Raw Materials Process Management Improvement in the Glass Industry

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“The struggle you´re in today is developing the strength you need tomorrow.”
Robert Tew

Abstract

In the container glass industry, operational efficiency, product quality, and company reliability determine success. Therefore, effective and cost-efficient logistics management is essential in an industry where it is difficult to differentiate from the competition.

Raw material management can be challenging with increased production due to shortages, increased inventory costs, quality control issues, and procurement challenges. These issues can disrupt production, lead to delays and higher prices, and result in product defects and customer complaints. Therefore, it is crucial to effectively manage your raw materials to minimise disruptions, reduce costs, and ensure that high-quality products are produced.

This dissertation focuses on an in-depth study of the different processes associated with raw materials in a glass company, consisting of continuous analysis of relevant information, identification of inefficiencies and improvement.

Initially, the current processes were described, and opportunities for improvement were identified. Subsequently, a measurement of the potential effects that changes in the processes associated with the flow of raw materials could have, leading to the definition of a strategy to deal with the inefficiencies found, was carried out. Finally, the key performance indicators are the basis for strategic and operational improvements and create an analytical basis for decision-making.

This research has contributed to a better understanding of the different processes and has the potential to inform what efficiencies and improvement points need to be analysed.

Resumo

Na indústria do vidro de embalagem o sucesso é muitas vezes determinado pela eficiência operacional, qualidade do produto e fiabilidade da empresa. Numa indústria, onde existe grande dificuldade em diferenciar-se da concorrência, é importante haver uma gestão logística eficaz e rentável.

A gestão de matérias-primas pode ser um desafio com o aumento da produção devido à escassez de matérias-primas, aumento dos custos de inventário, questões de controlo de qualidade, e desafios de aquisição. Estes problemas podem perturbar a produção, levar a atrasos e custos mais elevados, e resultar em defeitos de produto e reclamações de clientes. Por conseguinte, é crucial gerir eficazmente as suas matérias-primas a fim de minimizar as roturas, reduzir os custos, e assegurar que sejam produzidos produtos de alta qualidade.

A presente dissertação foca-se no estudo aprofundado dos diferentes processos associados as matérias-primas numa empresa de vidro, que consiste numa análise continua de informações relevantes, identificação das ineficiências e melhoramento.

Inicialmente, foram descritos os processos atuais e identificadas as oportunidades de melhoria. Posteriormente, foi realizada uma medição dos potenciais efeitos que as mudanças nos processos associados ao fluxo das matérias-primas poderiam ter, levando a definir uma estratégia para lidar com as ineficiências encontradas. Por fim, os principais indicadores de desempenho são a base para melhorias estratégicas e operacionais e criam uma base analítica para a tomada de decisões.

Esta investigação contribuiu para a melhor compreensão dos diferentes processos e tem como potencial informar quais as eficiências e pontos de melhoria a analisar.

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Contents

Abbreviations and Acronyms

AV	Avintes
EXW	Ex Works
DDP	Delivered Duty Paid
FCA	Free Carriage
CPT	Carriage paid to
CIP	Carriage and Insurance paid to
DAP	Delivery at Place
DPU	Delivered at place unloaded
FIFO	First In, First Out
JIT	Just-in-time
KPI	Key Performance Indicator
SCM	Supply Chain Management
TP	Transport Planning
SC	Supply Chain
EOQ	Economic Order Quantity

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1 Introduction

In the scope of the master's in mechanical engineering of the Faculty of Engineering of the University of Porto, this dissertation was developed in a business context in the Transport department of BA Glass, S.A.

The project focuses on process improvement and management in the supply and management of raw materials. Its central relevance lies in implementing processes to improve efficiency in the supply of raw materials to factories.

The first chapter briefly presents the project, the company where it was carried out, the main objectives, the methodology used, and the organisation of the issues addressed throughout the document.

1.1 BA Glass Presentation

BA Glass was founded in 1912 under "Barbosa e Almeida, LDa", a company dedicated to commercialising imported bottles from Germany until 1930. It then changed its name to "Barbosa Almeida Glass Factory PLC" when it started its industrial activity using semi-automatic technology in Porto, Campanhã.

Later, in 1969, the Campanhã factory closed to give birth to the Avintes factory in Vila Nova de Gaia, where automated technology was introduced to industrial production.

In the following years, the factory underwent several improvements, such as the installation of the first IS-type automatic moulding machine in 1971, the installation of a new regenerative oven, a new moulding machine in 1983, and a new oven in 1988, which allowed the installed capacity to be increased by 40%. This expansion confirmed Barbosa & Almeida as Portugal's largest glass container production unit.

In 1993, BA acquired 94,5% of 'CIVE - Companhia Industrial Vidreira, SA', in Marinha Grande, Portugal. Subsequently, in 1995 BA and CIVE merged.

Three years later, in 1998, the Sonae group acquired 19.9% of the company's share capital and detained 49.9% of the voting rights and management control. Also, in the same year, *"BA - Fabrica de evases de Vidrio Barbosa & Almeida, SA"* was incorporated into the BA group. A new factory was built in Villafranca de Los Barros.

The following year, in 1999, "Vidriera Leonesa, SA" (VILESA), located in Leon, Spain, was acquired by BA, and its name changed to "BA vidrios".

Since then, most of the factories have been rebuilt. The first, in 2001, was the Avintes factory, followed by Marinha Grande in 2005 and Venda Nova in 2009.

Following the reconstruction of the Marinha Grande plant in 2004, a "Management Buy Out" (MBO) took place when the Silva Domingues family, board members, and senior staff of the company acquired the entire share capital.

Later, in 2008, BA acquired the Sotancro group, allowing them to enter the pharmaceutical and cosmetics sectors, broadening its product range and customer portfolio.

In 2012, BA began the geographical expansion of its market into Eastern Europe through the acquisition of the Polish Warta Glass group. This acquisition enabled the company to strengthen its position in the spirits segment.

In 2017, the acquisition of the Yioula Group took place, consisting of 4 factories in Greece (Athens), Bulgaria (Sofia and Plovdiv) and Romania (Bucharest).

All this progress has allowed BA to reach a daily production of more than 11 billion units of glass containers in its twelve manufacturing units throughout Europe, as shown in figure 1.1.

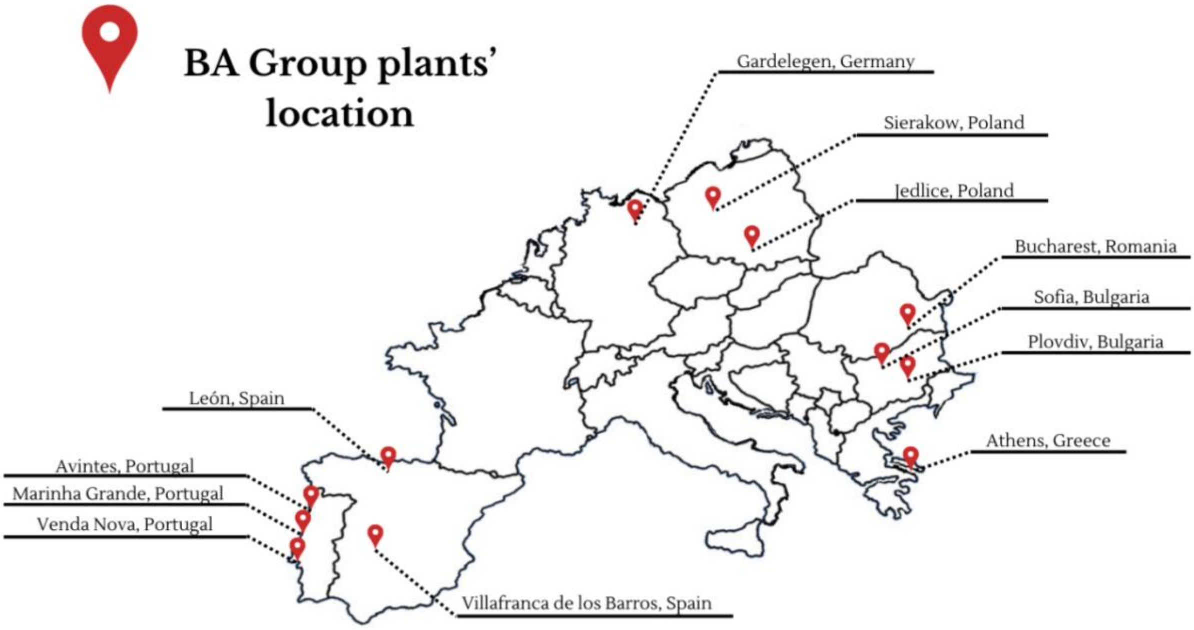

Figure 1.1: BA Group Plants´ Location

BA Group is composed of three divisions:

- Iberia (IB), formed by the plants of Avintes (AV), Marinha Grande (MG), Venda Nova (VN), Léon (LE) and Villafranca de Los Barros (VF), the first three located in Portugal and the last two in Spain;
- Central Europe (CE) consists of the plants of Sieraków (SI) and Jedlice (JE), located in Poland, and Gardelegen (GA), in Germany;
- Southeast Europe (SEE), composed of the plants of Athens (AT), located in Greece, Sofia (SO) and Plovdiv (PV), in Bulgaria, and Bucharest (BU), in Romania.

BA is currently present in over 80 countries with 3900 employees and a turnover of almost 900 million euros, giving it a significant share of the world glass market.

1.2 Motivation and Aim of the Project

The company has reached the level it is today as a result of growth caused either by increased production at the various plants or through plant acquisitions, thus combining both organic and inorganic growth.

Organic growth was achieved by increasing production and consequently internal sales, seeking to maximize growth from within with investments such as new ovens or the implementation of robots that improve the efficiency of production processes. Inorganic growth has been achieved through successful mergers and acquisitions, which puts the company in a favourable position given the diversity of the revenue base, allowing the company access to new markets.

With organic growth, associated with the upgrades made in the factories, comes a considerable increase in production capacity that translates into a greater need for raw materials. However, this has not translated into an increase in the plant's storage capacity.

Thus, due to the high costs to increase storage capacity and the little space available, there is a greater logistical demand for all processes associated with the supply of raw materials to our factory, such as the ordering of raw materials, unloading process and visibility of stocks in order to always guarantee the necessary quantities of each raw material in due time.

The factory has continuous production, twenty-four hours a day and seven days a week, corresponding to a period of one hundred and sixty-eight hours of consumption. On the other hand, the supply of raw materials has a more limited period, twenty hours per working day, which corresponds to seventy-five hours per week. This means that the weekly consumption period is much longer than the supply period. Thus, the supply period must be managed efficiently to reduce the risk of stock-outs as much as possible. The increased demand for raw materials management justifies the need to improve the organisation's procedures.

For the implementation of this project, the factory chosen was the Avintes factory due to its proximity to the company's head office, which corresponds to the location of the dissertation preparation, which facilitates data collection and the visit to the implementation site. In addition, the factory chosen by BA for the implementation of pilot projects of the group is always BA Avintes for the reasons already mentioned.

Firstly, in determining the needs of the factory, BA AV does not have information about the available stock of raw materials, so the needs are determined based on the previous week's consumption, without taking into account the stock or planning for the following week. In turn, orders are also placed manually based on a random distribution and not on consumption and stock data, when planning deliveries. For this reason, it is necessary first of all to find a solution that allows us to obtain the raw material stock in real time with the lowest cost for the company. This will allow us to increase the data on raw material consumption and receipts. Then, the process of placing orders should be carried out using stock and future consumption in an automatic way, freeing up purchasing workers for other functions.

Finally, in the planning of unloading there is only the restriction of the hourly period for unloading, in which the deliveries scheduled for that day can unload, however, other limitations are not considered. With this, it is hoped that with the data obtained from the stock and consumption a better management of the hourly period for unloading can be achieved.

The introduction of a raw material unloading function, capable of achieving the right balance between the needs of the plant and the storage capacity, is an essential step towards increasing the efficiency of the raw material supply process, and an important step for a fast growing company. Improving operational efficiency is achieved not only by analysing data in order to obtain an increase in efficiency of the different processes associated to the ordering of raw materials, but also by defining methodologies to be applied in order to make the different processes more efficient and at the same time obtain reports that allow us to evaluate the process, identify inefficiencies and consequently opportunities for improvement.

1.3 Method followed in the project

The basis of this project began by understanding the procedures followed by BA in the different processes associated with raw materials, from the determination of needs, acquisition, and allocation of transport to the unloading process in the factory.

Thus, to obtain a contextualisation of the subject of work and better integration of the work of the BA, it was essential to follow the different departments associated with the processes of making orders, management and unloading of raw materials obtaining an overview of the whole process.

Next, a study was carried out on how the requirements and the purchasing and unloading plan are constructed and what helpful information can be extracted from them with the accompaniment of the purchasing department.

Subsequently, to obtain a more precise and detailed understanding of the different processes and thus identify possible inefficiencies, the work of the batch and supply department was monitored to understand not only in theory how the raw material needs are determined but also how the process is carried out in practice. During the same period, it was also possible to understand how the logistics of unloading raw material trucks work.

Such monitoring allowed us to know which processes needed to be analysed, identify inefficiencies, and thus seek improvement solutions, intending to make them more efficient and straightforward.

Thus, in an initial phase, a study was carried out to implement the procedure that will allow the company to have the raw material consumptions in the ERP and thus obtain the actual stock of RM.

With the actual stock and production planning, it was possible to develop an excel model in which the planned tonnes for a month were considered and through the factory revenues to obtain the needs according to the factory rules. Furthermore, the analysis of this document allowed BA to study the feasibility of performing the automatic process in the company's ERP and describe the ideal process to implement.

An analysis of the restrictions and limitations of raw material unloading was carried out to develop an unloading planning system to improve the efficiency of the unloading period of the plant through a time slot management application based on restrictions, available stock and consumption.

Finally, key performance indicators (KPIs) were defined, necessary to monitor the processes associated with RM, the unloading planning, and the process control. Progress reports were also created to have a continuous evaluation of the situation.

All these steps allowed us to define actions to increase operational efficiency and, consequently, to have a better and more efficient unloading service.

1.4 Dissertation structure

This dissertation is structured into five chapters.

The first chapter presents the company where the project was conducted, the context, and an introduction to the methodology followed during the project.

In turn, the second chapter describes the literature review, where topics that helped the development of this dissertation are addressed, such as supply chain, logistics and process mapping. Finally, the third chapter describes BA's production process and presents the current processes in raw material planning.

In the fourth chapter, the opportunities for improvement are identified, and the corresponding means are used to measure and analyse the efficiency of these processes. Finally, chapter five concludes and summarises all the above chapters and the conclusions drawn.

All these steps made it possible to define actions to increase the operational efficiency of the different associated with the planning of raw materials.

2 Literature Review

This chapter contains the state of the art related to the project, thus providing a theoretical framework. Within the scope of this study, the literature review introduces and associates concepts related to the supply chain (SC) and Logistics, also presenting methods used to classify materials according to different criteria.

The emergence of adverse situations, such as a pandemic or a war in Europe, increases the SC complexity and a company's logistics functions. In the face of these adversities, as in any threatening situation, there is a need to innovate and improve services and product quality to stand out in the market and not be vulnerable to adversities.

In a company, one way to innovate and be competitive is to increase the efficiency of the SC to obtain a product with the best possible quality, precise delivery time and effective customer service for the lowest price. To achieve this objective, it is necessary to reconcile the technologies emerging on the market with the experience of the company's employees (Akkerman, Farahani, and Grunow 2010).

Improving the planning of raw materials is a competitive advantage for the company because besides having a considerable cost in the total costs of a company, the ability to respond to market demand represents a meaningful improvement in the efficiency of the SC (Kunrath, Dresch, and Veit 2022).

2.1 Supply Chain

As globalization increases the complexity of the supply chain, so do the types of flows and global consumption patterns.

SC concerns the process from when a customer places an order until he receives the final product. This process includes the planning, execution and control of all activities related to the flow of materials, as well as information, from the purchase of the raw material to the delivery to the customer (Ji and Chiadamrong 2022).

Generally, it is divided into three major parts: supply, production system and distribution system. Sourcing refers to determining how, where and when we obtain raw materials from our suppliers.

In turn, the production system concerns the planning, management, and execution of all the manufacturing stages that allow the final product to be obtained.

Finally, distribution concerns the phase from the collection of the finished product where it was produced to delivery to the customer at the agreed destination. Usually, these last two are planned independently.

All this is possible through networks of distributors, warehouses, physical shops or even at the destination.

2.1.1 Supply Chain Management

Supply chain management (SCM) is concerned with the supply, planning, execution and control of the flow of products in production and distribution to the customer to achieve the best cost-efficiency ratio, following market requirements and obtaining a more intelligent, flexible and adaptive SC (AndriiBoiko 2018).

