A Lean Approach to the Inefficiency of Natural Cork Stopper Sorting Processes

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Master Dissertation

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FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

Master's in Industrial Engineering and Management

2024-06-27

“disce quasi semper victurus, vive quasi cras morituros”

St. Edmund of Abingdon

Abstract

This thesis reflects a study that aims to improve the efficiency of the sorting processes for natural cork stoppers at SOCORI, an industrial unit of the Amorim Group, through Lean Thinking focused on continuous improvement.

After a detailed analysis of the sorting processes, it was possible to identify several problems. By field observation, it was discovered that the machines in the CIPs section were deficient in cleaning, resulting in numerous micro-stops that negatively impacted the OEE. Furthermore, it was noticed that the most frequent defect across all the sorting procedures was *repass*, specifically in the 2nd Electronic Sorting. This high value was related to the considerable number of false rejections during this phase, caused by a lack of process control. In the last sorting phase, X-Ray, after some inspections, it was discovered that certain defect output channels had stoppers that were free from defects. The stoppers were wasted and sent to grinding. Finally, it was concluded that visual management, both in terms of layout organization, bag identification and application of the 5s methodology, had a certain limitation.

Considering the problem in the CIPs, a cleaning Standard Work was developed and implemented. After implementing the cleaning standard, the average weekly OEE of the CIP section increased by around 7.5%. On the other hand, regarding the high rate of *repass* and false rejections in the 2nd Electronic Sorting, a dynamic control process was implemented. If the samples were rejected, the operators were forced to stop the machine and change the parameters of the sorting program. False rejects fell by around 72.5% after the dynamic control was implemented, which led to a big drop in *repass* rate. After controlling X-Ray's outputs, it was decided that the stoppers that had previously gone to grinding would now be sent to the colmation process. This change could benefit the company by around €8500 in the first 4 months after implementation. Finally, the layout was adjusted and solutions were implemented to improve visual management.

The project successfully accomplished its objective by optimizing all of these sorting process, resulting in increased efficiency and reduced waste on the shop floor.

Resumo

Uma Abordagem *Lean* à Ineficiência dos Processos de Escolha de Rolhas Naturais

Esta tese reflete um estudo que tem como objetivo aumentar a eficiência dos processos de escolha de rolhas naturais na SOCORI, uma unidade industrial do Grupo Amorim, através de um pensamento *Lean* focado em melhoria contínua.

Após uma análise detalhada dos processos de escolha, foi possível identificar vários problemas. Após observação no terreno, verificou-se que, na secção das CIPs, as máquinas careciam de limpeza e, por isso, sofriam muitas microparagens, afetando o OEE do equipamento. Além disso, concluiu-se que o defeito com mais percentagem em todos os processes de escolha era o repasse, na 2º Escolha Eletrónica. Este valor elevado foi causado pelo grande número de falsas rejeições desse mesmo defeito nessa fase, resultado da falta de controlo de processo. Na última fase de escolha, o Raio-X, após uma série de controlos ao processo, percebeu-se que alguns canais de saída de defeitos continham rolhas sem defeitos que eram desperdiçadas para trituração. Por fim, conclui-se que a gestão visual, tanto na organização de layout, identificação de sacos e aplicação da metodologia 5s, estava com certas deficiências.

Considerando o problema nas CIPs, foi desenvolvido e implementado um Standard Work de limpeza. O OEE médio semanal da secção das CIPs, após implementação da norma, aumentou cerca de 7.5%. Por outro lado, relativamente à grande incidência de repasse e falsas rejeições na 2º Escolha Eletrónica, foi implementado um processo de controlo dinâmico. Caso as amostras fossem rejeitadas, os operadores paravam a máquina e alteravam os parâmetros do programa de escolha. As falsas rejeições diminuíram cerca de 72.5% após a implementação da melhoria, o que levou a uma grande descida na percentagem de repasse no processo. Depois de alguns controlos às saídas do Raio-X, decidiu-se que as rolhas que antes iam para trituração, passariam a ser enviadas para o processo de colmatagem. Esta mudança poderá beneficiar a empresa em cerca de 8500€ nos primeiros 4 meses, após implementação. Por fim, o layout foi alterado e foram implementadas soluções em vista da melhoria da gestão visual.

O objetivo do projeto foi alcançado visto que todos estes processos de escolha mencionados foram otimizados, aumentando a sua eficiência e diminuindo os desperdícios em chão de fábrica.

Acknowledgements

To my family for all the love and support. Mostly to my mother, who patiently endured my late night arrivals, always supported my decisions and guided me through all the challenges and hard periods of a student's life. Also to my father, who, although far away, was, is and always will be an example, never ceasing to teach, encourage and help me become the man I am today.

To my friends. Although they're not family, they're like brothers and sisters. I spent more time with them than with my own family. From the oldest to those who were part of this journey during my five years at FEUP, I'll never forget the laughs, advices, late nights studying and moments that will last forever.

To FEUP and academic life. FEUP was my home, giving me the most memorable years of my life and lifelong friendships. Here I turned into a man. To all my teachers for providing me with an excellent education and getting me ready to enter the working life.

To my supervisor at FEUP, Armando Leitão, for his support and guidance in finishing this cycle and for his help during this project development.

Last but not least, to SOCORI. Mostly to Diana Dias, my supervisor at the company, for her availability, her happiness at work and the genuine way in which she likes to teach, helping me overcome the difficulties experienced. To all the employees and operators who, with their experience in the field, made me learn about industry and its challenges.

Contents

Acronyms and Symbols

SOCORI	Sociedade de Cortiças de Rio Meão
SGPS	Sociedade Gestora de Participações Sociais
TPS	Toyota Production System
JIT	Just-in-Time
PDCA	Plan-Do-Check-Act
SW	Standard Work
SOP	Standard Operating Procedures
TQM	Total Quality Management
OEE	Overall Equipment Effectiveness
TPM	Total Productive Maintenance
TCA	2,4,6-Trichloroanisole
MES	Manufacturing Execution System
SAP	Systems Applications and Products
1st EE	First Electronic Sorting
2nd EE	Second Electronic Sorting
VS	Vacuum System
ML	Milheiro

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1 Introduction

The current dissertation project represents the final outcome of the Master's degree in Industrial Engineering and Management at the Faculty of Engineering of University of Porto. This project took place between February and June 2024, at SOCORI, an Amorim Group's industrial unit that produces cork stoppers. The primary goal of this project is to optimize the sorting processes efficiency related with natural cork stoppers, mainly by reducing the number of false rejected units, optimizing the process control, enhancing production performance and reducing waste on factory floor.

Cork, a natural product with a two-century history, is derived from the cork oak tree (Quercus suber), which is typically found in Mediterranean coastal locations. Portugal is the world's leading producer and exporter of cork, with Spain coming in second (APCOR, 2023). Although the cork sector has experienced significant growth in the past, the pace observed in recent years has slowed down, leading SOCORI to implement initiatives to improve its existing processes in 2024.

As a result, the current dissertation project is based on methods that comply to Lean principles and Continuous Improvement techniques and methodologies.

1.1 Project Context and Motivation

Due to its historical background and significant economic impact, the cork industry has played a crucial role in the Portuguese industrial sector for a considerable period. It is worth mentioning that the cork sales have experienced substantial growth in recent years, particularly for natural cork stoppers. However, there is evidence indicating a deceleration in the pace of growth from 2023 to 2024 (Research, 2024), causing SOCORI to make a slight decrease in its ordering quantities.

Multiple reasons contribute to this transformation in the industry's landscape. One of the most important factors is the changing patterns of consumption, which has led, for example, to a clear decrease in wine consumption in recent years (Mariani, J. 2023). This tendency was drove by the increasing scarcity and declining quality of cork, which is caused by climate change and the rising demand for planting cork oak trees. The quality of cork is significantly influenced by the temperature and humidity of the location in which the cork oak tree is cultivated (Sánchez-González et al., 2023).

The cork oak lives for about 100 years and produces an average of nine cork crops, as cork takes nine years to mature. The first stripping occurs when the cork oak is 20 to 25 years old, resulting in low-quality virgin cork. The second stripping, done 9 years later, is of higher quality. However, only the third stripping yields such quality to produce a good cork stopper. (Cooke, 1931). Moreover, the influence of climate change has caused oscillations in cork quality, forcing adaptation and development within cork production processes.

In response to these challenges, SOCORI embarked on a strategic initiative in 2024, pinpointing it as a year dedicated to continuous improvement and internal optimization. Even though SOCORI had already put continuous improvement measures in place, the business took advantage of 2024 to go further with process improvements, with the goal of increasing profitability internally by improving current procedures.

Customer feedback, particularly concerning critical defects in natural cork stoppers, served as a trigger for SOCORI's intensified focus on this project. Natural cork stoppers are the primary source of revenue and are heavily dependent on the original cork treatment and selection. As such, they require big attention to detail to guarantee exceptional quality.

Therefore, the present dissertation project aligns with SOCORI's strategy for 2024. To guarantee continuous success in a changing market, it aims to analyze the complexities of cork production and sorting processes, pinpoint inefficiencies and implement target improvements.

1.2 Amorim Group

Established in 1870, the Amorim Group started its journey with a humble cork stopper production facility at Cais de Gaia. Recognizing the remarkable potential of cork, a 100% natural material, the company promptly invested in research, development and innovative design. This forward-thinking approach allowed the Amorim Group to emerge as one of Portugal's biggest multinational companies. Corticeira Amorim's ascension to such position is also linked to their constant commitment to the principles of the circular economy. With recycling initiatives all over the world, the company have a 90% trash recovery rate and get more than 70% of its energy from sustainable sources. (Amorim, 2022a).

Over the decades, a persistent commitment to vertical integration and global expansion has solidified the Group's position as a leader in cork product manufacturing and export. The Amorim Group is motivated by five core values, as it seeks to enhance the value of cork in a competitive, distinctive, and inventive way: Pride, Ambition, Initiative, Sobriety and Attitude. These values reinforce the Group's dedication to excellence, sustainability and social responsibility (Amorim, 2022b).

The Amorim Group operates through five distinct business units, as shown below in Figure 1.1 (Amorim, 2022c).

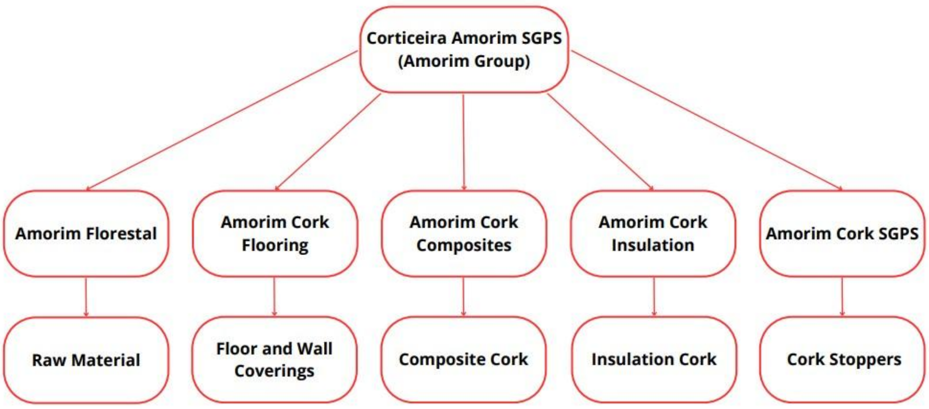


Figure 1.1: Amorim Group Organizational Chart

- **Raw Materials:** Amorim Florestal serves as the primary supplier of cork raw materials to the Group's other business units, meticulously sourcing, procuring and preparing cork for production.

- **Floor and Wall Coverings:** Amorim Cork Flooring leads the industry in crafting versatile, high-quality cork flooring and wall decorations known for their sustainability and suitability across residential, commercial and corporate projects.

- **Composite Cork**: Amorim Cork Composites pioneers sustainable reinvention, exploring new applications, shapes and functionalities for cork through cutting-edge research and development.

- **Insulation Cork:** Committed to eco-friendly solutions, Amorim Cork Insulation specializes in high-tech agglomerated cork products that provide natural acoustic, thermal and anti-vibration insulation.

- **Cork Stoppers:** Amorim Cork SGPS stands as the world's largest manufacturer, supplier and distributor of cork stoppers, renowned for advanced manufacturing technology and unparalleled product security.

1.2.1 SOCORI

The project was developed and carried out at SOCORI, one of Amorim Cork SGPS´s industrial units responsible to produce cork stoppers.

SOCORI (*Sociedade de Cortiças de Rio Meão*), a subsidiary of the Bourrassé Group, has a long-standing history of over a century in the manufacturing of natural cork stoppers. Jean Baptiste Bourrassé founded the company in 1900 at Tosse, France, and initially focused on rectifying cork stoppers that were obtained through acquisition. Following various stages of development and expansion, it was established in Portugal with the creation of SOCORI in 1989. “Delivering sophisticated solutions for wines of today and tomorrow”, Bourrassé excels in combining innovative technology with a refined style. The company´s leadership in cork ending technology has been cemented by its steadfast commitment to quality and innovation (Bourrassé, 2020).

In a strategic move, Corticeira Amorim acquired 60% of Bourrassé Group in 2017, fortifying its market presence and enhancing its corporate vision (Público, 2017). Despite the acquisition, Bourrassé retains its distinct identity and autonomy, emphasizing continuity and brand integrity for its clients.

SOCORI stands out within the Amorim Cork SGPS units due to its complete approach to cork processing and manufacturing. Unlike other industrial units, specialized in specific types of cork stoppers and stages of the production chain, SOCORI covers the entire production process of natural, agglomerated and technical cork stoppers, from raw material reception and treatment to final marking and packaging, at its facility.

1.3 Objectives

The primaries objectives of this project are the elimination of waste (*Muda*) and the enhancement of sorting processes efficiency through the continuous monitoring of predefined indicators against proposed objectives. These indicators encompass production output, quality standards, earnings or service levels. The goal is to optimize overall performance by identifying areas for improvement and putting focused interventions in place through close monitoring of key measures.

Gemba Walks and frequent but fast meetings with the workers, Daily Kaizen, helped with analysis and problem solving, guaranteeing ongoing improvement and incorporation of new techniques into daily operations like, for example, standardized procedures, cleaning schedules or better visual management.

Most importantly, the project's main goals are to understand the processes and workflow to reduce the number of false rejected units and improve productivity performance and process control. By minimizing waste, these goals seek to improve process efficiency and increase earnings without raising costs.

1.4 Methodology

This dissertation project uses the A3 methodology and *Gemba* principles to analyze SOCORI's processes. The A3 methodology, derived from Toyota's problem-solving culture, provides a structured framework for problem identification, analysis and resolution. *Gemba*, an integral part of the A3 methodology, emphasizes firsthand observation to gain a deep understanding of production processes. The A3 methodology has the following steps (DK Sobek II et al., 2004):

- Problem Definition: Clearly state the problem, its effects and the reasons it must be addressed.
- Current Situation Analysis: Collect relevant data, facts and observations to fully comprehend the situation as it stands today.
- Goal Setting: Define clear and achievable goals that align with resolving the identified problem.
- Countermeasure Identification: Determine potential solutions or countermeasures to deal with the root causes of the problem.
- Countermeasure Execution: Implement the selected countermeasures in a systematic manner.
- Monitoring and Evaluation: Track progress closely and adjust as necessary to ensure successful implementation. Evaluate the effectiveness in addressing the problem and achieving the desired goals.

Moreover, *Gemba* principles facilitate direct engagement with frontline workers and stakeholders. Regular *Gemba* walks help to observe production activities, identify inefficiencies and gather insights.

To sum up, the project aims to achieve sustainable improvements in SOCORI’s processes through collaborative problem-solving, data-driven analysis and continuous contact with the workers.

1.5 Structure of the Document

This dissertation is divided into five chapters. The dissertation begins with an overview of the project in the first chapter, presenting the company, outlining its goals and going over the methodology adopted.

The theoretical foundation is thoroughly examined in the second chapter. This section establishes a solid theoretical basis to support the designed solutions by offering a complete overview of pertinent methodologies and concepts used throughout the research.

An analysis of the company's current state is covered in Chapter 3. Defining the initial circumstances of the company, explaining the underlying reasons of the problems that arose and outlining possible improvements are the main priorities.

Chapter four transitions into the presentation of the proposed solutions in the context of the project development. Within this section, detailed solutions to the identified problems are presented, alongside the tools and the methods to achieve them, comparing the initial state to the final one, before and after the improvements implementation.

Finally, in Chapter 5, the focus is in analyzing the outcomes of the project and future views. This section critically looks at the results of the implemented solutions and presents initiatives for further development.

2 Literature Review

The theories and techniques applied in the development of this project are covered in this chapter, with a particular emphasis on Lean Thinking, Kaizen and Total Quality Management. These interconnected principles serve as the pillar for the theoretical framework and methodological approach. In addition to using fundamental books in the various areas described, searches were made in various electronic databases to read articles and discussions about the main topics.

2.1 Toyota Production System

The oil crisis of 1973 pushed Toyota Motor Company to reevaluate its manufacturing processes, resulting in the development of the revolutionary Toyota Production System (TPS) with the goal of improving flexibility and efficiency in the face of economic uncertainty. Mr. Taiichi Ohno led the development of TPS, a unique Japanese strategy that focuses on producing a wide range of vehicle models in small batches while maximizing efficiency. If the goals are to reduce costs, improve product quality and reduce lead times, this system applies to many other products besides vehicles. Ohno embraced simplicity, efficiency, and worker empowerment, drawing inspiration from Henry Ford's ideals. He placed great importance on continuous improvement and human-centric approaches in problem-solving and organizational development (Ohno.T ,1988).

Other companies have found it difficult to understand and replicate Toyota's manufacturing process, despite Toyota's open and clear dissemination of its procedures. Yet, the true essence resides in the contradiction of the system itself. Although operations in Toyota's factories appear to be tightly regulated, the system is extremely versatile and adaptive, promoting continuous invention and improvement. The TPS and its scientific methodology were not intentionally imposed, but rather developed organically over several decades within Toyota. Consequently, there is no official documentation available, which presents a challenge for anybody outside of Toyota, including its own employees, to understand the system. The concept of TPS can be defined by examining its elements, particularly emphasizing four fundamental principles (Spear & Bowen, 1999):

- **How people work:** All procedures must be completed sequentially, utilizing same tools, and adhering to identical specifications. Every assignment has a designated timeframe for execution, which enables accurate assessment of its quality. Any deviations in the work instructions should be viewed as an opportunity to improve.

- **How people connect:** Clear communication and standardized interactions are very important in facilitating human connections. Toyota incorporates methodologies, such as the *kanban* system to guarantee that demands are precise and that there is an assigned individual accountable for meeting those requirements.

- **How the production line is assembled**: The assembly of the production line ensures that there are no interruptions and that requests for supplies or assistance follow a predetermined route.

- **How to improve**: Toyota employees are motivated to utilize the system to identify areas that require improvement, verify hypotheses and implement necessary changes. Kaizen, or continuous improvement, by utilizing problem-solving and experimentation, promotes an organizational culture that values and encourages learning and innovation.

This methodology, more than any others, is built on people and operators, especially how they work and how they think about change and improvement all the time. However, is always needed theoretical support.

