Process Analysis and Implementation of Continuous Improvement Tools in Automated Warehouse Operations

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To My Parents.

Abstract

This dissertation, developed in the 2th year of the Master in Mechanical Engineering, with specialization in Production Management, emerged as the conclusion of a project, in an industrial context, carried out in a paint and coatings company, *Corporação Industrial do Norte, S.A (Tintas CIN)*.

The project presented appears to understand the causes and the errors that have a significant impact on the productivity of an automated warehouse. Taking this into account, the problem addressed in this project consists, precisely, of studying the industrial metrics at the level of operations performance, i.e., Overall Equipment Effectiveness (OEE) and continuous improvement methodologies in an automated warehouse.

It started with a literature review, around the manufacturing process of paints, logistics concepts, and some tools, such as: Lean Manufacturing, 5S, Kaizen, Kanban. These theoretical concepts would become essential for the solutions implemented in this project, with the main focus being to create a sustainable basis for the continuous dissipation of inefficiencies and elimination of waste.

Subsequently, to properly understand the critical sectors in this project it was necessary to analyze the current situation, in particular, the operations involved in the automated warehouse (picking, receiving, storage), as well as an evaluation of the productive state with the workers (through tools such as ErgoSafeCI). Combined with the absence of indicator analysis, lack of fundamental data for the correct maintenance, an inadequate and disorganized layout, information flow breakdown between workers, are some of the problems that affect the productivity of the warehouse. Additionally, the lack of process standardization gives rise to activities without added value and prevents the standardization of processes.

After identifying the problems and challenges to be solved, and with the help of the methodologies discussed, an optimization of the operations performed in the warehouse was proposed, without relevant investments. Some of the proposals presented were: the change and organization of workstations, the study of *Kanban* systems for supplying operational materials, the implementation of an OEE database, and the creation of a maintenance action plan. However, for a correct investigation, it was necessary to perform a diagnosis of the implemented solutions, through performance and financial indicators. One of the analyses was the possibility of implementing the *Kanban* system that would allow a gain of 33 hours per year, equivalent to 1.5% of the company's working hours per year.

The analysis of key indicators was also one of the action points of the project, with the creation of a dashboard to control operations, promoting visual management and transparency in the work, so that everything is visible, known and understood by all employees.

The last step of the project consisted in the definition of work methods, accompanied by standardization sheets for operations, which aim to achieve a more Lean warehouse.

Resumo

A presente dissertação, desenvolvida no âmbito do 2º ano do Mestrado em Engenharia Mecânica, com especialização em Gestão da Produção, surgiu como conclusão de um projeto, em contexto industrial, realizado numa empresa de tintas e vernizes, a Corporação Industrial do Norte, S.A (Tintas CIN).

O projeto apresentado surge no sentido de compreender as causas e os erros que tem impacto significativo na produtividade de um armazém automático. Tendo isto em conta, a problemática abordada neste projeto, consiste, precisamente, em estudar a métrica industrial ao nível do desempenho das operações, ou seja, *Overall Equipment Effectiveness* (OEE) e metodologias de melhoria contínua num armazém automático.

Iniciou-se, com uma revisão da literatura, em torno do produto, processo de fabrico, conceito de logística, e algumas ferramentas, como: *Lean Manufaturing*, 5S, *Kaizen, Kanban* que viriam a ser essenciais para as propostas realizadas para este projeto, sendo o principal foco criar uma base sustentável para a contínua dissipação de ineficiências e eliminação de desperdícios.

Posteriormente, para compreender devidamente os setores críticos neste projeto foi necessário analisar a situação atual, em particular, as operações envolvidas no armazém automático (separação, receção, armazenamento), assim como uma análise das condições laborais juntamente com os operários (através de ferramentas, como por exemplo o ErgoSafeCI). A questão de investigação emerge com a inquirição de quais os erros que têm um impacto na produtividade de um armazém automático, e, por conseguinte, pode-se salientar os seguintes fatores: um layout inadequado e desorganizado, quebra de fluxo de informação entre colaboradores, plano de ação da manutenção desatualizado às necessidades atuais do armazém, e ausência de métodos visuais para a correta monitorização dos indicadores. Adicionalmente, a carência de normalização dos processos que deu lugar a atividades sem valor acrescentado, e impediu a uniformização dos processos.

Após ter identificado os problemas e desafios a resolver, e com auxílio das ferramentas abordadas, foram propostas várias soluções e metodologias para intervir nas operações realizadas no armazém automático. Algumas das propostas apresentadas resumiam-se: à aquisição de novos postos de trabalho, estudo de sistemas *Kanban* para abastecimento de materiais durante as operações, criação de uma base de dados para os procedimentos de cálculo do indicador OEE, normalização de tarefas, como a organização e limpeza, através de cartões *Kamishibai* e 5S, e a reestruturação de um plano de ação de manutenção. Todavia, para uma correta investigação, deve-se realizar um diagnóstico do projeto investido, através de indicadores de performance e financeiros. Sendo que, uma das análises resumia-se à possibilidade da implementação do sistema *Kanban* que permitiria um ganho de 33 horas anuais, o equivalente a 1,5% das horas laborais da empresa por ano.

A análise de indicadores-chave foi, também, um dos pontos de atuação do projeto, com a criação de um *dashboard* para controlo das operações, promovendo a gestão visual e a transparência no trabalho, para que tudo seja visível, conhecido e entendido por todos os colaboradores.

O último passo do projeto consistiu na definição de métodos de trabalho, acompanhados de fichas de normalização das operações, que ambicionam o alcance de um armazém mais *Lean*.

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To my supervisor at the Faculty of Engineering of the University of Porto, Teacher Jonas André Rodrigues Henriques de Lima, for all the support and monitoring provided, and for the various suggestions both at the level of planning the activities and the preparation of the report.

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Acronyms

AHP- Analytic Hierarchy Process

ANOVA-Analysis of Variance

AW- Automated Warehouse

CI- Consistency Index

CIN- Corporação Industrial do Norte, S.A

CR-Consistency Ratio

CS-Compact System

DC- Distribution Center

FS- Fine Stocker

FTA- Fault Tree Analysis

FTE- Full Time Equivalent

KPI- Key Performance Indicator

MAVT- Multi Attribute Value of Three

MTBF-Mean Time Between Failures

MTTF- Mean Time to Failure

MTTR- Mean Time to Repair

OEE- Overall Equipment Effectiveness

OEEL -Overall Line Effectiveness

OPE- Overall Plant Effectiveness

OTE - Overall Throughput Effectiveness

OTIF- On-Time In-Full

PDCA - Plan, Do, Check, Act

PLC-Programmable Logic Controller

RCI-Random Consistency Index

SMED- Single Minute Exchange of Die

TD- Day shift

TEEP - Total Equipment Effectiveness Performance

TN- Night shift

TOEE -Total Overall Equipment Effectiveness

TPM- Total Productive Maintenance

VSM- Value Strem Mapping

5S -methodology for workplace organization with five actions: sorting (*Seiri*), tidiness (*Seiton*), cleanliness (*Seiketsu*), standardization (*Seisou*) and discipline (*Shitsuke*)

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1. Introduction

On this chapter the foundations of the project will be explained, as well as the roots of the company and the department that hosted this internship. In addition, at the beginning a schedule of the methodology forecast for both the dissertation and the company was carried out. Finally, a summary of the dissertation format will be presented.

1.1 Project background and motivation

This project was developed in the scope of the curricular unit of Dissertation in Business Environment in the 2nd year of the Master's in Mechanical Engineering of the Faculty of Engineering of the University of Porto. The development of the project occurred from March to June 2022 in the company *Corporação Industrial do Norte, S.A.*, in the Industrial Unit of the Distribution Center of Maia, in the logistics department.

In this company, the logistics department is subdivided into several sectors, as evidenced in Figure 1.

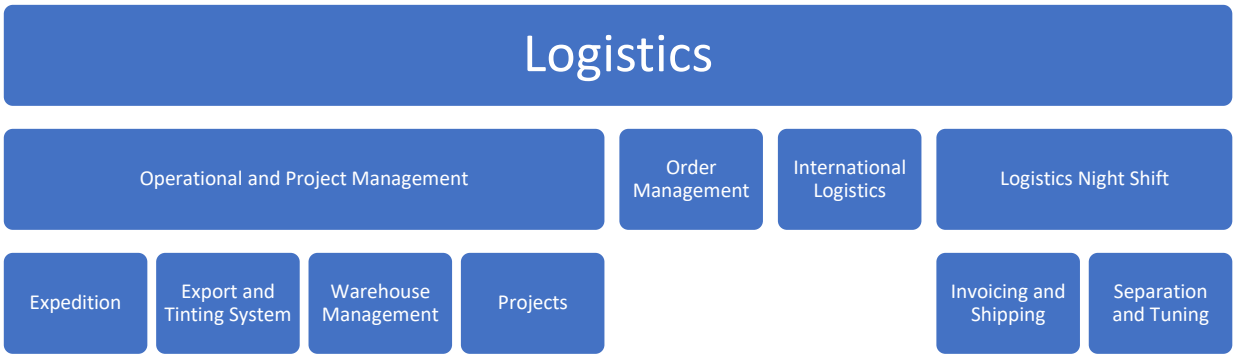


Figure 1-Diagram related to the logistics department of the company CIN.

The circulation of the product plays a key role for the company and covers a culture of continuous improvement; therefore, the distribution unit and the concept of this project culminate centrally. Thus, the project arises from the need to improve logistics processes and consequent studies of the performance indicators of operations, essential for the evolution of the logistics department.

This project involves two major areas, which are mutually interconnected. The first area consists of the evaluation of the OEE (Overall Equipment Effectiveness) indicator, analysis of the feasibility of the OEE data and other KPIs (Key Performance Indicator), and development of a dashboard. The second area concerns the implementation of continuous improvement methodologies.

1.2 CIN- Corporação Industrial do Norte

Corporação Industrial do Norte, S.A. is a Portuguese paint and coatings company, with more than 100 years of experience, with international recognition and reaching a level as the largest producer of paints and coatings in the world's top 50. Therefore, it can be found in several regions, such as Angola, Canary Islands, France, Italy, Poland, Portugal, Mexico, Mozambique, Spain, South Africa and Turkey, as illustrated in Figure 2.



Figure 2- International locations of the CIN Group's production, sales, and R&D (adapted from Macedo (2018)).

Over the years, the strategic and innovative vision of this company has led it to invest in the acquisition of several brands (Figure 3) and to launch innovative products, namely the COLORMIX system.



Figure 3 -Main brands of the CIN group (adapted from Oliveira (2022)).

CIN (*Corporação Industrial do Norte*) is dedicated to the main market segments: (Oliveira 2022)

- 53% in the construction industry- paints and coating used in construction;
- 34% in the industry - liquid and powder paints for protecting and finishing metal, wood, plastic and glass for industrial customers;
- 13% in corrosion protection- products for the protection of steel and concrete structures.

For a better future, sustainability emerges as a fundamental piece of the growth of a company. The prevention and control of environmental impact in all areas of its activity have always been a concern of CIN, materialized over the years in operational practices aimed at improving its eco-efficiency (CIN 2022).

CIN strategic priority, led to an important investment in an automated warehouse, which increased the efficiency of the logistics function and integrated the company's entire distribution in Portugal into a single center. This integration allowed for a significant reduction in operating costs and an increase in productivity.

1.2.1 Distribution Center

CIN's continuous search for operational excellence is a daily challenge, but it is as achievable as the capacity of each of its departments. With the tendency to increase exports, the logistics

processes take on a preponderant role in obtaining this excellence. Thus, in 2004, the new distribution center in Maia is opened, with a total area of 17 000 m^2 and a capacity for 14 000 pallets, as well as six automated robots. The AW (Automatic Warehouse) consists of two storage systems: (Rodrigues 2021)

- Compact pallet racking system, with a capacity for 13 610 pallets, composed of 15 height levels in total, of which 14 levels are 1,13 m and 1 level is 1,37 m high. Being that, it is composed of 5 stacker cranes, and each stacker crane has two rows, one row on each side.
- Miniload system,consists of a single stacker crane, to store a maximum of 6 032 boxes.

The DC (Distribution Center) is a storage unit, where the loading of vehicles for distribution and unloading of the finished product, from internal or external suppliers, takes place. The adoption of automated storage systems (green technology) has been an emerging trend in the manufacturing, logistics, and retail sectors. This system is linked to the flow of materials in companies and contributes to an improvement in business efficiency (Hao et al. 2020).

1.3 Project methodologies

At the beginning of this internship, a retrospective of what was intended to be accomplished in academic and business terms was carried out. Thus, Figure 4 and Figure 5 illustrate this rigorous planning.

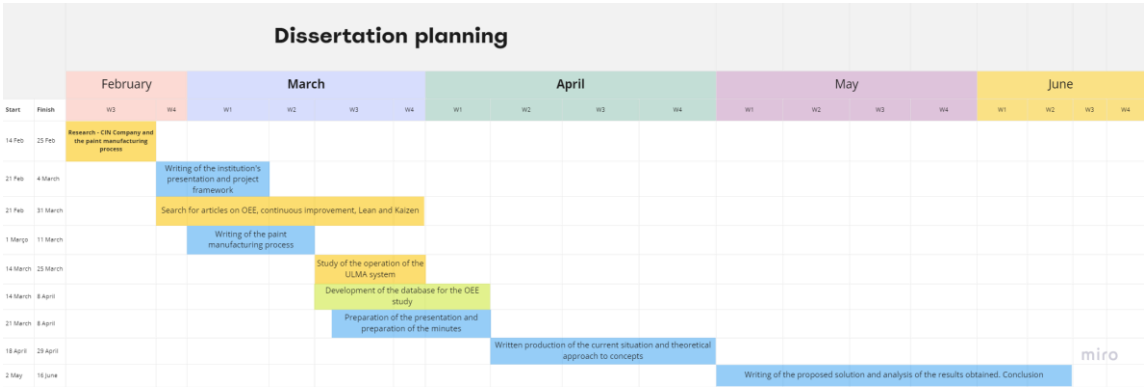


Figure 4-Initially scheduled timeline for the dissertation project.

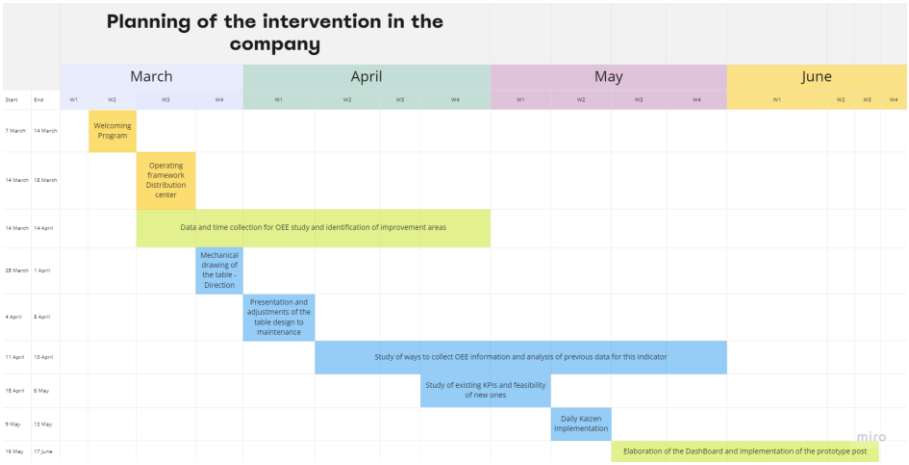


Figure 5-Initially scheduled timeline for the intervention project in the company.

The plan includes several activities that culminate in the two major objectives mentioned above. More explicitly, the first objective, OEE, addresses the following topics:

- Measuring and recording downtime;

- Current calculation of the overall OEE and of each machine that includes the AW;
- Characterization and typification of errors, with impact on the productivity of the warehouse;
- Identification of causes and suggested solutions for their resolution;
- Investigation of data extraction methods in the face of malfunctions;
- Analysis of the viability of existing KPIs and the addition of new ones;
- Development of a database (dashboard) that allows the use and presentation of data in a more intuitive way in the logistics department.

Regarding the area of continuous improvement, it was possible to identify several objectives to be implemented in this project, namely:

- Implementation of daily *Kaizen* in AW;
- Organization of workstations, with 5S methodology, and study and design of an ergonomic workstation;
- Updating and creation of work norms;
- Elaboration of the *Kanban* system for supplying material for use during operations;
- Elaboration of an action plan for the maintenance department;
- Implementation of safety and hygiene measures in the AW.

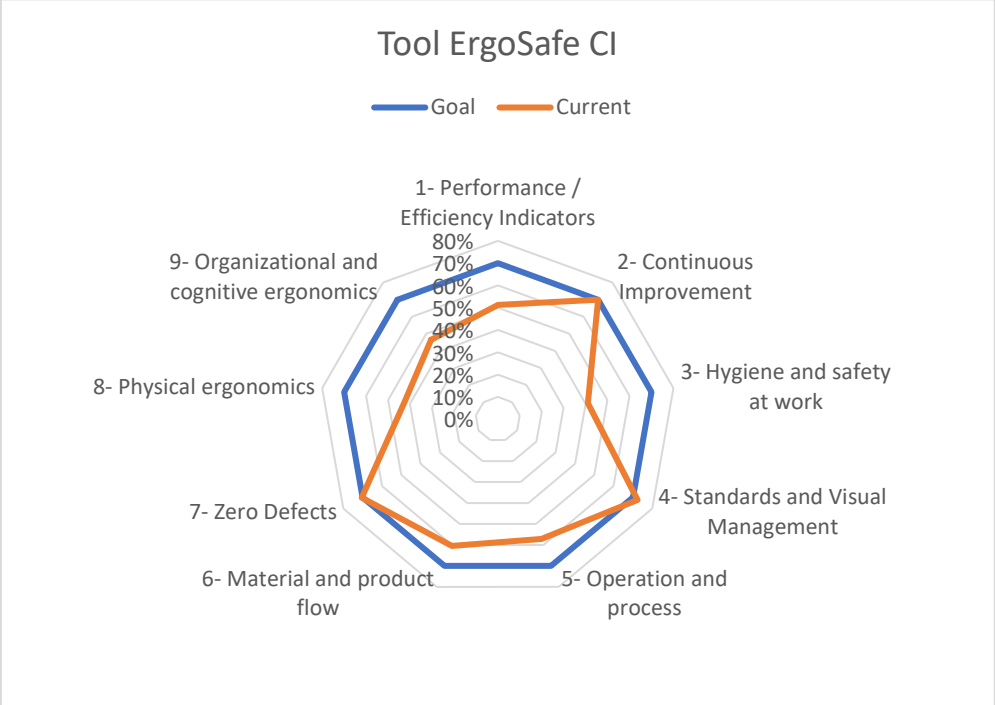


Figure 6-Radial graph based on the ErgoSafeCI tool in the automatic warehouse (adapted from Vale (2020) and Brito (2019)).

In addition, a statistical study was carried out with the workers, based on a tool developed in a university project, in order to understand which sectors were the most critical and the reasons for this. This study is a tool to evaluate and monitor certain topics in a productive area and is based on ten performance indicators that were considered fundamental to have a productive, safe and ergonomic workplace. This tool helps in the decision making process for project implementation based on continuous improvement (Vale 2020; Brito 2019). The Figure 6 illustrates the results obtained based on the project currently developed. Effectively, ergonomics, health and safety, workplace organization, and efficiency indicators are among the indicators with the lowest percentage. However, although the continuous improvement and visual management indicator has a high score, some of the questions were answered wrongly, due to the lack of transmission of information.

This matrix is intended to follow a logical sequence, as illustrated in the Figure 7.

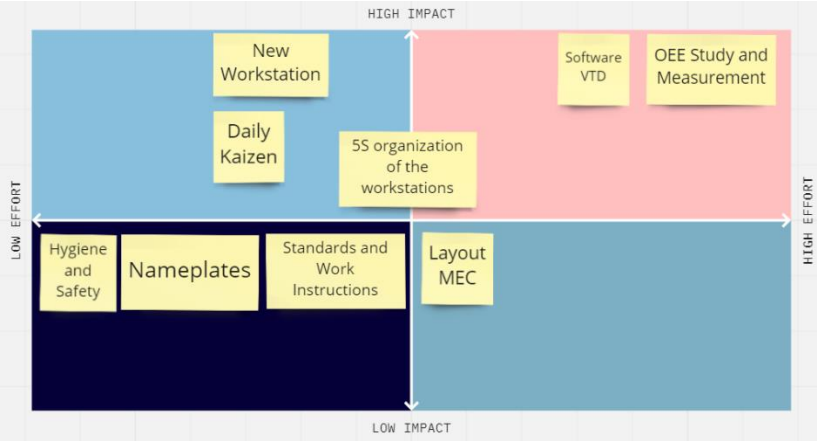


Figure 7- Effort-impact matrix on improvements to be implemented.

For a better intervention in the project, an importance-performance matrix is carried out with the company's supervisor.

1.4 Dissertation structure

The dissertation is structured into five key chapters.

Chapter 1 provides a brief introduction of the project and the company that embraced it, as well as highlights the main objectives of the project and the work methodologies used.

Chapter 2 represents the theoretical framework of the key tools for the development of this project. Initially, the product and the manufacturing process associated with the company in question are presented clearly and succinctly. Next, the theoretical concepts are addressed, namely Lean Manufacturing (Total Productive Maintenance, 5S, *Kanban*, Visual Management, PDCA, Single Minute Exchange of Die, *Kaizen*); Key Performance Indicators; Overall Equipment Effectiveness and Maintenance.

Chapter 3 aims to evaluate the situation at the beginning of the project, as well as to identify possible problems and/or challenges. This section begins with a summary study of the robotic warehouse, explaining the functions and processes involved. Subsequently, the indicators are evaluated, through the results of previous years, the way they are obtained, and their reliability. Allied to the indicators, the modes of maintenance intervention in the warehouse are also analyzed. Finally, the challenges to be solved are identified, both in terms of OEE, KPI, maintenance and continuous improvement.

Chapter 4 appears after having defined the main challenges to intervene in this project. In this way, it is possible to find several proposed solutions to the various problems raised, as well as the analysis of the results of the solutions that were possible to be implemented. It should be emphasized that not all the solutions presented were implemented.

Chapter 5 comes as the closing of this great project, where it is possible to verify the conclusions and future works.

2. Theoretical Framework

This second chapter arises, to address, theoretically, the key concepts that are interconnected to the project. Initially, the logistics flows will be addressed, and specifically automated warehouse, which is the focus of my dissertation. Afterwards, several types of methodologies are explored, namely Lean Manufacturing (TPM- Total Productive Maintenance, 5S, *Kanban*, Visual Management, PDCA- Plan, Do, Check, Act, *Kaizen*); Key Performance Indicators; Overall Equipment Effectiveness and Maintenance. These nomenclatures appear since they interfere with the availability and productivity of production resources and therefore, according to Fleischer, Weismann, and Niggeschmidt (2006), the competitiveness of companies depends on these two factors.

2.1 Product

Paints are defined as homogeneous mixtures (liquid, pasty, or powder) of various components, such as resins, pigments, fillers, additives, and solvents, which are applied as a coating, with decorative and protective functions, on various substrates. The protective capacity arises to increase the object's lifetime and reduce maintenance costs (Oliveira 2022).

A paint contains six fundamental characteristics, namely: applicability, yield, hiding power, resistance to washing, drying time and durability. In addition, it differs into three types, respectively: (T.e. Pintura 2020)

- Water-based - can be dissolved in water. They are more suitable and can be inserted either in metal or plastic containers.
- Solvent-based- they are diluted with the appropriate diluent. Since this is an aggressive product, it can only be stored in metal containers.
- Powder Paints - solid form elements (no solvents or water incorporated), are mixed and heated by extrusion. Then, they are spread on a mat where they form pallets and inserted in an oven (180ºC-200ºC).

Although there are different types of paint, they come from the same raw materials as presented in the following subchapter.

2.1.1 Raw Materials

Paint is made up of several components: Pigments; Varnish; Solvents; Binders (or Resins); Fillers; Volatile Vehicle; Additives, as summarized in Figure 8: (Oliveira 2022)

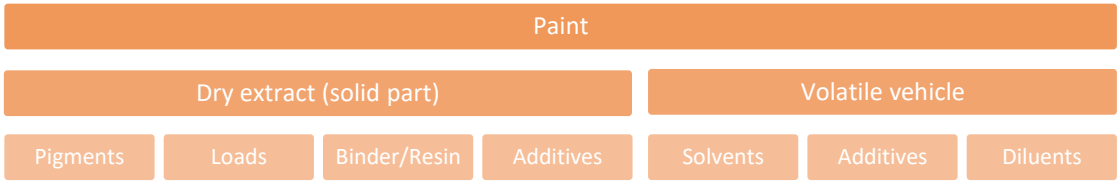


Figure 8-Paint raw material components (Adapted from Oliveira (2022)).

The raw material is the starting point to reach the final products, and for this, they need to be submitted to several manufacturing processes, which will be explained as follows.

2.1.2 Manufacturing Process

The manufacturing process of solvent-based and water-based paints are similar, as shown in Figure 9, differing only in that, in water-based paints, mixing and dispersing can be done simultaneously, while in solvent-based paints, these phenomena correspond to independent operations (T. Pintura 2018).

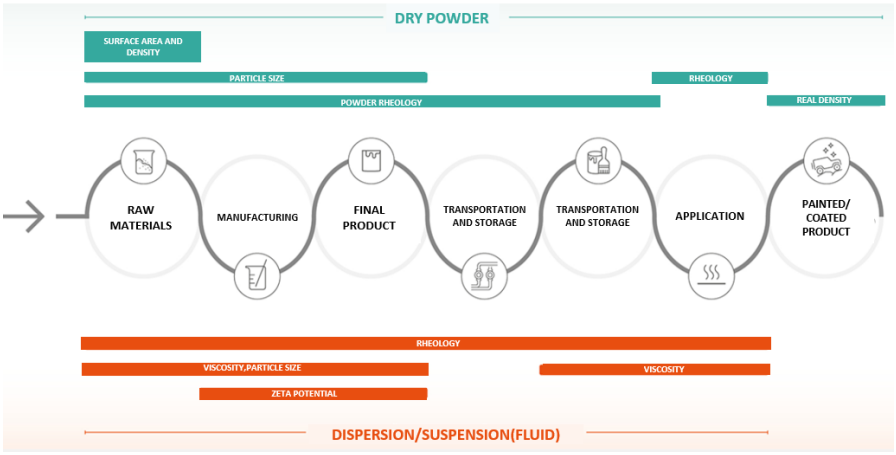


Figure 9-Life cycle from raw materials to applied product (adapted from Paar (2020)).

After this approach, one already has the necessary ingredients to understand the product design mode of this company. In any case, the project is in the distribution center and therefore the fundamental topics associated with this department will be addressed.

2.2 Logistics Concepts

This concept is the main key to this project, since the entire internship was developed in a distribution center, more specifically in an automated warehouse, which is governed by the principles of this concept.

According to Professionals (2022), logistics is “that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements”. The variables cost, time and quality form the trinomial dimensions of logistics. Logistics management is done through balances (trade-offs) between these dimensions (Crespo de Carvalho et al. 2010).

Logistics plays a strategic and fundamental role for all organizations. From the order request to the final consumer, logistics is in charge of controlling all the necessary movements and storage of materials, as illustrated in Figure 10 (Carrapatoso 2017; Santos 2017).

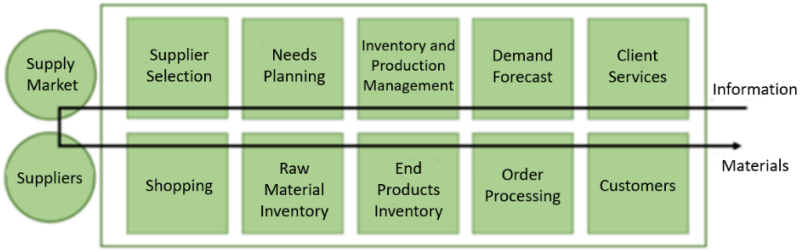


Figure 10-Activities that make up the logistical service (adapted from Pronaci (2002)).

All these activities directly affect the automated warehouse, from its speed, its production volume, the order format (pallets) or even the working hours. Of all the activities that make up logistics (warehousing, material handling, packaging, sourcing/supply and product scheduling) those that are crucial to look at closely are: warehousing, material handling and packaging.

For a thorough analysis of the production system, a set of logistic principles, known as the 7R's, must be followed, where the first one is about the right product (R1), the second one is about the right quantity (R2), the third one is related to the right quality (R3), the fourth one is related to the right delivery to the right place (R4), the fifth one is about the right delivery time (R5), then the right price (R6), and last but not least, the right customer (R7) (Michlowicz 2013).

Nowadays, it is considered that the supply chain is changing the meaning and importance of a warehouse, since this entity of the supply chain becomes more like “logistics platform” and were a number of logistics activities take place that add value (Guedes 2021). This next sub-chapter arises in the sense that this project focuses on a logistical flow and all the activities that occur (from receiving to shipping) affect the entire interaction.

2.2.1 The role of the warehouse

Warehouses are vital in supply chains and play a crucial role in a company's success or failure (Viana 2017). In Logistics, according to Hutt and Speh (2009), “warehousing is the management of space and time”, since the main objective is to achieve the best trade-off between maximizing storage space (usable space) and minimizing load handling operations. Since the two objectives are mutually exclusive, there must be a compromise between both (E.M.T. Batista 2016). Within the supply chain, there may be more than one type of warehouse, such as:

Table 1- Warehouse Types (E.M.T. Batista 2016).

Raw Material Warehouse	Intermediate Warehouse	Finished products warehouse	Consolidation Centers
• Stores any kind of product (including raw materials), however close to the production area	• Stores products throughout the various production stages and is also used to prepare orders before they are delivered to the customer.	• It stores final products, that is, ready for sale. In addition, it also serves as safety stock due to fluctuations and seasonality	• Receive products from various companies and consolidate them into one order that is shipped to the customer or production line.

In the case of the warehouse under study, it can be concluded that it is a culmination of all the types presented in the Table 1. According to de Koster, Le-Duc, and Roodbergen (2007), warehouses contribute about 20 percent of logistics costs. The main operational objective of a warehouse is to facilitate the movement of goods through the supply chain until they reach the end customer, however, there are other responsibilities to be taken into account, namely: (Viana 2017; E.M.T. Batista 2016)

- Cost reduction with advance purchase, quantification and inventory valuation;
- Encourage customer service policies;
- Analyze and control market conditions and uncertainties, such as seasonality, demand fluctuations, and competition;
- Provide short response times;
- Effective use of manpower, equipment and space;
- Maintaining management systems and controlling warehouse functionality;
- Performing operations safely.

In addition, these functions are divided into typical functional areas and flows in the warehouses, and the main activities are receiving, transfer and put away, order picking/selection, accumulation/sortation, cross-docking, and shipping, as evidenced in the Figure 11 (de Koster, Le-Duc, and Roodbergen 2007).

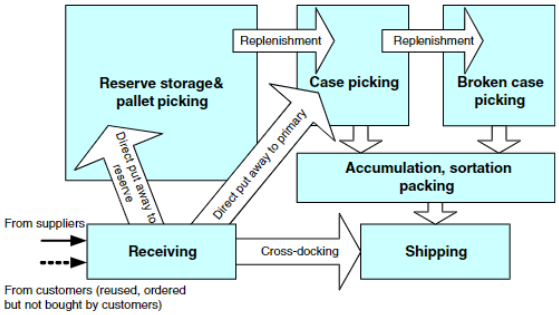


Figure 11-Typical warehouse functions and flows (de Koster, Le-Duc, and Roodbergen 2007).

Of all the activities, picking covers a large and important portion of most warehouses, as highlighted in Figure 12.

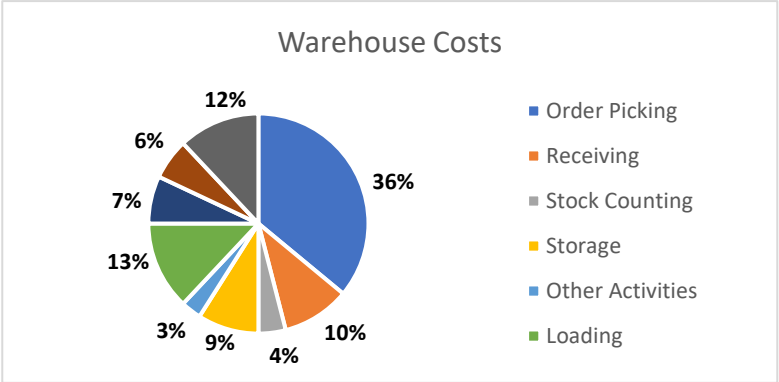


Figure 12-Percentage values of the costs of warehouse activities (Richards 2011).

Thus, I must have this sector as the focus, since it is where a greater amount of costs and work is centered, with direct implications on customer service.

2.3 Lean Manufacturing

The definition of Lean Manufacturing focuses on eliminating waste, reducing both inventory and production costs and increasing customer satisfaction (Womack and Jones 1996). In this context, the Japanese term *muda* (waste) does not simply refer to the recovery or destruction of non-conforming products, but to any activity that absorbs resources without creating added value (Viana 2017; Pereira 2015).

According Womack and Jones (1996), Fernandes (2018) and Liker and Morgan (2006), the Lean methodology is based on five principles:

1) Value - depends on customer demand, that is, there must be a need for it, and the company must respect the balance between quality and price.
2) Value Chain – a clear distinction must be made between tasks that add value and those that do not, as the latter only reflect cost. Therefore, a manufacturing line should be transparent throughout the entire process.
3) Flow - the main goal is to get the final product as quickly as possible.
4) Pull system - production is based on need and not the other way around, with the intention of reducing unnecessary stocks.
5) Perfection - by fulfilling all the previous steps it is possible to reach perfection, in the sense of eliminating all waste (the main principle).