SCM includes the planning and managing of all activities involved with purchasing, production, distribution and all logistics activities. It also includes coordination and collaboration with chain partners, which may be suppliers, intermediaries, external service providers and customers. In essence, SCM integrates supply and demand management within and across companies.

According to the literature of (Qi Li 2019), SCM presents four flows: business flow, material flow, capital flow and information flow. These flows are essential in a competitive business environment, impacting the organization's success.

Although these concepts can often be confused with logistics management concepts due to their similarities and points in common, it is important to understand their differences. SCM is the overall process of supplying a product, seen as a single entity where collaboration exists between manufacturers, suppliers, distributors, trading partners and customers. In contrast, logistics management refers to a part of SC with fragmented elements, such as managing the warehouse and the internal and external transport flows from sourcing (supply) to final delivery. The most significant change is that in SCM, suppliers and end users are included in the planning process, thus going beyond the boundaries of a single organization.

Its main objective is to achieve maximum competitiveness in the market and optimize its benefits in favor of logistics, which aims to achieve customer satisfaction through perfect order management.

Thus, SCM can be considered a strategic planning process, with strategic decision-making taking on greater relevance than operational systems.

SCM provides a different approach to dealing with inventory as it defines that inventory should be used as a last resort to balance the flow of the integrated product through the pipeline. Usually, inventory is used as a safety valve at different supply chain stages, leading to high inventory-related costs.

It relies on using integrated information systems that are part of the entire supply chain rather than acting in isolation for each stakeholder. These increase the visibility of product demand and stock levels throughout the SC.

The supply chain has been increasing its complexity which leads to the need for more careful management of processes and relationships along the supply chain.

Organizations function in a network to create value for the customer through products or services. Their interaction is both upstream and downstream, as it includes not only suppliers but also logistics service providers (LSP), carriers, and shippers, among others, for the physical movements of cargo, in addition to the information and financial flows associated with them, and in the end, customers (Konovalenko and Ludwig 2019).

SCM addresses three key challenges: coordinating with other decision levels, achieving global optimization and managing uncertainty (Guedes 2021).

Information sharing between stakeholders is key to coordination between parties in a supply chain (Kumar and Pugazhendhi 2012).

As for the direction of the information flow, it should relate to inventory and production plans and be two-way communication between downstream and upstream partners. Information regarding sales and demand forecasts is downstream to upstream flows in the supply chain. Good sharing of information can lead to cost reduction related to the whole supply chain and consequently improve customer service. Besides products and financial flow, effective information sharing is crucial in supply chain management (Pham et al. 2019).

According to AndriiBoiko (2018), implementing SCM solutions enables companies to gain competitive advantages:

- reduction of acquisition costs by 5-15%;

- reduction of warehouse inventory by 20-40%;
- reduction of production costs by 5-15%;
- reduction of order processing time and cost by 20-40%;
- reduction of time to market by 15-30%
- increased profits by 5-15%.

An optimized supply chain operation leads to an improved planning system, better warehouse inventory management, more on-time deliveries, demand conformity, cost reduction and, in the end, increased market value for the company.

2.1.2 Supply chain planning

Supply chain planning (SCP) is the coordination of all the stages of the supply chain to improve the flow of its products, services and information from the supplier to the customer, allowing a balance between supply and demand.

According to the author Akkerman, Farahani, and Grunow (2010), SCP problems are always associated with poor communication and coordination between different teams responsible for different parts of the supply chain.

Through a general trade-off analysis in the planning of services, expenses, costs and working capital in SC planning, it is possible to minimize costs and maximize profits.

An essential characteristic that a supply chain must have is to be flexible internally and externally, as this guarantees a long-term performance that is resilient and resistant to possible market changes (Qi Li 2019).

The problems related to the lack of planning in SC are due to poor communication and coordination. Through a combination of cost minimization and profit maximization, it is possible to address the overall planning commitment: service, costs, capital expenditure and working capital.

According to the author Rudberg and Thulin (2009), management decision-making is divided into different levels of decision-making, conditioned by their time horizon (long, medium or short term) or the type of planning (operational, strategic or tactical).

Thus, we can divide the SCP into three levels: the creation of the distribution network corresponds to a decision taken in the long term in which the physical structures of different parts of the SC are dimensioned, such as determining the need and characteristics of warehouses or transport links. In turn, the second level would be distribution network planning, in which distribution planning decisions are made. They are based on demand satisfaction and medium-term forecasts.

Finally, the last level, in the short term, is transport planning, which concerns transport allocation to confirmed customer orders.

2.2 Logistics

According to Christopher (2016), process logistics refers to the management of the flow of materials, information, and resources within a process. It is a key spectrum of supply chain management and focuses on optimizing process efficiency and effectiveness.

In process logistics, activities such as transportation, warehousing, inventory management and materials handling are carefully planned and coordinated to ensure that materials and resources are available when and where they are needed (Ballou 2003). This may involve designing and implementing inventory tracking and management systems (Heizer, Render, and Munson

2016), coordinating the movement of materials and resources within the process (Christopher 2016) and identifying and resolving bottlenecks and other inefficiencies (Ballou 2003).

Process logistics can be applied in a variety of industries, including manufacturing, healthcare, and retail (Christopher 2016). It can be used to improve efficiency, reduce costs, and increase customer satisfaction by ensuring that materials and resources are available when and where they are needed (Heizer, Render, and Munson 2016). In the case of the glass industry, logistics is the activity that aims to place the correct order in the agreed place and time at the lowest possible cost. This is responsible for planning and managing all product movements from the production stage to distribution to the customer, through packaging and storage in warehouses.

Logistics networks are complex, dynamic, and highly interconnected and require the coordination of simultaneous processes. A lack of logistics planning can lead to inefficiencies not only at the operational level, but also in terms of costs.

Logistics is often used in conjunction with other supply chain management techniques such as lean manufacturing and Six Sigma to optimize the flow of materials and resources within a process (Ballou 2003).

2.2.1 Incoterms

Incoterms (International Commercial Terms) are standard terms used in contracts and applied in national and international buying and selling transactions.

They consist of 11 rules that define who is responsible for different tasks during international transactions. They are used to define responsibility for goods throughout a shipment, i.e., they specify when responsibility for the goods is transferred from the supplier to the buyer. They also define who pays what costs for the goods and their transportation.

Each entity should consider which incoterm is best for them before negotiating the sales contract to avoid unexpected costs and unnecessary complications.

According to the obligation of both parties involved, there are four categories for grouping incoterms. EXW (Ex Works) is considered the minimum obligation for the seller, and DDP (Delivered Duty Paid) is the maximum obligation for the seller.

According to B.V (2017), the incoterms will be defined below:

- Ex Works (EXW): The seller is not responsible for the loading or delivery of the goods;
- Free carriage (FCA): The seller delivers the goods to an entity designated by the customer, and the risks of the delivery pass to the buyer;
- Carriage paid to (CPT): The seller delivers the goods to an entity designated by him and is responsible for delivery of the goods at the place of destination;
- Carriage and insurance paid to (CIP): It is the same as CPT, but in this case, the seller is not responsible for the conditions in which the goods will arrive at the place of destination;
- Delivered at Place (DAP): The Seller is responsible for delivery, and the buyer is again responsible for unloading the goods at the place of destination;
- Delivered at place unloaded (DPU): The Seller is responsible for the delivery and unloading of the goods, and only after that is the risk transferred to the buyer;
- Delivered Duty Paid (DDP): The seller bears all costs and risks up to delivery but also has the responsibility to clear the goods for both export and import, as well as to formalize all customs formalities;

The incoterms that are most used and have the most significant relevance in the market are the first two because in this way the company is free of any liability on the transport.

2.2.2 Digitalization in Logistics

In recent years, numerous researchers have contributed to the development of knowledge management and Industry 4.0 during the digital transformation era.

Industry 4.0 represents the fourth industrial revolution and is characterized by digital transformation.

While some companies still try to resist such changes, digital transformation technologies and models are increasingly gaining ground with the creation of ideas and prototypes.

Emerging technologies such as IoT (Internet of Things) and full process integration services allow industries to increase quality, flexibility and efficiencies with the lowest possible cost and environmental impact, thus creating intrinsic value for industries and society.

Digitization, in the practical concept of the word, represents the transformation of an analog signal from our physical supply chain into a digital signal that can be analysed and processed electronically. This allows communication anywhere, anytime, by any user with any device.

This process will allow outstanding communication and easy access to information at any stage of the supply chain, its processing and analysis. This will allow for easier and quicker decision-making.

Throughout the supply chain, the impact of this concept on logistics is essential, as it enables full real-time transparency from suppliers to customers and vice versa, connects and decentralizes processes and leads to autonomous management (Kayikci 2018).

Logistics can gain a broad view with the adoption of digital technologies such as cloud, data analysis, machine learning, blockchain, IoT, among others, on how to have sustainable development through appropriate technologies, enabling and horizontally integrating the supply chain actors.

The benefits of digitalization include planning, managing, and synchronizing transport and logistics operations based on cooperation, connectivity, adaptability, integration, autonomous control, and cognitive enhancement.

In addition, it enables full real-time transparency along the entire supply chain, increasing visibility and the efficiency of transport and logistics centres.

Big data analytics and collecting information in the Cloud achieve a higher optimization level.

Management decisions can be better informed through decentralized and autonomous decision-making, the design of intelligent and open user interfaces, enabling horizontal and vertical collaboration. Increased automation is achieved with human-machine interaction and by reducing errors in complex processes. Finally, a better understanding of the consumer experience is possible due to, for example, augmented reality solutions. In addition, digitized companies are better prepared to react promptly and adapt to disruptions along the supply chain, as their workflows are optimized, and lead times reduced.

Digitalization impacts logistics in sustainability's economic, environmental, and social dimensions. Regarding economic effects, the digital logistics ecosystem should provide an accessible and efficient operating system that includes collaborative solutions and a mix of transport mode choices and supports the local economy. From an environmental perspective, it is essential to enhance the use of renewable energy sources and technologies that reuse and recycle their components, minimizing gas emissions, pollution, and waste. At the social level, the community's needs must be met, promoting security, equity, and quality of life for individuals (Kayikci 2018).

2.2.3 Planning in Logistics

According to the literature Rushton, Croucher, and Baker (2010), planning in logistics should be carried out according to a specific hierarchy reflecting different time horizons. These are generally classified as strategic, tactical, and operational, as it is possible to visualize on the left side of figure 2.1. In the exact figure, it is possible to see an overlap between the main planning phases, which emphasizes that there are many factors that the different phases of this hierarchy can cover.

The choice of transport mode can, for example, be an initial strategic decision and a subsequent tactical decision for the same company.

So, this may be a strategic decision for a company setting up a new global logistics operation. However, it may also be a tactical decision for another company that is the leading supplier to the local company and only occasionally exports over long distances.

The figure 2.1 also indicates the interrelationship of planning and control within this hierarchy. Both elements are essential to an effective and efficient logistics operation.

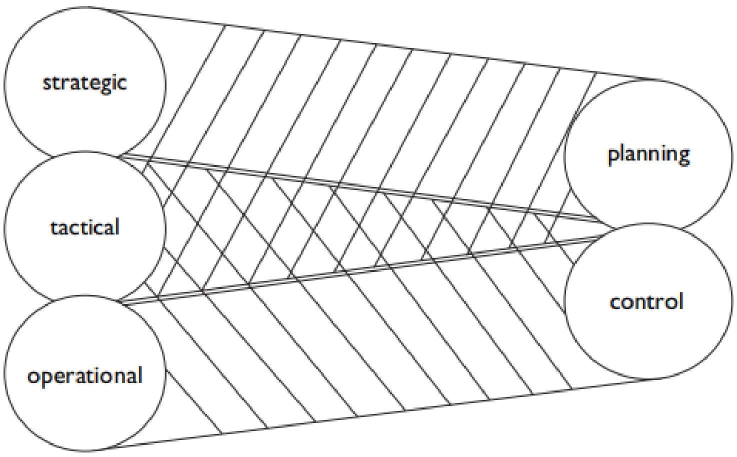

Figure 2.1: Logistics planning hierarchy (Rushton, Croucher, and Baker 2010)

Planning is about ensuring the operation is set up to work correctly, doing the right thing or preparing and planning the operation effectively. Control is about managing the operation correctly, doing the right thing, or ensuring that the operation is being run effectively.

Some of the main aspects and differences between the three-time horizons are summarised in Figure 2.1. The importance and relevance of these different aspects will, of course, vary according to the type and scale of the business, product, etc. It is helpful to be aware of the planning horizon and the associated implications for each decision taken.

The planning and control of an operation can also be described in the context of the more comprehensive planning cycle. This emphasizes the need for a systematic approach where continuous review occurs. This is a fundamental concept in logistics because most operations need to be highly dynamic and are subject to continuous change, as both demand and supply of goods and products regularly vary according to changing customer demands for new products and better product availability. An example of a reasonably common framework is shown as the planning and control cycle in Figure 2.2.

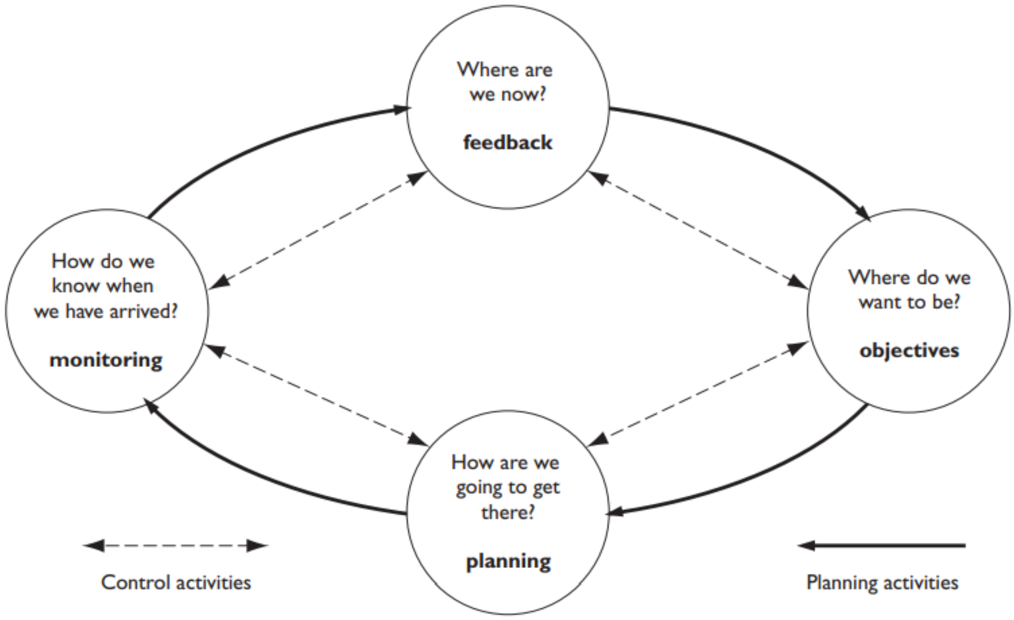

Figure 2.2: The planning and control cycle (Rushton, Croucher, and Baker 2010)

The cycle starts with the question, "Where are we now?" Here the aim is to provide a picture of the current position. This can be through an information feedback procedure or a logistics or distribution audit. The second phase is to determine the logistics process's objectives and identify what the operation should try to achieve. These need to relate to customer service requirements, marketing decisions, etc.

The third phase of the cycle is the planning process which covers the strategic and operational levels discussed earlier. Finally, there is a need for monitoring and control procedures to measure the effectiveness of the distribution operation against the plan. The cycle has become a full circle, and the process is ready to start again. This allows for the dynamic nature of logistics and the need for continuous review and revision of plans, policies, and operations. This must be undertaken within a positive planning framework to maintain continuity and progress.

2.2.4 Process Mapping

According to author Damelio (2011), process mapping is a visual representation of the steps and tasks involved in a business process. This is a helpful tool for process improvement and quality management.

It can be used to document, analyse, and improve processes by identifying bottlenecks, inefficiencies and areas for improvement and is often used in conjunction with other improvement techniques such as lean manufacturing and Six Sigma (Antonacci et al. 2021).

To create a process mapping, it is first necessary to define the scope of the process, what the purpose is, identify stakeholders and boundaries under analysis. Next, map the current process, using a process map to document the different steps and any outputs, inputs, or decision points.

The next step concerns the documentation of the revised process. Finally, using the knowledge gained from the process analysis, a new process map is created that reflects the changes made (Damelio 2011).

Finally, the planned process can be implemented by communicating the changes to all stakeholders and ensuring everyone understands their roles and responsibilities in the new process (Antonacci et al. 2021).

