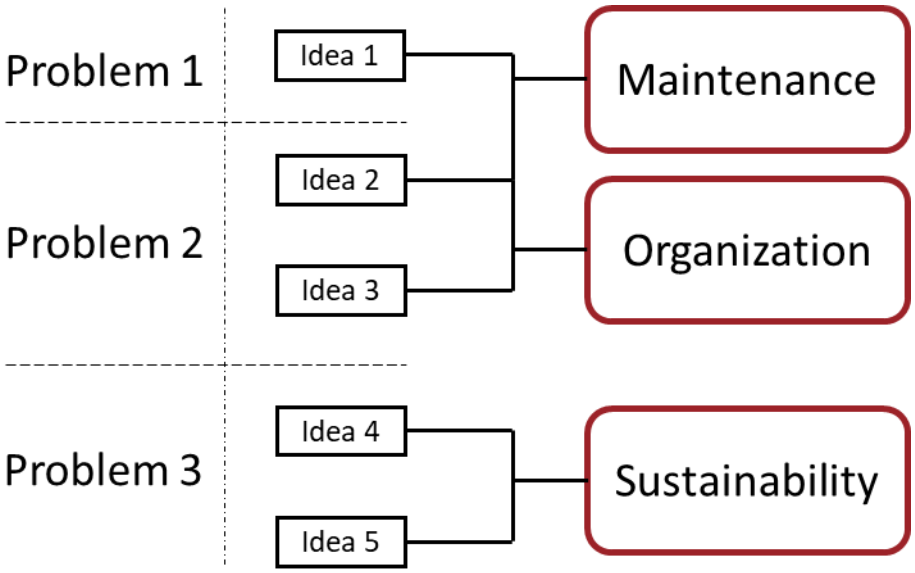

Figure 39 - Each idea will improve maintenance, organization and/or sustainability of the WWTP

3.3.4 SWOT Analysis + Costs expected

With all the ideas described, it's important to analyse each one of them to know their pros and cons. SWOT (Strengths, Weakness's, Opportunities, Threats) analysis is a great way to summarize each idea as it's simple and effective.

3.3.4.1 First Idea: Implement the maintenance plan on SAP PM

Starting with the first problem, implement a preventive maintenance plan, the first, and only, idea is to implement the plan on a CMMS, more specifically on SAP PM.

As pictured in figure 41, implementing SAP PM on the WWTP has a lot of strengths, but it will take time to construct it and, the biggest threat, is that it can create the illusion that SAP will resolve all the problems. It's believed that only around 25-40% of CMMS implementations are successful and the number of users that use CMMS on its full potential is around 6-15% [43].

In terms of costs expected, this kind of implementation has zero costs, considering that the license of SAP has been already purchased by SBG.

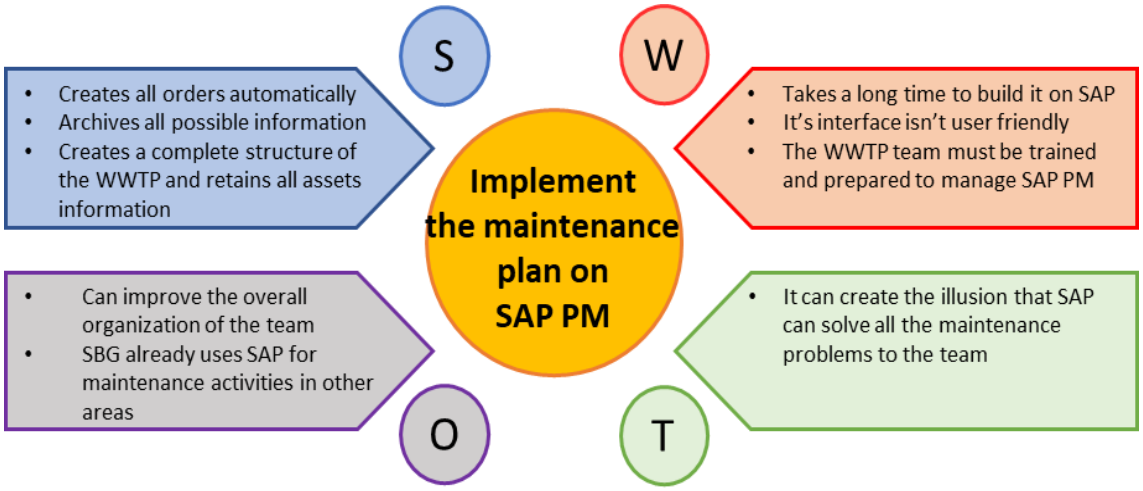

Figure 40 - SWOT analysis for implementing the plan on SAP

3.3.4.2 Second and Third Idea: KPIs Vs. CMMS to supervise maintenance

For the supervision issue, two ideas surged, either with KPIs or with a CMMS. On the KPIs side it has:

While KPIs are a good approach for this issue, with their fast implementation and very easy to visualize, they can lead to false data because the WWTP team can feel they're being supervised and may think it's important to always have a clean sheet when sometimes things aren't going the way they should be. (Figure 42)

On the other hand, implementation with a CMMS has some common aspects described in the first idea of implementing a maintenance plan.

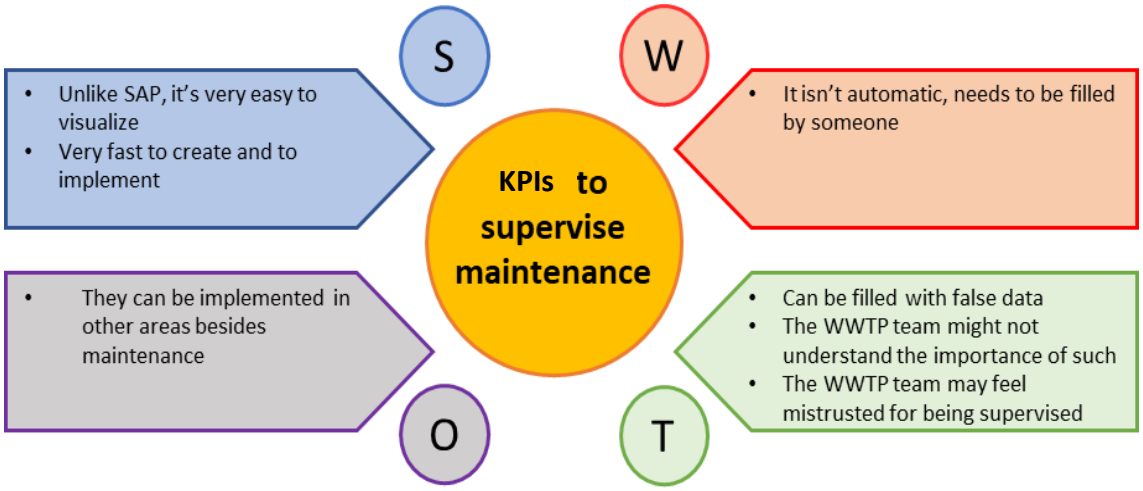

Figure 41 - SWOT analysis for supervising maintenance with KPIs

SAP PM is a good choice, but the time put to build the plan and its interface on SAP are its main weakness, making it difficult to implement in a short term as for the building aspect and training the staff aspect (Figure 43).

As for the costs, the same goes with the first idea, if the SAP license isn't considered, both supervising on KPIs or SAP PM has zero cost.

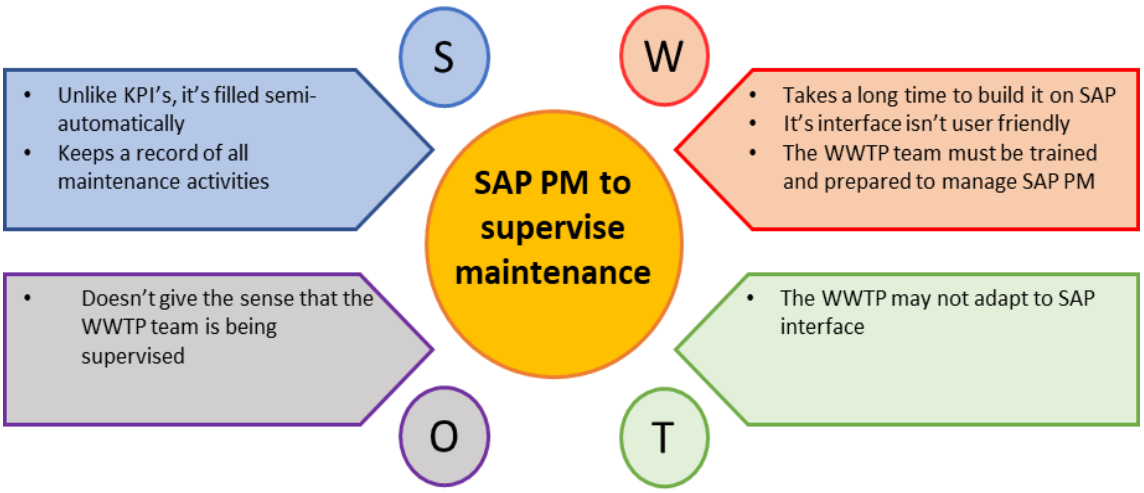

Figure 42 - SWOT analysis for supervising maintenance with SAP PM

3.3.4.3 *Fourth and Fifth Idea: Switching old assets to newer ones/new technology Vs. Use the cheapest electrical energy tariff*

For the last problem, two ideas will be analysed to see their pros and cons with SWOT analysis. For the fourth idea, SWOT resulted in:

Choosing this new form of technology has a lot of pros, beginning with the lower energy consumption. The efficiency of the process can increase and can add up the maximum capacity of treatment. Also, SBG is currently studying all of its process to increase production, new assets could carry out the increased production while current assets may not. The major downfall of this implementation is the cost of newer assets. While they can increase a lot of savings over the time, the comeback of those savings with the purchase of newer assets would take over 20 years win it back (Figure 44).

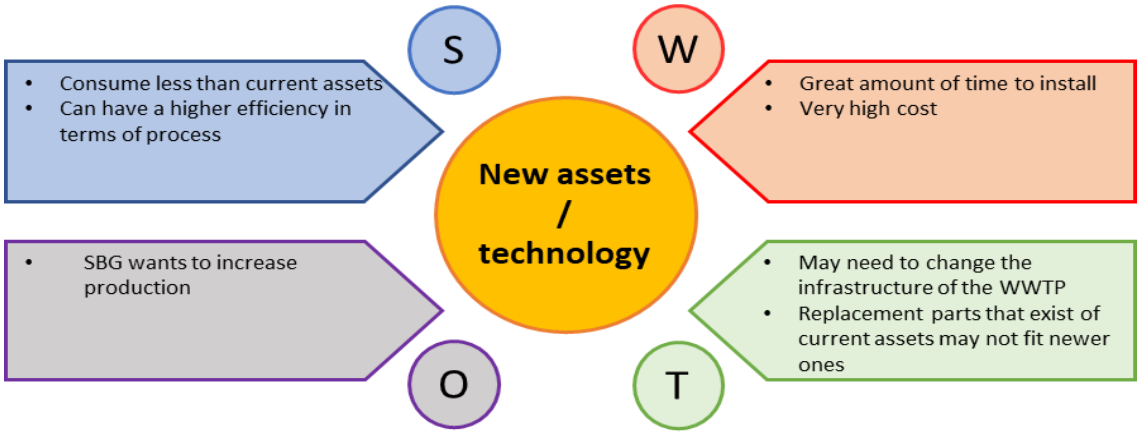

Figure 43 - SWOT analysis of switching assets with newer ones

As for the using the cheapest electrical energy tariff, it has:

When it comes to using the cheapest tariffs, savings generated with this method won't be as big as the ones created in the previous idea because current assets consume more than newer ones and it can only be implemented on the centrifuge decanters. The main advantage is that it's less pricy than newer assets. It might have some costs, but nowhere near the newer assets (Figure 45).

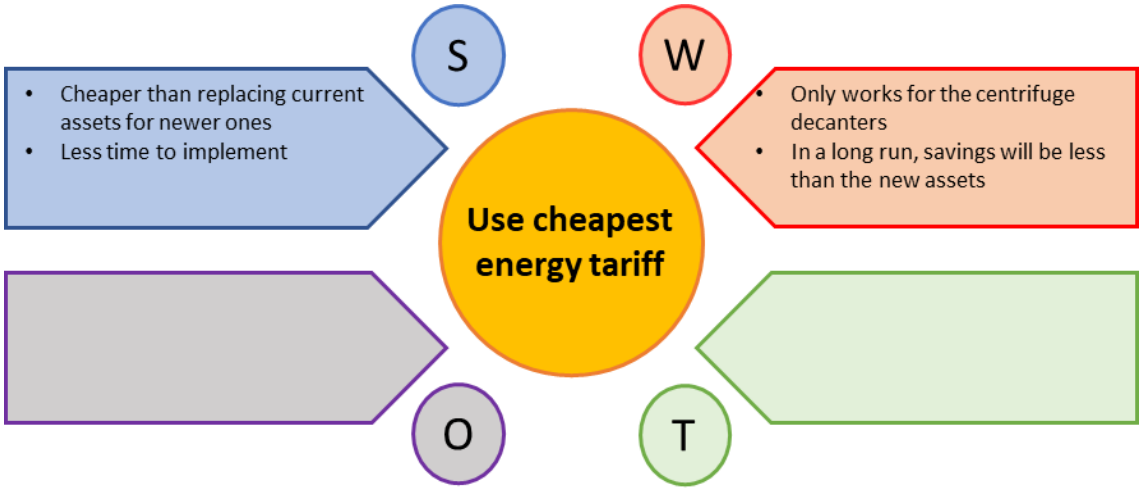

Figure 44 - SWOT analysis of using the cheapest tariff of energy

So, speaking of costs, it can be concluded that newer assets would cost more than using the cheapest period of time. The price range of the first could cost to 80000€ to 140000€, depending if the WWTP infrastructure would need to change. As for the latter one, price range would be between 10000€ to 30000€.

3.4 Selection

After analysing all the ideas that came up, after reviewing all their pros and cons with help of SWOT analysis, it was time to select which ones would come forward.

3.4.1 First Problem: Implementing a preventive maintenance plan

With only one solution covered, it is clear that the maintenance plan will be implemented with SAP PM. While SAP can be difficult to work with, which may discourage people to use it, and the time it takes to build things in it, with a good built WWTP infrastructure, a well-designed preventive maintenance plan and with training of the WWTP team about the software, it will lead to a WWTP more organized by creating preventive maintenance tasks automatically and keeping SBG more safe and aware of how things are going at the plant (Figure 46).

Another strong point is that SBG works entirely with SAP, whether be maintenance or sales. So, when it came the opportunity to improve the WWTP in terms of maintenance, it would be odd to use another solution, other than SAP.

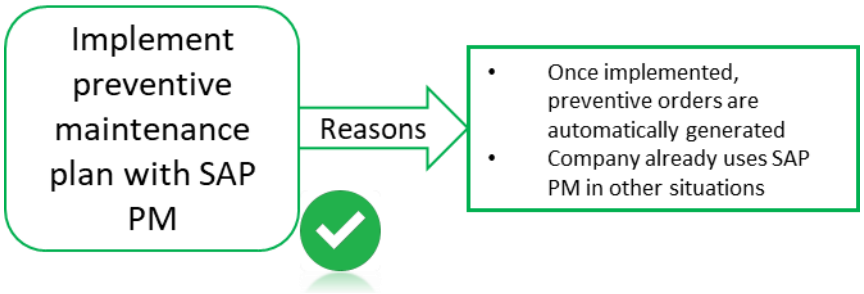

Figure 45 - Reasons why implementing the preventing maintenance on SAP was chosen

3.4.2 Second Problem: How to supervise a maintenance plan?

For this problem, two solutions were discussed and analysed to see which one would be chosen. The chosen one was supervising with KPIs just because of one factor - Time.
While the SAP one would seem the obvious choice because it is stated that on the previous problem maintenance will pass on SAP and SAP can also give supervision to maintenance, it was important to have some kind of supervision to the WWTP preventive maintenance while the plan was being built in SAP. It took nearly 7 months to build and organize the plan on SAP, thus, it can be seen the reason why the urge to create something in the middle to keep the WWTP under supervision (Figure 47).