However, as mentioned earlier there is associated waste, which can be derived from: (Costa 2017; Viana 2017; Liker and Morgan 2006; Castro 2016)

1. Defects - a product that does not conform to what is required is considered waste, even if it is repairable, since repair requires more time and intervention, which may negatively affect the quality of the product. In warehousing processes, mistakes are waste, therefore a focus on product improvement is necessary.
2. Waiting - time is an expense for any company, so any obstacle in time is seen as cost/waste. This type of waste can be caused by equipment breakdowns (bad conditions), inefficient layouts, setups, lack of material or labor, poor production planning, and bottlenecks in the process.
3. Motion - is not considered by many to be a worthless task, but any additional time should be avoided. Therefore, workstations must be adjusted for the successful execution of the process, combined with an ergonomic environment.
4. Over processing - results from excessive checking in the warehouse.
5. Inventory - excess inventory leads to storage costs, because of which there is a higher risk of spoilage, less efficiency in the process and diverts capital that could be invested.
6. Overproduction - is considered to be the most serious, since it gives rise to the other types of molting.
7. Transportation - the type of transport with added value is the transport to the customer, as this is the only one the customer is willing to pay for. Therefore, it should optimize the workspace in a sequential and close-knit way, in order to reduce time and movements that are not only a waste, but also a possibility of work accidents.
8. Unused creativity- employees' creativity, skills, and ideas for improvement, if not taken into account, represent a waste of human resources.

Previously, the most common wastes in companies were already defined, but there are other wastes depending on the type of industry. When this type of thinking is addressed, the comparison between TQM, Lean and Six Sigma always comes up. For a more explicit analysis, in Appendix A you can see the distinction between these three visions.

2.3.1 Total Productive Maintenance-TPM

TPM is considered one of the pillars of Lean Manufacturing and aims to eliminate waste and optimize the effective production time of equipment. However, it emphasizes people, in that it focuses on training all the company's employees for continuous improvement, generating greater productivity. TPM is based on eight pillars according to the traditional division or more recently on four fundamental pillars (plus the base corresponding to the 5S) (Reis 2006). The pillars of the TPM methodology have the following objectives: (Fernandes 2018; Oliveira;, Magnani;, and Silva)

- Continuous improvement- identify and address chronic equipment problems, improving corrective maintenance rates and minimizing machine losses;
- Autonomous maintenance - detect equipment malfunctions and solve them quickly;
- Planned Maintenance - create a maintenance plan, in order to decrease costs and increase equipment availability;
- Training - promote the training of the company's employees, in order to increase their skills in the performance of their activities;
- Early Management - shorten the start-up phases by minimizing losses. This can be achieved by creating machines that are easier to use;
- Quality Maintenance - guarantee zero defects while maintaining the equipment's original condition;
- Administrative TPM - allow the improvement of processes and reduce waste;

- Safety, Hygiene and Environment - prevent the risk of personal and environmental accidents in order to achieve zero accidents.

All the objectives presented have a single purpose of achieving zero defects, zero breakdowns and achieving maximization of warehouse capacity.

2.3.2 5S

The 5S method is one of the methodologies also focused on eliminating redundancy and increasing efficiency through basic techniques, and involves all employees with the goal of increasing team spirit (Allen ; Ackerman 2007).

The name 5S comes from the following Japanese words: *Seiri* (Separation), *Seiton* (Arrangement), *Seiso* (Cleanliness), *Seiketsu* (Standardization) and *Shitsuke* (Discipline), which can be described as follows: (Liker and Morgan 2006; Viana 2017; Castro 2016; Pereira 2015)

- *Seiri*: separating tools according to their usefulness, removing those that are not needed.
- *Seiton*: organization and identification of utensils to facilitate their use. The frequency of material used should be taken into consideration so that the most frequently used materials are more accessible to the worker. In this view, utensils with frequent use should be within reach, and visual communication aids should help in organizing the workstation.
- *Seiso*: tidying up and cleaning the work environment.
- *Seiketsu:* creating procedures to maintain the first 3S. Clear, functional and visible information about the procedures to be performed is crucial.
- *Shitsuke*: implementation of continuous improvement practices, such as audits.

Usually, the implementation of this methodology is a simple process, which does not imply great costs (Pereira 2015).

Often associated with the 5S methodology are other simple tools that assist in the stability of the flow, such as ergonomics. Being that, ergonomics is a scientific discipline focused on the interaction between humans and the other elements of a system and therefore optimizing human well-being and the overall performance of the system (Ferreira de Faria and Martins 2017).

2.3.3 PDCA

Werkema (1995), defines the PDCA cycle, also known as Deming's cycle, as "a management decision-making method to ensure the achievement of goals necessary for the survival of an organization".

The continuous improvement program of a company is made up of many small projects. Each one of them is managed according to the PDCA cycle, as illustrated in Figure 13 (J. Faria 2022).



Figure 13-Steps that make up the PDCA cycle (J. Faria 2022).

The steps that make it up are as follows: (Ferreira de Faria and Martins 2017; Mecalux 2021)

- Plan - depending on the target problem present, one must analyze the situation from its root point to the present, define measurable objectives and develop an action plan. Therefore, closely control of the warehouse must be maintained by means of defined metrics, since it is essential to identify the areas that are failing.
- Do– Implement actions taking into account what was analyzed.
- Check - Verify if the implemented actions had the expected results.
- Act - If the expected results have been verified, the procedures should be normalized, otherwise they should be rectified.

Associated with this cycle is the standardization of processes to reach continuous improvement, as illustrated in Figure 14.

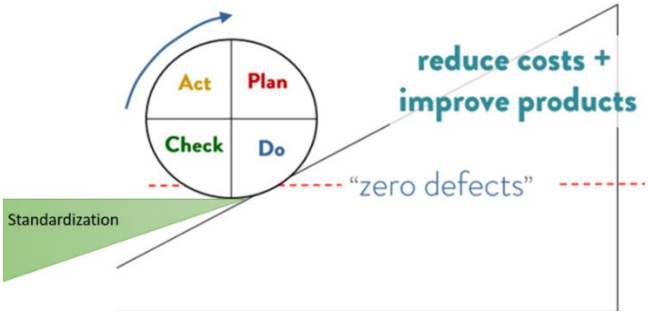


Figure 14-Second phase of PDCA method (adapted from J. Faria (2022)).

In some methodologies, the PDCA framework is developed using a three-level multi-attribute value approach (MAVT- Multi Attribute Value of Three), so this model considers different attributes with a different weighting according to their associated importance. As shown in Figure 15, the attributes are divided into three levels, therefore: (Chang and Liang 2009)

- First level attributes - these are the main factors that are essential to the management system, so the PDCA cycle is used;
- Second level attributes- address different themes such as organization, responsibility, risk assessment, education and training, research and evaluation models;
- Third level attributes - are measurable. The Analytic Hierarchy Process (AHP) and factor analysis are used to assign their weights.

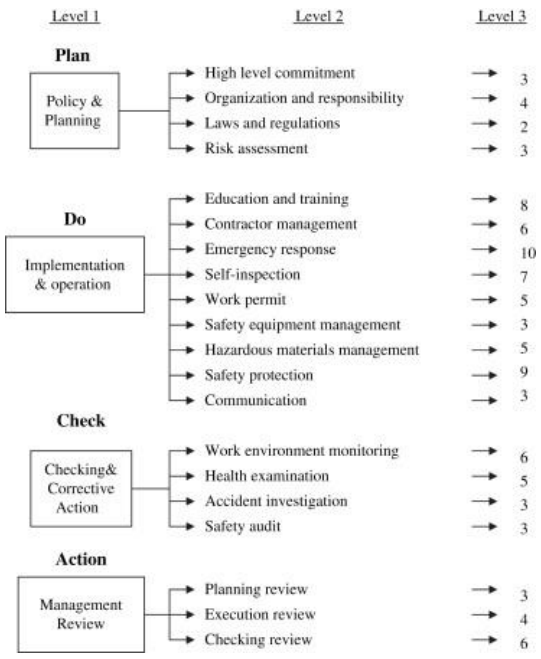


Figure 15-The hierarchy of the framework (Chang and Liang 2009).

To define the importance weights of the attributes, 0.1 was used as the default value for the consistency measure criterion. When the value of the index (CI) was less than or equal to default value, the consistency of the judgment matrix was considered satisfactory and consistent. In this way, a study was designed in which taking into account different sectors, for paint industry, it is possible to conclude that the most important phase is planning and the action phase is the least important (Chang and Liang 2009).

2.3.4 Single Minute Exchange of Die- SMED

SMED is a method that aims to reduce the time required to perform a setup operation, so that the time is less than ten minutes. In a nutshell, SMED consists in reducing the time required to make a certain change in a piece of equipment, within a production chain (Coutinho 2020).The practice of SMED methodology is not and should not be focused only on setups, since it can be applied to equipment, services, and simplification. In short, SMED can and should be seen as an aid in reducing unproductive times in any process (Araújo 2011).

2.3.5 Cause-and-effect diagram (Ishikawa)

In a deep analysis of the actions that affect the productivity of an industry, it is necessary to study the root causes in a comprehensive and detailed way (Oakland 2018). In this project, the diagram shows the following factors:

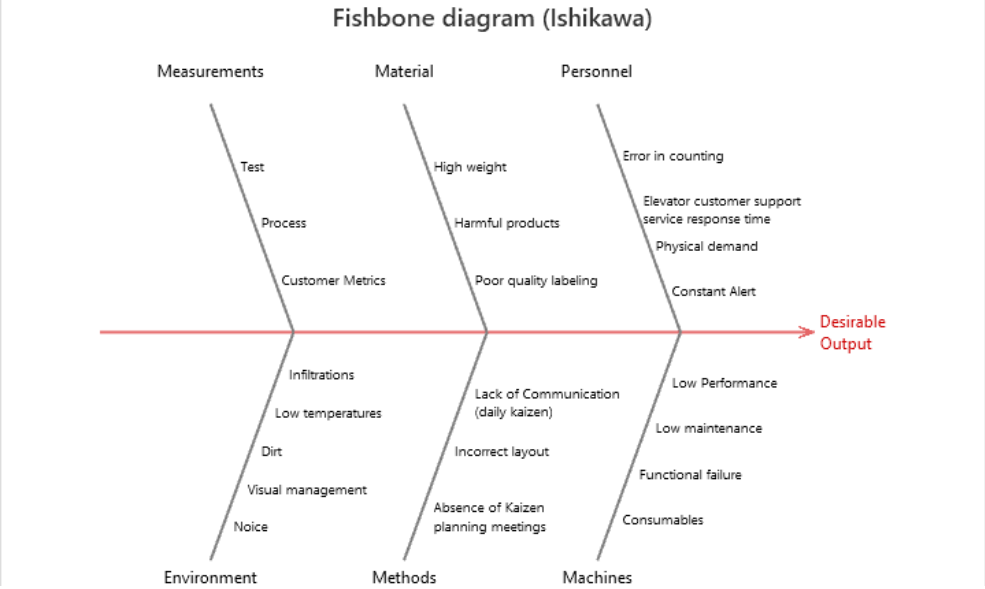


Figure 16-Fishbone diagram (Ishikawa) to the desired output in warehouse.

The Figure 16 illustrates the diagram applied to the developed project conditions. Ishikawa conceived seven quality tools, which would come to be widely used by quality improvement departments, namely: Pareto diagram, cause-effect diagram, histogram, stratification, checklist, control charts, and correlation diagram (Ferreira de Faria and Martins 2017).

2.3.6 Swimlane

The main purpose of the swimlane diagram is to illustrate the process flow, and it shows the key interactions and responsible persons associated with this flow in a clear and intuitive way (Zohra 2019). The elements may be freely disposed of in the model according to the “natural” workflow of the process. The main graphical elements of flowcharts are: process start, process end, task and decision point (J.A. Faria 2021).

2.3.7 Kanban

A *Kanban* board is an agile project management tool designed to help visualize work, limit work-in-progress, and maximize efficiency (Rehkopf). For this system to work well, certain rules must be followed: (Neto 2015)

- For a correct implementation, this methodology must be strictly applied, and therefore no material should be transported without the *Kanban* system, as well as any movement must follow the established rules. This is the only way to avoid waste.
- Production needs to be leveled throughout the entire process, with no fluctuations in the quantities of materials;
- This system should always work in conjunction with the material inventory.

This methodology can and should be applied to any industrial area, even if the tasks are unpredictable (Alliance 2022).

2.3.8 Daily Kaizen

Kaizen Change Management is a model of organizational transformation, which unfolds in three parts: Daily *Kaizen*, Project *Kaizen* and Support *Kaizen*. These are summarized in the following explanation: (Grösel 2015; Dinis 2016)

- Daily *Kaizen* - focused on changing mindsets and behaviors in order to create a solid foundation for developing and sustaining improvements, as well as inhibiting resistance reactions to change and changing behaviors in order to sustain improvements.
- Project *Kaizen* - has the purpose of improving processes through new solutions.
- Support *Kaizen* - is the tool that supports the two previous models and is divided into 3 phases: Audit and Communication; Strategy and Hoshin Kanri; Performance and Qualification.

Table 2- Daily Kaizen (Dinis 2016; Gomes 2019).

Level 1 - Team organization	**Level 2 - Space organization**	**Level 3 - Normalization**	**Level 4 - Process Improvement**
-Clear mission and KPI's. -Filling out the *Kaizen* framework.	-Improving working conditions through the application of the 5S's.	-Implementation of best practices. It is based on the adoption of the best methods, the reduction of time wastage and compliance with standards.	- Solving difficult problems and optimizing the workflow.

Appendix B presents the necessary indications for creating a *Kaizen* framework. After presenting several important methodologies in the vision of continuous improvement, other fields of analysis will be addressed next, such as the indicators that are central to defining the state of a process.

2.4 Key Performance Indicators- KPI

The definition of warehouse productivity metrics is fundamental to obtain a clear vision of possible problems and opportunities for improvement, so the choice of Key Performance Indicators, KPI, accompanied by tools and measurement criteria for them, is one of the fundamental steps in the process (Viana 2017).

The SMART KPI concept is related to a SMART way of selecting the objectives to be achieved. The indicators should follow the following criteria: (Doran 1981)

- Specific: It should be clear what it is used for and what the purpose of the KPI is;
- Measurable: It should be measurable, so that a standard can be set and making it comparable to the given value;
- Achievable: Must be achievable, i.e., choose reasonable and realistic goals;
- Relevant: It should lead to greater insight and understanding about the organization's performance in relation to the end goal.
- Timely: A clear timeline regarding the time dimension and the standardization of a KPI, are important aspects for the realization/achievement of a goal;
- Evaluate: A temporal assessment of usefulness and feasibility needs to be performed, since as the economy changes, indicators need to be adapted to that growth;
- Revise: As a result of the possible evaluation, some results may indicate that the KPI's need to be revised.

In Appendix C it is possible to see the various types of indicators used in the logistics branch, and some of them are used by the company.

2.5 Overall Equipment Effectiveness-OEE

OEE, a term presented in 1960 by Seiichi Nakajima, evaluates the efficiency with which a manufacturing operation is used, and by definition is a three-dimensional indicator (Figure 17) that monitors the performance of production lines, i.e., makes a comparison between actual performance and its ideal performance (Solutions 2019).

OEE was introduced as a quantitative metric for measuring productivity of individual equipment in a factory. This indicator is applicable to many processes, as it is considered the most suitable for semi-automatic and automatic manufacturing processes (Azevedo 2022).

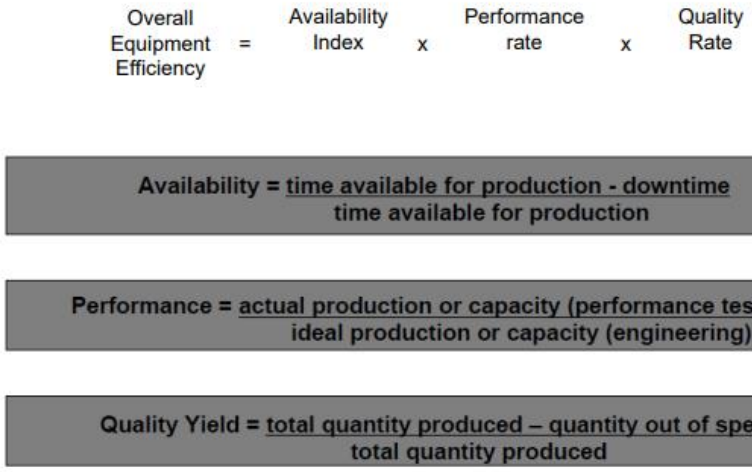


Figure 17-OEE formula resulting from the ratio of 3 parameters (Leitão 2021).

OEE is used for different purposes, namely: (Miyake and Busso 2013)

- Eliminate the losses;
- Improve quality;
- Measure initial benchmarking for comparisons within a plant;
- Helping to understand differences between production lines by comparing their results;
- Identify the machine that should be the focus of TPM efforts in order to rationalize investments;
- Identify chronic disturbances in equipment;
- To promote process improvement and increase its useful life.

Regarding the usual tabulated scales in the industry sector, Hansen (2006) indicates that the OEE results are as follows:

• < 65%: Unacceptable;

• 65%-75%: Acceptable only if quarterly trends are improving;
• 75%-85%: Very Good.

In line with Miyake and Busso (2013), the average value of the OEE companies corresponds to 55%.

2.5.1 Parameters

Regarding the definition of the three parameters it can be concluded that:(Solutions 2019)

- Availability- corresponds to the time available for operations compared to the planned production time. In this time, it also includes tasks, such as tool change, that although they cannot be eliminated, they can be reduced, through methodologies such as SMED (Single-Minute Exchange of Die).
- Performance - compares the actual production capacity (production/time) with the theoretical expected capacity, whether this is the one indicated by the supplier, or the maximum indicated speed of the machine.
- Quality-calculates the percentage of compliant product. This definition disregards defects detected later, however, it is too expensive to study the entire path of a part until the defect is detected.

2.5.2 Main losses

The OEE calculation is performed by identifying six basic types of losses, which are grouped into the following three classes, as illustrated in Figure 18. (Appendix D)

Overall Equipment Effectiveness	Recommended Six Big Losses	Traditional Six Big Losses
Availability Loss	Unplanned Stops	Equipment Failure
	Planned Stops	Setup and Adjustments
Performance Loss	Small Stops	Idling and Minor Stops
	Slow Cycles	Reduced Speed
Quality Loss	Production Rejects	Process Defects
	Startup Rejects	Reduced Yield
OEE	Fully Productive Time	Valuable Operating Time

Figure 18-Six Big Losses (OEE 2021).

This concept of the Big Six Losses, does not take into account planned equipment stoppages, such as: (Silva 2013)

- Time for operator meals and mandatory breaks;
- Scheduled time for autonomous maintenance by the operator (Ex. 10 min at the beginning of each shift);
- Scheduled time for planned maintenance (preventive, inspections, corrective);
- Time for operator training;
- Time for meetings (provided that foreseen in the production plan);
- Production tests (Ex: quality of product tests);
- Lack of production program.

There are several solutions to minimize any kind of losses, Appendix E gives some examples from industries. The parameters covered or not by the OEE are a subject of disagreement by several authors. Next, variations of this indicator and different ways of applying it will be presented.

2.5.3 OEE variations

According to some authors, the OEE is widely accepted as a primary measurement for the plant to help evaluate equipment and establishes a discipline for improvement. However, there are alternative indicators that seek to address the shortcomings of the OEE. Thus, indicators focused on the scope of the operations' system (Figure 19) are: (Miyake and Busso 2013)

- Overall Line Effectiveness (OEEL)-evaluation of a production cell, therefore, considers the main OEE losses, but also the losses related to planned maintenance downtime.
- Overall Throughput Effectiveness (OTE)- considers the form of connection that exists between the devices, for performance evaluation on a more global level.

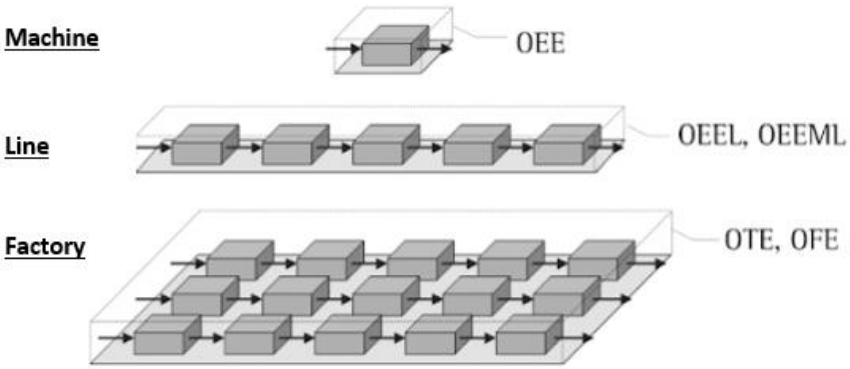


Figure 19-OEE variations according to system coverage (adapted from Miyake and Busso (2013)).

In addition, there are other external factors (seasonality, sales...) that prevent the full utilization of its capacity. The associated indicators are: (Miyake and Busso 2013; Klaess 2021)

- Total Equipment Effectiveness Performance (TEEP)-takes planned shutdowns into account when calculating the indicator. TEEP shows in a clearer way how the maintenance function interferes with the industry's productivity. TEEP considers the total time that can be used for production.
- Total Overall Equipment Effectiveness (TOEE)- focused on the effect of stoppages called losses independent of the equipment, such as: losses due to lack of operator, lack of supply and the performance of quality control, which does not depend on the operating conditions of the equipment itself.
- Overall Plant Effectiveness (OPE)- which, besides the losses considered by OEE, considers losses caused by other causes beyond the scope of the managers responsible for operating the production process. OPE integrates not only machine data but also everything around it that influences the process, namely human action.

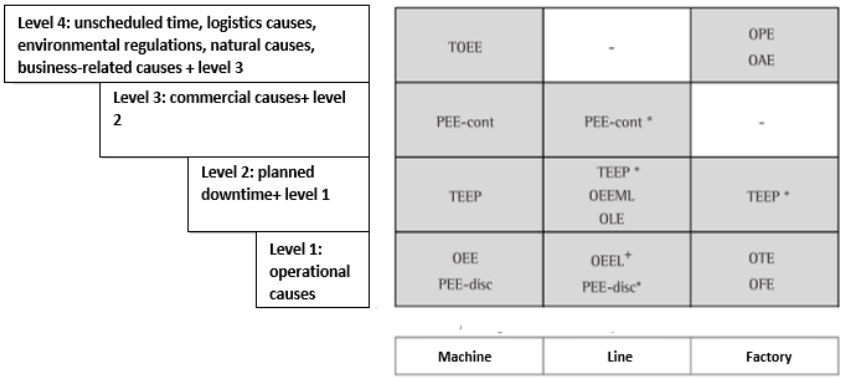


Figure 20-OEE and alternative indicators according to the classification of stop types and scope of the production system you consider (adapted from Miyake and Busso (2013)).

All these parameters presented above, are indicators, still little discussed in the literature that lack a more established definition. Figure 20 summarizes the classification of the types of stops and the scope of the indicators presented (Appendix F).

2.5.4 Advantages and Disadvantages

In Table 3, the main advantages and disadvantages associated with this indicator are summarized: (Miyake and Busso 2013; Silva 2013; Jonsson and Lesshammar 1999)

Table 3- Advantages and Disadvantages of OEE (Miyake and Busso 2013; Silva 2013; Jonsson and Lesshammar 1999).

Advantages	Disadvantages
•Enables the analysis of production or maintenance problems and consequent action on the root cause; •Allows internal comparison between the machines of the same plant; •Registration of shutdowns to identify losses allows the complementation of existing maintenance plans; •Tool to support continuous improvement.	•It is not a breakdown tracking system; •Does not provide a systematic view of business losses as it does not consider interactions beyond the equipment and external effectiveness dimensions; •Difficult to recognize other losses based on the taxonomy of the six big OEE losses, already mentioned in the previous chapter; •Needs to be complemented by other measurements; •No external efficiency, i.e. does not reflect customer satisfaction level.

Like any indicator, the OEE has its advantages and disadvantages. One of the advantages is that it facilitates maintenance analysis, therefore in the next subchapter this topic will be exposed.

2.6 Maintenance

Maintenance is a vital area for any industry, but even more important in an automated warehouse. In this way, different types of maintenance can be defined, Figure 21, namely: (Ahuja and Khamba 2008)

- Corrective maintenance- Repair is done only after the equipment breaks down/stops or after a severe performance decline occurs;
- Preventive maintenance - This depends on the estimated probability that the equipment malfunction within a specific time interval. Under these circumstances, it is calendar-based, clock-based or time-based, it is a maintenance action of an asset

according to a planned schedule. Preventive actions could be as simple as lubricating components, cleaning and replacing parts;

- Predictive maintenance- Diagnostic techniques were performed to evaluate indicators such as temperature, noise, vibration, lubrication, and corrosion.

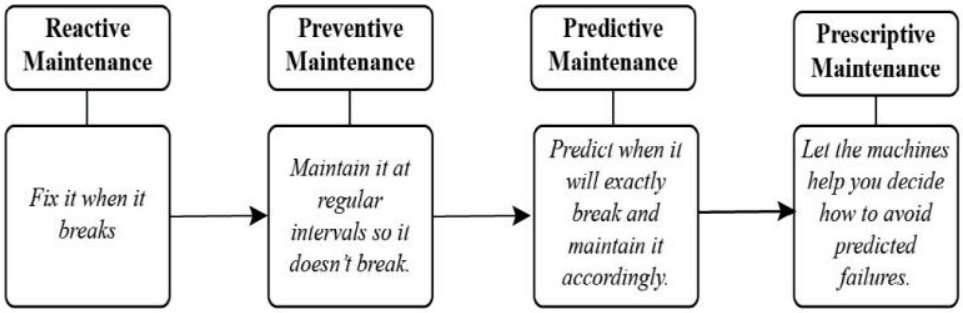


Figure 21-The evolution of maintenance strategies (Daneshkhah, Stocks, and Jeffrey 2017).

One of the rules they use to establish proportionality between corrective and preventive maintenance is the 80/20 rule, where 20% of the interventions should correspond to corrective maintenance and the remaining percentage should be proactive maintenance (preventive and predictive) (Infraspeak 2020).

FTA (Fault Tree Analysis) is the most used technique for causal analysis in risk and reliability studies. Thus, this methodology was implemented in the case study for a better perception of the problems, as illustrated in Figure 22 (Leitão 2021).

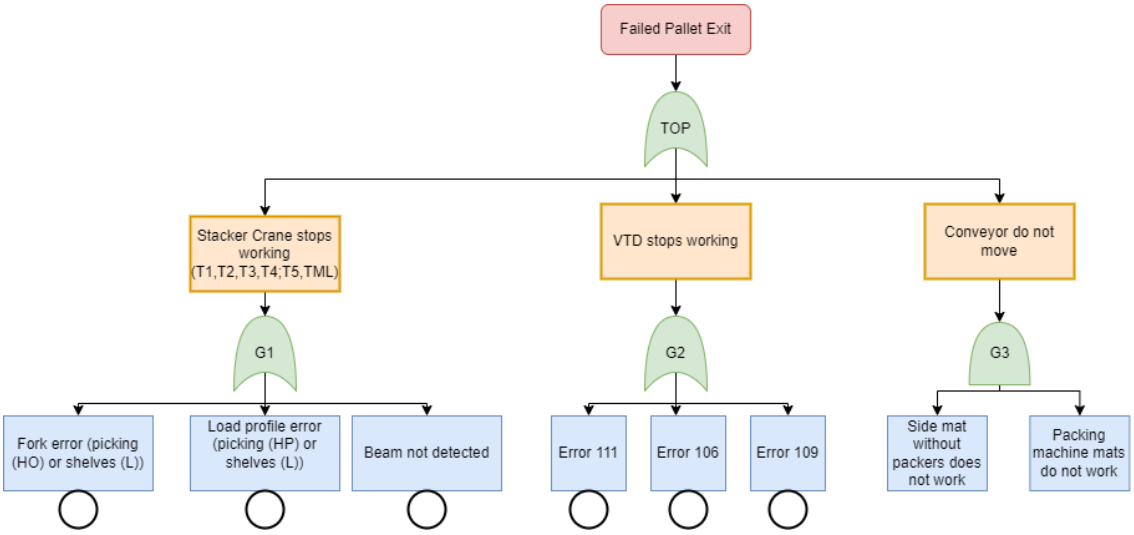


Figure 22-Fault tree analysis in the project case study.

The Figure 22 illustrates the application of the FTA methodology to the current project.

For correct preventive maintenance planning, it must take into account the following indicators: MTBF (mean time between failures); MTTR (mean time to repair); MTTF(mean time to failure); OEE; Percentage of unplanned maintenance; Maintenance cost (planned vs current); Replacement cost vs. repair cost (Infraspeak 2020).

Life cycle management and operation of a continuously deteriorating system can be improved by studying the sensitivity of optimized preventive maintenance decisions (Daneshkhah, Stocks, and Jeffrey 2017).

3. Presentation and analysis of the initial state

This chapter describes the logistics operation in the distribution center where the project was carried out. In addition, the methodology used to study the problems in this flow and an analysis of the data obtained with the study will be presented, as well as the identification of the problems detected. Finally, it is rectified the KPIs currently used by the company, in terms of usefulness, value and type of collection.

3.1 Automated Warehouse System

The growth of the industry, and consequently the increase in competitiveness, causes a relentless search for more efficient operations using continuous improvement methodologies. The automated warehouse corresponds to a specific area of the distribution center, located outside the manufacturing facilities and headquarters of the CIN company. The following functions can take place in the distribution center: storage, reception, production via colormix, and shipment of items to national and international areas.

3.1.1 Layout and operations

Figure 23 shows the layout of the distribution center, where eight main areas and accesses can be identified (Appendix G).

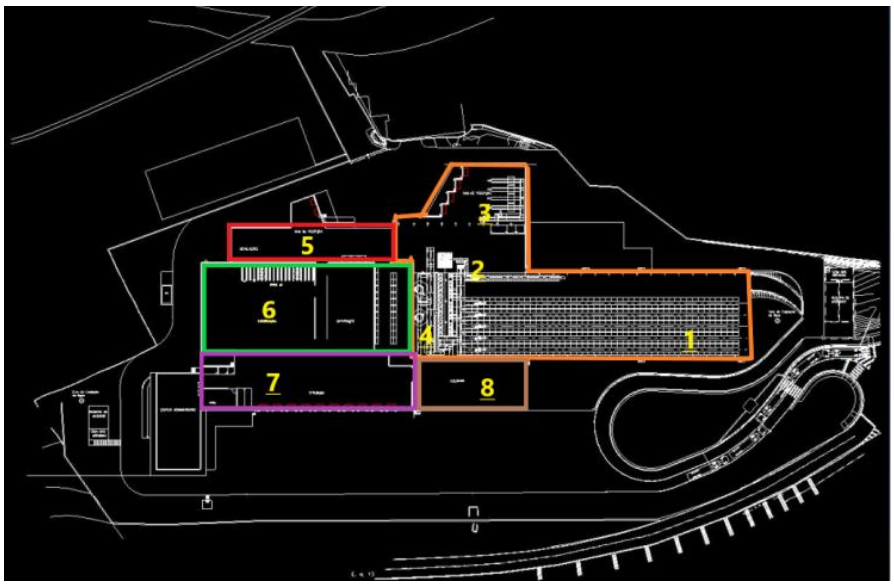


Figure 23-Layout of CIN's distribution center.

Zone 1-Storage- Automatic Warehouse System

The automatic warehouse system consists of subsystems (Compact System and Fine Stocker). There are two storage areas: Pallet Warehouse (CS) and Miniload Warehouse (FS).

For each material entry, the following attributes are set to the reference: lot (value to be entered in the reference); expiration date (expiration date of each material) and the status. There are three types of support: two types of pallet size (Pallet 1200x800 and Pallet 1140x1140) and container.

Zone 2- Extraction/Consolidation Zone

The process in this sector is called Separation and works as an intermediate step between order picking and shipping, adopting the discrete, batch and reverse picking method. In the separation is composed of three posts on the bottom floor and one post on the top floor, with each post having five tables assigned. Through the automatic warehouse system, the five stacker cranes (stacker crane 19(1), stacker crane 29 (2), stacker crane 39 (3), stacker crane 49 (4), stacker crane 59 (5)) pick up the pallets at the location assigned to the manufacturing order and deposit them on the conveyors. Each stacker crane has an entry and exit conveyor, then the pallet travels along the conveyors until it reaches the desired position, and there is a set of 4 conveyors that allow the pallets to circulate. If they are full pallets, they leave the compact pallet racking directly to the elevator, through the conveyor (5), located on the upper floor.

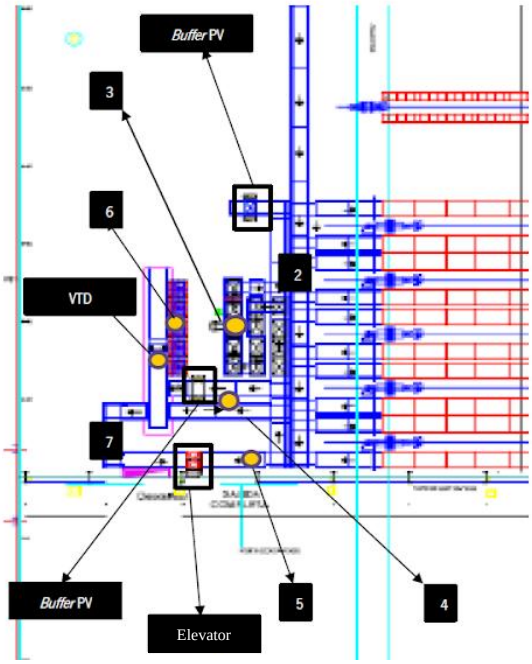


Figure 24-Approximate layout of top floor processes (Rodrigues 2021).

Each station has a computer system with the functionalities illustrated in Figure 25.



Figure 25-Previous Computer System, in use until March 2022.

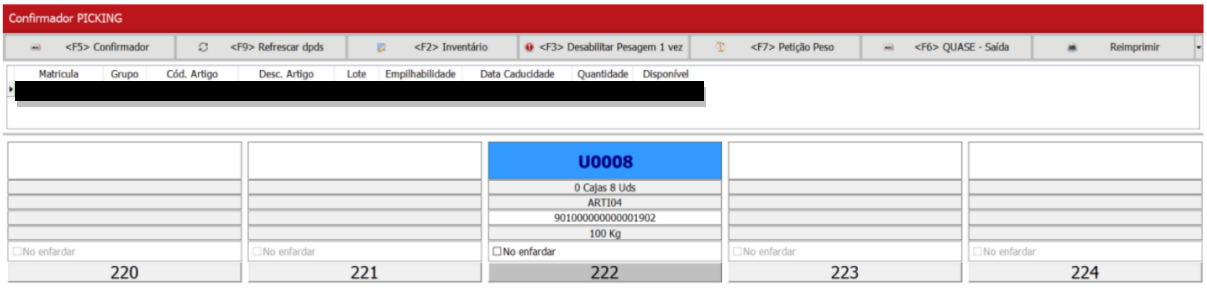


Figure 26-New IT system implemented in April 2022.