The two primary components of the system's structure are Just-in-Time (JIT) and *Jidoka*. The primary objective of the first approach is to reduce waste by manufacturing products only when there is a demand for them, drawing inspiration from the restocking model used in supermarkets. *Jidoka*, also known as autonomation, is the integration of automation with human problem-solving. The process includes the automatic shutdown of equipment and the notification of operators on any problems. This methodology minimizes the occurrence of problems by analyzing the underlying reasons and implementing measures to prevent their reoccurrence. Stability is the foundation of the structure, requiring standardized, stable, and dependable operations. *Heijunka* is necessary to balance the production schedule in terms of volume and diversity, thereby promoting stability and minimizing stock levels (Monden, 2011).

The people are at the core of this structure, as only through ongoing improvement can operations achieve the required stability. They must be trained to analyze waste and identify the root cause of problems directly on the shop floor, rather than relying on secondhand information (Womack et al., 1990).

"All we are doing is looking at the timeline, from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by removing the nonvalue-added wastes" (Ohno.T ,1988).

2.2 Lean Thinking

Lean Thinking begins by prioritizing the consumer and establishing a clear understanding of what is considered valuable. Therefore, the concepts of lean thinking should be applicable to the process industries and the manufacturing processes within that industry, since a manufacturing process is a way of delivering value (a product) to a client (Melton, 2005).

According to Womack & Jones (2003) Lean Thinking is based on five principles:

- **Value**: The importance of knowing customers' wants and needs and meet them to give goods or services that are valuable to them.

- **Value Stream**: Focuses essentially on a diagram of all the steps involved in creating value for the client, including both activities that add value and activities that are wasteful and should be removed.

- **Flow:** The importance of maintaining a consistent and uninterrupted movement of activities that generate value across the value stream to improve efficiency, decrease cycle times, and optimize workflow.

- **Pull:** System that triggers production based on client demand, reducing inventory and waste by creating only what is required to satisfy consumer requirements.

- **Perfection:** Aim for continuous improvement and excellence by evaluating and removing tasks that do not provide any value. Encourage a culture of creativity and problem-solving to give more value to consumers.

Lean Thinking is a philosophy that aims to maximize value creation through the systematic elimination of waste (Womack et al., 1990).

By adopting Lean Thinking, it is expected that anything that does not provide value and is considered wasteful will be continuously removed to generate increases in efficiency and reduce resource, time and space consumption. Therefore, the process of identifying value-generating activities and sequencing them, without compromising the process and at the same time minimizing interruptions (ensuring the flow of value), involves a continuous improvement process (Melton, 2005).

2.2.1 7 *Mudas*

The term "*Muda*", which means waste in Japanese, comprises a range of inefficiencies that affect organizational processes. Taiichi Ohno, "the Toyota executive who was the most ferocious foe of waste human history has produced", categorized many forms of *Muda*, emphasizing its presence in day-to-day operations (Womack & Jones, 2003).

There are seven distinct categories of waste (*Muda*), illustrated in Figure 2.1 (Melton, 2005):

Figure 2.1: The seven types of Waste (*Muda*)

- **Overproduction:** Generating products or processes that exceed current demand, leading to an excess of inventory and needless use of resources. Regarding the consequences on the organization, this waste has the most significant impact.

- **Waiting**: Downtime incurred when workers or equipment remain inactive, awaiting necessary materials or instructions, leading to inefficiency and delays in production flow.

- **Transportation:** Unnecessary movement of materials or information between processes or locations, causing longer lead times and the possibility of product damage. It happens, usually, due to inadequate layout.

- **Inventory:** Excessive inventory of raw materials or goods at different phases of production, resulting in higher costs and the possibility of becoming outdated units.

- **Over-Processing:** Operations or processes that run longer than needed without adding value to the end product, which wastes time and resources.

- **Motion:** Unimportant or redundant movements made by employees within facilities, which do not enhance product quality or efficiency.

- **Defects:** Failures or imperfections in the manufacturing procedure that cause defective products, resulting in additional work, delays and higher expenses, as well as potential damage to the company's reputation.

Approximately 95% of the overall assigned activities to the product result in waste, while only the remaining 5% contribute to value creation (Pinto, 2014). The identification and elimination of these seven categories of waste present organizations with the chance to enhance overall performance by improving productivity, decreasing costs and eliminating inefficiencies in their processes.

2.3 Kaizen

Emerged from the TPS, the Japanese word Kaizen, "*Kai*" (change) and "*Zen*" (good), means "change for the better" or continuous improvement. This concept was later popularized when Masaaki Imai founded the Kaizen Institute in 1985. According to Masaaki Imai, Kaizen refers to the ongoing improvement in personal life, social life and the workplace (Ohno. T, 1988).

This concept might be interpreted as a philosophy that aims for absolute perfection. Reducing non-value-added waste is the goal of the methodology, which involves implementing improvements, no matter how small, in order to reach this end. These improvements tend to be driven by employees at various levels of the business, with the goal of enhancing efficiency, quality, and effectiveness (Imai, 1986).

“The single worker and the team have to be encouraged to solve problems with no fear of potentially stopping the line or the machine.” (Chiarini et al., 2018).

According to Kaizen Institute Consulting Group (2023) the method is based on understanding and meeting customer standards so that businesses can stay successful in markets that are changing quickly. They strive for the improvement of internal processes so that resources and information can flow smoothly by eliminating of bottlenecks and reducing waste. Frontline workers are encouraged to be involved in *gemba* orientation, which helps them find and fix errors. Giving employees the power to make decisions is a key part of creating an atmosphere that encourages learning, openness and responsibility. Visual management, such as the 5S technique, and standard work methods also guarantee uniformity, responsibility, and ongoing improvement.

2.3.1 PDCA

The PDCA (Plan-Do-Check-Act) cycle, represented in Figure 2.2 is a fundamental component of both traditional project management and Lean techniques. It consists of four iterative processes aimed at achieving continuous improvement (Stern, 2017) (Imai ,1986):

1. **Plan:** Analyze potential areas for improvement and develop strategies for implementation, establishing specific goals and efficiently allocating resources.

2. **Do:** Implement strategies, conduct tests and collect empirical evidence to guide decision-making.

3. **Check:** Evaluate results, analyze efficiency and detect variances to improve plans and enhance future projects.

4. **Act**: React promptly in response to insights, standardize effective methods and establish new improvement goals for long-term success.

The benefit of using PDCA for problem-solving lays in the model's simplicity. A team may quickly understand the structure without much discussion or training. Based on the concepts of quality management pioneers such as Deming and Shewhart, PDCA cycle guarantees ongoing dynamic improvement (Stern, 2017).

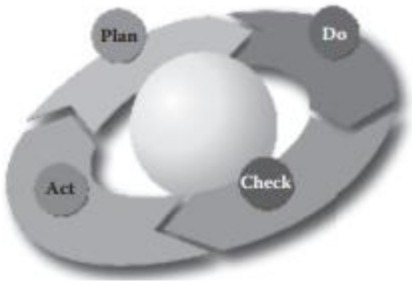


Figure 2.2: PDCA Cycle

“The first step in the Kaizen process establishes the plan-do-check-act (PDCA) cycle as a vehicle that ensures the continuity of Kaizen in pursuing a policy of maintaining and improving standards.” (Imai,1986).

2.3.2 5S

The 5S philosophy was originated in Japan and officially launched in the late 1960s. Osada and Hirano are recognized for developing the main foundation and implementing 5S (Randhawa & Ahuja, 2017).

The concept of 5S, derived from Lean Thinking and Kaizen, acts as an essential tool to enhance workplace efficiency. It is one of the three fundamental principles of Kaizen, along with standardization and waste elimination. The process consists of five essential steps, shown in Figure 2.3 (Imai, 2012):

1. **Sort** (*Seiri*): Separate all unnecessary items and remove them.

2. **Straighten** (*Seiton*): Arrange important things in a way that makes them easy to get to.

3. **Scrub** (*Seiso*): Properly clean all instruments and work areas, eliminating stains, spots and any sources of filth.

4. **Systematize** (*Seiketsu*): Establish a regular cleaning and inspection schedule.

5. **Standardize** (*Shitsuke*): Establish a set of standardized procedures, aiming to self-discipline, based on the preceding four steps, ensuring that the process is continuous and open to further improvements.

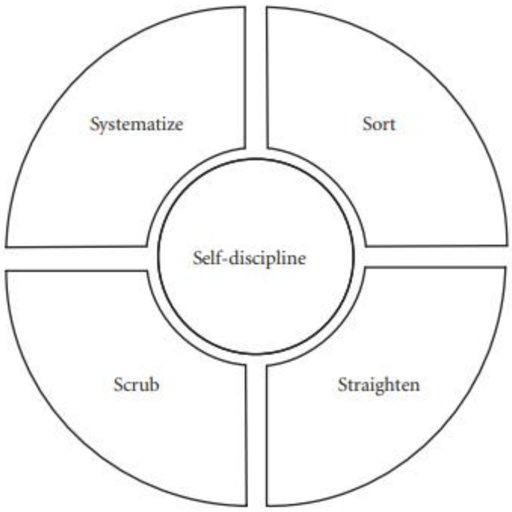


Figure 2.3: The Five Steps of 5S

“It is evident that it is not just a pure cleanup or housekeeping process. It brings overall improvements in employee involvement, organizational communication, teamwork, production, quality, workflow, safety, maintenance, customer complaints, in-process rejections, delivery compliance, absenteeism, inventory management and work environment thereby enhancing the competitiveness of the organization” (Randhawa & Ahuja, 2017).

2.3.3 Standard Work

The initial stage in eliminating waste is standardization, or more accurately, the execution of standard work, which is discovered throughout the basic process of examining work. Often, variations and irregularities in the process are noticed due to the lack of standardization in the execution of jobs by different persons, which is caused by the existence of multiple shifts (Imai, 1996)

Standard Work is an essential instrument for continuous improvement, ensuring safe and effective job execution in the shortest time (Berger, 1997)

This approach involves the use of analytical techniques to create Standard Operating Procedures (SOPs), serving as the best instructions for carrying out a work within a particular time range. “SOP contain operator work process such as process steps, work sequences, cycle time, work-in-process, process control etc.” (Sundar et al., 2014).

Standardization ensures that all procedures are executed in the same manner, regardless of the worker performing them. Once the tasks are perfectly defined, variability and inconsistency in the results will be eliminated. For this reason, it is essential to gather all the relevant documentation detailing the particular features that each operator must try to achieve in the performance of their duties. This documentation should be as clear, concise, and visually appealing as possible, to eliminate any ambiguity (Lu & Yang, 2014).

“Standardized work can be an ugly thing in the hands of control-oriented bureaucrats and a beautiful thing when it enables creativity and continuous improvement.” (Liker, 2021).

2.3.4 *Gemba* Walks

The term "*gemba*" in Japanese refers to the physical location where work is performed. In the context of a manufacturing environment, it specifically represents the area where value is added into the product or service. The primary responsibility of the managers is to enhance the *gemba*, by minimizing any factors that may negatively affect production efficiency. Hence, it is crucial to examine and assess each activity to determine its contribution in terms of value, comprehend its goal and significance, and evaluate the suitability of the methods employed (Imai, 2012).

“As a combination of *Gemba* (“the real thing”), *Genchi Genbutsu* (“go and see”), and *Genjitsu* (“real facts”)”, a *Gemba* Walk is a lean methodology that centers around the act of observing, engaging with, and collecting data on human and machine labor. This technique promote growth within an organization by cultivating the capabilities of individuals to address issues and generate ideas for improvement. *Gemba* Walks comprise four essential components: location, observation, teaming, and reflection. They offer a clear perspective on behaviors inside a specific setting, making it easier to comprehend and pinpoint chances for enhancing processes. Efficient managers have the ability to personally interact with employees at their place of work, expressing gratitude for their efforts, boosting motivation and establishing a sense of confidence. *Gemba* Walks help and improve organizations by fostering knowledge development, assisting managers in making well-informed decisions and promoting concordance among all people involved (Lalic et al., 2020).

2.3.5 Visual Management

Visual Management is a Lean tool that facilitates understanding for all stakeholders by making critical information visible through visual signals. It seeks to improve the flow of information inside the workplace and eliminate obstacles. In order to increase transparency, efficiency, value and clarity, the design should be displayed in a way that is easy to understand and communicate with everyone. (Singh & Kumar, 2021)

Visual management can be implemented in different ways, from *kanbans* to floor markings. It makes it easy to identify errors and prevent undesirable situations, acting as a form of process control. The use of color codes, graphics and images facilitates the sharing of information and the process of interpreting data between operators and managers. It is closely associated with the 5S concept since it enables actions to be taken in terms of organization and cleanliness (Pinto, 2014).

“A motorway is visually structured, so that as a place, it highly manages itself.” (Tezel, 2009).

2.4 Total Quality Management

To understand Total Quality Management (TQM), it is necessary to have a clear understanding of the concept of quality itself. Companies and organizations establish the concept of quality by utilizing specifications, standards and other metrics, so emphasizing that quality can really be defined and quantified. Nevertheless, the perception of quality is subjective and ultimately determined by customers. The assessment of quality plays a significant role in differentiating products in the market. Individuals apply specific criteria when making a purchase, and how well that purchase meets these criteria impacts its perceived quality (Goetsch & Davis, 2015).

TQM is a philosophical approach that emphasizes consumer satisfaction as a key driver of quality standards. The three-legged stool, presented in Figure 2.4, comprises metrics, people, and procedures. The first one highlights the significance of quality assessment and evaluation. The second one, people, stress the importance of quality being integrated by individuals who have the authority to perform their tasks accurately. Lastly, processes focus on the ongoing enhancement of procedures. Because the perspective of quality is constantly changing, "good enough" is never an adequate standard (Goetsch & Davis, 2015).

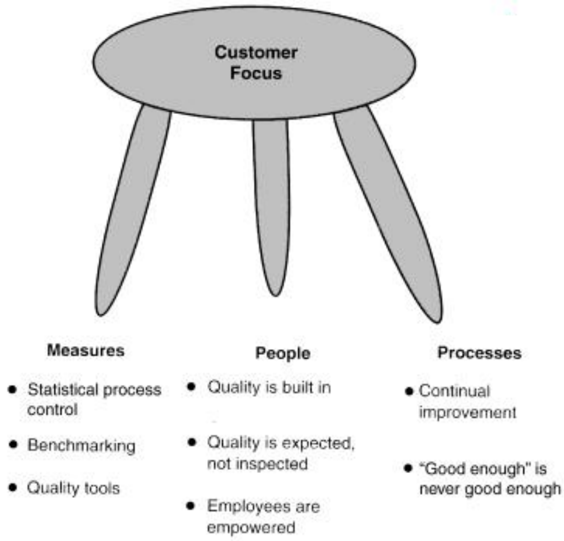


Figure 2.4: Three-Legged Stool of TQM

The goal is to continuously improve all aspects. Enhancing job performance, optimizing process efficiency and ensuring the excellence of goods and services are all integral components of this philosophy.

According to Juran and Godfrey (1999), the specific and universal goals of TQM are:

- **Lower Costs**: Higher quality frequently results in reduced costs by minimizing errors, rework, and non-value-added tasks. Preventing failures at the design phase is typically more cost-effective than rectifying them during manufacturing, post final inspection, or after the client has received the goods or services.

- **Higher Revenues**: Quality products and services result in increased consumer satisfaction, greater market dominance, stronger client retention and potential for higher prices.

- **Empowered Employees**: One of the key goals in TQM, since empowered workers possess self-control and the capacity to evaluate and understand their work processes. This strategy seeks to build an organization that can solve or prevent issues in the future, along with helping to address existing ones.

- **Delighted Customers**: Customers who are "delighted" are those that make repeat purchases, often promote and actively seek out new items or services.

"To achieve total quality, it is necessary to focus more on solving problems and continually improving and less on blaming individuals for problems." (Goetsch & Davis, 2015).

2.4.1 5 Why's

The 5 Whys strategy is a simple yet effective technique for uncovering the root cause of a problem. It can be used for troubleshooting and quality-improvement projects. The approach begins by identifying the problem, then conducting a series of "why" questions, each based on facts. This cyclical process continues until the root cause is identified, enabling the creation of efficient countermeasures to avoid its reoccurrence (Pojasek, 2000).

According to Poiasek (2000), it is important to mention that although the 5 Whys method is effective in dealing with straightforward problems, more complex issues may necessitate a more subtle and sophisticated approach. However, even in such situations, utilizing the 5 Whys methodology can provide valuable insights.

2.4.2 Ishikawa Diagram

The Ishikawa Diagram, alternatively referred to as the Fishbone Diagram or Cause-and-Effect Diagram, is an essential instrument used in quality management and continuous improvement processes. Developed by Dr. Kaoru Ishikawa in the 1960s, this methodology offers an approach to uncover and analyze the root causes of issues in industrial processes. The diagram is a graphical representation of the relationship between a certain outcome and the elements that influence it. It provides an overview of the causes that lead to a particular effect. The main phases of the Ishikawa diagram are problem identification, visual representation, information analysis, and formulation of an action plan based on the observations made in the preceding stages (Botezatu et al., 2019).

Figure 2.5 shows the Ishikawa diagram used as example in Botezatu et al. (2019) to demonstrate the factors that can affect the outcomes of a computer's reliability. These factors are the underlying causes of equipment failure or malfunction.

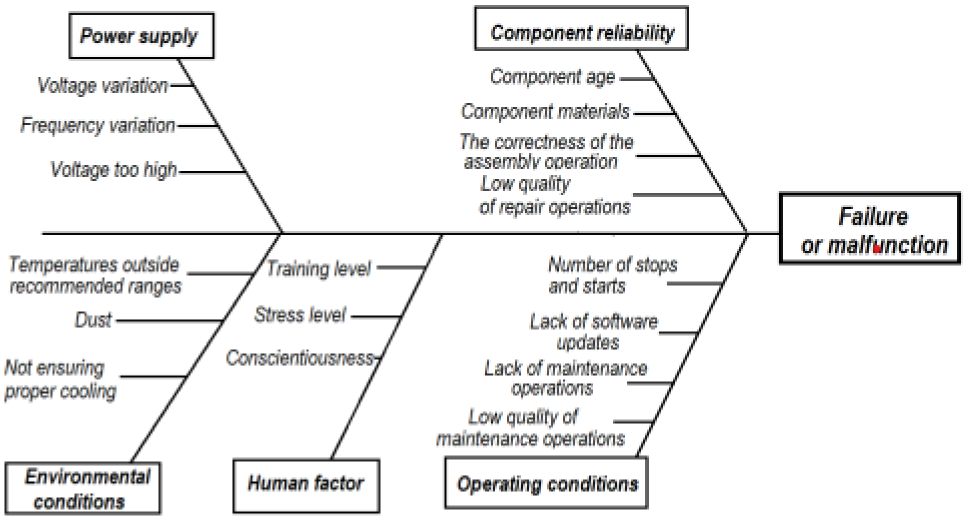


Figure 2.5: Example of Ishikawa diagram highlighting factors that affect the reliability of a computer

After organizing all potential causes, it is crucial to prioritize them to identify the ones that are most likely to be the root of the problem. Before discussing corrective steps, it is essential to verify the credibility of the identified reasons. During this process, the diagram might be updated to structure the scope of study (Montgomery, 2013).

2.5 Overall Equipment Effectiveness (OEE)

The Overall Equipment Effectiveness (OEE) is a tool developed directly from the Total Productive Maintenance (TPM) concept, created by Nakajima in 1988. “OEE is defined as a measure of total equipment performance” (Pintelon & Muchiri, 2010).

This metric, represented in Figure 2.6, is used in TPM to quantify the efficiency or productivity of equipment. Since it allows an assessment of the impact of implemented measures toward reducing or eliminating substantial losses, it is considered the most effective metric for promoting improvements in the workplace (Robinson and Ginder, 1995).