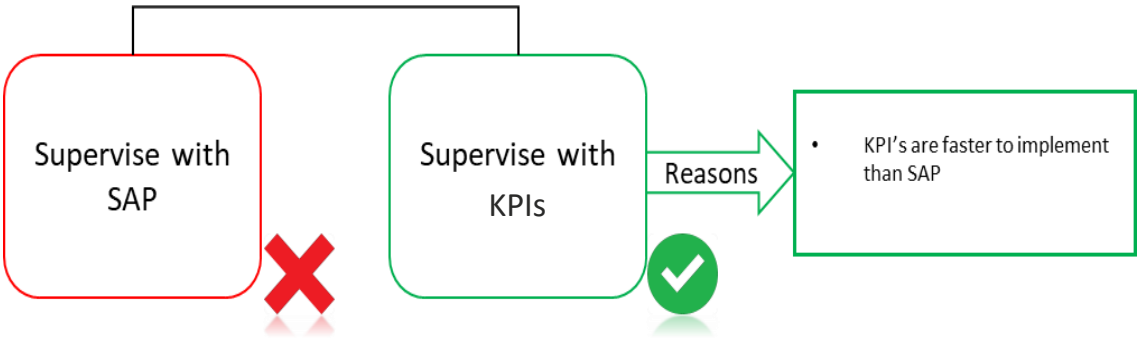

Figure 46 - Reason why supervising with KPIs was chosen over with SAP

3.4.3 Third Problem: How to reduce electrical energy cost?

With the ideas mentioned above, the one which was selected was "Use the cheapest energy tariff" because among all the ideas, this is the cheapest one. Even though exchanging the current assets with newer ones would generate great savings, it isn't sufficient due to high price of switching them (Figure 48).

For this situation, SBG wanted something quick to implement and which wouldn't implicate a huge amount of money. Another thing is that switching assets justifies more when the current ones are broken or when the capacity of the plant needs to be increased due to an increase of the factory production.

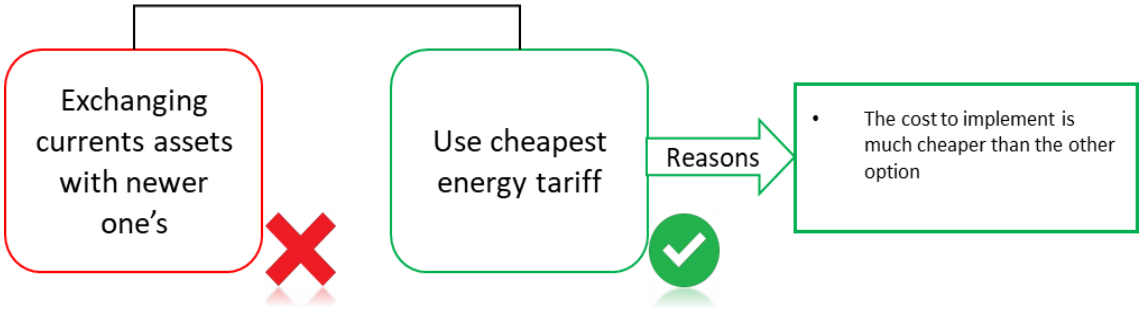

Figure 47 - Reason why using the cheapest period of time was chosen over exchanging current assets

It's true that, at the moment, SBG is studying all of its assets to know if they can increase production. Knowing that the equipment on the WWTP can reach their full capacity at certain points of the year, it would be a good option to switch them to increase the capacity. But it's just a project yet, it's still at an early phase, so, it doesn't justify switching assets at such an early stage.

3.5 Development/Project of ideas

In this chapter, it will be explained how the ideas selected in the previous chapter were developed and carried out in real life or as part of a future project.

3.5.1 Development of Implementing a preventive maintenance plan

As stated in the previous chapter, maintenance on SAP PM is the chosen idea.

3.5.1.1 First steps: Gathering information of each asset

In order to start building the plan on SAP, the first thing to know is what the company wants to have on the preventive maintenance plan. After a debate with both parts, SBG and the WWTP team, preventive maintenance would be important to implement on all the assets that are part of the process of the WWTP, this includes equipment, instrumentation and accessories such as valves.

In SAP PM, to do maintenance on a certain asset, that particular asset must exist on the data base of SAP. Without it, it is impossible to attach a maintenance plan to a particular asset. So, it is known that the assets responsible for the WWTP process must be created on SAP.

In order to create these assets on SAP, it's important to know the manufacturer, the model, the serial number, the tag and any other extra information whether it's an equipment, instrument or valve. The WWTP didn't have any kind of a detailed list with the description of each asset of the plant. Then, a search was made to find out any possible information of all the assets.

The main specifications to find were:

- Name and type of the asset;
- The tag associated;
- The manufacturer;

- The model, and
- The serial number.

To acknowledge all the specifications of each item, there are four main sources to consult: the rating plate, the labels associated with each asset, the supervision software and the archive of the WWTP (Figure 49).

Figure 48 - Different ways to retrieve information of the assets

These sources are sufficient to gather all possible information. The rating plate of each asset has most of the information, but sometimes they are difficult to view due to their poor condition, so, the other sources can complement what is missing or difficult to see.

In the final, a list was made of all identified assets and with all their specifications. As example, table 4, shown below, has a pump and other specific information that can be added like its capacity, power, dimensions or other. In this example, capacity was added.

Table 4 - Example of different types of information of an asset

Asset	Tag	Producer	Model	Serial Number	Capacity (m^3/h)	Power (kW)
Elevation Pump	P-001A	KSB	Amarex KRTK 300-315/164 UGH-S	9971123914/001500	250	16

All this gathering of information might not seem important for the final purpose, maintenance plan on SAP, but it's crucial as the other parts. With over 60 equipment, 70 instruments and 350 valves on the WWTP, this kind of information will help organize the equipment internally on the SAP structure.

3.5.1.2 WWTP structure

After all the information gathered, it's important to imagine and draw the best structure the plant can have to improve its organization and navigation on SAP.

The first two levels were already created, the first one indicates the type of activity that is held. In this case its “Energia & Fluidos” or Energy & Fluids, since a WWTP is responsible for treating a fluid (wastewater).

Next, inside the Type of Activity comes the localization. A lot of localizations exist inside Energy & Fluids, for example, Boiler Room and the Water Treatment Plant (WTP). One of the localizations is the WWTP, since it’s isolated, whether, by other processes and geographically.

The final levels were the ones that needed to be thought. As mentioned before, the WWTP has around 400 assets and it wouldn’t make sense having all of them in the same level. If so, it would be very difficult to navigate. So, the idea was to view associations between all the assets and create the structure from there. For example, following figure 50, a pump (equipment, 4th level) can have a level switch (instrument, 5th level) that turns on or off the pump depending on the level of water in a tank. The same pump can be divided into a sub-equipment (5th level) like its gearbox or electrical engine. And that sub-equipment can be divided into the materials (6th level) they consist, such as bearing, shaft, screws and so on. Also, the pump can have accessories (5th level), such as valves that affect directly its operation.

Even with this division, it isn’t enough. Hence, the final idea was to group assets with their individual process. As seen before (figure 33), the WWTP has 3 three main processes, Pre-Treatment, Anaerobic Treatment and Aerobic Treatment. These were also used to help organize the WWTP, with the latter two being divided since they’re very large. This can be viewed as sub-localizations.

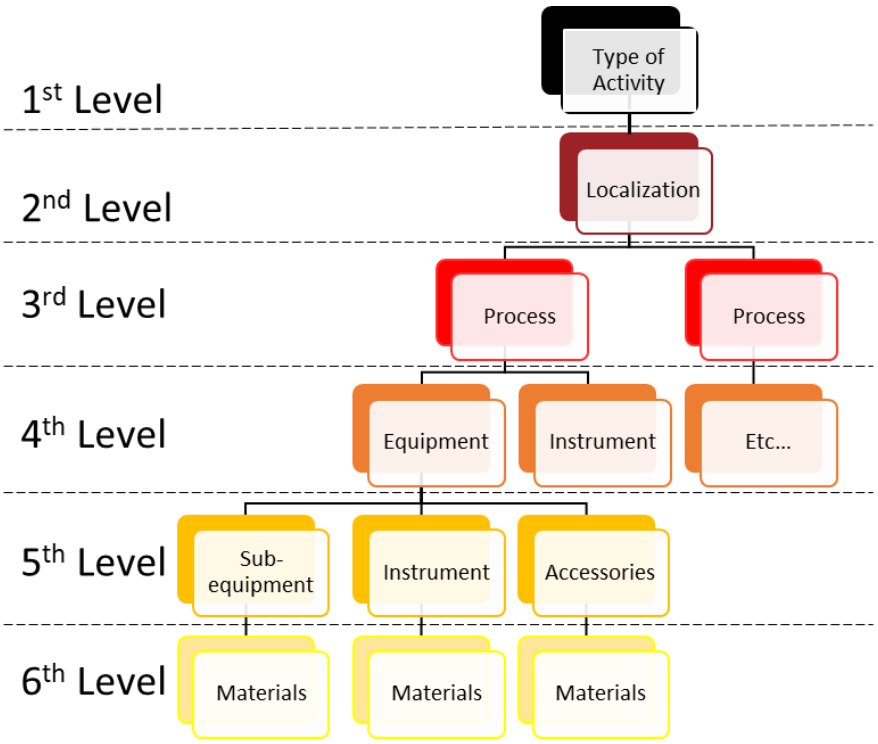

Figure 49 - Example of the structure of the WWTP

In the final, the WWTP has 7 different categories:

- Type of Activity;
- Localization;
- Processes (Sub-localizations);
- Equipment/Instruments;
- Sub-equipment;
- Accessories, and
- Materials.

After figuring out the best way to structure the WWTP, it was time to pass all the assets to SAP.

3.5.1.3 Create the WWTP on SAP

In SAP, creating assets isn't a hard task to complete, but it can take a long time.

To start, SAP PM has a lot of menus, or transactions, that are organized depending on what type of activity the user wants. In this case, the user wants to create sub-localizations (processes mentioned before) and all the assets and associate them. The type of activity and the localization of the WWTP were already created in the past.

Normally, every asset must be created one by one taking a single item on average three minutes to be created. With over 400 assets, it can take up to 20 hours.

After completing the structure in SAP, all the assets created in SAP are given a specific number. This number helps identify the asset created in SAP and it can also be used in the field. So, as a good practice, for all the equipment and instruments created, they were identified in the field with their SAP number, as seen in figure 51.

Figure 50 - Examples of SAP number labels on equipment

Accessories and sub-equipment don't need to be identified as they're easy to search if the equipment or instrument they are attached has a SAP number.

3.5.1.4 Going beyond the structure and assets over maintenance

By creating this structure of SAP and all its assets, it's now possible to apply a preventive maintenance plan to each one and other maintenance tasks. But SAP is also a powerful archive for various information and it's possible to attach to every individual object all sorts of information, such as manuals, PDF (Portable Document Format) drawings, CAD (Computer-aided Design) drawings, certificates of conformity and much more.

Although the archive has all the information that exists in the WWTP, physical archives have some issues, such as:

- Lack of organization;
- Susceptible to hazardous situations, and
- Loss of information can occur.

All these issues can exist in all physical archives and all of them exist in the WWTP archive. Starting with lack of organization, the archive has lots of folders without organization. Most of the documents, such as manuals, drawings and other types of information are all mixed with minimal association within those folders. Also, without having any reason, there are a lot of duplicates of information (Figure 52).

This is the most common problem and was a recurring one in SBG WWTP. In the beginning of the author's work, it was noticeable the amount of time that the WWTP team spent just to find a particular document at the archive, sometimes reaching 15 minutes.

Hazardous situations, such as fire, can lead to the total destruction of the site, including the archive, leading to the loss of all information. It might be a rare thing to happen, but they can occur anytime.

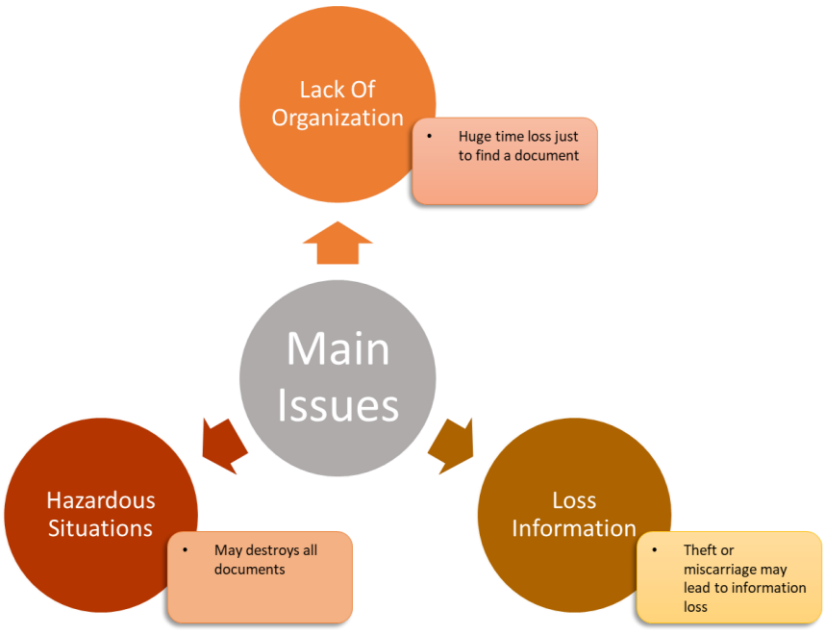

Figure 51 - Issues that can occur to physical archived information

Loss of information is possible if people aren't careful with the documents held in the archive, they might damage or destroy them. Being taken away is also a possibility, although, very rare.

This is the main reason to implement archive documents on SAP. Therefore, all the documentation was transformed in a digital form, whether by searching online, scanning the documents or asking for the original manufacturer to supply in a digital format. After this transformation, all the documents were transferred to SAP according to each object, avoiding the issues mentioned above.

As for processes, they all have attached their equivalent PID (Piping and Instrumentation Diagram), and some of them also have 3D models. Annex 5 is an example of the Pre-Treatment, having all its PID's.

As for equipment or instruments, they all have their equivalent manual, drawings and documentation of the valves that affect their operation, since it isn't possible to attach documents on accessories on SAP. Annex 6 shows a water pump with its manuals, drawings and the valves documentation.

Finally, for all electrical panels it was added their equivalent circuit diagram, as seen in Annex 7.

3.5.1.5 Create and discuss all the preventive maintenance tasks for each asset

After the construction of the WWTP on SAP, it was time to add the preventive maintenance plan. In order to accomplish this; the plan must be defined for every asset present in the plant, especially the more critical ones.

As part of the contract, Veolia was responsible to develop every preventive maintenance activity for each asset. What they gave was a generic list for groups of equipment. For example, for all water pumps, the tasks were the same. This is the easiest, quickest and the most used way to implement a preventive plan. Since the assets are similar, the same tasks are implemented.

In fact, most of them were associated with similar plans, since the variation of equipment, instrument or accessories isn't very high. However, some were not created and couldn't be linked with other plans, and others were created but they would have some minor differences from the original.

So, the next work was to view each maintenance plan and implement any opportunity to improve it according to the asset it was associated with. For those that weren't created, maintenance tasks were developed. All these improvements were conducted by the author and by the maintenance technician of the WWTP.

The main sources to improve the tasks were: The manuals of the items, the experience with current items and the experience of the maintenance technician.

Another important part of the plan is the frequency given to each task. Frequency of tasks depends on various factors, mainly the wear out of materials, time required and the criticism of each. For example, inspection tasks such as verifying the operation (output of residues) is an important task that can be quickly checked; so, it will be a weekly task. If we need to change the bearings of a pump, this task takes a lot of time and the bearings won't wear out that easily, depending on the number of working hours. So, in most of the pumps, this task will have a frequency of one year.

The final part is to create a chronogram in order to view when the plan for each asset will start. After finalizing the frequency for each task, it was clear that most of the yearly tasks were the most time-consuming ones. So, it's important that the yearly tasks of an asset won't coincide with another asset yearly tasks.

With the number of assets present in the WWTP, it's impossible to have weeks with just one asset, since it has more than 52 (number of weeks in a year) assets. Then, the group decided to have similar assets in the same week since they have almost the same tasks and share the same space. This means that the time put up to organize a maintenance task for one item can be transformed to multiple items.

This was one of the most exhausting work, since it took many hours to complete because of the consulting of various documents and the number of assets present in the WWTP.

3.5.1.6 Create the preventive maintenance on SAP

With all the preventive maintenance tasks defined, their frequency and when they will start, the user has all the necessary information to start implementing the maintenance plan on SAP.

As for creating the structure, the logic is the same, if the user wants to create maintenance plan, he must follow the specific transactions for that task.

In this case, there are four main transactions to follow:

- Create a list of tasks (List);
- Associate a list to an asset (Item);
- Create a plan to the item (Plan), and
- Automatic plan (Automatic).

Each one of them is explained in table 5.