When creating a map, it is essential to be as accurate and detailed as possible so that processes or areas for improvement can be identified more easily. Consider adding notes and annotations to the map to provide more context and explanation.

There are several examples of making a process map. However, the most common is the use of flowchart symbols to represent the different steps in the process. The symbols used in these process maps are the following:

- the rectangle: represents a task or action
- the arrow: to the process flow
- the diamond: represents a decision point.

Consequently, there are also various types of process maps, such as flowcharts swim lane diagrams, value flow charts, and SIPOC diagrams are represented in figure 2.3 in the respective order (Damelio 2011).

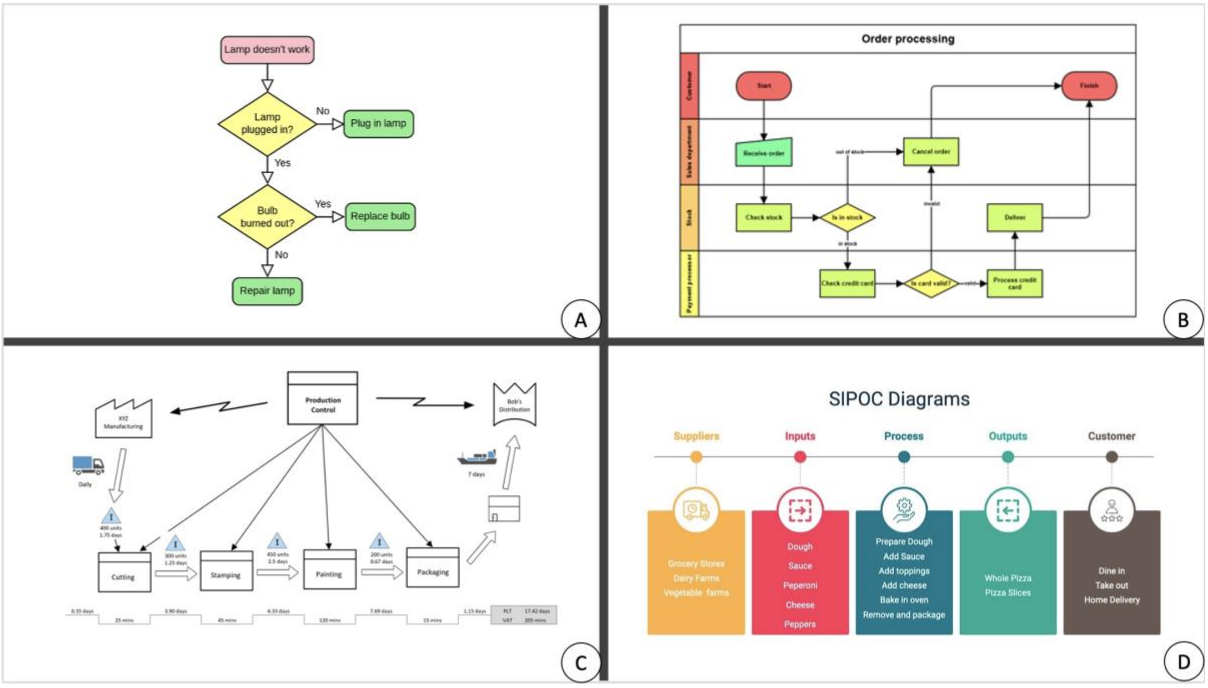

Figure 2.3: Process Maps (A- Flowchart; B- Swim Lane; C- Value Flow Chart ; D- SIPOC Diagram) referenced respectively in (Heiliger. ; Grapholite 2020; Navvia 2021; Roseke 2019)

The Flowchart, represented by the letter A, is the most common process map and is used to show the steps of a process sequentially, from beginning to end, using the previously mentioned symbols to represent different activities.

In turn, represented by the letter B, the Swim Lane diagram's primary purpose is to show the flow of work between different teams or departments, using the lines to represent each team.

Next, the Value flow chart (letter D) allows you to describe the flow of materials and information from supplier to customer, highlighting inefficiencies. Value flow charts identify and eliminate waste in a process and focus on the flow of materials and information.

Finally, the SIPOC diagram, letter C, demonstrates the suppliers, inputs, process, outputs, and customers involved in the process.

Process mapping can be a valuable tool for identifying and improving business processes. However, it is essential to involve all relevant stakeholders and regularly review and update the process to ensure it remains effective.

2.2.5 Six Sigma

According to McCarty et al. (2005) Motorola engineer Bill Smith developed the Six Sigma programme in response to the need to improve quality and reduce defects in their products.

Six Sigma is a methodology that aims to improve the quality and efficiency of business processes by identifying and eliminating defects and variability.

It uses a data-driven approach to decision-making and a systematic approach to problem-solving, focusing on customer needs and continuous improvement.

The main objectives of Six Sigma are to reduce defects and variability in business processes, improve customer satisfaction, and increase profitability. To achieve these objectives, a range of tools and techniques, such as statistical analysis and process mapping, are used to identify and prioritize areas for improvement.

The two main methods used in the Six Sigma methodology are the DMAIC (Define, Measure, Analyse, Improve, Control) method and the DMADV (Define, Measure, Analyse, Design, Verify) method.

In the DMAIC method, practitioners follow a structured process to identify and solve problems:

- Define: Identify the problem and define the objectives of the improvement project.
- Measure: Collect data on the current process and identify areas for improvement.
- Analyse: Analyse the data to understand the root causes of the problem.
- Improve: Develop and implement solutions to address the root causes of the problem.
- Control: Monitor the process to ensure improvements are sustained over time.

In the DMADV method, practitioners follow a similar process to design new processes that are optimised in terms of quality and efficiency:

- Define: Identify customer needs and define the objectives of the design project.
- Measure: Collect data on the current process and identify areas for improvement.
- Analyse: Analyse the data to understand the root causes of the problem.
- Design: Develop and design new processes that meet customer needs.
- Verify: Verify that the new processes meet the design criteria and requirements.

The DMAIC method is used to improve existing processes, while the DMADV method is used to design new processes.

2.2.6 Pareto Principle

According to author Koch (2014), the Pareto Principle was developed by economist Vilfredo Pareto. This principle, also known as the 80/20 rule, is a general rule that states that in many situations, about 80% of the effects come from 20% of the causes. It is a helpful heuristic for identifying the most critical factors in each situation and making decisions about allocating resources.

Applying this principle to existing stocks in a company, it is usually found that a small portion of items is responsible for almost the entire stock value in the warehouse. Therefore, such a rule constitutes an important management support tool, allowing priorities to be assigned in stock management, focusing the attention of managers and existing resources on those items capable of generating the most excellent profits for the company.

In turn, the ABC curve, also known as the Pareto chart or ABC analysis, is a graphical representation of the Pareto principle and is used to identify the most important items of a given set and to prioritise them for management attention (Kaplan 2001).

To construct it, the items in each set are ranked according to their impact or importance and then plotted on a graph with impact on the y-axis and items on the x-axis. The resulting curve usually takes the form of a "long tail, " as depicted in figure 2.4.

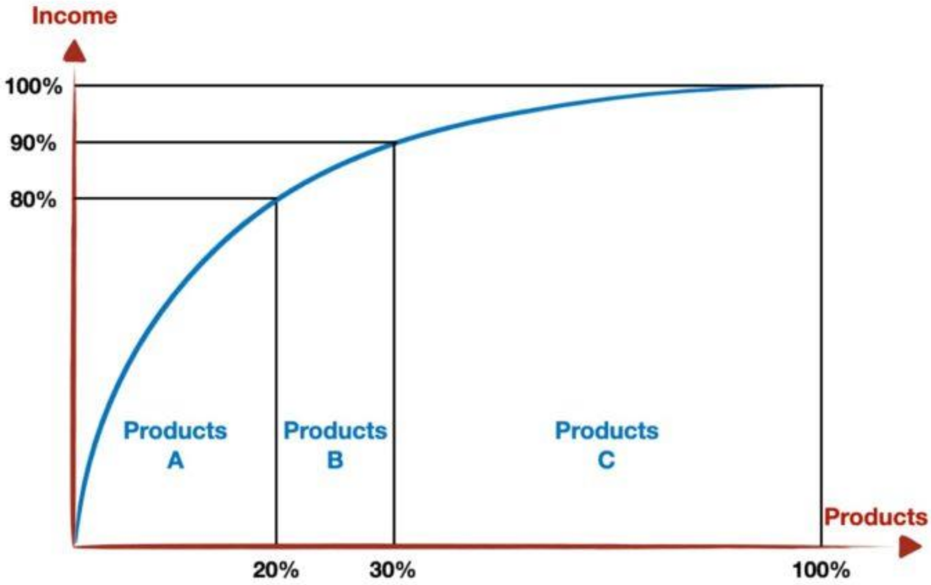

Figure 2.4: Graph with ABC analysis (Inventory 2020)

- Class A: It is estimated that about 20% of the items account for 80% of the usage value. This class refers to items of greater economic importance, which should be managed more carefully and controlled more strictly to avoid breakdowns.
- Class B: It is estimated that about 30% of the items correspond to 15% of the use value. It is a class of articles with intermediate importance, requiring medium care in management.
- Class C: It is estimated that about 50% of the articles corresponding to 5% of the use value. This is the class of most minor relative importance and, therefore, the least critical. Therefore, the corresponding items do not require as strict control compared to the other item classifications presented.

The ABC curve is often used in inventory management to identify the most important items in a company's inventory and to allocate resources accordingly. However, it can also be used in other contexts, such as marketing, supply chain management and project management, to prioritize actions and allocate resources efficiently (Kaplan 2001).

2.2.7 Stock Management Models

Inventory management is supervising the flow of goods in and out of a warehouse or inventory. This includes the receipt, storage, and distribution of products. There are several different models of stock management, each with its advantages and disadvantages.

Since one of the main objectives of stock management is to reduce the total cost associated with inventories, it is essential first to define the portions to account for it.

Firstly, the cost of holding stocks encompasses storage costs related to facilities, taxes, insurance costs, deterioration and obsolescence, and the cost of tied-up capital (Jacobs and Chase 2016).

The cost of orders, on the other hand, includes direct and indirect expenses associated with the purchase of material, from the amount paid to the supplier, which represents the cost of acquisition, to the cost of transport, reception, storage and order processing.

Finally, the out-of-stock cost represents the costs associated with unfulfilled demand due to out-of-stock items. These are the most difficult costs to estimate since they consider lost sales, the effect of customer loss and compensation for delay (Jacobs and Chase 2016).

Considering that demand and delivery time are constant, there are no stock-outs, deliveries are instantaneous, and there are no quantity discounts, it is possible to determine the total cost according to equation 1 and 2 (Vasconcelos 1991). Figure 2.5 shows the total cost curve.

$$Total\ annual\ cost = Annual\ order\ cost + Cost\ of\ holding\ annual\ stock \qquad (1)$$

$$= DC + \frac{D}{Q} \times S + \frac{Q}{2} \times H \qquad (2)$$

Where:

- D is the annual demand;
- C is the unit cost;
- Q is the quantity to be ordered;
- S is the cost of placing an order and H is the cost of holding unit stock.

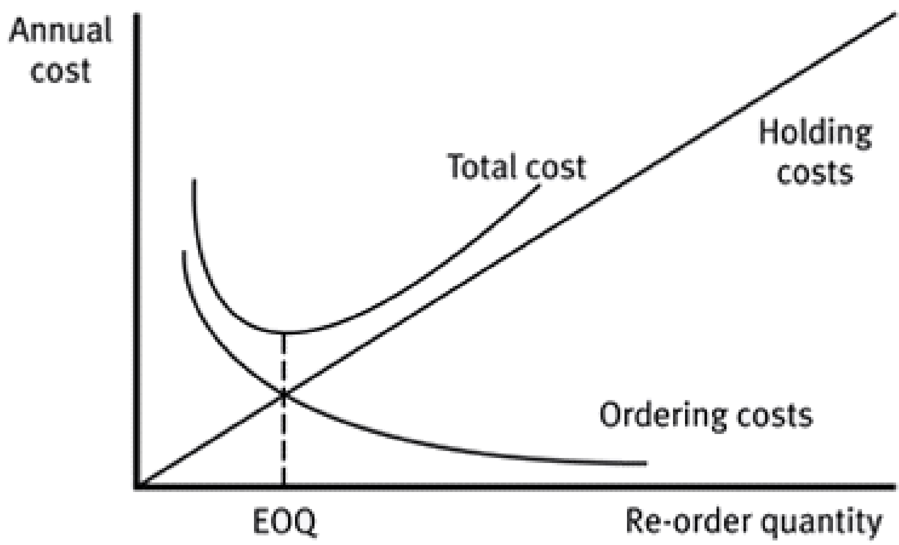

Figure 2.5: Total cost curve (KONGTARAT 2018)

Analysing the graph in figure 2.5 concluded that the minimum total cost occurs for a given quantity to be ordered, called Economic Order Quantity (EOQ) when the cost of holding stock equals the cost of ordering (Chase 2004).

Thus, the Economic Order Quantity is determined by equating to zero the derivative to "Q" of the total cost equation, giving rise to equation 3.

$$EOQ = \sqrt{\frac{2DS}{H}} \qquad (3)$$

Where:

- QEE is the Economic Order Quantity;
- D is the annual demand;
- S is the cost of placing an order and H is the cost of holding unit stock.
- H is the cost of holding unit stock.

According to Chase (2004), there are two classical methods of replenishment: the continuous review model, and the periodic review model.

The following analysis considers constant demand and delivery time.

Model Continuing Review

The continuous review model defines that when a new order is placed at the reorder point (R), the quantity (Q) equal to EOQ should be ordered, as shown in figure 2.6.

This model requires permanent control of stocks (Chase 2004).

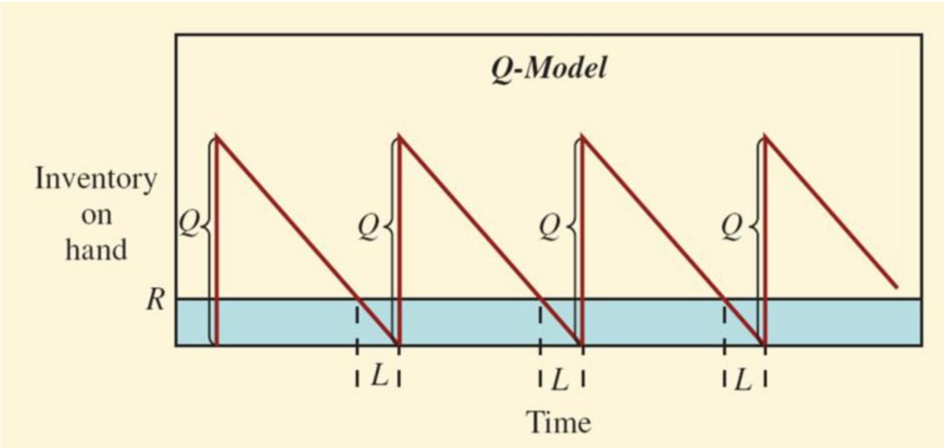

Figure 2.6: Model continuing review (Almeida and Teixeira 2005)

Considering the uncertainty associated with the business reality, it is possible to see that the model under analysis presents some assumptions that are hardly applicable to conditions such as constant demand and delivery time. In this context, the need to build a safety stock arises to ensure some protection against the possibility of rupture during the delivery period.

Safety stock can be defined according to different approaches (Jacobs and Chase 2016). In practical terms, generally, an acceptable service level or rate of rupture is established, for which the safety stock is calculated according to equation 4.

$$SS = z \times \sigma_l \tag{4}$$

Where:

SS is the safety stock;

z is the safety factor (taken from the Normal Table) as a function of the defined service level;

σL is the standard deviation of the on-time demand.

Therefore, the calculation of the order point (R), considering the safety stock, is carried out according to equation 5 (Jacobs and Chase 2016).

$$R = \overline{\mathrm{d}}\mathrm{L} + \mathrm{z}\sigma_l \tag{5}$$

Where:

- R is the order point in units;
- $\bar{d}$ is the average daily demand;
- L is the delivery time in days;
- z is the safety factor (taken from the Normal Table) as a function of the defined service level;
- σ_l is the standard deviation of the demand in delivery time.

Periodic Review Model

In the Periodic Review Model, stocks are reviewed, and orders are placed at the end of a predefined period, P.

This model has the particularity of generating orders of variable quantities, from period to period, according to demand (Jacobs and Chase 2016).

In this model, represented in Figure 2.7, the safety stock is generally higher than the previous model for the same probability of shortage since the period of the risk of shortage is also higher (Vasconcelos 1991).