These losses were categorized into six major groups of waste Nakajima (1988):

- **Equipment failures**: Stoppages of equipment caused by natural, random or negligent malfunctions.

- **Setups and adjustments**: Processes of making changes to the production line. This includes interruptions to change equipment tools when there are changes in production or when is necessary make modifications using fine-tuning and conducting testing.

- **Idling and minor stoppages**: Irregular functioning of equipment parts that lead to short periods of downtime, often without discovering the reason or recording its occurrence.

- **Reduced speed**: Reduction that occurs due to the difference between equipment design speed and actual operating speed.

- **Defects in process**: The decrease in production volume is caused by the presence of non-conforming products, while the reduction in operating time is a result of the necessity to repair defective items on the corresponding equipment.

- **Reduced Yield**: Time wasted due to delays in initiating production, such as the use of inadequate tools and the lack of operational stability.

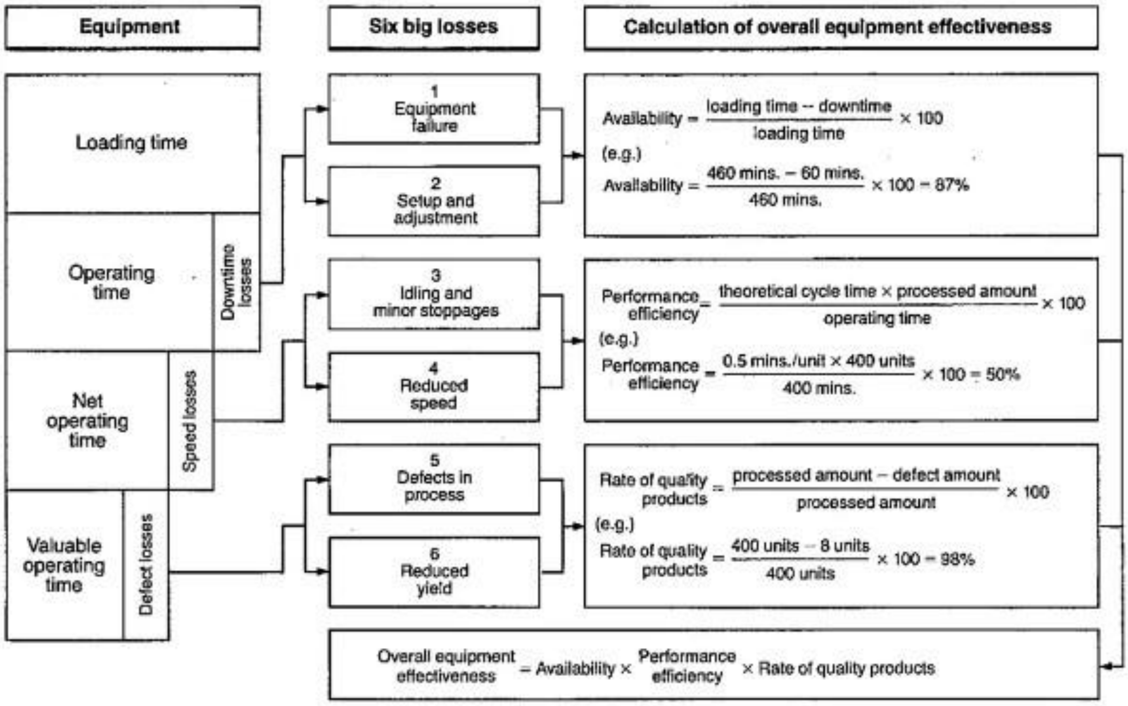


Figure 2.6: The relationship between the 6 losses and OEE (Nakajima, 1988)

These measurements are consolidated into three categories, particularly equipment utilization (Availability), operational rate (Performance), and satisfying output (Quality) (Basak et al., 2022)

The decrease in availability is associated with unplanned interruptions caused by equipment failures or scheduled interruptions due to setup and adjustments activities. This loss is related to the operational effectiveness of the equipment, which ensures that the equipment remains available for production. On the other hand, performance losses refer to temporary interruptions in production caused by machine failures, specifically micro-stoppages, as well as decreases in speed resulting from the disparity between the standard speed and the actual production speed. Lastly, the loss of quality includes mistakes, rework, and start-up losses, which mean making units that don't meet standards.

By combining these three major components, it is possible to calculate the Overall Equipment Effectiveness, as presented in Figure 2.7 (Nakajima, 1988):

$$OEE = Availability \times \ Performance \times Quality$$

Figure 2.7: OEE Calculation Formula 1

A		Shift Length
B		Planned shutdown
C	A - B	Loading Time
D		Availability Losses (Unplanned downtime)
E	C - D	Operating Time
G		Total Pieces
H		Quality
I		Theoretical Cycle Time
J		Real Cycle Time
F	J x G	Effective Operation Time
T	E / C	Global Operational Time
M	I / J	Operational Run Rate Index
N	F / E	Real Operational Time Index
L	M x N	Performance Index
OEE	T x L x H	Overall Equipment Efficiency

2.8: OEE Indicators (Armando Leitão, Bernardo Almada-Lobo & Luis Guimarães, 2019)

Additionally, the following expression is equivalent to the previous OEE formula, and it can be obtained by examining figure 2.8, illustrated above, leading to the same conclusions (Armando Leitão, Bernardo Almada-Lobo & Luis Guimarães, 2019):

$$OEE = T \times L \times H = \frac{E}{C} \times \frac{I}{J} \times \frac{J \times G}{E} \times H = \frac{\boldsymbol{IGH}}{\boldsymbol{C}}$$

2.9: OEE Calculation Formula 2

Upon analyzing figure 2.9, it can be inferred that the OEE can be enhanced by increasing production output (G), minimizing machine-detected flaws, consequently improving quality (H), or enhancing the machine's features related to theoretical cycle time (I). Moreover, if these three criteria remain consistent while the loading time lowers (C), the OEE will also rise.

Globally, the OEE can be classified (Crowter, 2023):

- 85% and above = “World class”, which only a few manufacturers can accomplish.

- 60% - 85% = Good target range for manufacturers and great expectations for the future.

- 40% - 60% = This range is a reasonable OEE score, where many manufacturers find themselves, however, is necessary an intervention because it can be happening impactful losses.

- 40% or less = Excessively low and unacceptable OEE value. Immediate action must be done to urgently increase OEE.

3 Problem Description

The initial section of this chapter involves describing the production process of a natural cork stopper at SOCORI's facility. Gaining knowledge of the relation between the different stages in the process is crucial for understanding the repercussions and effects they have on the end-product. Afterwards, an evaluation of the current situation within the project's framework will be conducted to identify current problems and potential improvements.

3.1 Production Process of Natural Cork Stoppers

As previously stated in Chapter 1, the project is carried out at SOCORI, an industrial unit that covers the full process of producing natural cork stoppers. This includes receiving and treating the cork in its pure and natural state as a raw material, along with packing the cork stoppers as the finished product. The flow is divided into a pull component and a push component. The first phase, considered since the reception of the cork to washing, is classified as a push system. Once the cork stoppers have been washed, they remain idle until a sales order is received, at which point they proceed the production process till packing. This second phase is considered as the pull component.

During the fabrication of natural cork stoppers, the stoppers are categorized into various classes to maximize the use of the cork's qualities and minimize waste. Natural stoppers are utilized for a variety of wines and are categorized based on their caliber, washing type and class. The caliber is determined by considering the diameter and length of the cork, with the most frequently used dimensions being 49x*2*4 mm. The washing process, which will be described afterwards, can involve several types such as *ECO*, *LNX*, *NATURA*, and *HIDRO*, Finally, the class determines the quality of the cork stopper by assessing its visual characteristics. The price of the cork stopper increases proportionally with its quality, and as a result, the bottled wine becomes more exclusive. The existent classes are represented above in Table 3.1, categorized based on the corresponding level of quality.

Table 3.1: Types of natural cork stoppers classes

Quality Level	**Class**
Premium	Flor
	Ext
High	Sup
Average	1st
	2nd
	3rd
Colmation	from 4th to 7th

After an important explanation of the key concepts of the process and natural cork stoppers, an overview of SOCORI's manufacturing flow, represented in Appendix A, is presented:

1. **Reception of the raw cork (raw material)**

   The first phase involves the reception of the raw material, which has as its primary objective to ensure the traceability of the cork. The cork arrives in the form of planks, which are stacked and then stored in the open-air yard, as presented in Figure 3.1, for 6 to 12 months to stabilize and acquire a uniform percentage of humidity. After this period, the cork is ready to be processed and is pre-sorted by experienced workers into four categories, still in the open-air yard: *cheio*, *delgado*, *cork waste* e *yellow stain*. The cork planks classified as *cheio* are the thicker ones that appear to be suitable for natural cork stoppers production, and therefore, they go to the next stage. The *delgado* class refers to those that are thinner and, thus, unsuitable for stoppers production. Instead, they are used to produce discs and are sold to another Group's industrial unit. *Cork waste* refers to the degraded raw material that is sent for grinding to produce agglomerated cork. Finally, those boards that have the yellow stain are useless and are sold as composites to Amorim Cork Composites.

Figure 3.1: Open-Air Yard at SOCORI facility

2. **Boiling**

   After choosing the planks, the next step is boiling. The planks are boiled in closed, filtered stainless steel tanks, as shown in figure 3.2. The process cleans the cork, eliminates organic particles from the ports and increases the thickness by fully submerging the planks in clean boiling water. This technique also enhances the flexibility of the cork and enables it to reach the optimal level of humidity required to produce cork stoppers. The duration should be a minimum of one hour at a temperature near 100ºC. As the volume of the board increases, it becomes more regular and simpler to handle, making thickness a crucial aspect.

Figure 3.2: Boiling Process (Amorim, 2022d)

3. Trimming

After undergoing the process of boiling, the cork needs to stabilize at least one day, but never more than three. Once the planks have been stabilized, the edges are prepped and the corners are trimmed, as presented in Figure 3.3. The cork, then, is categorized, based on specific features such as their look, thickness and porosity, into the same groups that were mentioned in the previous process (reception of the raw cork). At this stage, there is a sub-categorization of the *cheio* class, making it possible to distinguish, within the planks that continue into production, those that are of higher or lower quality. In this phase is very important to identify a crucial defect, "*bicho*" (hole in the cork). Due to its highly visual and subjective nature, it is crucial the expertise of the workers during the process.

Figure 3.3: Trimming Process (Amorim, 2022d)

4. Punching

Following preparation, the cork planks are now prepared to be transformed into the familiar shape of a cork stopper, as seen in Figure 3.4. At SOCORI, there are two methods for achieving this goal: manual punching and semi-automatic punching. The first one is intended for superior-grade cork planks. It is costly and slower than the second, but far more effective. The operator, who has decades of experience in this process, drills several perfect holes in the cork board to take advantage of the highest quality sections and waste as little as possible. In contrast, semi-automatic punching involves the worker inserting the plank into a machine that automatically creates the holes. Despite being faster, the machine lacks consideration for the board's composition and drills uniformly. This approach results in more waste and is less rigorous compared to the first method, which is why it is specifically designed for average and poor grade plank corks.

Figure 3.4: Punching Process (Amorim, 2022d)

5. **Waste Cork Selection**

   After the punching process, the stoppers are sent to a waste cork selection electric machine. The objective of this procedure is to choose the cork stoppers that are good to be produced from the cork waste associated with the preceding process. The system categorizes the corks into three distinct types: *not graded corks*, *repass* and *cork waste*. The first category consists of cork stoppers that have been drilled without any defects and are within the specified parameters for the standard production process, being the only type that is use in the normal production flow. The *repass* stoppers have a surface defect that occurs on the tops and, for this reason, are used for lower calibers after the defect elimination. The *cork waste* stoppers have a big quantity of defects and distortions. Consequently, rather than following the usual production process, they are directed to grinding to create agglomerated stoppers.

6. **VXX**

   After the waste selection, all the cork stoppers, except the cork waste, are transported to the VXX, a steam treatment, where the main goal is the near-complete eradication of TCA (2,4,6-Trichloroanisole) and the regulation of humidity levels. This process involves a low-pressure steam flow and water which, together with vacuuming and suction, remove the harmful particle from the corks. TCA, the most well-known and feared defect in the cork industry, is responsible for the typical "cork taste". When exposed to wine, this chemical compound generates an unpleasant smell and contributes to a moldy flavor on it.

7. **Dimensional Rectification**

   Once the units without defects have been into the VXX, they are sent to the dimensional rectification machines. The TCA treatment is aggressive, using steam, water, some chemicals and a lot of strength what can damage significantly the cork stoppers. In this process, the stoppers undergo mechanical operations to polish the tops (capping) and/or smooth the body of the stopper. The aim of this phase is to guarantee and correct the dimensional specifications, length and diameter, for each stopper batch.

8. **Pre-Selection Eletric Machine**

   After the corks have been adjusted to the proper dimensions, they are placed into the first commercial class grouping. The pre-selection machine is responsible for examining the visual characteristics of the cork and categorizing it into one of two main groups: *ext* to *3rd* or *4th* to *7th*, based on its appearance. The corks in the first group may potentially belong to a more premium and superior quality category, unlike the second group. Like the most electronic machines in SOCORI, there are also outputs channels for *repass* and *cork waste*, which always have the same destination in all the processes that are identified.

9. **1st Electronic Sorting (1st EE)**

   At this point, the stoppers have already been correctly sized and have a high probability of being TCA-free. Furthermore, the cork transitions from SOCORI I to SOCORI II, which is the designated name for the other warehouse where the complete sorting process occurs. During this phase, the corks are transported and inserted into an electric machine that will individually select the very first (individual) commercial grade. The machine utilizes a 2D representation of the cork to identify and categorize faults and visual aspect. The stoppers are classified as*: flor, ext, sup, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, repass* and *cork waste*. As stated in the beginning of this section, the *flor* class is the stopper with higher quality and *7th* with the lowest. Cork stoppers with a grade higher than *4th* are processed according to their natural production flow, while those with a grade between *4th* and *7th* are outsourced to the colmation process.

10. CIP

Once the batches have been classified according to the corresponding class, they are sent to another machine known as the CIP. Unlike the others electronic sorting machines, the CIP does not evaluate the visual characteristics of the cork. This process is only responsible for checking whether or not the corks have *bicho*. The equipment consists of sensors and pipes that emit air. *Bicho* is a defect that can create an opening from one end of the cork to the other. If the sensor detects air at the opposite end, it means there is a hole in the cork and the cork is classified as *"not sealing"*. If the sensor fails to detect the flow of air, the cork is classified as "*sealing*". Those that have through holes (*bicho*) are sent to grinding, while those that do not, are kept in the normal production process.

11. VS

Most of the stoppers, categorized from *flor* to *sup*, are sent to SOCORI I for VS treatment after undergoing analysis by CIP. This procedure shares similarities to VXX, as it operates on the same principles and aims to eliminate TCA that may still exist. The main distinction is in the fact that this treatment is only reserved for high-quality corks, resulting in a less aggressive approach that minimizes the risk of significant damage to the corks.

12. 2nd Electronic Sorting (2nd EE)

After the initial commercial grade has been assigned and the *bicho* defect has been checked, the corks are sent to the second electronic sorting machine. The main difference between this and the 1st EE is in the utilization of 3D technology to assess the visual characteristics of the cork. This process involves refining the selection of grades by dividing the present grade into two grades above, two grades below, and the grade itself. For example, if a batch of cork stoppers entering 2nd EE has left 1st EE categorized as *1st*, the machine will split that batch into *ext*, *sup*, *1st*, *2nd* and *3rd*. Additionally, 2nd EE not only produces the *repass*, but also has a distinct output for *bicho*. This defect can sometimes originate a hole in the top of the cork that has the body as an exit point. Because it is not a top-to-top hole, CIPs can't detect it.

13. Individual Detection by Bourrasé (idB)

Only the finest corks, categorized between *flor* and *sup*, undergo the idB process (almost the same as NDTech at Amorim Cork). The client usually requires this operation to be done to make sure the stoppers don't have any TCA in them. As it is an additional process, it adds value and increases the price of the cork, however, it gives the customer the guarantee that their stoppers have been completely checked and examined by a high-technology system to ensure they don't contain any residual amounts of TCA.

14. Washing

Almost every single type of natural cork goes through this section which is located in SOCORI I. From the most premium corks to those that are going to be filled (colmation procedure), this process is essential because it cleans and disinfects the cork using water and chemicals (essentially peroxide). The type of washing depends on the stopper's final destination, as well its quality and the requirements of the customer's order. The visual appearance of the cork stoppers can vary depending on the chemical agents used, allowing customers to select the desired color of their cork.

After washing, the stoppers batches require a period of time to stabilize and reduce the humidity level to an acceptable one. This stabilization procedure is necessary to eliminate undesirable compounds like TCA. The washing process can take between 30 min and 2 hours, depending on the type, and the stabilization time should be between 12 and 36 hours. Some cork stoppers may not undergo this process, either because they are being sold in their raw form without being washed, or because they are being used for product testing purposes.

15. Manual Sorting

Once the post-washing stabilization time is complete, the stoppers are introduced into the pull component of the production flow. They are once again transported to SOCORI II, where they wait for a sales order and then proceed to Manual Sorting. This process involves a designated area with six conveyor belts, each operated by one highly skilled worker (occasionally there may be two). These workers visually assess and categorize the cork stoppers. During this stage, they carefully inspect for any significant and critical flaws that may have been generated in previous processes. These defects include *pronounced repass*, *deep fissures*, *verdura*, *costa*, *deformations* or *cork waste*. Furthermore, corks that should have been categorized as a lower class in the previous sorting procedures are placed in a small carrier. For example, when a batch categorized as *sup* enter this stage, the workers in the conveyors, not only eliminate the listed flaws, but also remove the stoppers they consider to be *1st*. These units await a sales order for batches that are classified as *1st* and are then returned to the conveyor belt together with them. The corks that have faults are subsequently sent to grinding.

16. X-Ray Machine

Finally, only the cork stoppers that don't have critical defects and don't belong to the class below the one analyzed in the Manual Sorting are directed to the X-Ray machine, the last sorting process. This machine was put into operation around one and a half year ago. The technology utilized by this machine is cutting-edge, since it is capable of analyzing the 3D structure of both the exterior and interior layers of the cork, as well as its weight. This enables the identification of defects like as *clay*, *cobrilha*, *nail* and *deformations* that may not be easy to spot in the previous processes. The machine has three potential outputs: *X1*, *X2*, and *X3*. The first category refers to non-defective stoppers that are prepared for packaging. The designation *X2* is used to refer to cork stoppers that are considered "doubtful", meaning they contain a small number of flaws or belong to a lower quality category than the one being examined. These items are sent back for Manual Sorting to be reexamined. Lastly, the output associated with *X3* consists of stoppers that possess significant defects such as *bicho* and *cobrilha*, making them unusable, being removed from the production process and conducted to grinding.

17. Control Check and Packing

Once the cork stoppers, identified as *X1*, exit the X-Ray machine, they immediately drop into the prepared bags for shipment. After being filled, the bags are transferred to a designated area close to the X-Ray equipment. There, a sample of 50 stoppers is inspected in every bag per order. If the sample has over 2% of *bicho*, for corks graded from *flor* to *sup*, or 4%, for the lower quality classes, the batch is rejected and sent to washing process, being reintroduced into the production process. On the other hand. if the requirements are met, the batch is accepted and the bag is sealed and placed on a pallet, ready for delivery.