The computer system illustrated in Figure 26, shows the order form with product references, and quantities, among others. As the pallet arrives on the conveyor, the operator already has visual knowledge of which table should deposit the product and the respective quantity (either units or boxes). Finally, when the order and the respective pallet are finalized, the computer system alerts the operator, and the same operator activates the mechanism (button), so that the VTD collects the pallet and places it on the output conveyor.

Zone 3- Reception

This sector consists of four docks, in which trucks are unloaded (internal and external suppliers) and internal trucks are loaded (internal dispatch). In the internal expedition, only material and/or pallets are returned.
When receiving material from the external supplier, two documents must be provided to the supervisor: transport guide (which must contain the following data: address, number of pallets and the supplier) and the delivery note (in which must contain the following data: indication of the supplier, order number, description of products and quantity of pallets).
As far as unloading is concerned, it can have three destinations, as informed in the pallet check-in, namely: floor storage (zone 5), exportation (zone 6) or going directly to the automatic warehouse system (zone 1). When it is stored in the automatic warehouse system, the forklifts place the product on the initial conveyor (9), where the pallet weight is calibrated, and if it complies with the computer tabulation, it continues on the conveyor, according to the tolerances duly established.



Figure 27-Warehouse Reception Layout.

Typically, the most common types of errors identified by the system are: width (material outside of the pallets), crooked cues, height (if it is greater than the warehouse limit), and depth. If an error is detected, the pallets are rejected and routed through a specific conveyor (Buffer-10). If no defect is detected, the pallets proceed to the elevator (elevator 1) through the conveyor (11), and then to the warehouse on the upper floor (1 and 2). This sensory barrier appears as a safety measure for the automatic warehouse, in case of an error in the sensory barrier, it means that inside the automatic warehouse there could also be an error or even an accident. The monitor in the Figure 27, indicates the type of error and the product's license plate.

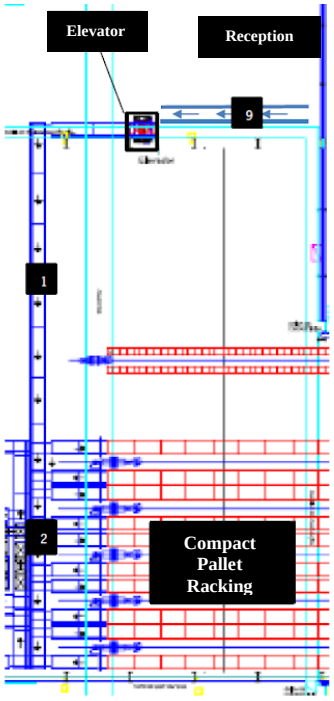


Figure 28-Layout of the automated warehouse, specialized in receiving (Rodrigues 2021).

Finally, the last phase of this operation consists in passing all the information about the goods that have entered the computer system, where the stock levels will be updated, and where a location will be assigned to the product.

Zone 4- Wholesale Fully Automatic Pallet

The pallet during the exit conveyor may suffer several interventions, i.e.:

- Consolidation - accessories from the miniload zone are added to the previously separated pallet, with the same type of separation.
- Filming - consists of two filming machines, with the first phase being the placement of the top plastic on the pallet, and then the placement of the film around the pallet.

Rest of Warehouse

- Zone 5- consists of two docks and a storage system. This system serves to store immediate shipping as well as return products. In addition, it contains a cleaning area and an area for loading the equipment used.
- Zone 6- this is the expedition, and is used as a warehouse, where the products from both the reception and export are deposited. Expedition is considered the last step in the flow of operations. In this operation, it is necessary to verify that the orders are complete and meet the requirements demanded by the customer.
- Zone 7- corresponds to the export zone and consists of ten docks.
- Zone 8- is divided into two sections: production by colormix (color tuning process) and exportation performed by an external company for northern, central and southern regions.

In summary, swimlane (Figure 29) was performed in order to illustrate the main activities of the automated warehouse and that were studied during this project.

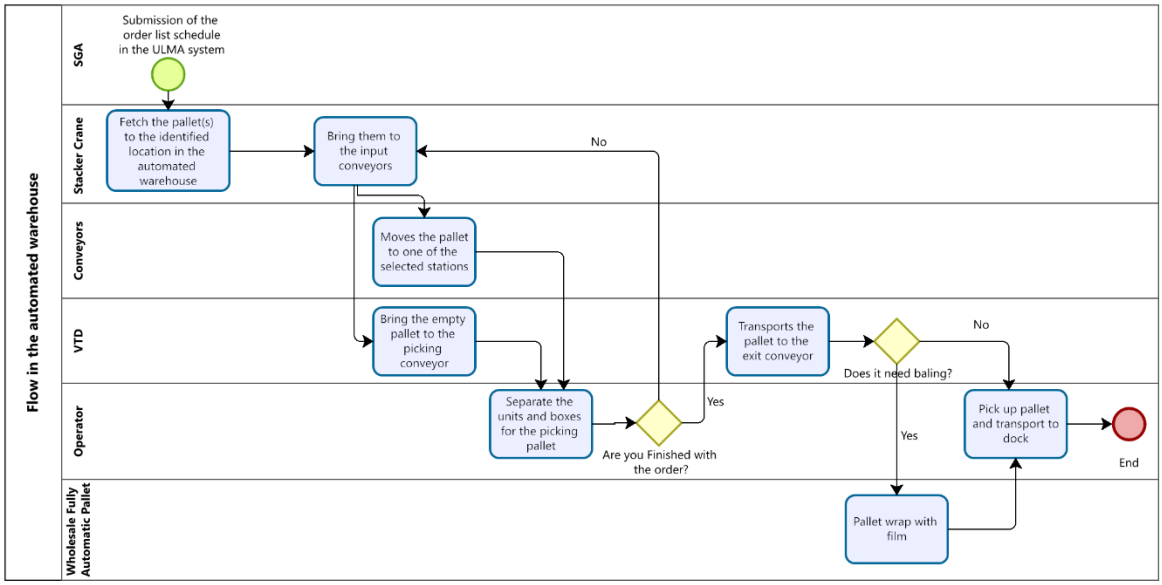


Figure 29-Swimlane of the principal activities of the automated warehouse.

After having covered the logistic processes of this automated warehouse, next it will analyze specific related topics.

3.1.2 Analysis of Variance- ANOVA

The automated warehouse sector has employees working in different shifts, five days a week. The schedules and number of people involved in each shift are shown in Table 4:

Table 4- Shift times performed at the AW.

Shift	Schedule	No. Employees
A (daytime)	8h-17h	7
B (nocturnal)	17h -2h	6

Both the A and B shifts have a manager and a supervisor, responsible for reception, separation, storage, among others. In picking, there are usually four people (one on the top floor and three on the bottom floor) and they are distributed by the picking and miniload area.

Reasons for and Advantages of this study

In order to detect the similarity between the shifts, an ANOVA analysis was performed. This desire to understand the similarities between shifts arises from the fact that the study was carried out during the day period, and, therefore, only the day shift was evaluated. Thus, the need was felt to understand whether the analysis, collection, and conclusion of data from only one shift could be reflected for the night shift.

By running the one-way ANOVA, a input factor is varied across the different levels, in order to compare the means of replicating the experiments (Calandrin 2017). In addition, another advantage associated with this study is that it can be used to compare the averages of three or more shifts and allow for more intuitive decision-making.

In the automated warehouse, the productivity study is performed daily in each shift and analyzed in weekly meetings. This indicator is calculated based on the total number of picks, divided by the total number of hours in these positions (the total number of hours includes the workdays of the workers included).

Study Application

To understand if there is a difference in productivity between the two shifts, it is central to use hypothesis testing and determine if there is a difference.

H_o: First shift productivity = Second shift productivity

And the alternative hypothesis will be:

H_1: There is a difference between the productivity of at least two shifts

Table 5-Total Hours and Picks and productivity in each shift, in 2022.

Week	Picks TD	Hours TD	Picks TN	Hours TN
1	0	0	0	0
2	5310	123	4956	104
3	7556	172	6389	115,5
4	7038	164	6596	133
5	6341	156	6338	162
6	5531	132	4569	126,5
7	5466	132	5790	137
8	6704	160	5636	127
9	6229	153	6629	157,5
10	4779	116	5911	129,5
11	6596	162	6930	164,25
12	6583	169	5584	142,5
13	5402	127	6332	160,5
14	5828	140	5530	141
15	4548	N	2780	63
16	4850	N	5215	136.5
17	4721	N	6058	186
18	4090	99	5544	143
19	6325	155	6328	166
20	5847	141.8	3838	148.5
21	6976	170	6893	178,5
22	7093	175	5280	135

This study use α=0.05, significance level(α). By definition, the alpha level is the probability of rejecting the null hypothesis when the null hypothesis is true (Nóvoa 2021).

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	50,29	50,29	1,31	0,260
Error	32	1225,21	38,29		
Total	33	1275,50			

Figure 30-ANOVA statistical analysis between day and night shift.

Since p>0.05, then we do not reject H0 and consider that the shifts are equal. (Appendix H) Furthermore, the ANOVA study was conducted for the years 2020 and 2021, and the conclusions are:

- In 2020, the productivity between shifts was one of the years with the closest proximity (proof value= 0.821). The mean value of TD (Day shift) was 43.11 and TN was 43.47;

- In 2021, although the proof value is greater than 5%, it is not significant;
- Evaluating the productivity of the day shift and the night shift since there is record, it can be concluded that, on average, the TD's productivity amounts to 41.47 picks/hour-man and the TN's(Night shift) productivity averages 45.34 picks/hour-man.;
- The night shift always has a higher productivity value than the day shift.

Although the ANOVA study indicated that the shifts show equality, the truth is that it is based on only one indicator, which is productivity. When evaluating shifts, they focus on this one indicator and not others. In my opinion, there are other factors that influence the equality between shifts, such as the number of pallets that enter the warehouse at reception, because during the day they receive several trucks, during the night there are no receiving trucks. In addition, there are other factors that differ between shifts, such as the type of orders (which is defined by planning) and the type of pallets, that is, according to the number of picks and the number of units. Therefore, further ahead it will present other indicators to evaluate the productivity of the shifts, and not only the indicator used by the company.

3.2 OEE Analysis - Overall Equipment Efficiency and Cadence

This indicator, in the AW, was analyzed during the period from 2017 to 2020, and, in this analysis, only a global OEE of the warehouse and the banding machines was considered. The last record was made in February 2020, where the value reached was 51%. (Appendix I) Currently, the distribution center has no control and record of this indicator. Using the information from the previously mentioned period, with the warning that 2020 was a pandemic year and the company was closed at certain times, it was possible to see that the evolution of the OEE took the following trend:

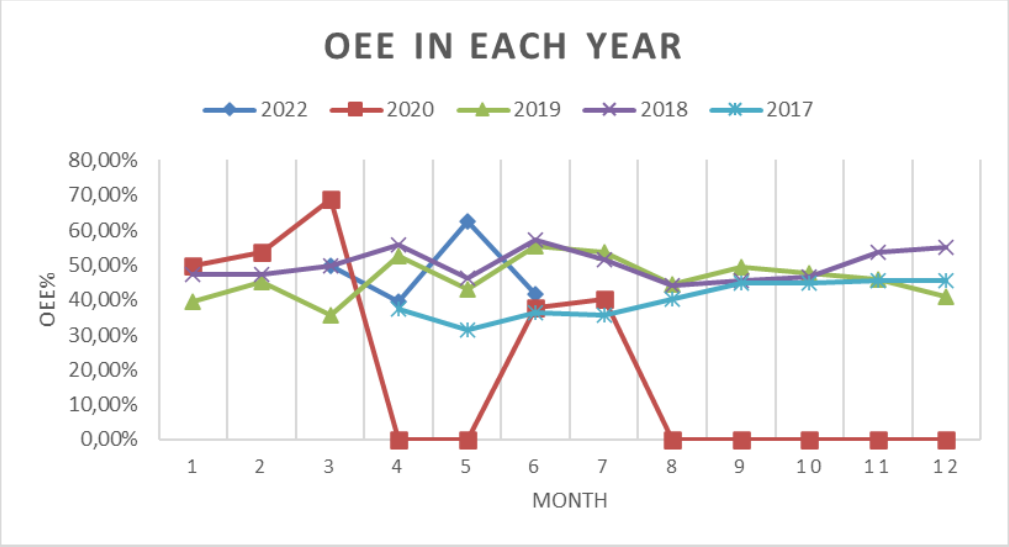


Figure 31-OEE values of the automated warehouse from 2017 to 2022.

As shown in Figure 31, in 2019 and 2018, a similar trend can be seen, in the 40%-50% range (an increase compared to 2017). Regarding 2020, from April until the end of the year, the performance values (and consequently the OEE) were quite irregular and abnormal (null and negative values). The average OEE until the month of April was 58.28%. In 2020, the stacker crane that presented the longest failure time was the third (3221 min=53.7 hours, Figure 59 in Appendix I).

As for 2019, the OEE values were all positive and took results close to the average (46.22%). Therefore, it can be concluded that there was an increase in OEE from 2019 to 2020. In 2019,

the stacker crane that showed the longest breakdown time was the third (5850 min=97.5 hours, Figure 60 in Appendix I).

For 2018, the OEE target was set at 45%. The peak OEE occurred at the end of the year (week 52). There are no programmed stops in the stacker cranes, and the 354 stacker cranes present a higher OEE than the 348. The stacker crane that presented the longest breakdown time was the third (5728 min= 95.5 hours, Figure 61 in Appendix I).

In all years, the stacker crane which presented the longest breakdown time was the third and the one which presented the least breakdowns was the miniload. The longest breakdown time, in all years, was seen in the 354 Wholesale Fully Automatic Pallet. These situation points can be explained by the fact that:

- The 354 Wholesale Fully Automatic Pallet and 348 Wholesale Fully Automatic Pallet are in line and the pallets filmed by the 348 may or may not follow up by the 354, so even though they are not palletized, the mats suffer mechanical wear and tear.
- The miniload has the least breakdowns, since it stores products of smaller dimensions and weights. However, it does not have as much use as the other stacker cranes and contains products considered *monos*. In addition, it contains products stored for long periods and products that are not sold, namely merchandising.

Usefulness and Advantages

With the passage of time and the increase in the number and severity of failures, it was necessary to have more recurrent interventional maintenance. However, in order to have the right maintenance, whether preventive or corrective, it was essential that it was based on data. In addition, it was essential for the management to have a perception of the profitability of the heart of the company since there is only this warehouse and it is the only central distribution center in Portugal. That is, there are two key factors for the emergence of this indicator, namely: knowing the performance of the warehouse at the moment and performing efficient maintenance, therefore reducing the number of breakdowns. As was evident, this indicator has other advantages already mentioned in the chapter Overall Equipment Effectiveness.

Data Collection Methods

For the acquisition of information, a manual record was made on an already defined spreadsheet (Figure 53 in Appendix I) on each shift. Under these circumstances, there was a worker who had the task of collecting this data, which was later entered into a database by the supervisor. With the high increase of breakdowns, as well as the high volume of sales, this task was considered redundant by others and this record was discontinued in 2020.

Viability of data and observations

The initial study made it possible to understand the following aspects:

- Given the major overhaul that has taken place at CIN in the last two years (processes and new software) the task of recording times has fallen into disuse in the face of the greater importance of other issues. Furthermore, it was tried throughout the project to restart this task, however without success due to some resistance from employees and supervisors.
- Mealtimes respect the schedule imposed by the company to the sector in question. Currently, the workers do not participate in daily meetings or cleaning, the latter being performed by an external company. The change of position refers to a schedule in which the operator performs other tasks outside the machine.
- The equipment that constitutes the automated warehouse (conveyors, elevators, stacker cranes, VTD, banding machines, among others) are quite degraded in mechanical terms. It was frequent that the stacker cranes stopped due to errors, the VTD malfunctioned and there were jams in the entry and exit of pallets, often forcing workers to leave their posts to repair them.

- Allied to the point of lack of information, given the breakdowns that have occurred, the maintenance department does not have enough information to apply preventive maintenance that is better suited to the current situation.
- It is considered in all years, a quality index of 100%. Regarding this assumption, the consideration is valid since there is not exactly a production line and the products that may leave the warehouse not in conformity are relatively low to be considered.
- The production value considered is the number of pallets filmed per week, and this value was obtained by making the difference in the counters of each bander at the beginning of the week and at the end of the week. However, the counters of the wholesale fully automatic pallet present many anomalies since they reset to 0 randomly. However, there are many pallets that are not filmed (due to the fact that they are grouped), so they had a lower production value and reduced the OEE value. According to the supervisor, 70% of the pallets are not filmed and 30% are filmed.
- The cycle speed value (theoretical and real) is 2.5 min/pallet, that is, the speed index is 100%.
- There is no analysis of the efficiency of each cell of the logistic line, they only did the study of the two wholesale fully automatic pallet and the global one.
- The two shifts are also considered in the working hours since the records refer to both shifts.

Problems Detected

The problems detected are in line with the observations made previously, but briefly we can define the following:

- They only consider filmed pallets as production value, whereas the overall OEE should consider all pallets processed in the warehouse, whether they are complete, filmed and/or not filmed.
- Not performing, currently and in 2021, a record of the breakdown times.
- The warehouse capacity is at its storage limit.
- Consider the real and theoretical speed to be the same for the two wholesale fully automatic pallet and in the global OEE.
- Not to perform an individualized study of the components that make up the automated warehouse.

3.3 Key Performance Indicators- KPI

In the company, according to the section, the indicators vary, and can highlight the ones currently used:

- Service Level: OTIF (On-Time In-Full);
- Productivity: No. pallets received; No. Picks/Productivity Automatic warehouse; Productivity in picking (No. Picks/Hour/Human);
- Quality: Delivery Error rate; Average response time to complaints.

OTIF

OTIF is intended to control the company's service level, which is essentially about how well you serve your customers. The KPI is the multiplication of two plots (On Time and In Full) and this unit of analysis is the order line/delivery date. Accurate considers the errors made throughout the Distribution activity, which can originate from internal errors or service complaints. On time considers of the sets that were served within the time agreed between the company and the customer, being that only a part of the set is found. On Time, that it is all On Time. If only one unit of the set is not delivered at the time of the first delivery, it will be penalized in Full. The purpose of the analysis is not only to monitor the service level, but also to find out what the causes are behind the failures. By categorizing the reasons, we can act on them and try to prevent them from continuing to occur.

NUMBER OF PALLETS RECEIVED AND TREATED

Corresponds to all pallets that enter the distribution center, whether they are CIN (internal supplier) or not CIN. Pallets are handled at the reception area, as explained previously in chapter 2, it can have different destinations.

NUMBER OF PICKS /HOUR/MAN

The productivity indicator of the automated warehouse is the number of picks/hour/man. A pick is understood as all the manipulation of a set of product/batch that is equivalent to one line of the picking plan (regardless of the quantity). This indicator allows us to have a general notion of how they are taking advantage of our human resources. This indicator should not be used for a direct judgment of the activity and should be complemented with other reports in order to obtain a more in-depth analysis: stoppages of the automated warehouse, number of entries during the period considered (this will affect the number of pallets circulating in the system until they are stored, which will limit the overall activity), nature of the picking plans (the more orders are grouped, the higher the throughput).

DELIVERY ERROR RATE

It is a service indicator, the main purpose is to evaluate the number of errors declared in relation to the total number of shipments. Thus, the deliveries may be made by the company itself (internal) or by external suppliers. With this analysis it intends to analyze and make subcontracted suppliers aware of their performance and quality rate, always with the focus on continuous improvement. Currently, the target set by the company is 0.8%.

AVERAGE RESPONSE TIME TO COMPLAINTS

This indicator appears as a support to customer service, that is, to have the perception of the response time to the customer. The formula calculates the number of days of treatment of non-conformities from its opening to its closing.

3.4 Maintenance

This company has a maintenance department located in the factory, not in the distribution center. As far as maintenance is concerned, there are three types of maintenance performed: corrective, conditioned preventive, and preventive. It should be noted that maintenance is performed by external suppliers (ULMA, TUFAMA) and internal suppliers (department). Usually, ULMA is responsible only for preventive maintenance. For corrective maintenance, the department intervenes if it has the capacity to do so. It should be noted that most of the spare parts are from the ULMA company and that this company only has facilities in Spain.

Considering the number of interventions, it turns out the following data in the Table 6.

Table 6-Percentage of corrective, conditioned and preventive maintenance in the automated warehouse.

No.Interventions/ Year	2021	2020	2019	2018
No. of hours of breakdowns	228	480	769	818
No. Picks	698.227	725.500	722.131	706.324
% Preventive	4%	9%	9%	10%
% Corrective	96%	13%	19%	30%
% Conditional		78%	72%	60%

As evident in the Table 6, there was a reduction in the percentage of preventive maintenance, and it is known, as mentioned in chapter 2, that companies should focus on identifying the optimal balance between preventive interventions, considering a given criterion-costs. This discrepancy of values may be due to the fact that they have little information and data, about causality and frequency of errors. In addition, the maintenance activity reports from 2018 to 2021 were investigated, it was found that most of the corrective interventions resulted from failures due to incorrect preventive maintenance planning, namely: problems related to component cleaning, lubrication, repairs on sensors, receivers, encoder and brushes. These failures were common in the various pieces of equipment as well as their frequency over the four years is evident.

One of the other problems is related to the fact that the maintenance department is located in the factory, and not in the distribution center, therefore does not have such a frequent presence, and consequently, it is not possible to make a constant monitoring of the equipment, ending up not knowing when it is necessary to perform inspections. In short, the problems can be summarized as follows: preventive maintenance is performed by a distant company (longer response time); they only buy parts from Spanish companies (discontinued parts); they don't have a regular maintenance presence in the AW; and finally, the corrective maintenance results from a low frequency of preventive maintenance (ending up ceasing the activity of the AW for simple tasks such as cleaning, lubrication, among others).

3.5 Problems and Challenges to be Solved

Throughout this chapter, the opinion on the company's current situation has been indicated, and therefore it is already possible to identify some red flags. However, in this subchapter, it is possible to verify all the problems identified in this automated warehouse project.

OEE

With regard to the OEE indicator, it is possible to list several problems detected, from the fact that there is no type of control of the times and types of breakdowns that occur in the automated warehouse (having been more frequent and lasting) since 2021, as well as in the assessment of the performance of the AW, not considering it as a key KPI. Before 2021, this record existed, but the way it was calculated was not the most correct, since they only considered the filmed pallets as a production value, whereas the overall OEE should consider all the processed pallets in the warehouse, whether they were complete, filmed and/or not filmed, as well as considering the real and theoretical speed to be the same for both the two stacker cranes and the overall OEE, and another fact is that they did not perform an individualized study of the components that make up the automated warehouse (stacker cranes, VTD, among others). Another problem in the implementation of the OEE indicator was undoubtedly the acceptance and interpretation of it by the operators, and the supervisor dismissed any solution for extracting fault data that involved the intervention of the workers.

Indicators

As far as KPIs are concerned, there is no visual management of the indicators used by the logistics department, i.e., there is no dashboard that allows an intuitive and accessible analysis to the external and internal eyes of the company. Both workers and supervisor are not familiar with or informed on a daily basis of the status of the shop floor. At the same time, it doesn't take into account indicators that affect the productivity of the AW (number of pallets rejected; the number of units and boxes associated with the picks) as well as the devaluation of the control of the capacity of the automated warehouse and existing *monos* (e.g., marketing products).

Maintenance

Regarding the maintenance department, there are some points to be solved, such as: the low percentage of preventive maintenance, lack of spare parts and components and the elevated number and duration of breakdowns. This point, maybe a result of the absence of information regarding the types, frequency and durability of errors occurring in the AW. In addition, they present a high response time to intervention, which may be due to longevity and language barrier with the external supplier, ULMA. Finally, another very important challenge is related to the number of pallets that are rejected at reception (before entering the AW, as mentioned in chapter 3.1). Pallets are rejected when they pass through a sensor barrier, the latter has the function of understanding the pallet's stability inside AW. Any error that gives in the sensor barrier before entering has a high probability of generating errors later inside the AW (associated with the stacker cranes). Just having a pallet strap out, an off-center can, or even a card being improperly conditioned is enough. The pallet has two ways of being built: operator intervention or robot-operator intervention. On average 50 pallets are rejected per day (this value is conditioned by seasonality, number of trucks, and production volume, among others). In these circumstances, the operator will have to stop his duties, leave the forklift, detect the error, and go to the computer system to enter the pallet, therefore corresponding to 4/5 min per pallet. Associated with this problem, sometimes there is not the best approach in the treatment of rejected pallets (covering the sensors in the passage of the sensory barrier), which will later reflect in stacker crane malfunctions, with a longer response time to these malfunctions and more difficult access.

Continuous Improvement -AW

Regarding continuous improvement, there are several challenges to be improved such as updating the computer system, and the work rules associated with AW (reception, separation, banding) that are outdated and are not always available in the workplace for consultation. In the previous circumstance, the workstations are not very ergonomic and with a high risk of equipment destruction. In addition, and taking into account the results of the ErgoSafeCI tool (Figure 6), other points to be corrected are:

- Difficult visibility and labeling of all carpet labels every six months, as they are critical when performing reset;
- Inhibition of daily *kaizen*, since before the pandemic they had started this methodology, but in 2020 they ended up suspending it and never resuming;
- Absence of tool and raw material list for operations;
- Risk between machines and humans, i.e., high risk of forklift-human collision;
- Layout MEC disorganized, no record and no identifications;
- Workplace disorganization in receiving, maintenance and sorting;
- On the exit conveyor, the operator only knew the destination of the conveyor if he read its label, therefore there is not a more interactive and inductive mode in this process.
- There is no *kanban* system in the replenishment of materials needed for the work in the picking section, thus the utensils were badly packed, disorganized and the employees ended up having the materials in excess of their needs. In addition, there is no employee responsible for supplying the stations.
- There is no work standard associated with 5S and its workstation, and employees do not perform standardized tasks of organization, self-discipline, and cleanliness.

Thus, an action plan was made, which contained the following actions in the Figure 32.

Area of intervention	Improvement Actions / Suggestions	Status	Creation date	End date	Responsible
Maintenance	Steel plates for robotized warehouse conveyor belts		28/03/2022	Under Development	Inês Canedo/Diogo Neto/ Eng.Pinto
Safety	Sharp edge protection in Picking Protection of pillars		06/04/2022	Under Development	Inês Canedo/ Cassandra Carneiro / Margarida Alpalhão
Continuous Improvement	Update and Create the following work standards: 1-Separation 2-Reception of internal and external suppliers 3-VTD 4- Wholesale Fully Automatic Pallet breakdown		11/04/2022	Under Development	Inês Canedo/Diogo Neto/ Mariana Martins
Hygiene	Ecopoint for empty rolls in area of the Wholesale Fully Automatic Pallet		11/04/2022	20/abr	Inês Canedo/ Cassandra Carneiro /Paulo
Maintenance	Table for workstation		14/04/2022	Under Development	Inês Canedo/Diogo Neto/ Eng.Pinto
IT	Addition of a program for VTD error identification		18/04/2022	Canceled	Inês Canedo/Diogo Neto
Safety	See new location of basket and manipulator and Identify correctly		19/04/2022	20/abr	Inês Canedo/ Cassandra Carneiro
Continuous Improvement	Update whiteboard for daily kaizen		19/04/2022	15/mai	Inês Canedo/Diogo Neto/ Mariana Martins
Continuous Improvement	Adapt the color to the name of the tables		20/04/2022	Under Development	Inês Canedo/Diogo Neto/ Mariana Martins
Continuous Improvement	Replacing cardboard boxes in the sorting area with labeled transparent boxes		20/04/2022	Under Development	Inês Canedo/Diogo Neto/ Mariana Martins
Continuous Improvement	Reception desk- tidy up and adapt to needs		20/04/2022	To start	Inês Canedo/Diogo Neto/ Mariana Martins
Continuous Improvement	Create work standard for VTD		21/04/2022	09/jun	Inês Canedo/Diogo Neto/ Mariana Martins
Safety	Ensure access to all fire hydrants and extinguishers in all areas of the sector		01/04/2022	09/jun	Inês Canedo
Logistics	Delimit and organize places to hold stock (MEC)		01/05/2022	To start	Inês Canedo
Continuous Improvement	Create a visual management system that allows quick and easy identification of where each type of material is in the stock areas		28/05/2022	To start	Inês Canedo
Continuous Improvement	Kaizen all over the distribution center		25/05/2022	To start	Inês Canedo
Continuous Improvement	Review the allocation of tools per work area and identify them		28/05/2022	Under Development	Inês Canedo
Maintenance	Create preventive maintenance plans		10/05/2022	Under Development	Inês Canedo
Logistics	Develop a database of KPI's needed for analysis in AA		19/05/2022	Under Development	Inês Canedo
Logistics	Build Dashboard with all the information of the CD		20/05/2022	Under Development	Inês Canedo

Figure 32-Action plan carried out during the project.

Appendix J highlights the points mentioned above, in order to illustrate the before implementation of the solutions that will be presented in the next chapter.

4. Presentation of improvement proposals

Chapter 4 comes after having defined the main challenges to intervene in this project. Thus, in this section it is possible to find several proposed solutions to the various problems raised, as well as analysis of the result of the solutions that were possible to implement. As in any project, not everything goes as expected, due to obstacles and setbacks. However, of the solutions that were not implemented, there remains the suggestion of possible resources that may be possible to introduce soon. The truth is that at the time the project was developed, it culminated in a time of changes in the distribution center, which not only affected the conclusion on the results but also a lower availability to interact and discuss the topics generated by this project.

4.1 Overall Equipment Efficiency – OEE

Initially, for the OEE analysis, it was necessary to constantly collect data regarding the parameters previously addressed. For this, it was used an excel base oriented to assist me in the registration of breakdowns. (Appendix I)

Although the historical OEE of the company concerns globally, it was decided to make a more in-depth analysis, therefore the OEE of most of the equipment that make up the robotic warehouse was studied, namely: VTD (lower floor and upper floor); Stacker Cranes (1,2,3,4,5 and Miniload); Wholesale Fully Automatic Pallet (348 and 345) and Global. For this analysis the following assumptions had to be made:

- In the operating time only the hours of one shift (9 hours) were considered, as well as the scheduled downtime of only one shift, since all the fault records relate to one and only one shift.
- The theoretical cycle time was based on a study conducted by the company ULMA in 2021, and considered the maximum speed presented in that same study. Since the study is quite recent (2021) and was conducted in the seasonal period identical to the internship period, it meets all the factors for the feasibility of the results.
- The effective cycle time corresponds to the inverse of the average speed of each stacker crane, according to the ULMA study in 2021.
- In the stacker cranes, the number of pallets moved weekly corresponds to the total number of picks made divided by the 6 stacker cranes. Although the production value is pallets, in the stacker cranes it was not possible to consider the number of pallets but the number of picks. It was tried to perform a Pearson correlation between the number of picks and the number of outgoing pallets, however r=0.1920 and according to Jaadi (2019), it is considered a negligible correlation.
- In the stacker cranes, the downtime concerns all the periods where malfunctions, or resets, occurred.
- In the Wholesale Fully Automatic Pallet, the theoretical cycle time was acquired through the equipment's technical specifications existing in the company. And the production cycle was only considered for filmed pallets.

- The effective cycle time of the banding machines was calculated with daily records.
- The theoretical cycle time and the effective cycle time of the VTD was based on the ULMA study. However, there is a rough approximation here of considering these times equal for both top floor VTD and bottom floor VTD, since the top VTD only works for 5 picking tables, while the bottom VTD works for 15 picking tables.
- For the initial calculation of this OEE a quality of 100% was assumed.

4.1.1 OEE Analysis

Although the operation of the AW does not resemble a usual production line, the movement of the pallet follows a serial path, so it can create a scenario of a logistics line of three pieces of equipment (stacker cranes - VTD - banding machines). Thus, it was chosen to measure OEE separately. So far, the OEE of each element and overall OEEL concern the values are shown in the Table 7.

Table 7-OEE values for each component of the AW, as well as for the overall system.

Month	Week	OEEL	OEE T1	OEE T2	OEE T3	OEE T4	OEE T5	OEE ML	OEE Band 348	OEE Band 354	OEE VTD PI	OEE VTD PS
3	12	48,80%	27,23%	37,51%	36,84%	36,06%	41,41%	11,34%	18,22%	22,87%	43,96%	22,98%
3	13	48,45%	26,41%	36,38%	35,73%	34,97%	33,98%	9,31%	23,71%	29,46%	51,95%	27,16%
3	14	51,78%	28,49%	39,25%	38,54%	37,73%	36,66%	10,04%	22,98%	28,80%	51,95%	27,16%
4	15	42,89%	22,83%	31,44%	30,88%	30,23%	28,61%	7,84%	16,41%	20,59%	53,33%	27,88%
4	16	39,06%	20,98%	28,91%	28,39%	27,79%	30,51%	8,36%	#N/A	22,30%	45,98%	24,04%
4	17	42,04%	22,49%	30,99%	30,43%	29,79%	29,70%	8,13%	34,58%	24,56%	50,63%	26,47%
4	18	33,81%	17,70%	24,38%	23,94%	23,44%	25,73%	7,05%	16,03%	20,31%	45,98%	24,04%
5	19	57,14%	31,74%	43,73%	42,95%	42,04%	39,78%	10,90%	25,15%	40,30%	70,18%	27,88%
5	20	53,31%	29,35%	40,42%	39,70%	38,86%	36,78%	10,07%	28,46%	32,34%	53,33%	27,88%
5	21	57,67%	35,01%	48,23%	47,37%	46,37%	45,35%	12,85%	30,04%	34,01%	53,33%	27,88%
6	24	68,73%	25,65%	35,33%	34,70%	33,97%	31,43%	12,58%	30,97%	38,55%	54,55%	22,35%

The OEE of the components showed variability, a decrease was evident due to the testing and implementation of the new computer system in week 16, which drastically decreased the production volume for the safety of the warehouse. When in week 18 normal production volume returned, there was a disconnection between computer systems and problems were detected and immediately solved. This analysis and study lasted for two weeks, affecting these indicators. It will not be able to compare the OEE value with previous years, because the previous assumptions were completely different from the assumptions currently considered, as mentioned above. Anyway, can see that there was a significant increase, which can be explained by the changes that occurred and with the implementation of the solutions.

