

Application of lean methodologies to the logistics operation of a woodcutting tools industry

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“Faz porque queres e sentes, não porque deves e tens...”

Samuel Mira, 2006

Abstract

The current status of the global economy motivates an optimization and effective management of the available resources, in order to ensure their maximum efficiency. The common starting point for this approach consists on a profound analysis of the supply chain, to identify, reduce, or even eliminate, its primary sources of waste.

Frezite's growth has been remarkable. The demand for more adaptation capabilities to the surrounding environment, are a constant reality in this organization, imposing a frenetic rhythm that hinders the possibility of a thorough study on the current situation. However, all the resulting changes vouch for a readjustment of the various sectors composing its strategic business units (SBU's), especially the oldest ones. This is the case of the one dedicated to the production of wood cutting tools where the logistics department, which serves this dissertation's case study, is located.

This is the setting for the hereby presented project, aimed at studying and improving the beforementioned department's workflow, in the hopes of achieving more productivity and efficiency. In order to do so, the use of Lean tools is essential and specifically tailored for the identification and reduction of the main sources of waste associated with an industry where products are highly customizable.

The daily presence in the department allowed closer contact with the collaborators and practical involvement in some of their tasks, which was crucial during the elaboration of the project when observing potential improvement opportunities. This initial analysis was complemented with the information extracted from the external complaints data, spaghetti diagrams, and an ABC analysis of the average consumption rates. Improvement actions were implemented using the 5S methodology, with the aim of optimizing the layout, organize the available space, and shortening the distance between the different workstations, the associated equipment and items that were mostly used in the daily routine. A set of graphic instructions were implemented in order to improve the available documentation, with the goal of bringing more transparency and standardization to the packing process. A Kanban system was introduced for the front office's top-selling circular saw blades. Finally, the autonomous maintenance program was extended to the logistics department, with the elaboration of a visual guide that was used on a cutting machine.

Through the used methodologies, it was possible to improve the overall productivity, resulting in annual savings of nearly 8300 euros, an increase in the available area destined for storage and working activities (13,5 m²), and finally, a steep decrease of the costs associated with external complaints (six times inferior), when comparing with the same period of the previous year. The success of the project was dependent on the motivation of the collaborators, their familiarity with previous continuous improvement initiatives, commitment and feedback. Despite the absences, among other external factors that threatened the conclusion of the project, it is possible to state that the set of implemented initiatives added value to the initial situation, for the previously mentioned reasons. Nevertheless, there are other improvement opportunities which were either not implemented or studied during the elaboration of this dissertation, constituting an important part of the department's continuous improvement program.

In conclusion, the number of developed improvement actions resulted in tangible gains in terms of space, productivity, external complaints, resulting in more efficient management of the available resources, as initially intended. Additionally, better working conditions were created stemming from the involvement and intervention of the collaborators. As a result, for the previously mentioned reasons, the project has achieved its goals and has been successful.

Aplicação de metodologias Lean na operação logística de uma indústria de ferramentas de corte para madeira

Resumo

A atual conjuntura económica motiva uma otimização e gestão eficiente dos recursos existentes, garantindo a sua utilização, de uma forma responsável. O ponto de partida comum a esta abordagem consiste numa análise profunda da cadeia de abastecimento, com o objetivo de identificar e reduzir, ou até mesmo eliminar, os principais desperdícios associados.

A Frezite tem vindo a crescer consideravelmente. A exigência de uma maior flexibilidade e capacidade de adaptação ao ambiente circundante, são uma constante na realidade desta organização, impondo um ritmo frenético que impossibilita estudos aprofundados sobre o fluxo atual. Ainda assim, todas as mudanças que advêm destes acontecimentos obrigam a um reajuste dos vários setores que compõem as suas unidades estratégicas de negócio (UEN's), sobretudo das mais antigas. É o caso da UEN que se dedica à produção de ferramentas de corte para madeira, onde se insere o departamento de logística, que serve de caso de estudo para esta dissertação.

É este o âmbito em que surge o projeto aqui apresentado, cujo principal objetivo consiste em estudar e melhorar o fluxo de trabalho adotado pelos colaboradores do departamento mencionado anteriormente, traduzindo-se em ganhos de produtividade e maior eficiência. Para tal, o uso de ferramentas Lean revela-se essencial e extremamente oportuno na identificação e redução dos principais desperdícios associados a uma indústria, cuja produção é maioritariamente customizada.

A presença diária no departamento possibilitou um contacto próximo com os colaboradores e o envolvimento prático em algumas das suas tarefas, tornando-se essencial na identificação de oportunidades de melhoria durante o projeto. A análise inicial foi ainda complementada com a informação extraída das reclamações externas, diagramas de Spaghetti, e uma análise ABC aos consumos médios. Implementaram-se ações de melhoria no âmbito dos 5S no sentido de otimizar o layout, organizar o espaço, descongestioná-lo e aproximar os locais de trabalho de cada um dos operadores, do respetivo equipamento e itens mais utilizados no seu dia-a-dia. Foi implementado um conjunto de instruções gráficas no sentido de melhorar a documentação, transparência e padronização dos procedimentos de embalagem. Introduziu-se um sistema Kanban para as serras circulares mais vendidas ao balcão. Finalmente, estendeu-se a implementação do programa de manutenção autónoma ao departamento de logística, através da elaboração de um guia visual alusivo, aplicado na máquina de corte.

Através das metodologias utilizadas atingiram-se ganhos de produtividade que se traduzem numa poupança na ordem dos 8300 euros anuais, um aumento da área disponível para armazenamento e trabalho de cerca de 13,5 m² e, finalmente, numa diminuição drástica dos custos associados às reclamações externas (cerca de seis vezes inferiores), quando comparados com o mesmo período do ano anterior. Para o sucesso do projeto considerou-se relevante a motivação dos colaboradores, a familiaridade com iniciativas de melhoria contínua anteriores, o seu empenho e feedback. Apesar das ausências verificadas, entre outros fatores externos que ameaçaram a conclusão do projeto, é possível determinar que o conjunto de implementações acrescentou valor à situação inicial, pelos motivos enunciados anteriormente. Ainda assim, existem outras oportunidades de melhoria, não implementadas ou não estudadas aprofundadamente durante a realização da dissertação, que constituem uma parte importante no plano de melhoria contínua do departamento.

Concluindo, o conjunto de melhorias desenvolvidas resultou em ganhos tangíveis a nível de espaço, produtividade, e reclamações externas, resultando numa gestão mais eficiente dos recursos, tal como pretendido. Adicionalmente, foram criadas melhores condições de trabalho, resultantes do envolvimento e intervenção dos operadores. Considera-se, por estes motivos, que o projeto atingiu os seus objetivos com sucesso.

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1 Introduction

The work developed and disclosed in the hereby presented document was motivated by the elaboration of a final presentation, to mark the end of the integrated master's degree in industrial engineering and management, taught at Oporto's University. The project was developed in collaboration with a multinational cutting tools company: "Frezite – Ferramentas de Corte SA". The main objective was to improve the efficiency and organization of the logistics department of the woodcutting tools production unit. In order to do so, lean methodologies were used during the short period dedicated to the venture, of approximately four months.

1.1 The Project

The world of manufacturing has become a fertile ground for numerous technological advancements that have been changing the human civilization. The widespread use of information technology to access data about operations, integrate the entire supply chain, and reach the end customer, has represented a giant leap during the last decades, compared to what was achieved during the last century. The industry has become very competitive as customers also become more demanding with fewer costs, shorter lead times, and more product quality and variety. The level of flexibility required to achieve those objectives represents a pitfall for modern businesses. As processes keep changing, there is little time to study and identify possible wasteful steps thoroughly. The cumulative effect of such an outcome will hurt the overall efficiency in the short to long term.

Frezite has grown to become one of the leading cutting tool solution providers in the world. The key for its success has been the focus on its customers, resulting in a wide variety of products, where seventy percent of the total annual production is custom-made. This growth has motivated several readjustments to many of the company's sectors, including its logistics departments. The project described in this document consists in identifying and possibly eliminating sources of waste that may have emerged within this element of its supply chain. As previously stated, adaptation is a crucial step towards competitiveness and entrepreneurial success. Being so, vouching for smarter use of the currently available resources is deeply tied with the application of lean methodologies.

1.2 The Setting

Frezite is a company that provides engineering solutions for cutting tools used in the wood processing, plastic, composite materials, and metals industries.



Figure 1: Frezite's logo.

“At Frezite, our entire organization and company strategy is focused on the customer. Founded in 1978, it boasts a vast experience in the design, development and production of cutting tools by chip removal.

Supplying the highly competitive professional and industrial market, the company has solidly guided its sound and sustainable growth. Frezite is currently present, with its products and technologies, in more than 50 countries across all five continents.” (in <http://www.frezite.pt/en/company>)

1.2.1 Company History

“Frezite – Ferramentas de Corte S.A.” as previously mentioned, was founded in 1978 by twelve employees. Initially, it launched with the local production of cutters for the woodworking industry.

Over the years, the company has been growing by solidifying its position in both the external and internal markets. Its first ever presence in an international fair was in 1981, which marked the establishment of its global distributor network, and its role as an essential supplier of the industry. However, the company’s worldwide expansion would only start in 1996 with the creation of “Frezite Brazil”.

Around the early twenty-first century, the company becomes notorious for its evolution regarding its “know-how”, production levels, degree of innovation, and technology use. In 2005, the company divided itself into two strategic business units (SBU’s), with the creation of “Frezite Metal Tooling - FMT”, dedicated to the metal cutting tools industry.



Figure 2: FMT’s logo.

After several acquisitions, the company starts expanding rapidly across the world, mainly in Europe and America, once again leveraging its full potential into becoming an important player in the tooling solutions industry. Currently, the group is made of a third SBU that encompasses “SERI” and “Frezite High Performance - FHP”, two companies focused on developing and launching advanced products for the automotive and aerospace industries.



Figure 3: SERI and FHP’s logos.

Frezite is proud to have been certified with the ISO 9001 standard by “APCER”, the Portuguese member of “IQNET” (The International Certificate Network), ensuring the quality of its products. Additionally, since 2000, it was one of the first Portuguese manufacturing companies to have been certified by the same agency with the ISO 14001 standard, for its environmentally friendly policies.



Figure 4: ISO 9001 and ISO 14001 certifications.

The cultural environment promoted at this company is based on three essential pillars: integrity, teamwork, and innovation. Frezite aims to become an “organization that is noticeable for its efficiency in maintaining and creating value, through innovation and creativity that can be transferred to its clients, shareholders, collaborators and remaining stakeholders” (company’s mission).

1.2.2 Woodcutting Tools SBU

As formerly mentioned, the woodcutting tools SBU was the first to be established in the company. Being one of the oldest, it is also the one that encompasses the highest level of accumulated expertise and relationship bonds of the company between various stakeholders.