3.2 Analysis of the Current Situation

Section 3.1 provided a crucial explanation that allowed the awareness and understanding that any stage in the production process can potentially cause an error and loss of a cork stopper, regardless of its commercial class. Due to their inherent nature, natural cork stoppers possess characteristics that can be challenging to comprehend and perceive. Therefore, it is essential to have a clear understanding of the process and the specific stages where issues may arise. This section will provide a more in-depth analysis of the processes that have pointed out problems that need to be mitigated, along with the possible causes and solutions for them.

The area of SOCORI II where the sorting processes occur has an apparent problem related to the inefficiency of the production flow. Therefore, every issue mentioned will be related to this specific processes. The primary causes of this inefficiency can be attributed to five categories: machinery and equipment, labor, process control, materials and processes. The primary factors contributing to inefficiency in sorting processes, to be outlined in this chapter, include lack of standardized procedures, insufficient operator training in visual analysis of stoppers, lack of cleaning and preventive maintenance schedules for machines, inadequately calibrated programs in machines and inefficient process controls. Additional causes that may contribute to the described issue can be observed in the Ishikawa Diagram provided in Appendix B.

3.2.1 CIP Perfomance

The first stage where problems were found was in the CIPs, the machines accountable for detecting *bicho*. As previously stated in section 3.1, *bicho* is a crucial defect that represents a significant threat to wine. To clarify the visual perception of the defect, Figure 3.5 displays several instances of corks containing *bicho,* which is a hole that extends from one top of the cork stopper to the other.

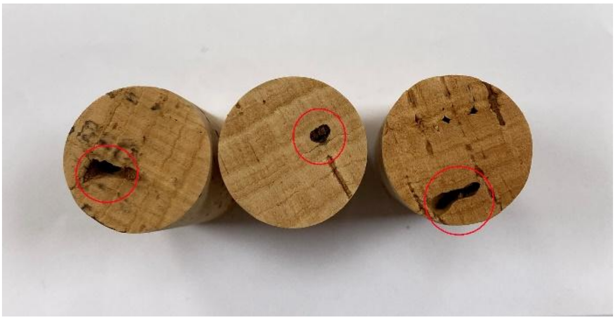


Figure 3.5: Cork Stoppers with *bicho* defect

The CIP area consists of three machines that operate in two shifts: the first shift runs from 6am to 2pm, and the second shift runs from 2pm to 10pm. Each shift allows for two 15-minute breaks. The CIPs, unlike other machines in the sorting process, lack 3D or 2D intelligence and rely solely on mechanicals operations. The equipment is composed of cylinders, clamps for securing the cork, sensors, and channels that apply air pressure to the examined cork, as depicted in Figure 3.6. The six air channels, observed in same Figure, verify the efficacy of the cork seals. If the sensor detects airflow from one end of the stopper to the other, it indicates that the cork stopper is not sealed.

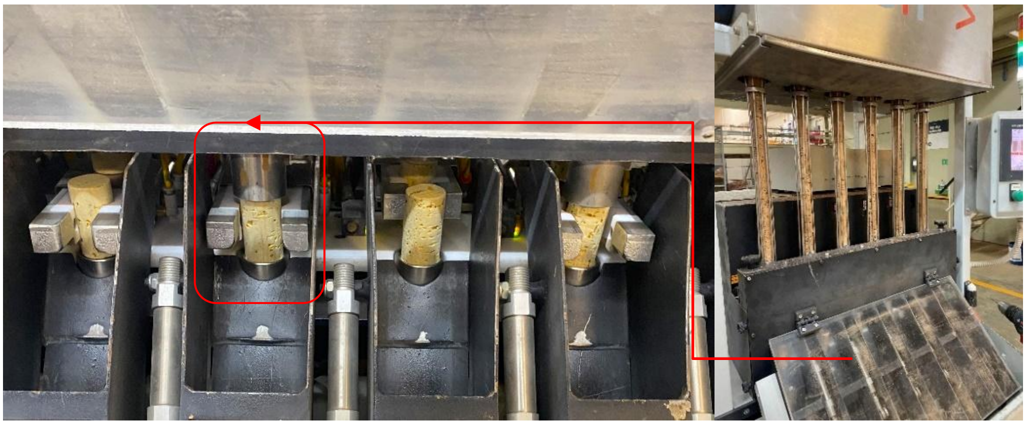


Figure 3.6: CIP Mechanism

Due to maintenance, one of the three machines has been non-operational since January 2024. Therefore, only two machines, namely CIP 02 and CIP 03, are being evaluated for this study. The CIPs do not require any setup and are calibrated manually (a process that takes a few seconds) if there is a change in the caliber of the batch of corks being produced. Furthermore, the machines lack a cleaning treatment, resulting in visible grime that is clear at all periods of the day. Figure 3.7 illustrate different instances of dust accumulation on the equipment. The operator who is in charge for the CIPs is responsible for calibrating and unblocking channels, as well as providing the machine with new batches. In addition to the CIPs, the operator also is accountable for the 1st EE,

Figure 3.7: Examples of dust accumulation on CIP

Due to its entire mechanical system relying on various parts, the machine is very sensitive to dust and dirt. Any cork fragment or particle has the potential to interrupt the sensor or enter one of the channels, causing the machine to interrupt its operation in some channels and deform cork stoppers.

Additionally, aside these issues, the machine's breakdown record is nearly non-existent or incomplete, making it impossible to determine occurrences of unplanned breakdowns that result in an entire interruption of production. Only recently was implemented a breakdown system history via SAP (Systems Applications and Products), but it still struggles, leading to the assumption that there were no unplanned breakdowns. Channel stoppages are common, but the simultaneous stoppage of all six channels is extremely rare.

After conducting multiple *gemba* walks and observations, it was clear that there were a considerable number of stoppages detected in the channels. There were only a few occasions when all the channels were functioning for extended periods of time. Despite being common, these interruptions can be promptly and easily addressed by the operator with the removal of the blocked stopper or the application of compressed air into the sensor to remove dust. Table

3.2 presents one of the several empirical observations on the functioning of the machines. For example, CIP 02 operated for a duration of 21 minutes with two stopped channels, only achieving 66.67% of its full performance during that time.

Table 3.2: Records of empirical observation of CIP Performance

Machine	Day	Start of the stop	NºChannels Stopped	End of Stop	Channels that stopped	Minutes of downtime	%Channels working
CIP 02	16-abr	14:53	2	15:14	2,5	21	66,67%
CIP 02	16-abr	15:14	3	15:18	2,4,5	4	**50,00%**
CIP 03	16-abr	15:04	3	15:06	1,4,6	2	**50,00%**
CIP 03	16-abr	15:06	1	15:20	4	14	83,33%
CIP 03	16-abr	15:20	3	15:23	4,5,6	3	**50,00%**

After analyzing Table 3.2, illustrated above, is clear that the machine's performance is low, with periods where can reach only 50% of channels working. Due to this situation, it is important to understand the machine's current overall equipment effectiveness (OEE), the main indicator in this section.

This indicator is made up of three parameters: availability, performance and quality. Since the machine, as mentioned above, does not require setups, has no cleaning plans and unplanned downtime is not consider, the machine's availability per shift is assume as maximum (100%). It should be noted that in reality, achieving this value is not possible, however, it was considered for calculation purposes. Theoretical operational time, therefore, can varies on every week, solely based on the number of working days in that particular week. Channel stoppages, which influence performance but do not completely stop the machine, will have the most significant impact on OEE. The performance is calculated by dividing the real production output by the theoretical output. Theoretical production capacity was determined by conducting field observations, which involved measuring the time taken to manufacture a certain quantity of stoppers. This allowed the calculation of the theoretical production rate in stoppers per second. The real production data is accessible through MES (Manufacturing Execution System), which is a factory floor system that cloud real-time production information from all machines in every sector. Additionally, quality is determined by evaluating the number of stoppers that are accepted in the process, also possible to gather in MES.

Table 3.3: Average of CIP OEE Indicators

Period	Perfomance	Quality	Availability	OEE
Week 1 to 16	53,40%	99,91%	100,00%	**53,35%**

The data shown in Table 3.3 clearly shows that performance is the only element that has a considerable impact on OEE. Furthermore, despite its importance, it can be concluded that the machine typically rejects a small number of cork stoppers, making it a residual process for *bicho* identification, with average quality being almost 100%. The results presented in Table 3.3 correspond to the initial 16 weeks of the year 2024. These values represent the average measurements for both machines and both shifts, considering all categories of stoppers.

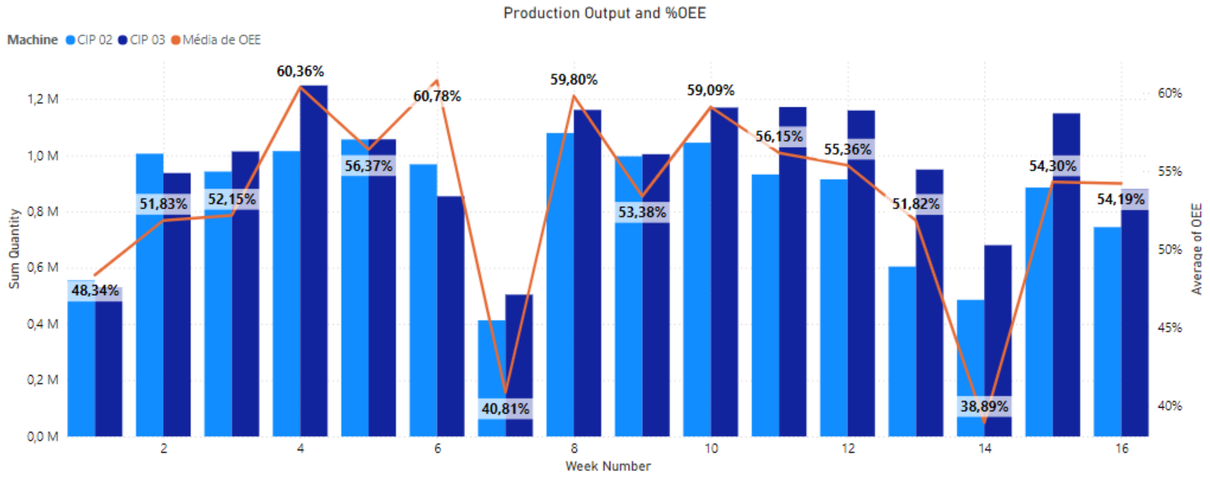


Figure 3.8: CIP weekly production output per machine with the average OEE of the two machines

The Figure 3.8, displayed above, illustrates the weekly production output per machine, along with the average OEE of the two machines. During the 16-week period, the CIPs had an average OEE of approximately 53.35%. The observed variation in OEE values over time is noticeable, however, the production amounts can be deceptive due to weeks with fewer working days than others. Nevertheless, it is evident that CIP 03 produces more than CIP 02. In the next section, Chapter 4, the differences in the performance of each machine and their evolution after the solutions implemented will be analyzed in more detail. The focus will be on the OEE of each machine in separate.

The average OEE, while not particularly alarming, is not higher due to two main identified causes: the presence of dirt and dust that negatively impacts the machine's delicate systems and the absence of operators in the CIPs sector to promptly address issues in the channels. Additionally, the lack of a preventive maintenance plan and the inability to regularly check the parts' condition contributes to the main problem. Furthermore, not having a reliable record of machine breakdowns also makes it difficult to analyze the machine's performance.

Implementing a standardized work or machine cleaning plan will greatly enhance the performance of this section, as dirt is one of its primary issues. Furthermore, increasing operators' awareness of issues such as dirt, absence in the CIPs section and the condition of the parts might potentially lead to higher productivity of the section. The primary objective is to enhance the efficiency and OEE of the machine by increasing its performance.

3.2.2 *Repass* on 2nd EE

A customer's complaint regarding defects in a specific order triggered a detailed study of the defect rate in the different sorting processes at SOCORI II. This study specifically focuses on the most profitable and often ordered caliber and class group of corks stoppers, 49x24 from *flor* to *3rd*. Table 3.4 displays the average percentage of stoppers classified as incorrect, categorized by defect type and process, during the first four months of 2024. The figure is obtained by dividing the quantity of faulty stoppers by the total quantity of stoppers undergoing the process. The study did not include the Manual Sorting since it was challenging to collect accurate and reliable data due to the subjectivity of the procedure and the lack of production statistics in the MES. The data of Table 3.4 was collected, selected and processed using MES.

Table 3.4: Average rate of defects by process (first four months of 2024)

Process	**Cork Waste**	***Bicho***	**Repass**
1st EE	0,99%	0%	2,00%
CIP	0%	0,07%	0%
2nd EE	0%	0,97%	**2,57%**
X-Ray	0,55%	2,50%	0%

After examining the Table 3.4, it can be concluded that the predominant flaw observed in the stoppers that undergo the sorting procedures was the *repass*. In addition, among all the defects, *repass* is the only one that can be repurposed for cork stoppers of different sizes, resulting in a greater profit. In contrast, cork stoppers with *bicho* can only be grinded or used for colmation and have no other viable use. Given that the proportion of *repass* is greater in the 2nd EE, the study focuses only in this specific process. The figure 3.9, below represented, displays cork stoppers that are classified as *repass* in the 2nd EE, exhibiting damaged top surfaces.

Figure 3.9: Cork stoppers with *repass*

The 2nd EE is a crucial stage in the sorting process, where the stopper obtains its most accurate commercial grade. This phase uses a machine equipped with 3D visualization, enabling more efficient elimination of defects. The section has six machines, which, in addition to producing various outputs for different grades as described in subchapter 3.1, also include two dedicated output channels for *repass* and *bicho*, illustrated in Figure 3.10. Each machine consists of a 3D lens and a 2D lens that examine the surface, tops and size of the cork stopper based on a set of parameters particular to each program matching to each type of stopper.

Figure 3.10: Output channels for *bicho* and *repass* (2nd EE)

Consequently, a more complete analysis was conducted on the production data of 2nd EE, specifically focusing on the *repass* rate during the initial 16 weeks of the year, from January to April. The Figure 3.11 represents the average weekly *repass* rate, considering all grades between *flor* and *3rd*. with 49x24 caliber, across all machines.

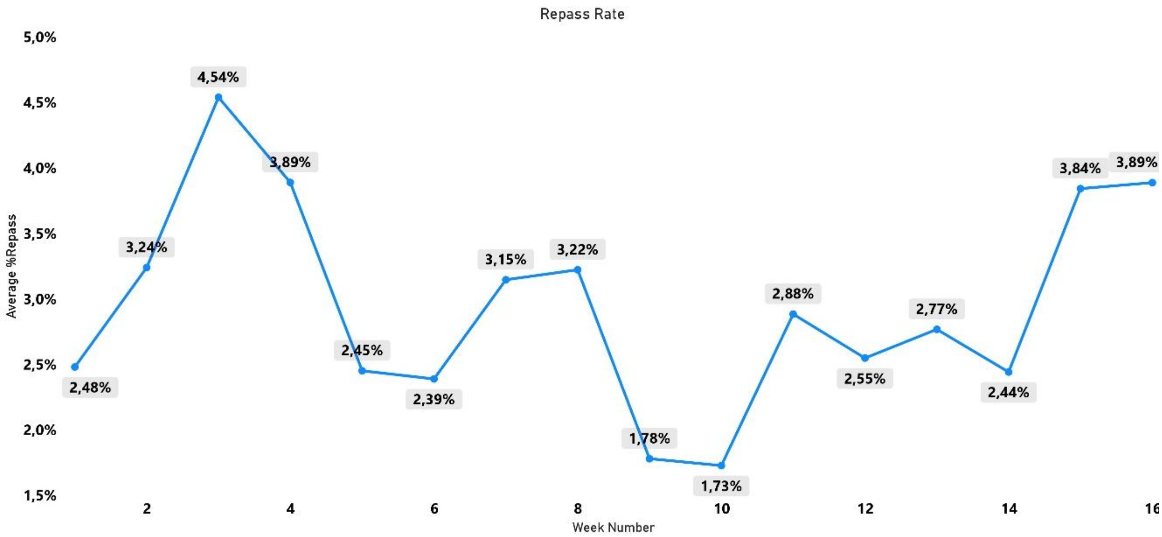


Figure 3.11: Average weekly *repass* rate across all 2nd EE Machines

The disparity in data is evident, characterized by distinct spikes and declines in the *repass* rate with time. The observed divergence over time clearly suggests a clear lack of process control. The average *repass* rate observed over the studied period in the 2nd EE section was around 2.57%.

Following a macro-analysis, it is imperative to study the types of cork stoppers that have the most influence, both in terms of the total quantity produced and of the *repass* rate. The Table 3.5, displayed below, illustrates the items with the most *repass* output, with all the data being gathered in the MES, from the first four months of 2024. To ensure confidentiality, the articles have been assigned with generic names. Nevertheless, it is crucial to realize that an article encompasses its class, its caliber, and its washing type.

Table 3.5: 2nd EE total quantity produced and repass rate (first four months of 2024)

Article	**Total Output**	**Repass Output**	**Repass Rate**
Cork Stopper Type 1 (CS1)	4139082	43917	1,06%
Cork Stopper Type 2 (CS2)	4499137	62832	1,40%
Cork Stopper Type 3 (CS3)	1083187	43256	3,99%
Cork Stopper Type 4 (CS4)	3856584	154922	4,02%
Cork Stopper Type 5 (CS5)	3413783	202141	5,92%

Table 3.5 shows that the CS4 and CS5 have the most impact from the *repass* occurrence. Additionally, the CS1 and CS2 contribute with the highest number of stoppers to the electronic sorting process. The proportion of *repass* increases as the quality of the cork is worse, as would be expected. To gain a deeper understanding of these numbers, various controls, with 100 cork stoppers per sample, were conducted at the exit of *repass* output channel to verify the machine's accurate identification of this kind of defect. It is crucial to emphasize that this process control was previously non-existent, making it the first control data on the machine's efficiency in detecting this specific issue.

Table 3.6: Average rate of false rejected stoppers, repass, weak tops and cork waste (date collected with process control to 2nd EE repass output channel)

Period	% False Rejections	% Repass	% Week Tops	% Cork Waste
Week 8 to 16	**19,45%**	62,71%	10,74%	7,03%

The data in Table 3.6 corresponds to the controls conducted between February and April 2024, on the classes of cork stoppers that have been recognized as having the greatest impact on the *repass* rate. The records can be observed with more detail in Appendix C. The table displays the average percentage of all the controls for *false rejected* stoppers, *repass*, *weak tops* and *cork waste*. In other words, the machine incorrectly rejects approximately 20% of the untis that are actually considered acceptable. On average, approximately 63% of the cork stoppers that undergo the *repass* output channel are, in fact, defective, while the remaining ones have visually poor tops (lower quality category cork stoppers), be considered *cork waste* or be defect-free. The most worrying figure is the high number of wrongly rejected stoppers which should have followed their normal production flow. It is crucial to understand that false rejected stoppers are defect-free units that are mistakenly classified as defective, resulting in a substantial financial loss that could have been avoided if the corks had been correctly selected.

In order to address the main issue in this section, the 5 Why's analysis technique was utilized:

Problem: There is a high number of false rejections on the *repass* output

- Why?: Inefficiency of the sorting machine
- Why?: Unsuitable programming (wrong parameters or different programs for the same type of stopper on different machines)
- Why?: The operators are unaware of any issues with the *repass* output.
- Why?: The *repass* output does not have process control
- Why?: The indicator is not considered for analysis in section

Root Cause: The indicator is not included on process monitoring and control objectives.