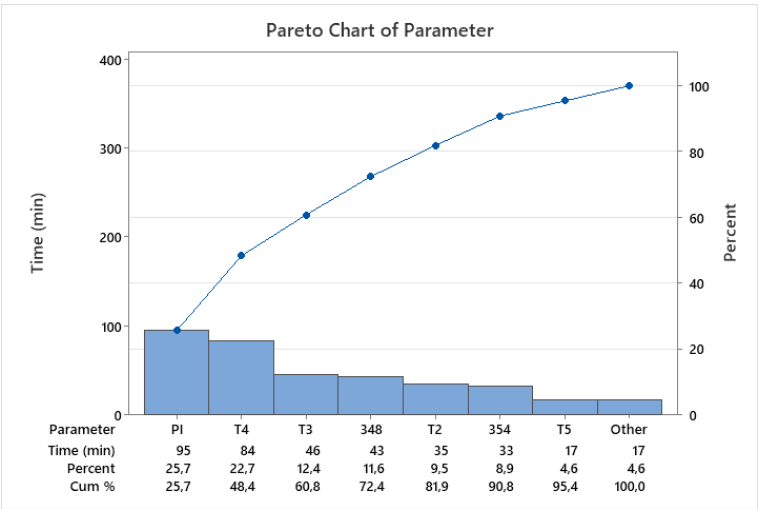


Figure 33-Pareto diagram of the main stops.

With the registered failures it was possible to perform a pareto diagram (Figure 33) to understand where to focus our attention for improvement, and this way it is verified that 25.7% of the failures are due to the VTD of the lower floor.

The OEE do not cover losses such as downtime due to lack of demand, research and development tests (such as the tests performed for the implementation of the new software) or causes external to the plant, such as missing pallet stacks. For these reasons, it was decided losses not considered by OEE. It was then decided to adopt the broader measurement approach proposed by OPE, since this considered line is not only made of machines, but there is also involvement of the human hand in the intermediary of the line, and this hand varies according to the speed of the employee, the number of workers, state of manipulators, among others. These are just some of the reasons why production may have slowed down, and they are all factors whose responsibility cannot be identified through OEE alone. OPE integrates machine data with responsibility for what happens around the machines.

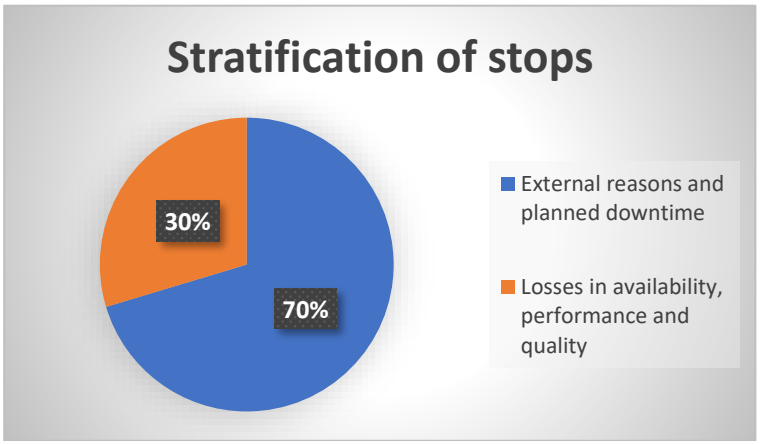


Figure 34-Stratification of recorded breakdowns.

In the Figure 34 illustrated that 70% of the losses are not considered in the OEE. The OPE (blue color) integrates the data from the machines with the responsibility for what happens around the machines. Thus, during the internship period, the OPE, on average, was 41.8%, and the OEEL was 55.6%.

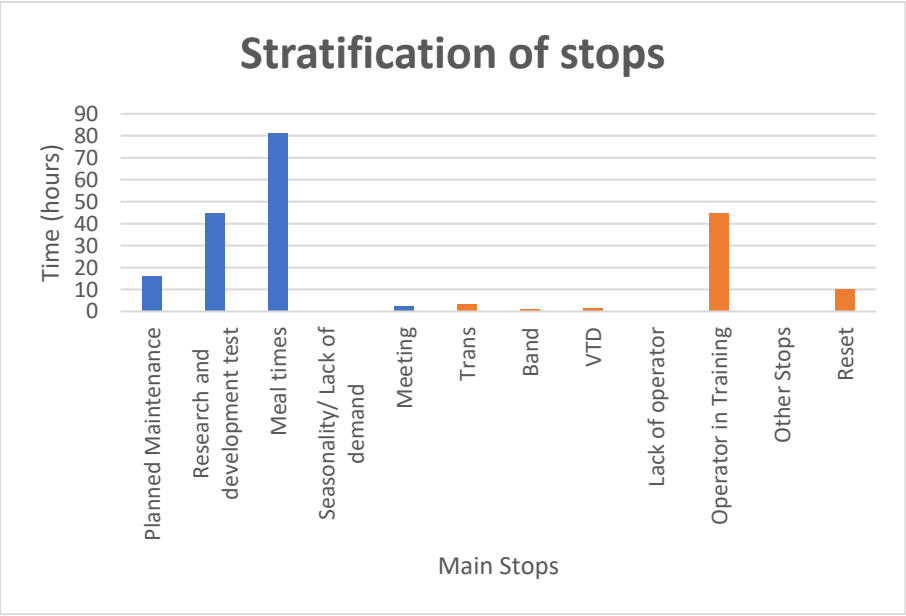


Figure 35-Stops considered and not considered in the OEE impact.

The joint measurement of OEE and OPE is intended to establish a more strategic level of analysis and decision-making.

The OPE measurement brought a clearer perception of downtime. According to the authors Miyake and Busso (2013), it is evident that "it is more advantageous for the company to invest in the increase and adequacy of its warehouses than to live with losses and expenses".

Due to the importance of monitoring this tool, a dashboard with the key data was developed, with the main objectives of transmitting in a transparent and visual way the key data to any worker. Due to the short duration, it was developed a dashboard in excel, that later due to the positive feedback was transferred to the whole department (Figure 36).



Figure 36-Dashboard developed for the study of OEE in the automatic warehouse.

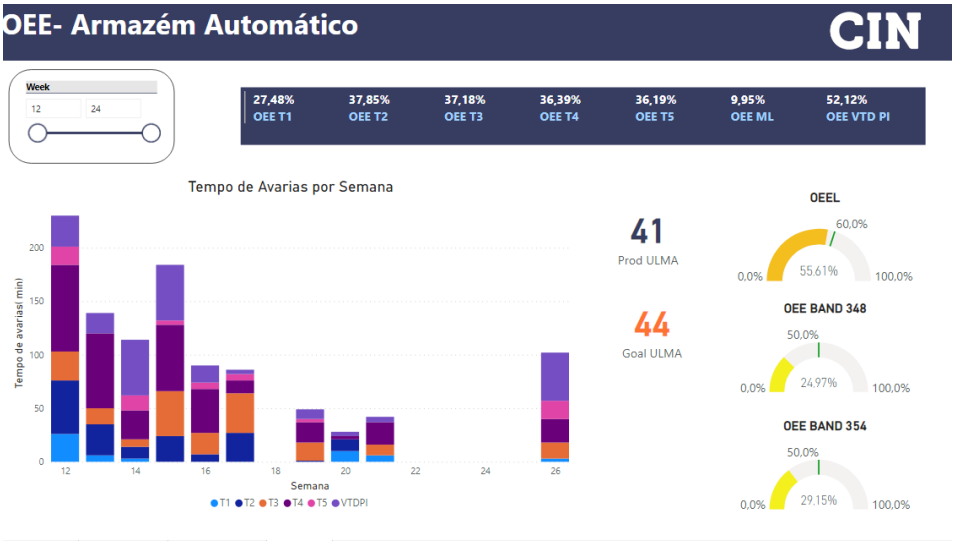


Figure 37- Dashboard developed, in power bi, for the study of OEE in the automatic warehouse.

In the final stretch, this project was transported to a higher level, i.e., from excel to Power BI (Figure 37). The objective of developing this platform was to transmit in a visual and simple way the current performance status of the distribution center, and the next step is to have a monitor on the shop floor that transmits this transformed data to the workers.

However, for any dashboard a range of data is required, so the following subchapter will discuss how to extract the data.

4.1.2 Data Extraction Methods

Any OEE analysis system requires feasible, intuitive, and instantaneous monitoring and control. As mentioned before, the method used to later define OEE was based on manual recording. Considering, the inefficiency of the process and the lack of collaboration in this method, alternatives were elaborated, namely: electromechanical registration and computerized registration.

Before explaining the systems used in each register, will discuss how faults are signaled. In the case of the stacker cranes, each one has an alarm that goes off whenever it detects an error and there is a sound and visual signal (permanent orange light). After this trigger, one of the employees must go to the control panel that is located next to his station and read the error, through a reader that is on-site. After the reading and with the key, you must go directly to the stacker crane with the reader and correct this same error (yellow flashing light). Afterwards, he returns to the return panel and activates the forward command. With the new computer system, the error signaling is also visible on all computers at the AW workstations (Figure 79 from Appendix L). In the VTD case there is a red visual signal whenever the error occurs, and the error is highlighted in the computer (Figure 74 from Appendix K).

Electromechanical registration

This registration consists of using a mechanical system inserted in the console cavity (Figure 77 from Appendix L) with a time controller, and when the operator removed the machine to read the error, he would start counting the time and would only stop when the error reader returned to its initial position. Then, the time recording could be done by a PLC (Programmable Logic Controller) or manually.

The mechanical system may consist of two types of solutions:

- Limit switches with the timing with a PLC or a time totalizer;
- Photocells with the timing with a PLC or a time totalizer.

Finally, there would be a whiteboard, with *Kanban* cards, where each color corresponded to a specific error (normally there are four types of errors) and the operator only had to place the card on the board. At the end of the shift, the supervisor would collect the sequence of error types that occurred and process the information obtained through the PLC.

This approach has its disadvantages, as it: requires operator intervention; it requires the processing of information, in order to match the time intervals with the types of errors that occurred and the timing does not correspond to the total stop of the stacker crane, since at the moment the stacker crane stops, the employee only moves after finishing his picking task, that is, his repair does not occur immediately.

IT Register-VTD

In VTD, whenever an error occurs it is necessary to reset, and this action is done on a computer available only for these occasions. This way, it would be necessary to add a software that would detect the image change and trigger a code. This code was developed in python (compatible with Windows XP, Figure 75 and Figure 76 in Appendix K), where it has a timer that triggers and stops whenever this anomaly occurs and registers it in a notepad. Later, a form was developed where it questions the employee about the type of error and stores it in the same text line of the notepad. This solution does not add tasks to the workers and it is an efficient and necessary process. However, this solution was rejected by the IT department, as the computer system of the VTD computer is Windows XP and this is a risky process.

IT Register-Stacker Crane

This computer record is only possible due to the implementation of the new computer system in April 2022, since it contains a tab available with the instantaneous display of the status of all the elements that include the AW (from VTD to the stacker cranes). For the stacker cranes, a computer would be implemented with the sole function of controlling the time and type of error that occurs in the automatic warehouse system, through the same software but with a different code (Appendix L). This software would have the function of detecting a change in the monitor, running a code that would press the button to download the excel document. Afterwards, all these documents would be stored in a folder, with a code that would open each excel one by one, and then copy and compile the error lines into a single document.

4.2 Key Performance Indicators- KPI

Additional indicators recommended for better analysis in AW are:

- Reception: Rejected pallets/Incoming pallet;
- Sorting: (No. Boxes + No. Units)/No. Picks; OEE and OPE;
- Filming: Outgoing Pallets;
- Maintenance: MTBF; MTTR; MTTF;

Regarding receiving, this indicator is suggested, given that, and considering the explanation of the buffer (five pallets), the pallets are stopped daily, due to the buffer has reaching maximum capacity, preventing the entry of the pallets into the AW. On average 50 pallets are rejected per day (this value is conditioned by seasonality, number of trucks, and production volume, among others). In these circumstances, the operator will have to stop his duties, leave the forklift, detect the error, and go to the computer system to enter the pallet, therefore corresponding to 4/5 min per pallet, so 40 min per day are wasted (200 min/week). When manual palletizing occurs, the suggestion is to train the workers so that they follow the established norms. In the case of palletization by a robot, a system must be acquired to rotate the cans, according to the count, placing the handles inside and not on the outside of the pallet.

In the picking sector, three indicators are presented. The first one is suggested, since productivity only evaluates the number of picks, and a pick can correspond to either one box or many more boxes. Thus, the productivity analysis should take this factor into consideration, since it directly influences the operation time. As for the others, the reasons for this selection have already been explained in chapter 4.1.

As for the wholesale fully automatic, currently, there is no control on the number of pallets extracted from the exit belt, thus, it is crucial to take into account that the man on the belt is the bottleneck.

Regarding maintenance, it was suggested these indicators that will be monitored together with the maintenance department. In this way, it is fundamental in a warehouse like this to have thorough control of maintenance so that it never stops, and when it does, it is as fast as possible. Although the department calculates these indicators, they only do so in a global way (factory plus distribution center). Therefore, it was recommend looking specifically at these indicators in AW.

4.3 Maintenance

Preventive maintenance and restoring the equipment to its optimal operating conditions would certainly contribute to an increase in efficiency, but it should be noted that this is an automated warehouse that is more than 15 years old. This work would, however, must be done by the equipment manufacturer itself and the maintenance team, since one provided the

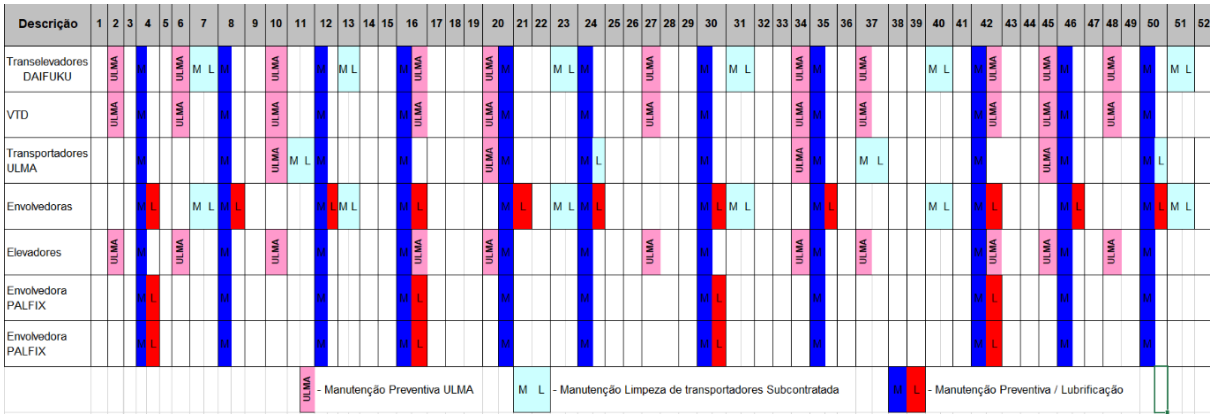
resources and the other had the training to apply and correct. The fact of not having an assiduous and continuous presence of the maintenance in a titled automated warehouse is a prejudicial factor since the maintenance department is fixed in the headquarters/factory, which is far away from the distribution center. Taking into account the necessary interventions in the factory and the necessary interventions in the warehouse, it would make sense to allocate this department. Another important aspect to point out is the fact that the company uses a foreign parts supplier far away, which ends up hindering and reducing the response speed and increasing downtimes. The preventive maintenance actions are defined together with the maintenance department and the company ULMA. The latter presents a pre-defined checklist, as well as the adequate periods that follow the following criteria as shown in the Table 8.

Table 8- Periodicity of preventive maintenance in an AW, according to the ULMA company (ULMA 2022).

	F1	**F2**	**F3**	**F4**
Stress High (16-24h)	1M	2M	6M	12M
Stress Medium(12-16h)	2M	2M	6M	12M
Stress low (8h)	3-4M	3-4M	6-8M	12M

Considering the main failures of corrective maintenance, it is recommended to clean and lubricate the VTD (including cells, sensors,...) with a periodicity of one month, as for the stacker cranes, the optical receivers, encoder, sensors, brushes and gearmotor should be analyzed and cleaned every month, and finally, in the Wholesale Fully Automatic , the periodicity for preventive maintenance should be one month and should focus on the following components: collector, arm, brushes, shaft and roller (including lubrication and cleaning of components). Thus, considering the tasks and periods, the category "Stress High" was selected, due to the age and durability of the warehouse use, and consequently, readjustments of the action plan, as illustrated in Table 9. (Appendix M)

Table 9-Suggested annual action plan for the maintenance department.



Despite these solutions (registration and control of times and types of malfunctions, introduction of the new maintenance action plan, continuous improvement) the main goal is to reduce the number and time of malfunctions, with an increase in preventive maintenance and reduction of corrective maintenance, and therefore, an increase in OEE. With the new maintenance plan, which increases the frequency of intervention, but more importantly focuses on the components that normally have more breakdowns, the vision is to reduce by half the corrective maintenance (on average around 160 hours) to 80 hours plus the reduction of the time of breakdowns (on average 793.5) to less than 15%, so the company would gain available time of about 200 hours per year.

4.4 Continuous Improvement

This sub-chapter involves a culmination of Lean, Six Sigma, TPM methodologies for the reasons. Not all the solutions presented were implemented, due to the durability of the internship. The Figure 38 and Figure 39 summarize the before and after implementation of the solutions to the problems presented, and in the Appendix J presents in a detailed.

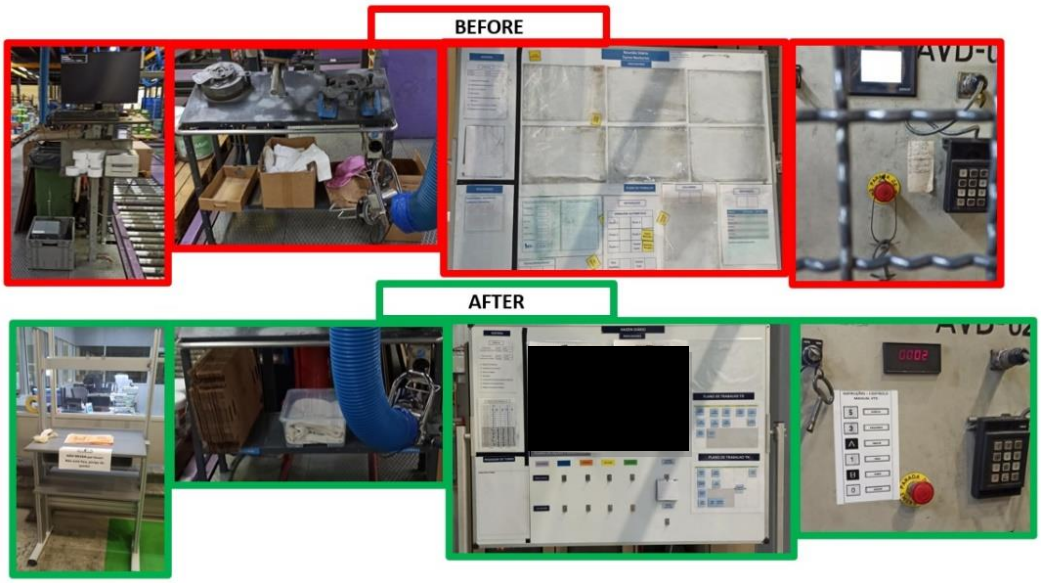


Figure 38-Photographic records of before and after implementation of continuous improvement methodologies.

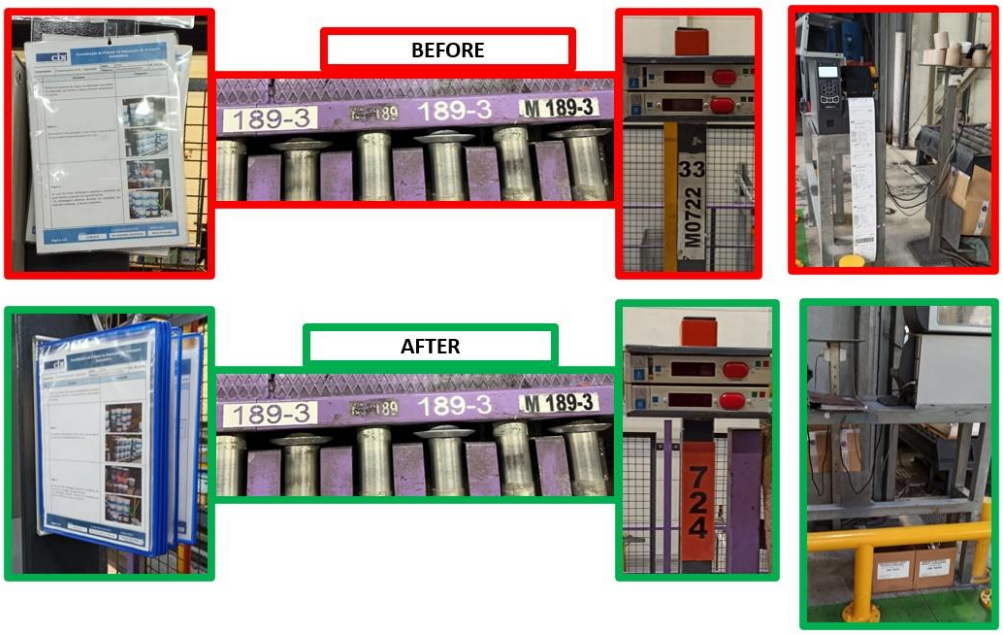


Figure 39-Photographic records of before and after implementation of continuous improvement methodologies.

The solutions presented will be discussed and an investment analysis of them performed in the next chapter.

Workstations

Another point that appeared during the project was software updating, which consequently implied the acquisition of new computer equipment that was not adequate for the existing workstations (Figure 68 in Appendix I). Thus, a market search for the ideal solution was conducted. This search involved a survey of workers, design, and mechanical construction (SolidWorks), and contacting of suppliers. Considering the specific requirements, a

workstation from scratch was designed to be produced in metalworking industries (Figure 83 and Figure 84 in Appendix N).
For the decision making process, and after having presented the AHP nomenclature, it will proceed to apply it to one of the solutions presented, and the workstation was selected for this analysis. First, the criteria to be prioritized was defined, based on the opinions of the employees and the team leaders:

Table 10-Criteria considered in the experiment and their definitions.

Criterion	Settings in the experiment
CR1: Value of impact on ergonomics	Ergonomics is fundamental to a workstation that affects the entire dynamics of operations, from operating time and well-being.
CR2: Value in productivity impact	The workstation should have all the needs of the operations and interfere positively with productivity.
CR3: Price of the presented solution	Limited to the value of 500 euros.
CR4: Lead Time	Limited to the time of 1 month.
CR5: Safety and Hygiene for employees and equipment	The workstation should preserve the electronic equipment from possible damage.

Subsequently, the preference of the criteria must be evaluated. Secondly, the alternatives will be defined and their performance studied:

Table 11-Set of alternatives (working table) considered in the problem.

Alternatives
A1-Current Job Position
A2- Root post with metallurgy
A3-Adaptation of the current post with metallurgy
A4-Workshop bought and prefect
A5-Workplace purchased and adaptable

Table 12-Worktable performances considering the criteria.

	Alternatives (Workstation)				
Criterion	A1	A2	A3	A4	A5
CR1: Ergonomics impact value	X	X X X	X X	X X	X X X X
CR2: Value in productivity impact	X	X X X	X X	X X X	X X X X
CR3: Price of the presented solution (Euros)	0	600	400	774	500
CR4: Lead Time (Weeks)	0	8	5	3	2
CR5: Safety and Hygiene	X	X X X X	X X X	X X	X X X X

In this step initially judgments of importance were made between pairs of criteria (pairwise judgments) in relation to the main focus. To this end, the scale of values established by Saaty .

Table 13-Parity judgments of the criteria in light of the main focus.

Main Focus	CR1	CR2	CR3	CR4	CR5	Weighted Sum Value	Criteria Weights	Indicator
CR1	0,345253796	0,3335	0,5087	0,384	0,2789	1,849990569	0,3452538	5,358349683
CR2	0,345253796	0,3335	0,5087	0,384	0,2231	1,794208735	0,33348909	5,380112236
CR3	0,115084599	0,1112	0,1696	0,288	0,2231	0,906675592	0,16956261	5,347143526
CR4	0,086313449	0,0834	0,0565	0,096	0,1673	0,489464766	0,09591267	5,103233485
CR5	0,069050759	0,0834	0,0424	0,032	0,0558	0,282566409	0,05578183	5,065563238
Total	**0,96**	**0,94**	**1,29**	**1,18**	**0,95**	**5,32290607**		

With these data and considering the normalized value of RCI (n=5, RCI=1.12), it can be determined that CI takes the value of 0,062 and CR has the value of 0,056. As CR<0.1, according to Saaty , the judgments for this matrix are considered consistent.

Table 14-Local medium priorities (LMP's) and global priorities (GP).

Main Focus	CR1	CR2	CR3	CR4	CR5	GLOBAL PRIORITY
A1	0,05	0,04	0,50	0,31	0,05	0,22785321
A2	0,37	0,23	0,13	0,06	0,36	0,27924041
A3	0,10	0,29	0,18	0,09	0,13	0,21791108
A4	0,10	0,10	0,04	0,17	0,06	0,13120325
A5	0,38	0,34	0,15	0,37	0,39	0,45290831
Total	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	

Considering the results in Table 14, it was consider that the best desk analyzed in light of all criteria is model A5, because this desk has the highest overall priority.
This solution was presented to the directors, consequently a prototype workstation was acquired. (Appendix N) Being that the advantageous points of this workstation are: adjustable measurements, thus making it ergonomic for the sorting workers, adjustment of the monitor in the line of sight and secure fastening of the technological components.

Health and Safety

In the separation section, there were dangerous areas for the workers, such as sharp corners. Thus, the hygiene department was informed of a possible solution (rubber corners), which is still under development. Another aspect to take into consideration is the high noise in the automated warehouse, which makes it difficult to detect forklift movements, which are quite frequent, and accidents may occur. The solution suggested for the previously mentioned fact is the use of infrared sensors, and visual signaling, which detect the movement or presence of forklifts and pedestrians where the aisles cross. Whenever a collision hazard is detected, a SpotMe warning unit is activated to help prevent accidents. In these circumstances, the most critical place would be the entrance gate to the AW.

5S

In this category, there were several areas of the automated warehouse where an intervention with the introduction of 5S was necessary. In the bander area, a container was created in order to store chemical waste from the printer rolls, instead of leaving them lying on the worktable (Figure 69 in Appendix J). Another solution implemented concerns the standardization and normalization of 3S at the workstations through Kamishibai cards as illustrated in Figure 40.

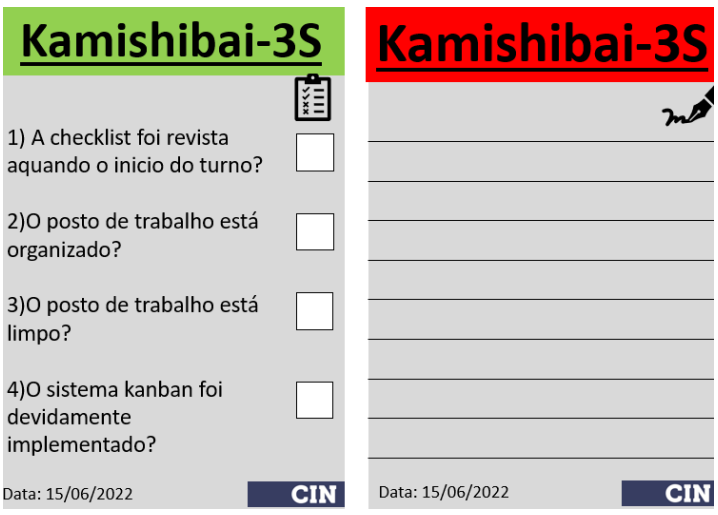


Figure 40-Kamishibai method based on the 3S.

Given the suggestions still to be implemented, I would recommend the use of the whiteboard with the identification of the products for immediate shipment that are not in the secondary warehouse (MEC).

4.4.1 Daily Kaizen

As mentioned in the chapter Problems and Challenges to be Solved, before the pandemic Daily *Kaizen* was held, with the objective of involving workers in the daily activity plans of their sector and to discuss emerging issues. In this perspective, I started the Daily *Kaizen* meetings with a duration of 10 minutes, at the beginning of each shift (Figure 86 in Appendix O). In this project, the necessary conditions were met to reestablish this methodology and improve aspects in comparison with the previous framework. The improved aspects are:

- Only one side of the board for the two shifts, for the two shifts to be in sync both in work plans and in indicators;
- Introduction of improvement suggestions and PDCA, to give voice to the workers and enhance the knowledge and creativity of those who use the equipment daily;
- Addition of an area titled "Shift transition". This tab converges with the goal of being the two shifts in accordance, and before starting the next shift, the supervisor are familiar with the status of equipment and work plans.

At the end of the day, the coordinator must update the indicators so that the next day she can discuss the results. Considering, the dropout of this methodology previously and the resistance of the workers, a regular audit is performed (Figure 87 in Appendix O).

In addition, an analysis was implemented in the weekly kaizen meeting between team leaders, which consisted of an evaluation of the team leaders' performance during their daily kaizen meetings, following the logic of the PDCA methodology, where the team leaders prepare the meeting, hold it and this evaluation enters the check phase, where they review what was done and suggest improvements, which will be implemented in the ACT phase. And this evaluation must be done in a continuous and frequent way. This analysis would follow the logic presented in the Table 15.

Table 15-Evaluation of team meetings (UpFlip 2021).

Name	Passion	Prepared	Engaging	Questions	Transitions	Humor	Control	Time	Average	Grade	Improve
Person X	B	A	A	A	A	B	A	5	2,6	A	Passion
Person Y	A	B	A	A	A	A	A	4	2,9	A	Volume
Person Z	B	B	B	B	A	B	A	8	2,3	B	Prepared

4.4.2 Kanban

Initially for the *Kanban* system, it was decided to use *Kanban* cards (illustrated in Figure 41), with product identification, maximum stock and minimum stock (Appendix P).



Figure 41-Kanban cards.

The stipulations of these values were based on the following parameters: the values previously defined in the work standard, the box capacity and data currently collected based on employee opinion as well as visually collected data. In this methodology visual management is used to characterize the stock status (i.e., green for within the established levels and red when minimum stock is reached).



Figure 42-Kanban system through realized cards.

Considering the location of the *Kanban* cards (low visibility and ergonomics), another solution associated with the use of the full box and empty box method was suggested. This method was not implemented due to lack of time during the internship period.

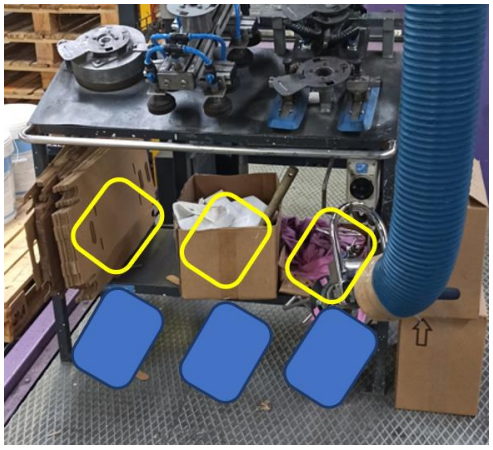


Figure 43-Full-box and empty-box kanban system.

In the Figure 43, the yellow boxes illustrate full boxes and the blue boxes represent empty boxes. The yellow area is the stock and functions as inactive *Kanban*. The zone outlined in blue functions as active *Kanban* and informs the supplier that that reference must be replenished on the next route. The operator at the sorting station is responsible for managing his own stock, activating or not the *Kanban*, placing the respective plastic boxes (full or empty) in the correct place. The person in charge at the indicated time is responsible for

retrieving the empty boxes and placing them on the cart, where they will move to the storage location.

The layout of the AW was reformulated to allow a more efficient circuit, as illustrated in the Figure 44, with a new storage area for materials and an alternative solution to the current layout was presented (option 2 is the current and option 1 is the suggested one).

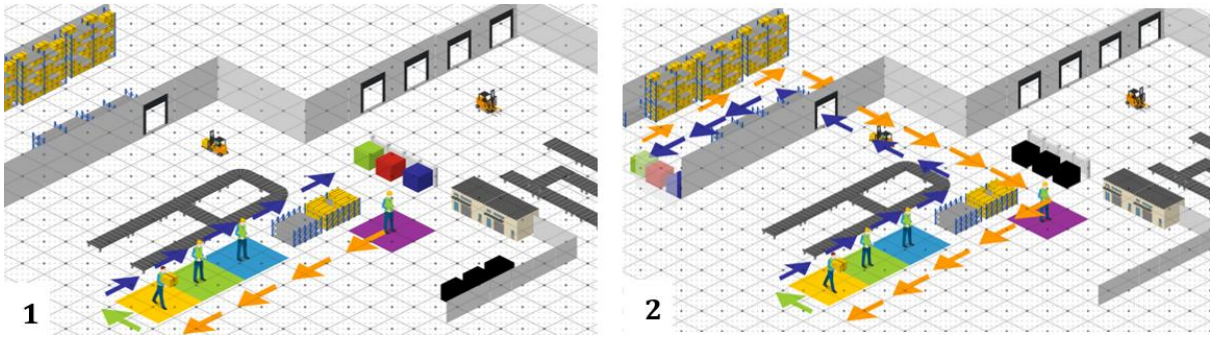


Figure 44-Layout options for the kanban system.

Option 2 represents the current layout, and the area with black bins is currently intended to store all materials that will undergo recycling. The handling of these materials is done by an external cleaner and not by the employees. In the designed layout, the green, red and blue blocks represent the pallets of materials used in sorting (cardboard boxes, tape rolls, plastic bags and cards). The purple area represents the upper floor (floor 1), affecting the *Mizusumashi's* time, therefore one of the solutions identified would be for the worker on the upper floor to be responsible for updating the data on the lower floor, when he moves down for breaks or end of service. For the two routes presented (current and suggested) the times were studied and the difference is approximately 86 seconds, that is, the new route allows a gain of 86 seconds. Considering that they perform this route once per shift, it would save approximately 14 minutes per week.

4.4.3 Normalization of Operations

There were no operating rules for the various equipment in the distribution center and when a doubt arose the need to ask the person in charge how to proceed, wasting a lot of time on these tasks, as mentioned in Problems and Challenges to be Solved. Therefore, to reduce waste, each process was analyzed and the tasks central to its execution were documented. Once documented, the work rules were reviewed by the team leaders, and then approved. Upon approval, the work rules were made available at the operational locations to which they concern. These were posted on the machines, allowing quick access by any operator, as in the reception, separation, and filming. (Appendix Q) However, due to constraints motivated by the duration of the dissertation project, there were no conditions to carry out training on the new work standards and therefore to carry out the follow-up.