Table 5 - Tasks, in descending order, to create the preventive maintenance plan on SAP

Create a list of tasks	This operation will create a list of tasks. These lists can, furtherly, be associated to more than one asset. It will also set the frequency to each task and can indicate what material will be used and other least important information.
Associate a list to an asset	This will only associate a list to an asset. Since, a list can be associated to more than one asset, some assets will have the same lists.
Create a plan to the item	After creating the item, this will need to be transformed into a plan. This consists in indicating when the plan will start and other information such as the range of time the plan needs to be confirmed
Automatic plan	It will allow the plans to update automatically

After all this work is set up, the preventive maintenance plan of the WWTP is concluded, leaving to a more organized maintenance of the site. However, a crucial part of the development of the plan is still missing.

3.5.1.7 Training the WWTP team

Whether the plan is organized the best way possible, it will be ineffective if the future user won't know how to operate it. As stated before, SAP has a difficult interface, making it not user friendly. Knowing this, the final part of the problem is to train and develop ways to train the WWTP team to master SAP interface for the transactions that are important for the preventive maintenance plan.

The best way the author found was to create a SOP (Standard Operational Procedure). A SOP is a document that explains how to do an operation step by step with the help of figures and text.

To develop a SOP, it's important to add all the tasks made to start an operation. With SAP by the side and following each step is optimum for its construction. Combining a SOP with a local explanation with the WWTP team is a good way to train the team as all the members are present and can ask questions throughout the explanation. After the explanation, improvements can be made to the SOP.

The other advantage is if a person has some sort of doubt in the future, he can always consult the SOP for assistance.

3.5.2 Development of the KPIs to Supervise a Maintenance Plan

In chapter 3.4.2 it was concluded that KPIs are the chosen idea due to their fast implementation.

3.5.2.1 Understand what was failing

There is a tremendous amount of KPIs the author could have adopted to implement on the WWTP. But, given the circumstances of what was failing on the WWTP, not all of them are indicated for this problem.

As stated previously, SBG didn't know how well maintenance activities were being carried out at the WWTP. So, at an early stage of the problem, it was observed and asked what the main issues could be.

Previous preventive maintenance was done by the previous company responsible for WWTP. Most of the current WWTP team worked at the previous company and they know how the maintenance operated. When asked about how the maintenance was carried out their answer was: "Sometimes the maintenance technician would come and view some equipment, other times we wouldn't come and others we would come but do almost absolutely nothing".

Another issue that was observed as time went by was the lack of materials and tools. For many times, the maintenance technician would end up not making a proper work or even initializing it due to the lack of materials or tools. This was caused by many of the assets not having materials on stock or because the current company still didn't supply enough tools to the WWTP. So, it would also be important to know which maintenance orders would be paralysed due to this issue.

To sum up the WWTP maintenance, most maintenance orders were not only being neglected in the past but there was a constant lack of materials and tools as well.

3.5.2.2 Which indicators suit best

With the problems stated previously, KPIs needed to be found or create in order to help supervise the WWTP.

Conventional KPIs, such as MTBF (Mean Time Between Failures), are always interesting to implement, but they don't help with these problems. They're used to supervise and retrieve data from assets, not a group of persons.

So, for the following, four major indicators, shown on table 6, were developed to help supervise the problems.

Table 6 - KPIs developed for supervising the WWTP with the corresponding equation

Keep up with the preventive maintenance plan	$CM_{Prev.} = \frac{Completed\ Preventive\ Maintenance\ Orders}{Programmed\ Preventive\ Maintenance\ Orders} * 100\%$
Meeting the maintenance schedule	$MS = \frac{Nº\ of\ preventive\ orders\ completed\ as\ schedule}{Nº\ of\ total\ preventive\ orders} * 100\%$
Orders paralysed by lack of material	$LM = \frac{Nº\ of\ preventive\ orders\ paralysed\ by\ lack\ of\ material}{Nº\ of\ total\ preventive\ orders} * 100\%$
Orders paralysed by lack of tools	$LT = \frac{Nº\ of\ preventive\ orders\ paralysed\ by\ lack\ of\ tools}{Nº\ of\ total\ preventive\ orders} * 100\%$

These indicators were the ones used at the WWTP since they will help SBG supervising it. The first one will allow SBG to know if maintenance tasks are being carried out by comparing the programmed preventive maintenance orders with the already completed preventive maintenance orders. Annual orders

The second one will help figuring out if the preventive maintenance orders are being carried out on the programmed schedule. This will indicate how well the team is organized and will raise questions if they aren't done on schedule.

The last two ones are indicators that will help determine if orders aren't being carried out because the plant has no materials or tools for the team to proceed a preventive maintenance order.

These indicators are considered key because for SBG, as mentioned before, a poor maintenance on the WWTP could lead to a shutdown to the entire factory or other disastrous situations that would cost heavily to SBG. Therefore, supervising the plant maintenance is extremely important.

3.5.3 Development of using the cheapest electrical energy tariff

At chapter 3.4.3, it was concluded that the best option to implement was to use the cheapest electrical energy tariff due to its lower cost compared to the other option.

3.5.3.1 The decanter centrifuges

The centrifuges are used at the WWTP to dehydrate mud that is generated at the whole process. Dehydrated mud is, then, sold for agriculture purposes.

Their operation depends on a few factors (Figure 53):

- The amount of mud at the thickener tank;
- The operation of the pumps which withdraw mud from the thickener tank;
- The addition of polyelectrolyte to the mud, and

- The addition of water to the polyelectrolyte line.

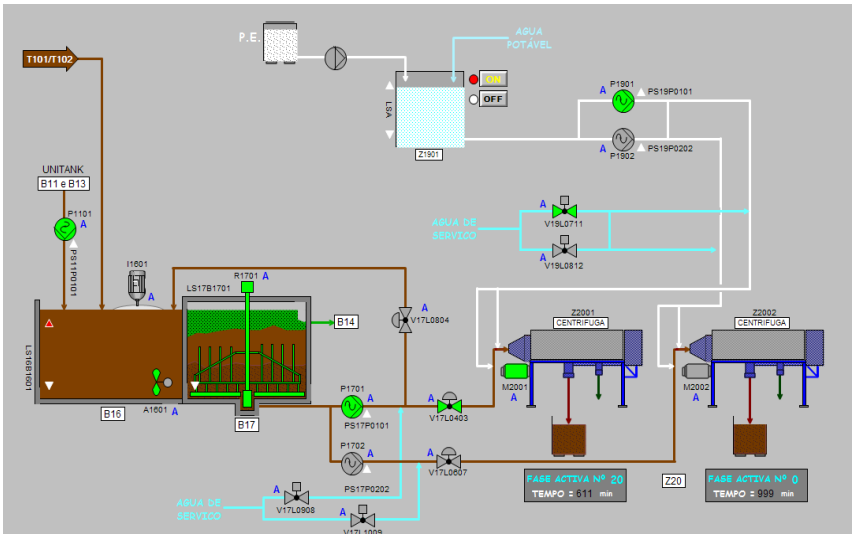

Figure 52 - Diagram of the mud dehydration process at the software WinCC

Once the mud is dehydrated, it falls to a container bellow the centrifuge with the help of an aluminium plate (Figure 54), so the mud can disperse throughout the container. The water which is removed from the mud is sent back to the aerobic process.

Figure 53 - Aluminium plate is turned over manually

3.5.3.2 Gather all necessary information

To start, there is key information is required for studying this project:

- Consumption;
- Nº of working hours, and
- Cost of electrical energy associated with the period of time.

Consumption is key to know about the exact amount of electrical energy the decanter centrifuges consume. The higher they consume; the more energy cost is spent. The number of working hours is also important for the project, since the cheapest period of time will depend on the hours the centrifuges work. The final is key because it's what will give the different costs on different periods of time.

Starting with consumption, it is the simplest of them all. Four different methods could be applied to this equipment (Figure 55):

- Ampere Meter;
- Circuit Diagram;
- Clamp Meter, and
- Rating Plate.

The circuit diagram or rating plate are project data of the asset and they only show the maximum the asset can spend. The other two are instruments that measure the current energy consumption, being the running counter less precise because it's analogic, as opposed to the digital clamp meter.

Figure 54 – a) Running counter; b) Circuit Diagram; c) Clamp Meter; d) Rating Plate

For this project, the running counter was used, since there was no clamp meter at the time.

Knowing that both centrifuges have a three-phase engine at 690 volts, after measuring the results were (Table 7):

Table 7 - Energy specifications for each centrifuge

	V	A	W	kW
M2001	690	16.8	13550	13.55
M2002	690	15.5	12502	12.50

As for the working hours, it's more complicated due to the amount of variables the centrifuges have. For this situation, it was used a record of one year, with weekly data, of the total of working hours which is registered by the WWTP team.

Since there were some weeks that had zero or very few hours due to a malfunction, they were considered outliers and were removed from the calculus. In the final, the average amount of working hours were 16 hours a day or 8 hours a day for each centrifuge, which were the same hours they were working at the time of the project.

For the final factor, it was used an energy invoice to understand the costs and the different periods of time.

As for the periods of time, there are four as previously stated:

- Peak Tariff;
- Half-Peak Tariff;
- Normal Off-Peak Tariff, and
- Super Normal Off-Peak Tariff.

The number of hours they have per day depends on whether it's a week day, a Saturday or a Sunday. As for week days, they follow as illustrated in figure 56.

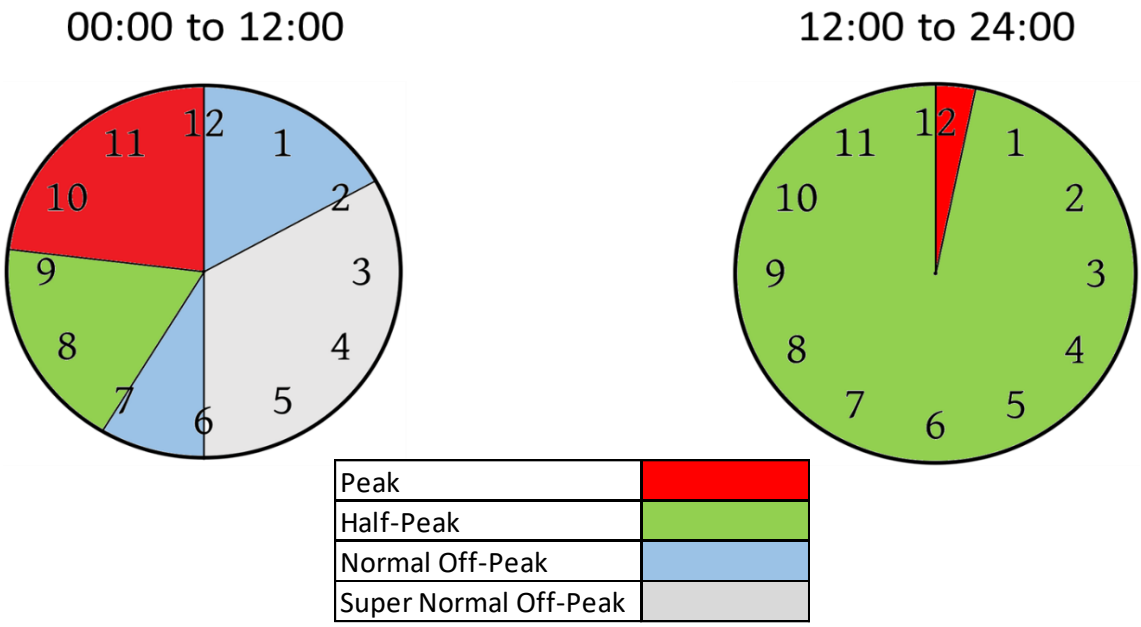

Figure 55 - How energy tariffs vary on a week day

Which, in total, there is:

- Peak – 3 hours;
- Half-Peak – 14 hours;
- Normal Off-Peak – 3 hours, and
- Super Normal Off-Peak – 4 hours.

Saturday with the figure 57.

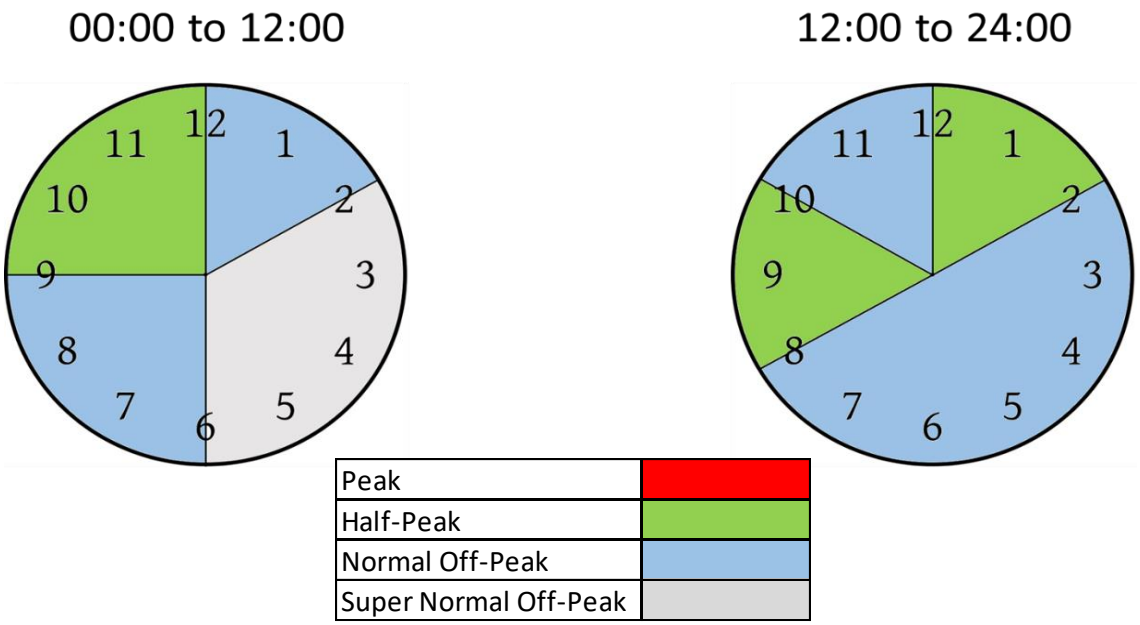

Figure 56 - How energy shifts vary at Saturday

And with:

- Peak – 0 hours;
- Half-Peak – 7 hours;
- Normal Off-Peak – 13 hours, and
- Super Normal Off-Peak – 4 hours.

And, finally, Sunday with figure 58.

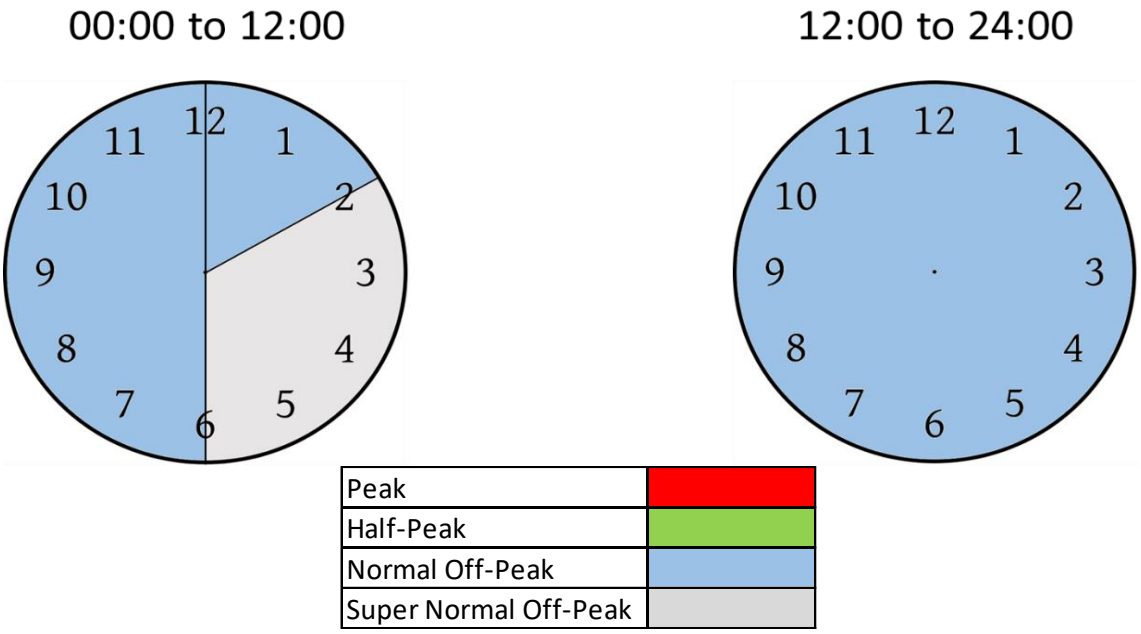

Figure 57 - How energy shifts vary at Sunday

With:

- Peak – 0 hours;
- Half-Peak – 0 hours;
- Normal Off-Peak – 20 hours, and
- Super Normal Off-Peak – 4 hours.