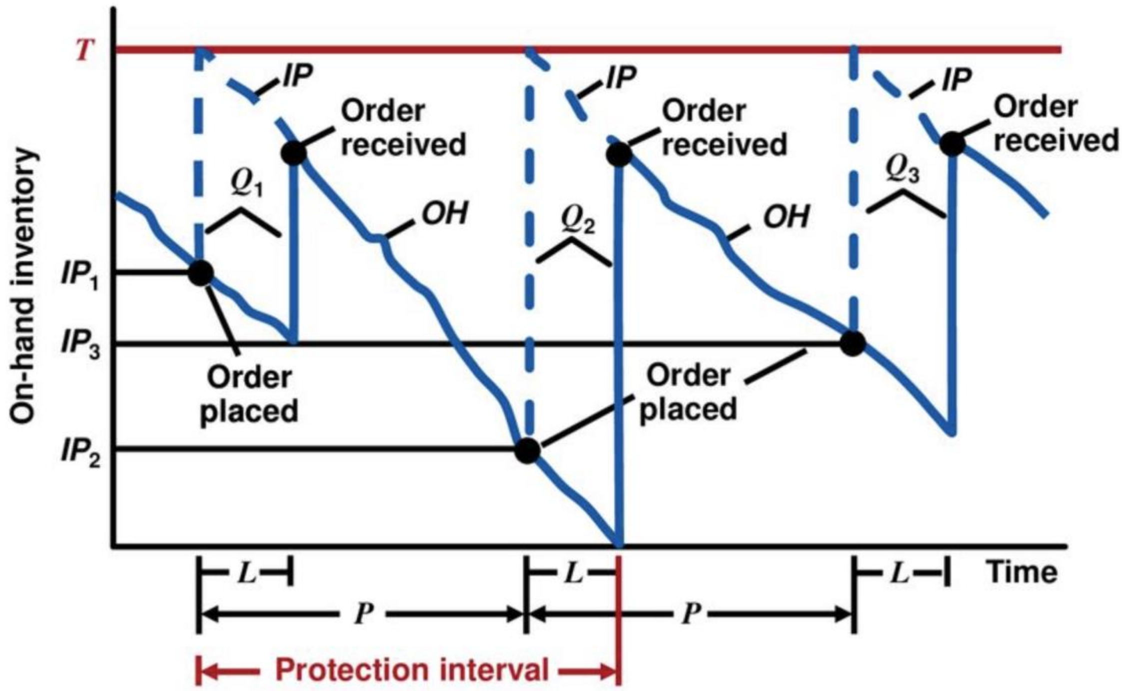

Figure 2.7: Periodic Review Model (Boeg)

In the case of this model, the safety stock is calculated according to equation 6 (Jacobs and Chase 2016).

$$SS = z\sigma_{P+L} \tag{6}$$

Where:

- SS is the safety stock;
- z is the safety factor (taken from the Normal Table) as a function of the defined service level;
- P is the revision period;
- L is the delivery time;
- σ_{P+L} is the standard deviation of demand in the breakdown risk period (P+L).

In turn, the quantity to be ordered is determined, in each review period, according to the parameters set out in equation 7 (Jacobs and Chase 2016).

$$q = \overline{\mathrm{d}} \times (\mathrm{P} + \mathrm{L}) + z\sigma_{P+L} - I \quad (7)$$

Where:

- q is the quantity to be ordered;
- P is the review period in days;
- L is the delivery time in days;
- $\overline{\mathrm{d}}$ is the average daily demand;
- z is the safety factor (taken from the Normal Table) as a function of the defined service level;
- $\sigma T{+}L$ is the standard deviation of demand in the risk period (T+L);
- I is the stock in the warehouse and, if any, the ordered undelivered quantity.

Of the models exposed, the periodic review model has the highest average stock and safety level compared to the fixed order quantity model. However, it does not require such strict control of stock quantities.

2.3 Supply

In economics, the term "supply" refers to the total quantity of a specific good or service that is available for purchase at a given time. It is one of the fundamental concepts in economics, along with demand, which refers to the desire and ability of consumers to purchase goods and services.

However, it is important to apply the right management methods so that you do not incur costs either through understocking or overstocking. For this reason, in the following chapters the different management methods will be studied and then the relationship between forecasting and replenishment.

2.3.1 Supply Models

The provisioning model aims to know when and in what quantities we must supply our inventory with a particular product. There are two distinct policies regarding the time of checking the inventory: continuous review and periodic review.

The continuous review, the evaluation of the need to place a new order, takes place every time there is consumption in the warehouses or depots.

In the periodic review, the assessment of the need for a new order is made within a defined time interval. The periodic revision is more straightforward and accessible, although it is not as flexible as the former. However, in situations with a high variability of demand and delivery deadlines, the continuous revision system is more effective for avoiding stock rupture. (Ivanov, Tsipoulanidis, and Schonberger 2019)

Generally, when a fixed order quantity is defined, it is necessary to consider certain costs, such as ordering and storage costs. For ordering some materials, we can define a fixed lot policy which consists of always ordering the same quantity when there is a need for an order.

Variable batches can also be used, equal to the difference between the stock we want to obtain after the order and what exists at the moment so as not to exceed our warehouse capacity or deposit. The latter allows greater control of the individual stock of each material, ensuring that the inventory is not excessive.

On the other hand, this practice increases the number of orders placed, and consequently, the associated costs are higher.

A fixed lot policy reduces the probability of stock-outs due to demand variability, as more extensive stocks are usually generated to compensate for the transport. (Ivanov, Tsipoulanidis, and Schonberger 2019)

2.3.2 Correspondence between forecasting and replenishment

Efficient inventory management is based on optimization processes, such as minimizing costs and meeting a certain service level. Due to the uncertainty associated with demand and delivery time, it is necessary to establish an optimal stock level. This procedure begins with using predictive models to know the average and variance of demand over the delivery time. Parametric models assume that demand follows a given probability distribution and thus use the forecast and its error to define service levels and reorder points. (Pinçe, Turrini, and Meissner 2021).

The literature on inventory management assumes from the outset that demand is independent and identically distributed over the delivery time. Thus, the safety stock is easily obtained by multiplying the demand variance by a factor corresponding to the desired service level. However, this assumption should not be taken for granted; therefore, the correct approach starts by knowing the distribution of demand beforehand (Prak, Teunter, and Syntetos 2017).

As mentioned above, the imposition of safety stock is due to the inability to forecast demand accurately. Logically, the increased uncertainty associated with forecasting requires the setting of higher safety stocks. Prak and Teunter (2019) list some factors that cause the referred uncertainty. These include the model parameters to be estimated, the small number of historical data, long lead times, and the high demand variance.

3 Raw Materials Operation – AS IS

This chapter describes the current flow of raw materials in the BA, from determining future needs until their delivery to the factory, with subsequent analysis of the inefficiencies identified in this process.

This description will be divided into three essential phases of the flow. The determination of future demand and consequent determination of requirements and placing of orders considering the rules and limits of the factory and finally the process of delivery of raw materials.

To reveal the circumstances that led to the project's development, it is crucial to contextualize the existing problems at BA, starting by explaining its operational activity. The knowledge of the procedures adopted by the company allows us to identify better the processes that can be improved, and which strategy has the potential to lead to such a direction.

3.1 Productive Process

BA, a company specializing in the production of glass packaging and bottles, presents different phases of production, from raw materials to obtain the final product.

According to author Alves (2012) in the compounding phase, the different raw materials are stored, dosed and mixed to make up the vitrifying mass, which will be sent to the furnaces where the melting occurs.

The melted glass is composed mainly of recycled glass, waste ground glass, sand (SiO_2), sodium oxide (Na_2O) and calcium oxide (CaO). Also, it includes small amounts of magnesium oxide (MgO), aluminium oxide (Al_2O_3) and potassium oxide (K_2O). The color intended to be produced influences the proportions and may also generate the need to include other substances.

In the furnaces, the material is melted at a temperature of between 1500 ºC and 1600 °C. The liquefied glass moves along the tank through the gravitational action of the material being poured, passing through a "tuning" phase, where the aim is to ensure thermal homogeneity of the entire melted mass, an essential condition for obtaining a quality product.

After melting, the molten glass goes on to the molding phase, carried out in two stages: in the first, the glass is introduced into the starter mold, located on one side of the machine, where it takes its initial shape (pre-mold); in the second phase, the pre-mold is transferred to the final mold, located on the opposite side of the machine, where the final shape of the article is given, represented in the figure 3.1.

Figure 3.1: Bootles after final moulding (Larguesa 2015)

During this process, the glass comes into contact with the mold walls at relatively low temperatures. The external layers of the articles are, therefore, much colder than the internal ones, and the temperature differential tends to remain due to the low conductivity of the glass so that a thermal treatment called annealing is carried out, which consists of thermally homogenizing the entire glass mass, resulting in the disappearance of all tensions.

After this phase, the articles are taken to the automatic quality inspection machines, which, through various defect detection mechanisms, eliminate non-conforming articles.

Finally, the glass containers are packaged on the exit of the production lines, in layers, on pallets. These are covered with plastic film, which protects all the units and facilitates their transport. The pallets thus formed are transported to the storage location.

Nowadays, the whole process is highly automated and therefore dependent on the proper functioning of the machines and the need for raw materials. Since the furnaces need to be continuously operated, it is crucial to ensure efficient raw material flow management to avoid as much as possible lengthy stoppages due to stock shortages.

3.2 Raw Materials Flow

To produce glass packaging by the process described above seven days a week and twenty-four hours a day, it is necessary to carry out rigorous and careful management to avoid stock rupture. This management is made even more challenging due to the limitations of the raw materials storage depots, their reception schedule, and the rules of the unloading site.

The factory has a continuous production, so the variation in consumption is minimal per raw material if there are no colour changes. However, if there is a shortage of raw materials, there is the possibility of increasing the amount of cullet in the recipe, thus reducing the overall consumption of raw materials. This method is very effective since the recycled glass is transformed into the final product without losses, which does not occur with the other raw materials, where there are considerable losses with the release of carbon into the atmosphere due to the melting process.

With this, it becomes essential to understand how the management and differentiation of the different raw materials are managed and then describe their process from determining the factory's needs to their unloading at the facilities for subsequent ensiling.

3.2.1 Raw Materials description

Raw materials represent the basis of the company's production process and, consequently, the base of the entire business because, without raw materials, there is no production. Without production, the company does not generate business. Thus, the whole supply chain process is broken.

With this, to understand the limitations of managing raw materials in the factory is necessary, first to know what raw materials are under study and how they are transported and stored.

Table 3.1 shows a diagram of the raw materials under analysis, which have different types of transport, packaging, and storage capacities. This difference comes mainly from their characteristics and quantities consumed daily.

Raw Material	*Transport Type*	*Group*
Sand 1	Tipper Truck	Big
Sand 2	Tipper Truck	Big
Sodium Carbonate	Tanker Truck	Big
Limestone	Tanker Truck	Big
Slag	Tanker Truck	Big
Wollastonite	Tanker Truck	Big
Sodium Sulphate	Tanker Truck	Big
Chromite	Big Bags	Small
Coal	Big Bags	Small
Iron Oxide	Big bags	Small

Table 3.1: Raw Materials classification

These were divided into two main groups: large and small raw materials. This distinction is mainly related to the quantity consumed and how their stock is managed.

The large raw materials are transported in tipper trucks, in the case of sand, or tanker trucks for the rest. The sand is the only raw material transported in tipper trucks, so when it arrives at the factory, it is unloaded differently from the others. It is emptied into a place called "tremonha" that has a vibrating base that allows the sand to move to a conveyor belt that will enable it to move until it reaches a lift called "alcatruz" that raises the sand in height, allowing it to be unloaded in the upper part of the silo, represented on figure 3.2.

Figure 3.2: Silo for sand storage

This procedure reduces contamination in this raw material, avoiding its exposure to atmospheric factors as much as possible.

In turn, the remaining large raw materials are unloaded through pipes using a compressed air system that allows the raw material to be moved to its silo through pressure differences.

The small raw materials are transported by trailer trucks in large bags. Each bag allows for the transport of around 1000kg of material, protecting it from contamination both during transport and when stored in the factory, ensuring no alteration to its properties. This fact allows these raw materials to be stored in the factory without the need to put them in a silo when they are received.

Therefore, part of this material can be stored inside our facilities and another part in a silo for consumption. When it is necessary to restock the silo, the factory has direct access to the material, reducing the urgency of the new order.

In this way, we eliminate an important limitation with large raw materials, which is that storage capacity is limited to the capacity of the storage tanks.

These raw materials have a lead time of 21 days, and the management of these materials is done so that we always have stock for 21 days. In other words, knowing the daily consumption and the real stock measured manually, we estimate when there will be a rupture. The collaborator counts back 21 days on that day, and an order is placed to receive the raw material before the stock is out.

All orders are placed considering the defined economic quantity, which is a truck with 26 big bags of 1 tonne each. Another limitation in the management of raw materials has to do with the fact that consumption is not proportional to its reception. The Avintes unit consumes raw materials at the weekend. Still, it can only replenish on Mondays because it does not receive raw material during the weekend, so there is not much storage on Mondays.

As can be seen in table 3.2. even if all silos are at their maximum capacity on Friday, on Monday, some raw materials have stock for a few days, as is the case of sand 1 which has stock for 2 days or soda ash which has an inventory of 3 days, excluding the same day in both. This leads to a high probability of stock rupture in case of a breakdown in one of the pieces of equipment that allows the ensilage of the material, with a repair period exceeding 2 days, which may lead to a stock outage.

Raw Materials	*Storage capacity (ton)*	*Average consumption (TON/Day)*	*Stock Days*	*Monday stock days (TON)*
Sand 1	899	180	4	2
Sand 2	789	130	6	4
Sodium Carbonate	462	90	5	3
Limestone	477	61	7	5
Slag	92	11	8	6
Wallastonite	524	20	25	23
Sodium Sulphate	81	3	29	27
Chromite	15	1.2	12	10
Coal	22	0.2	93	91
Iron Oxide	21	1	21	19

Table 3.2: Raw Materials Stock Analysis

A stock outage could have incalculable consequences because, in addition to stopping production, the stoppage of the furnaces leads to their degradation.

To prevent this from happening, it has been defined as a rule that the silos must always be complete at the end of the day to ensure production in the face of stock shortages.

The management of this type of materials is done in such a way as to receive on Mondays the consumption of Saturday, Sunday and Monday and on the other days the consumption of the day, as represented in figure 3.3 through an example of the factory orders for a week in November. This method allows the silos are always full and thus avoid stock ruptures.

	Areia 1	Areia 2	Calcário	Soda	Escórias	Wollastonita
Pedidos para 2ª feira						
6ª Feira 20h						
Sábado 20h	201	150	66	97	12	22
Domingo 20h	201	150	66	97	12	22
2ª feira 20h	201	150	66	97	12	22
Total	**603**	**450**	**198**	**291**	**35**	**65**
Pedidos diários para o resto da semana						
3ª feira 20h	201	150	66	97	12	22
4ª feira 20h	201	150	66	97	12	22
5ª feira 20h	201	150	66	97	12	22
6ª feira 20h	201	150	66	97	12	22
Silos cheios todos os dias às 20h00						

Figure 3.3: Excel document sent from the batch and furnace team to purchasing

Based on this management principle and the employees' experience, the factory's needs for one week are then defined as described in the following chapter.

3.2.2 Forecasting needs

The flow of raw materials starts with the determination of production requirements. The production requirements are defined at the beginning of the year when the annual production is set.

Subsequently, throughout the year, the requirements are determined each week for the following week so that as close to consumption as possible is received each week.

So that the whole process runs continuously, every week, the needs for the following week are determined by the Batch and Furnace department and sent to the purchasing department, allowing the factory's needs to be transformed into planned receipts.

The placing of orders considers an average consumption per raw material in the current week and, with this value, defines the daily consumption per raw material for the following week. This approximation is only possible because BA has continuous production with reduced variation in consumption. In the event of a colour change, adjustments are made to the order either by the experience of the Batch and Furnace employee or in the production week itself by requesting reinforcements from the supplier.

Thus, the factory has software that automates the weighing of the different raw materials based on the recipe in production. In turn, this system also allows past consumption in the desired period to be obtained.

With this, the factory uses this software to analyse the previous week's consumption, makes a simple daily average of the current week's consumption and estimates the daily consumption of the following week equal to this simple average of the previous week's consumption. If there are changes at the recipe level and consequently at the needs level, the employee adjusts the needs according to his experience.

After estimating needs, the Batch and Furnace team prepares an Excel document, as shown in figure 3.4 and sends it to the purchasing team.