4.4.4 Analysis of results and conclusions

By looking back at the problems and their solutions, it is possible to build an investment analysis of them. This investment analysis can be reflected in the following subtopics:

Reception

In this sector, many of the pallets are rejected due to the inadequate construction of the pallet, but also the dividers inserted between the products (because they are too large for the stipulated dimensions). Thus, it was suggested a reduction in the size of the dividers to 740x1140 mm, as well as placing them on top of the pallet, in order to difficult the sliding of the product on the pallet (due to transportation of pallets from the factory to the warehouse).

To evaluate the impact on the performance of this suggestion, the following data can be verified:

Table 16-Financial analysis of the implementation of the new card divider, at the reception.

Proposal	Losses (in hours)	Gain (in hours)	% Gain	RECEIVING EFFICIENCY Before	RECEIVING EFFICIENCY After
Non-Slip Paper	173,33	52	70%	3,54	3,76

The receiving efficiency indicator results from dividing the volume by the number of man-hours. Although the reason for pallets being rejected due to dividers is lower than the other reasons, it is possible to verify through the tables that there is an increase in efficiency with the suggested change.

Pallet Dispenser

One of the ergonomic problems that affects productivity in pallet consolidation concerns the manual placement of pallets on the conveyors during manual consolidation in the miniload. Thus, there is no automatic pallet distribution system, and therefore it requires the operator to pick up a pallet manually, which, on average, takes 10s. An investment analysis was performed on this component and the hypothesis of acquiring an automatic pallet dispenser, namely:

Table 17-Investment analysis with implementation of an automatic pallet dispenser.

Proposal	Cost (euros)	Annual Losses (in H)	Annual Gain (in H)	Monetary Gains	Payback (in years)
Pallet Dispenser	5000	14,44	0,347%	101,11	49,45

Based on the results, it can be concluded that the purchase of an automatic dispenser is not worthwhile, given the high number of years until the investment is reached. However, this task is not without ergonomics, and will therefore be an aspect to explore in the future.

Kanban system

As previously explained the methodologies intended to be implemented, the following table presents the results:

Table 18-Net Present Value analysis at the Kanban system level.

Proposal	Cost (euros)	Annual Earnings (in H)	% Gain	Monetary Gains	Net Present Value	Hours
Kanban system with boxes with old layout	80	21,38	50,00%	149,64	679,53	21,38
Kanban system with boxes with new layout	80	33,80	79,05%	236,60	1120,91	8,96

As can be seen with adaptation of the layout to the introduction of the *Kanban* system, it would have a net value increase of 1.65 times over the current layout. The *Kanban* system allow a gain of 33 hours per year, equivalent to 1.5% of the company's working hours per year.

FTE-Full-time equivalent indicator

In addition, an analysis of the picking and receiving sector was performed in terms of the FTE, with the objective of understanding the amount of people allocated to the company's activities, helping to reduce costs and delegate activities without overloading employees.

The analysis of the implementation of an OEE recording system as well as the action plan is quite complicated, since it is something difficult to measure given the range of factors. For a correct maintenance it is necessary to be based on realistic data. To understand the influence of the number and time of breakdowns, the number of employees needed was analyzed

according to the partial reduction of waste. Initially, with a 15% reduction in downtime, then 50% and finally 100%.

Table 19-FTE analysis in the separation zone, with implementation of an action plan.

Separation 2022	Required Operational Time	FT required	Total monthly salaries (minimum)	New Prod. Average	Actual Operating Time	Obs
Currently	36,23	5,07	4500	41,40	8,00	5 Full Time Employees
Reduction 100%	32,31	4,04	3600	46,43	7,13	4 Full Time employees
Reduction 50%	34,16	4,27	3600	43,91	7,57	3 full time employees and 2 part time employees (25 hours per week)
Reduction 15%	35,64	4,46	3975	42,08	7,87	4 full time employees and one 20H weekly part

If it were possible to reduce the down time at AW by 15% (with stacker cranes, or VTD, or banding machines), it would save 11.6% of the costs annually. Appendix R contains the data used for this study.

5. Conclusions and Perspectives for Future Work

In this section, it will be present the conclusions of the work done at the warehouse, as well as the limitations that were encountered and how the results were received by the company. Also, will also be discuss some directions for the future work of the warehouse.

5.1 Summary of the work developed

The general objective of this project covers two main areas, namely the study of indicators, with a central focus on monitoring and control of OEE, and implementation of continuous improvement methodologies. Thus, from the objectives presented (chapter 1), the following were executed:

- The KPI and OEE concept was studied, with subsequent analysis of the viability of the indicators used by the company;
- Recorded and monitored fault times and their error typology;
- Development of tools to control the status of AW components (computer and electromechanical);
- Building a Database and Dashboard;
- Financial and performance analysis of the implementation of a *kanban* system;
- Presentation of new KPI indicators;
- Planned *Kaizen* and 5S implementation activities at AW;
- Standardization of work instructions;
- Mechanical design and project development as part of the acquisition of new workstation.

5.2 Main conclusions and limitations-KPIs

Analyzing indicator values, without really understanding what is behind their numbers, could lead to wrong actions. In this case, they were only looking at AW as a whole and not at the equipment, which can be quite risky. One of the focal points of this work was to understand not only the advantages that OEE measurement has, but also, what its limitations were. OEE can only effectively result in improvement if the loss record is monitored over long periods of time and considering the various standards that exist.

First, a study and measurement of the OEE parameters were performed, in order to evaluate each component and the system as a whole (which was not done before). These two tasks allowed the characterization of the types of errors, thus detecting the root cause of the problems. Furthermore, inconsistencies in the calculation forms of the old database were identified, and a new database was corrected and established. The problems could be summarized as follows: inadequate operator intervention in error correction (by forcing the validation of signaled errors), to obstruction of the sensors (due to rejected pallets), the high presence of *monos* in a warehouse whose daily capacity was at the red line, and finally, the difficulties of maintenance intervention. For the mentioned problems, the operators were sensitized to a correct intervention, the elaboration of an action plan for maintenance and the

development of a database with the necessary information for the collection and study of the OEE indicator.

Secondly, two solutions were developed with the intention of registering and monitoring the faults in the AW, in a more autonomous way and with as little human intervention as possible. However, there was no opportunity (in terms of time and availability of the IT department) for the study and subsequent implementation of the solutions presented. It is important to note that the workers do not perform any record of malfunctions/anomalies that occur during their workdays, although there was an attempt to implement this key task without success, and this situation is due to a high resistance from the supervisors. For this methodology development, the academic knowledge of programming was used, more specifically visual basic, VBA and excel.

Third, the OEE study is insufficient to evaluate any system, so the viability of the KPI indicators used by the company was analyzed, as well as the introduction of other measurable indicators and complementary to the study. Thus, a dashboard was built from scratch both at the level of OEE and the entire logistics department since it is essential to have transparency and visual flow and continuous indicators not only in the direction as well as in the employees. One of the obstacles overcome was to synthesize and organize the extracted data in a uniform way throughout the department, so that they could be optimized in Power Bi in an efficient way and without the aid of auxiliary calculations. Another obstacle to note is the fact that I do not have an academic background in Power Bi, therefore everything I learned and developed was acquired by myself.

Regarding the limitations, it is possible to highlight some of them throughout this project. In fact, this project was started in a very complex period, where a change in the company's management system occurred, which not only interfered with the extracted data (volume fluctuation, speeds, among others) but also in terms of limited availability. In addition, major limitations were imposed on access to the company's software and information systems, thus making it difficult to understand the information available and to evaluate the warehouse status, so one had to depend on others to develop the project. Another limitation was the difficulty in acquiring data from other departments. With the shortage of time, it was not possible to give the project the volume initially expected, but it was possible to reach the bases of what was intended.

All these interventions were based on concepts covered during my academic career, such as asset management (maintenance, OEE, KPI), quality management (Lean, TPM, six sigma), statistical analysis (ANOVA), among others. However, these tools, presented in an academic environment, were always approached in terms of a production line, and not in an automated warehouse. Allied to the fact that there were not many case studies related to the framework of this project, making it difficult to adapt the lessons to the current reality.

5.3 Main conclusions and limitations- Continuous Improvement

Regarding the second area, where the continuous improvement methodologies are reflected in the automated warehouse area.

Firstly, due to the update of the computer system, some equipment had to be changed and were not appropriate for the existing posts. Thus, a study of possible solutions to this problem was conducted, where a prototype was developed from scratch with the specifications requested through a survey of workers. For a correct product selection the AHP methodology was implemented, which allowed, according to the prioritized criteria, to make the best decision.

Secondly, due to the lack of communication and interconnection between shifts, daily *kaizen* was re-established with some modifications (such as the introduction of shift changeover).

The entire implementation process of this tool was monitored and evaluated under audits, with the objective of reaching the established indicators.

Thirdly 5S methodologies were implemented in AW, making the workplace more productive and organized. Allied to 5S, the possibility of implementing the *Kanban* methodology was studied, which allowed a gain of 33 hours per year.

Fourthly, and as previously mentioned, due to the change of system, the work rules were updated and displayed in visible places. It should be noted that this project was always subject to a resistance from the sector's leadership. Thus, it is essential for a project of continuous improvement and implementation of Lean tools, that there is a strong sense of improvement in senior positions and a good management of the change process. Since it is a collaborative project, it is necessary that the management shows interest in the tasks performed, not only because their knowledge about the functioning of the sector is important, but also because there is the need to motivate operators to do what is proposed.

Finally, despite having presented the SMED methodology and having analyzed its possible implementation in the bottleneck, that is, to the operator of the exit conveyor, the conclusion was reached that it would not be possible. This analysis consisted in the analysis of the times of internal and external tasks, since the process under analysis does not have a fixed structure, since it consists in the removal of the pallet from the exit conveyor, labeling and transport to the destination dock, and the distribution center has 10 docks. Anyway, the times were collected and normalized, concluding that it was not feasible to implement SMED in this process.

5.4 Future work perspective

By concluding this project, it is possible to suggest some future work that can be developed by the company. Firstly, the implementation of a control and monitoring system of the status of components, therefore the time and type of breakdowns for the calculation of OEE. Secondly, advancing the design of workstations from prototype to all workstations. Third, implementing *Kaizen* and 5S methodologies throughout the distribution center. Fourth, developing a Dashboard for the entire center and making it visually available to the workers. Fifth, after having started the restructuring of the layout in the automated warehouse, due to the short duration it was not possible to develop as intended, and it is a very important aspect considering the constant lack of space in the warehouse, it is a major internal struggle. Finally, to solve the problem of robotic palletizing, in order to reduce the number of rejected pallets and analysis and improvement of the maintenance department's intervention vis-à-vis the automated warehouse.

In conclusion, not all of the objectives were achieved considering the short duration of the internship as well as some obstacles that arose along the way. However, solutions are presented for later implementation, and it is crucial to keep the mindset focused on continuous improvement.

Bibliography

Ackerman, Phillip L. 2007. "New Developments in Understanding Skilled Performance." *Current Directions in Psychological Science* 16 (5): 235-239. https://doi.org/10.1111/j.1467-8721.2007.00511.x.

Ahuja, I. P. S., and J. S. Khamba. 2008. "Total productive maintenance: literature review and directions." *International Journal of Quality & Reliability Management* 25 (7): 709-756. https://doi.org/10.1108/02656710810890890.

Allen, Theodore T. *Introduction to Engineering Statistics and Lean Sigma*. edited by Springer London.

Alliance, Agile. 2022. "Kanban." Accessed 22/06/2022. https://www.agilealliance.org/glossary/kanban/#q=~(infinite~false~filters~(postType~(~'page~'post~'aa_book~'aa_event_session~'aa_experience_report~'aa_glossary~'aa_research_paper~'aa_video)~tags~(~'kanban))~searchTerm~'~sort~false~sortDirection~'asc~page~1).

Andersson, Roy., Henrik. Eriksson, and Håkan. Torstensson. 2006. "Similarities and differences between TQM, six sigma and lean." *The TQM Magazine* 18 (3): 282-296. https://doi.org/10.1108/09544780610660004.

Araújo, M. M. 2011. "Redução tempos de Setup (SMED)." Accessed 9/06/2022. http://melhoriacontinua.blogs.sapo.pt/19450.html.

Azevedo, Américo Lopes de. 2022. *Apontamentos da unidade curricular Fábricas Inteligentes.* FEUP.

Batista, Bárbara João Traqueia Labrincha. 2017. "Criação de Fluxo numa Indústria de Passamanarias." Mestrado Integrado em Engenharia e Gestão Industrial, FEUP.

Batista, Elisa Maria Tiago. 2016. "Eficácia das Operações Logísticas em Armazém de Produto Acabado." Mestrado Integrado em Engenharia Industrial e Gestão, FEUP.

Brito, Marlene Ferreira. 2019. "Lean manufacturing and ergonomics in the metallurgical industry: an integrated approach for performance improvement." Universidade de Aveiro.

Calandrin, Moisés. 2017. "Problemas envolvendo Teste de Hipóteses e ANOVA Completamente Randomizado (ANOVA One-Way)." Accessed 6/05/2022 14:17. https://www.linkedin.com/pulse/problemas-envolvendo-teste-de-hip%C3%B3teses-e-anova-mois%C3%A9s-calandrin-1/?originalSubdomain=pt.

Carrapatoso, Beatriz Sampaio da Nóvoa. 2017. "Improving Retail Warehouse Operations: a Simulation Approach." Mestrado Integrado em Engenharia e Gestão Industrial.

Castro, Ana Patrícia Barros. 2016. "Implementação de metodologias Lean e desenvolvimento de processos de medição do OEE."

Chang, James I., and Chiu-Lan. Liang. 2009. "Performance evaluation of process safety management systems of paint manufacturing facilities." *Journal of Loss Prevention in the Process Industries* 22 (4): 398-402. https://doi.org/https://doi.org/10.1016/j.jlp.2009.02.004. https://www.sciencedirect.com/science/article/pii/S095042300900014X.

CIN, Tintas. 2022. "Tintas CIN-Prevenção e controlo do impacto ambiental." Accessed 19/06/2022 10:28. https://cin.com/corporate/pt/eco-eficiencia.

Costa, Maria Manuel Fernandes Dias da. 2017. "Otimização das linhas de Enchimento no Setor de Tintas de Base Aquosa." Mestrado Integrado em Engenharia Mecânica, FEUP.

Coutinho, Thiago. 2020. "Aprenda como aplicar a ferramenta SMED na sua empresa." https://www.voitto.com.br/blog/artigo/smed.

Crespo de Carvalho, J., E. B. Dias, A. Martins, J. Menezes, and T. Ramos. 2010. *Logística e Gestão da Cadeia de Abastecimento*.

Daneshkhah, A., N. G. Stocks, and P. Jeffrey. 2017. "Probabilistic sensitivity analysis of optimised preventive maintenance strategies for deteriorating infrastructure assets." *Reliability Engineering & System Safety* 163: 33-45. https://doi.org/https://doi.org/10.1016/j.ress.2017.02.002. https://www.sciencedirect.com/science/article/pii/S0951832017302119.

de Koster, René, Tho Le-Duc, and Kees Jan Roodbergen. 2007. "Design and control of warehouse order picking: A literature review." *European Journal of Operational Research* 182 (2): 481-501. https://doi.org/https://doi.org/10.1016/j.ejor.2006.07.009. https://www.sciencedirect.com/science/article/pii/S0377221706006473.

Dinis, Cláudia. 2016. "A Metodologia 5S e Kaizen Diário." Mestrado em Engenharia Alimentar. http://hdl.handle.net/10400.26/17747.

Doran, George T. 1981. "There's a S.M.A.R.T. way to write managements's goals and objectives." 70.

Faria, José. 2022. *Continuous Improvement- Kaizen.* FEUP.

Faria, José A. 2021. *Introduction to business processes.* FEUP.

Fernandes, Ricardo Joaquim Nunes. 2018. "Otimização de Processos e Procedimentos em Linhas de Produção."

Ferreira de Faria, Adriana, and Danielle Martins. 2017. *Introdução à Engenharia de Produção*.

Fleischer, Jürgen, Udo Weismann, and Stephan Niggeschmidt. 2006. "Calculation and optimisation model for costs and effects of availability relevant service elements."

Gomes, Micael António Ferreira. 2019. "Impacto da filosofia Kaizen no sistema de controlo interno das empresas." ISCAL - Instituto Superior de Contabilidade e Administração de Lisboa http://hdl.handle.net/10400.21/10866.

Grösel, Nils Alves. 2015. "Implementação da metodologia Kaizen Diário numa empresa de elevadores."

Guedes, Alcibíades Paulo. 2021. *Warehousing & Materials Handling.* FEUP.

Hansen, Robert C. 2006. *Eficiência Global dos Equipamentos.Uma Poderosa Ferramenta de Produção Manutenção Para o Aumento dos Lucros*

Hao, Jingjing, Haoming Shi, Victor Shi, and Chenchen Yang. 2020. "Adoption of Automatic Warehousing Systems in Logistics Firms: A Technology–Organization–Environment Framework." *Sustainability* 12 (12): 5185. https://www.mdpi.com/2071-1050/12/12/5185.

Hutt, M.D., and T.W. Speh. 2009. *Business Marketing Management: B2B*. Cengage Learning.

Infraspeak. 2020. "Corrective Maintenance." Accessed 06/05/2022 15:30. https://infraspeak.com/glossary-corrective-maintenance/.

Jaadi, Zakaria. 2019. "Everything you need to know about interpreting correlations." Accessed 08/07/2022. https://towardsdatascience.com/eveything-you-need-to-know-about-interpreting-correlations-2c485841c0b8.

Jonsson, Patrik, and Magnus Lesshammar. 1999. "Evaluation and improvement of manufacturing performance measurement systems - the role of OEE." *International Journal of Operations & Production Management* 19 (1): 55-78. https://doi.org/10.1108/01443579910244223.

Klaess, John. 2021. "OEE vs. OPE – Toward a Holistic Understanding of Your Machine Data." Accessed 02/07/2022. https://tulip.co/blog/oee-vs-ope-toward-a-holistic-understanding-of-your-machine-data/.

Leitão, Armando Luís Ferreira. 2021. *Course notes Asset Management.* FEUP.

Liker, Jeffrey, and James Morgan. 2006. "The Toyota Way in Services: The Case of Lean Product Development." *Academy of Management Perspectives* 20. https://doi.org/10.5465/AMP.2006.20591002.

Macedo, Paula. 2018. *Relatório e Contas 2018- CIN*.

Mecalux. 2021. "Como aplicar o ciclo de Deming (PDCA) na logística?". Accessed 7/05/2022 8:50. https://www.mecalux.pt/blog/ciclo-deming-pdca-logistica.

Michlowicz, Edward. 2013. "Logistics in production processes." *Journal of Machine Engineering* 13.

Miyake, Dario, and Christianne Busso. 2013. "Análise da aplicação de indicadores alternativos ao Overall Equipment Effectiveness (OEE) na gestão do desempenho global de uma fábrica." *Produção* 23: 205-225. https://doi.org/10.1590/S0103-65132012005000068.

Neto, Ismael Diogo Pereira Moutinho. 2015. "Projeto de Melhoria do Processo de Abastecimento de matérias-primas à Produção - MIZUSUMASHI." Departamento de Economia, Gestão e Engenharia Industrial, Universidade de Aveiro.

Nóvoa, Henriqueta. 2021. *Quality Management* FEUP.

Oakland, John S. 2018. *Statistical Process Control*. edited by 7th Edition.

OEE. 2021. "SIX BIG LOSSES." Accessed 07/05/2022 9:00. https://www.oee.com/oee-six-big-losses/.

Oliveira, Fernanda. 2022.

Oliveira;, Andressa Fagundes de, Eduardo Gonçalves Magnani;, and Geraldo Magela Pereira da Silva. *Aumento da Eficiência Global do Equipamento (OEE) Através da Identificação e Tratamento de Problemas Crônicos: Um Estudo de Caso Realizado em uma Indústria de Refratários.*

Paar, Anton. 2020. "Controle de qualidade e pesquisa na indústria de tintas e revestimentos." https://www.anton-paar.com/br-pt/viscosimetria-e-reometria/tintas-e-revestimentos-controle-de-qualidade-e-pesquisa/.

Pereira, Ana Isabel de Sá Couto. 2015. "Reorganização do armazém e gestão de stocks das matérias-primas."

Pintura, Tintas &. 2018. "A Tinta e o seu processo fabrico ". Accessed 09/06/2022. https://tintasepintura.pt/o-que-e-uma-tinta/.

Pintura, Tintas e. 2020. "Tipos de Tintas e suas Finalidades." Accessed 05/05/2022. https://tintasepintura.pt/escolher-a-tinta-certa/.

Professionals, Council of Supply Chain Management. 2022. "CSCMP Supply Chain Management Definitions and Glossary." https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx.

Pronaci. 2002. *Ficha Técnica PRONACI: Logística*. Edited by AEP.

Rehkopf, Max. "What is a kanban board?". Accessed 22/06/2022 10:12. https://www.atlassian.com/agile/kanban/boards.

Reis, Pedro Miguel Gonçalves dos. 2006. "OEE System & Milk Run - PCBA ". https://repositorio-aberto.up.pt/handle/10216/58737.

Richards, G. 2011. *Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse*. Kogan Page.

Rodrigues, Carolina Oliveira. 2021. "Atualização Processual e Tecnológica de um Armazém Automático." Universidade do Minho.

Saaty, T.L. *Fundamentals of Decision Making and Priority Theory With the Analytic Hierarchy Process*. RWS Publications.

Santos, Carlos Alberto Teixeira dos. 2017. "Implementação de ferramentas de gestão num armazém de consumíveis." FEUP.

Silva, José Pedro Amorim Rodrigues da. 2013. "OEE – THE WAY TO MEASURE EQUIPMENT EFFECTIVENESS."

Solutions, ACCEPT Quality Control. 2019. "OEE: O QUE É E COMO CALCULAR?". Accessed 07/05/2022 17:02. https://www.accept.pt/oee-o-que-e-e-como-calcular-2/.

ULMA. 2022.

UpFlip. 2021. "KAIZEN: Change Your Business and Create Success (with Paul Akers) Pt. 1." Accessed 30/6/2022. https://www.youtube.com/watch?v=Zah9panf7ag.

Vale, Mariana Azenha de Sousa. 2020. "Aplicação da ferramenta ErgoSafeCI numa empresa de embalagens de plástico." Mestrado em Engenharia e Gestão Industrial, ISEP.

Viana, Ana Luísa Cunha. 2017. "Implementação de Ferramentas de Melhoria no Armazém de Produto Acabado de uma Indústria de Cortiça." FEUP.

Werkema, Maria Cristina Catarino. 1995. "Ferramentas estatísticas básicas para o gerenciamento de processos / Total quality management."

Womack, James, and Daniel Jones. 1996. *Lean Thinking : Banish Waste and Create Wealth in Your Corporation*. Vol. 48.

Zohra, Fatema Tuz. 2019. "Why Use Swim-lane Diagram?". Accessed 03/07/2022 21:50. https://www.linkedin.com/pulse/why-use-swim-lane-diagram-fatema-tuz-zohra/.

Appendix A: Similarities and differences between TQM, Six Sigma, and Lean

Table 20-Similarities and differences Between the famous method: TQM, Six Sigma, and Lean (Andersson, Eriksson, and Torstensson 2006).

Concepts	TQM	Six Sigma	Lean
Origin	The quality evolution in Japan	The quality evolution in Japan and Motorola	The quality evolution in Japan and Toyota
Theory **Process view** **Approach** **Methodologies**	Focus on customers Improve and uniform processes Let everybody be committed Plan,do,study,act	No defects Reduce variation and improve processes Project management Define, measure, analyze, improve (for design), control(or verify)	Remove waste Improve flow in processes Project management Understanding customer value, value stream, analysis, flow, pull, perfection
Tools **Primary effects** **Secondary effects** **Criticism**	Analytical and statistical tools Increase customer satisfaction Achieves customer loyalty and improves performance No tangible improvements, resource-demanding, the unclear notion	Advanced business goals and improves financial performance Does not involve everybody, does not improve customer satisfaction, and does not have a system view.	Analytical tools Reduce lead time Reduces inventory, increases productivity and customer satisfaction Reduce flexibility, causes congestion in the supply chain, not applicable in all industries

Appendix B: Kaizen Change Management

Table 21-Instructions for creating a team framework according to the kaizen methodology (Grösel 2015).

Colour	Objective	Elements	Description
Red	Meeting Discipline	Meeting agenda; Attendance map; *Kamishibai*	The meeting agenda requires that there be a specific time to gather the team and discuss a certain sequence of topics with a certain duration. The attendance map reflects the attendance and punctuality of the meeting participants; The *Kamishibai* is an element that indicates whether the information on the board is up to date, through the exposed side.
Green	Team Objectives	Indicators.	The indicators represent the team's performance, so they must be analyzed as often as they are updated.
Yellow	Improvement Projects	Improvement Groups; PDCA.	The improvement groups show which of the employees of a team are integrated in improvement groups led internally and externally by the same.
Blue	Suport	Work Plan; Train Plan; Norms.	The remaining elements are the structure that supports the team in achieving its goals and developing its improvement projects. The format of the work plan varies according to the type of team and the type of tasks allocated to it;



Figure 45-Example of a kaizen framework typology (Grösel 2015).

Appendix C: Key Performance Indicators Improve Industrial Performance

Table 22-Examples of the most suitable indicators according to the intended sector (Rodrigues 2021).

SECTION	INDICATORS
RAW MATERIALS	-Raw Material Input / Raw Material Produced -Emission / Raw Material Produced -Waste Deposit / Raw Material Produced
OPERATION	-OEE- Overall Equipment Effectiveness -% of the scheduled operation time over a period of time -% of the actual activity time in relation to the scheduled time over a period of time -% of the production rate in relation to the maximum rate for the type of product produced during a period of time -% of products of full quality in relation to production , over a period of time
PERFORMANCE MONITORING	-Number of control cycles in manual mode/ Total number of control cycles -Variation of the control error (setpoint - measured value) -Settling time after a change of setpoint
MAINTENANCE	-Maintenance Costs / What is produced over a period of time -Maintenance Time / What is produced over a period of time -Number of alarms over a period of time
PLANNING	-Integrated sum of only positive values of (planned production -actual production) over a period of time
INVENTORY USAGE AND BUFFERING	-Throughput/average inventory; -Buffer level variation; -Time portion of the buffer level is >95% or <5% over a period of time.
EQUIPMENT	-Different types of efficiency -Equipment wear and tear -Vibration amplitude of equipment -Measurement- Predicted performance.

Appendix D: Common manufacturing losses and consequences

Table 23- Examples of loss occurrences and consequences (Silva 2013).

Losses	Occurrences	Consequences	Observations
1)Faults	-Mechanical, electrical, or other system malfunctions that cause the interruption of production. -General equipment failure. -Unplanned stoppages for maintenance interventions. -Power/utility failures.	Reduce the time available for the equipment to produce or operate	Stops longer than 5-10 minutes, recorded by the operator or automatically
2)Changing, adjusting, and other stops	-Product change. -Warming up/cooling down for tool change. -Replacing wear tools. -Stopping for cleaning. -Material and Operator shortage.		Change losses are reduced or eliminated by implementing SMED techniques.
3)Short stops	-Cleaning and minor adjustments. -Obstruction in upstream or downstream product flow. -Failure in material feed; -Replacement of wear tools by the operator. -Parameter checking/regulation.	They affect the efficiency of the equipment, not allowing it to run at the normal cycle time.	Stops of less than 5-10 minutes and requiring no intervention by maintenance personnel, usually not recorded by the operator.
4) Speed reduction	-Functioning below the specified speed; -Irregular operation; -Inability of the operator to ensure regular operation.		All occurrences that make it impossible to produce at the maximum speed specified for the product.
5)Defects and rework	-Out-of-specification product. -Incorrect assembly and/or component. -Lack of components.	Reduce the amount of product that meets specifications the first time	Product rejected during normal operation of the equipment.
6) Startup losses	- Scrap; -Out-of-specification product.		Product rejected during startup or shutdown.

Appendix E: Strategies for eliminating the Six Big Losses

Table 24-Solutions to eliminate waste (Silva 2013).

Losses	Elimination/Reduction Strategies	Prevention Strategies	Applicable Tools
1-Breakdowns	- Repair quickly and effectively; - Detect and correct the causes of malfunctions.	- Preventive maintenance; - Predictive maintenance; - Autonomous maintenance; - RCM- Reliability-centric maintenance.	-5S; -FTA – Fault Tree Analysis; -Ishikawa Diagram.
2-Changing, tuning and other stops	- Reduce changeover time.	- Design or change equipment incorporating SMED techniques; - Single-product equipment (no need for change)	-SMED; -Poka-Yoke; -Visual Systems; - Standardized Work.
3-Small stops	- Elimination of small stops.	- RCM- Maintenance focused on reliability; - Automation; - Autonomation; - Modify equipment for continuous power.	-5S; -FTA- Fault Tree Analysis; *-Kaizen*; -Ishikawa Diagram; -Pareto Diagram.
4-Speed reduction	- Balancing production lines.	- Reliability engineering.	-5S; -FTA – Fault Tree Analysis. *-Kaizen*
5- Defects and rework	- Detect and correct the causes of quality problems.	- Quality maintenance; - Preventive actions; - Automation.	-Six-sigma; *-Kaizen*; -Poka-Yoke.
6- Startup losses	- Detect and correct the causes of losses.	- Study and implement the ideal starting conditions; - Modify equipment and tools.	-SMED; -Formation and training; *-Kaizen*.

Appendix F: Alternative OEE Indicators

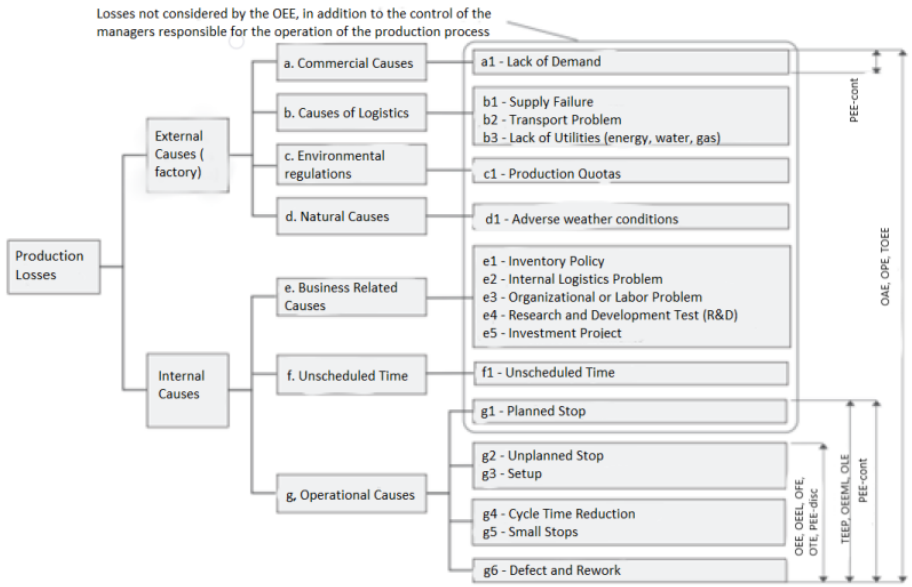


Figure 46-Classification of production losses to evaluate manufacturing performance (Adapted from Miyake and Busso (2013).

Table 25-Comparison of indicators vis-à-vis dimensions and characteristics of a global performance measurement system (Adapted from Miyake and Busso (2013)).

		OEE	OEEL	OTE and OFE	OEEML and OLE	TEEP	PEE-disc	PEE-cont	TOEE	OPE e OAE
Dimensions	Strategy	It works when linked to an improvement program.						It reflects some strategy regarding demand.	It may reflect strategies regarding demand, R&D, environment and other factors.	
	Flow Orientation	It does not consider.	Reflects manufacturing-level flow conditions.			It does not consider.		It captures the influence of support areas in the manufacturing flow.		
	Internal Efficiency	It does not always allow comparison.						Offers more possibilities for comparison.		
	External Effectiveness		It does not consider.					It can capture when the lack of demand is related to the level of customer satisfaction.		
Characteristics	Improvement Driver	It contributes as long as it is systematically used by the organization as a tool for the continuous improvement process.								
	Simple and Dynamic	It simplifies measurement, but needs to be complemented with other measurements.	It may require review if there is a change in the layout of the equipment and makes the measurement more complex. It needs to be complemented with other measurements.			Simplifies measurement. Requires data consolidation. It needs to be complemented with other measurements.		Simplifies measurement.		Simplifies measurement. Requires greater data consolidation.