After retrieving all the data about how the time tariffs of electrical energy work, it just remains the cost for each tariff. This was also retrieved from the electricity invoice as figured in table 8. The costs used were the ones related to the last month on the invoice, which was December.

Table 8 – Electrical energy prices for different tariff until December 2017

Peak	0.100853 €
Half-Peak	0.089916 €
Normal Off-Peak	0.067554 €
Super Normal Off-Peak	0.062062 €

3.5.3.3 Find the best schedule

Currently, the centrifuges work from 08:00 to 24:00 alternately. They start at 08:00 because it's the time that the WWTP team arrives and put the machine to work. They end the operation at 24:00 because is when the last member of the team leaves the WWTP.

Normally, they switch the operation of one to another when one fills the whole container, but the hour that occurs is uncertain. Even though both centrifuges may not work 8 hours each day, one more than the other, the next day the other one will compensate. In the end they will have an average of 8 hours and they have similar consumption, giving no difference to the calculation. So, it was assumed that one works from 08:00 to 16:00 and the other one from 16:00 to 24:00 (table 9).

Table 9 - Current working schedule

	Centrifuge	Schedule
Week Days	1	08:00 - 16:00
	2	16:00 - 24:00
	Centrifuge	Schedule
Saturday	1	08:00 - 16:00
	2	16:00 - 24:00
	Centrifuge	Schedule
Sunday	1	08:00 - 16:00
	2	16:00 - 24:00

There were discussed three possible solutions to improve:

- Working in a better shift alternately
- Working in a better shift at the same time
- Avoiding Peak

For the first solution, it has to follow the main objective function:

$$\min \sum x_{ij} * c_j \, , x_{ij} \in \{0,1\}$$

Which calculates the minimum of the sum of Xij times Cj, where “i” is centrifuge 1 or 2, “j” is the period of time which is associated with (each period corresponds to 15 minutes), Xij indicates if the centrifuge “i” works on the period of time “j” (Binary number) and Cj is the cost associated with the period of time “j”.

Also, it must indicate that each centrifuge works 8 hours per day:

$$\sum_j x_{ij} = 4 * 8 = 32$$

Since each period corresponds to 15 minutes, it has to be equal to 32.

The final restriction is that the centrifuges can't work at the same time:

$$x_{1j} + x_{2j} \leq 1$$

After all these equations, it was used the function Solver on Excel to determine what was the best shift for each machine to work with the least amount of money spent on energy. The schedules given by Solver are represented in table 10.

Table 10 - Improved working schedule with the centrifuges operating alternately

	Centrifuge	Schedule
Week Days	1	12:15 - 20:15
	2	00:00 - 08:00
	Centrifuge	Schedule
Saturday	1	14:00 - 20:00 + 22:00 - 00:00
	2	00:00 - 08:00
	Centrifuge	Schedule
Sunday	1	08:00 - 16:00
	2	00:00 - 08:00

The solution when the two machines work at the same time is almost the same as the previous one but instead of having the restriction when they can't work at the same time, it will have a restriction to force them to work at the same time, such as:

$$x_{1j} - x_{2j} = 0$$

For this solution, the schedule for each centrifuge is very simple, as shown in table 11.

Table 11 - Improved working schedule if both centrifuges operating at the same time

	Centrifuge	Schedule
Week Days	1	00:00 - 08:00
	2	00:00 - 08:00
	Centrifuge	Schedule
Saturday	1	00:00 - 08:00
	2	00:00 - 08:00
	Centrifuge	Schedule
Sunday	1	00:00 - 08:00
	2	00:00 - 08:00

As it can be seen, the centrifuges work every day at the same time between 00:00 to 08:00, exactly when the WWTP has no one working there.

The final solution doesn't need Solver to resolve. The solution is to maintain the alternately operation of the machines, but it also has to maintain the working hours from 08:00 to 24:00 while avoiding the Peak. So, inevitably, they will work, at some point, at the same time. It will only change the week day, since Saturday and Sunday don't have the Peak. Table 12 demonstrates this new schedule.

Table 12 - Improved working schedule with the centrifuges operating alternately and avoiding rush hour shift

	Centrifuge	Schedule
Week Days	1	08:00 - 9:15 + 12:15 - 18:00
	2	16:00 - 24:00
	Centrifuge	Schedule
Saturday	1	08:00 - 16:00
	2	16:00 - 24:00
	Centrifuge	Schedule
Sunday	1	08:00 - 16:00
	2	16:00 - 24:00

3.5.3.4 Characterize each solution

After obtaining the three studied solutions, they need to be analysed to know what technology must be implemented and to review the pros and cons of each one.

Starting with the improved alternately shift, it can be seen centrifuge 2 works everyday between 00:00 to 08:00. This is the main issue because of one simple thing: the container. As mud falls from the centrifuge to the container, it has a movable plate, as demonstrated before.

This plate serves to distribute, evenly, the dehydrated mud all over the container. If not, one side would fill to the point of spilling mud out and the other side would be almost empty. The issue is that the plate is manually changed by a WWTP worker, and they change it to the other side when it appears slightly full. And, even with that change, it is not sufficient. Regularly, a member of the WWTP needs to disperse evenly the dehydrated mud across the container with a shovel.

So, a solution to modify this system to automatic would be ideal, removing the possibility of spillage and would remove a task for the WWTP team. Two solutions were discussed:

- Have a motorized movable plate, or
- Have a silo with a screw conveyor.

The motorized movable plate would seem the obvious one because it has the same mechanism as the current one and only adds up an electrical engine to the plate and a few other equipment (Figure 59).

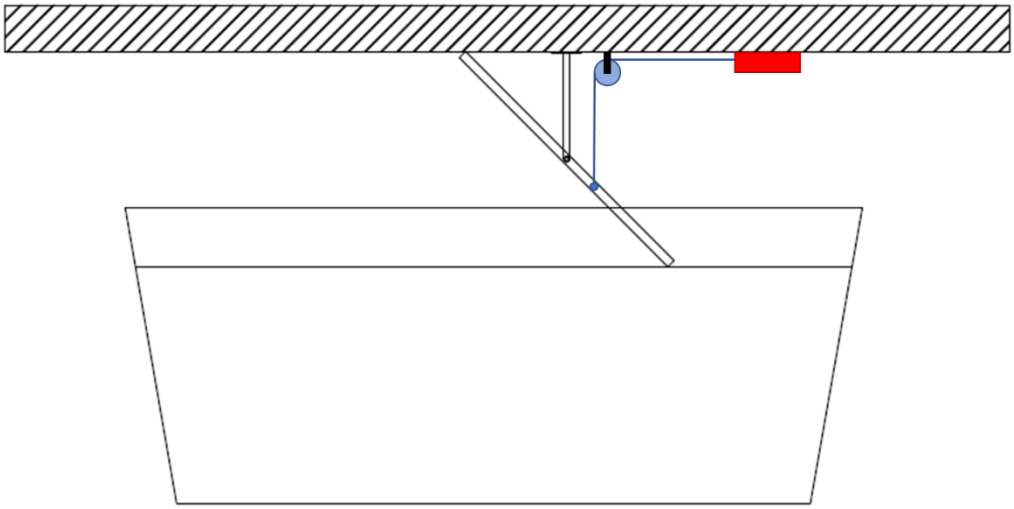

Figure 58 - Possible fixture of a motorized plate

Figure 60 shows a possible solution where the plate could move with the help of an electrical engine.

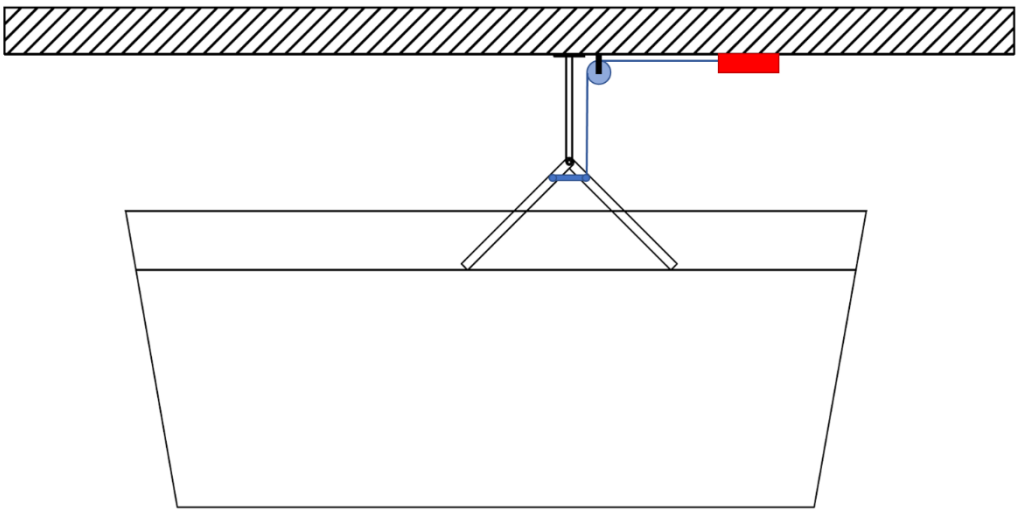

Figure 59 - Another possible fixture but with a V shape plate

Figure 61 is also a possible solution, which can disperse more evenly than the previous one with its V shape plate.

These solutions would need to be automated with the current PLC (Power Line Communication) so that the electrical engines will know when to operate. Also, to improve dispersion of the mud, the plate would need more than one position. This would be regulated with some sort of sensor. Since the containers are constantly removed to be emptied, a fixed sensor on the container is out of question. So, an ultrasonic sensor would be more appropriated to this situation (figure 61). The sensor would be the command of the PLC to know when the plates could move.

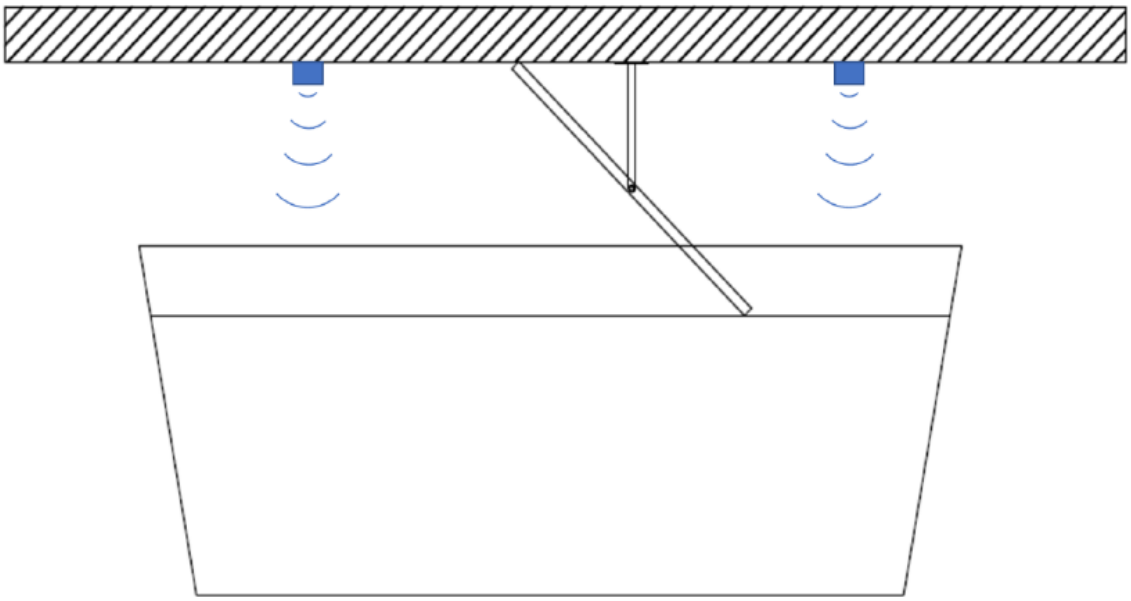

Figure 60 - Ultrasonic sensors in each extremity to calculate the level of each

These solutions would enable the centrifuge to work at night without anyone supervising it. However, it is uncertain how efficient the process would be. The dispersion of the mud would be uneven, even with the supersonic sensors.

A silo with a screw conveyor would be a more efficient way to work with. When the mud is dehydrated from the centrifuge, instead of falling into the container, it would fall to a screw conveyor which would push the mud to a silo (Figure 62). The silo would be at an upper level, so it could discharge to a truck. This would improve the method of filling the truck. Currently, the truck arrives with an empty container and needs to switch it with a filled one. With this method, the truck wouldn't need to change the container, it would only need to fill it.

Also, the silo should have a capacity superior to a one-day production of dehydrated mud and would have a superior level sensor in order to act as a mechanism of safety if the mud reaches high levels on the silo.

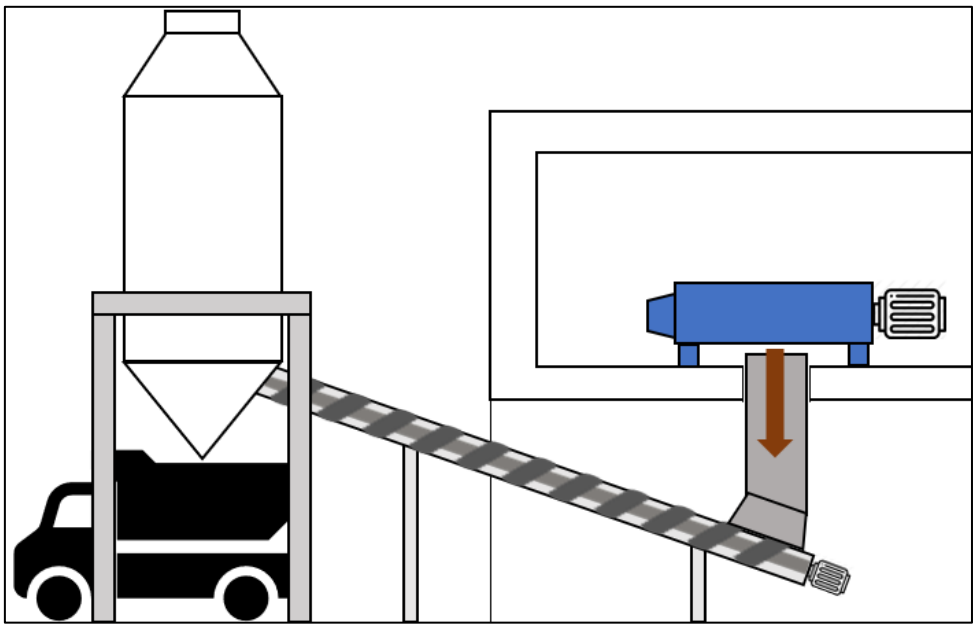

Figure 61 - A diagram of the solution with a Silo and a Screw Conveyor

This solution can be more efficient and practical than the other one. But, the cost of equipment (silo and screw conveyor) is much higher, and the screw conveyor would have superior maintenance and energy costs over the electrical engines of the previous solutions.

Both of these solutions can be implemented in the improved alternately shift or at the improved shift with both centrifuges operating at the same time, since, both have schedules when one of the centrifuges is working at the WWTP from 00:00 to 08:00.

To compare each solution, figure 63 demonstrates:

	Advantages	Disadvantages
Motorized Plate	• Low energy and maintenance and equipment costs	• Not sure how well the system would work
Silo & Screw Conveyor	• Can be more efficient • Improves the operation of the filling of the truck	• Its maintenance, energy and equipment costs would be superior compared to the other option

Figure 62 - Advantages and Disavantages of both solutions

To sum up, implementing a silo and a screw conveyor would be the best way to implement since it is the safest one because some examples already exist in other WWTP's and work properly, as opposed to the motorized plate one which the author and people on SBG don't have any clue if a system like this could work.

Another possible solution is to review the contract of the WWTP company, Veolia, to add another member to the team to work at the night shift, between 00:00 to 08:00. This would have a responsible person for the WWTP at night and could perform the current tasks of the centrifuges at the containers. This would lead to the centrifuges to work at that period of time without implementing any kind of new equipment. However, the contract would need to be changed and would cost more to SBG, leaving to the question if the savings generated from this method would cover significantly the rise of price of the contract.

As for the of avoiding the Peak tariff, no modifications are needed. It only needs the WWTP team to be instructed to shutting down the centrifuge at the beginning of the Rush Hour period and restarting the centrifuge at the end of the Rush Hour period.

3.6 Implementation

3.6.1 Implementation of the First Solution

The implementation of the preventive maintenance plan on SAP occurred as it was developed.

After uploading everything necessary on SAP, since the assets to form the structure, the tasks of preventive maintenance for each asset and additional parts such as the creating a digital archive, the plan was ready to use by the WWTP team, which would give the team an improved organization over the preventive maintenance orders and general work.