Expected consumption for the week 48

	Daily cons.	Weekly order
Sand 1	201	**1407**
Sand 2	150	**1050**
Sodium Carbonate	97	**679**
Limestone	66	**462**
Slag	12	**81**
Wollastonita	22	**152**
Sodium Sulphate	3	**19**

Figure 3.4: Excel document with the week's needs

Based on this document, the purchasing group will place the orders for the following week, as described below.

3.2.3 Raw materials ordering process

At the beginning of each year, the team carries out a procedure called "Budget", which aims to determine the budget for the following year. This procedure determines what the annual production will be and what the needs will be throughout the year.

The supplier selection procedure is based on five criteria described below:

- Assessment of the supplier's internal organisational capabilities, valuing the certifications that BA believes increase its level of confidence (0-20 points);
- Assessment of the supplier's position in the market and its availability to support volume variation (0-20 points);
- Measurement of the ability to add value to the product (goods or services) through its adaptability, initiative, ability to fulfil purchase orders, technical knowledge, development of innovative solutions, good communication and flexibility. The supplier's social responsibilities are also considered (0-20 points);
- Measurement of the frequency of Supplier complaints per number of deliveries. The supplier's learning and adaptation capacity and the damage caused by the complaint in BA are also assessed (0-20 points);
- Audit score is assessed, if applicable. If a previously assessed supplier is audited, it is imperative to consider this information (0-20 points);

Each evaluation parameter has a comment field where the score given from zero to twenty points must be justified. The supplier evaluation process must be carried out during the 1st quarter of each year so that the performance of the evaluation may be better controlled.

Whenever a Supplier is approved, an evaluation is carried out to obtain a classification according to the table in figure 3.5:

Rating	Supplier's class	Evaluation
> 95	A	Very Good
80 – 95	B	Good
60 – 79	C	Acceptable
< 60	D	Bad

Figure 3.5: Supplier evaluation table

This assessment positively impacts the management of raw materials, as it reduces the degree of uncertainty in both deliveries and supply, which makes planning the different processes easier and reduces situations of raw material supply risk.

After the selection, a contract is formalised in which the quantity to be purchased is agreed upon, and the value per ton is defined.

Based on this contract, the purchasing team receives the factory's needs every week throughout the year and carries out the procedure described in figure 3.6.

After receiving the consumption forecast, it divides the consumption by the transport capacity and by raw material, obtaining the number of lorries to be ordered. Subsequently, they are distributed throughout the week according to the unloading limitations of the factory and the employee's experience, and then the orders are placed. The orders are placed every Thursday, where a line is created in the company's ERP for each lorry, raw material and day. With this procedure, the company's ERP automatically sends an e-mail message to the supplier and haulier with the orders, so that they can supply and transport the goods and deliver them to our installations. This message details the quantity ordered, the agreed value, billing information and the terms and conditions of the BA. This stage is already very efficient and there is little room for improvement.

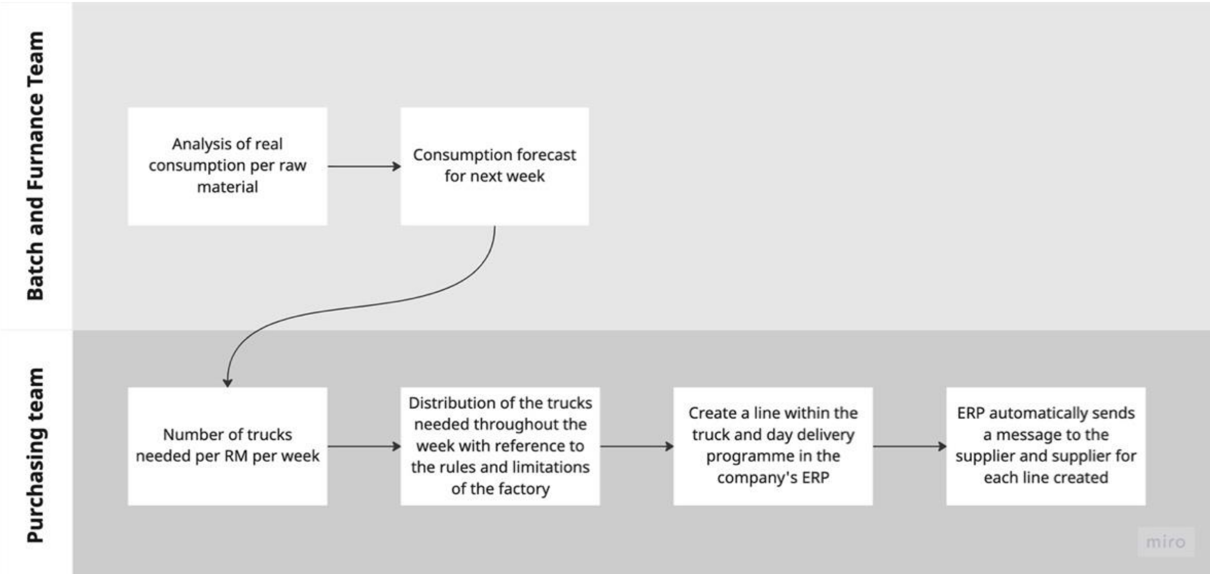

Figure 3.6: Raw materials ordering process

This procedure is schematized in figure 3.6 through a swim lane that describes the consequent steps from the determination of the needs by the Batch and Furnace team and then the ordering of raw materials.

3.2.4 Unloading Process

Concerning the BA unloading process, there is no time reservation, being restricted only to the unloading time of the plant, which in the case of the Avintes unit is from 6 am to 9 pm. This process is based on the FIFO (first in, first out) management and organization rule, that the loads are unloaded sequentially by order of arrival.

However, when trucks or raw materials are considered urgent, either to have better management of the unloading park or due to lack of raw materials, these have priority. Then the FIFO rule is no longer respected.

As we can see in figure 3.7, the whole process begins when the carrier arrives at the plant of destination of the goods with the document "Delivery Note" provided by the supplier of the raw material.

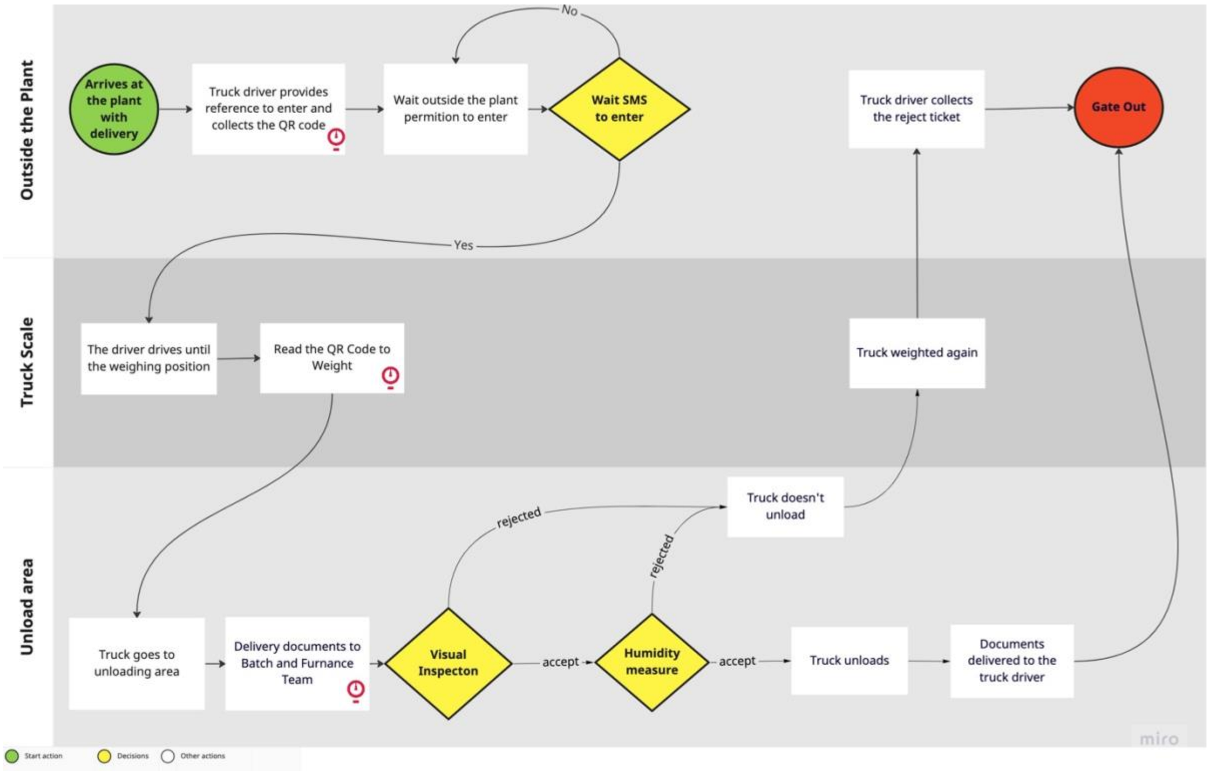

Figure 3.7: Raw materials unloading process

At that moment, he should go to the kiosk at the factory entrance and check the machine shown in figure 3.8.

Figure 3.8: Machine with unloading software

In this machine you will enter the information described in the following table 3.3.

Software required information
• **CMR;** • **Name;** • **Plate Number;** • **Phone Number;** • **Delivery Note;** • **Net Weight;** • **Provider.**

Table 3.3: Information to be inserted by the transporter

After check-in, the driver gets a QR code and waits in the truck queue outside the plant until a message is sent with authorization to enter. At that moment, the system reads the truck's number plate and opens the gate allowing it to move to the scale, represented in the figure 3.9.

Figure 3.9: Weighing scale for raw material

At this point, the driver validates the QR code to perform the weighing and then leaves for the unloading site, represented in figure 3.10, where two cargo inspections are performed by an employee of the Batch and Furnace team after delivering the cargo documents if sand.

Figure 3.10: Sand unloading site

The employee performs a visual inspection and takes a sample of the load to analyse the percentage of humidity. If the cargo passes the visual inspection and has a moisture level below the limit allowed by the plant, it is accepted; if it does not meet the acceptable requirements, the cargo is rejected. In both cases, all the information is recorded in software that sends the information to the company's ERP. The humidity verification is only performed once a day per supplier due to the high affluence and the similar sand path.

These inspections are fundamental for the delivered raw material following factory standards. This allows us to control the quality standards of the material received so that this is not reflected in the quality of the final product and at the same time, reduce costs because the higher the humidity, the higher the weight and the higher the price.

If the truck is accepted, the cargo is unloaded, and the appropriate cargo documents are handed over to the transporter so he can leave. If the load is rejected, the truck is weighed again as proof that it was not unloaded, and then the driver returns and receives the denied goods ticket and gates out of the factory plant.

This process completes the flow of raw materials in the BA Avintes. The detailed analysis of all these processes made it possible to determine and analyse the inefficiencies, as described below.

3.3 Inefficiencies of the process and points to be improved

An impact analysis of the inefficiencies detected was carried out based on company information to understand better the effects of the raw material flow performance in the Avintes plant. This allowed identifying at which levels the efficiency in the processes of raw materials should be improved for further study of its opportunity for improvement.

The actions in the raw material flow mainly impacted the computerization process of consumption, the ordering process and the organization of the unloading period. Currently, all the described raw material flow is very manual and based on inaccurate considerations and little data monitoring.

With this, the objective of this project is to improve the flow of raw materials in the different associated processes, making it more efficient and with more transparent information, thus allowing a better data analysis for continuous improvement.

3.3.1 Raw materials consumption

The first point for improvement concerns recording raw material consumption in the company's ERP. Currently, the raw material consumptions are not given in real-time, but at the end of the month. The raw material entries are offered daily and automatically through the registration software. However, the consumptions are only entered into the ERP system at the end of the month, subtracting the amount of stock available in the system from the one measured manually.

Raw material consumption is an essential aspect of ERP because it impacts different areas of a company, including production, inventory management (Purchasing Team) and financial reporting (Finance team).

Raw materials are essential to the production process in manufacturing organisations such as BA. Therefore, ERP systems can help control the consumption of raw materials, ensuring that sufficient quantities are available for production and that inventory levels are accurately reflected in the system. This helps improve the efficiency of processes along the flow of raw materials and reduce risk situations due to raw material shortages.

At BA this process is manual and inefficient and does not provide company-wide access to available stock. In turn, the lack of information regarding consumption throughout the month means that the process of determining consumption forecasts for subsequent determination of needs is a very manual process that requires the collaboration of several departments. For example, the purchasing team could estimate consumption directly without consulting, and the batch and supply team could only use the current week's consumption in the company's ERP or based on the planning for the next week.

Furthermore, this implements an automatic stock management system impossible, as we cannot have direct access to raw material consumption and consequently to the stock in the system.

This process corresponded to the first part of the project, where the process was described so that the IT and Data Science departments could develop and prepare the company's ERP so that the consumptions could be given daily and compared with the raw material entries, thus obtaining the stock in real time.

Overall, real-time raw material consumption is an important aspect to implement with the company's ERP system to help the organisation effectively manage its resources and make informed decisions about its operations.

3.3.2 Raw materials ordering process

The process of placing orders for raw materials starts when the purchasing team receives the requirements from the factory for the following week. These requirements are based on the previous week's history and planning for the next week.

If production for the following week is similar to the previous one, the consumption data from the last week is considered, compared with the production planning, and forecasts are made.

On the other hand, if the production varies in the type of glass to be produced and consequently the general consumption of raw materials, the order has to be placed based only on the production planning and the employee's experience.

This process is entirely manual and inaccurate, which sometimes leads to excesses or shortages of raw materials during the week that is solved with last-minute adjustments that require both administrative costs (more time spent by employees) and extra transportation costs.

In addition, once the purchasing team has the requirements in an excel file, the data is transferred to another file which divides the total requirements by days of the week and by the number of lorries to be ordered, as one lorry is the economic quantity stipulated by the company.

Afterwards, an employee from the purchasing team must manually enter this information into the company's ERP to make the orders.

As described, this whole process, apart from being unreliable, since it considers the previous week's consumption and not the production for which we want the needs, is inefficient since it is necessary to go through different teams to obtain information which can easily be determined by consulting the consumption in the ERP or the production for the following week.

Furthermore, the current management type always aims to end the day with full silos. Although this type of management reduces the probability of breakdown, it brings other problems, such as the difficulty in unloading all the lorries necessary due to limitations such as silage times, park unloading capacity or consumption being lower than the unloading capacity, which results in long waiting times for the lorry drivers.

This will increase the availability of employees for other tasks and the traceability of the flow of raw materials.

3.3.3 Delivery operation

The average time between check-in and check-out at the Avintes Plant is, on average, about 0:21h above the standard time. Figure 3.11 represents this average time per plant per raw material. The excessive time is mainly due to the time trucks spend waiting until they start to be unloaded. This situation is caused by two factors, the presence of other trucks waiting to be emptied and the lack of consideration of the gradual consumption throughout the day since there is a lack of control over the trucks' arrival time.

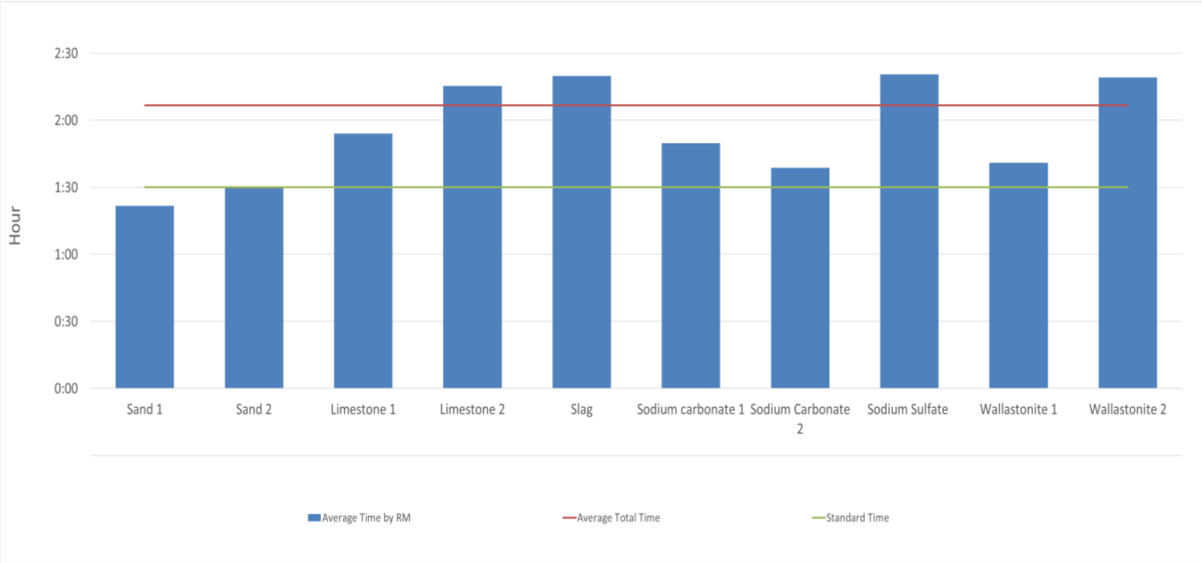

Figure 3.11: Unloading time by raw material

More than half of the raw material trucks spent two or more hours between check-in and check-out, as shown in figure 3.11.