Appendix G: Distribution Center and Automated Warehouse Layout

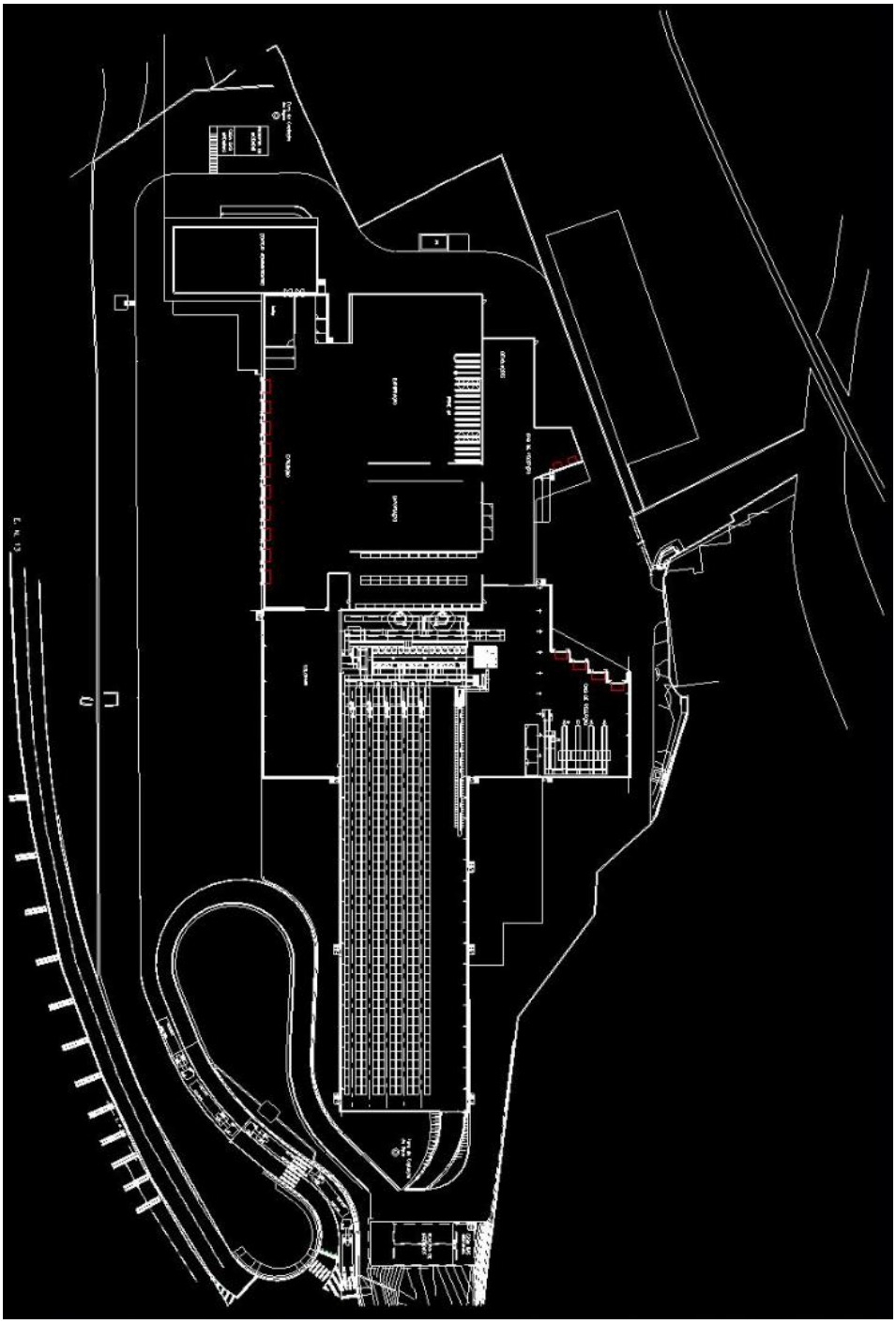


Figure 47-Illustration of the distribution center layout.

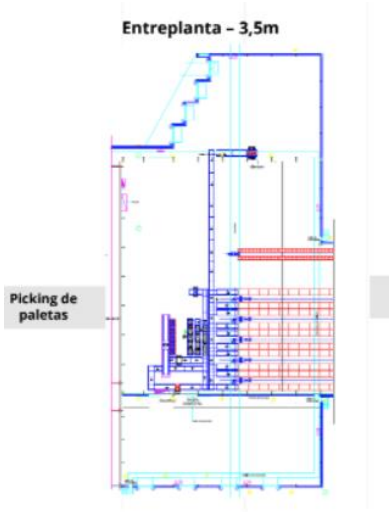


Figure 48-Illustration of the AW layout on the upper floor (ULMA 2022).

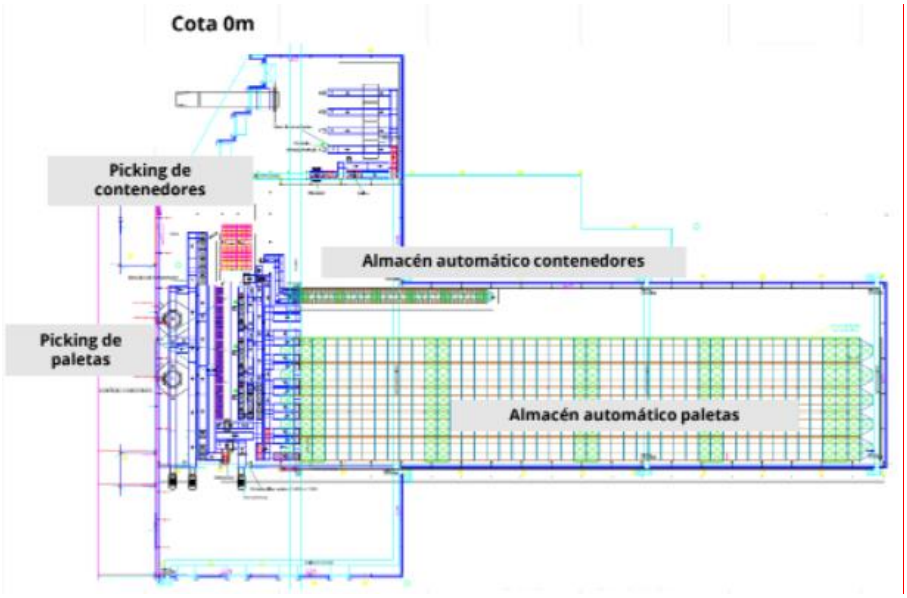


Figure 49-Layout Illustration of the AW on the lower floor (ULMA 2022).

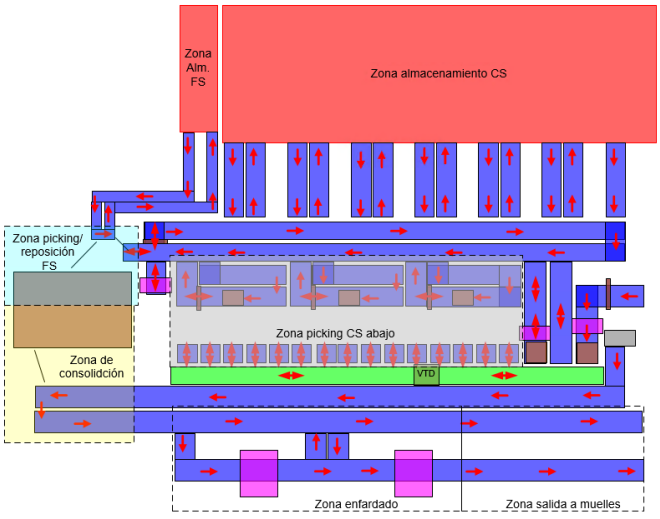


Figure 50-The sequence of pallet movements on the conveyors in the automated warehouse (ULMA 2022).

Appendix H: ANOVA Study

WORKSHEET 5

One-way ANOVA: Prod TD; Prod TN

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0,05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Factor	2	Prod TD; Prod TN

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0,584	0,5836	0,04	0,840
Error	34	478,365	14,0695		
Total	35	478,948			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3,75094	0,12%	0,00%	0,00%

Means

Factor	N	Mean	StDev	95% CI
Prod TD	18	41,470	1,151	(39,673; 43,267)
Prod TN	18	41,72	5,18	(39,93; 43,52)

Pooled StDev = 3,75094

Figure 51-ANOVA Study.

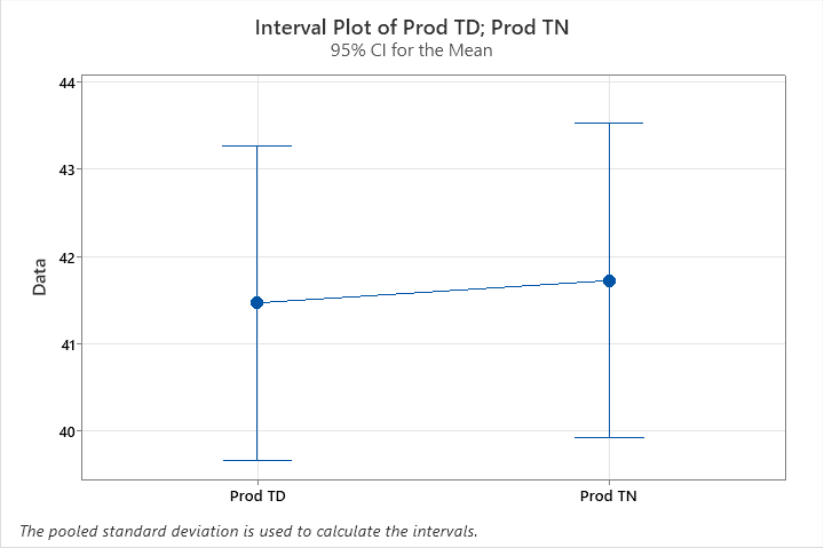


Figure 52- ANOVA Study

Appendix I: OEE

Armazém Automático

Semana	Tempo - min	Ocorrência nos Transelevadores														Resets						VTDs		Avaria	Paragem programad	Nível do armazém	Turno	Observações
		Transelevador						Horquilla		Perfil Carga						Zonas						Local						
										HP			L															
		1	2	3	4	5	ML	HP	L	E	P	S	E	P	S	Viga não detectada	Outro	Geral	1	2	3	4	ML	Piso Inf.	Piso Sup.					
41	3			X				X																			TD	
41	6	X								X																	TD	15 LT
41	50			X																					X		TD	
41	65						X																		X		TD	
41	70			X																					X		TD	
41	25						X																		X		TD	
41	40				X																				X		TD	
41	60					X																			X		TD	
41	3			X					X																		TD	

Figure 53- Copy of the database used to collect breakdown data in the automatic storage.

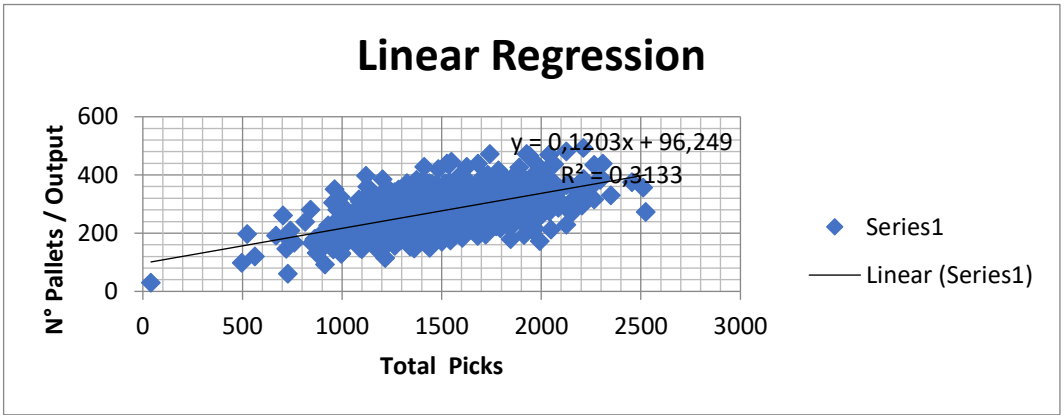


Figure 54-Linear approximation of the number of picks and number of pallets extracted from the warehouse.

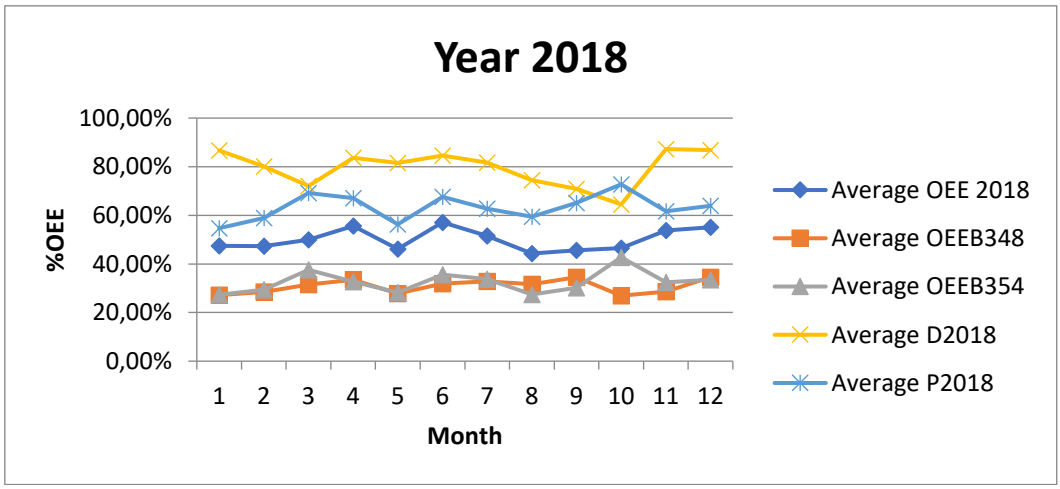


Figure 55-Analysis of the global OEE and wholesale fully automatic during 2018.

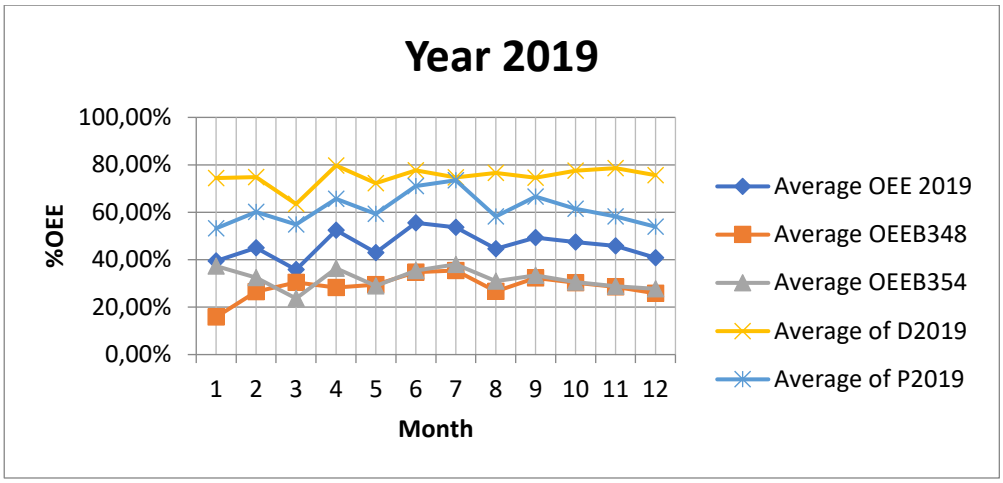


Figure 56-Analysis of the global OEE and wholesale fully automatic during 2019.

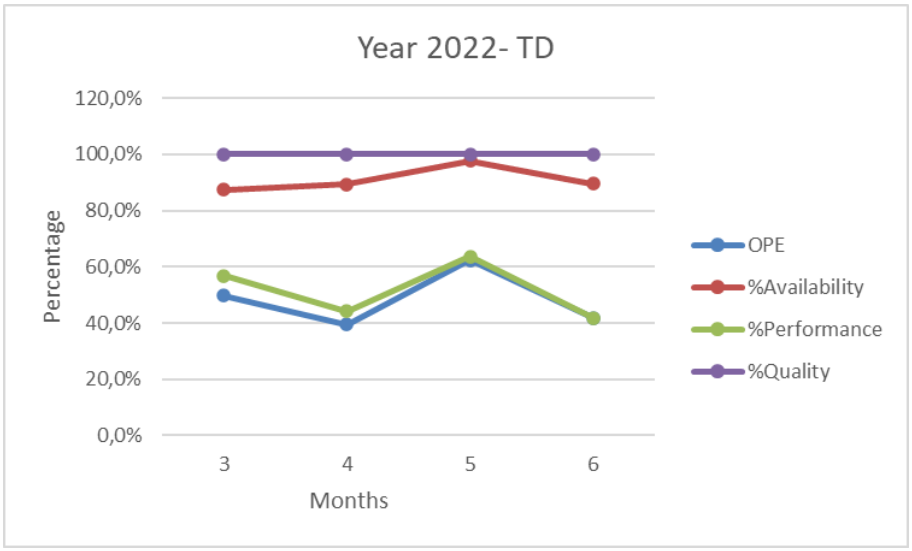


Figure 57-Analysis of performance, quality and availability in 2022, on the shift TD.

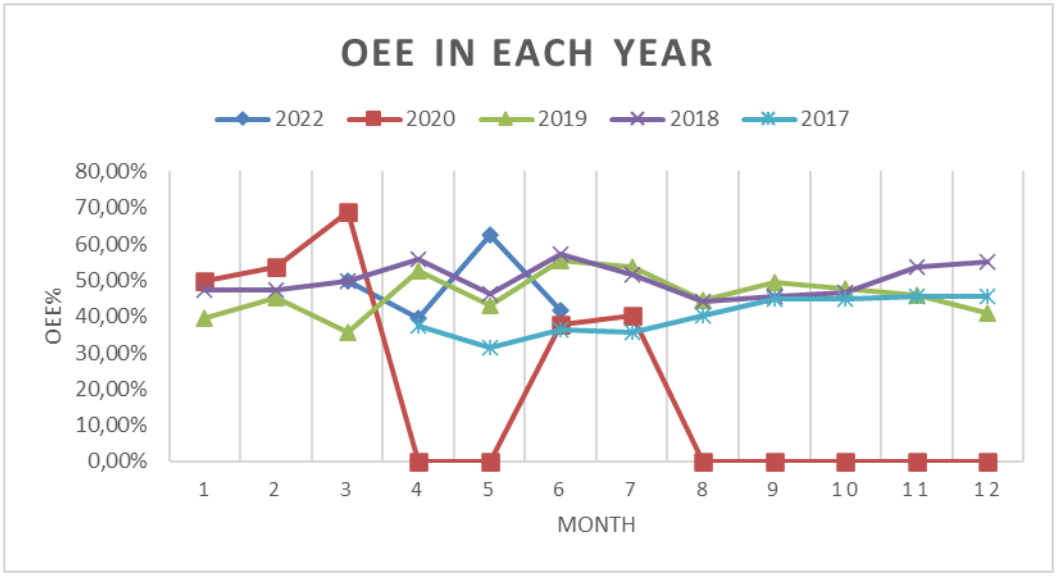


Figure 58-Global OEE analysis from 2017 to 2022.

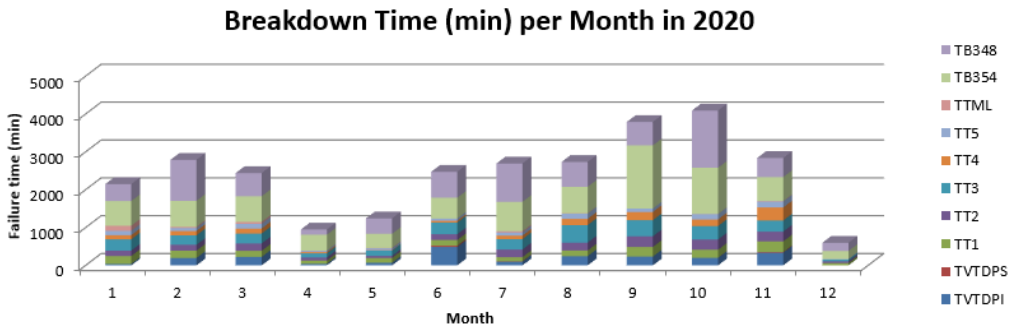


Figure 59- Breakdown times of each component compared to each month, in 2020.

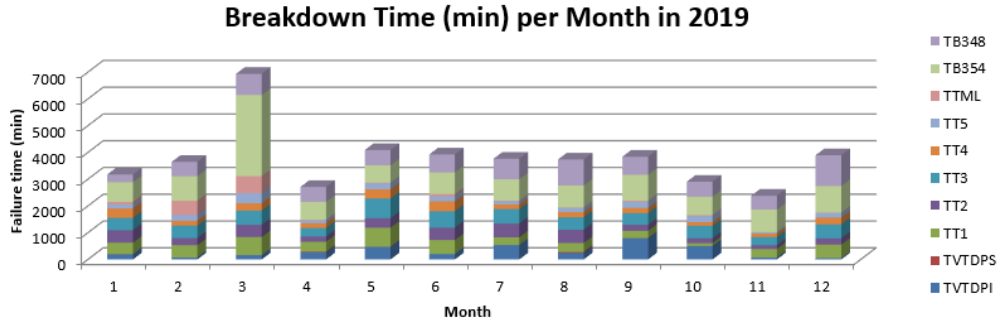


Figure 60-Breakdown times of each component compared to each month, in 2019.

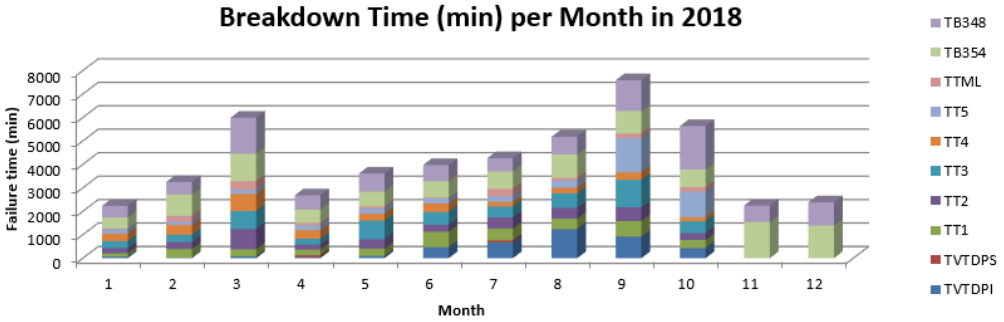


Figure 61-Breakdown times of each component compared to each month, in 2018.

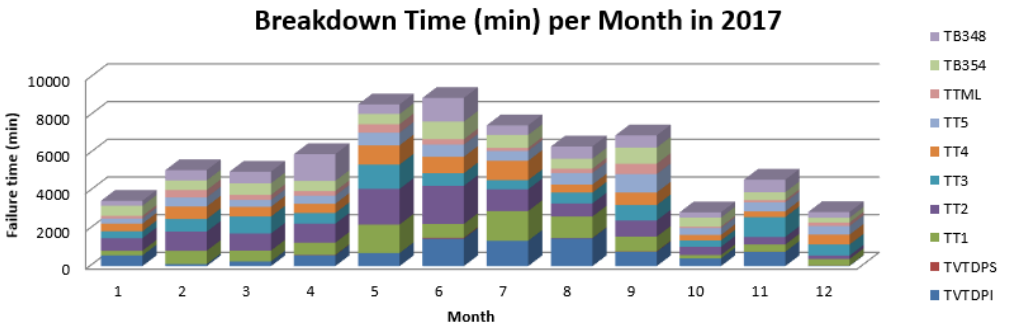


Figure 62-Breakdown times of each component compared to each month, in 2017.

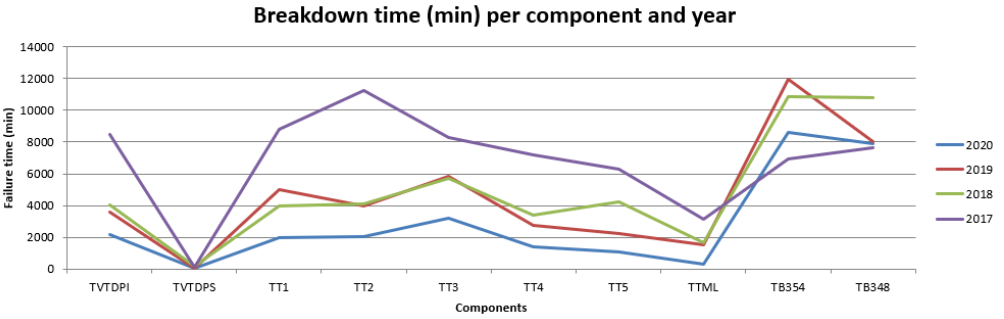


Figure 63-Breakdown times of each component during 2017-2020.

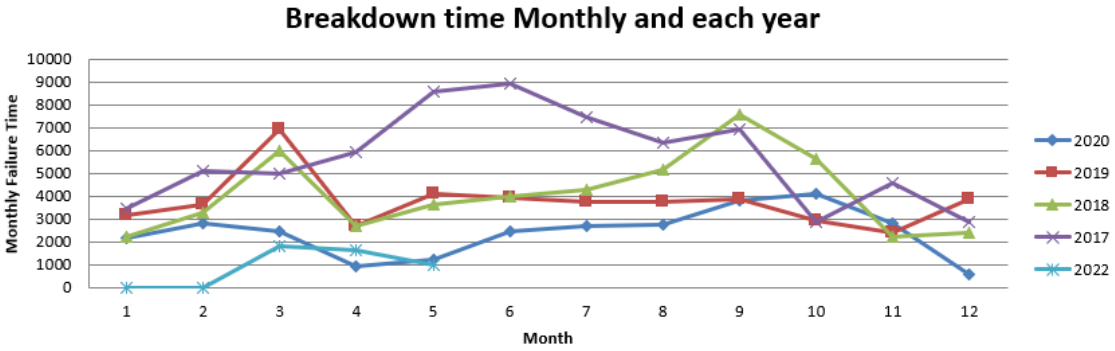


Figure 64- Breakdown time monthly and each year.

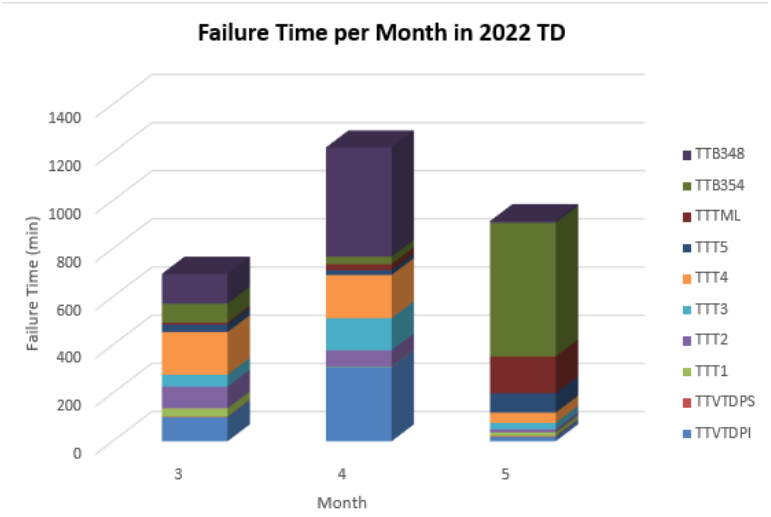


Figure 65- Failure Time per month in 2022, during the first shift.



Figure 66- Dashboard developed for the study of OEE in the automatic warehouse.

Appendix J: Identified Problem and its Solution



Figure 67-The disorganization and dirtiness of each post, it would be necessary to use boxes and labels adequate to the real needs



Figure 68-The problem corresponds to the lack of space for essential tools and a poorly ergonomic post. The solution consisted of acquiring a pilot station.

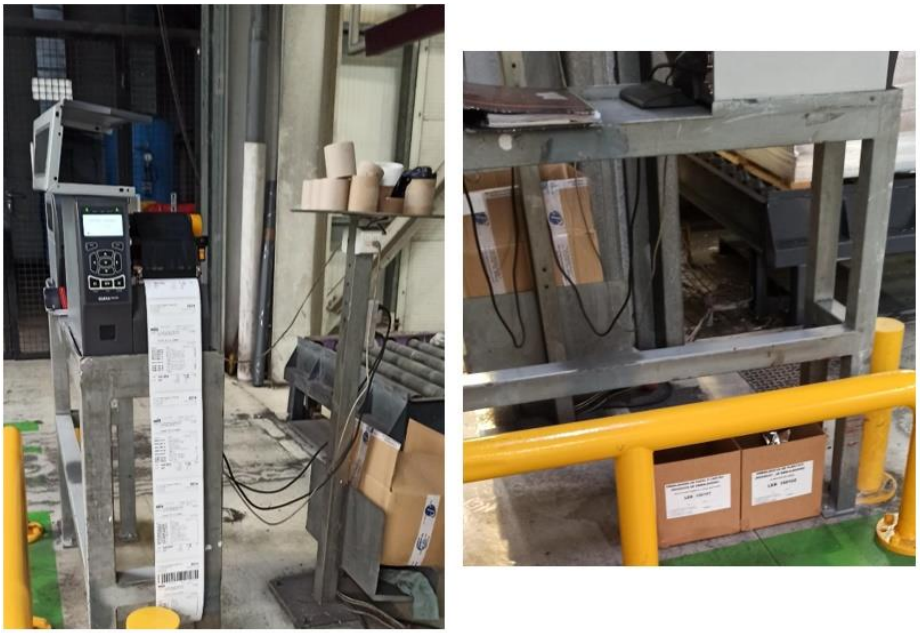


Figure 69-The problem concerns the accumulation of leftover materials, which had no place to store. The solution consists of developing a specific area for material recycling.

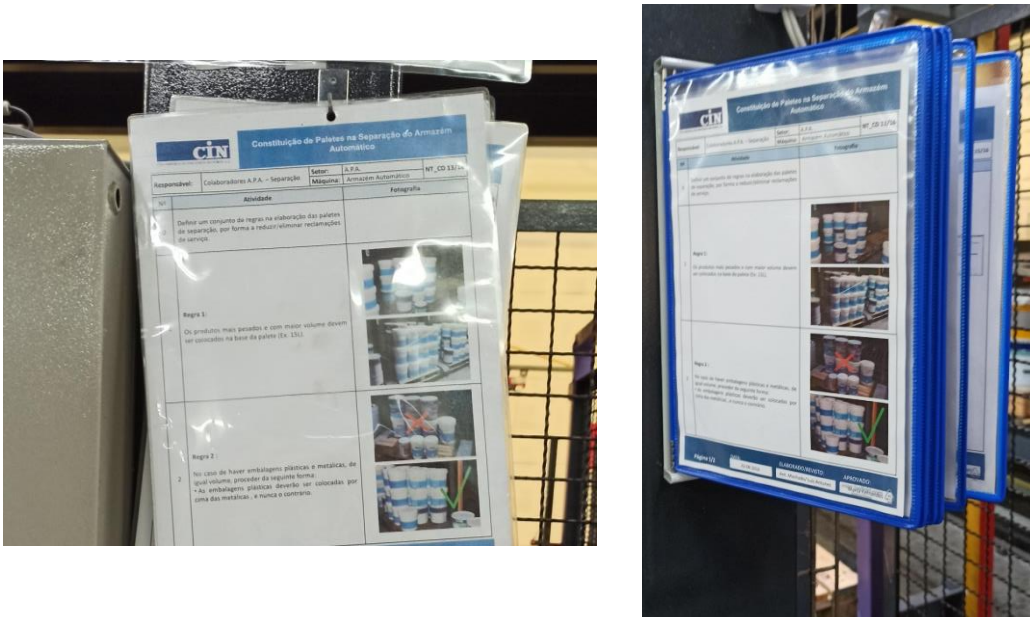


Figure 70-The problem is that the standards are not accessible in the workplace and are outdated. The solution consists of updating all standards and making them available in a visible and easily accessible location.



Figure 71-The problem is related to poorly visible instructions for manual control of the VTD. The solution is to make the instructions easy and intuitive for those who use it.



Figure 72-Daily Kaizen old board

Appendix K: Computer Registration in VTD

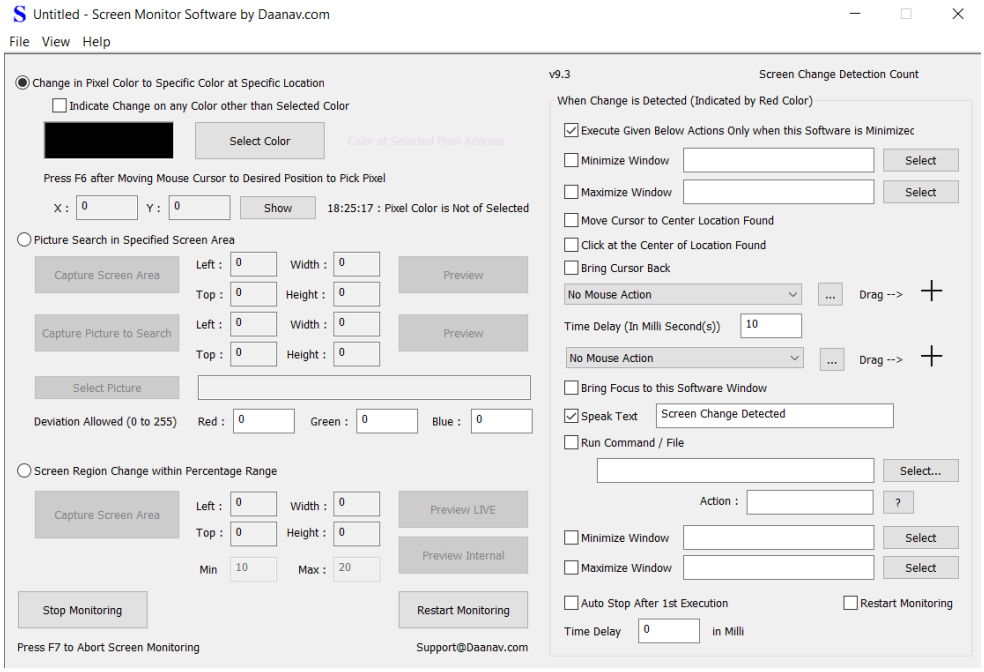


Figure 73- Programs to control VTD status.

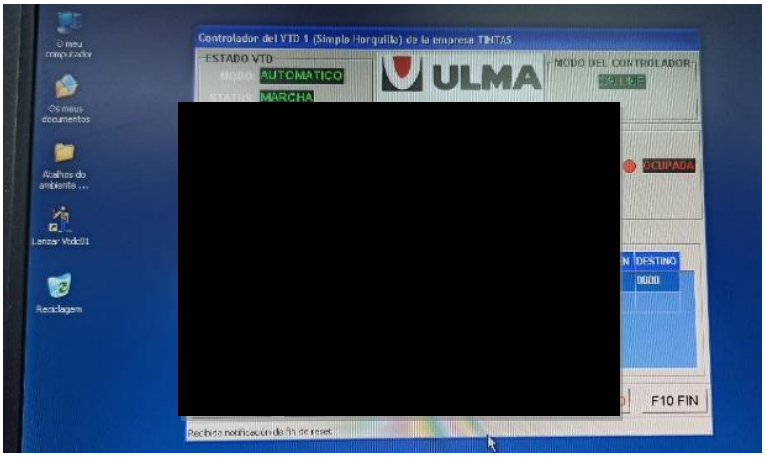


Figure 74-VTD monitor with the automatic warehouse computer system.