The project described in this document was developed in the logistics department of this strategic business unit. Products can be sorted into seven groups:

- Cutters and cutter heads with bore;
- Cutters and cutter heads with shank;
- Polycrystalline diamond tools;
- Drills;
- Circular saw blades;
- Clamping systems;
- Knives and tooling accessories.

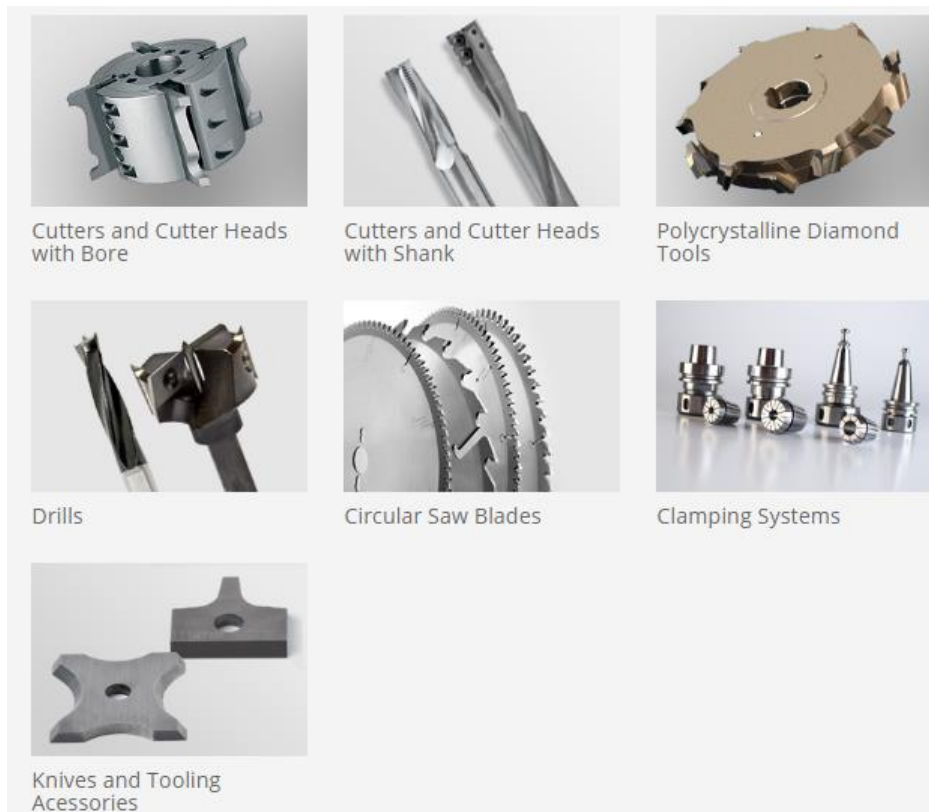


Figure 5: Woodcutting tools SBU's products.

Currently, production within this unit is divided into two main production facilities. Circular saw blades are produced in one of them, with 35% being custom-made. The remaining products are produced in the other facility, where the logistics department is located, with only 30% of the total production being standard. Beyond production, Frezite also provides repairing and resharpening services to its clients.

1.3 Objectives

Since most of the company's core business revolves around the production of highly customized products, the variety and impact of the associated wastes can be severe. This situation has been increasingly more noticeable with the readjustment of other sectors of the company, including the one where this project was developed.

Using lean methodologies, the project aims to improve the productivity and efficiency of the logistics department, through the reduction of the identified wastes. Hopefully, this can be translatable into superior operational excellence through three main perspectives: the service level, lead time, and external complaints.

1.4 Methodology

The hereby presented project can be divided into four main phases.

Initially (Phase One), relevant literature about lean was carefully analyzed and reviewed. After examining the state of the art (Phase Two), the flow and activities performed within the logistics department were closely monitored through mainly direct observation, including other complementary tools. This was only possible due to a daily presence on the department itself, and practical involvement in some of the tasks. The formerly mentioned study allowed the emergence and implementation of suggestions (Phase Three), to improve the organization and

overall productivity of the sector. Lastly, the results were evaluated (Phase Four), and conclusions were drawn, comparing with the initial situation.

1.5 Document structure

This dissertation is organized into five chapters. The contents within each one of these are described as follows:

- This initial chapter contained a summarized presentation of the project's setting, its motivations, the followed methodology, and the objectives. It also included a short description of the company and the sector where the project was developed.
- Secondly, the literature review about the lean principles and methodologies used in this project is disclosed.
- The third chapter includes a more in-depth analysis of the activities and processes involved, intending to provide a better insight into the problems found and their solution, including additional remarks on relevant improvement opportunities.
- The fourth chapter encompasses all the studied solutions, including their respective description on the implementation process, if applicable. Included in this section are also the observed results.
- Finally, the conclusions are unveiled in the last chapter, including improvement suggestions that could be of interest for future projects.

2 Literature Review

Along this chapter, there will be an attempt to disclose and define all the relevant concepts and theoretical background for the project. The aim is to provide enough understanding of the motivations behind the use of some of the forwardly mentioned methodologies, in order to conduct the required improvements.

Initially, Lean will be presented using a historic perspective, as well as its pillars, followed by the specific methodologies used in this project.

2.1 Lean Philosophy and the Toyota Production System (TPS)

The concept of “Lean Manufacturing” has had its origins in Japan, after one of the direst events in human history: World War II. Because of its magnitude and global reach, the impact in the world’s economy and society was severe. Japanese manufacturing companies were in an unfavorable position because of the scarcity of resources and investment. However, their need to compete with the leading American industry motivated a revolution in industrial engineering, that would forever change our world. The visionary behind this new movement was Toyota’s Chief Engineer at the time, Taiichi Ohno, who is mostly known for creating one of the most recognized, battle-tested and successful lean production systems: the TPS (Wilson, 2010).

According to its creator, the TPS was created with the goal of reducing overall costs, through the “absolute elimination of waste”. “After World War II, our main concern was how to produce high-quality goods. After 1955, however, the question became how to make the exact quantity needed” (Ohno, 1988). In fact, some of the most notorious characteristics of Ohno’s new system was its emphasis on quality, quantity and process control. There was also an evolving nature to it, which could only be sustained through a strong healthy culture (Wilson, 2010). According to Ohno, waste reduction is based on two pillars: just-in-time and *jidoka*.

Just-in-time refers to an idea that goes beyond inventory control. The importance of producing the right quantities to be supplied at the right time, as it will be seen later, is crucial for lean’s success as it represents a fertile source of waste. Doing so is not an easy task since it demands a deep understanding and control of variation, as Wilson (2010) points out.

Before the introduction of this concept in the late ‘80s, there was little study on lead time and how it could be approached in order to improve business processes. Ohno (1988) had mentioned that the aim with waste reduction initiatives was to shorten the timeline between the customer’s order and the moment where cash would be collected, creating a smoother flow. When this is achieved, variation ends up decreasing because processes become less vulnerable to external effects, which can improve flexibility in a business and manufacturing perspective. In some cases, this could even help minimize damage or deterioration effects due to minimal exposure to the environment.

Jidoka is a Japanese term that can be translated into autonomation (Subramaniam et al, 2009). It refers to an ideal reality where machines and humans work together, but independently, in a manufacturing system. Machines were invented by humans to perform repetitive and often unsafe tasks. However, human intervention is often needed. This symbiotic relationship is based on the fact that efficiency and flexibility’s coexistence is mandatory and necessary. Humans possess versatile and unique physical, and psychological, capabilities no machine can be trained on, and are essential to maximizing quality. In other words, automation must always be achieved with a human touch.

Nevertheless, humans can be relieved from the burden of constantly supervising a machine’s state to focus on other value-adding activities. This can be translated into the idea of self-regulated machines, which will emit a physical alert (“andon”) whenever human intervention is needed (Liker and Meier, 2006). Feld (2000), also touches this concept when he describes

the concept of automaton, which is a practical consequence of previous. In his words, the “machine stays shut down until a human being intervenes, solves the problem, and starts the machine again”. In the past, signaling devices like paper lanterns were commonly used. Nowadays, with the advancement of science and technology, many industries use electronic devices, armed with an audio and color-coded display that can provide richer and more accurate information. It has also been possible to fully integrate a wide array of complex information gathering and distributing architectures that comprise modern production monitoring systems (Subramaniam et al, 2009).

2.2 Kaizen

The Japanese word, “*kaizen*” translates to “change for the better”. The concept was introduced as part of the lean philosophy, determining that improvements are conducted through small and incremental steps. This ideal contrasts with “*kaikaku*” or “radical improvement” initiatives (Womack and Jones, 1996), which are characterized by being heavily impactful, when supported by significant financial investment and resources.

According to Brunet and New (2003), “*kaizen*” has been found to encompass several key features, however, most can be summarized into three important aspects:

- It is a continuous process. Therefore “*kaizen*” is ultimately tied to the idea of “continuous improvement” since its practice is described as a “never-ending journey towards quality and efficiency”. Berger (1997) suggests that this “journey” can be better sustained through a process-oriented perspective, using proper support and evaluation to exert control. The practical outcomes of this approach include using the workforce’s existent skills and experience, furthered with training; the emphasis and encouragement on improvement efforts and the inclusion of rewards for the achieved results;
- It is incremental in nature, as it was mentioned before. Often, improvements are too small to be measured effectively, however, as Wilson (2010) points out, the key takeaway when using the “*kaizen*” perspective is to consider the accumulated effect of these small changes over time, in producing significant results. A good framework for small step improvement includes the use of standard operating procedures (SOP), and separating improving and standard developing tasks (Berger, 1997). This way, the discipline required to maintain standards can be achieved, and the process of improving work standards can follow a common problem-solving format;
- It is participative. The aim of this practice is to involve the workforce, combining its intelligence to produce meaningful work-life benefits for employees. Top management should be supportive when acting as a facilitator for the involvement process of every individual through a process described, as “mandatory volunteerism” (Berger, 1997). Everyone is required to join, but contributions are voluntary. In practice, broad participation can be achieved with the creation of temporary or permanent groups for problem-solving, and individual suggestion systems for training and motivation.

2.3 Value and Waste

The TPS is an example of a Lean manufacturing system because it advocates improvements that will fundamentally translate into the use of less material, investment, inventory, space and people (Wilson, 2010). In other words, processes become “leaner”, as it is possible to achieve higher productivity and quality with the same, or less, amount of resources. In order to put this into practice, it is important to define the concept of waste and analyze how it can be identified before it can be reduced in any way.

The Japanese word for waste, “*Muda*”, specifically refers to activities that consume resources but end up not producing any value. There is a broad consensus on the fact that this is a subjective concept, and that it is ultimately defined by the end customer. In fact, the whole point of the value chain is to meet the final element’s needs and demands, which are specific in terms of time and therefore, price. Value, by definition, is created by the producers who are committed to providing the right product or service. Everything else is “*muda*” (Womack & Jones, 1996).