Following operational improvements in the flow of raw materials, with the use of a tool to cope with the increased loads and detect the unexpected need for trucks, the standard time expected between check-in and check-out at the Avintes plant is one hour and half. This is the time required for the entire process between check-in and check-out of the trucks at the plant.

In addition, the significant increase in operational efficiency that the above actions can achieve allows not only to save much waiting time for all parts involved in raw material receipts but also to increase stock predictability and consequently decrease the probability of stock-outs and the response time in eventual crisis periods in the procurement of raw materials.

4 Raw materials flow planning

This chapter outlines the methodology adopted to combat the inefficiencies detected in the previous chapter. The objective was to improve efficiency in the different procedures associated with raw materials to achieve a smoother and more constant logistics operation.

Firstly, the process of computerising consumption in the company's ERP is mentioned, which includes a description of how the process will take place and what the advantages of this considerable improvement will be, as well as enabling other processes or supply chain analyses.

Next, the procedure studied is described, which allows the automatic determination of the company's needs in terms of raw materials and the consequent increase in the visibility of these materials by the purchasing team.

The whole proposal for improving the flow of raw materials ends with the implementation of time slot management according to the needs and physical constraints of the factory, which will allow the transporters and BA to schedule a more restricted period for delivery.

Other opportunities for improvement emerged throughout the study and design of the different processes, also mentioned in the following chapters.

Finally, in order to evaluate the implementation of the different processes not only during this project but also continuously, Key Performance Indicators (KPI) necessary to follow the different processes in the raw material flow were defined, as well as process reports that allow the following the operational performance through the display of the defined KPIs.

4.1 Raw materials flow planning – TO BE

Raw material planning identifies, procures, and manages the raw materials required to produce the final production output. It plays a crucial role in supply chain management by forecasting the raw materials that will be needed in the future, determining required inventory levels, and coordinating the procurement and delivery of these materials to maintain a stable production process.

This chapter has sought to describe how the processes are envisioned, what changes have been made and why to reduce the uncertainty associated with the stock, increasing visibility, and improving the coordination of deliveries of different raw materials.

The planning of raw materials represents a significant improvement in the efficiency of the supply chain and, consequently, a reduction in supply costs and uncertainties.

4.1.1 Consumption process

As described previously, in the current period, the raw material consumptions are manually computerised in the company's ERP at the end of each month. This procedure involves several factory departments, takes about a day to be carried out and represents reduced visibility and control over consumption. Hence, its automation and computerisation are essential. This will not only reduce the manual work of employees from various departments but also improve the visibility of the stock in real-time, and the information will be available transversally to the entire company through the ERP.

Following and monitoring the use of raw materials in real-time, according to their consumption in the production process, will also allow a better understanding of the need for any adjustments to production plans or in managing raw material stocks.

With real-time tracking of raw material consumption comes several benefits, such as:

- Improved efficiency: By monitoring raw material usage in real-time, the organisation can identify areas where raw materials are being wasted and adjust its production process to improve efficiency.
- Improved forecasting: Real-time tracking of raw material consumption can help make more accurate predictions about future raw material requirements.
- Better inventory management: Real-time tracking gives a more accurate picture of the current inventory of raw materials, which helps to manage inventory levels better, adjust needs and study this data to conclude more easily.

For the tracking of raw material consumption, there is the manual tracking method and different automated tracking systems, such as the use of sensors and other monitoring technologies.

Manual tracking was used until then by the plant and concerned with the procedure in which the employee goes to the site to measure manually.

The automated tracking system, with sensors to prove the calculations determined by the automatic tracking, would be the most appropriate method to be applied. However, for reasons internal to the company under analysis, only the process for an automated tracking system with manual verification will be applied and developed.

As represented in figure 4.1, the raw material, when it arrives at the factory from the supplier, will be given input in the company's ERP directly in the silo, on the threshing floor or in the warehouse. In the case of materials stored in the threshing floor or warehouse, they must be physically moved to the silo to be consumed. These raw materials will be consumed when the material leaves the silo to the scales.

To obtain information about the consumption of the factory in the company's ERP, it is first necessary to have a system that allows the reading of these consumptions. In the case of BA Avintes, there is software that assists in weighing the different raw materials in the ideal quantities for the mixture that will later be subject to fusion to produce glass.

When the raw materials leave the respective storage silo, they are weighed, and the weighing information is registered in this software. As the information is already being recorded in the factory's internal programme, it must only be transferred automatically to the company's ERP.

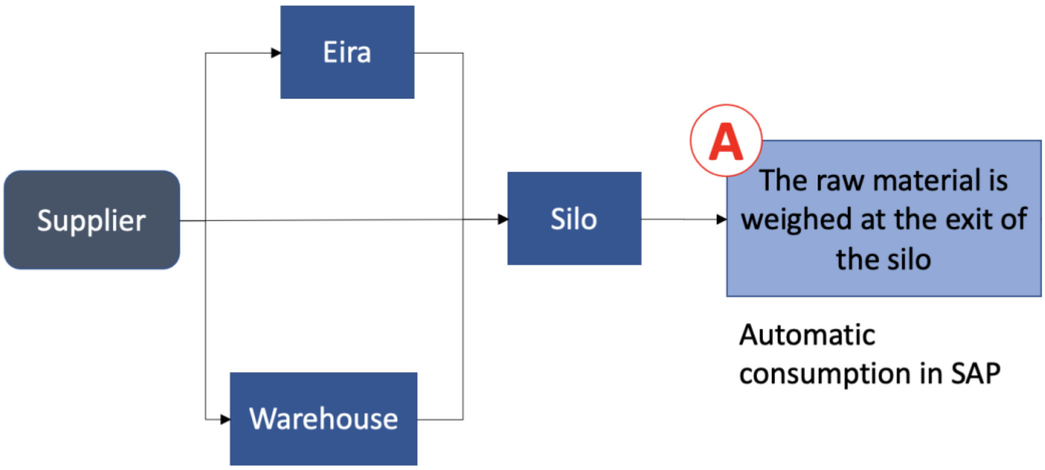

Figure 4.1: Flow of raw materials in BA's factory

With this, the first stage of this project was the treatment of the data obtained by the auxiliary factory software to make them available in the company's ERP. The data science team carried out this task.

After making this data available in the company's ERP, the intelligence team handles the way the data is displayed. For example, the use of inventory management tools available in the ERP allows tracking the movement of raw materials, including consumption, in real-time and consequently determining stock.

This automation makes it possible to identify consumption patterns, improve the efficiency of associated processes and identify and reduce online waste.

Its implementation will be the starting point for the following processes to be improved, as well as for the identification of new ones, given that the computerisation of consumption allows stocks to be obtained from the storage silos.

4.1.2 Raw Materials Management

Determination of Needs

In the glass industry, planning and ordering raw materials carefully over the long term is crucial to ensure a continuous, stable and efficient production process. This involves forecasting demand and determining the corresponding requirements. Several factors must be considered when making these projections and ordering raw materials, including the availability and cost of raw materials, the capacity of the production facilities, and market demand.

To make informed decisions about ordering raw materials, a company may need to analyse various data and information, such as historical production and sales data, industry trends, and market studies.

However, as described in the previous chapter, the raw material determination process at BA needs to consider these considerations, resulting in an inefficient process.

For this reason, this study sought to determine a more efficient process, both in terms of the number of employees involved and the time spent by employees at each stage, and to determine needs more closely to the real situation.

The mapping of this procedure is shown in figure 4.2.

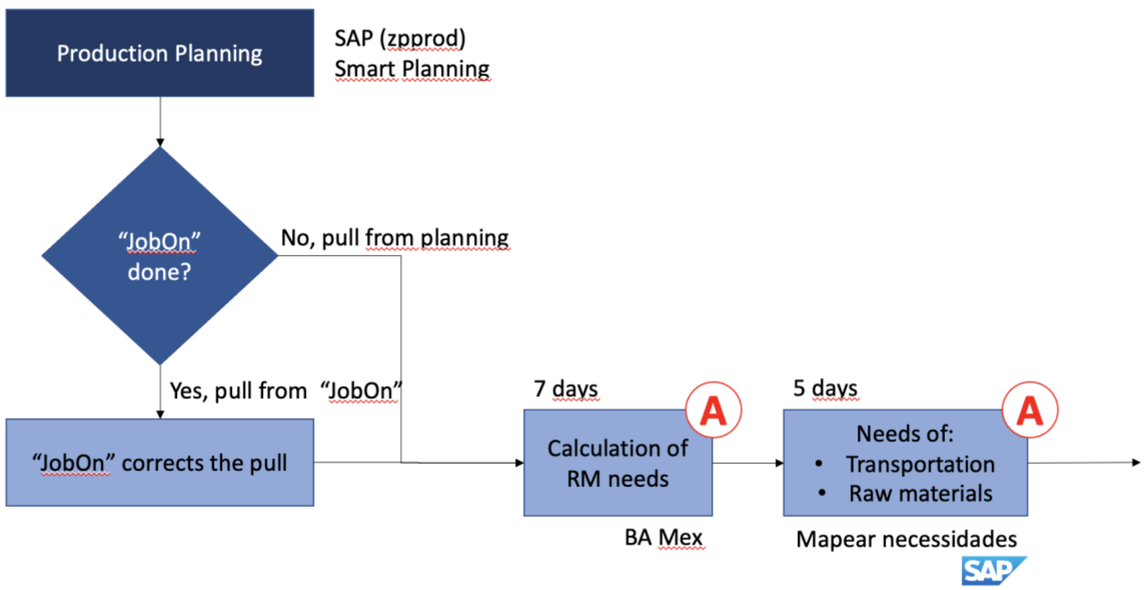

Figure 4.2: Process for automatic needs calculation – 1st part

The starting point of this process was the production planning developed by the planning team. This team collects data from other teams, such as sales and the front office, to forecast demand over the coming year. This work may involve the analysis of historical production and sales data, industry trends, and market research. Planning is provided for one month's production, although this may change over this period.

In turn, every week, the factory holds a meeting called "JobOn", which aims to analyse the quantity defined by the planning to be produced and based on factory limits and other internal factors, adjust the quantities of melted glass to be produced per line.

Therefore, when we determine the needs for the following week to be delivered to the plant, we should base ourselves on the quantity produced per furnace at the plant meeting rather than on the planning. However, in the absence of the former, we resort to the latter.

Once this data has been determined, it is necessary to calculate the requirements per day and per raw material for the following week (seven days) based on the revenues of each furnace and the quantity of molten glass to be produced per furnace.

To determine the needs, the dashboard represented in figure 4.3 is used. It automatically calculates the necessary quantities of each raw material per day, using the daily pull obtained from the "JobOn" meeting or if this has not yet been done from the Planning.

This dashboard is made available to the batch and furnace team so that they can manually set the amount of hull to be used and change recipe values in such a way that it translates into the needs of the plant. There will be one such dashboard per kiln and day of the week.

PLANT	**AV**		Plant can change
FURNACE	**AV2**		Automatic

MONDAY			
Color	**AM**		
PULL (tons)	500		
Culet (%)	**75%**	13 650	Ton
Losses	50,00%		
Final RM	14,286%	2,27500	Ton
Melted Glass by massas	50,000%	15,92500	
# Massas	31,40		

Raw Materials	**1 Massa**	**Necessidade**	
Areia 1	1 500	47 096	
Areia 2	1 500	47 096	
Carbonato Sódio	400	12 559	
Wollastonite	400	12 559	
Calcário	400	12 559	
Sulfato de Sódio	50	1 570	
Ox. de Ferro Puro	50	1 570	
Carvão Muco	50	1 570	**KG**
Cromite	50	1 570	
Carvão Carbol	50	1 570	
Escórias	50	1 570	
Partículas (AV2/AV4)	0	0	
Mistura Ox. Cobre	50	1 570	
	4 550	142 857	

Figure 4.3: Batch and Furnace team dashboard – determination of needs

This dashboard translates the daily requirements per furnace by multiplying the quantity used in a mass by the number of masses.

Before orders are automatically placed, they must be able to be altered and validated by the batch and furnace team to ensure there are no errors. Figure 4.3 presents only random values for dashboard representation, not corresponding these values to any revenue of the plant.

To determine this quantity, it was necessary to determine the number of batters made per day, per oven and the percentage of cullet. This number is determined from the following equation:

$$Nº\ Mixture = \frac{Pull\ (tons\ by\ day)}{Melted\ Glass\ (tons\ by\ mixture)} \tag{8}$$

To determine the number of mixtures, it is necessary to know the pull and the melted glass. The pull is obtained through the mill meeting or the JobOn. On the other hand, the melted glass will be obtained by the equation (9)

$$Melted\ Glass\ by\ mixture = Cullet + final\ RM \tag{9}$$

However, we know neither the amount of the cullet nor the final RM.

The final RM can be determined using equation (10)

$$Final\ RM = Initial\ RM\ \times (100 - \%perdas) \tag{10}$$

Knowing that the dashboard has the amount of each raw material needed for a mass, we know the initial RM. In turn, the loss percentage in the melt is also on the dashboard, allowing us to obtain the final RM for a mass.

To obtain the amount of melted glass by mixture, it is necessary to determine the amount of the cullet. For this, the cullet percentage is set by the Batch and Furnace collaborator. This quantity can be determined using the cullet percentage and the initial RM in the equation (11).

$$Cullet = \frac{initial\ RM\ \times \%\ Cullet}{(1 - \%Cullet)} \tag{11}$$

With this equation, we can now calculate the equation (9) and consequently determine the number of mixes through equation (8).

We obtain the daily requirement per line and raw material by multiplying the number of mixes by the quantity of each one.

This methodology does not reflect any error in the determination of the needs. It allows the batch and furnace team to adjust the recipe according to their internal management.

By adding up these quantities for all the lines in the factory and the seven days of the week, it is possible to obtain the weekly requirements, which should be transformed into weekly orders divided by five days in a non-equal manner.

On the first day of the week, we must receive the corresponding requirements for Saturday, Sunday, and Monday if these requirements are less than the unloading capacity of the raw material in question.

In case it is superior, what is left undelivered must be transferred to the following day, in which the needs of the day plus what is left undelivered from the previous day must be received. This procedure should guarantee that the storage deposits are total Friday at the end of the day.

The determination of the needs and sending to the transporters and suppliers according to the previously mentioned rules is done after the approval of the batch and supply team and the purchasing team.

As shown in figure 4.3, after both approvals, a Schedule Agreement is automatically made in the company's ERP, which is also sent automatically to the suppliers, who may confirm or not the order.

If the supplier accepts, he will receive a link via e-mail with the delivery schedule, as will be reported in the following chapter. If he rejects it, the transport and sales teams receive a notification by e-mail.

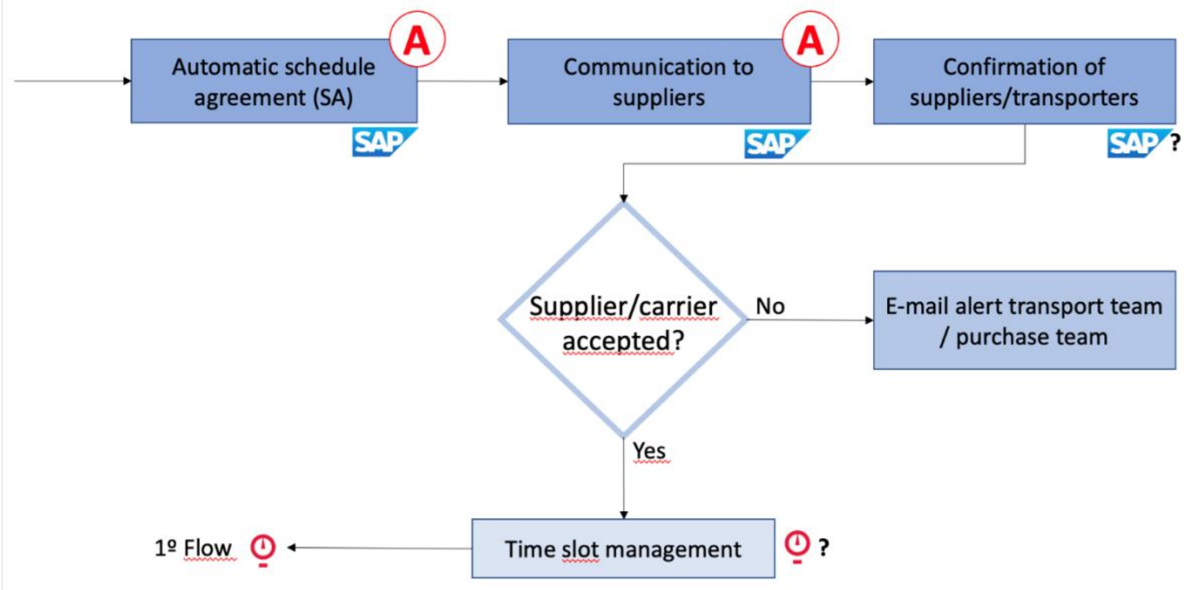

Figure 4.4: Process for automatic needs calculation - 2nd Part

If the supplier accepts, they will receive a link via email with the delivery schedule as will be reported in the following chapter, if they reject the transport team and the sales team receive a notification via email. In the case of BA it is necessary to contact both, because the transport of raw material from Iberia is EXW.