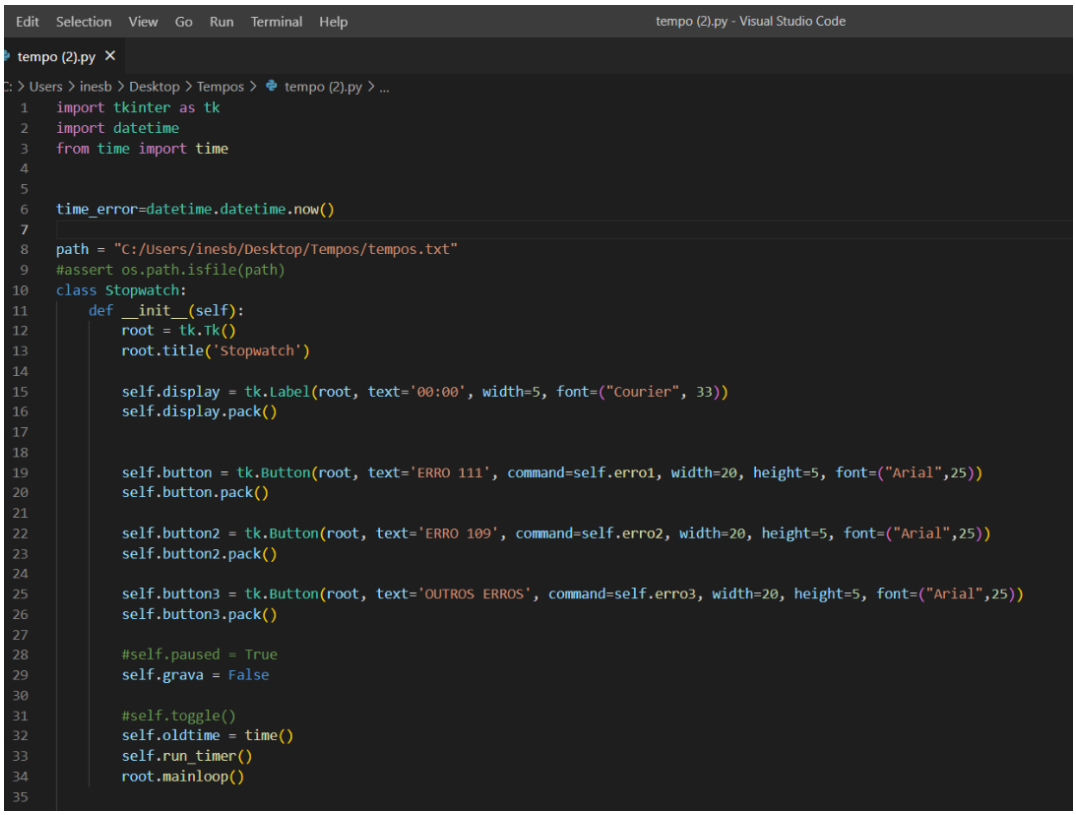


Figure 75- Code used to store information regarding VTD malfunctions- part one.

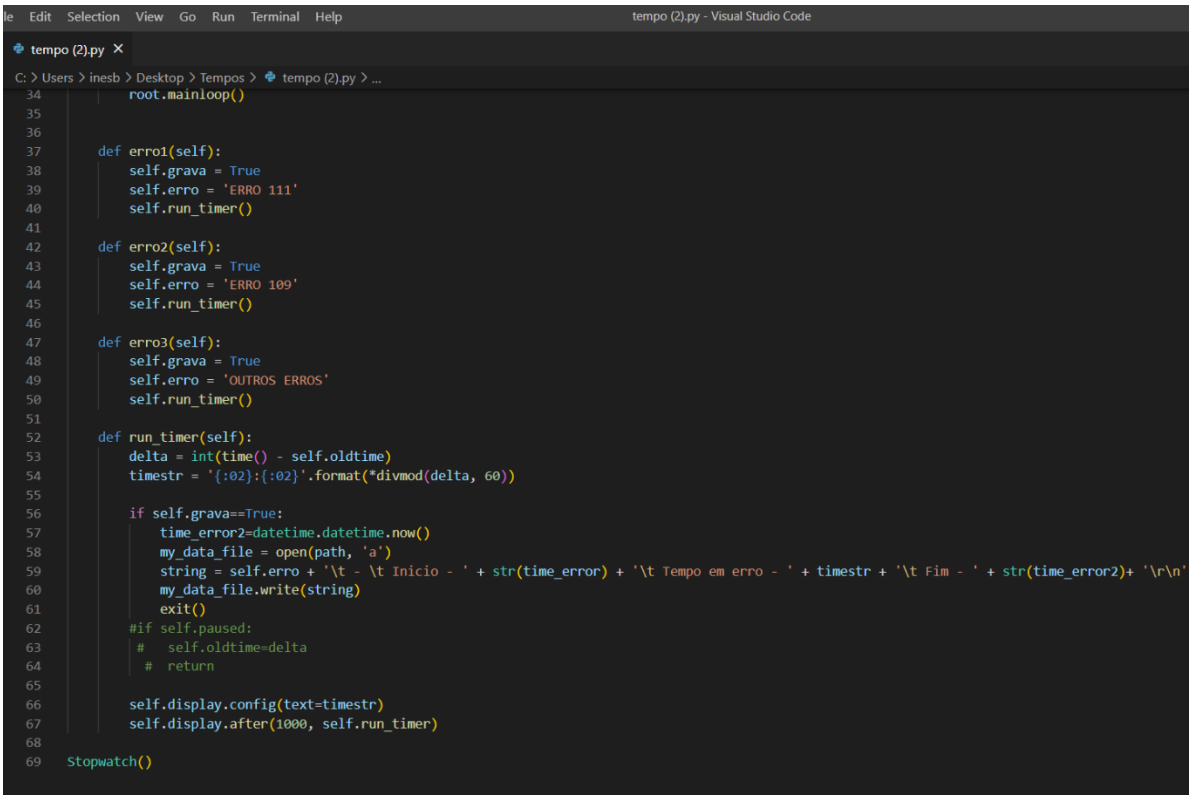


Figure 76-Code used to store information regarding VTD malfunctions- part two.

Appendix L: Computer Registration in Stacker Crane



Figure 77-Reader used to read the errors of the stacker crane.

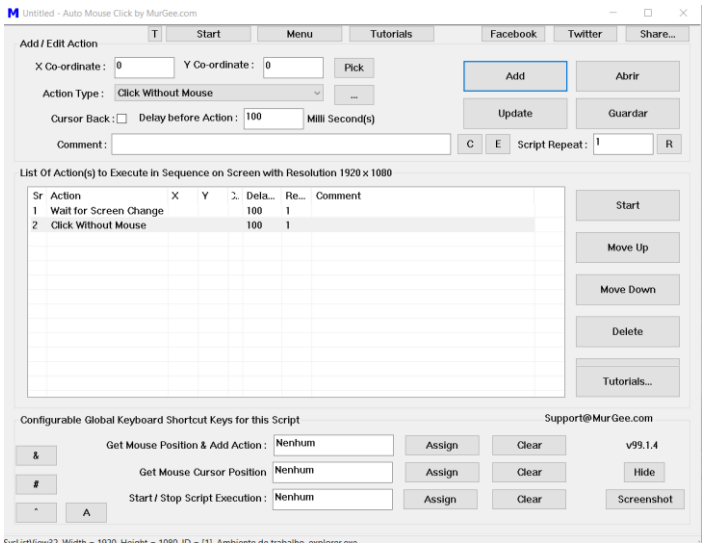


Figure 78- Program used to control the status of automatic warehouse components.

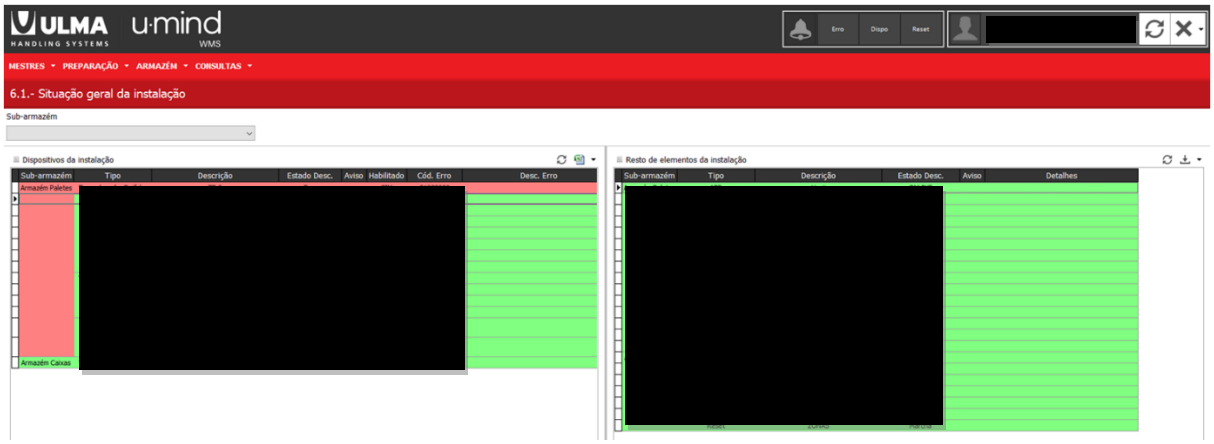


Figure 79- Automatic warehouse computer system with "Dispo" tab.

Appendix M: Maintenance Action Plan

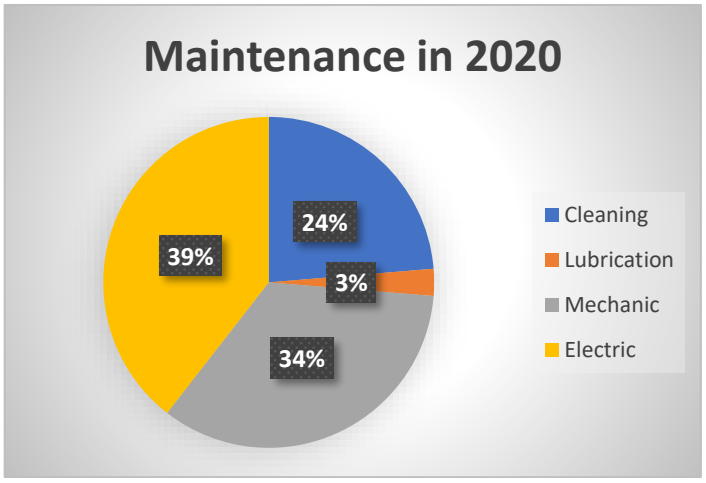


Figure 80-Percentage of the reasons for the intervention of corrective and conditioned maintenance in 2020.

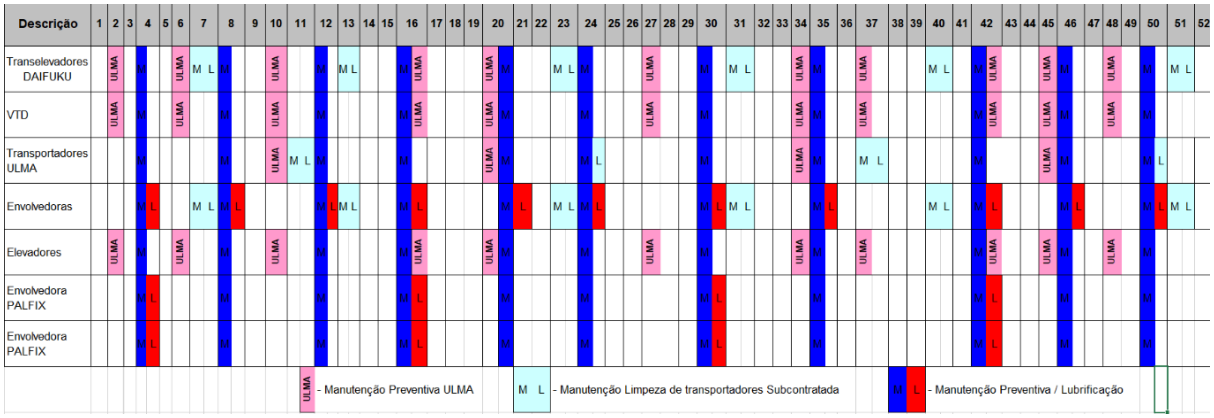


Figure 81-Suggested action plan to improve maintenance intervention in AW.

Appendix N: WorkStation for separation in AW and AHP Methodology



Figure 82- Pilot workstation acquired based on the study of this project.

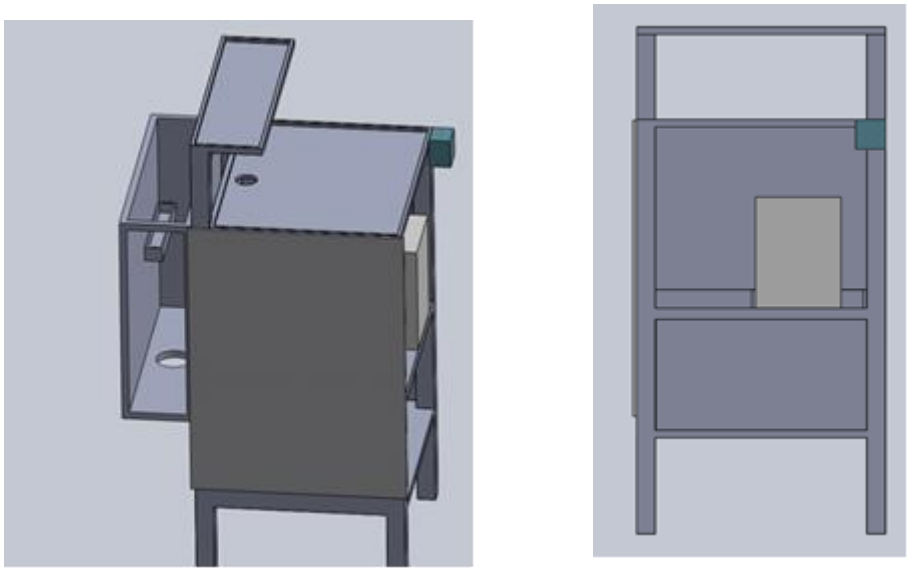


Figure 83- Mechanical drawing of the workstation idealized for the separation stations, in SolidWorks.

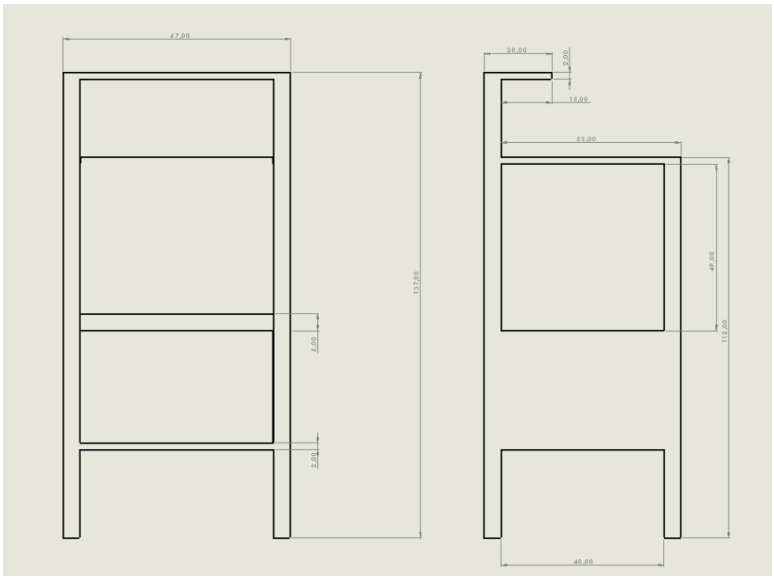


Figure 84-Measurements of the mechanical design of the workstation, in SolidWorks.

Foco Principal	CR1	CR2	CR3	CR4	CR5	PML´s
CR1	1,00	1,00	3,00	4,00	5,00	
CR2	1,00	1,00	3,00	4,00	4,00	
CR3	0,33	0,33	1,00	3,00	4,00	
CR4	0,25	0,25	0,33	1,00	3,00	
CR5	0,20	0,25	0,25	0,33	1,00	
Total	**2,78**	**2,83**	**7,58**	**12,33**	**17,00**	

Foco Principal	CR1	CR2	CR3	CR4	CR5	Criteria Weights
CR1	0,3593	0,3529	0,3956	0,324	0,2941	0,3452538
CR2	0,36	0,3529	0,3956	0,324	0,2353	0,33348909
CR3	0,12	0,12	0,1319	0,243	0,2353	0,16956261
CR4	0,09	0,09	0,04	0,08	0,18	0,09591267
CR5	0,07	0,09	0,03	0,03	0,06	0,05578183
Total	**2,78**	**2,83**	**7,58**	**12,33**	**17,00**	**1**

	0,345253796	0,3335	0,1696	0,096	0,0558			
Main Focus	**CR1**	**CR2**	**CR3**	**CR4**	**CR5**	**Weighted Sum Value**	**Criteria Weights**	**Indicator**
CR1	0,345253796	0,3335	0,5087	0,384	0,2789	1,849990569	0,3452538	5,358349683
CR2	0,345253796	0,3335	0,5087	0,384	0,2231	1,794208735	0,33348909	5,380112236
CR3	0,115084599	0,1112	0,1696	0,288	0,2231	0,906675592	0,16956261	5,347143526
CR4	0,086313449	0,0834	0,0565	0,096	0,1673	0,489464766	0,09591267	5,103233485
CR5	0,069050759	0,0834	0,0424	0,032	0,0558	0,282566409	0,05578183	5,065563238
Total	**0,96**	**0,94**	**1,29**	**1,18**	**0,95**	**5,32290607**		
	λmax=	5,2509				RI (tabelado)=	1,12	
	CI=	0,0627						
	CR=	0,056	<0,1					

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

(iv) Cálculo do índice de consistência (*IC*), através da expressão:

$$IC = \frac{\lambda_{max} - n}{n-1} = \frac{5.05-5}{4} = 0.0125$$

(v) Cálculo da Razão de Consistência (*RC*) através da expressão: $RC = \frac{IC}{IR} = \frac{0.0125}{1.12} = 0.011$

Figure 85-Auxiliary Calculations in the AHP Methodology for Worktable.

Appendix O: Daily Kaizen

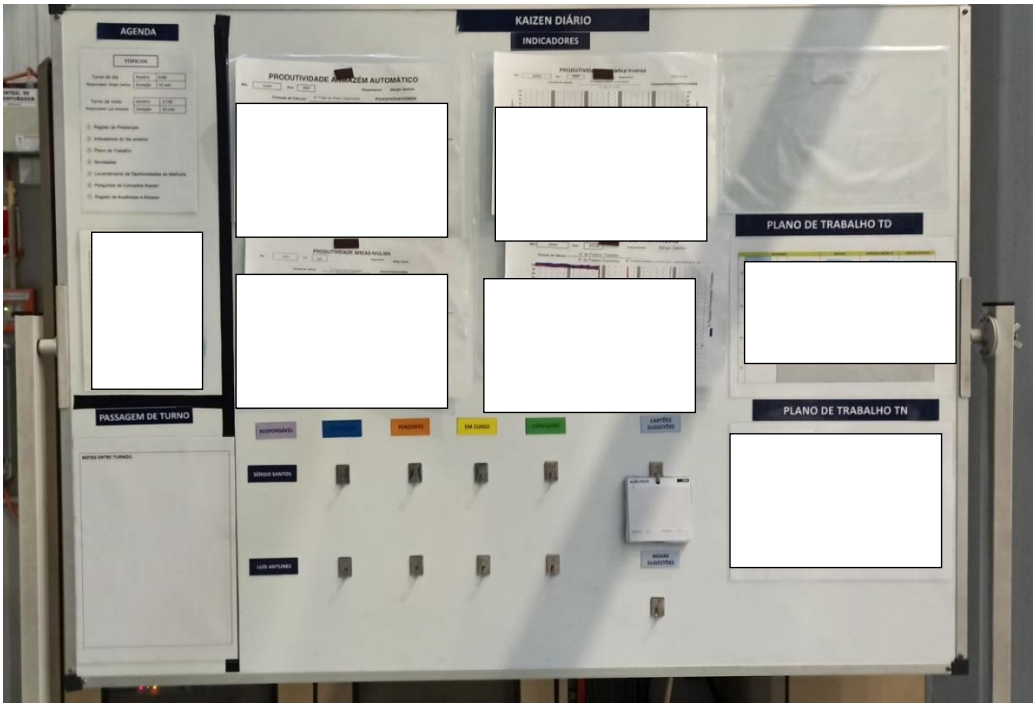


Figure 86- Daily Kaizen in automated warehouse.

		Auditor	Inês Barros Canedo	
		Line/Area	AA- Separação, Receção e Logística Inversa	
			Minimum grade for approval: 75%	
		Date	02/06/2022	
	Nº	**Checked Item**	**Evaluation Criteria**	**Nota (0/1)**
Schedule	1	Schedule	The selected employee knows how to explain the meeting agenda and the role of each participant in the meeting	1
	2	Schedule	Is the sequence of the meeting in accordance with the agenda?	0
	3	Schedule	Does the agenda include the analysis of the indicators and review of the work plan?	1
	4	Schedule	Does the team start on time?	1
	5	Schedule	Is the team able to meet the allotted time?	1
	6	Schedule	Does the team meet as often as defined?	0
Team	7	Presences	The chart for recording attendance and tardiness at meetings is correctly filled out.	0
	8	Presences	Are at least 80% of the team members present at the meetings?	1
	9	Culture	The selected employee knows how to explain the purpose of team meetings.	1
	10	Team	Does the team leader involve the members , asking them the causes of unmet indicators and asking for proposals for improvement?	0
	11	Team	Have clear and balanced responsibilities been assigned by all members?	0
	12	Team	Is there a substitute leader for the meetings in each of the shifts?	0
	13	Team	The team is identified in the framework.	1
Indicators	14	Indicators	A process of collecting indicators over the time period between meetings was set up	1
	15	Indicators	The selected employee knows the purpose of each indicator analyzed in the meeting	1
	16	Indicators	The indicators are updated	1
	17	Indicators	The goals of the indicators are marked in the indicator's representation.	1
Action Plan	18	Action Plan	The selected employee can explain how the action plan works	0
	19	Action Plan	The action plan contemplates at least one improvement action being implemented	0
	20	Action Plan	There is a balance of the different people responsible for actions within the team.	0
	21	Action Plan	For the actions already planned, the expected date of completion is identified.	0
Work Pl	22	Work Plan	The selected employee knows how to explain how the work plan works.	1
	23	Work Plan	The frequency of updating the plan is greater than or equal to the frequency of the frequent	1
	24	Work Plan	The work plan is up to date with information on the work to be started/run.	1

Figure 87- Daily Kaizen Audit (based on B.J.T.L. Batista (2017)).

Appendix P: CheckList and Kanban for picking post



Figure 88-Confirmation of required materials - Kaizen.

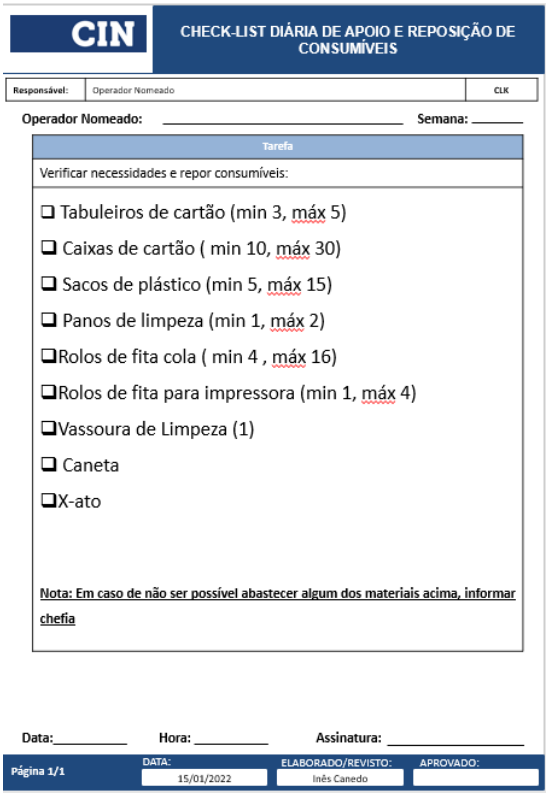


Figure 89-Daily completion sheet by the person in charge of confirming the required materials.

Appendix Q: Work standards in AW



Figure 90-Instructions for manual control of the VTD, to be placed on the equipment.

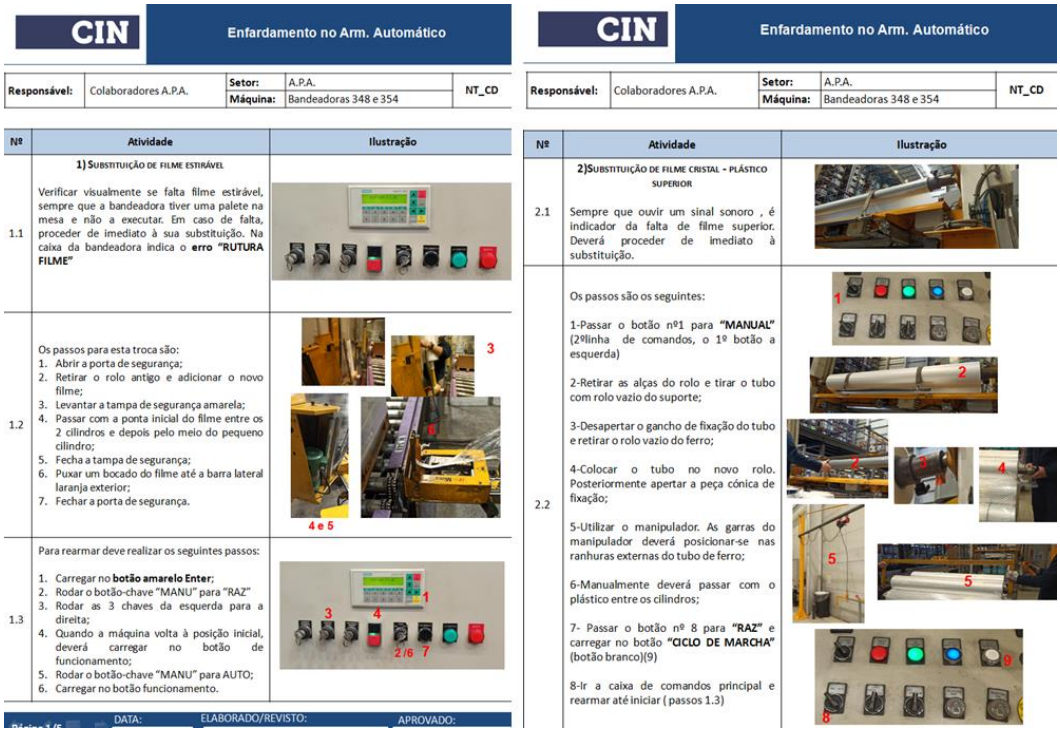
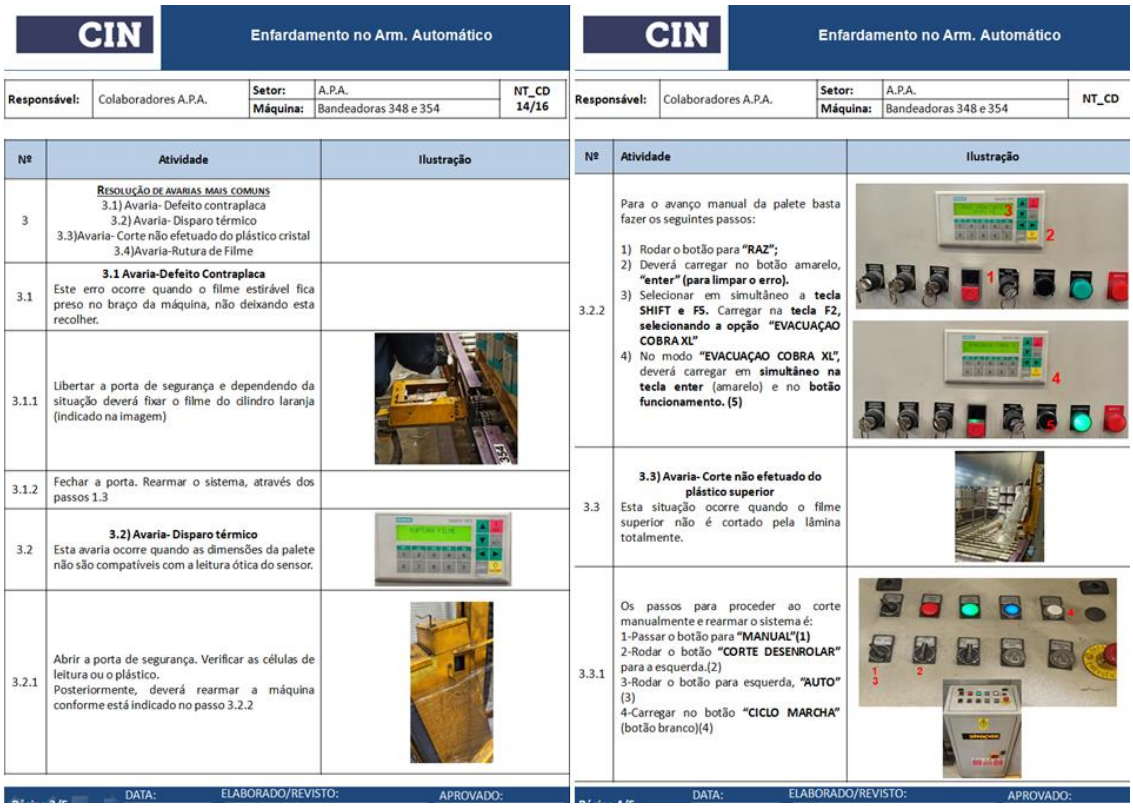


Figure 91-Work standards for the pallet bander.



CIN — Enfardamento no Arm. Automático

Responsável:	Colaboradores A.P.A.	Setor:	A.P.A.	NT_CD 14/16
		Máquina:	Bandeadoras 348 e 354	

Nº	Atividade	Ilustração
3	**Resolução de avarias mais comuns** 3.1) Avaria- Defeito contraplaca 3.2) Avaria- Disparo térmico 3.3)Avaria- Corte não efetuado do plástico cristal 3.4)Avaria-Rutura de Filme	
3.1	**3.1 Avaria-Defeito Contraplaca** Este erro ocorre quando o filme estirável fica preso no braço da máquina, não deixando esta recolher.	
3.1.1	Libertar a porta de segurança e dependendo da situação deverá fixar o filme do cilindro laranja (indicado na imagem)	
3.1.2	Fechar a porta. Rearmar o sistema, através dos passos 1.3	
3.2	**3.2) Avaria- Disparo térmico** Esta avaria ocorre quando as dimensões da palete não são compatíveis com a leitura ótica do sensor.	
3.2.1	Abrir a porta de segurança. Verificar as células de leitura ou o plástico. Posteriormente, deverá rearmar a máquina conforme está indicado no passo 3.2.2	

DATA: ELABORADO/REVISTO: APROVADO:

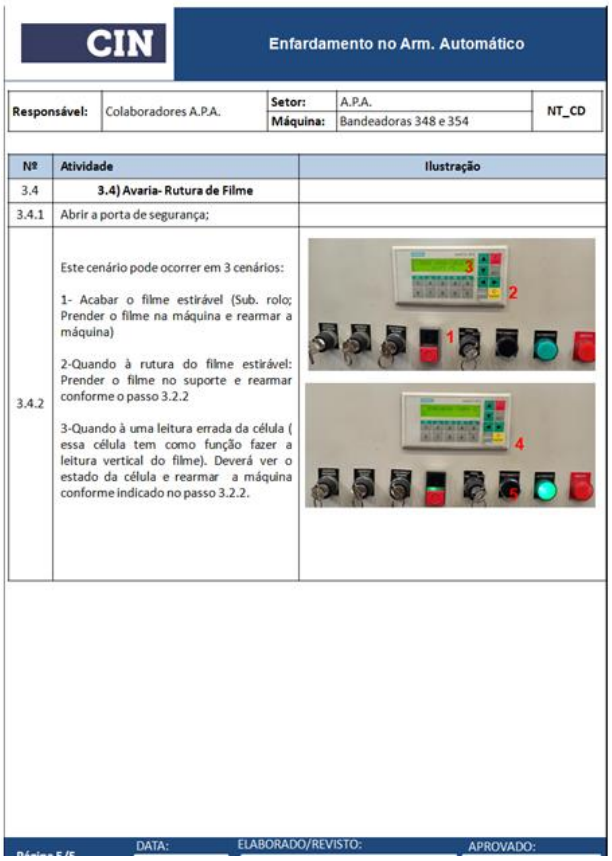
CIN — Enfardamento no Arm. Automático

Responsável:	Colaboradores A.P.A.	Setor:	A.P.A.	NT_CD
		Máquina:	Bandeadoras 348 e 354	

Nº	Atividade	Ilustração
3.2.2	Para o avanço manual da palete basta fazer os seguintes passos: 1) Rodar o botão para **"RAZ";** 2) Deverá carregar no botão amarelo, **"enter" (para limpar o erro).** 3) Selecionar em simultâneo a **tecla SHIFT e F5.** Carregar na **tecla F2, selecionando a opção "EVACUAÇAO COBRA XL"** 4) No modo **"EVACUAÇAO COBRA XL",** deverá carregar em **simultâneo na tecla enter** (amarelo) e no **botão funcionamento. (5)**	
3.3	**3.3) Avaria- Corte não efetuado do plástico superior** Esta situação ocorre quando o filme superior não é cortado pela lâmina totalmente.	
3.3.1	Os passos para proceder ao corte manualmente e rearmar o sistema é: 1-Passar o botão para **"MANUAL"(1)** 2-Rodar o botão **"CORTE DESENROLAR"** para a esquerda.(2) 3-Rodar o botão para esquerda, **"AUTO"** (3) 4-Carregar no botão **"CICLO MARCHA"** (botão branco)(4)	

DATA: ELABORADO/REVISTO: APROVADO:

Figure 92-Work standards for the pallet bander.