Based on this analysis, it can be assumed that the primary cause for the high proportion of incorrect rejections on *repass* output is the exclusion of this indicator from the objectives of process monitoring and control. If such a scenario were to occur, it would result in the implementation of process control measures, leading to a further improvement in the operators' understanding and knowledge of the existing data. Once operators were granted access to the real numbers and realized the issue, they would possess the power to enhance and modify the programming for each stopper. Ultimately, the machine's efficiency would increase and occurrence of false rejections would decrease. Automatically decreasing the quantity of incorrect rejections results in a corresponding reduction in the *repass* rate.

A potential answer to address the issue is to provide training to operators on programming parameters for different types of cork stoppers and on visually assessing the quality and defects of the cork. Furthermore, the adoption of process controls and the establishment of a performance indicator that involves all operators would certainly enhance their understanding of the problem.

3.2.3 X-Ray Output Channels

The X-Ray process is the final step in the production flow before packaging the cork stoppers for customer delivery. This cutting-edge technology machine was installed and made ready for production on the shop floor in the early months of 2023, indicating that it is a relatively new addition to the company's assets. The X-Ray is not designed to detect basic flaws that should have been eliminated in earlier stages, but rather to identify defects that cannot be detected by other machines technology, such as *cobrilha*, a critical defect similar to *bicho*, as well as *nail* and *clay*, which, although less severe, still have a detrimental effect on the cork stopper. Certain defects can be identified either by examining the external appearance of the stopper or by analyzing its internal structure. The X-ray is specifically tasked with examining both the interior and exterior of the stopper.

The machine has three output channels: *X1*, where the corks are defect-free and ready for final control; *X2*, which includes "doubtful" corks with minor defects or of a lower quality that need to be reprocessed on Manual Sorting process; and *X3*, which consists of corks that are considered *cork waste* and therefore useless, being sent to grinding.

Similarly to the analysis of the 2nd EE prompted by customer complaints regarding flaws, the X-Ray process was also studied. This process serves as the final step in selecting stoppers and carries the ultimate duty of accepting or rejecting units from a batch.

Table 3.7: X-Ray total quantity produced per output channel (from January to April 2024)

	X1	***X2***	***X3***	**Total**	**%*X1***	**%*X2***	**%*X3***
49x*2*4	13502465	316801	68789	13888055	97,22%	2,28%	0,50%
45x*2*4	10227981	610930	74712	10913623	93,72%	5,60%	0,68%

The Table 3.7 displays the quantity of cork stoppers produced and corresponding percentages by the X-Ray machine from January to April 2024. The data is categorized by caliber and output channel. It is evident that the majority of the stoppers are identified as *X1*, while the 49x*2*4 stoppers are less frequently rejected. It is assumed that a stopper is considered rejected when its output is either *X2* or *X3*. There is a notable disparity in the proportion of *X2*, with 45x*2*4 stoppers being classified as "doubtful" approximately twice as frequently as larger ones.

In contrast to *repass* on the 2nd EE, the batches that go through the X-Ray are subsequently submitted to a final control to avoid sending faulty batches to clients. Until January 2024, the machine's effectiveness was assessed by examining the outputs *X1* and *X2*. However, following that month, only *X1* output was inspected Therefore, it was necessary to conduct additional controls to *X2* output and initiate a first-ever examination of the stoppers classified as *X3* in order to collect current and reliable data.

Table 3.8: Average rate of defects per X-Ray output channel and caliber, gather with process control

Output Channel	**Period**	**Caliber**	**%Defects**
X1	January (2024) -April (2024)	49*X2*4	0,68%
		45*X2*4	0,73%
X2	March (2023) - April (2024)	49*X2*4	31,8%
		45*X2*4	31,6%
X3	February (2024) -April (2024)	49*X2*4	77,7%
		45*X2*4	68,6%

Table 3.8 provides an overview of the process controls performed at the three output channels on different caliber cork stoppers during the indicated periods. The stoppers leaving

channel *X1*, free of defects, are placed in bags with a maximum quantity of 5000 stoppers per bag. This process control is done by collecting 50 cork stoppers from each bag (equivalent to 1% of the total) per sales order. For instance, in the case of an order for 20000 stoppers, four samples consisting of 50 stoppers each will be gathered. Each sample will correspond to one bag containing 5000 cork stoppers. An order is dismissed if one or more samples are considered rejected. A sample is rejected if the proportion of *bicho* or *cobrilha*, referred to as "defects" in Table 3.8, exceed 2% for grades from *flor* to *sup* or 4% for the others. The process control to *X1* has been continuous since the X-ray equipment became operational. On the other hand, *X2* underwent inspection during the initial year, lasting from March 2023 to January 2024, while *X3* has not been inspected at any moment. The absence of specifications for critical defects other than *bicho* and *cobrilha* results in a minimal amount of rejected batches.

By analyzing the *X2* control data presented in Table 3.8 it is evident that the majority of the stoppers considered "doubtful" are either free of defects or of inferior quality. The problem arises from the fact that approximately 30% of defective cork stoppers are reprocessed back into the production flow for Manual Sorting. In contrast to *X1* control process, all the stoppers in the batch, without exception, that were identified as *X2* were inspected, resulting in a high amount of time spent analyzing them. For this reason and the occurrence of reprocessing, the control process responsible made the decision to discontinue this inspection protocol.

Finally, the *X3* output, which is concerned with the *cork waste*, has never undergone any form of control. This is because all of these stoppers are considered to be worthless and, therefore, are sent for grinding, having no further impact on the production flow. After analyzing Table 3.8, it is evident that over 70% of the cork stoppers examined have *bicho* or *cobrilha*. Nevertheless, even though the quantity is small, the company is still discarding approximately 25% to 30% of defect-free stoppers by subjecting them to grinding. If these cork stoppers were used in a different manner, minimizing their waste, the financial gains linked to *X3* output in the process would increase.

Introducing process controls for the *X2* and *X3* outputs, along with verifying and adjusting program parameters or specifying an alternative final destination for the stoppers from these groups, could be helpful improvements to address the reprocessing of defects and the waste of cork stoppers without any defect.

3.2.4 Visual Management

As mentioned in Chapter 2, there is a concept known as 5S, derived from Lean and Kaizen principles, that emphasizes the importance of workplace order and cleanliness. Furthermore, it is imperative for a workplace to possess a simple and unambiguous identification system. A clean, structured, and well-identified site significantly enhances the efficiency of existing workers, consequently improving the overall performance of a section. It also assists new employees in learning the production flow and helps visitors understand the fabric floor. Unfortunately, certain sorting sections at SOCORI II suffer by poor visual management. The area where this is most apparent is the final step of the production process, specifically in the X-Ray and Manual Selection section.

The fact that bags or containers produced via the Manual Sorting and X-Ray processes share the same waiting area is the first obvious visual defect. As illustrated in Figure 3.12, it is difficult to visually distinguish between the bags or containers that have been processed by the Manual Sorting and are going to the X-Ray, and those that have already undergone the X-Ray process and are prepared for placement on the pallet. Multiple bags or containers are present in close proximity.

Figure 3.12: Waiting bag area in SOCORI II

Another significant issue at this particular location is the challenge of not only differentiating between bags, but also being unable to determine which bags have already been controlled after X-Ray process and what the outcome of the inspection was. As represented in Figure 3.14. below illustrated, the bags lack clear indication that determine whether they have undergone quality control or if the corresponding batch is validated to be placed on the pallet.

Figure 3.13: Waiting bags without quality control identification

The last problem identified in the context of visual management in this section relates to the fact that the final control table, where the samples of the bags from the x-rayed batches are analyzed, is relatively far and hidden from the bag waiting area, as Figure 3.15 illustrates.

Figure 3.14: Overview layout of SOCORI II (X-Ray and Manual Sorting sections)

When taking a wider perspective on Figure 3.15, it becomes apparent that there is a deficiency in visual identification and a unclear layout. Besides the distance between control point and waiting area, the standards used for comparison with the samples are not located at the control point due to the small size of the table. Whenever the worker wants a standard, which is a sample used as a reference to validate or invalidate another, they must ascend to the top floor of this section, resulting in a big loss of productive working time. These factors may have an adverse effect on the section's performance and production.

Implementing signs, cards or other means to clearly designate various areas and procedures in the layout is crucial for enhancing visual management at SOCORI II. This initiative fosters a more optimal, simplified and productive working environment.

4 Project Development

This chapter presents the proposed solutions to the various problems described in the different subchapters of the previous section. Additionally, it explains the methodologies used to develop those solutions and the improvements resulting from their implementation. This section also examines the initial stage compared to the final stage after each modification was implemented, mainly focusing on the OEE of the CIPs, the *repass* rate and the number of false rejections in the 2nd EE, the waste of cork stoppers classified as *X3* on X-Ray and the SOCORI II visual management.

4.1 CIPs cleaning Standard Work

As stated in the problem description about the performance of the CIPs section, this area involves machines that are highly vulnerable to dust and fragments of cork. Hence, the primary objective of the solution is to establish a cleaning Standard Work (SW) procedure to mitigate the accumulation of dust and cork in the machines. This implementation aims to enhance the performance and consequently the OEE of the CIPs.

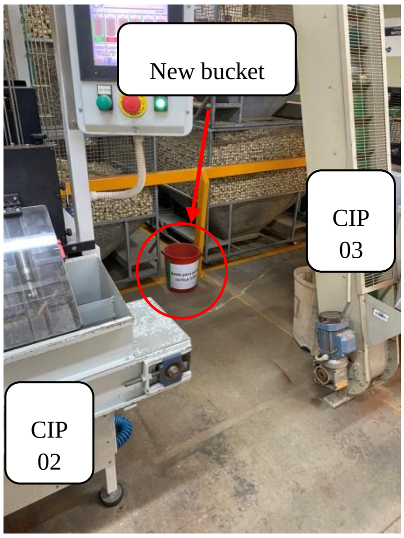
As a result, a set of procedures for cleaning the CIPs was developed with the assistance of maintenance and cleaning personnel from various departments. The objective was to ensure that the machine cleaning process was efficient and fast, enabling any operator to perform the operation. The timing of each job instruction was determined by careful observation and field experience. Operators responsible for the task were provided with training and clarification on the most efficient method to carry out their tasks on both shifts. Their collaboration and expertise in this field have significantly contributed to the development of the cleaning standardization. The objective of the SW is also to enable operators to decrease job duration by increasing the frequency of task execution.

The SW procedures mostly include utilizing compressed air to remove dust from the equipment. The machine is cleaned from both the front and rear parts, covering both the outside and interior. Furthermore, after stopping the machine, a inspection is conducted to check whether any corks got stuck within a channel or on the edge of blocking it. Each channel is thoroughly cleaned using compressed air, and subsequently, the entire machine undergoes a superficial cleaning process. The full description of this standardized work can be observed in Appendix D, which includes detailed images of each task along with their respective durations. The total duration of the cleaning process is 3 minutes, being executed at the end of each shift. Hence, it is important to mention again that the initial shift covers from 6am to 2pm, while the second shift extends from 2pm to 10pm. After finishing the shift, the operator responsible for the cleaning task must sign a record sheet, presented in Appendix E. The purpose of this sheet is to verify the execution of the cleaning, identify the person who performed it and record the time it was done.

The main goal of this procedure is to enhance the machine's performance by minimizing the presence of dust and cork fragments, without compromising the equipment's availability. As stated in sub-chapter 3.2, the availability up to week 16, before the introduction of the standardized cleaning, was considered to be total (100%). Considering that the cleaning tasks require approximately 3 minutes in total and a shift lasts for 7.5 hours, the availability will remain essentially the same.

A few days of testing and empirical observations of the operators performing this work led to the realization that, despite its extremely short duration, it would still be possible to reduce the total cleaning time. The third cleaning procedure step has the most duration. This phase involves placing the dust located on the upper, front, and rear parts of the machine into an assigned dust bag. The bag was situated at a considerable distance from the machines, as illustrated in Figure 4.1(a), resulting in a task duration of approximately 30 seconds. By reusing a basic bucket and positioning it behind both machines to perform the same function as the bag, as shown in Figure 4.1(b), the duration of this procedure was reduced to just 10 seconds. Appendix F illustrates the effects and differences in the level of cleanliness of some machine parts after the implementation of SW.

((a)) Before



((b)) After

Figure 4.1: Changes in dust bag

After this change, although the overall cleaning time was reduced, there was no meaningful influence on machine availability. The shorts minutes of cleaning are insignificant when compared to the machine's running time of 7 hours and 30 minutes every shift.

Table 4.1: Average weekly OEE indicators (Before SW vs After SW)

Period (Weeks)	Perfomance	Quality	Availabilty	OEE
1-16 **(Before SW)**	53,40%	99,91%	100,00%	53,35%
17-22 **(After SW)**	57,55%	99,92%	99,71%	**57,33%**

Table 4.1 displays the disparities in the average OEE values and their corresponding indicators for both CIP machines together. This analysis considers their performance during both shifts, before and after the implementation of the SW. After analyzing the data, it can be concluded that the average OEE of the CIPs increased by approximately 7.47%, resulting in a close to 4 percentage points (pp) rise from 53.35% to 57.33%. The quality and availability indicators remained essentially the same. As stated in the problem description, the performance indicator has the greatest impact on OEE. Therefore, it is crucial to evaluate it to understand the reasons behind the increase in OEE and provide a valid justification. In

order to accomplish this, an analysis was conducted to assess the impact of improving performance on each particular machine. While the calculations for OEE were carried per machine and per shift, as demonstrated in Appendix G, was decided to solely analyze the impact per machine for its contribution to the project's development.

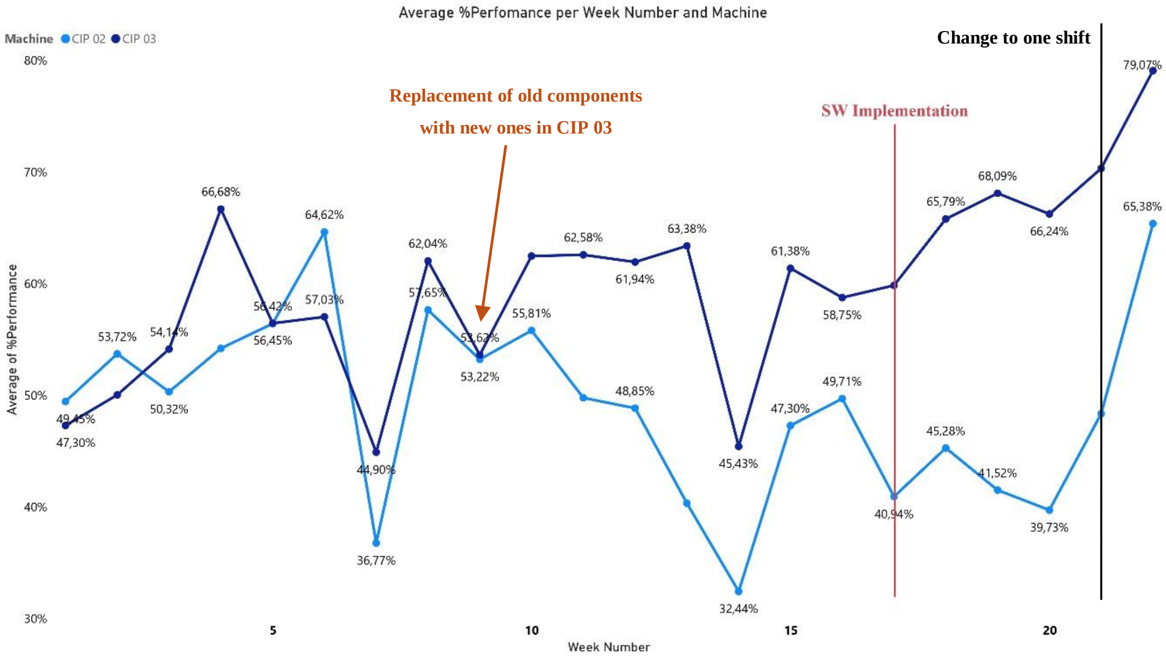


Figure 4.2: Average weekly Performance per machine (Considering all the study period)

Figure 4.2 represents the weekly performance of each machine over the whole studied period starting from the beginning of 2024 and ending in middle of May (week 22). By examining Figure 4.2, it is visible that there are three distinct moments depicted in the graph that noticeable influence all the results: weeks 9, 17, and 21. During Week 9, a preventive maintenance, not related to the project, was performed on CIP 03, which involved replacing the old components of the machine with new ones, by installing new cylinders and clamps. Week 17 marks implementation of SW cleaning process at the conclusion of every shift. One the other hand, in Week 21, there was a transition from two shifts to a single shift, from 8am to 5pm.

The first moment, although unrelated to the project's development, has significant importance as it explains the reason behind the higher performance values observed in CIP 03 as compared to CIP 02. Week 9 marks the stabilization in the performance of CIP 03, except in week 14, and an increase in the discrepancies with the values of the other machine. By incorporating the new components, the equipment experienced reduced frequency of channel interruptions compared to the CIP 02, achieving a more consistent and stable cadence as a result of the better condition of the new parts. Therefore, it is evident why CIP 03 shows also a greater level of production.

Over time, the components deteriorate, leading to a decline in the performance of the machines. This make the machines more reliant on the operator's presence and quickness to unblock the channels and clean them. The importance of the condition of the parts becomes even more evident and solidified after the introduction of SW. Starting from week 17, there was a notable improvement in performance on CIP 03. On the other hand, CIP 02 had a certain stabilization in the performance values, which prevented the expected decline caused by the condition of the components. However, the machine's average performance experienced a substantial rise over the final weeks of the project.

After analyzing Figure 4.2 once more, it is evident that the most significant performance improvement, on both machines, was from week 21 to 22. As a result of ongoing decrease in sales and quantities produced, a decision was made to transition from two shifts to a single shift, operating from 8am to 5pm. With this change the machine runs for a total of 8 hours each day, with the operators receiving a 1-hour lunch break. From week 22 onwards, a worker was assigned only to the CIPS and 1st EE sections, with the primary responsibility of unlocking the devices.

Table 4.2: Average weekly OEE indicators per machine (Before SW vs After SW)

Machine	Period (Weeks)	Perfomance	Quality	Availabilty	OEE
CIP 02	1-16 (Before SW)	50,04%	99,94%	100,00%	50,01%
	17-22 (After SW)	46,87%	99,92%	99,71%	**46,69%**
CIP 03	1-16 (Before SW)	56,76%	99,89%	100,00%	56,69%
	17-22 (After SW)	68,23%	99,92%	99,71%	**67,97%**

Table 4.2 displays the weekly average OEE and its corresponding indicatores per machine, both before and after the application of standard work. The weekly average OEE of CIP 02 decreased by around 6.62%, corresponding to a decline of around 3.5 pp, in contrast to CIP 03, which had a 19.89% rise in OEE, equivalent to nearly 11.5 pp.

Therefore, it can be concluded that cleanliness, the condition of the machine's components and the operator's commitment and awareness for the problem are the crucial factors for achieving improved OEE performance. Maintaining cleanliness is crucial for keeping the machine's OEE at a stable level and gradually improving it. The applied cleaning plan had a greater effect on CIP 03 due to the presence of new components that were in better condition compared to those of CIP 02. It is unrealistic to believe that just one cleaning throughout each shift will significantly enhance components' conditions in such a way that performance rises quickly. Essentially, on a machine with well-maintained components, the cleaning SW can play a stable role and gradually have a significant influence on enhancing the machine's OEE. On the other hand, in a machine with older and more worn components, cleaning can mitigate the reduction in performance caused by equipment component issues and subsequent machine microstoppages.