According to Carreira (2005), there are three types of activities:

- Value Added: the type which contributes to the process of turning a product into a more complete state;
- Non-Value-Added: activities which do not advance the product into a more complete state and the customer is not willing to pay for;
- Required non-Value-Added: activities that do not add value to a product but are necessary as the customer is willing to pay for them. A common example of this would be testing a product and documenting the process. This is a non-value-added activity that is required and included as part of the manufacturing process whenever the product gets sold.

Reducing waste is a difficult and challenging process, but it can greatly increase a company’s flexibility and responsiveness (Wilson, 2010). One of lean’s most important concepts is the “value stream”. For every product or service, there is a set of required actions before it can be considered as complete. In most processes, it is relatively straightforward to identify the most critical steps for value creation. However, as these become more and more complex, the need arises for a more thorough study of all the different phases required to transform what it is that brings value to an organization. According to Taiichi Ohno (1988), there are seven known types of waste:

Overproduction

According to Carreira (2005) and Wilson (2010), overproduction is the hardest waste to be managed since it will end up affecting the remaining wastes in some way. In various situations, overproduction is a consequence of a premeditated forecast in the hopes of bringing more flexibility to the business, by increasing the responsiveness during peak times. However, when production rises above customer demand, resources are being wasted into finished goods that will not be directly translated into financial gains.

Inventory

Any kind of inventory that is sitting idle, is not adding value to an organization. From raw materials to work-in-process (WIP) or finished goods, if it “does not directly protect sales” (Wilson, 2010), it is considered a form of waste.

Transportation

Frequent movement of people or parts is considered a form of waste. When moving these, the goal will most likely be maintaining the value creation flow. Nevertheless, the only parameter that changes during transportation activities is the location which, by itself, does not add any value.

Excess Processing

This type of waste can occur in two separate contexts. Initially, during the design stage, a product can be over-specified and therefore require more steps until being transformed into a finished goods than it would take, considering what the customer wants. On the other hand,

excess processing might occur at later stages if value-adding activities are being performed using the least efficient equipment.

Defective Parts

Similarly to overproduction, when a defective part is rejected, there is a considerable investment in resources devoted to it which are lost. As Ohno (1988) points out, the loss does not only refer to the part itself but also the energy, time, effort and materials to manufacture it.

Waiting

This type of waste specifically refers to the occasions when workers are in an idle state, not devoting their time into value-adding activities. It is important to evaluate the production flow very closely in order to spot the causes leading to excess waiting time such as stock-outs, failures or poorly balanced production lines.

Unnecessary Motion

Motion, contrary to transportation, only refers to people. When designing a work environment or a set of workstations, it is important to evaluate the need for workers to move in order to perform their routine tasks. A commonly successful procedure would be dividing a workspace into several compound stations, according to the task that is being performed. However, it is important to note that distance is just one of the factors that increase unnecessary motion. The complexity of the motion itself and the discomfort it might cause are also parameters to take into consideration.

2.4 Pull Systems

As previously mentioned, one of the key sources of waste has to do with the disparity between the outputs of the value stream, versus customer needs.

With the introduction of mass production systems by Henry Ford, in the early twentieth century, one of the main objectives was to minimize costs by increasing the volume of production to create economies of scale (Duguay et al, 1997). “Make-to-stock”, or push systems were popular as goods were produced according to a forecasted plan, with the aim of stockpiling the right quantities to instantly meet customers’ demands. Many lean systems still also use variations of this production system for the same reason (Wilson, 2010). The problem is, as it was previously reviewed, that the waste associated with inventory and overproduction are significant when doing so. In order to minimize such wastes, pull systems, or “make-to-order” systems, were part of Ohno’s plan to control produced quantities, as deduced from one of Lean’s pillars: “Just-in-time”. Doing so can prove to be extremely difficult as it involves thorough preparation, training, coordination and close monitoring.

Kanban

The *Kanban* system is a visual tool that allows for a better understanding of the inventory replenishment process. This will allow inventory control without focusing on non-value-added activities such as scheduling or planning. It is seen as an example of a practical application of “Just-in-time” combined with a pull system perspective that is highly versatile in terms of use cases. The essence of the *Kanban* is a signal that will trigger a replenishment activity.

In order to effectively apply this method, it is necessary to perform the required calculations. The basic formula for the *Kanban* quantity corresponds to the period of usage, multiplied by the replenishment time, plus safety stock (Carreira, 2004). The flow of the *Kanban* system is usually from a downstream to an upstream perspective. According to Feld (2000), the typical *Kanban* system is ruled by the following guidelines:

- The *Kanban* signals an authorization to begin work;

- It controls the amount of work in process that is part of the current flow;
- Demand is what starts the job releasing process;
- Material flows in a “First-In-First-out” (FIFO) logic;
- *Kanbans* will control the manufacturing lead time through an imaginary queue;
- Defective items are not allowed in the queue (Quality Control).

2.5 5S

The 5S methodology is both a philosophy as well as a set of guiding principles, which can mark the beginning of significant changes within an organization, by improving processes through cost and pollution reductions, including increased safety and overall efficiency and effectiveness (Michalska and Szewieczek, 2007). Its implementation is highly dependable on providing correct training to the people involved. It has proved to be a very successful initiative in organizing workplaces of various settings, as it is a highly accessible and a low-cost methodology. It can be very empirical, and it is highly based on creative problem-solving techniques using mainly observation (Ablanedo-Rosas et al, 2010).

Seiri (Sort)

The first S refers to the elimination of unnecessary materials, which are not used in the workplace, by sorting and keeping only the essential ones. The rest can be either stored for later use or discarded. Sorting will increase productivity through an increase of the available space that was formerly occupied by nonconforming materials or damaged tools. In what concerns the working time, more is spent on useful activities rather than others related to cleaning or searching. In some situations, stops might occur if an essential item is lost. Sorting initiatives commence with the use of red labels by workers, used to identify the “unnecessary” materials.

Seiton (Set in Order)

Setting in order, similarly to sorting, will help by resulting in a clearer and more organized view of the workplace. Items must be divided according to their relevance and accessibility to the worker that is using them. This will increase productivity by shortening the time between seeking and finding what is necessary to perform the job. Seldomly used items must be stored at a further location, however, the frequency of use for these items can help decide the distance at where they will be stored and should always be accompanied by its correct identification.

Seiso (Shine)

A clean workplace is key for efficient processes, as it was analyzed before. Not only it becomes easier for the worker to perform its task, but it is also easy to convey information about the performed activities, which can help greatly in identifying new sources of waste. The same can be said about the way current waste sources are being evaluated as well as the maintenance state of the equipment that is being used. If this is the case, then it becomes easy to manage potential sources of damage, stops or even accidents, contributing to a better working environment.

Seiketsu (Standardize)

One of the best ways to bring order to a workplace is to create instructions or procedures that can be easily followed and understood by every worker, who is directly involved with the respective process or activity. When engaging in standardization initiatives, processes must be closely monitored in order to ensure that useful information is being transmitted. After this, they must be disclosed in constantly visible places. The fourth S is an important measure when defining the course of action. By having a reference, workers spend more time performing

value-adding activities, instead of asking questions that can emerge when being doubtful of their work.

Shitsuke (Sustain)

Sorting, cleaning and introducing procedures in the workplace, are core improvements that the 5S methodology can offer, but its true success comes from making sure that these will endure. Continuous improvement can only be truly achieved if the people involved are consistently conscious about the actions to perform in order to sustain such improvements. Self-knowledge and self-control play a role in this process as well as internal communication and relations. The morale and awareness inside a workplace can greatly increase if everyone can be involved. Routine inspections can be periodically conducted in order to evaluate the results produced and help with identifying improvement points.

The human factor is a very important part of lean methodologies, and this is no exception. Top management and personnel commitment are the pillars when implementation challenges. The idea that quality must be a lifestyle rather than an operational tool is important in including the 5S practice as part of the strategic planning of an organization. As it was previously analyzed, the implementation of this technique is only possible through proper training and communication, before implementing advanced quality and continuous improvement philosophies (Ablanedo-Rosas et al, 2010). According to Chapman (2005), most 5S initiatives ended with the first 3S's as organizations assume that the visual factory standards of organization and cleanliness, will be automatically met. The last two S's are rarely formalized which ends up contradicting the idea of a self-explaining, self-ordering and self-improving workspace. With this in mind, regular audits, schedule commitments or check sheets must be implemented in order to make a habit out of the 5S system and sustain its effects for as long as possible.

2.6 Visual Management

“People are visual creatures” (Liker and Meier, 2006). This is the basic principle that explains the reason why visual controls are needed, even though information technology is highly used and accessible. Using a computer screen as a means to convey information can prove to be disengaging because it drives away the attention from the workplace.

According to Liff and Posey (2004), visual management encompasses more than just visual stimuli, including all human senses; resulting in a wide variety of use cases. On one side, these can be used to communicate relevant metrics about the processes that are being performed, or simple visual guides to locate the correct tools or equipment. On a more holistic perspective, the end result should be an effective way to communicate the organization's vision, core values, goals and culture in order to improve general performance.

As Liker and Meier (2006) point out, creating an effective visual communication system can prove to be a daunting task because it is subject to misinterpretation and, consequently, misguidance. Therefore, it should be noted that this will always be an agreement on a standard that has to be broadly discussed and accepted. With this idea in mind, the functions of visual management (Tezel et al, 2009) can be summarized as the following:

- Transparency: the ability to communicate effectively. In practice, it can be translated into the correct distribution of information among people and their workplaces instead of leaving it hidden in their minds. Some of the practical impacts of transparency can range from more coherent decision making, autonomy and increased morale and participation (Moser and Santos, 2002).
- Discipline: allowing the correct procedures to be made as a habit for workers, instead of engaging in punitive actions towards non-conforming ones. This will certainly reduce

wasted associated with asked/unasked basic questions (the what, the where, the who, the how, the how many and the then) and several workplace identities (space, tools, equipment, material, and machinery).

- Continuous Improvement: creating the right conditions to facilitate small, incremental, sustained and organization-wide innovations. This idea contrasts with sudden improvement leaps that require considerable investments and learning curves.
- Job Facilitation: in an attempt to physically or mentally ease people's efforts on routine tasks, various aids can be offered to help them perform the correct procedures. As seen before, humans are constantly being stimulated in various ways, making them prone to mistakes. If they are let without a proper visual management system, they cannot be expected to abide by current standards, or even identify non-conformant ones.
- On-the-job Training: the work environment becomes a fertile ground for practical learning initiatives. Workers learn from their own, or shared, experience as they become acquainted with the application of the new visual management system to their daily activities, by gaining tacit knowledge (Choo, 1996).
- Creating shared ownership: will contribute towards the revitalization and creation of an open and collaborative work culture inside the organization. This is because aiding elements convey a message of support for the employee, which will then result in a feeling of possessiveness because of the emerging psychological ties between these and their workplace. Their involvement will result in a joint working environment where new synergies can emerge, supporting the shaping of new goals and values.
- Management by Facts: using metrics based on real data and statistics that can translate the current state with maximum verisimilitude, instead of using subjective judgment or vague and confusing terms.
- Simplification: visual management can help decipher the complexity associated with the external environment, by presenting a way to structure and condense the organizational realities into simple representations. Their sustenance and regular updating are key to create an effective feedback mechanism, which is essential to continuous improvement.
- Unification: by contributing to the removal of barriers or boundaries across the organization and creating empathy through effective information sharing. This idea is compatible with that of a shared working environment where people are sensitive to each other's roles, contrasting to a fragmented and silo mentality approach since managers "will more clearly see the strengths and the weaknesses of their subordinates. Subordinates will understand the expectations and the priorities of their managers better" (Tezel et al, 2009).