3.6.2 Implementation of the Second Solution

Implementing supervision KPIs would result on an Excel sheet. This sheet would accompany the WWTP team daily as they would fill it each day of work. The sheet not also calculate the KPIs mentioned at table 6 but would also give them information of the preventive maintenance tasks they would need to perform (Annex 8) while SAP was still in development.

In the other end of the sheet, it will appear something like Annex 9). In this part, each cell is filled according to the frequency of each task. They are filled with different colours and numbers, where each colour or number is associated with a different action. In the beginning, all the non-blank cells where filled with red (not completed), but as time goes by, preventive maintenance tasks are executed, and these red cells will transform to the other colours depending how they occurred.

So, the only thing the WWTP team needs to do is to fill each task with the corresponding number. The colour changes automatically and only serve to improve its visualization. The calculation of the KPIs is also automatically as it counts the number put in each cell to a general equation.

In the final, results can be viewed monthly, quarterly, half-yearly or yearly in the form of percentage and it also generates a graph which shows monthly results to understand how well maintenance is performing. Figure 64 illustrates an example.

Annual

KPI's	Keep up with PM plan	Meeting maintenance schedule	Orders paralysed by lack of material	Orders paralysed by lack of tools
Results	20.52%	96.51%	0.82%	6.69%

Monthly

Month April

KPI's	Keep up with PM plan	Meeting maintenance schedule	Orders paralysed by lack of material	Orders paralysed by lack of tools
Results	63.15%	98.73%	1.27%	7.40%

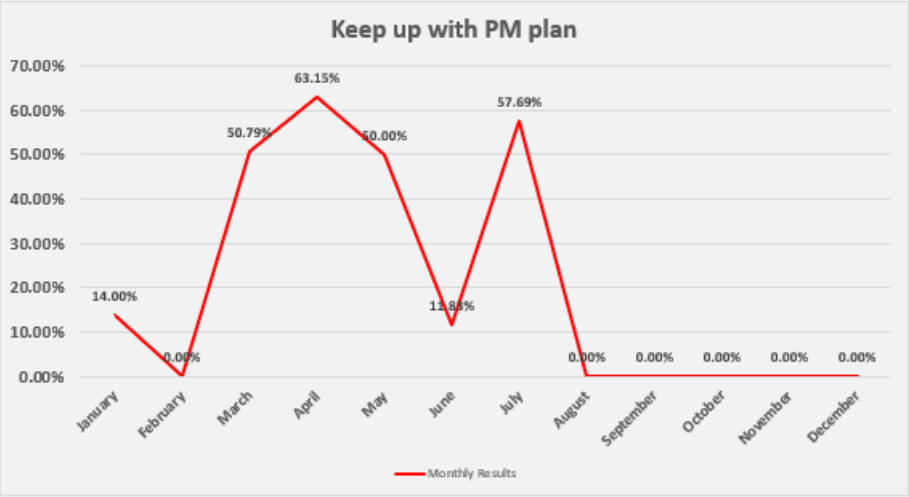

Figure 63 - Results and the monthly graph of Keeping up with the preventive maintenance plan

This information is the one that, in the final, matters to SBG. But, to work properly, the part of filling the document must be very accessible in order to succeed or the WWTP team could ignore or manipulate the document if it were difficult to operate.

3.6.3 Project of the Third Solution

The final problem of reducing electrical energy cost, at this date, is still not implemented at the WWTP. Reasons can be found in the not profound interest of SBG at this time. As stated before, SBG is in a current study to augment their production capacity and to see if all the equipment can keep up this increase. The WWTP at this moment as a fair capacity for the current production and can even handle some peaks of wastewater. But, SBG knows that the plant can't handle much more of what it is currently operating and with an increased production, it would be almost impossible.

With that in place, future modifications will happen to the WWTP, and when they occur, vast improvements will be made and one of them could be this solution to improve the process of mud dehydration.

3.7 Analysis of Results

3.7.1 Results of the Preventive Maintenance Plan on SAP

The preventive maintenance plan on SAP was a success. The effort put in constructing an organized structure proved to be a key point of the process. At this point, the WWTP as over 1100 assets catalogued in its structure as illustrated in figure 65.

As figure 65 shows, no materials were created during the process, and that is because materials created in SAP are for use of SBG, not Veolia. Materials are used in SAP mainly to keep track of quantities of materials used in maintenance activities, the cost of each maintenance task and to reserve (have stock) of these materials in time for a maintenance task. Veolia can't reserve materials that don't belong to them, therefore, the WWTP does not have access to materials.

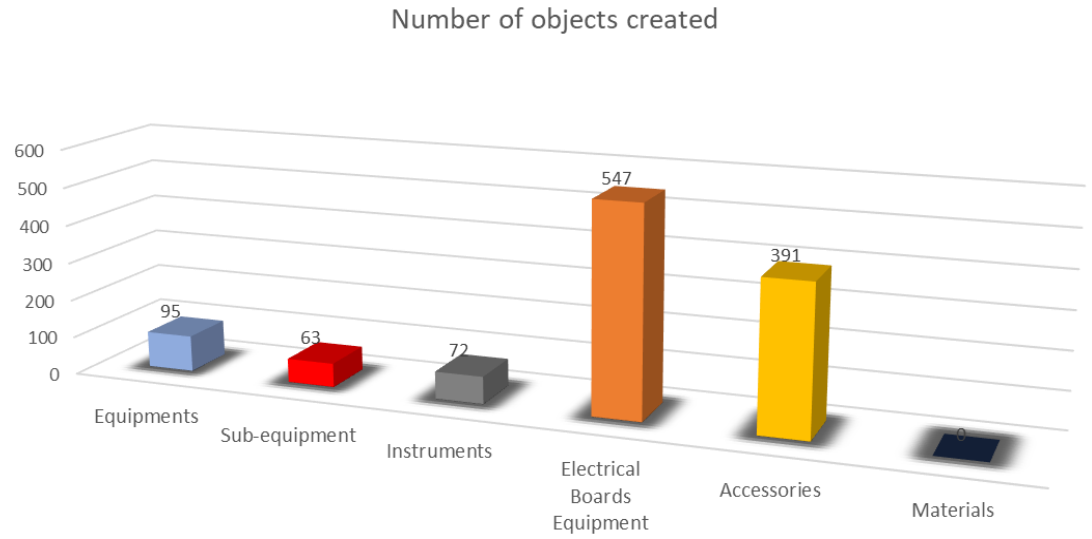

Figure 64 - Number of assets created to the WWTP on SAP

The figure also separates the electrical board equipment from general equipment (although at the same level) to demonstrate the vast amount of equipment present in the electrical boards. Also, accessories number is very high due to the number of valves and actuators all over the plant.

As for the preventive maintenance plan in SAP it resulted in 88 different plans and over 700 tasks created (Figure 66).

The number of tasks is extremely high, but when they are grouped into lists the number reduces exponentially, dropping from 772 to 68. Also, the lists have a lower number than the plans because it is possible to associate equal lists to the different plans (Figure 66).

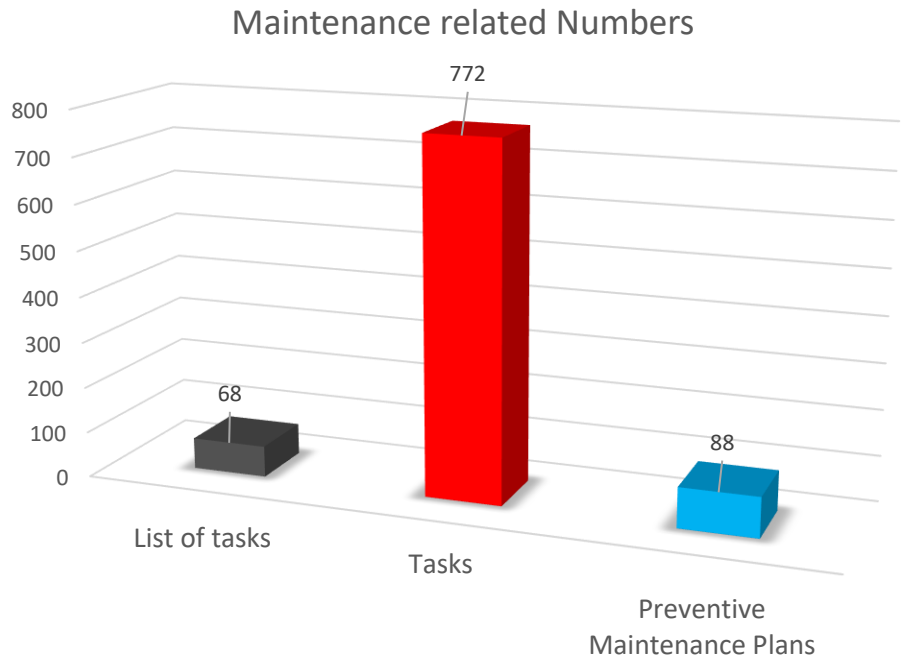

Figure 65 - Number of preventive maintenance tasks, lists and plans created

As for the results of the WWTP team working with SAP, it is pretty clear that their work is much more organized than previously. Maintenance orders will automatically alarm, and the order sheet will have all the tasks which are in need to be executed at the time. They will also be archived permanently in SAP, giving a more secure way of having this information archived. Plus, it will give another form of supervision of the maintenance to SBG. Training the WWTP team was also a success thanks to the developed POS (Annex 10).

At this point, the maintenance implementation on SAP brings strong improvements over the WWTP and the team seems to have adjusted to its works. However, they were only observed in a very early stage and it would be interesting to see how well they will perform in a long run.

3.7.2 Results of the supervision KPIs

After the implementation of KPIs, results where positive over the time. The KPIs do demonstrate a real approach of the keep up of the preventive maintenance plan by the WWTP team.

Current results can be seen in the graph at figure 64.

The graph demonstrates the keep up of the preventive maintenance plan from March (Beginning of the implementation) till July and can be seen that an average of 50% of the tasks

are completed, except for the month of June where PM was not executed due to a high number of corrective maintenance tasks. In the future, SBG can establish a monthly goal of this parameter which can add up a slight pressure to the WWTP to improve their keep up of the maintenance.

Maintenance not done on schedule and maintenance delayed due to lack of tools is a very low result but could also have a defined goal each month.

As for maintenance delayed due to lack of materials, while not very significant, as a slight high value. This lies in the fact that the WWTP as little stock of materials at their workshop. This could be improved if the materials stored at the warehouse of SBG could also be used for Veolia, but, at this moment, it's impossible as explained previously. But a change in this situation could be changed to improve this parameter.

3.7.3 Possible savings generated by working with the improved time shifts

As previously referred, the solution to reduce electrical energy costs was not implemented because at this point of time SBG is not interested to implement it.

Every equipment of the process took consideration, meaning, not only the two centrifuges were considered, but also the two pumps that remove the mud from the thickener and the machines associated with the polyelectrolyte, three pumps and a stirrer. These machines also follow the same schedule as the centrifuges, and, therefore, they will also save energy cost.

All solutions, including the current method, result in the following prevision as figured in table 13.

Table 13 - Cost Prevision for each method

	Total Costs			
	Current	**Alternately**	**Same Time**	**Avoiding Rush Hour**
Daily	54.86 €	47.45 €	44.09 €	54.37 €
Weekly	384.05 €	332.17 €	308.61 €	380.58 €
Monthly	1,645.93 €	1,423.57 €	1,322.62 €	1,631.04 €
Annual	**20,025.43 €**	**17,320.10 €**	**16,091.85 €**	**19,844.5 €**

Comparing annual savings, result in (figure 67):

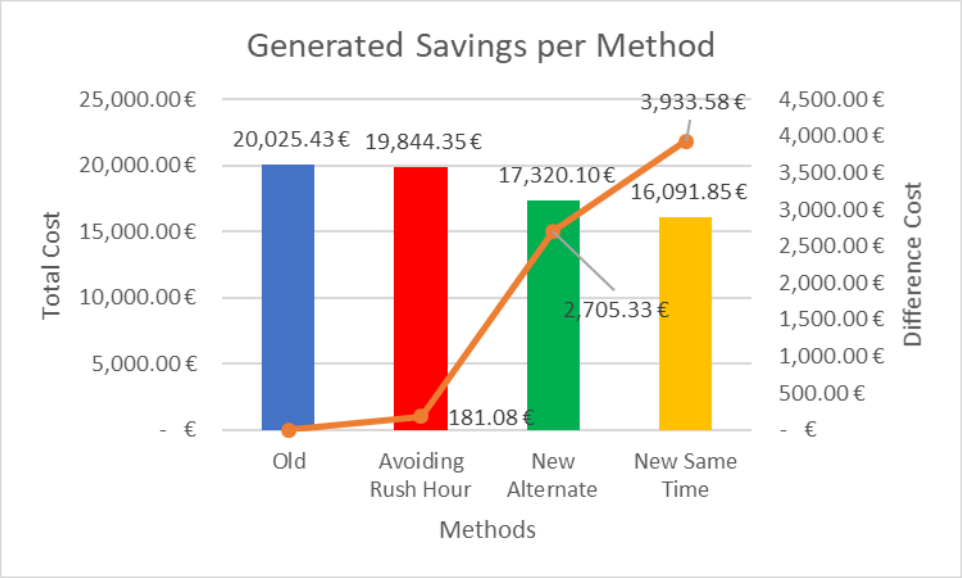

Figure 66 - Total cost and difference of cost of methods

With the comparison of figure 67, it can be seen the method of both centrifuges working at the same time from 00:00 to 08:00 is the best method to save money, compared with the current method, followed by the alternately working and finally with avoiding the rush hour.

The first two methods, as explained before, need new technology for them to start working properly, so, they will need an investment at the beginning. Because this is still a very young phase of the project it is not certain how long the comeback of the investment would return.

As for the method of avoiding the rush hour, which doesn't need any sort of new technology, was not implemented because SBG didn't find the savings significant for the WWTP shutdown the centrifuges between 9:15 to 12:15 every day.

CONCLUSIONS

4 CONCLUSIONS

4.1 CONCLUSIONS

To sum up, the objectives established by SBG, the work came out very successful. With the conclusion of the main objective, the preventive maintenance plan on SAP, and the two other secondary objectives.

Table 14 demonstrates all the objectives, conclusions and current state of each project

Table 14 - Sum up of each project

Project	Objective	Conclusion	State
Implementing Preventive Maintenance Plan	Create a preventive maintenance plan using SAP software to have an organized maintenance all over the WWTP	By implementing a maintenance plan in the WWTP on SAP, results were immediate, turning the WWTP in a more organized place	Concluded
How to supervise the WWTP maintenance	Create some sort of system to supervise all maintenance tasks of the WWTP	Choosing KPIs to supervise the WWTP maintenance resulted in a simple and effective way to supervise, discuss and analyse how maintenance is being handled	Concluded
How to reduce cost	Study a solution to reduce overall energy costs of the WWTP	By studying a form of modifying the dehydration mud process working hours with the different electrical energy tariffs, it is possible to have significant savings over the years	Still in study

In the final, the work resulted in:

- An organized WWTP structure on SAP with over 1100 assets created;
- The creation of 88 preventive maintenance plans;
- A digital archive;
- Four supervision KPIs, and
- A future project of reducing energy costs.

With these creations, the wastewater treatment plant at SBG became more organized not only in a maintenance perspective, but in a general perspective. Maintenance reports become more trustworthy due to their immediate archive on SAP. The risk of disappearance of information was diminished as a threat because of the digital archive.

As for problems, the main problem was the lack of organization of the maintenance tasks by the side of Veolia, it took a lot of time to have a complete maintenance plan. The author had to improve this plan even though the work should be exclusive to Veolia side. Also, for the WWTP have access to SAP PM, SBG needs to give them access and it took nearly three months to do that task, something that should take at least one day.

4.2 PROPOSALS OF FUTURE WORKS

In the future, the author suggests:

- SBG to keep updating the WWTP structure in case something is changed;
- In case of change, also update the digital archive (new manuals, drawings, etc.);
- Even with SAP, to still use the KPIs sheet because it is very easy to visualise and seek always for improvement,
- If any major changes are made to the WWTP, to use the energy reduction costs project developed in the mud dehydration process.