There is no such thing as a perfect world, and there are indeed weeks when performance drops due to too many stoppages or moments when the operator was busy with other tasks and took too long to unblock the machine's channels. This study proved the impact of dust and dirt on the machine, as well as the condition of its components. Ensuring the cleanliness of the machines and the commitment of the operator responsible for monitoring the CIPs were crucial strategies to address the problem of low CIP performance. These actions effectively increase the machine’s OEE, reduce the negative effects of waiting (*Muda*) and enhance the cleanliness and organization of the section.

4.2 Implementing a dynamic process control to 2nd EE *repass* ouput channel

Another problem highlighted in section 3.2, was the fluctuating and relatively high *repass* rate observed in the 2nd EE. The instability observed is a direct result of the lack of process control to the *repass* output. Considering the process controls presented in Appendix C and outlined in the previous chapter, it was determined that, on average, 20% of the stoppers identified, by the machines, as *repass* were incorrectly rejected and could have follow the normal production flow. The study primarily analyzed stoppers measuring 49x*24*, ranging from *flor* to *3rd*.

To address the problem, the priority was to establish a dynamic control process. This involved having the section's workers conduct multiple controls on the different machines in the repass output channel. The goal was to assess the machine's ability to detect *repass* defect and make any necessary adjustments or program standardizations. The implementation utilized the PDCA (Plan-Do-Act-Check) approach. First of all, it was imperative to meet and plan with the operators in charge of the 2nd EE machines to ensure their awareness of the issue and obtain their valuable insights. Afterwards, the operators received training in visual examination of a stopper to ensure that they were capable of accurately identifying defects and differentiating between various grades. They were also trained to understand the parameters of the programs and how they work. After this stage, the parameters of some programs were evaluated and adjustments were tested to determine their impact and how to act after the process control implementation.

The dynamic process control consists of collecting a sample of around 50 cork stoppers from the *repass* output channel of one of the 2nd EE machines and identifying how many are truly *repass* and how many are non-defective stoppers that were incorrectly rejected. If the number of false rejects exceeds 5 stoppers, or 10% of the sample, the batch is rejected. In this case, the operator must stop the machine and determine which parameters need to be changed and adjusted so that the incorrectly rejected stoppers are accepted by the machine. The worker must also ensure that the other machines have identical parameters for this type of cork stopper in the corresponding program. Following the operators training and a week of evaluating and testing the programs, the controls were implemented.

There are two operators, one for each shift, who are responsible for the 2nd EE section Additionally, there is a quality control worker who is responsible for conducting controls across the SOCORI II area. Consequently, it was determined that each of these professionals would do a control on distinct machines, twice a day. To ensure the collection of accurate control data, a record sheet was distributed to the 2nd EE section, as presented in Appendix H, for use by all individuals accountable for process control. Besides providing the number of false rejections, it also includes the decision made (whether to approve or reject the batch) and any subsequent actions taken following the control.

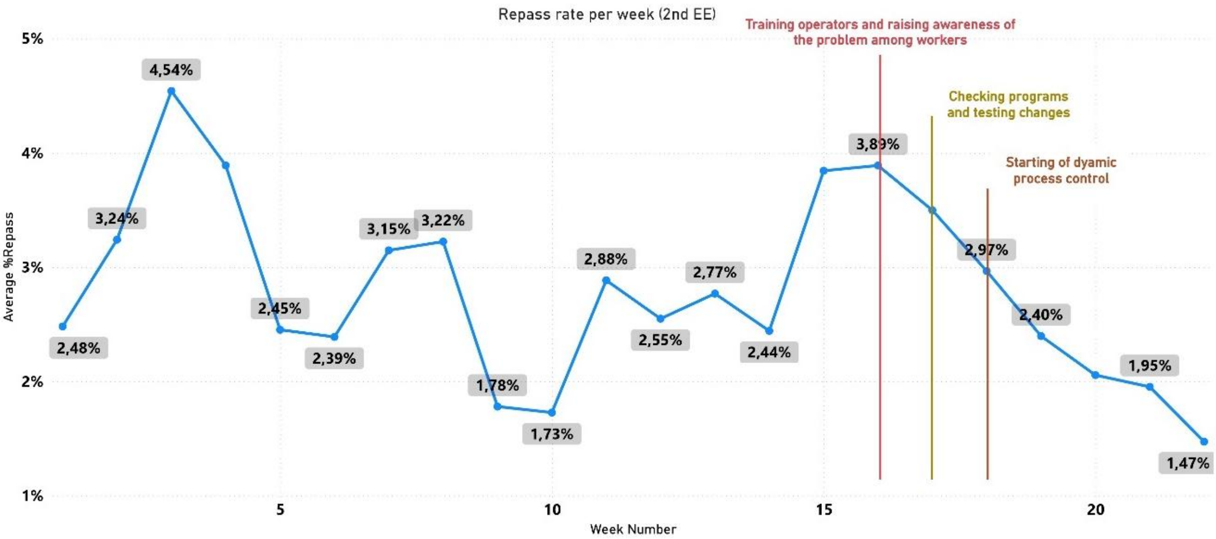


Figure 4.3: Average weekly *repass* rate across all 2nd EE Machines (Considering all the study period)

Figure 4.3 displays the average weekly *repass* rate of 49x24 stoppers, from *flor* to *3rd* grades, considering all the machines. The graph additionally outlines the periods during which the different phases of the implementation occurred. During the week 16, employees received training and were informed about the issue. After that, during week 17, the programs of the machine underwent evaluation and several tests were conducted in order to modify some settings (parameters). At last, the week 18 marked the begging of dynamic process control. After observing Figure 4.3, it is evident that the implementation of these process controls has had a favorable influence on the decrease in repass rate numbers. Since the planning and testing phase, in weeks 16 and 17, that the graph clearly illustrates a sharp drop in the average *repass* rate. It's important to note that all these values were obtained by MES, by collecting the output of each machine, more precisely, by dividing the number of stoppers identified, by the 2nd EE machine, as *repass* by the total number of stoppers in that batch.

It was concluded that the operators' lack of awareness of the problem was indeed one of the primary factors contributing to the high and fluctuating *repass* rate. The problem was promptly addressed and resolved as a result of workers' increased knowledge and training, enabling them to promptly take appropriate action. The introduction of dynamic process control in week 18 solidified the significance of this measure, resulting in a consistent decrease in the average *repass* rate from 3.89% in week 16 to 1.47% in week 22.

The primary cause for the decrease in the *repass* rate was the big decline in the occurrence of false *repass* rejections at 2nd EE machines, with the actions of dynamic process controls.

Table 4.3: Average of false rejections rate in the articles previously identified as most affected by *repass*

Article	Before	After	Descrease pp	Descrease %
CS1	18,04%	6,00%	12,04 pp	66,75%
CS2	20,50%	7,09%	13,40 pp	65,43%
CS3	21,79%	3,00%	18,79 pp	86,23%
CS4	21,56%	5,00%	16,56 pp	76,81%
CS5	13,95%	5,33%	8,62 pp	61,77%
Total	19,17%	5,28%	**13,88 pp**	**72,43%**

Table 4.3 demonstrates a considerable reduction in the percentage of false rejections in the articles previously indicated in sub-chapter 3.2 as being most impacted by the *repass* defect. These particular articles were examined in greater detail and were particularly chosen because they had the potential to generate more financial benefit for the company. Table 4.3 compares the percentages of false rejections related to controls shown in Appendix C, before the implementation, with the new ones carried out from week 18 onwards. Some of these particular records, not all, can be seen in Appendix I. The adjustment, correction and normalization of the programs, through the controls, did in fact result in a drop in the value of false rejections of around 72.43%, equivalent to 13.88 pp. Following the implementation of dynamic process controls, the average rate of false rejections decreased from 19.17% to 5.28%. Furthermore, by adjusting the settings appropriately, it was possible to transfer the *cork waste* stoppers, previously found at the *repass* output, to the *bicho* output for grinding. Additionally, stoppers with weakened tops ended up going to the channel of the lower grade cork stoppers. Essentially, this adjustments and parameter corrections mean that the *repass* output channel will only have stoppers that have been identified with the *repass* defect, making control easier.

Reducing the number of wrong rejections is crucial, but it is even more important to maintain this reduction. In order to fully execute the PDCA cycle, which stands on the idea of continuous improvement, it is imperative to actively observe the outcomes and make adjustments as needed, similar to how controls operate. A bar chart was created for all operators, including those not participating in the project. The chart displays a significant indicator and is physically displayed in the section for everyone to examine. The indicator, provided in Appendix J (an example) and obtained from MES data, is gathered on a daily basis. It indicates the *repass* rate by a specific class on a particular machine (limited to articles of size 49x24, from *flor* to *3rd*) on the previous day. The entire department is now aware of the average *repass* rate from the previous day, for each class on a specific machine. This information allows the workers to make any necessary adjustments that might have been missed or left out the previous day and enables them to always be up to date on the problem.

Table 4.4: Financial earnings, supposing the implementation of the dynamic process control on 2nd EE (initial 4 months)

Article	**Total repass output quantity**	**False Rejected decrease pp (FRd)**	**No. of ML recovered (1000 cork stoppers units)**	**Earnings (first 4 months)**
CS1	43917	12,04%	5,3	2.705,24 €
CS2	62832	13,41%	8,4	3.041,32 €
CS3	43256	18,79%	8,1	2.020,64 €
CS4	154922	16,56%	25,7	4.583,06 €
CS5	202141	8,62%	17,4	1.639,03 €
		Total		**13.989,28 €**

Table 4.4 represents the financial earnings achieved in the initial four months of the year, supposing the utilization of dynamic process control during this timeframe. The benefits presented solely correspond to the articles that have been specifically identified as being the most impacted by the *repass*, being nearly 14000€. If, in a given article with a certain class, the false rejects have decreased by a certain percentage point, it means that instead of being identified as *repass*, as before, those number of stoppers will be identified without defects by 2nd EE. In other words, the value of the decrease in false rejects in percentage points (FRd) is the percentage of stoppers recovered to the normal production flow. As stated in the description of the process in Chapter 3.1, a stopper that is defect-free and enters this stage might be categorized into the same class it was in the 1st EE (C), one or two classes lower with inferior quality (C-1 or C-2), or into classes with superior quality (C+1 or C+2). By analyzing the data obtained from MES of the 2nd EE, it was possible to track the machine's behavior throughout this sorting process and calculate the probability of a cork stopper of a specific class being produced to a certain output channel. For that reason, the data from the initial 4-month period, specified in Appendix K, was examined. Then, was calculated the probability by dividing by the number of stoppers in each output category (C-2, C-3, C, C+1, and C+2) by the total amount, considering the input class.

The Equation 4.1 was used to calculate the earnings generated by the decrease in false rejections:

$$earnings = \sum_{x=-2}^{2} \frac{rep.total.output(CS) \times FRd(CS) \times P(CS = C + x)}{1000} \times price/ML(C + x) \tag{4.1}$$

In the given Equation 4.1, CS represents an article of a given class that is being analyzed and enters the machine. P(CS=C + x) represents the probability of this article having the output of class C+x, where x is a value between -2 and 2. In the cork industry, the unit of measurement used for sales is the "milheiro" (ML), which represents one thousand stoppers. The fractional part of the calculation represents the number of ML that would have been recovered during the initial 4 months if dynamic control had been adopted and the rate of false rejections had decreased accordingly. This number needs to be multiplied by the price per ML at which the class identified by the machine is sold. As a cork stopper can have 5 outputs, all these cases need to be added up to see how many ML of different classes could be gained by recovering the defect-free stoppers. An example of a calculation for one of the classes is shown in Appendix L for a better understanding and the probabilities considered are found in Appendix M.

Given that the study covered a period of 4 months, it was assumed that the machine's output probabilities would only be modified if the company's management decided to change the class characteristics standards. Thus, it is concluded that this calculating formula remains applicable until this alteration occurs.

To sum up, the *Muda* of defects was reduced by applying a dynamic process control, training operators and making them aware of the problem of high *repass* rate in 2nd EE. The development of the mentioned indicator, presented in Appendix J, enables the continuous tracking and monitoring of this issue on a daily basis.

4.3 Defining a new destination to x-rayed cork stoppers classified as *X3*

In the X-Ray process, two significant issues were mentioned in sub-chapter 3.2. Firstly, it was found, by process control. that approximately 30% of the cork stoppers identified as *X2* have critical defects, which are reprocessed in Manual Sorting. Secondly, approximately 30% of the stoppers at *X3* output are found to be defect-free, yet they are sent to grinding, resulting in waste. An ideal situation would involve modifying the X-Ray programs' and their parameters in such a way that all the cork stoppers identified as *X3* have critical defects and *cork waste*, while those at *X2* output are defect-free stoppers of a lower quality category than *X1*.

This action wasn't possible due to the lack of operators trained to do so, and it was also not feasible to find a qualified expert with the necessary training to modify the programs of the high-tech machine during the project period. Therefore, the study concentrated on the *X3*'s output, specifically the stoppers considered defective and subsequently destined for grinding. One possible solution would be for the stoppers from *X3* to have the same output as those from *X2*. In other words, instead of being grinded, the *X3* stoppers would undergo a reprocessing procedure in Manual Sorting in order to maximize the utilization of the 30% of non-defective cork stoppers. However, this solution maintains and could increase the reprocessing *Muda*, putting even more defects, around 70%, back into the production flow.

In order to prevent waste in *X3* output, it was imperative to find an alternate solution. Consequently, a deeper analysis was conducted at *X3* cork stoppers. After a series of empirical observations and controls at *X3* output channel, besides confirming what the previous inspections had already indicated, that 30% of good corks were wasted, it was concluded that all the cork stoppers examine in the samples could be colmated. It is crucial to note that, usually, only the stoppers from the *flor* to *3rd* grades undergo X-Ray process. Furthermore, the cork stoppers that are colmated are typically of low quality, ranging from 4th to 7th grade, and display numerous holes, flaws, and imperfections. Any cork that isn't deformed, broken or has defects on the top can be colmated. The main idea here is that the quality of a cork stopper, from *flor* to *3rd*, even when considering the presence of flaws, is typically superior to stoppers from *4th* to *7th*. Essentially, a good quality stopper (*flor* to *3rd*) that undergone colmation process is easily considered and sold to customers as a cork stopper of the 4th grade.

Colmation procedure involves the process of filling in any openings or holes in cork stoppers using cork, glue, water, and various chemical substances. Consequently, it can be concluded that colmation process is just meant to fill spaces in the cork and is not used in deformed or *repass* cork stoppers.

Table 4.5: X-Ray *X3* Output and colmation potential earnings

Month	Caliber	*X3* Total Output	Earnings
jan	49X24	19543	1.169,40 €
	45X24	23940	1.432,51 €
fev	49X24	13753	822,94 €
	45X24	22733	1.360,28 €
mar	49X24	14396	861,42 €
	45X24	19495	1.166,53 €
abr	49X24	21097	1.262,39 €
	45X24	8544	511,25 €
Total	49X24	**68789**	**4.116,15 €**
	45X24	**74712**	**4.470,57 €**

Table 4.5, displayed above, represents the quantity of stoppers produced by the X-Ray in *X3* output and the potential earnings associated with them being sent to colmation process. The data was gathered utilizing MES and refers to the initial four months of 2024, considering the caliber of the examined corks and the potential financial gains that would be obtained if these corks were colmated instead of being grinded. The earnings were determined by considering the quantity of stoppers produced by *X3,* the price per ML of 4th class cork stoppers (price/ML) and the cost per ML of outsourcing the colmation procedure (cost/ML). The Equation 4.2 below explains the way of calculating earnings:

$$Earnings = \frac{X3\ Total\ Output}{1000} \times (\mathrm{price}/ML - colmation\mathrm{cost/ML}) \tag{4.2}$$

According to Table 4.5, colmating and selling the stoppers as 4th class stoppers would result in earnings of around €8500 in the first 4 months, considering stoppers of both calibers. Over 12 months, there is the potential to achieve around €25,500, which is three times the 4 months amount. This projection assumes that there will be no sudden changes in the monthly production quantities and sales for each caliber. It is important to noticed that SOCORI's process of grinding defectives cork stoppers or *cork waste* results in the production of agglomerated cork stoppers. These stoppers are sold at around half of the price of natural 4th stoppers, depending on the caliber. There are more sales of 45x$2$4 colmated stoppers, however, the company has a monthly sales figure for colmated stoppers that guarantees that these earnings would be easily achievable in both calibers.

Colmation process carries intrinsic risks, as it is ineffective for top defects or deformations. This approach may result in consumer complaints if any of the stoppers provided to colmation possess such defects. Therefore, it is crucial to closely control and monitor the process at *X3* output. Nevertheless, a fundamental aspect is that the stoppers, after being colmated, are brought back to SOCORI II for manual sorting once again. After manually sorting, the colmated 4th class stoppers can undergo X-Ray in some cases. The combination of the expertise of manual sorting workers and the utilization of X-Ray technology enables a reduction in the risk originated by colmation process.

While it may be appealing to use this approach for other defect outputs in different sections and machines, it is only logical to do this action just in the X-Ray section. The reason for implementing this procedure only in the final step of the production flow is that the cork stopper has already undergone all preceding production and sorting phases, reaching its highest value-added state. Typically, at the X-Ray stage, the cork have previously undergone seven processes of sorting and defect selection, along with two TCA removal procedures, leading to significant costs. Sending a cork with significant added value for grinding is illogical, as it more beneficial to colmate it, even if the resulting earning is not as initial expected to the company.

Therefore, changing the final destination of cork stoppers identified as *X3* on the X-Ray, shifting from grinding to colmation, resulted in reduced waste and higher utilization. By making a minor alteration, it was feasible to achieve a bigger monetary return than currently observed.

4.4 Quality control cards and layout adjustments at SOCORI II

A good visual management, as well the application of the 5s methodology, can significantly influence the performance of a section and the overall working environment. SOCORI II demonstrated problems in this regard within the X-Ray and Manual Sorting sections, particularly in the designated area for bag and container waiting. Modifications were implemented in this context to enhance the visual management and organization of this particular section of SOCORI II.

After the production process is completed, the cork stoppers that are identified as *X1* by the X-Ray machine, undergo a quality control, per order and per bag, before being shipped to the customer, as mentioned in subsection 3.2.

The creation of laminated cards has enhanced the determination of whether a bag that has undergone X-Ray and final control, has achieved a satisfactory outcome in terms of that quality control, i.e., whether it has been approved or not. The card consists of two pages, a front page in green and a rear page in red, as depicted in Appendix N. The information provided includes the article and final customer, the quantity of bags in the order, the date of the control, and the individual responsible for conducting the quality inspection. If an order batch is approved, the card will be oriented with the green side facing upwards. Conversely, if the batch is rejected, the card will display the red side along with the explanation for the rejection. An order may contain many bags, therefore, a card is placed at the start of a queue and another card is placed when the bags in that order are completed. The bags that don't have a card are because they haven't been through quality control yet. With this implementation, every person in the section is now aware of the outcome of the final inspection and the bags that have or have not undergone quality control. Prior to the implementation, the bags lacked any form of quality control identification, as seen in Figure 4.4(a) On the other hand, Figure 4.4(b), clearly demonstrates the visual enhancement achieved by implementing cards on the bags.

((a)) Before

((b)) After

Figure 4.4: Changes in bags identification

To complement and enhance the previous measure, it was essential to make certain modifications to the layout. These adjustments were made to ensure visual understanding about the bags that have already undergone X-Ray and are awaiting final control, as well as the bags that have passed through Manual Sorting and are awaiting to go to X-Ray machine. An observation to consider is that all the bags share the same color. It would be beneficial to have bags with separate colors to differentiate between different stages. Due to client demand for the current bags and the existing use of different colored bags for other purposes, it is not viable to implement this idea during the project development.