Graphic Work Instructions

Graphic work instructions are intended to be part of visual management with the aim of aligning everyone with the current work standards. In a more functional perspective, these act on a specific subset: "transparency", "discipline", "job facilitation", "on-the-job-training", "creating shared ownership" and "simplification". This is because they are meant to be part of the working environment as an extension of the value-adding activities performed when it comes to creating the right habits, providing guidance and a solid venue for continuous improvement (Tezel et al, 2009).

The documentation process of work procedures can be done using different formats. Text is the most popular, for its simplicity and accessibility, however, it is also one of the least stimulating. Conveniently, with the current advancements in image manipulation and capturing technology,

documentation becomes richer as it is possible to use color, complex graphics, and symbols; that will certainly make it more appealing to human beings. This, combined with the use of software, will speed up the process of updating such documentation, allowing it to be easily maintained and streamlining the iterative feedback process of their improvement (Feld, 2000).

2.7 Spaghetti Diagrams

One of the challenges of optimizing working procedures has to do with motion. As previously presented, it is one of the known sources of waste according to Taiichi Ohno. Wilson (2010) reminds us that, when it comes to people, it not only important to measure the distances themselves but also the ergonomic conditions in which they are traveled. If workers are not capable to engage in routine tasks without feeling pain or discomfort, they will not be productive, not to mention the exposure to security and health hazards.

Spaghetti diagrams are an important tool to visualize and analyze the movement of goods, materials or people, which are typically represented by a line drawn on top of a bi-dimensional representation of the current layout. These lines are usually drawn by hand but can also be automatically represented using a coordinate system. The interpretation of this diagram can be useful to create improvement opportunities that will result in more efficient work organization and workstation layouts, with better space utilization and cost reduction (Senderská et al, 2017).

2.8 Total Productive Maintenance

According to Carreira (2005), maintenance is described as a set of activities performed on a piece of equipment, or a machine, which allows it to keep working in the best conditions. He also describes the nature of maintenance as being preventive, rather than corrective. This is because when stops occur due to failures or malfunctions, the domain of maintenance is left, and repair is the only solution.

Total productive maintenance is a lean tool necessary in a manufacturing environment, used to increase overall equipment reliability, productivity, and quality; by reducing the impact of the six known equipment-related losses (Wilson, 2010): breakdown losses, setup and adjustment losses, minor stoppage losses, speed losses, quality losses and startup yield losses.

Total Productive Maintenance (TPM) encompasses preventive maintenance, corrective maintenance, and maintenance prevention (Feld, 2000). The first type refers to all scheduled activities that will aim at preventing breakdowns. Corrective maintenance concentrates on the repairing aspect. Finally, there is maintenance prevention, also described as “autonomous maintenance” which refers to the daily activities performed by the users of a specific equipment in order to monitor its condition. This component, mentioned in the last paragraph, is an essential part of TPM because it fundamentally represents the distinctive part of this methodology. The goal is to extend maintenance activities to a larger group of people inside an organization, especially those who use certain equipment on a regular basis. These people, provided with proper training, when trusted to vouch for the quality of their tools of trade, will be the most qualified in detecting anomalies and keeping it in the best working conditions. Autonomous maintenance tasks must be flexible and simple enough so that workers stay motivated to perform them together with what is their daily responsibilities.

2.9 Warehouse Design

In many situations, due to cost minimization and lead time fulfillment, building inventory is a better option to serve customers than from direct orders. Warehouses are presented as a versatile component since these can be used for many other purposes such as goods consolidation, aid in providing a smoother flow for volatile market activities, cross-docking points, returned goods

centers or even service and repair. No matter the function, it is broadly accepted that their goal is to cover increasingly higher service levels while achieving the required speed, accuracy, and quality requirements (Baker and Canessa, 2009). Currently, logistics constitute a significant part of the overall costs, contributing immensely to the competitiveness levels of an organization. Other recent trends such as increased product variety have been threatening the efficiency of logistics operations, which intensifies the need for clearer and more structured approaches to the hereby mentioned topic (Rowenhorst et al, 1999).

The five most common decisions to focus on are the overall warehouse structure, its sizing, and dimensions (including its departments), determining its layout, selecting the proper equipment and operational strategies. Performance evaluation is also critical and should be taken into consideration during both the design and operational phases, especially in what concern costs, space utilization, throughput and service (Gu et al, 2010).

Warehouses can be viewed according to three different perspectives (Rouwenhorst et al, 2000): processes, resources, and organization. The first one refers to the different phases in the item flow, as follows:

- Receiving: happens right after goods arrive to be checked or repacked before being moved;
- Storage: in economical quantities in a reserved area, or smaller ones in a forward area to be easily retrieved. The act of moving a product from the first to the second area is called replenishment;
- Order picking: retrieval from storage to be sorted or grouped according to the customer (consolidation);
- Shipping: when products are checked, packed and loaded to be transported to the end customer.

The resources perspective encompasses all of the means that support their activities such as storage units, storage systems, picking equipment or order picking auxiliaries, warehouse management systems, material handling equipment, and personnel. Finally, the organizational aspect of warehouses focuses on planning and control activities concerned with the process flow and other specific organizational policies.

According to Baker and Canessa (2009), there are some recurring themes on warehousing design methodologies. Firstly, these are highly complex problems to be solved. Often an interrelated step-by-step approach is used to find solutions that need reiteration, because finding the optimal one might be impossible. These authors propose a framework accompanied by a set of tools and key references for problems that were reviewed:

- Define system requirements: clarify the scenario and plan the strategy, including the role of the warehouse;
- Define and obtain data;
- Analyze data;
- Establish a unit load to be used;
- Determine operating procedures and methods;
- Consider possible equipment types and characteristics;
- Calculate equipment capacities and quantities;
- Define service and ancillary operations;
- Prepare possible layouts;

- Evaluate and assess;
- Identify the preferred design.

Hassan (2002) presents a complementary framework that is more focused on how to detail space requirements depending on material classes. When looking at these requirements, there are key aspects to consider such as the different storage partitions, aisles, I/O points, docks, and zones. Similarly, Baker and Canessa's (2009) highlight that design decisions originate combinatorial problems that are often hard to solve optimally. There is a broad consensus on the fact that there are many factors influencing the latest, without excluding their interactions. There is no doubt that it represents a daunting task but necessary in order to increase productivity levels by smoothing the operation through essential characteristics such as modularity, adaptability, accessibility, flexibility, and compactness; in order to improve space utilization and reduce congestion and movement.

ABC Analysis

A very common practice in a lean environment is to consider different approaches on organizing and managing inventories, processes, and people. Naturally, as it was analyzed before, in order to reduce overall waste, it is imperative to understand that different activities require different investments of resources in order to produce their respective outputs. By making sure that the right amount of energy, time or currency is devoted, maximum efficiency and quality can be guaranteed whenever needed. Categorization is a popular method in order to segregate how different units are handled in an inventory system, for example (Feld, 2000).

One of the most popular examples of categorization is the ABC-analysis. Since 1951, it has been used in many applications, especially in warehousing, when choosing the best course of action to meet customer demand and produce better forecasts.

The Pareto's Principle or the 80/20 rule is the base for this method. According to it, 80% of the effects come from 20% of the causes (Sanders, 1987). This can be translatable into the idea that the most important part of an inventory system, the one that brings more profit and the one that should be more carefully monitored to avoid stockouts; should fall within this figure: category A. Items belonging to category B can be more loosely managed, allowing for some shortages. Finally, category C items are usually the slowest movers, non-demanded, or even obsolete ones (Zenkova and Kbanova, 2018). The classic algorithm for this method starts with sorting goods by their revenue in decreasing order. Next, the respective share is calculated using the total revenue. Lastly, the cumulative share is calculated, and the categories are chosen as follows: A until 80%, B until 95% and C for the remaining 5% (Zenkova and Kbanova, 2018).

3 Current Situation

In the present chapter, a more detailed description of the logistics department and its activities will be conducted. Beyond the necessary understanding of the underlying processes, it is also important to comprehend other relevant topics concerning the current situation that have led to the proposal of new improvement solutions, such as the current division of labor and the main sources of waste.

The involvement and constant presence in the location where the project was developed were key in understanding the functioning aspects of the different activities and its intricacies, frequent problems and difficulties that would often arise, including suggestions that were given by some of the employees.

3.1 The Subunit

The woodcutting tools subunit of Frezite is divided into two main facilities: one dedicated to the production of circular saw blades (category 2 products), and another to produce the remaining six groups that were mentioned previously in the introduction (category 1). Operationally, the same subunit is supported by the following software solutions:

- Infor's "M3", the enterprise resource planning system (ERP): used for tracking all goods;
- "Narum", the customer relationship management system (CRM): used to manage complaints, quality audits and order tracking;
- "Autoflow", the shop floor management system (SMS), for production-related activities.

Production is triggered by the different client orders that must be previously accepted by the commercial department. However, there are some exceptions. Standard items followed a make-to-stock policy, and part of the orders were automatically introduced since these had a specific weekly schedule. Some of the company's clients (mainly local manufacturers or vendors) would purchase directly from the front office, and their orders always had priority over the remaining ones. In this case, products would be simply packed and delivered.

In order to provide an overview and better understanding of the production processes (finished goods transformation) Figure 6 contains a visual representation of both. For simplification purposes, since the productive aspect was not included in the scope of this work, the different involved steps have been named according to their functional aspect and are not going to be described in detail. The same can be said about supplying activities.