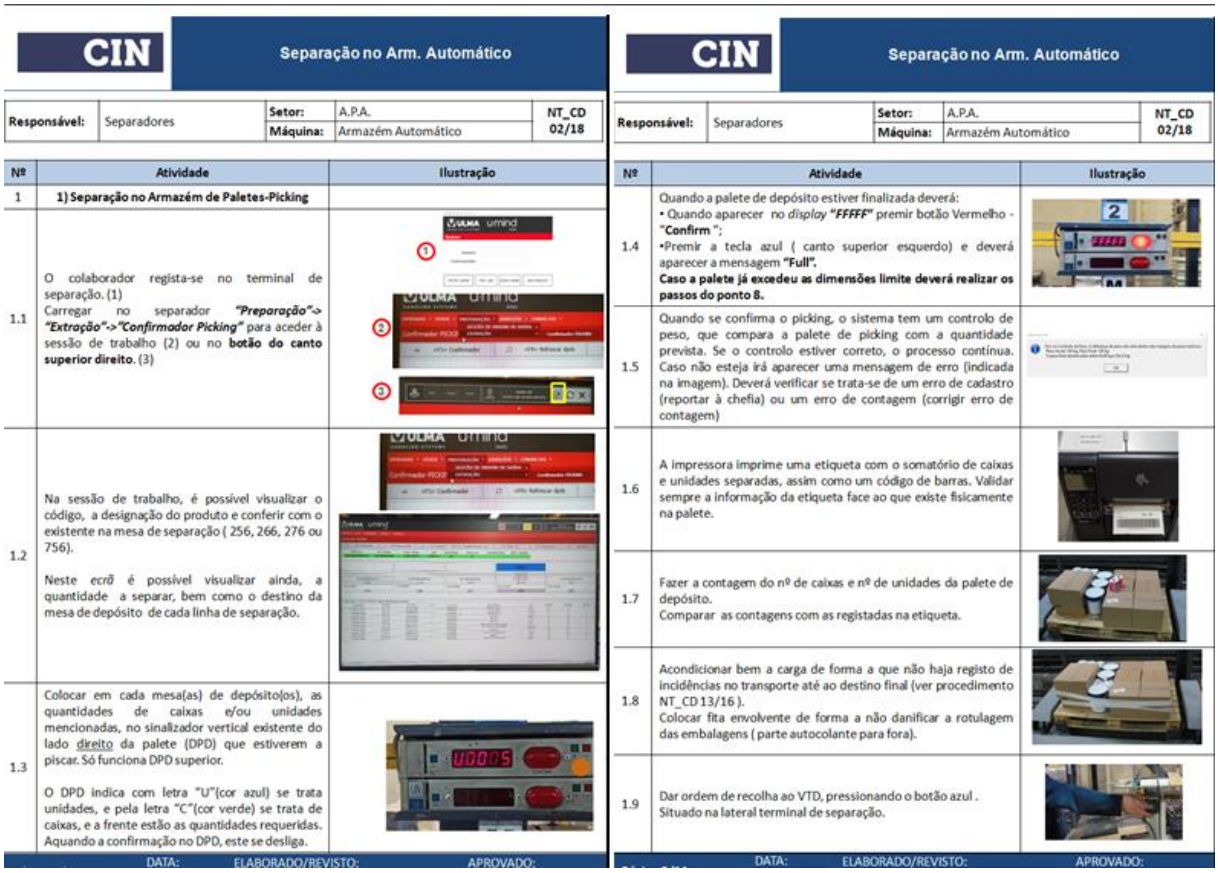
CIN — Enfardamento no Arm. Automático

Responsável:	Colaboradores A.P.A.	Setor:	A.P.A.	NT_CD
		Máquina:	Bandeadoras 348 e 354	

Nº	Atividade	Ilustração
3.4	**3.4) Avaria- Rutura de Filme**	
3.4.1	Abrir a porta de segurança;	
3.4.2	Este cenário pode ocorrer em 3 cenários: 1- Acabar o filme estirável (Sub. rolo; Prender o filme na máquina e rearmar a máquina) 2-Quando à rutura do filme estirável: Prender o filme no suporte e rearmar conforme o passo 3.2.2 3-Quando à uma leitura errada da célula (essa célula tem como função fazer a leitura vertical do filme). Deverá ver o estado da célula e rearmar a máquina conforme indicado no passo 3.2.2.	

DATA: ELABORADO/REVISTO: APROVADO:

Figure 93-Work standards for the pallet bander.



CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
1	**1) Separação no Armazém de Paletes-Picking**	
1.1	O colaborador regista-se no terminal de separação. (1) Carregar no separador ***"Preparação"-> "Extração"->"Confirmador Picking"*** para aceder à sessão de trabalho (2) ou no **botão do canto superior direito.** (3)	
1.2	Na sessão de trabalho, é possível visualizar o código, a designação do produto e conferir com o existente na mesa de separação (256, 266, 276 ou 756). Neste *ecrã* é possível visualizar ainda, a quantidade a separar, bem como o destino da mesa de depósito de cada linha de separação.	
1.3	Colocar em cada mesa(as) de depósito(os), as quantidades de caixas e/ou unidades mencionadas, no sinalizador vertical existente do lado direito da palete (DPD) que estiverem a piscar. Só funciona DPD superior. O DPD indica com letra "U"(cor azul) se trata unidades, e pela letra "C"(cor verde) se trata de caixas, e a frente estão as quantidades requeridas. Aquando a confirmação no DPD, este se desliga.	

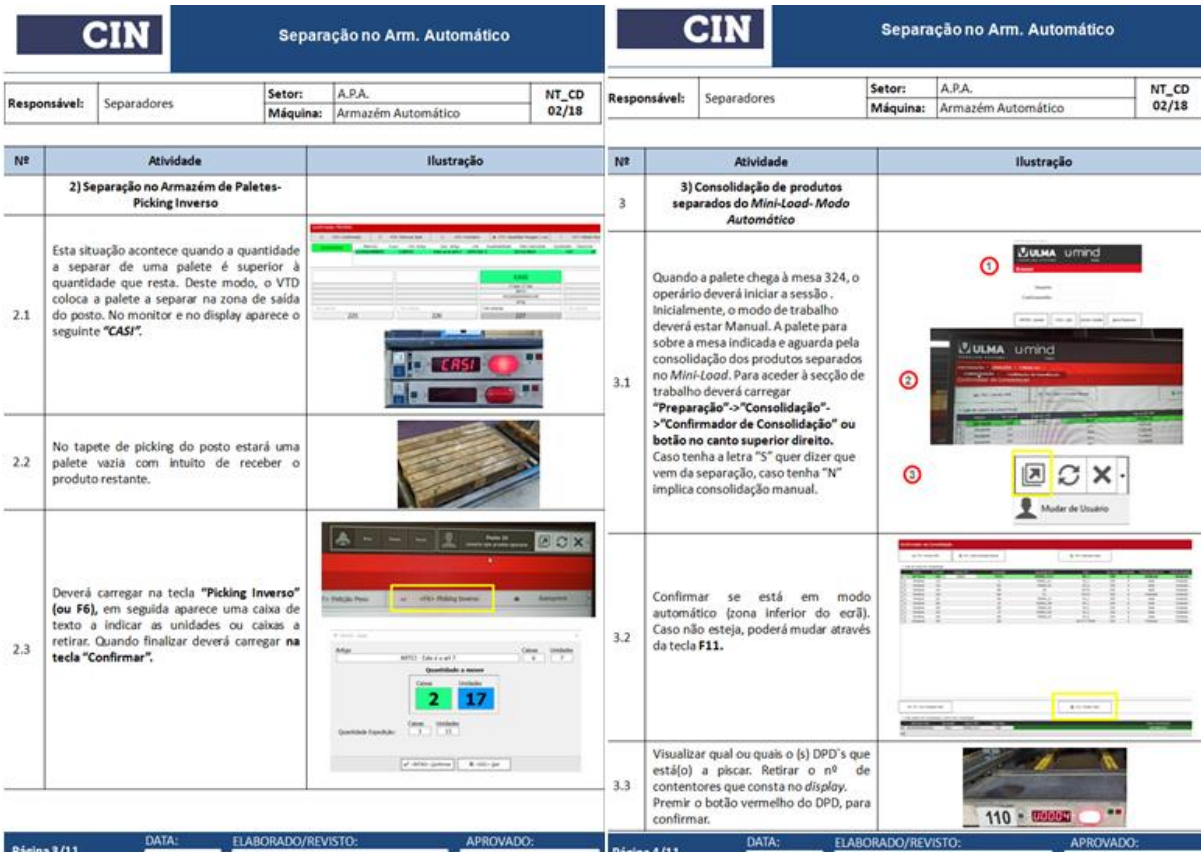
CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
1.4	Quando a palete de depósito estiver finalizada deverá: • Quando aparecer no *display* **"FFFFF"** premir botão Vermelho - **"Confirm "**; •Premir a tecla azul (canto superior esquerdo) e deverá aparecer a mensagem **"Full".** **Caso a palete já excedeu as dimensões limite deverá realizar os passos do ponto 8.**	
1.5	Quando se confirma o picking, o sistema tem um controlo de peso, que compara a palete de picking com a quantidade prevista. Se o controlo estiver correto, o processo continua. Caso não esteja irá aparecer uma mensagem de erro (indicada na imagem). Deverá verificar se trata-se de um erro de cadastro (reportar à chefia) ou um erro de contagem (corrigir erro de contagem)	
1.6	A impressora imprime uma etiqueta com o somatório de caixas e unidades separadas, assim como um código de barras. Validar sempre a informação da etiqueta face ao que existe fisicamente na palete.	
1.7	Fazer a contagem do nº de caixas e nº de unidades da palete de depósito. Comparar as contagens com as registadas na etiqueta.	
1.8	Acondicionar bem a carga de forma a que não haja registo de incidências no transporte até ao destino final (ver procedimento NT_CD 13/16). Colocar fita envolvente de forma a não danificar a rotulagem das embalagens (parte autocolante para fora).	
1.9	Dar ordem de recolha ao VTD, pressionando o botão azul . Situado na lateral terminal de separação.	

DATA: ELABORADO/REVISTO: APROVADO:

Figure 94-Work standards for the picking sector in AW.



CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
	2) Separação no Armazém de Paletes-Picking Inverso	
2.1	Esta situação acontece quando a quantidade a separar de uma palete é superior à quantidade que resta. Deste modo, o VTD coloca a palete a separar na zona de saída do posto. No monitor e no display aparece o seguinte ***"CASI".***	
2.2	No tapete de picking do posto estará uma palete vazia com intuito de receber o produto restante.	
2.3	Deverá carregar na tecla **"Picking Inverso" (ou F6),** em seguida aparece uma caixa de texto a indicar as unidades ou caixas a retirar. Quando finalizar deverá carregar **na tecla "Confirmar".**	

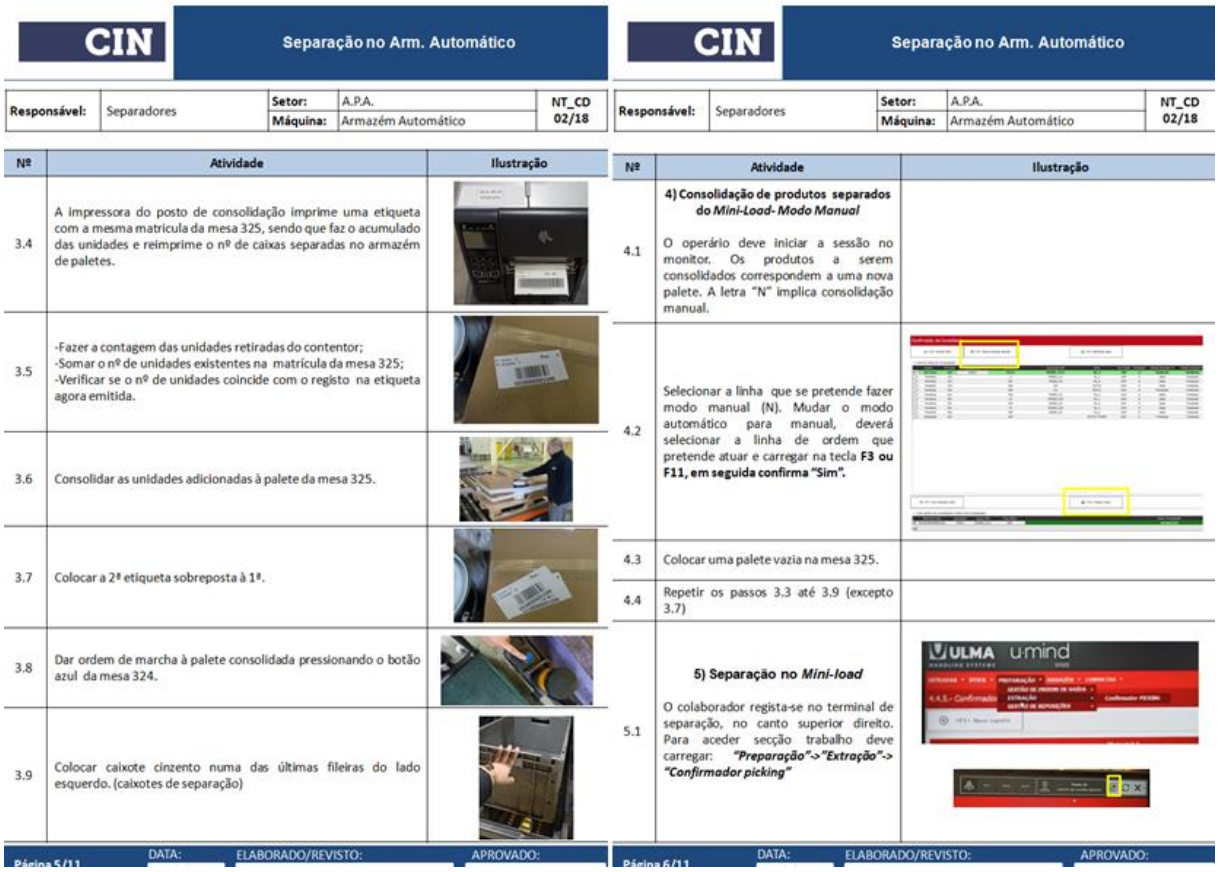
CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
3	**3) Consolidação de produtos separados do *Mini-Load- Modo Automático***	
3.1	Quando a palete chega à mesa 324, o operário deverá iniciar a sessão . Inicialmente, o modo de trabalho deverá estar Manual. A palete para sobre a mesa indicada e aguarda pela consolidação dos produtos separados no *Mini-Load*. Para aceder à secção de trabalho deverá carregar **"Preparação"->"Consolidação"->"Confirmador de Consolidação" ou botão no canto superior direito.** Caso tenha a letra "S" quer dizer que vem da separação, caso tenha "N" implica consolidação manual.	
3.2	Confirmar se está em modo automático (zona inferior do ecrã). Caso não esteja, poderá mudar através da tecla **F11.**	
3.3	Visualizar qual ou quais o (s) DPD´s que está(o) a piscar. Retirar o nº de contentores que consta no *display*. Premir o botão vermelho do DPD, para confirmar.	

DATA: ELABORADO/REVISTO: APROVADO:

Figure 95-Work standards for the picking sector in AW.



CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
3.4	A impressora do posto de consolidação imprime uma etiqueta com a mesma matrícula da mesa 325, sendo que faz o acumulado das unidades e reimprime o nº de caixas separadas no armazém de paletes.	
3.5	-Fazer a contagem das unidades retiradas do contentor; -Somar o nº de unidades existentes na matrícula da mesa 325; -Verificar se o nº de unidades coincide com o registo na etiqueta agora emitida.	
3.6	Consolidar as unidades adicionadas à palete da mesa 325.	
3.7	Colocar a 2ª etiqueta sobreposta à 1ª.	
3.8	Dar ordem de marcha à palete consolidada pressionando o botão azul da mesa 324.	
3.9	Colocar caixote cinzento numa das últimas fileiras do lado esquerdo. (caixotes de separação)	

Página 5/11 DATA: ELABORADO/REVISTO: APROVADO:

CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
4.1	**4) Consolidação de produtos separados do *Mini-Load- Modo Manual*** O operário deve iniciar a sessão no monitor. Os produtos a serem consolidados correspondem a uma nova palete. A letra "N" implica consolidação manual.	
4.2	Selecionar a linha que se pretende fazer modo manual (N). Mudar o modo automático para manual, deverá selecionar a linha de ordem que pretende atuar e carregar na tecla **F3 ou F11, em seguida confirma "Sim".**	
4.3	Colocar uma palete vazia na mesa 325.	
4.4	Repetir os passos 3.3 até 3.9 (excepto 3.7)	
5.1	**5) Separação no *Mini-load*** O colaborador regista-se no terminal de separação, no canto superior direito. Para aceder secção trabalho deve carregar: ***"Preparação"->"Extração"->"Confirmador picking"***	

Página 6/11 DATA: ELABORADO/REVISTO: APROVADO:

Figure 96-Work standards for the picking sector in AW.



CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
5.2	Neste posto de trabalho, o colaborador visualiza o código, a descrição do produto, disponibilidade (o que sobrará a posteriori na caixa), a quantidade de unidades a separar, bem como o destino do canal de cada linha de separação.	
5.3	Quando a caixa azul chega à mesa 908 deverá verificar se o código e a designação do produto coincide com o que aparece no terminal.	
5.4	No(s) canal(ais) de separação, o(s) DPD(s) piscam, indicando a quantidade ("U" para Unidades) a separar. Premir o botão vermelho do DPD, para confirmar.	
5.5	Recolher as caixas cinzentas da zona de armazenamento de caixas (lado direito) e colocar uma em cada canal com o(s) DPD(s) a piscar.	
5.6	Após o enchimento dos produtos nos canais correspondentes deve confirmar no botão vermelho. Caso seja o último produto no picking (e aparecer no *display* ***"FFFFF"***) deverá carregar ***Fn (botão azul)-> Confirmar (botão vermelho)***. Posteriormente, empurra o caixote para o fim da linha.	

DATA: ELABORADO/REVISTO: APROVADO:

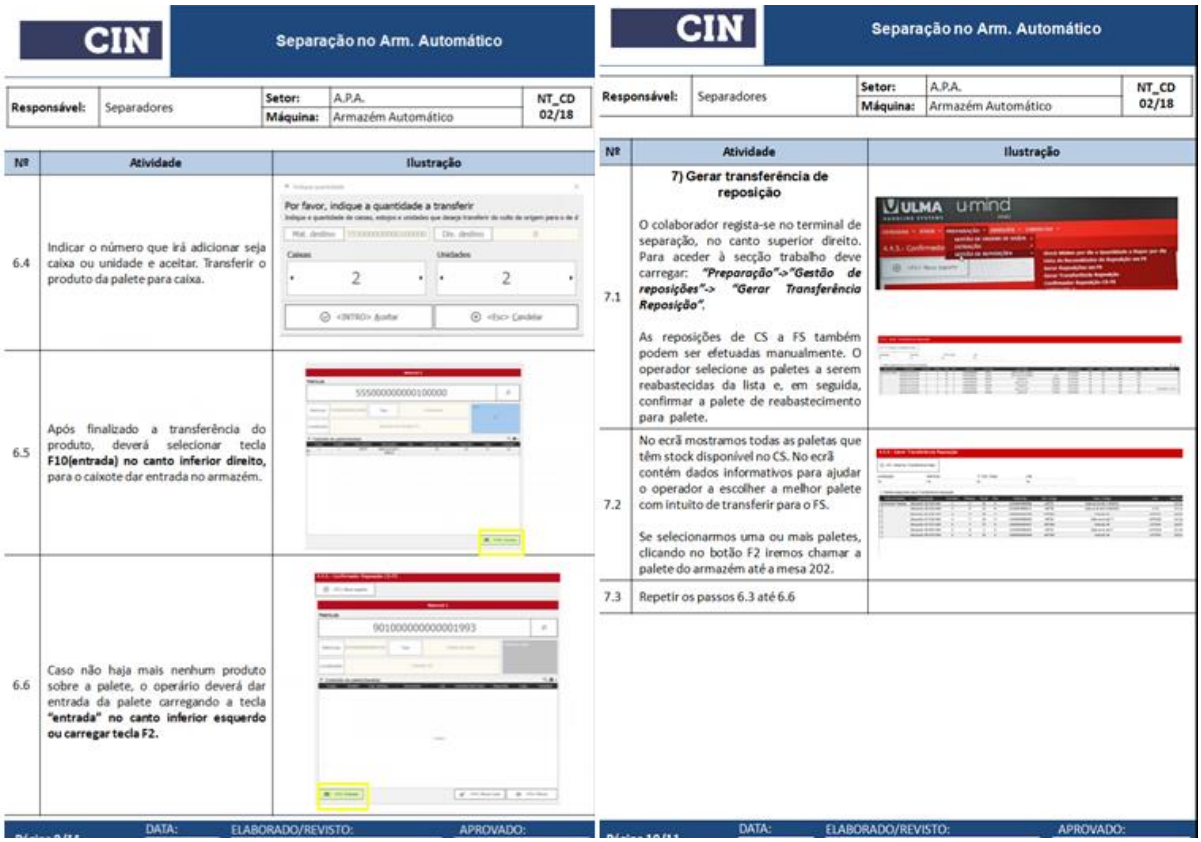
CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
5.7	No visor, no canto superior esquerdo, irá aparecer um **aviso amarelo cuja mensagem "RETIRAR"**, e significa que deverá retirar da mesa o caixote azul e colocar na zona lateral indicada ou alternativamente ocorre a recolha automática do caixote vazio (parâmetro de gestão de armazém)	
6.1	**6) Reposição CS-FS no *Mini-load*** O colaborador regista-se no terminal de separação, no canto superior direito. Para aceder à secção trabalho deve carregar: ***"Preparação"->"Gestão de reposição"-> "Confirmador Reposição CS-FS"***.	
6.2	No visor do lado esquerdo é visível os detalhes da palete na mesa 202 e apresenta os conteúdos da mesma. No visor do lado direito, apresenta as informações.	
6.3	O operário deve ler o código de barras da caixa e selecionar com o rato o artigo que pretende armazenar no caixote e carregar em **F5 (mover) ou F4(mover tudo).**	

DATA: ELABORADO/REVISTO: APROVADO:

Figure 97-Work standards for the picking sector in AW.



CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
6.4	Indicar o número que irá adicionar seja caixa ou unidade e aceitar. Transferir o produto da palete para caixa.	
6.5	Após finalizado a transferência do produto, deverá selecionar tecla **F10(entrada) no canto inferior direito,** para o caixote dar entrada no armazém.	
6.6	Caso não haja mais nenhum produto sobre a palete, o operário deverá dar entrada da palete carregando a tecla **"entrada" no canto inferior esquerdo ou carregar tecla F2.**	

DATA: ELABORADO/REVISTO: APROVADO:

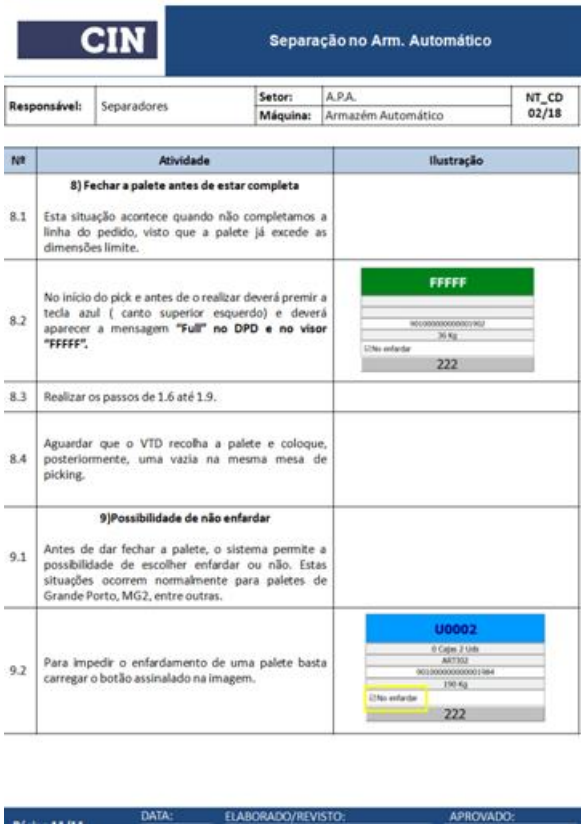
CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
7.1	**7) Gerar transferência de reposição** O colaborador regista-se no terminal de separação, no canto superior direito. Para aceder à secção trabalho deve carregar: ***"Preparação"->"Gestão de reposições"-> "Gerar Transferência Reposição".*** As reposições de CS a FS também podem ser efetuadas manualmente. O operador selecione as paletes a serem reabastecidas da lista e, em seguida, confirmar a palete de reabastecimento para palete.	
7.2	No ecrã mostramos todas as paletas que têm stock disponível no CS. No ecrã contém dados informativos para ajudar o operador a escolher a melhor palete com intuito de transferir para o FS. Se selecionarmos uma ou mais paletes, clicando no botão F2 iremos chamar a palete do armazém até a mesa 202.	
7.3	Repetir os passos 6.3 até 6.6	

DATA: ELABORADO/REVISTO: APROVADO:

Figure 98-Work standards for the picking sector in AW.



CIN — Separação no Arm. Automático

Responsável:	Separadores	Setor:	A.P.A.	NT_CD 02/18
		Máquina:	Armazém Automático	

Nº	Atividade	Ilustração
8.1	**8) Fechar a palete antes de estar completa** Esta situação acontece quando não completamos a linha do pedido, visto que a palete já excede as dimensões limite.	
8.2	No início do pick e antes de o realizar deverá premir a tecla azul (canto superior esquerdo) e deverá aparecer a mensagem **"Full" no DPD e no visor "FFFFF".**	FFFFF 222
8.3	Realizar os passos de 1.6 até 1.9.	
8.4	Aguardar que o VTD recolha a palete e coloque, posteriormente, uma vazia na mesma mesa de picking.	
9.1	**9)Possibilidade de não enfardar** Antes de dar fechar a palete, o sistema permite a possibilidade de escolher enfardar ou não. Estas situações ocorrem normalmente para paletes de Grande Porto, MG2, entre outras.	
9.2	Para impedir o enfardamento de uma palete basta carregar o botão assinalado na imagem.	U0002 222

DATA: ELABORADO/REVISTO: APROVADO:

Figure 99-Work standards for the picking sector in AW.



CIN — Receção de encomendas de Fornecedor Interno

Responsável:	Colaboradores de A.P.A./ Expedição/ Exportação e Motorista de circuito interno	Setor:	Receção de Fornecedores	NT_CD 04/16
		Máquina:	Empilhadores e terminais RF	

Nº	Atividade	Ilustração
1	**Descarga-Motorista:** Encostar camião a cais de Receção do CDM disponível e entregar "**Listagem de Carga no Camião**" ao colaborador da Receção.	
2	**Colaborador de receção:** Descarregar e retirar das paletes as cantoneiras e cintas verticais que as suportam, colocando-as nos ecopontos existentes para o efeito.	
3	**Motorista:** A descarga deve-se efetuar consoante os seguintes parâmetros: 1. Produtos com destino ao **Armazém Automático (etiquetas para área ULM – (1))**: Confirmação da receção do produto, pela etiqueta de receção, utilizando PDT com terminal RF: Menu – "**Entrada de stock**": colocar palete na mesa de entrada (830), ler a matrícula da etiqueta de receção. Caso seja conjunto de paletes, no menu principal do PDT deverá selecionar "**Entrada Pilha**" e ler a matrícula da empilhadora. **(2)** 2. Produtos com destino a **Expedição imediata (etiquetas para área EXP – (3))**: Efetuar descarga na zona convencionada. 3. Produtos com destino a **Estanteria Convencional (etiquetas para Localizações – (4))**: Efetuar descarregar na zona convencionada ou, caso esta esteja sem espaço, descarregar numa 2ª fila na zona de EXP. 4. Produtos com destino a **Exportação (etiquetas para Exportação)**: Efetuar descarregar na zona da Exportação, mediante informação ao Colaborador de Exportação. 5. Descarga para um só cliente deve ser efetuada na zona da Expedição, mediante informação ao Responsável Expedição.	

Página 1/3 — DATA: 05/05/2022 — ELABORADO/REVISTO: — APROVADO:

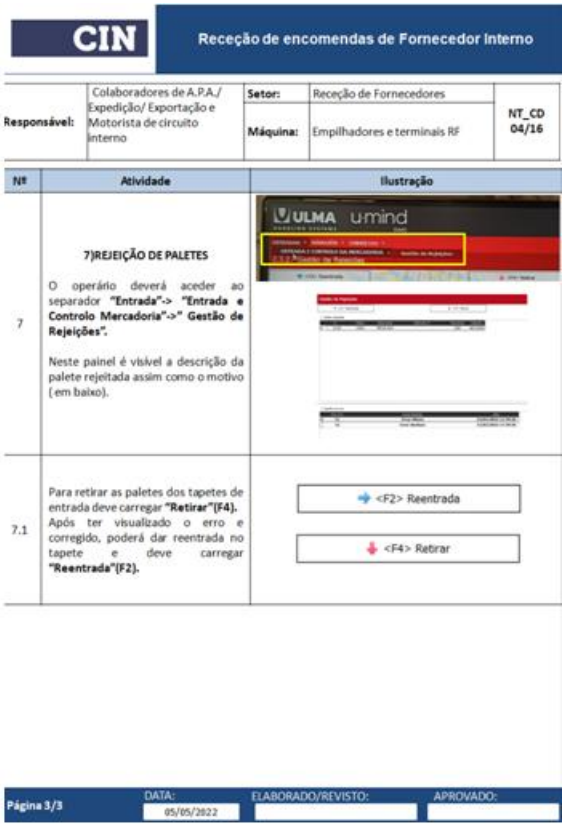
CIN — Receção de encomendas de Fornecedor Interno

Responsável:	Colaboradores de A.P.A./ Expedição/ Exportação e Motorista de circuito interno	Setor:	Receção de Fornecedores	NT_CD 04/16
		Máquina:	Empilhadores e terminais RF	

Nº	Atividade	Ilustração
4	Quando o operário deposita a palete sobre o tapete, se o peso estiver dentro das tolerâncias estipuladas pelo sistema, esta irá avançar.	
5	Caso no sistema de sensores seja detetada uma anomalia, a palete será rejeitada e deslocada para zona de rejeição. Só poderá dar entrada novamente a partir do sistema.	
6	**6)ERRO DE SENSOR** Caso a palete ultrapasse a barreira sensorial indicada na imagem (acende luz verde), o elevador será interrompido. A palete terá de ser ajustada para a posição anterior ao sensor e no quadro do elevador (piso superior do lado esquerdo- **"CCPIF2")** deverá rearmar o quadro, **carregando no botão vermelho.**	

Página 2/3 — DATA: 05/05/2022 — ELABORADO/REVISTO: — APROVADO:

Figure 100-Work standards for the reception sector at AW.



CIN — Receção de encomendas de Fornecedor Interno

Responsável:	Colaboradores de A.P.A./ Expedição/ Exportação e Motorista de circuito interno	Setor:	Receção de Fornecedores	NT_CD 04/16
		Máquina:	Empilhadores e terminais RF	

Nº	Atividade	Ilustração
7	**7)REJEIÇÃO DE PALETES** O operário deverá aceder ao separador **"Entrada"-> "Entrada e Controlo Mercadoria"->" Gestão de Rejeições".** Neste painel é visível a descrição da palete rejeitada assim como o motivo (em baixo).	ULMA u-mind
7.1	Para retirar as paletes dos tapetes de entrada deve carregar **"Retirar"(F4).** Após ter visualizado o erro e corrigido, poderá dar reentrada no tapete e deve carregar **"Reentrada"(F2).**	<F2> Reentrada <F4> Retirar

Página 3/3 — DATA: 05/05/2022 — ELABORADO/REVISTO: — APROVADO:

Figure 101-Work standards for the reception sector at AW.

Appendix R: Study FTE

A tradução literal é "equivalente em tempo integral". Na prática, o indicador compara as horas de trabalho com a jornada esperada para um profissional em tempo integral. O resultado é um percentual de FTE.

Per day working Hours	8		Per month working days		20		Só se considera o TD					
	Separação 2022		Volume pretendido	1500	picks/dia/turno		Salario Min Full	900				
Prod. Média=	41,4	picks/Hora/Homem	Tempo disponivel	8	Horas							
Nº Funcionários	5		Total tempo requerido	36,23188406	hora/homem		Salario Mini Part	450	375	300		
Horas semanais laborais	200	h/sem/turno	FT required	5,070652174				25h	20h	16h		
Tempo avarias médio	260	min/semana	Total de salarios mensais (minimo)	4500								
			Se reduzir a 100% as perdas ocorridas por avarias				Se reduzir a 50% as perdas ocorridas por avarias	34,15693				
Tempo avarias	4,333333333	horas/ semana		32,31								
Tempo de operação real	97,8%		FT required	4,038345411			FT required	4,269616	(4 funcionários a full time e um part time)			
Nº Picks perdidos	179,4		Total de salarios mensais (minimo)	3600			Total salarios mensais (minimo)	4000				
	7,133333333		Novo Prod. Média	46,430			Novo prod Médio	43,91495				
			Se reduzir a 15% as perdas ocorridas por avarias	35,64311594				7,566667				
			FT required	4,455389493								
			Total de salarios mensais (minimo)	3975								
			Novo Prod. Média	42,084								
			Tempo Operacional Real	7,87								

Figure 102-FTE study for the AW Separation sector.

Per day working Hours	8		Per month working days		20		Só se considera o TD
	Receção 2022				%eficiencia	91,7%	
Prod. Média=	8,48	paletes/Hora			Trabalho perdido mensalmente	13	Horas
Nº Funcionários	1						
Horas semanais laborais	40	h/sem/turno					
Tempo avarias médio	0,80	palete/min					
Nº Médio de paletes rejeitadas	50	paletes/dia/turno					
Tempo de operação real	36,67						
Nº Paletes não tratadas	0,706667	5,653333	paletes/turno/dia				

Figure 103-FTE study for the AW Reception sector.

Appendix S: Summary of implemented solutions

Table 26-Summary of implemented solutions.

Focus of Action	Implemented Actions	Goals Achieved	Next Steps
Team Organization	-Conducting daily meetings for each team; -Analysis of existing Performance Indicators and possible adhesion of new indicators; -Creating an information board.	-Involve operators and motivate team spirit by analyzing the overall performance of each team.	-Pass the methodologies implemented in the AW zone to the rest of the distribution center.
Organization of Work Stations	-Implementation of the 5S methodology; -Creation of audit forms for the work stations. -Study and mechanical design of a more ergonomic workstation. -Implementation of the Kanban system to supply the materials needed for the operations	-Organize the work stations; -Ensuring the conservation of the organization in order to have a safer and more ergonomic area.	-Addition of new work stations. -Redefine a more efficient layout.
Normalization	-Creation of standards for work instructions - Sorting, Receiving and Banding; -Creation of a place of quick access to the rules, next to the work stations.	-Enable a quick consultation of documents, which allows for the reduction of errors and speeding up the performance of tasks.	-Standardization of the use of equipment and missing processes (VTD).
OEE	-Creation of a tool for calculating the OEE; -Training of operators in recording downtime. -Adherence to OEE analysis in daily Kaizen meetings.	-Increase visibility of performance and equipment availability.	-Increase the OEE to a level of 50% to 60%.
Maintenance	-Creating an action plan for maintenance in AW.	-Storage of the AW maintenance area.	-Implement the suggested action plan; -Decrease corrective maintenance.