ABC analysis and management methods

Stock-outs in a glass production plant can lead to reduced productivity, increased delivery times, customer dissatisfaction, increased costs, and damage to equipment. For this reason, at the BA Avintes factory, it was defined as a rule that the storage silos should always be complete at the end of each working day. This rule was established because the reduced storage capacity does not allow having higher safety stocks, which translates into a higher risk of breakage.

In order to avoid this situation, it is essential to select the materials that present a higher risk of rupture and apply management methods that are best suited to each type.

As previously mentioned, there are different types of transport, storage and consumption among all raw materials. For this reason, it was realised that the management of some raw materials should be differentiated from others. Therefore, an ABC analysis was used to differentiate them, where the effect considered was the consumption and stock rotation of raw materials.

These two factors were considered because the storage capacity of the factory for each raw material is not proportional to consumption, which means that raw materials with lower consumption need more careful management.

This is because raw materials are stored in silos, which leads to the existence of limitations on the use of total storage capacity.

This analysis enables the distribution in table 4.1 and figure 4.4 to be obtained.

Class	*Nº of Articles*	*% Articles*	*Estimated frequency of weighted usage*
Class A	2	20%	67.8%
Class B	3	30%	32.3%
Class C	5	50%	0.2%

Table 4.1: ABC distribution for BA raw materials

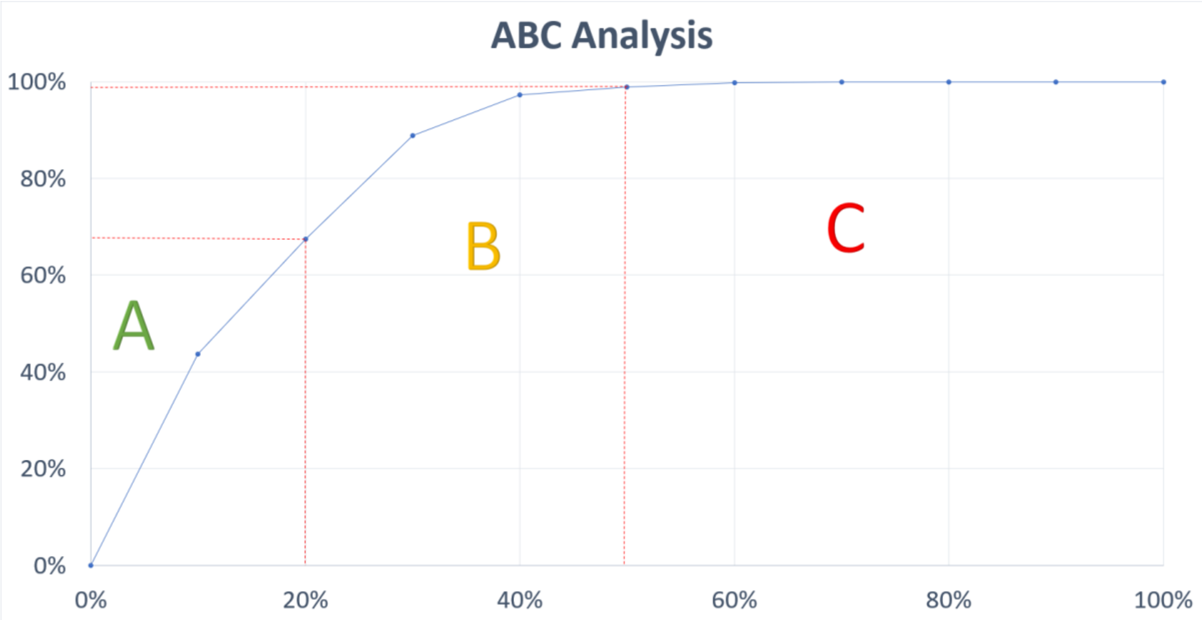

Figure 4.5: Graph with ABC distribution for the raw materials under study

In the ABC analysis, the items selected for class A will be sands 1 and 2, which represent 67.8% of the weighted usage frequency of the plant. Therefore, these will be the materials that will have a significantly more careful stock management need.

These raw materials consume about 19% of their storage capacity daily. Considering that there is no restocking during the weekend, the silos arrive on Monday with less than half of their capacity, which translates into stock periods of about two days for some raw materials.

In addition, according to the experience of the batch and supply team, it was possible to verify that the safety stock should be strictly complied with because a failure in an item of equipment with a repair time of over two days could lead to stock rupture and consequent factory stoppage.

In situations of risk of stock rupture, as the one mentioned, the plant adds more recycled glass to the mixture, reducing RM consumption and consequently increasing the durability of the stock to be able to repair without the plant stopping.

Because of the facts presented above, it was defined that the best method to manage the stock of RM of class A would be through Periodic Revision with daily revision, having as a goal that the stock always stays at the maximum possible, according to its limitations.

To study this method of stock management, a demo of the process was carried out in November, starting from the planning pull.

To begin this analysis considering the stock in the silos, the first day was considered as a reference, a Friday with total stocks.

Afterwards, the stock on the following days was analysed at the beginning of the unloading period at 6 am and the end of the day at 9:30 pm. Considering receipt of requirements from Monday to Friday.

Therefore, based on the above, we can forecast the stock at the beginning of the raw material unloading period in the Avintes factory (6 am). With the stock and silo capacity, it is possible to obtain the raw material availability at the time mentioned above. This availability corresponds to the maximum value we can supply during the day without any overcrowding risk.

However, the raw materials of class A present a very significant consumption, which leads to a high need to try to supply as much as possible, considering the consumption throughout the delivery period.

Therefore, it will be necessary to determine the number of trucks spent in the delivery period rounded down.

$$Nº\ of\ trucks = \frac{daily\ consumption\ \times duration\ of\ the\ delivery\ period}{24(hours) \times max\ capacity\ of\ a\ truck} \qquad (12)$$

For Sand 1 it will be three trucks/per day, and for Sand 2 it will be two trucks/per day.

However, a maximum was defined to avoid overloading the unloading process due to the limitations of the unloading site.

In turn, the raw materials of class B, although not as critical as the A, deserve a similar analysis because although they present a significantly lower consumption, their storage capacity is also lower, which leads to the safety stock having durability very similar to the materials of class A.

For this reason, it was decided to perform stock management similar to that performed in A, periodic review, with daily review with a similar process.

Finally, the elements of class C are represented by the following five recipe elements: Wollastonite, Sodium Sulphate, Chromite, Iron Oxide and Mucous Coal. These elements are no less essential than the others and require management analysis.

The elements of selected class C can be divided into two parts, those transported in BIG BAGS (bags with a limited quantity of raw material), which have the advantage of not being limited by the storage capacities of the factory (silos). For this reason, it is possible to manage them more carefully. The other part represents materials transported in tanks or bathtub lorries.

For the elements of class C, the most appropriate stock management would be the continuous review with an order point corresponding to the stock for 21 days. This value was considered considering these products' maximum lead time.

4.1.3 Delivery Process

As mentioned in the previous chapter, there are currently many problems associated with unloading raw materials. Trucks are waiting considerably longer than necessary, and the transporter may even have to stay at the BA site overnight to unload. These waiting times imply considerable and unplanned costs for the company.

According to Fallahtafti et al. (2021), to improve the raw material unloading process, it was decided to complement it with a time slot management system that will allow the organisation and scheduling of slots, resulting in the efficient management of the delivery period.

This increases the number of unloads for the defined period and decreases the waiting time of transporters, increasing the efficiency of the supply chain as a whole.

This management often ensures that resources are used effectively and efficiently, minimising scheduling overlaps or conflicts.

Careful management of schedule slots helps the company reduce costs and improve efficiency by minimising the time and resources required to complete tasks. This will increase the predictability of deliveries and considerably decrease unloading time.

Slot management is often used to ensure that resources are used efficiently and effectively and to minimise scheduling conflicts or overlaps.

Transporeon Process

At BA, time slot management will be used to improve daily unloading periods and ensure that deliveries are made in due time.

This system is already implemented in the company for the finished product through the "Transporeon" platform, which allows BA to allocate the loads and routes on the platform to be subsequently allocated to the hauliers according to an order predefined by the company.

This selection is carried out based on the prices agreed with the suppliers, type of loads, routes, and reliability.

After the acceptance of the loads by the suppliers, they must proceed to the slot marking through the platform, as represented in figure 4.6.

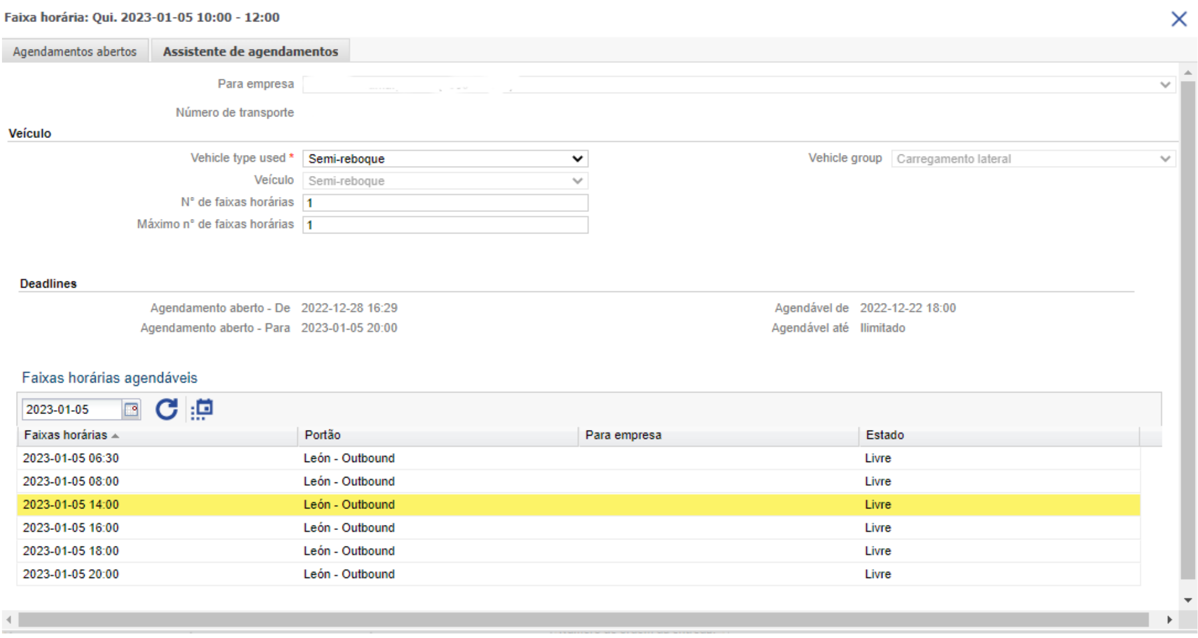

Figure 4.6: Transporeon platform - scheduling slots

After marking, the platform allows viewing all the markings in calendars per factory, as shown in figure 4.7.

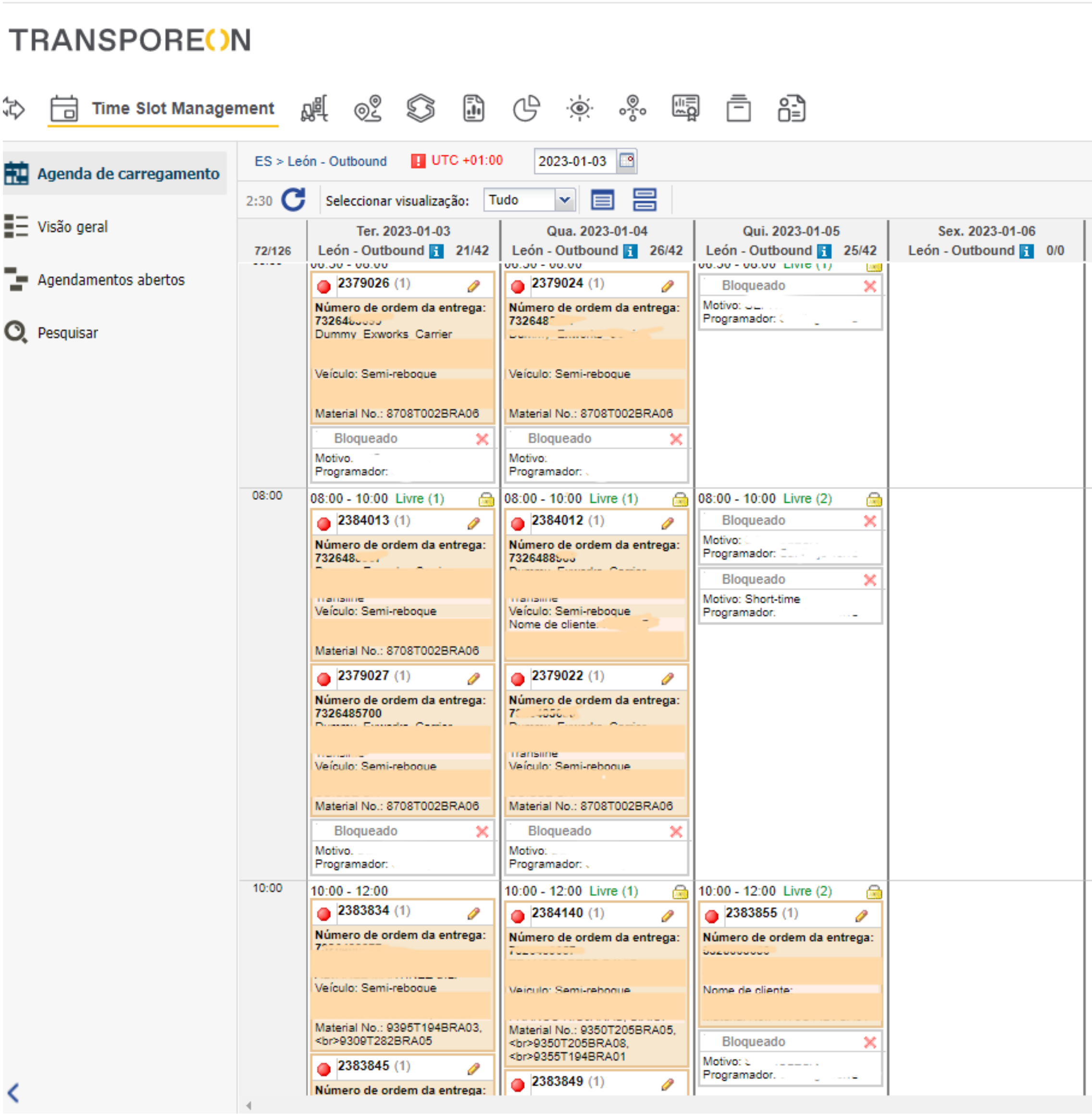

Figure 4.7: Transporeon platform - calendar with selected slots

Transporeon also allows hauliers to share its tracking through another platform called SixFold. This allows them to know where the truck is and how long it will take to arrive, according to the rules of circulation and expected transit, through a link provided from the moment the transporter collects the cargo.

Since the transport team already has this platform operational for the finished product it was concluded that this would be the best solution for the application of this technology.

However, due to the impossibility of moving directly from the project to implementation, it was considered necessary first to apply a pilot project to understand whether the project works in practice. For this reason, we sought an accessory system that would allow us to test this process for raw materials in the first phase.

Time Slot Management Demo Process

In order to determine an alternative process, it is first necessary to survey the described discharge constraints. The following constraints were defined based on the experience of the batch and furnace team:

- Unloading hours (6 am to 9 pm);
- Slag only unloads after 5 pm;
- Maximum two trucks of sand simultaneously;
- Maximum two trucks of soda at the same time;
- Maximum one truck of limestone at a time;
- Maximum unloading of 5 trucks at the same time (unloading site space);

Implementing these restrictions in the time slot management system will mean no more trucks will have to wait due to overcrowding in the unloading area.