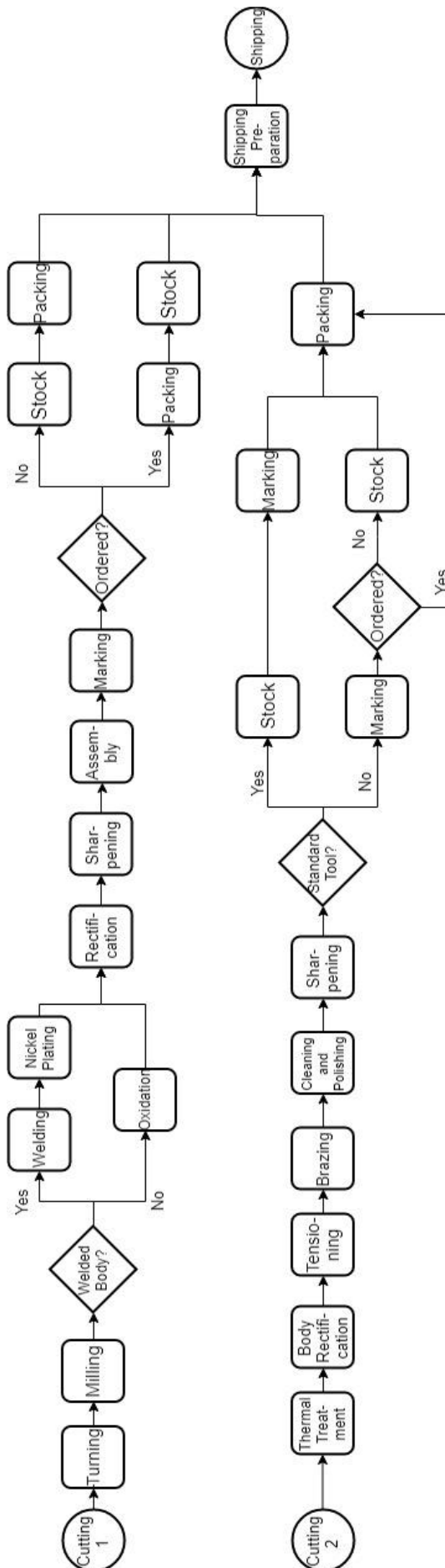


Figure 6: Production Processes Overview: Woodcutting Tools SBU.

Every production job is initiated with its respective manufacturing order, that is carried alongside the product (or products) until it is stored or packed. This document also includes the technical drawing and a quality control checklist. Category 1 and 2 products start being produced from raw steel that comes in two different shapes, consequently following different cutting procedures (“Cutting” 1 and 2, respectively). The productive flow is conducted separately in its corresponding facility, as mentioned earlier. The last steps, however, namely the phases which proceed “Assembly” (category 1) and “Sharpening” (category 2) are conducted inside the logistics department.

3.2 The logistics department

As previously mentioned, the logistics department is part of the oldest business unit of the company and is located on a building that is dedicated to the production of wood cutting tools (that do not include circular saw blades). It is often referred to as simply “the warehouse” by the collaborators of the company, since most of its area is dedicated to storing items depending on their purpose. However, this department also comprises other activities, including some connected with the production aspect, that have been included over the years in order to provide more flexibility to the subunit’s global operation. In total, 10 collaborators work in this department:

- One head of department, assigned with more bureaucratic tasks (worker 1);
- Shipping preparation: one worker for the Iberian market (worker 3) and another for the remaining ones (worker 2);
- Packing: one for category 1 products (worker 4) and one for category 2 (worker 5);
- Receiving/General Storage: one worker (worker 6);
- Production supplying activities: one worker (worker 7);
- Marking: two (in different shifts: morning and evening respectively) for category 1 products (workers 10 and 8) and another for category 2 (worker 9);

It is important to note that workers 7 and 10 start their schedule two and a half hours before the rest, while worker 9 starts one hour before; because their work had to be synchronized with their preceding production activities. This would ensure that there was enough work in progress (WIP) for the subsequent steps.

As evidenced by Figure 7 the logistics department was placed in an area of the building that is the closest possible to the exterior (area highlighted in red near number 0), in order to facilitate the process of moving goods, where the connection is made through a gate and a revolving door. The latter is exclusively used by the workers of the company, as movement is only triggered by the correct reading of a personal company id card, through a scanner. The remaining personnel enter directly to the entrance hall and have their access limited to this area of the facility, unless given special permission. This group of people also includes local customers who could buy their products directly through the counter, at the front desk. The gate (number 0) is open/closed whenever a vehicle needs to load/unload goods.



Figure 7: General current Layout.

Still within Figure 7, there is an area highlighted in red, on the top, that is supposed to exist for storing purposes. Typically, the items that are left there were rendered either obsolete or not used very frequently. Still, this is an area to consider for the current situation analysis since it is managed by the department where the work hereby present was conducted.

Highlighted in green is the production area, which is divided by functional sections, in accordance with the production flow. The area highlighted in yellow is dedicated to the administrative spectrum of the subunit.

Figure 8 shows a more detailed layout of the logistics department. As presented, it can be divided into eight distinct sections, that will be subsequently described in more detail according to the provided numeration. Numbers 1 and 10 represent gates where people and goods are moved across. The first connects with the production area that was formerly presented. The second connects with the exterior. Section 9 represents the front office area, which is not part of the logistic department's activities *per se*, however, it is somehow connected with some of them, especially the direct ordering process that was described earlier.



Figure 8: Logistics department Layout.

Section 2 – Marking

Marking is one of the final steps of the production flow for all the items, and it is done using laser engraving machines that are managed through a computer interface. All operators must set up the engraving stands according to the product's size before starting the operation. Information such as the product's serial number, dimensions, and the logo, are then included in the engraving operation using the proper software. Despite the similarities between procedures, they differ depending on the product category.

On the left side of Figure 8, highlighted in red, is the area dedicated to circular saw blades marking. The worker uses both the laser machine and a robot connected to another laser machine, to aid the process. Circular saw blades are produced in higher amounts for each serial number, as 65% of the orders are for standard products (typically engraved with the company's logo), which justifies the installation of the previously mentioned aid. However, most of the marking process is managed by the operator since the robotic arm cannot withstand much heavier loads, and not all client logos are available in the laser machine's software. Circular saws arrive at the logistics department after being produced in carts that are pushed by an automated guided vehicle (AGV), along both facilities (Figure 9). The AGV can push several fully loaded carts, however, the queue cannot be too long otherwise it might crash, and the movement will stop. Standard products of this category are destined for stock and are only engraved later depending on the order, which provides more flexibility to this operation. When the marking process has been finished, carts loaded with engraved circular saws are finally pushed by the worker to an area that is close to section 5, where they wait for the proceeding stages.



Figure 9: Circular saw blades cart, robotic arm (Section 2), WIP, AVG (left to right).

On the right side of Figure 8, highlighted in green, is the area where category 1 products are engraved. Since nearly 70% of these products are customized, the average weight loads are lower because the ordered quantities are also lower. Despite this, there are some exceptions, although the produced amounts for each reference, in these situations, rarely exceed the count of two products. Due to the smaller volume and the fact that the logistics department is in the same facility where these are produced, the transportation of such products is more efficient since it can be done using smaller reinforced plastic boxes, that are automatically moved along a conveyor belt when arriving the section (Figure 10). After being marked they are pushed manually through a gravity roller conveyor that sits next to the automatic warehouse (Section 3). During the evening shift, worker 8 would also conduct the marking of category 2 products whenever necessary, mainly using the robot.



Figure 10: Conveyor belts, Section 2.

Section 3 - Automatic Warehouse

The automatic warehouse section is divided into four units. The interface between these and the operators is done using a computer for each pair, equipped with a specific warehouse management system (WMS) named “PowerPicker”, that is integrated with the ERP. Each one of the four units is divided into compartments that resemble drawers (Figure 11), which are vertically stacked. Inside them, separators hold different items according to their function and size.

Units 3 and 4 store materials which are destined to supply most of the production activities that occur in both facilities of the subunit. Worker 7 is exclusively assigned with the task of receiving orders from the various production units and fulfilling them using the previously mentioned stock, as well as maintaining it. Frequently, the same worker makes use of a metal cutting machine (Figure 11) that was envisioned for less demanding cutting operations, in order to dimension some of the ordered materials such as blades and small steel cylinders. After

gathering the required orders, this worker must transport them using a cart, along the production area, in order to deliver these to their respective “customers”.



Figure 11: cutting machine, automatic warehouse (left to right).

Units 1 and 2 store mainly category 1 products including other related articles, such as accessories that must be packed together with the former. The replenishment process of these types of goods is done by multiple workers, depending on their availability and if their responsibilities are tied to the product’s type. Removing from the stock is usually done by the operators assigned with shipping preparation activities, when the product has been packed before storage; otherwise, it is done by worker 4.

Section 4 – Packing Items Storage

This area of the department is dedicated to storing mainly cardboard boxes and fillers that would be used for packing or shipping purposes (Figure 12). However, still within this area, other items can be found such as plastic boxes for smaller saw blades, bubble wrap, and foam rolls. There was also a designated area to temporarily place large orders that would wait inside big wooden boxes, which took longer to prepare.

Since items are stored vertically, on top of pallets (European standard sized), their replenishment and storing procedures must be conducted with the use of two important pieces of equipment: a manual pallet transporter and an electric pallet stacker. Worker 6 is allowed to drive warehousing equipment. This permit is necessary in order to use the previously mentioned equipment in the required safety conditions. Worker 3 has the same permit. As such, both often move storage units within this section, whenever one of them cannot do so. Frequently, this led to situations where the pallets are placed in different locations, or simply left on the floor, causing congestion or inability to perform the previous activities. Additionally, there was no clear identification system in place for more than half of the slots, contributing to the same problem.

Section 5 – Circular Saw Blade Storage

In order to provide more flexibility to the logistics operation, an area dedicated to storing standard circular saw blades was envisioned (Figure 12). Since these are usually produced in higher quantities, it is also impractical to accumulate carts for several reasons such as the obvious waste of space, unnecessary congestion, lack of safety and poor conditioning of the materials.

This had been a recent implementation that was still under development. Depending on the production planning decisions, in what concerns this product’s category, the need to provide an efficient identification system and new action plans to accommodate new references was a

constant challenge. Additionally, some of the procedures connected with the quality of the stored goods were not being followed, which could cause severe damage to the products.

The task of maintaining stock levels within this section was part of the responsibilities of worker 5. These products would be manually retrieved or stored according to the needs. When the previously mentioned carts were empty, they would be pushed by the same worker to an area near gate number one, where they got connected with the AGV to be transported back to the other facility.

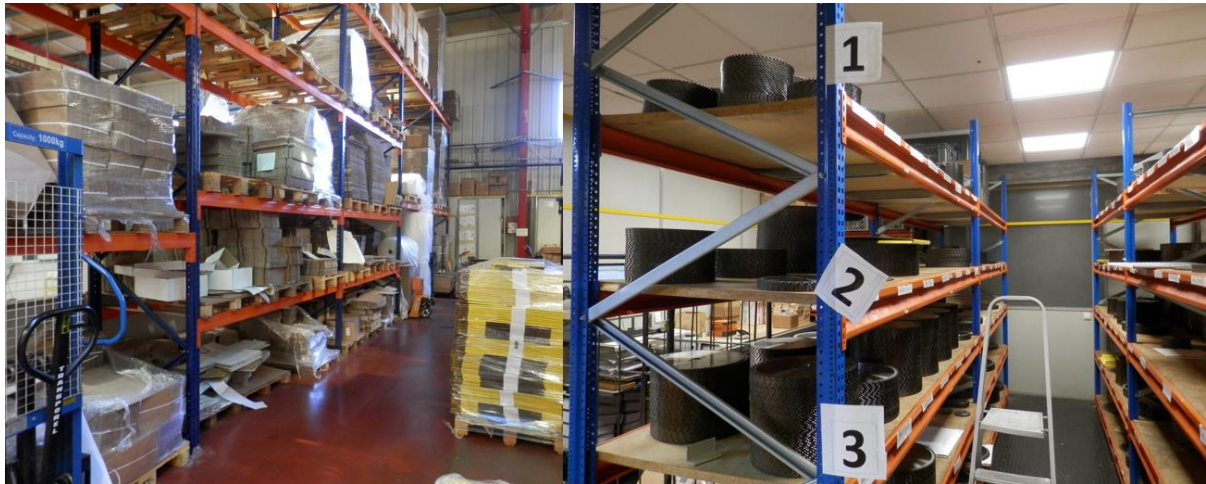


Figure 12: Sections 4 and 5 (left to right).