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5 REFERENCES AND OTHER SOURCES OF INFORMATION

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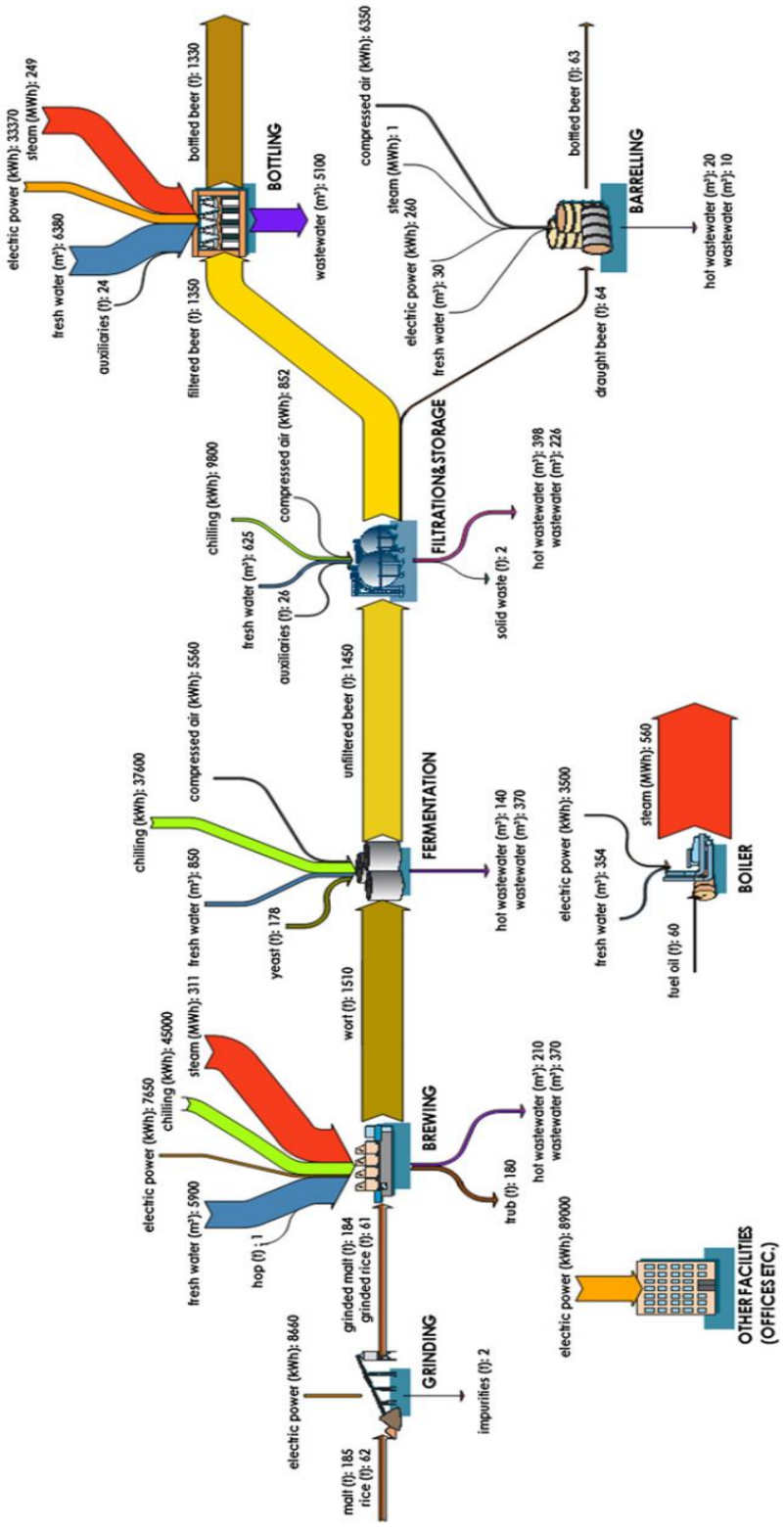
ANNEXES

6 ANNEXES

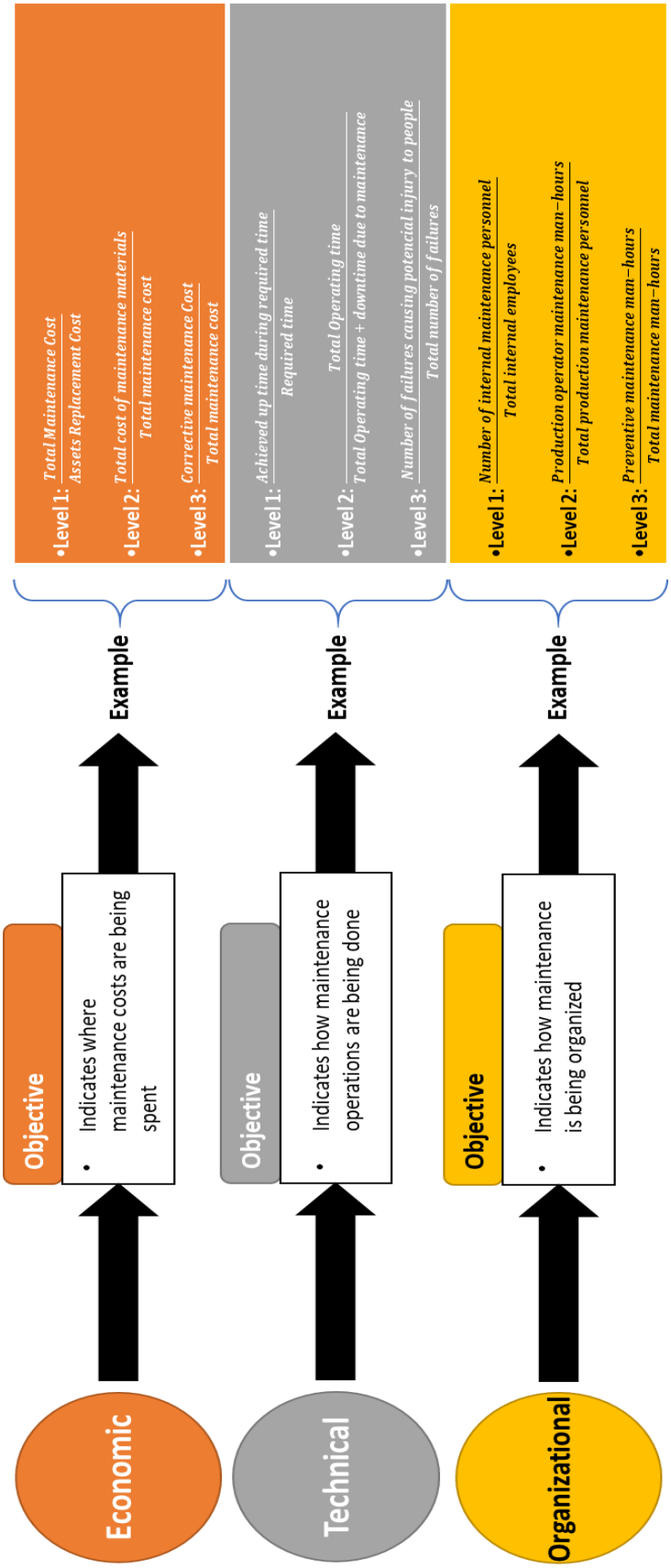
6.1 ANNEX 1

Quantities of resources spent on different processes of beer production [21].



6.2 ANNEX 2

Different maintenance KPIs with their objective and some examples



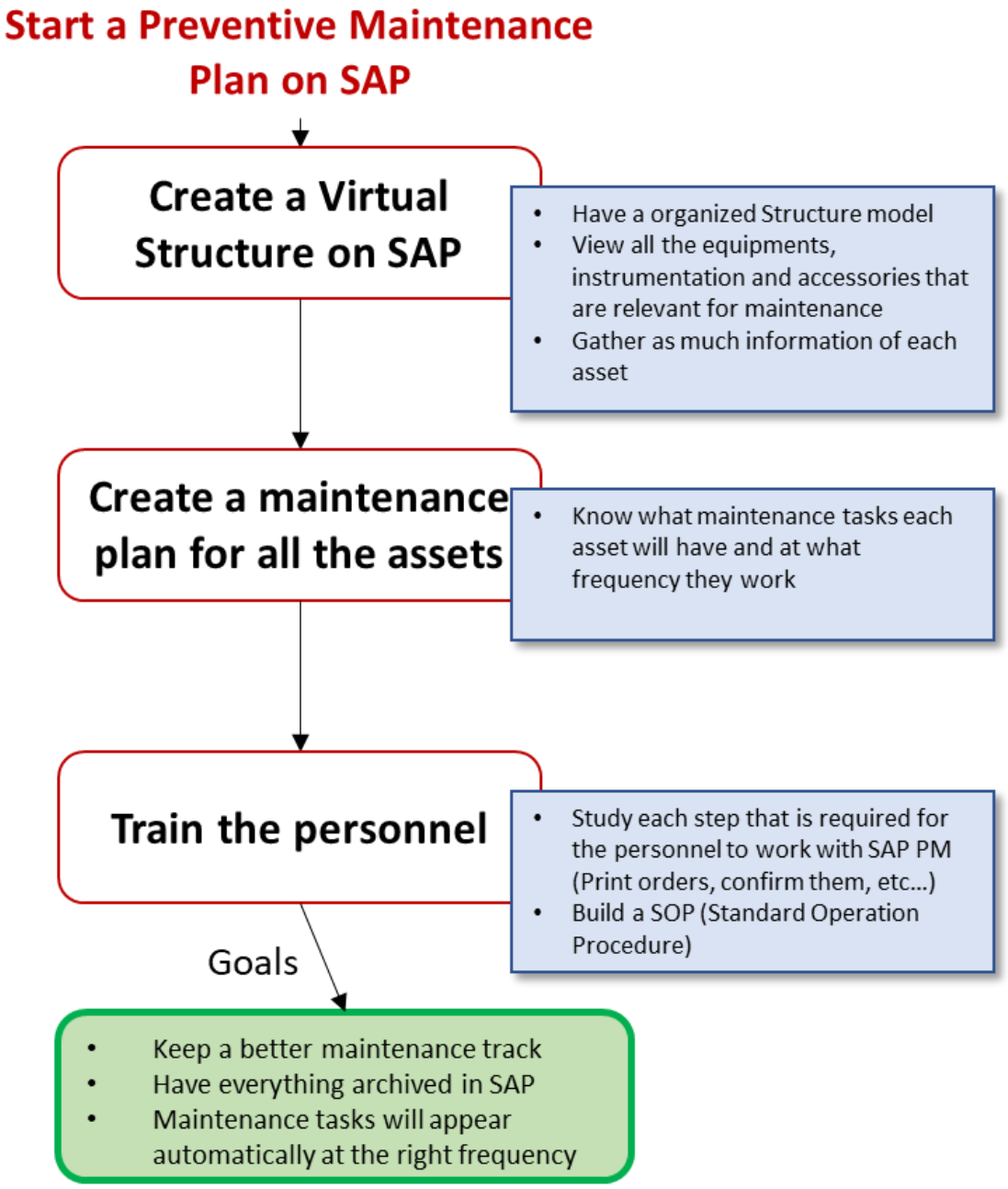
6.3 ANNEX 3

SBG values between 2014 to 2016 represented in thousands [70]

Dimensões	2014	2015	2016
Receitas	449.951,95	425.493,40	420.203,84
Valor económico direto gerado (milhares de euros)	**449.951,95**	**425.493,40**	**420.203,84**
Custos Operacionais	311.787,12	291.134,35	282.842,91
Salários e Benefícios de Empregados	50.904,96	50.142,35	48.579,32
Pagamentos a Fornecedores de Capital	23.111,71	26.362,69	26.092,10
Pagamentos ao Estado	12.461,74	12.405,39	13.588,41
Investimentos na comunidade	204,31	326,76	326,20
Valor económico distribuído (milhares de euros)	**398.469,84**	**380.371,54**	**371.428,94**
Valor económico acumulado (milhares de euros)	**51.482,11**	**45.121,86**	**48.774,90**