During a visit to one of Amorim Cork's industrial units, it was noted that there were designated waiting places for bags, complete with a floor mat, as depicted in Appendix O. These floor mats enhance the food safety of the cork stoppers by preventing the bag that is delivered to the customer from touching the floor. Additionally, they facilitate improvements in visual management. It is crucial to note that containers are unable to move over these floor mats as they have the potential to crush them. To mark the area exclusively for bags coming out of the X-Ray, green tape was set on the floor, as depicted in Figure 4.5.

Figure 4.5: Green tape marking the tested area for bag that undergone X-Ray

An experiment was conducted over several weeks to evaluate the best size of the area to be selected, considering the daily production and its variability. After a few weeks, the decision was to proceed with the investment and purchase the floor mat only for the designated waiting area where bags are placed after undergoing X-Ray Machine.

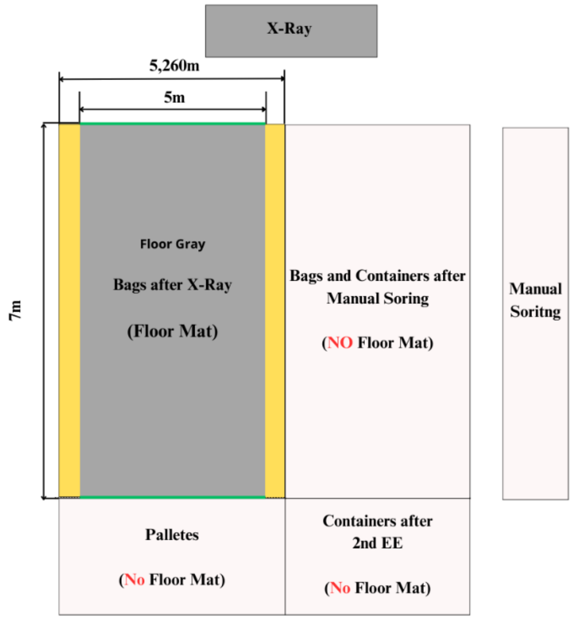


Figure 4.6: Final dimensions for the floor mat and layout organization

Figure 4.6 illustrates the final decision regarding the area's final dimensions and the new layout organization. This revised layout only considers improvements in organization and visual management. After observing Figure 4.6 , it becomes evident that the floor mat will only be present in the waiting area that follows the X-Ray. This decision ensures clear visual identification and differentiation between bags that have passed through the X-Ray process and those that have gone through Manual Sorting. Furthermore, it enhances food safety by preventing the bags that are delivered to the consumer from making direct touch with the floor. Although the cork itself is not food, it is in contact with the wine that is going to be consumed. The floor mat has a price of approximately 2525€, for the chosen area. Unfortunately, the order did not arrive in time for the project's conclusion, so there are no pictures to show the scene once the floor mat was in place. Essentially, the floor type illustrated in Appendix O will be put inside the boundaries marked by the green tapes illustrated in Figure 4.5.

Another problem highlighted in subchapter 3.2 in terms of visual management and the 5s technique, was the lack of proximity between the final quality control point and the waiting area for cork stoppers after X-Ray. Additionally, there were no sample standards available in close proximity to the control point.

In order to address this issue, it was necessary to purchase two additional control tables, which incurred a cost of around 550€, and expand the area close to the X-Ray machine. The tables were positioned near the waiting area and the X-Ray, allowing for more efficient control of the bags, as depicted in Figure 4.7.

Figure 4.7: Changes in quality control workplace

Additionally, by acquiring the new tables, it was able to place the standards near the shop floor. Figure 4.8(a) shows the appearance of the quality control supervisor's former workplace. The introduction of the new tables has resulted in considerable differences in terms of working space, proximity to the bag area, working environment and convenience as depicted in Figure 4.8(b).

((a)) Before ((b)) After

Figure 4.8: Changes in the table use for quality inspection

By moving the quality control workplace, it was possible to minimize the effects of *Mudas* associated with transport and motion, leading to a reduction in time wasted in both carrying corks for inspection and for the individual responsible for comparing an analyzed sample with its standard, when necessary. In addition, this change has led to a more dignified and friendly working environment that allows for a better execution of the job.

5 Conclusion and future work

This chapter presents in a concise and objective way all the results obtained with the improvements presented in the previous section. An analysis is done, by examining the progression of indicators and issues from their initial stage to their final stage, following the implementation of the improvements. Finally, recommendations are provided for future work, considering each problem, with the aim of further improving the final situation, monitoring it, and mitigating any Mudas or associated inefficiencies.

5.1 Results

It is essential to remember that the global problem reported initially was the inefficiency of natural cork stoppers sorting processes. This issue led to an analysis of four further associated problems, for which solutions were provided in Chapter 4. The entire work methodology was based on making small improvements, engaging employees and operators, and fostering a more efficient and productive work environment to achieve big operational and financial benefits.

The first problem analyzed was the inefficiency of the CIPs which resulted in a low OEE. Due to their mechanical complexity, these machines rely heavily on the performance of their individual components. After a few observations in the field, it became evident that the machine's channels were experiencing frequent interruptions. The main causes contributing to these problems were dust and fragments of cork.

The implementation of cleaning standardized procedures resulted in improved cleanliness of the machine, leading to a decrease in the interruptions of channels, as evidenced by the enhanced performance of the CIPs. Furthermore, by raising operators' awareness of the issue, they started to work closer to the machine, increasing their commitment and motivation. In addition, the implementation of a single shift effectively enhanced the operators' focus and availability for the unblocking of the channels. The implemented improvements resulted in an increase in the average weekly OEE, considering both CIPs, from 53.35% to 57.33%. On an individual basis, the average weekly OEE of CIP 02 experienced a predictable decline of 6.62% as a result of the deteriorated and old state of its components. Nevertheless, it successfully reversed the decline that appeared inevitable and noticeable increased the OEE in last weeks of study. On the other hand, CIP 03, which has received new components in February, experienced a big improvement in its average weekly OEE, from 56.69% to 67.97%, representing an approximately 20% increase. While the overall goal of improving the OEE of CIPs was achieved, the ideal outcome would have been to reach a 60% average weekly OEE for each individual machine. Despite the target was only accomplished for CIP 03, it is crucial to underline the importance of the quality state of the components of the CIPs and the substantial positive influence that cleaning can have when they are in optimal condition.

The second issue studied was the inefficiency of 2nd EE on selecting the *repass* stoppers. Through the analysis of the MES data and conducting process controls, it was determined that the *repass* rate was elevated due to a high occurrence of false rejections. The main causes that led to the problem were the lack of control, the operators' lack of awareness, and the resulting absence of a measurable indicator for analysis. Consequently, a dynamic control process was developed on the different machines. After the implementation of the control, a daily-updated indicator was established and made visible to the entire section. This indicator displays a graphic with the *repass* rate, categorized by cork stopper type and machine, enabling daily monitoring of the problem.

By implementing the improvements mentioned and with the active involvement of the workers, the number of false rejections was successfully reduced by around 72.5%. This reduction specifically targeted the stoppers that were previously most impacted by *repass*. Throughout the whole project, since the initial week of planning and testing, there was a consistent decrease in the average *repasse* rate, on a weekly basis, dropping from 3.89% to 1.47%. This reduction is expected to result in the company earning approximately €14,000 over a period of 4 months since the solution implementation. The gains in question are related to the corks that would now be classified as non-defective and sold based on their quality, rather than being mistakenly identified as *repass*. These results can only be confirmed after the next 4-month period. It will only be hard to achieve this amount if sales experience a significant decline, which is not expected.

After an analysis and examination of the X-Ray machine's outcomes, it was concluded that the *X3* stoppers demonstrated a significant potential for use. Approximately 30% of these stoppers, which were considered to be of free of defects, were discarded and sent to grinding. After conducting more inspections and receiving inputs from staff in charge of the corks stoppers quality control, it was determined that it would be possible to colmate all the corks with an *X3* output.

Assuming the company sustains its sales volume of colmate stoppers of *4th* grade as in the examined months, this implementation would result in a profit of around €8500 in the initial 4 months. If sales persist throughout the year, as expected, the company will generate approximately €25500 in earnings. Essentially, all of the *X3* stoppers that were originally destined for grinding, with minimal potential for recovery, will now be repurposed and sold as colmated stoppers of 4th class. As mentioned in the study on the financial gains from 2nd EE, it is only possible to check if this amount was achieved after the conclusion of initial 4-month period following its implementation.

The last problem tackled in the project was the poor visual management in the X-Ray and manual sorting sections of SOCORI II. Laminated cards were created to indicate the result of the final quality control process following the X-Ray stage. Furthermore, a floor mat was acquired specifically to distinguish bags that have left X-Ray machine from those that have been into Manual Sorting. Another improvement was the relocation of the quality control workplace, buying two more tables to place the standards which were previously far from the factory floor. These measures collectively improve visual management, the working environment and the organization of the section, consequently contributing to operational enhancement. All the expenses incurred in this domain are almost insignificant when compared to the possible gains from the other improvements mentioned above on this section.

Overall, the objective of enhancing efficiency and minimizing waste on both the manufacturing floor and natural cork stoppers sorting processes has been accomplished, as outlined in this section. The following *Mudas* were reduced: waiting in CIPs, defects in 2nd EE, and transport and motion in the waiting area for bags and containers.

5.2 Proposals for future work

Continuous improvement is based on the principle of lean thinking, which claims that there is always room for enhancement. It is crucial to monitor and follow closely any improvement to make necessary adjustments based on new information or results.

Regarding the CIP section, it is essential to establish a preventative maintenance plan to evaluate the state of the components and replace them with new ones when necessary. Therefore, is recommended that operators start to accurately and properly document machine stops and failures. Furthermore, allocating an employee to supervise exclusively the CIPS could be a good way of increasing the machine's performance, as the operator would promptly address any problems in the channels. For effective cleaning, it is recommended to establish a local vacuum cleaner system, similar to those currently present in other machines within the facility. This system would continuously clean all the channels of the machine, ensuring that no dust accumulates. Implementing these steps will definitely result in an enhancement of OEE

The process controls conducted on the 2nd EE are documented on paper. For this reason, directly entering the data into a computer system would simplify the process and allow for more coherent data analysis. Furthermore, the machine has two lenses, which may also be vulnerable to the cork dust inherent in the process. Developing a cleaning strategy would certainly improve the cleanliness of the area and the equipment, as well as its sorting efficacy. Given the proven effectiveness of these dynamic process controls in yielding results and promoting employee engagement, it is recommended to expand their implementation to address other defect problems in different areas of the factory and cork stopper types.

In order to prevent and detect any deformed or *repass* stoppers from entering the colmation process, it is essential to have process control for the *X3* output in the X-Ray. This control should be implemented in a planned and systematic manner. Similarly, it is crucial to have a detailed quality control for post-colmation process and before client delivery to avoid customer complaints. Furthermore, it is advisable to consult a specialist in X-Ray machine to examine and evaluate modifications made to the machine's program parameters to minimize the reprocessing defects observed in the *X2* output. To improve the analysis of the final quality control before packing for the final client (*X1* output), it is also recommended to create specifications for critical defects other than *bicho* and *cobrilha*.

Conducting an in-depth study on the feasibility of relocating machines and personnel within the industrial layout would be important to evaluate and enhance all the section's performance. Additionally, exploring the option of changing the color of the bags while ensuring that their quality remains the same would make it even easier to differentiate bags from X-Ray and Manual Sorting.

References

Amorim (2022a). About us. https://www.amorim.com/en/corticeira-amorim/about-us/ (accessed 14 March, 2024)

Amorim (2022b). Mission, Vision and Values. https://www.amorim.com/en/corticeira-amorim/mission-vision-and-values/ (accessed 14 March, 2024)

Amorim (2022c). Business Overview. https://www.amorim.com/en/business/overview/ (accessed 16 March, 2024)

Amorim (2022d). Processo Produtivo. https://www.amorimcork.com/pt/a-cortica-e-o-vinho/materia-prima-e-processo-produtivo/ (accessed 16 March, 2024)

APCOR (2023). The Cork Sector Descripiton

Armando Leitão, Bernardo Almada-Lobo & Luis Guimarães (2019). Maintenance Management

Basak, S., Baumers, M., Holweg, M., Hague, R., & Tuck, C. (2022). Reducing production losses in additive manufacturing using overall equipment effectiveness. Additive Manufacturing, 56, 102904

Berger, A. (1997). Continuous improvement and kaizen: standardization and organizational designs. Integrated Manufacturing Systems, 8(2), 110–117

Bourrassé (2020). Portrait. https://www.bourrasse.com/en/cork-closure-manufacturer/

Botezatu, C., Condrea, I., Oroian, B., Hriţuc, A., Eţcu, M., & Slătineanu, L. (2019). Use of the Ishikawa diagram in the investigation of some industrial processes. IOP Conference Series. Materials Science and Engineering, 682(1), 012012

Chiarini, A., Baccarani, C., & Mascherpa, V. (2018). Lean production, Toyota Production System and Kaizen philosophy. The TQM Journal, 30(4), 425–438.

Cooks, G. B. (1931). Cork and it's use. 8.

Crowter, R. (2023). Understand OEE: Calculation, Components, Comparisons and Tips. Innius. https://innius.com/overall-equipment-effectiveness-oee/#which-is-best-oee-ooe-or-teep

DK Sobek II et al., (2004). A3 Reports: Tool for Process Improvement

Goetsch, D. L., & Davis, S. (2015). Quality Management for organizational excellence: Introduction to Total Quality. Pearson.

Kaizen Institute Consulting Group. (2023). KAIZENTM Article | Mastering KAIZENTM Principles.

Imai, M. (1986). Kaizen: The Key to Japan’s Competitive Success. Becoming lean Inside stories of US manufacturers.

Imai, M. (2012). Gemba Kaizen: A Commonsense Approach to a Continuous Improvement Strategy, Second edition. McGraw Hill Professional.

Juran, J. M., & Godfrey, A. B. (1999). Juran's Quality Handbook. McGraw-Hill Professional Publishing.

Lalic, B., Majstorovic, V., Marjanovic, U., Von Cieminski, G., & Romero, D. (2020). Advances in production management systems. towards smart and digital manufacturing: IFIP WG 5.7 International Conference, APMS 2020, Novi Sad, Serbia, August 30 – September 3, 2020, Proceedings, Part II. Springer Nature.

Liker, J. (2021). Standardized Work is a Goal To Work Toward, Not a Tool to Implement. Lean Enterprise Institute.

Lu, J.-C., & Yang, T. (2014). Implementing lean standard work to solve a low work-in-process buffer problem in a highly automated manufacturing environment. International Journal of Production Research, 53(8), 2285–2305

Mariani, J. (2023). Why the world has a huge wine glut and why it's only going to get worse. Forbes

Melton, T. (2005). The benefits of lean manufacturing: What lean thinking has to offer the process industries. Chemical Engineering Research and Design, 83:662–673.

Monden, Y. (2011). Toyota Production System: An Integrated Approach to Just-In-Time, 4th Edition. CRC Press.

Montgomery, D. C. (2013). Statistical quality control: A Modern Introduction. John Wiley & Sons

Nakajima, S. (1988). Introduction to TPM: Total Productive Maintenance.

Ohno.T (1988). The Toyota production system goes beyond large-scale production.

Pintelon, L. M. A., & Muchiri, P. N. (2010). Performance Measurement Using Overall Equipment Effectiveness (OEE): Literature Review & Practical Application Discussion. International Journal of Production Research, Taylor & Francis.

Pojasek, R. B. (2000). Asking ?Why?? five times. Environmental Quality Management, 10(1), 79–84.

Pinto, J. P. (2014). Pensamento Lean. A filosofia das organizações vencedoras (6ª ed.). Lisboa: Lidel - Edições Técnicas, Lda.

Público (2017). Corticeira Amorim adquire grupo francês Bourrassé. https://www.publico.pt/2017/07/19/economia/noticia/corticeira-amorim-adquire-empresa-francesa-bourasse-1779684

Randhawa, J. S., & Ahuja, I. S. (2017). 5S – a quality improvement tool for sustainable performance: literature review and directions. International Journal of Quality and Reliability Management/International Journal of Quality & Reliability Management, 34(3), 334–36

Research (2024), Cork Stopper Market Report 2024, Market size, share, growth, CAGR, Forecast, revenue. Cognitive Market Research. https://www.cognitivemarketresearch.com/cork-stopper-market-report

Robinson, C. J. e A. P. Ginder. 1995. Implementing TPM: The North American Experience: Portland, OR, Productivity Press

Sánchez-González et al. (2023). Analysis of cork quality and cork tree health in stands of western Spain

Singh, S., & Kumar, K. (2021). A study of lean construction and visual management tools through cluster analysis. Ain Shams Engineering Journal/Ain Shams Engineering Journal, 12(1), 1153–1162.

Spear & Bowen. (1999). Decoding the DNA of the Toyota production system. *Harvard Business Review*, *77*(5), 96–106.

Stern, T. V. (2017). Lean and agile project management. In Productivity Press eBooks.

Sundar, R., Balaji, A. N., & Kumar, R. M. S. (2014). A Review on Lean Manufacturing Implementation Techniques. Procedia Engineering, 97, 1875–1885. Science Direct.

Tezel, A. B., K. J. L. T. P. (2009). The functions of visual management. International Research Symposium, pages 201–219

Womack, James P., J. D. T. (2003). Lean Thinking: Banish waste and create wealth in your corporation

Womack, J. P., Womack, J. P., Jones, D. T., & Roos, D. (1990). Machine that changed the world.

Sustainable Development Goals

This dissertation, focused on a lean approach to addressing inefficiencies in the natural cork stoppers sorting processes, contributes to several United Nations' Sustainable Development Goals (SDGs). Despite not explicitly aligning the primary aim of this research with these goals, it is evident that the applied principles and achieved results focus the environmental, social, and economic aspects emphasized by the SDGs.

Fitrstly, enhancing operational efficiency and visual management not only optimizes processes but also improves the working environment for operators. A more organized, cleaner and efficient workspace can lead to increased job satisfaction and reduced work-related stress. In addition, by increasing efficiency and reducing costs associated with waste, this study promotes sustainable and inclusive economic growth. This aligns with the objective of **SDG 8** to promote sustainable economic growth and decent work for all.