Section 6 – Packing

Before being distributed, products must be packed in order to make sure that arrive at their destination in full working conditions and with minimal damage. Most of the packing was done using cardboard boxes and fillers, as previously mentioned. However, other items were also used such as plastic cylinder cases, smaller plastic cases, and wooden rectangular boxes. This area of the department was assigned to the least experienced and qualified workers in the department, who were not yet familiar with all working practices. As a result, their work was inefficient and could disrupt other activities whenever doubts arose or rework had to be done.

Before packing, workers had to do the picking and print the respective labels. The packing process followed a first in first out logic (FIFO) in accordance with the orders, unless workers were instructed otherwise by their superiors. The information on what to pack was available in the respective order invoices that were printed and shared by the department's head worker. When the packing was finished, both workers had to keep the manufacturing orders for record purposes and shred the drawings using a machine.

Both workstations were supported by a shelf each, where they could keep a closer stock of packing items, resembling line-side storage, that also had to be replenished by the same workers. The initial idea of bringing both stations together was to promote cooperation between the two workers, who could help one another whenever needed.

Category 1 products were packed in the subsection highlighted in red by worker 4. Comparing with the other category, the number of available references for packing-related items was considerable. Additionally, the proper installation of some of the cutting tools implied that several items had to be packed with their respective accessories: mainly metal washers and keys. This would add more complexity to the process of organizing and memorizing both the references and their associated procedures. However, most of the labels for the products that had to be packed had already been printed when these were marked, and the picking process was easier because of the lighter loads and shorter traveling distances.

Category 2 products were packed in the area highlighted in green by worker 5. The procedures involved were easier to understand. Nevertheless, since a considerable number of circular saws were stored without being engraved, the worker had to frequently transport these into the marking section, which would delay the packing process. Since most of the transport was manual, picking was a more tiresome process. A computer was installed here, which was used by both workers to print labels and update the ERP records as the packing references were being consumed.

Section 7 – Shipping Preparation

Packed products would be manually placed on a shelved area, in their respective client slot (area highlighted in yellow), while heavier loads would be transported using a flat cart. In this area, shelves were divided using labels for the different clients. It is important to mention that not all products were distributed by carriers, but also by some of the company's vendors (Iberian market) who also had a reserved space within these shelves.

Workers 3 and 2 were tasked with shipping preparation activities (Iberian market and the rest of the world respectively). This area (highlighted in red in Figure 8) was equipped with two computers where both workers could get relevant information of the clients or shipment costs and print the adequate transportation documents (Figure 13). Frequently, both workers did part of the picking (mainly category 1 products) or aided with packing, whenever these were delayed. Packages had to be checked, weighed and packed together in bigger volumes according to their orders. The ones which were outside of the EU were bigger on average and the documentation had to be more thorough, hence the labor division.

Worker 1, the head of the department, was stationed in the green area of this section. Most of his responsibilities involved processing the order listings that were on display, printing invoices, credit notes, budgets and coordinating the work among the other sections. Other tasks included dealing with daily problems and delays since he was at the forefront of communication with other departments and entities.

Section 8 – Shipping/Receiving

After making sure that all products were properly accommodated within their package, they would be moved to this area, using manual load carriers, where they would sit before being picked for transportation (Figure 13). This would be carried out by workers 2 and 3, after shipping preparation. Depending on the incoming entity that oversaw the transportation of the merchandise, products would be placed in their designated slots.

Worker 6 was responsible for registering, processing as well as storing most incoming goods. The area highlighted in blue in Figure 8, is where smaller loads would sit next to, while the ERP records were being updated. Bigger loads, however, would be transported using a forklift by the same worker, using an alternative route that would take them through a wider gate, into the facility, and then through gate 1, into the logistics department. In seldom occasions, the receiving process would take this worker into the other production facility. Since registering could only be done using his computer (in the former blue area), keeping track of all the associated records would be a daunting task.

Since both shipping and receiving were done through the same exit and placed on the same area, this would lead to congestion at various times of the day. Additionally, the process of loading goods into the transporting vehicles was impractical and tiring, because there wasn't a direct interface with the exterior such as a loading dock.



Figure 13: Sections 7 and 8 (left to right).

3.3 Other sources of waste and improvement opportunities

During the initial stage, while the analysis of the current state was being performed, there were a few observations worthy of mentioning.

Even though there had been several attempts and remainders of Lean initiatives, sustaining such improvements was a daunting task. The difficulty with establishing clear objectives and courses of action was often causing unnecessary conflicts or tensions that were inhibiting teamwork.

The logistics department encompasses many different activities, where the know-how is very specific. This would also often result in communication problems because work procedures were complex and could not be easily translated. This was also inhibiting cooperation among coworkers. Lastly, the team was also imbalanced in terms of working experience, with less experienced workers being the focus of disorganization due to their absent preparation.

3.3.1 Complaints Analysis

One of the expected outcomes of the hereby presented work was to reduce the number of external complaints. This was a key aspect in what concerns the relationships with some of the company's clients. The required data was acquired and studied with the support of the CRM.

Since February of 2018 until the start of the project (February of 2019), the logistics department was the third department of the subunit with the highest count of external complaints, with also the third-highest associated costs. The causes for the complaints had been grouped in the CRM according to the following categories, by descending order of importance:

- Lack of the right procedures (50%). This includes cases where orders were incomplete or wrong because there were mistakes when counting the items. The remaining ones had to do with missing accessories in the product's package, mainly metal washers (category 1 products);
- Inadequate preparation of work (33%), which was resulting in damage to some of the products, including two accidents;
- Incorrect packaging (17%). Products were either shipped inside the wrong package, or groups of equal products were shipped inside different package types.

3.3.2 Work Sampling Analysis

Several data points were collected in order to have a clearer picture of each worker's daily routine activities (presented in Appendix A). This sampling method did not follow any specific methodology other than observing and measuring the different activities in terms of outputs and time of completion, as well as the frequency in which these were being performed.

Workers were shadowed for a total of 50 hours during the previous stage. Many intricacies and sources of variability were found in the studied procedures. However, the required time to perform a thorough and complete analysis would exceed the given timeframe for the project. Nevertheless, the information obtained was still useful to prioritize the improvement efforts and support some of the later findings, that emerged with the use of other analyzing methods. As such, there are some key points to highlight:

- Workers 2 and 3 had to wait approximately 15 minutes daily, because of packing delays;
- Worker 6 spent close to one hour per day, walking and transporting goods;
- Worker 4 spent on average 30 minutes helping worker 5. Fetching items for packing purposes took nearly 15% of the time, including motion. This happened because the most used items were further from his section, and whenever an item got replenished there was not a clear identification on its location.
- Worker 5 spent 10% of his time fetching the required items for packing. Despite there was more organization, the quantity was higher, hence the difficulty. Nearly 23% of the working time was devoted to retrieving category 2 products for section 5 and sending them to section 2. This had to do with the daily ordering process, specially the interruption of the flow whenever an order came from the front office, because these had priority;
- Both workers 4 and 5 were wasting time whenever they needed to find the correct slot to place packed goods (shelves area, section 7). This was because it was hard to memorize all the locations, which kept changing depending on the occupied space.
- Whenever something had to be stored/retrieved at the extra storage area, the process would take around 30 minutes. This was due to the lack of organization and congestion in this area, because pallets were frequently left on the floor;

3.3.3 Spaghetti Diagram Analysis

For simplification purposes, the analyzed movements which have been documented (Appendix B), were constrained to the facility where the project was developed.

Workers 8, 9, 10 were mostly confined to their workstations. Worker 9 would seldomly enter section 9 to deliver smaller engraved products by hand or push the carts as previously mentioned.

Similarly, worker 1 would be mainly at his desk, processing orders, printing documents, or communicating. Usually, the reason for him leaving this area would be the resolution of occasional problems, especially related with doubts on category 1 packing procedures, or urgencies in either retrieving certain items from the automatic warehouse or sending unmarked products to section 2.

Workers 2 and 3 also helped with packing or picking activities, as previously mentioned. Since the shipping preparation process of Iberian orders was less time-consuming, worker 3 was more cooperative which is evidenced by the corresponding diagram.

Worker 7 would spend most of his time working between the automatic warehouse and the cutting machine. The increased traveling distance was due to the need to supply the remaining production sections. In previous iterations of the facility's layout, units 3 and 4 of the automatic warehouse occupied a more central position, however, it changed due to the nature of the production processes and the need to create room for other sections.

Worker 6 had the highest traveled distance of all the workers, which was not necessarily covered on foot. It was clear that the area where products were processed after being received was too small, and there was a need for a better mechanism to ensure his mobility. This was

because there was no other way than to memorize or write on a piece of paper all the records to be updated on the ERP, whenever there was the need to move away from the logistics department for storing goods.

Worker 5 would move towards section 4 from behind the supporting shelves because it was the least congested corridor. Worker 4 would only resort to the respective supporting shelf from behind because a “wall” of containers with plastic capsules were blocking the direct access, as will be shown later. Since this shelf was not organized, whenever there was the need for a specific cardboard box, the worker would have to move directly towards section 4, where more time would be spent finding the correct reference by comparison or direct measuring (taking up to 3 minutes, on average). Despite this worker’s efforts of bringing more than what was needed, in order to avoid repeating the same movement, some of the items were not used very often; hence the waste of space and congestion occupied by what was left. Comparing to worker 5, worker 4 would move more often towards the circular saw blade production facility to retrieve category 2 items from their stock (since there wasn’t enough space for all the series of products stored in section 5). This was because, often, this task was performed to help worker 5 fulfill the orders, however, these cases were not so disruptive. The same can be said about the use of the shredding machine, which was positioned near category 1 marking stand (section 2). However, in this case, the tendency was to ignore its use until there were too many papers to be shredded, which would increase the time to complete the task (taking between 2 to 15 minutes). Lastly, the extra storage at the end of the facility was also accessed at least three times a day by both workers, since some of the items were eventually necessary (mainly wooden boxes).