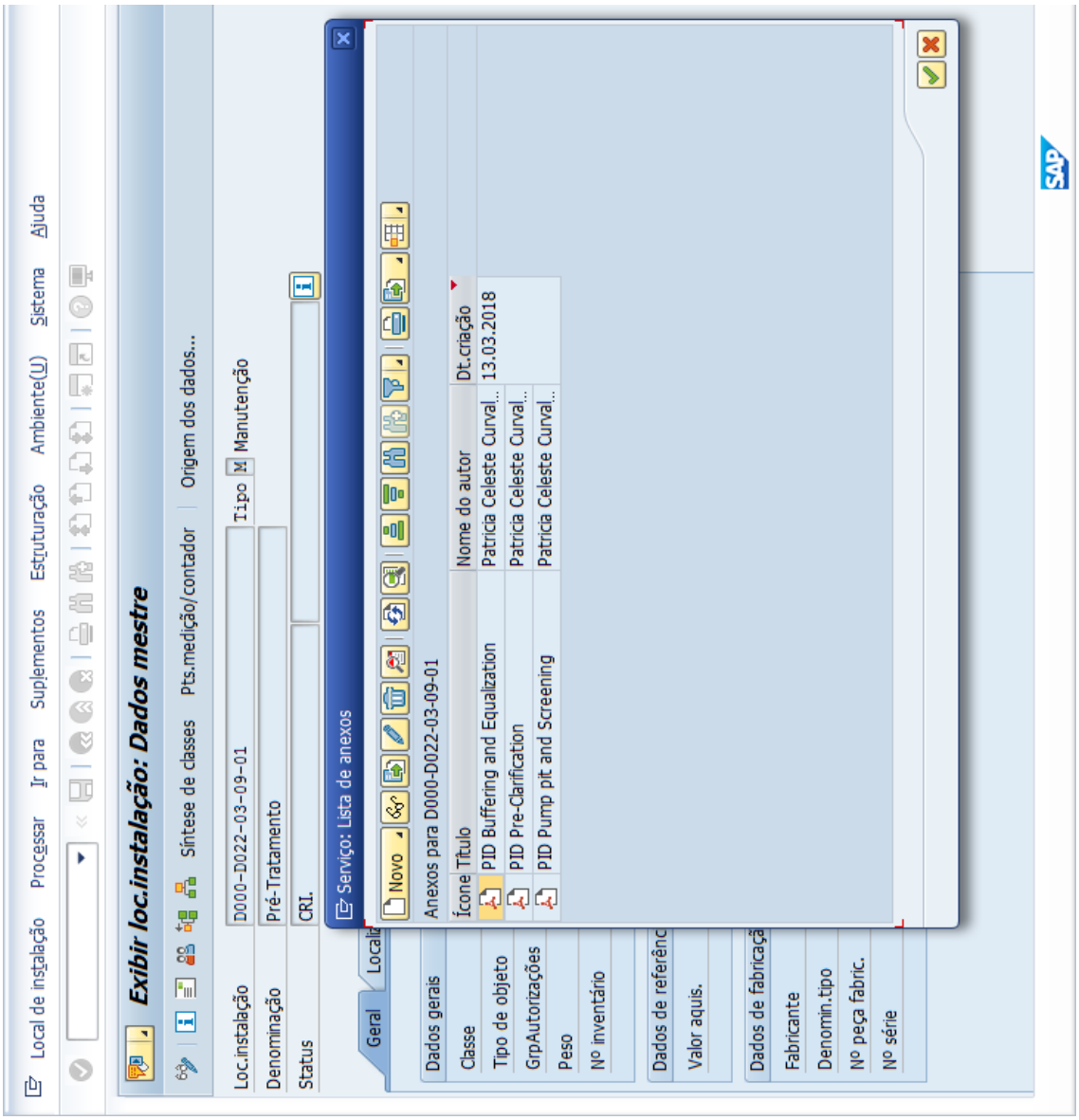
6.4 ANNEX 4

How to start and prepare the preventive maintenance plan on SAP



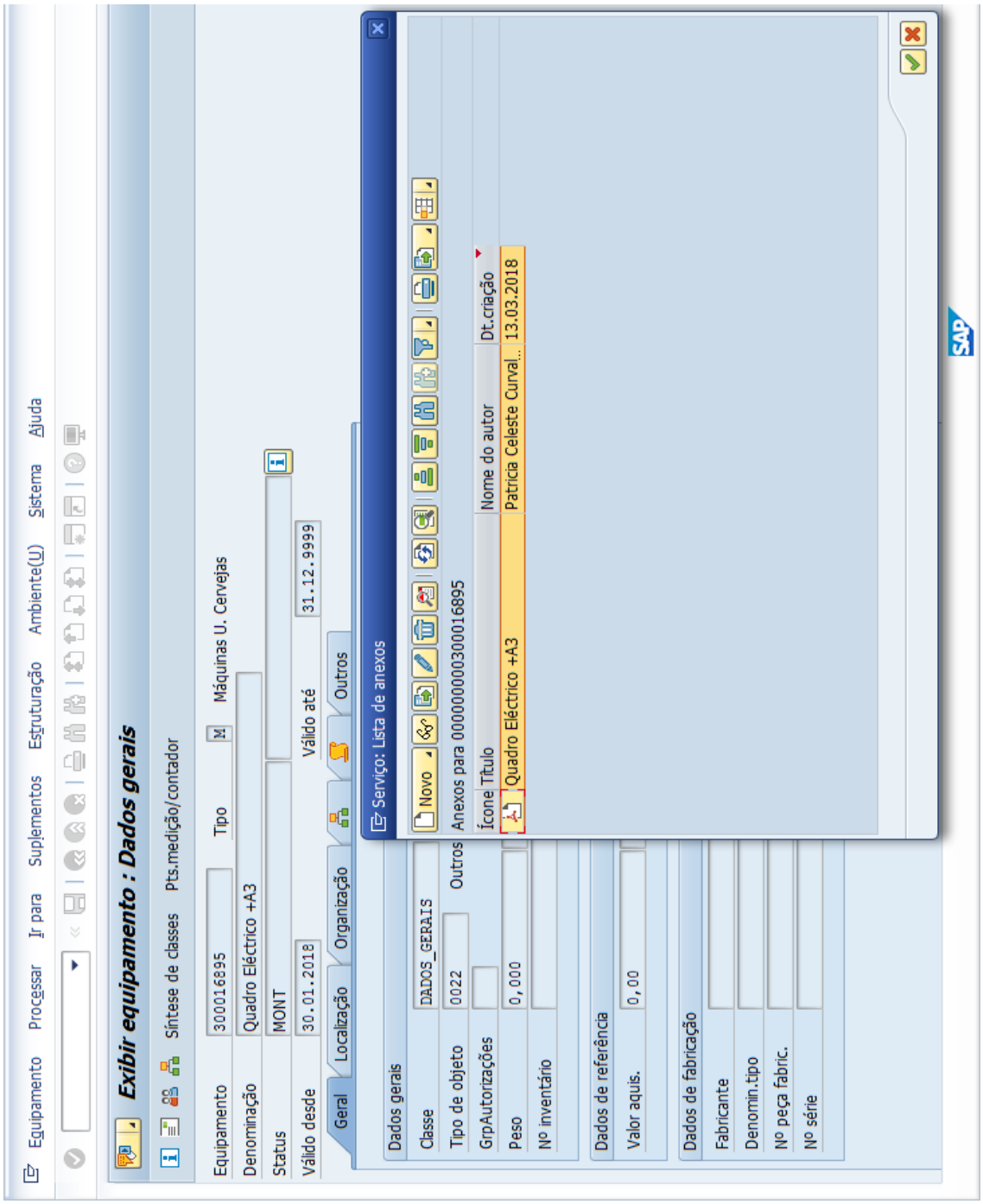
6.5 ANNEX 5

Example of archived information for processes on SAP



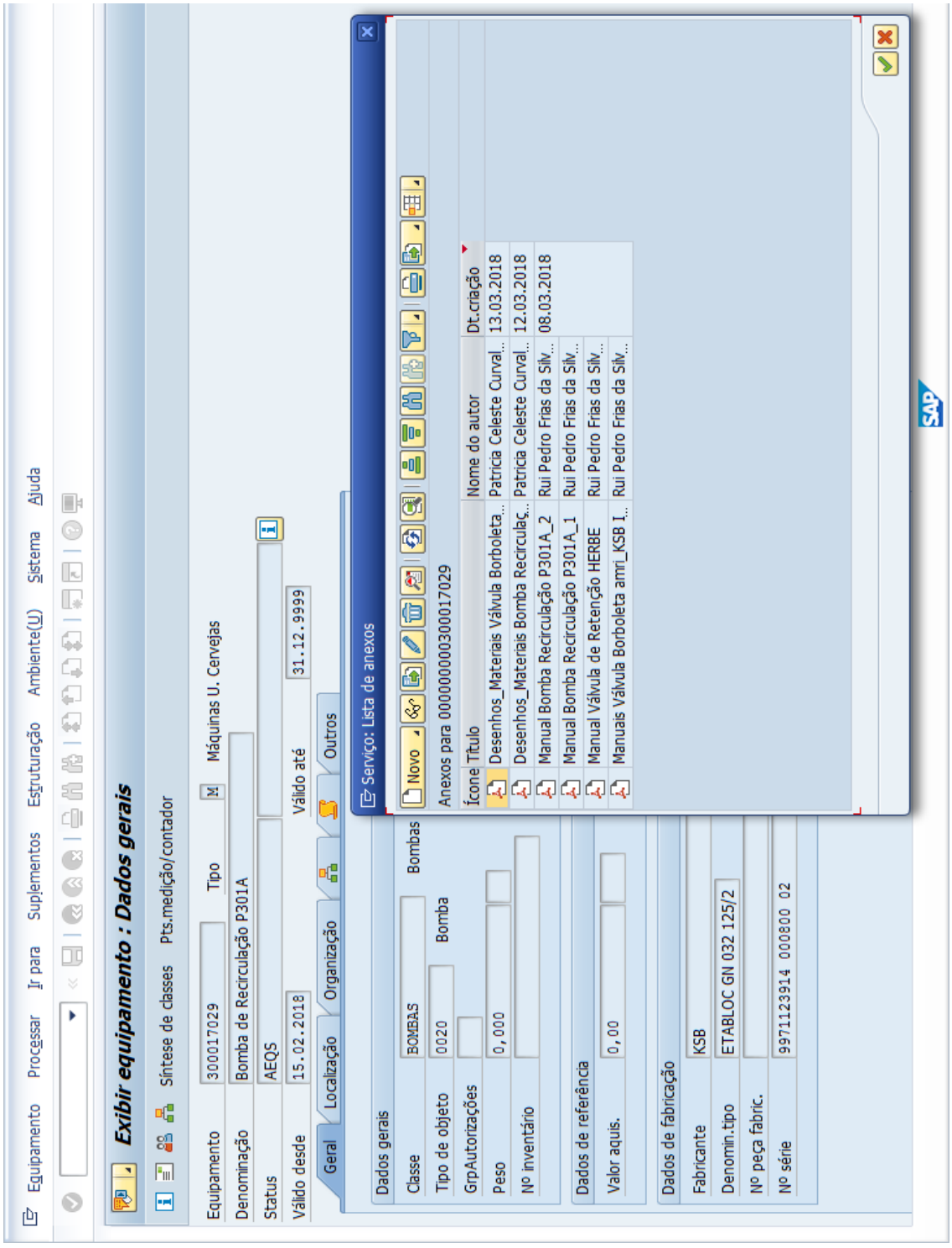
6.6 ANNEX 6

Example of archived information for an asset on SAP



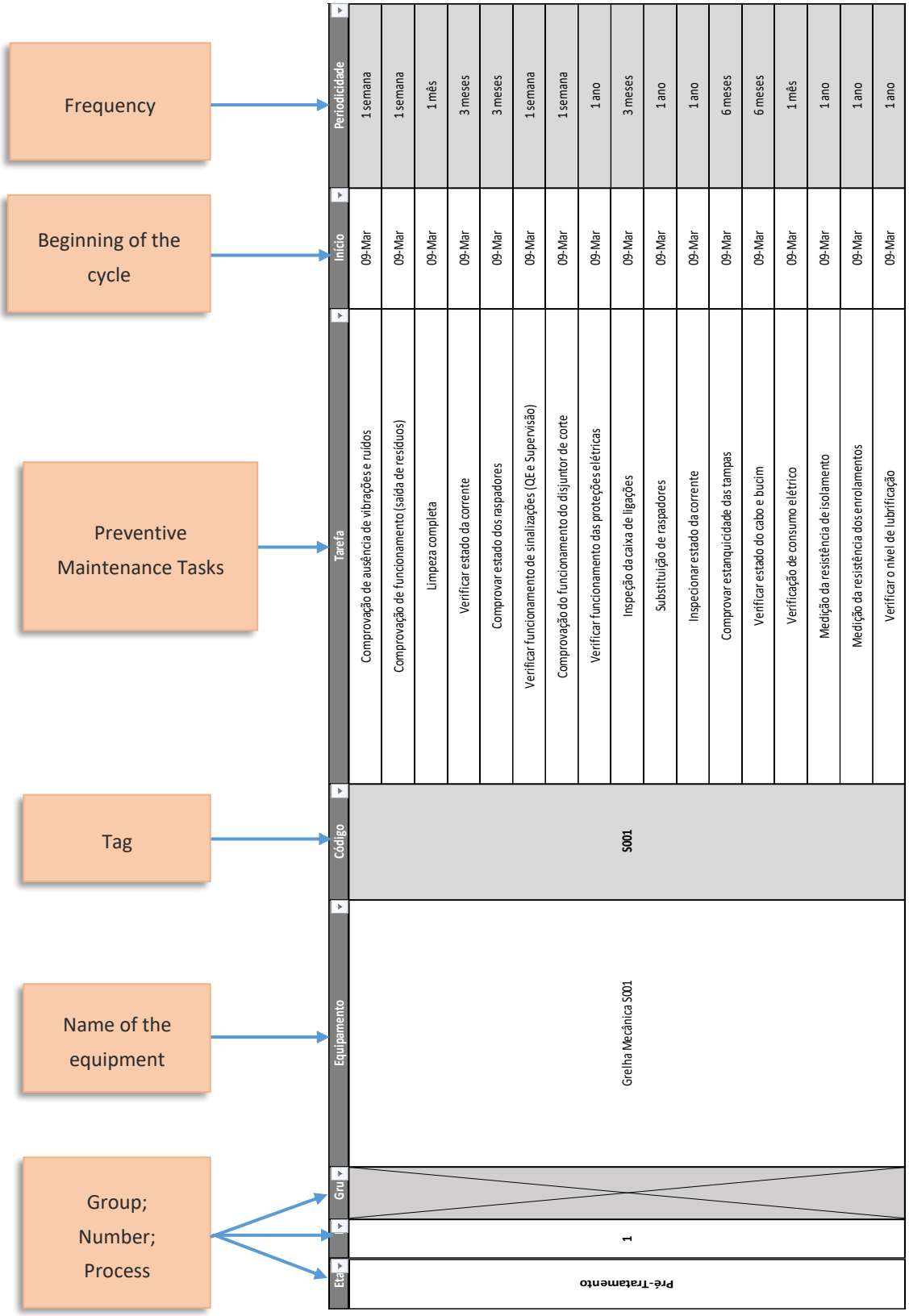
6.7 ANNEX 7

Example of archived information on an electrical panel on SAP



6.8 ANNEX 8

An example of the Excel sheet



6.9 ANNEX 9

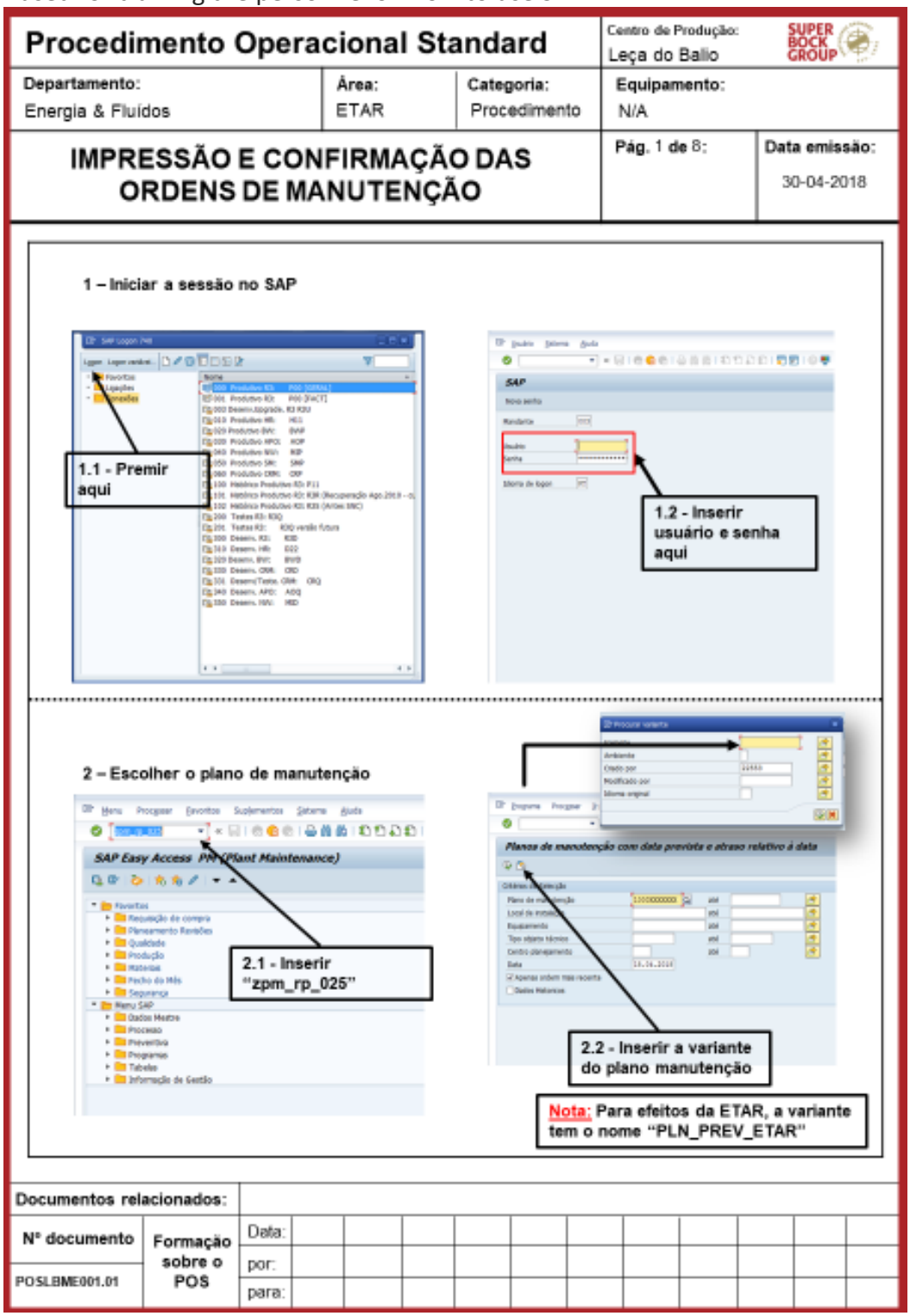
Association of the numbers by colour and an example of filling the tasks in the Excel sheet

Nº	Description	Colour
1	Not completed	
2	Completed and on schedule	
3	Completed but with delay	
4	Delayed because of lack of tools	
5	Delayed because of lack of materials	

March					April			
9	10	11	12	13	14	15	16	17
	2	2	2	2	2	2	2	1
	2	2	2	2	2	2	2	1
	1					1		
	1							
	1							
	2	2	2	2	2	2	2	1
	2	2	2	2	2	2	2	1
	2							
	3							
	1							
	1							
	2							
	2							
	4							
	1							
	1							
	1							

6.10 ANNEX 10

SOP used for training the personnel on how to use SAP PM.