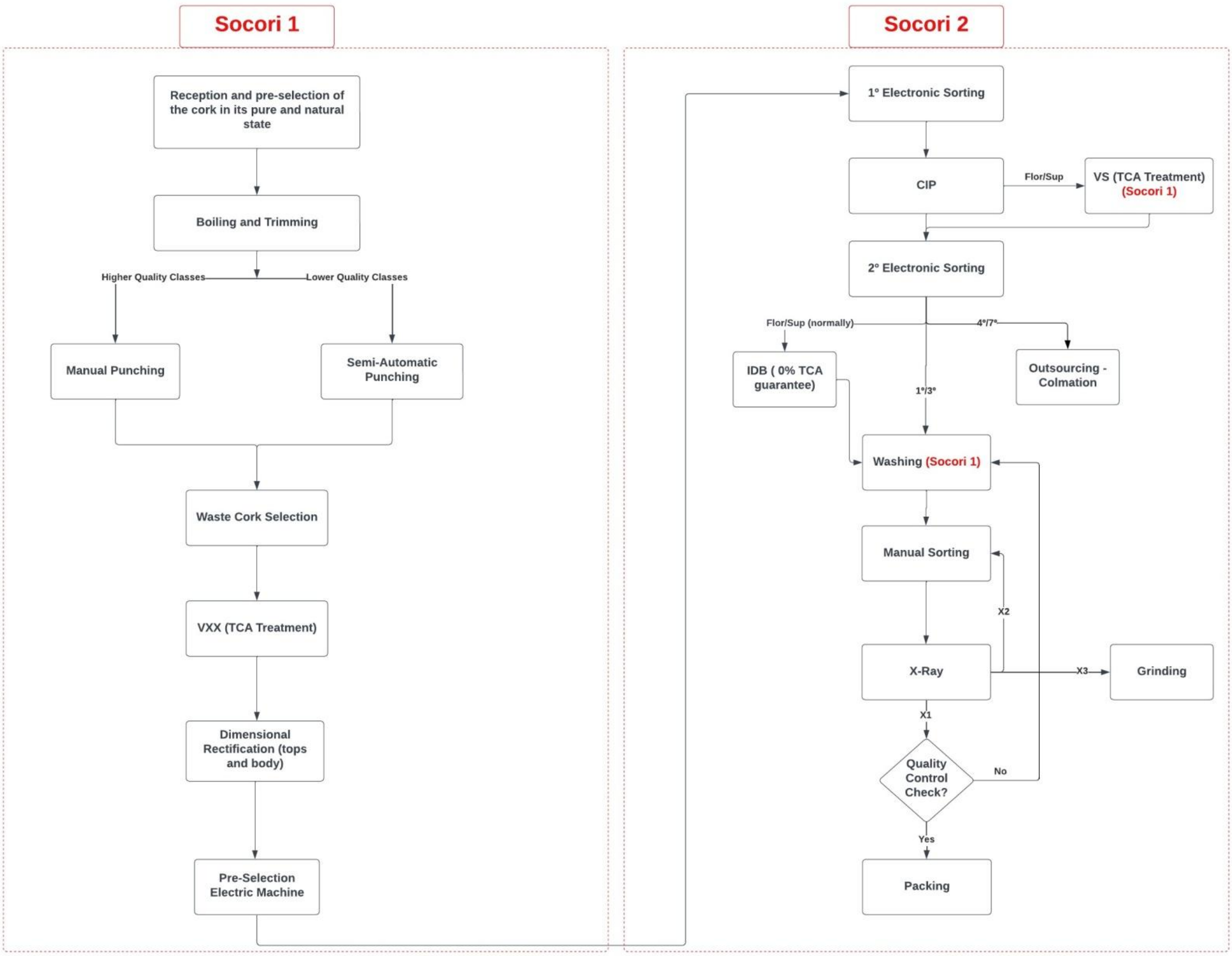
The implementation of standard work procedures for cleaning and the reduction of false rejections through dynamic process control are examples of sustainable industrial practices. These improvements not only enhance operational efficiency but also reduce waste and optimize resource usage, aligning with the goal of fostering resilient infrastructure and promoting inclusive and sustainable industrialization, **SDG 9**.

Furthermore, the lean approach adopted in this dissertation is intrinsically linked to **SDG 12**, which aims to ensure sustainable consumption and production patterns. The reduction of waste and the improvement of visual management in the production section facilitate a more efficient use of resources, promoting a responsible production cycle. Therefore, the study contributes to minimizing the environmental impact associated with the production process.

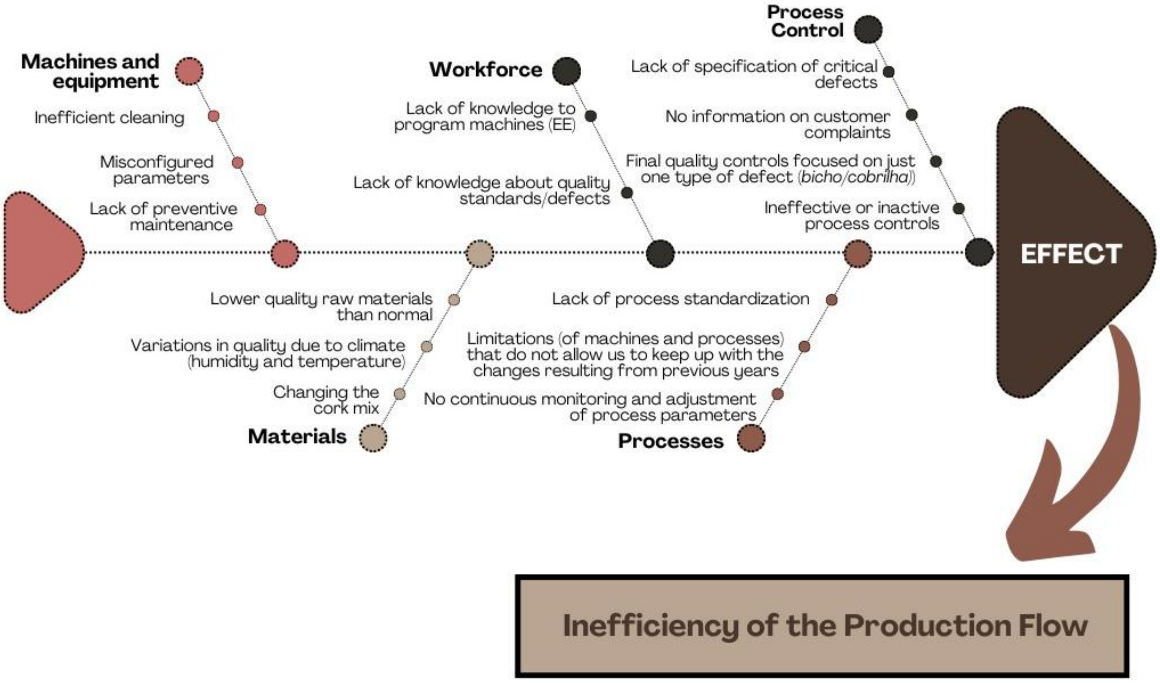
Lastly, this measures needed collaboration and involvement from various stakeholders, ranging from machine operators to production managers. This dissertation demonstrates how cooperation and the adoption of best practices can lead to significant improvements in process efficiency and sustainability. By fostering effective collaboration, the study contributes to **SDG 17**, which emphasizes the importance of enhancing the implementation of sustainable goals and renewing the global partnership for sustainable development.

In summary, this dissertation emphasizes the importance of incorporating sustainability into engineering processes, therefore making a contribution towards the wider objectives of sustainable development and responsible industry. These initiatives are crucial in guaranteeing a future that is both environmentally sustainable and socially responsible, following the principles established by the United Nations.

Appendix A: Production Flow of Natural Cork Stoppers at SOCORI



Appendix B: Ishikawa Diagram – Sorting Process at SOCORI II



Appendix C: *Repass* Process Control Data Before Improvements

Type	% False Rejected	% Repass	% Week Tops	% Cork Waste	Nº Cork Stoppers on Sample	% Repass (Machine Info)
49X24 , 1º natura	15,00%	74,80%	10,30%	0%	107	1,60%
	28,57%	71,43%	0%	0%	84	4,01%
	6,80%	80,60%	0%	12,60%	103	1,80%
	41,80%	36,90%	19,40%	2,00%	103	6,50%
	16,50%	64,08%	11,65%	7,77%	103	4,00%
	21,15%	66,35%	6,73%	5,77%	104	3,50%
	4,10%	31,60%	55,10%	9,20%	98	4,30%
	23,80%	37,60%	18,80%	19,80%	101	5,40%
	26,00%	70,00%	4,00%	0%	100	1,50%
	15,00%	85,00%	0%	0%	100	2,34%
	7,90%	73,00%	0%	19,10%	63	0,30%
	12,60%	65,50%	9,20%	11,60%	87	0,60%
	33,63%	58,41%	4,42%	3,54%	113	1,10%
Average	19,45%	62,71%	10,74%	7,03%	97,38462	2,84%

Appendix D: CIP Cleaning Standard Work

SOCORI
Groupe Bourrassé

LIMPEZA CIP

Unidade Industrial	SOCORI	Sector / Máquina	CIP	Código	
Elaborado por	Bernardo Xavier	Aprovado por		Data da aprovação	

Objetivo: Implementação e uniformização da limpeza das CIP.

Sequência	Descrição tarefa	Tempo (s)	Frequência	Fotografia
1	Parar a Máquina	-		
2	Tira a "gaveta" superior frontal , com cuidado para o pó não cair	3		
3	Despejar pó no balde de limpeza e deixar "gaveta" ao lado da máquina	30		
4	Repetir passos 2. e 3. para a "gaveta" superior traseira	33		
5	Limpar com ar comprimido a parte superior (frontal e traseira) da máquina (canais de saída incluidos).	25		
6	Abrir parte traseira da máquina e verificar se tem alguma rolha encravada ou impedindo sensor	6	1x no **final** de cada turno	
7	Limpar com ar comprimido da parte traseira da máquina (limpar bem a saída de cada canal) e fechar parte traseira.	25		
8	Abrir proteção de plástico frontal e utillizar ar comprimido para limpar saídas de canal	15		
9	Limpar gavetas com ar comprimido e colocá-las nos respetivos locais do equipamento	25		
10	Utilizar ar comprimido para limpeza geral do pó que possa ter ficado em todo o exterior da máquina e ligar a máquina	15		
	Total	**177 s**	**= 3 min**	

Appendix E: CIP Cleaning Record Sheet

SOCORI
Groupe Bourrassé

Registo de Limpeza CIP

Nome	Data	Hora

Appendix F: Differences in CIP's Parts Before and After SW Implementation

BEFORE Cleaning Standard Work

AFTER Cleaning Standard Work

Appendix G: Data for CIPs OEE Calculation

Week id	SystemArea	Machine	Shift	TransactionTypeGroup	Sum Quantity (<>0)	%Perfomance	prod.defeitos	%quality	%availability	OEE
1	CIP	CIP 02	Turno 1	Produções	324248	0,577364672	177	0,999454	1	0,57705
1	CIP	CIP 02	Turno 2	Produções		0,411593661	168		1	0,411295
1	CIP	CIP 03	Turno 1	Produções		0,519186254	300		1	0,518652
1	CIP	CIP 03	Turno 2	Produções		0,426794872	183		1	0,426469
2	CIP	CIP 02	Turno 1	Produções		0,619541667	202		1	0,619326
2	CIP	CIP 02	Turno 2	Produções		0,454839744	253		1	0,454569
2	CIP	CIP 03	Turno 1	Produções		0,568338675	801		1	0,567483
2	CIP	CIP 03	Turno 2	Produções		0,432478632	518		1	0,431925
3	CIP	CIP 02	Turno 1	Produções		0,547916667	514		1	0,547368
3	CIP	CIP 02	Turno 2	Produções		0,458441239	352		1	0,458065
3	CIP	CIP 03	Turno 1	Produções		0,593002137	964		1	0,591957
3	CIP	CIP 03	Turno 2	Produções		0,489740385	906		1	0,488772
4	CIP	CIP 02	Turno 1	Produções		0,617724359	344		1	0,617357
4	CIP	CIP 02	Turno 2	Produções		0,466355769	367		1	0,465964
4	CIP	CIP 03	Turno 1	Produções		0,763464744	1550		1	0,761809
4	CIP	CIP 03	Turno 2	Produções		0,570186966	983		1	0,569137
5	CIP	CIP 02	Turno 1	Produções		0,588337607	211		1	0,588112
5	CIP	CIP 02	Turno 2	Produções	505470	0,540032051	218	0,999569	1	0,539799

Appendix H: *Repass* Process Control Record Sheet

Controlo do Repasse na 2ºEE					Amostra de 50 rlhs - A:45/R5			
Nome	**Data**	**N.º Máquina**	**Artigo**	**% Rep. Máquina**	**Nº Rolhas Rep.**	**Nº Falsas Rejeições**	**Decisão(A/R)**	**Acção**

Regra: Controlar 50 rolhas de repasse, 2x turno de máquinas alternadas, e se existirem mais do que 5 rlhs boas no repasse, então devemos colocar que o lote está rejeitado: neste caso tomar ação de parar a máquina e acertar o programa.

Appendix I: *Repass* Process Control Data After Improvements

					Amostra de 50 rlhs - A:45/R5								
Nome	Data	Máq. N	Artigo	% Rep. Máquina	Nº Rolhas Rep	Nº Rolhas FR	% Rep	% Falsas rejeiçõ	Decisã	Acção	Calib	Class	Lavaç
	09/mai	1	49x24 3º NAT	0,78%	46	4	92,00%	8,00%	Aprovado		49x24	3º	NAT
	09/mai	2			42	8	84,00%	16,00%	Rejeitado	A máquina estava a ver as rolhas curtas			
	09/mai	3			46	4	92,00%	8,00%	Aprovado				
	10/mai	1			48	2	96,00%	4,00%	Aprovado				
	10/mai	2			45	5	90,00%	10,00%	Aprovado				
	10/mai	3			48	2	96,00%	4,00%	Aprovado				
	10/mai	5			48	2	96,00%	4,00%	Aprovado				
	10/mai	4			48	2	96,00%	4,00%	Aprovado				
	13/mai	2			46	4	92,00%	8,00%	Aprovado				
	13/mai	6			44	6	88,00%	12,00%	Rejeitado	Correção do Programa			
	13/mai	4			48	2	96,00%	4,00%	Aprovado				
	13/mai	3			47	3	94,00%	6,00%	Aprovado				
	13/mai	6			45	1	97,83%	2,17%	Aprovado				
Cátia	14/mai	2	49x24 EXT VS	0,59%	46	4	92,00%	8,00%	Aprovado		49x24	EXT	VS

Appendix J: *Repass* Rate Daily Indicator (Example)

Appendix K: 2nd EE Sorting Productions Data (Initial 4 months of 2024)

Classe que sai 2nd

Classe	C-2	C-1	C	C+1	C+2	REP	Lav bicho	Total
Classe que entra 2nd EE	0	153440	193012	90768	15980	41635	17855	512690
	103131	895841	1405364	462912	127875	142428	31983	3169534
	155860	762696	1510934	576825	112384	117629	45757	3282085
	64346	826559	1693758	673356	81877	100351	13293	3453540
	282939	837413	1792381	696098	0	45178	2362	3687982
	1723	521926	1250075	441745	339026	26472	436	2581403
	0	21937	326871	47374	0	1070	0	397252

Appendix L: Earnings calculation considering the decrease of false rejections on 2nd EE

Article	Total Entry	Total Repasse	% Repasse
Cork Sopper Type 1 (CS1)	4139082	43917	1,06%
Cork Sopper Type 2 (CS2)	4499137	62832	1,40%
Cork Sopper Type 3 (CS3)	1083187	43256	3,99%
Cork Sopper Type 4 (CS4)	3856584	154922	4,02%
Cork Sopper Type 5 (CS5)	3413783	202141	5,92%

ASSUMINDO que RX E TAPETE não tiram

Quando entra na 2ºEE, temos a distribuição média do MÊS, dos últimos 4 meses

% de Repasse de volta **CS1 (False Rejections decrease)**	**12,04%**

Total Repasse × FRd =

Número Rolhas Recuperadas	5287

Número de Rolhas Recuperadas × Probablidade de CS1 ser escolhido uma classe acima (CS1 + 1)

Classe	Preço de Venda p/ML
FLOR_TP	
FLOR	
EXT	
SUP	
1º	
2º	
3º	
4º	

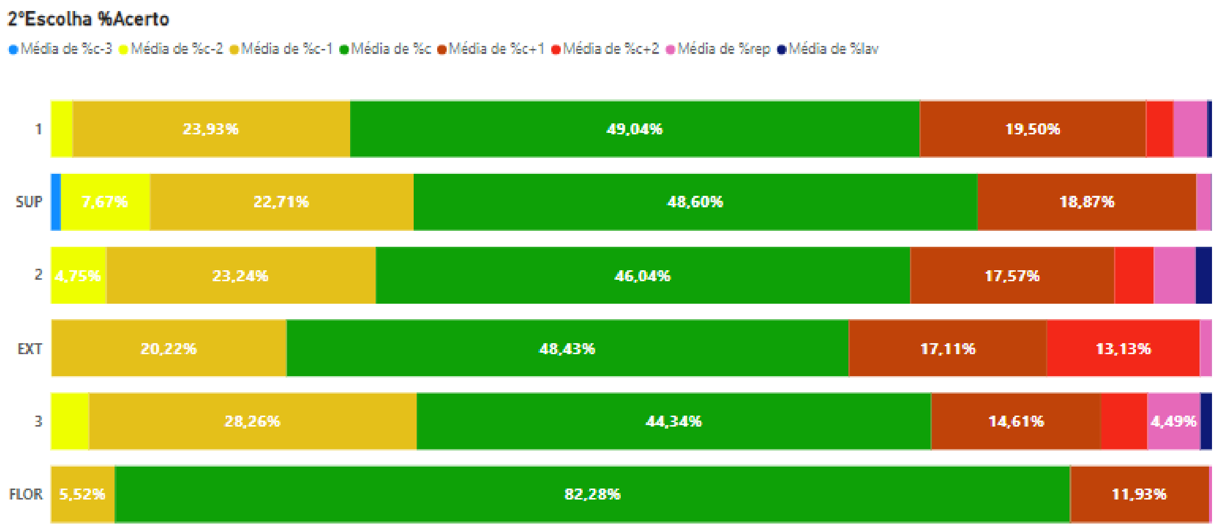
CS1		CS1-2	**CS1-1**	**CS1**	**CS1+1**	**CS1+2**	REP	Bicho
Quantidade Rolhas Recuperadas		3	1068	2560	904	694	54	0
Quant Milheiros		0	1,068	2,56	0,904	0,694	0	0
Receita								

RECEITA	**2 705,24 €**

Appendix M: 2nd EE Sorting Probabilities

Classe que sai 2nd EE

Classe	C-2	C-1	C	C+1	C+2	REP	Lav bicho	Total	%c-2	%c-1	%c	%c+1	%c+2	%rep	%Lav bicho
Classe que entra 2nd EE	0	153440	193012	90768	15980	41635	17855	512690	0,00%	29,93%	37,65%	17,70%	3,12%	8,12%	3,48%
	103131	895841	1405364	462912	127875	142428	31983	3169534	3,25%	28,26%	44,34%	14,61%	4,03%	4,49%	1,01%
	155860	762696	1510934	576825	112384	117629	45757	3282085	4,75%	23,24%	46,04%	17,57%	3,42%	3,58%	1,39%
	64346	826559	1693758	673356	81877	100351	13293	3453540	1,86%	23,93%	49,04%	19,50%	2,37%	2,91%	0,38%
	282939	837413	1792381	696098	0	45178	2362	3687982	7,67%	22,71%	48,60%	18,87%	0,00%	1,23%	0,06%
	1723	521926	1250075	441745	339026	26472	436	2581403	0,07%	20,22%	48,43%	17,11%	13,13%	1,03%	0,02%
	0	21937	326871	47374	0	1070	0	397252	0,00%	5,52%	82,28%	11,93%	0,00%	0,27%	0,00%



Appendix N: Batch Quality Control Card

SOCORI Groupe Bourrassé

Controlo de Qualidade de Lote - Raio X

Cliente:

LOTE APROVADO

Calibre: Classe:

Lavação: Nº Sacos:

Nome: Data:

SOCORI Groupe Bourrassé

Controlo de Qualidade de Lote - Raio X

Cliente:

Motivo/defeito:

LOTE REPROVADO

Calibre: Classe:

Lavação: Nº Sacos:

Nome: Data:

Appendix O: Floor Mat (Example from Another Industrial Unit)