So, for its implementation, we sought to use a system that would be easy to apply, would not imply costs for the company, and would be secure, as it would record confidential information about our suppliers. For this, the solution was to use a scheduling and slot booking service called Microsoft Bookings, which is part of the Office 365 suite of products.

According to the constraints defined previously, six calendars with ninety-minute slots were created. Each calendar corresponds to one or more raw materials. Therefore, there can be one or two downloads for each slot, as shown in table 4.2.

Class	*Schedule*	*Material*	*Unloading by slot*	*Unloading Time*
A	Schedule 1	Sand 1	1	6h to 21h
A	Schedule 2	Sand 2	1	6h to 21h
B	Schedule 3	Soda ash	2	6h to 21h
B	Schedule 4	Limestone	1	6h to 21h
B	Schedule 5	Slag	1	17h to 21h
C	Schedule 6	Others	1	6h to 21h

Table 4.2: Timetables defined for scheduling slots per raw material

Also, the unloading time will be different for Schedule 5 as it was previously defined that slag is only unloaded in the evening. An example of this schedule from the BA employee's point of view is represented in figure 4.8.

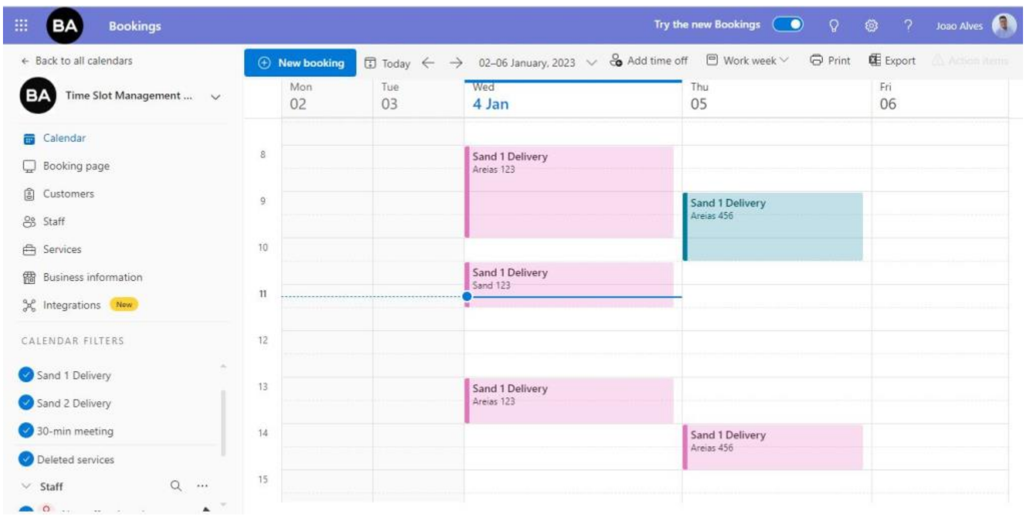

Figure 4.8: Calendar with scheduled slots - BA Collaborator view

After the transporter and supplier accept the transport, the transporter will receive a link in his e-mail to mark his unloading slot for the raw material he has agreed to transport. When the transporter opens the link for slot booking, a web page is represented in figures 4.9.

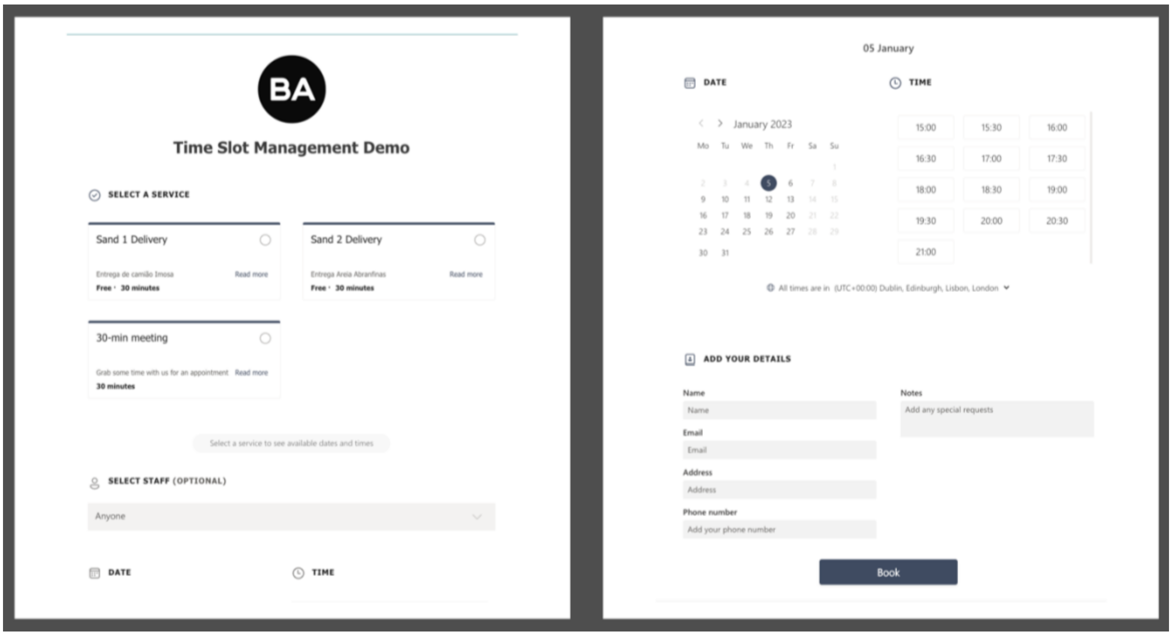

Figure 4.9: Scheduling slot by the transporter – web page

Once the form has been filled in, the slot is saved, and the transport team receives a notification confirming the booking.

Since it is not possible to unload more than five trucks in the same slot due to unloading space limitations whenever the sum of unloads of a given time slot in all schedules is equal to five, the slot is no longer available in all schedules, thus avoiding overbooking of the unloading site.

This system will also include a transport tracking system by link sharing by transporters that tracks the truck during the transport period. Tracking the transport of raw materials enables greater efficiency in the logistical processes associated with transport. It is easier to predict when a truck will arrive at the facility without having to contact the transport company for this information.

4.2 Performance Evaluation

Performance Evaluation is the process of assessing the performance of an organisation by measuring actual performance, setting performance standards, and comparing the two to determine how well we are performing against those standards. This evaluation enables the identification of strengths and weaknesses setting objectives, targets, and feedback. It is essential for the organisation to identify areas for improvement and develop strategies to achieve better performance. (López 2008)

Different KPIs are used to assess the performance of processes associated with raw materials and their planning effectiveness in achieving their objectives. They provide insights for strategic and operational improvement and create an analytical basis for decision-making, allowing the most critical aspects to be focused on.

In addition to the KPIs already used to assess process performance, some were also defined to evaluate and measure the operational performance of the unloading site and the performance of transport providers that potentially impact delivery delays (table 4.3).

KPI	*Description*	*Units*
Supplier Satisfaction Index	Metric that evaluates the supplier's satisfaction on the parameters defined: waiting time and communication effectiveness.	
Waiting time	Average time between check-in and check-out.	Min
Overcapacity days	Metric that measures the number of days with a number of planned unloads above the maximum daily capacity.	Days
Punctuality of the carrier	It helps detect inappropriate carrier behaviour.	
Extra Transport Costs	Metric that measures the additional transport costs charged by customers to BA for various reasons, usually excessive waiting times or last-minute planned deliveries	EUR
Unloading time	Metric that measures the unloading time of trucks, serves to understand unloading times for different raw materials and transporters.	Min
Changes to the order	Number of weekly order changes. Can alert to find potential improvement points	

Table 4.3: Suggested KPIs for the assessment of raw materials

These were defined together with the purchasing and transport teams and aimed to analyse not only the different processes in their entirety but also to find inefficiencies to improve in the future in both teams. All KPIs defined were approved and are easy to collect.

The evaluation of these KPIs will monitor the different processes, communicate performance and improve the efficiency and effectiveness of the processes.

4.3 Expected results

The expected results and process mapping, demonstrated in figure 4.10, serve to understand where the outcome is intended and where we are starting from.

Adopting the raw material planning solutions presented in the previous sections, the inefficiencies measured in chapter 4 are expected to be significantly reduced.

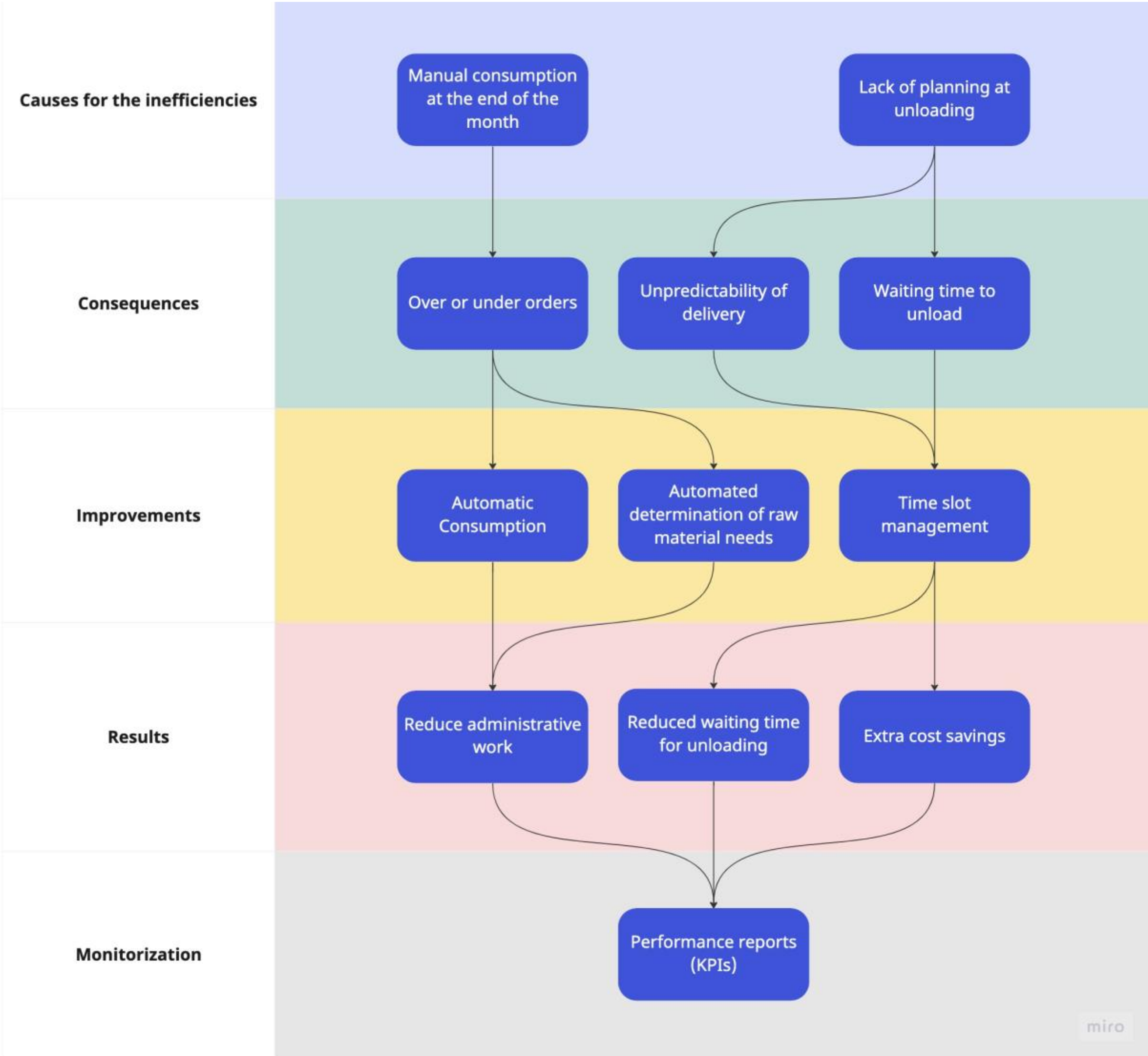

Figure 4.10: Expected results and mapping of raw materials processes

Thus, with the increase in the traceability of raw material processes and the substantial decrease in the average waiting time for unloading at the plant, there was a reduction in the number of delays in deliveries, a decrease in administrative work and a decrease in extra costs associated with inefficiencies in this project.

This reduction in waiting time for transporters to unload causes a reduction in the number of claims associated with them and a decrease in additional transport costs. In general, BA Avintes hauliers only charge extra costs for each hour from three hours of waiting. Thus, a haulier waiting three hours and fifteen minutes should be charged 50€, while a haulier waiting four hours and five minutes should be charged 100€.

Based on this analysis, the waiting times for November were determined, and it was concluded that these represented a monthly cost of approximately 5,800€. This amount is intended to be saved with the delivery scheduling system.

Furthermore, implementing a system that automatically determines the factory's needs saves the purchasing department around forty-eight hours of work per year.

The results achieved with the operational improvement also reduced the factory employees' time-consuming work in analysing the different information that is now available in the company's ERP, freeing up employees for other tasks.

5 Conclusions and future work

The main objective of this dissertation is to identify opportunities to improve the processes associated with the planning and management of raw materials, to increase their efficiency, reduce costs and increase the traceability of these products. To achieve this objective, a thorough analysis of current processes was carried out, data was collected, and stakeholders were involved in continuous improvement.

The effectiveness of the implemented solutions was also evaluated, as their impact on the organisation's performance. In conclusion, the study's main conclusions will be summarised, and the implications of the proposed improvements for the organisation will be discussed.

On the other hand, future works will suggest future investigations in the field of process improvement, results that were not analysed and studies that this project can drive.

5.1 Conclusions

This research contributed to understanding the different processes associated with managing and planning raw materials in the supply chain. Process improvement interventions can significantly impact organisational performance.

The development of a process that allows raw material consumption data to be made available in the company's ERP automatically and in real-time results in greater visibility over raw materials, which translates into the real-time determination of factory stock, ease of obtaining data for analysis and boosting other projects also associated with raw materials. The improvement of this process allowed for a reduction in administrative work time for the employees from the purchasing team with greater ease in obtaining available stock information and also for the employees from the Batch and Furnance team who do not need to check stocks so regularly hand, saving both teams around an hour's work per week.

In turn, to improve the process of the raw materials as a whole, we tried to automate and enhance the ordering of raw materials. This process brought advantages to the reduction of work both for the Batch and Furnance team and purchasing with the determination of needs in a more accurate way. Furthermore, this procedure allows the evaluation and analysis of the number of changes to the orders during the week, determining the difference between the needs and the real consumption.

Both processes are intended to be implemented firstly in the Avintes factory as a pilot project, but in a way that is easy to implement and equal in all BA factories. For this reason, before their implementation, it is necessary to see if the processes follow the methodologies and systems of all factories. Unfortunately, this procedure took longer than the stage, so its implementation was impossible.

Finally, a time slot management system not only allows us to increase the efficiency of the unloading period of the factory but also to analyse the punctuality of the suppliers and the unloading times for different transporters and raw materials. Therefore, this system efficiently schedules delivery periods, considerably reducing waiting times and associated costs.

This procedure is now ready for implementation. If suppliers comply and adopt our system, we estimate a saving of around 69600€. This figure considers the elimination of waiting times of more than three hours by hauliers.

Due to the short timeframe of this dissertation and the fact that some of the proposed measures have a long-term impact, it was not possible to measure the exact improvement results and cost savings associated with the new processes.

5.2 Future Works

This dissertation has contributed to a more detailed and deeper understanding of the different processes associated with raw materials, their inefficiencies, and how we can change those processes to improve them. However, there are still areas to explore, and many questions remain unanswered. In this section, we have outlined plans to continue the research and expand on the results presented

Firstly, it is crucial to note that this study was based on the materials used in the Avintes factory. Thus, a similar analysis is advised in the remaining BA plants to implement the processes correctly.

Future work is focused on applying and studying predictive models and forecasting methods in analysing the company's consumptions to use the data obtained in the automatic consumptions to decrease the error in the determination of the needs.

Furthermore, after the time slot management demo test mentioned in this dissertation, it would be essential to develop a time slot management system that allows all raw materials to be delivered on the same schedule according to the restrictions mentioned above and with a truck tracking system that allows us to predict the arrival time of the raw material at our facilities, through the Transporeon platform.

Overall, the future work outlined in this dissertation has the potential to significantly advance our understanding of the different processes associated with raw materials and to make essential contributions to the field.

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