Procedimento Operacional Standard

Centro de Produção: Leça do Balio

Departamento:	Área:	Categoria:	Equipamento:
Energia & Fluídos	ETAR	Procedimento	N/A

IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO

Pág. 1 de 8: | Data emissão: 30-04-2018

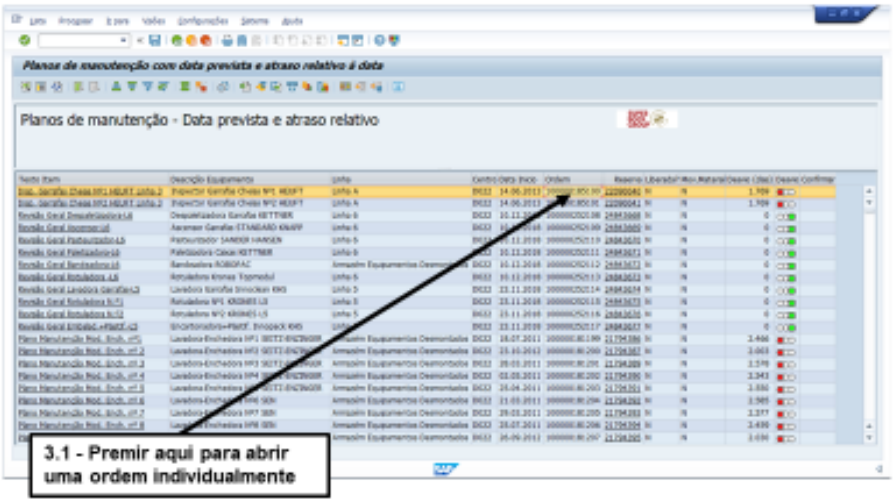
1 – Iniciar a sessão no SAP

2 – Escolher o plano de manutenção

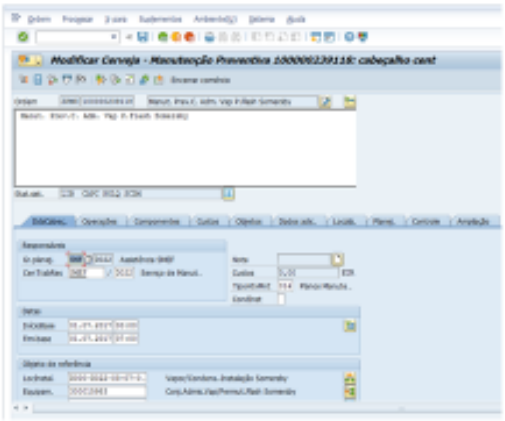
Documentos relacionados:													
Nº documento	Formação sobre o POS	Data:											
POSLBME001.01		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Balio
Departamento: Energia & Fluídos	Área: ETAR	Categoria: Procedimento	Equipamento: N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO		Pág. 2 de 8:	Data emissão: 30-04-2018

3 – Dentro do plano de manutenção, ver quais as ordens que se tem de fazer



4 - Verificar se é esta a ordem pretendida



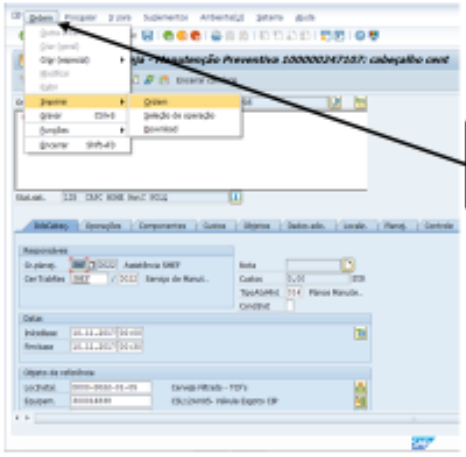
Nota

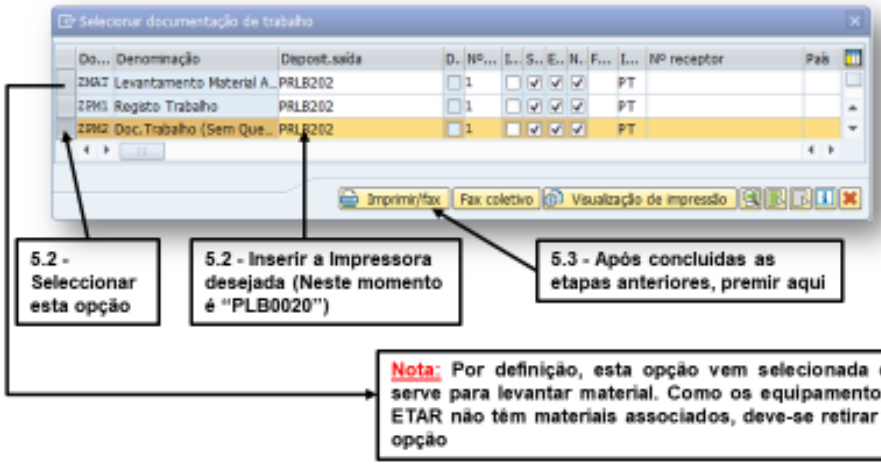
- Aqui pode se consultar a que local esta ordem foi atribuida
- Ao equipamento (N° SAP) a que foi atribuida
- A lista de tarefas do plano
- Imprimir a ordem

Documentos relacionados:													
N° documento	Formação sobre o POS	Data:											
POSLBME001.01		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Bailio
Departamento: Energia & Fluídos	Área: ETAR	Categoria: Procedimento	Equipamento: N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO		Pág. 3 de 8:	Data emissão: 30-04-2018

5 – Imprimir a ordem
Individual (Nota: Para imprimir várias ver capitulo 7)



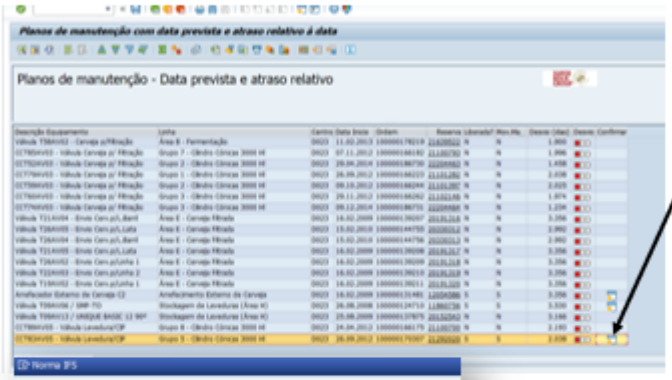


Nota: Por definição, esta opção vem selecionada e só serve para levantar material. Como os equipamentos da ETAR não têm materiais associados, deve-se retirar esta opção

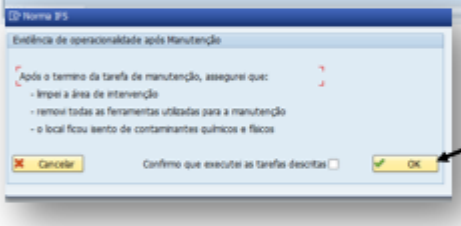
Documentos relacionados:													
Nº documento	Formação sobre o POS	Data:											
POSLBME001.01		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Balio
Departamento: Energia & Fluídos	Área: ETAR	Categoria: Procedimento	Equipamento: N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO		Pág. 4 de 8:	Data emissão: 30-04-2018

6- Confirmar a ordem

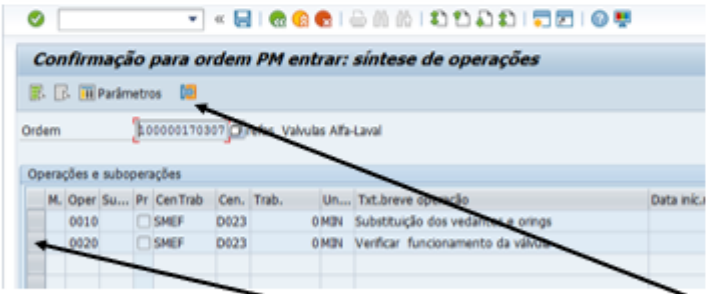


6.1 - Duplo clique aqui



6.2 - Confirmar a notificação da norma IFS

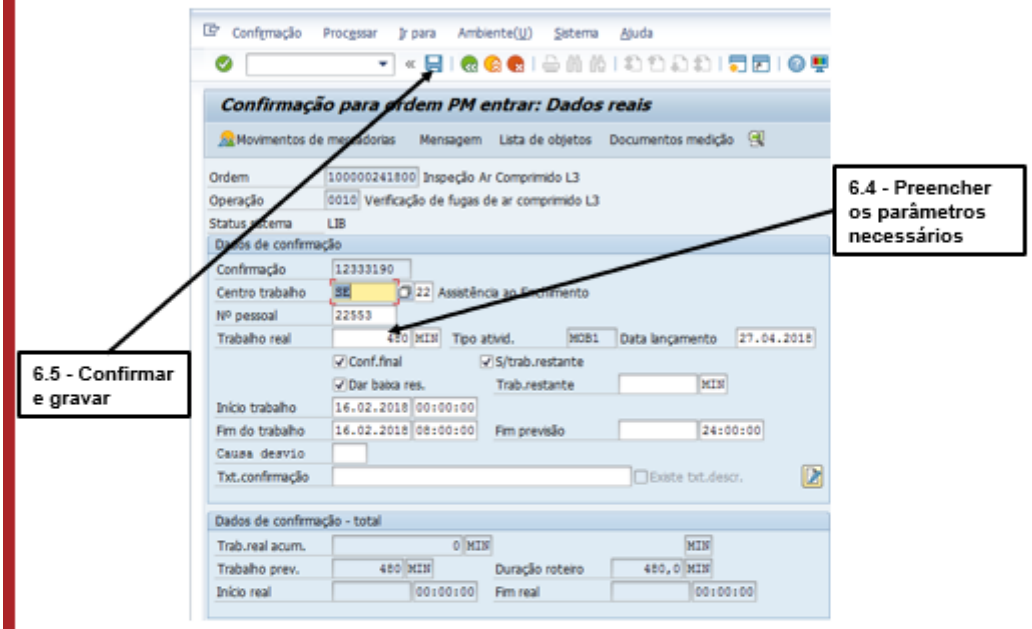
Nota: Para efeitos da ETAR, a norma IFS não afecta a sua área, apenas áreas alimentares



6.3 - Seleccionar as tarefas desejadas e premir em cima

Documentos relacionados:													
Nº documento	Formação sobre o POS	Data:											
		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Balio
Departamento: Energia & Fluídos	Área: ETAR	Categoria: Procedimento	Equipamento: N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO		Pág. 5 de 8:	Data emissão: 30-04-2018



6.4 - Preencher os parâmetros necessários

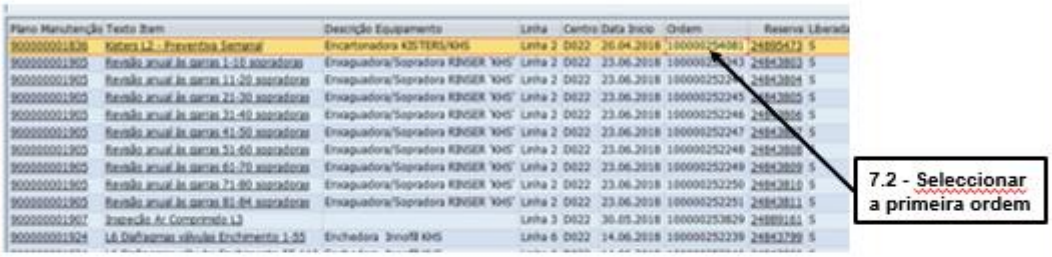
6.5 - Confirmar e gravar

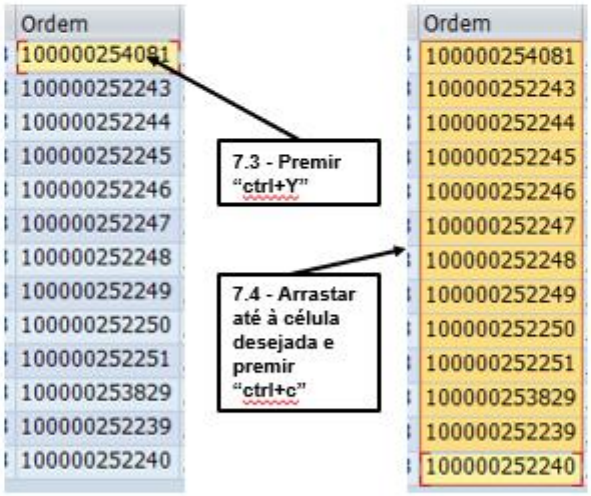
Documentos relacionados:													
Nº documento	Formação sobre o POS	Data:											
		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Balio
Departamento: Energia & Fluídos	Área: ETAR	Categoria: Procedimento	Equipamento: N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO			Pág. 6 de 8: / Data emissão: 30-04-2018

7 - Imprimir Ordens
Colectivo

7.1 - Voltar à transação zpm_rp_025 e inserir a variante já mencionada anteriormente (PLN_PREV_ETAR)

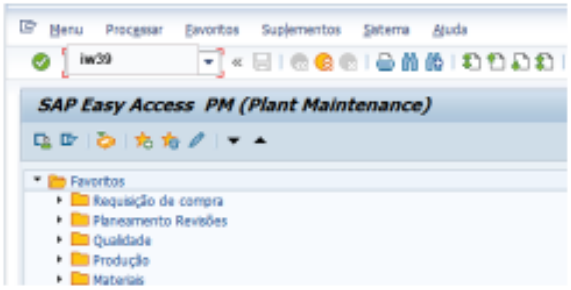


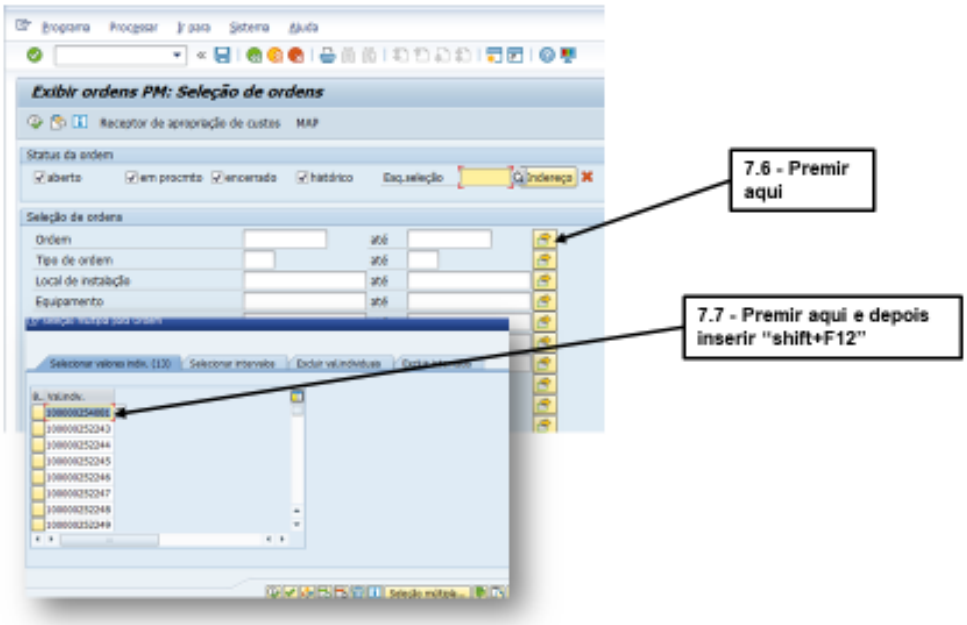


Documentos relacionados:													
Nº documento	Formação sobre o POS	Data:											
		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Balio
Departamento: Energia & Fluídos	**Área:** ETAR	**Categoria:** Procedimento	**Equipamento:** N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO			**Pág.** 7 **de** 8: / **Data emissão:** 30-04-2018

7.5 - Voltar ao menu inicial e inserir "iw39"

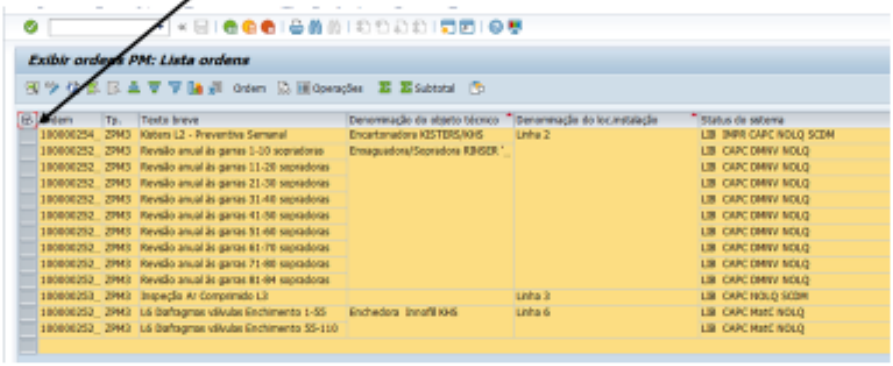




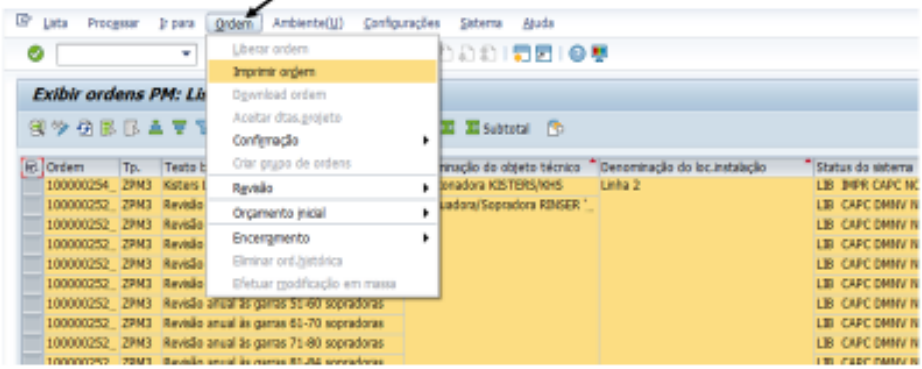
Documentos relacionados:													
Nº documento	**Formação sobre o POS**	Data:											
		por:											
		para:											

Procedimento Operacional Standard			Centro de Produção: Leça do Balio
Departamento: Energia & Fluídos	**Área:** ETAR	**Categoria:** Procedimento	**Equipamento:** N/A
IMPRESSÃO E CONFIRMAÇÃO DAS ORDENS DE MANUTENÇÃO		**Pág.** 8 **de** 8:	**Data emissão:** 30-04-2018

7.8 – Verificar e seleccionar todas as ordens



7.9 – Premir aqui e, em seguida, "Imprimir Ordem"



Documentos relacionados:													
Nº documento	**Formação sobre o POS**	Data:											
		por:											
		para:											