3.3.4 ABC Analysis

In order to understand the consumption rates of some of the items an ABC analysis was performed to reorganize the placement of the different goods that were being stored in the department. The data was obtained in collaboration with the purchasing department. Consumed quantities were grouped by their daily average, over a year (starting on March of 2018). This period was considered because of its relatively narrow time frame in what concerns the inclusion of recently adopted items. A total of 123 different average daily consumption rates were analyzed.

Most of the products included in category A were related to the packing processes (category 1). Once again it was noticeable that most of these items needed to be closer to worker 4, and that their respective consumed quantities were superior to what was initially thought. Additionally, there were cases of other references taking up too much space because the needed quantities had not been adjusted for over more than 18 months. For confidentiality reasons, it was only possible to disclose the information displayed in Figure 14.

Referência	Descrição	Cons Diário	%cum	Categoria			% Refs	% Cum Refs
EM91.173.173			11,20%	A	A	até 80%	13%	13%
EM91.173.000			21,14%	A	B	até 95%	15%	27%
EM91.218.185			26,32%	A	C	até 100%	73%	100%
EM52.15			31,43%	A				
EM29.01			36,13%	A				
EM91.218.000			40,11%	A				
EM42.01			43,14%	A				
EM29.02			46,00%	A				
EM91.288.255			48,35%	A				
EM52.12			50,66%	A				
EM52.14			52,90%	A				
EM52.06			55,12%	A				
EM52.16			57,27%	A				
EM29.03			59,36%	A				
EM60.01			61,38%	A				
EM52.13			63,09%	A				
EM29.04			64,75%	A				
EM90.175.040			66,28%	A				
EM76.02			67,73%	A				
EM52.17			69,18%	A				
EM91.173.145			70,53%	A				
EM60.02			71,95%	A				
EM63.02			73,17%	A				
EM91.288.000			74,39%	A				
EM61.09			75,53%	A				
EM52.18			76,68%	A				
EM08.01			77,63%	A				
EM52.05			78,65%	A				
EM76.01			79,54%	A				
EM52.03			80,37%	B				

Figure 14: ABC analysis, consumed items between 03/2018 and 03/2019.

4 Solutions

Along this chapter, several improvement initiatives will be presented. Most of them were successfully implemented during the project, others were idealized for future development. The analysis that was disclosed in the previous chapter was the supporting basis for the ventures, however, proper additional justification will be provided whenever necessary.

4.1 5S

The first initiative to be implemented within this project was the 5S methodology. Naturally, since awareness and training had not been provided to the workers on these procedures, and there was evidence of little monitoring over the tidiness and organization of the department, there was a clear need to improve the layout and the workflow using this technique.

Section 4 - Labeling

The identification of all the cardboard boxes and filling slots that were stored in section 4, was one of the most critical aspects to be solved because it was a source of waste for several activities inside the department. As previously described, a considerable amount of time was lost when trying to find an adequate item to serve the packing process. Typically, in order to determine the right reference to be used, workers would pick one of the boxes, shape it, and measure to be sure of the size. Since these are stored in a flat position, visual identification is impossible to the untrained eye. Additionally, the complexity of this process was also increased with the fact that there were two types of boxes for each reference, one with the company's logo and another without it; and slightly different designs, depending if these were to be the bottom or top part of the box.

Labels were elaborated (Figure 15) with the aim of providing several important pieces of information: the reference code, the maximum diameter size of the item that would fit in the box, the dimensions of the box and its position (top or bottom), as it can be seen in Appendix C. Similarly, cardboard fillings were labeled with the same information, however, the size indicated which cardboard box these could be paired with. The font size of the text displaying the mentioned information ensured readability from a distance of 4 meters. Since the labels are plasticized, some of the fields can be handwritten, ensuring their reuse and flexibility. In some cases, magnetic tape was used to make them more mobile. These were essential characteristics that were demanded by some of the workers.

Finally, a proposal for a new layout of the pallets in this section was elaborated, considering two main factors: the frequency in which the held references were used (supported by the ABC analysis) and the size/weight of the items. It was noted that heavier ones were being placed on higher slots for being used seldomly. This was encouraging the act of removing additional units that would end up taking up necessary space elsewhere, as previously described.



Figure 15: Section 4, before (left) and after labelling (right).

Section 7 - labeling and layout standardization

As previously mentioned, one of the primary sources of waste related to movement and transportation had to do with the lack of standardization inside the shelved area of Section 7. As it was possible to understand when interviewing the staff, this area had never been formally organized. Instead, workers would occasionally take the initiative to label some of the rectangular plastic containers that had been placed to store smaller items. As a result, these were not properly identified, and their location kept changing. A simple and effective way to solve this problem was envisioned by developing a visual system to organize and sustain the layout.

Initially, information was gathered on the current placement of the items. It was noted that some of the items were taking unnecessary space because they did not belong to any planned order. Some of the customers had sent them back after filing a complaint, and they were left to be stored later. Additionally, there were product catalogs that did not belong to this area. After sorting all the items, two of the top shelves were freed, and more space was gained. Every shelf was then numbered with plastic labels, to aid the map creation process (Figure 16).

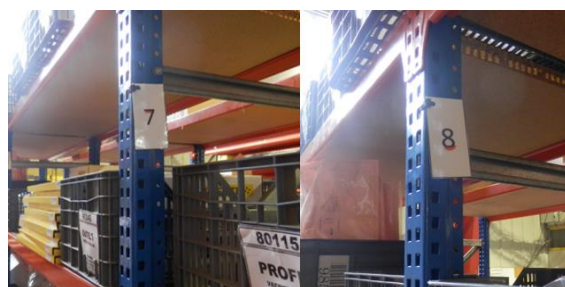


Figure 16: Shelf labeling (Section 7).

Since workers 2 and 3 were already familiar with most of the placement within this area, mostly because they were the ones taking the initiative to organize it, the majority of the organization was kept as it was found, with minimal changes. Additionally, some of the shelves were already fully occupied, and the process of reorganizing all of the accommodated items would take unnecessary efforts.

A visual representation of the layout was created (Figure 17). The previously mentioned labels were acting as a support to streamline the identification process, and the layout was numbered in accordance. For every number, a list of the respective clients or vendors was attached with

the respective country flag. It is important to note that the items placed in shelves number 1 to 3 had been strategically placed near Section 8, as it was closer to the exterior, to ease the daily flow. Others were grouped according to the daily ordering schedule. The map was positioned on a visible area, lateral to the central shelves so that workers 4 and 5 could examine it before transporting the packed goods.

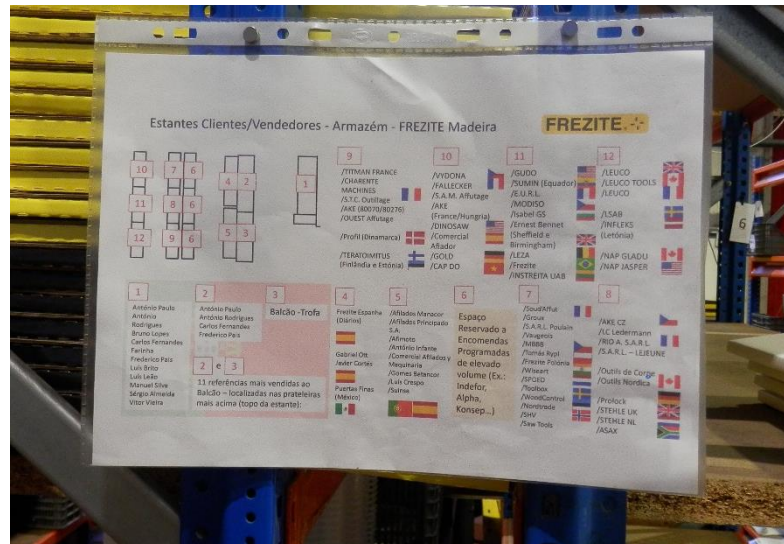


Figure 17: Shelved area layout (Section 7).

Finally, some of the plastic containers had been inadequately identified. This was because most of the labels were improvised, as they were needed. As a result, after analyzing the displayed information and assuring it was in accordance with the ERP, new labels were created and placed according to the map as seen on Figure 18.

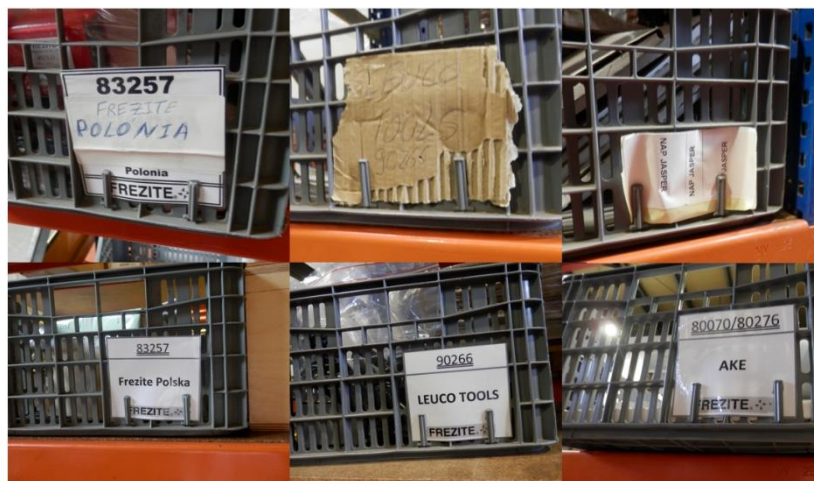


Figure 18: Re-labeling at Section 7 (before, top and after, bottom).

Section 2 – Stabilizers cart

During the robotic marking process, worker 9 uses a set of auxiliary pieces of equipment known as stabilizers. These metallic cylinders are meant to be installed vertically and support the circular saw blade stacks as the robotic arm picks them up, one by one, into the laser engraving machine. Their sizes vary according to the diameter of the central hole of the circular saw blade stacks.

As it can be seen in Figure 19, the stabilizers were stored in a designated cart without a clear order, which was causing the worker to try different sizes until the correct one was found.



Figure 19: Stabilizers cart (before).

Stabilizers were sorted in ascending order according to their diameter (Figure 20), and small magnetic labels were used to identify the previous, to sustain their placement.



Figure 20: Stabilizers cart (after).

Section 3 – Shelf

Similarly to the shelved area in Section 7, the automatic warehouse was also supported by analogous equipment, which presented opportunities to improve the sorting and identification process of the stored goods. This area was mainly used for storing plastic canisters containing hardened steel tips. As it can be noted in Figure 21, some of these were mixed because the spacing requirements were not being followed.



Figure 21: Automatic warehouse shelf (before).

Once again, most of the labels had been improvised, as needed, resulting in unclear information. Some were already missing because the materials used for their creation were fragile. New plastic labels were elaborated and placed in their predefined locations. Additionally, separators were included to ensure a clear division among the item references (Figure 22).



Figure 22: Automatic warehouse shelf (after).

Section 6

As previously mentioned Section 6 was the most problematic area of the department, especially the area dedicated to the packing of category 1 products, which opened the possibility for several improvement initiatives to boost the productivity of the involved personnel. It was clear from the very beginning, that only targeting this area would not be sufficient without continuously involving and empowering workers 4 and 5, to provide them with enough on-the-job training and awareness to intervene whenever new challenges emerged.

Tools shadow board

One of the priorities was to organize the most essential tools used by worker 4. The respective workstation was equipped with a manual press puncher, used when foaming was involved in the packing process. Since it had been placed near this worker's position, a shadow board was envisioned to occupy the lower area and contain the mentioned tools. Previously, it had been occupied with waste and obsolete materials. After discarding the previous, the shadow board was elaborated using recycled remainders from the packaging foam, as it can be seen in Figure 23.



Figure 23: Shadow board (before and after).

Label and Ink Rolls Cabinet

While the daily flow was being observed, it was noted that the cabinet which contained the label and ink rolls was also not correctly organized. This was mostly being accessed by workers 4 and 5, but it supplied all the label printing machines of the department. Initially, items were randomly stored, mostly without being unpacked. Since these were hidden, it was hard to identify and select the correct labels when the printing machines had to be refilled.

As can be seen in Figure 24, items were sorted and set in order accordingly, with some of the cardboard boxes used as separators. Since disposable material was discarded, it was also possible to gain more space in the cabinet.



Figure 24: Labels and ink cabinet (before and after).

Supporting Shelf

Another critical point to improve the organization within this Section, once again referring to the packing process of category 1 products, was the respective supporting shelf. It was intended to be an integral part of the workstation, providing the worker with line-side storage for the most used references that occupied the highest volume of space. Instead, it was being used as a storage area for waste and the remainder of the packing process.

Initially, the supporting shelf was not in its intended conditions. Leftovers of packages and other items were found scattered and mixed among each other. Because the process of setting the items in order had been neglected for long, identifying these was even more complicated before these could be properly sorted. In contrast, after cleaning and pinpointing the needed item references, the supporting shelf could have its expected use. The implemented labeling system

was identical to the one used in Section 4. The layout of the items, once again, followed similar criteria, to make the replenishing task as ergonomic as possible. The involvement of worker 4 was crucial in achieving the needed improvements. Both situations are evidenced in Figure 25.



Figure 25: Supporting shelf (before and after).

Despite the previous initiative, the supporting shelf was not yet being used at its full potential because the direct interface between this and the workers' table was being blocked by a "wall" of plastic containers (Figure 26). After being moved aside, the number of containers was also reduced because the devoted volume was excessive for the held product references. According to the performed calculations, the total devoted volume could be reduced by 52% when taking into account the total average volume that was occupied every month. Presumably, the plastic containers had been dimensioned to facilitate the replenishment process, since their capacity was close to the reorder quantities for each reference. However, it was considered that the main priority was to optimize the current available space at the workstation, which will definitely result in the readjustment of the reorder points for these products in the future.

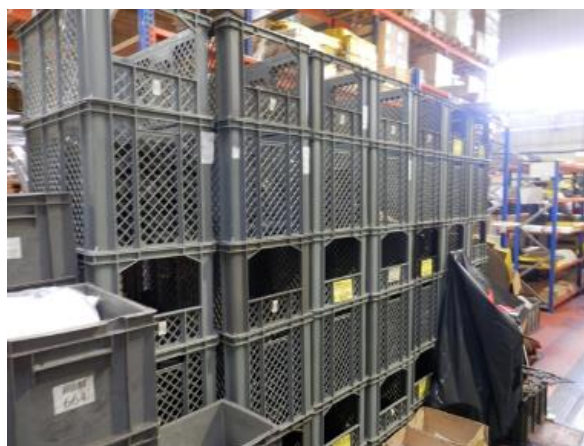


Figure 26: "Wall" of plastic containers.

Other layout changes to this section also included the repositioning of the paper shredding machine, which was placed between both workstations, in order to encourage its frequent use; and the decongestion of one of its corridors. A metallic wire cable tray was installed, to provide electrical power for the previous (Figure 27).



Figure 27: Repositioning of the plastic container “wall” and shredding machine.

As both category 1 and 2 products were packed, workers 4 and 5 kept littering the floor with packaging waste from their activity (Figure 28). This was hindering their movement and access to the respective supporting shelves. For these reasons, cleaning and sorting procedures were carried out to avoid the previous situation.



Figure 28: Congestion corridor with packing waste.

Wooden Separators

Initially, worker 4 did not have enough space to maintain a line-side storage of all the cardboard models. These were the most important items to keep as near as possible to the workstation, in order to minimize movement towards Section 4.

Instead of ordering a custom-made solution due to time constraints, a wooden prototype for the presented solution was manufactured and placed on top of the workstation (Figure 29). Since items could be stored vertically, each separator could hold up to 50 units, on average. Nevertheless, this was meant to be a temporary solution since the used materials were not adequately reinforced.

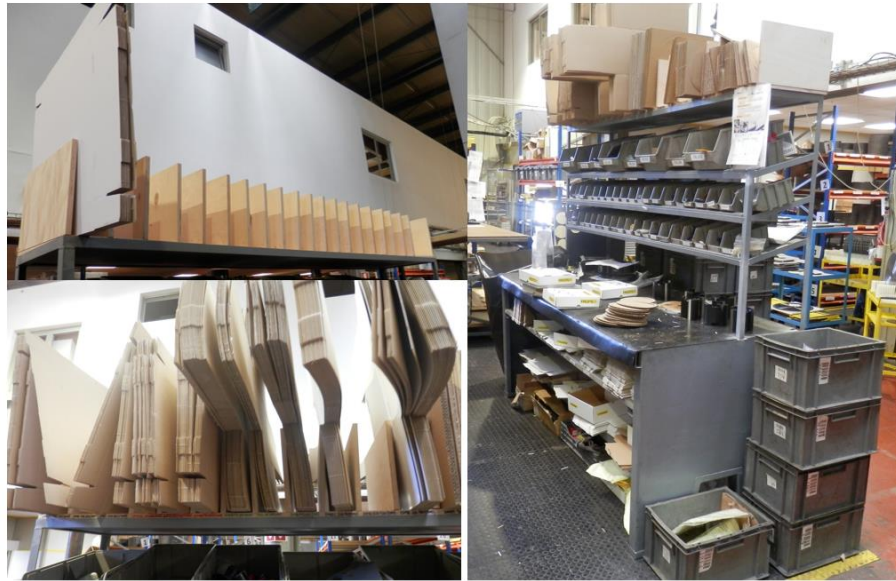


Figure 29: Wooden separators.

Finally, all sorting mechanisms that were already in place within the previous workstation, were closely reviewed, and improved in some cases (Figure 30). This was motivated by some of the external complaints in what concerns the absence of packaging accessories that were stored in this location. Once again, cooperation with the workers allowed the process to be more efficient.

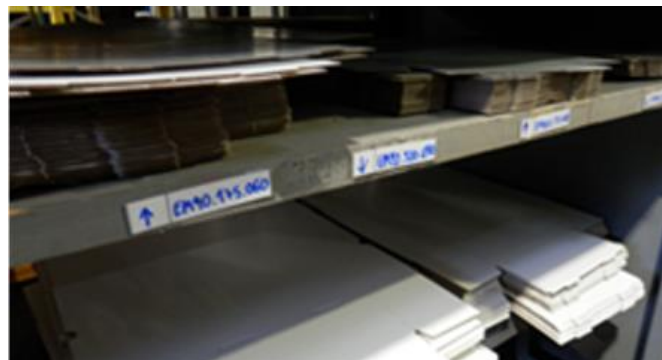


Figure 30: Packing table labeling (category 1).

Category 2 products packing table

In order to help worker 5 with the daily organization of his workstation, two new sorting elements were included. As the day progressed, the accumulation of materials on the surface of the table kept reducing the available space for packing, hindering his productivity. Circular saw blade cardboard boxes were voluminous, which contributed towards this even more. As this worker kept organizing his daily tasks with the use of the invoices printed by worker 1, most would end up disorganized and occupying the same surface area. Additionally, a designated container, away from this workstation, kept the invoices with circular saw blades waiting to be engraved on an unorganized stack. This was forcing unnecessary motion.

The first element was a plastic container where smaller items could be placed (Figure 31). Most of these included the ones with a similar shape that would be used more often by the worker, and could be easily lost, namely: markers, a pencil, a pair of scissors and a cutter knife. The second was a set of drawers where invoices could be kept (Figure 31). These drawers were divided in three color-coded categories: red for urgent, blue for normal and yellow for the ones which the included product orders were still waiting to be marked in Section 2. The last was

meant to be a temporary solution, since drawers were made from cardboard, however, since the placed amounts of paper weren't too heavy, it proved to be robust.



Figure 31: Packing table labeling (category 1).

Section 5

This section of the department was described as a recent implementation, that was needing close monitoring and intervention. In fact, this new storage area was critical in providing enough flexibility to the daily operations, even though some improvement opportunities required consolidation.

Instead of merely gluing labels into to their respective shelves, as is can be seen in Figure 32, a new way of maintaining their positions was envisioned. Small plastic cable ties were used for this matter since with the accumulation of dust; the glue would lose its strength and labels would end up on the floor.



Figure 32: Cable tie holding a label.

Finally, Figure 33 displays an example of one of the incorrect practices that were damaging to category 2 products. Since shelves were narrow, positioning saw blades in their respective stack was a difficult task. Occasionally, these would end up being placed offset to the center. As the pile grew taller, higher positioned items' weight would be supported by the teeth of lower ones, causing severe tensions which could deform or even break the previous. To correct this, several audits and initiatives were taken to manually reposition the items in the hopes of spreading awareness and on-the-job training to the involved workers.



Figure 33: Improper circular saw blade placement (right side).

Zoning

Beyond the previously mentioned waste that was congesting the available space inside the department, carts that were used to transport category 2 products were also causing the same problem (Figure 34). This was because there was no designated area where these should be placed. As such worker 9 would simply push them near Section 5, and worker 5 would readjust their location as needed. In some situations, the aisles between shelves in Section 5 would be also blocked and the placement of newly received items would also be impossible.



Figure 34: Congestion caused by the transporting carts.

In order to counteract the previous problems, the floor should be clearly marked with the designated zones for placement that would still allow continuous motion and avoid blockage across the mentioned sections. Initially, there was evidence of previous zoning initiatives that had to be updated (Figure 35). Old floor marks were removed and cleaned to prepare their replacement. This was followed by the planning of the zoning layout, which was validated by all the workers, in the hopes of adding new suggestions that could improve the chosen solution.



Figure 35: Example of previous zoning initiatives.

Due to time constraints, this initiative's implementation was not carried out. Nevertheless, the hereby presented justification and plan compose a solid base for future endeavors. The proposed layout can be visualized on Figure 36. Area number 2 was envisioned for received goods, which need to be unpacked and registered. The remaining ones were designated for placing carts.

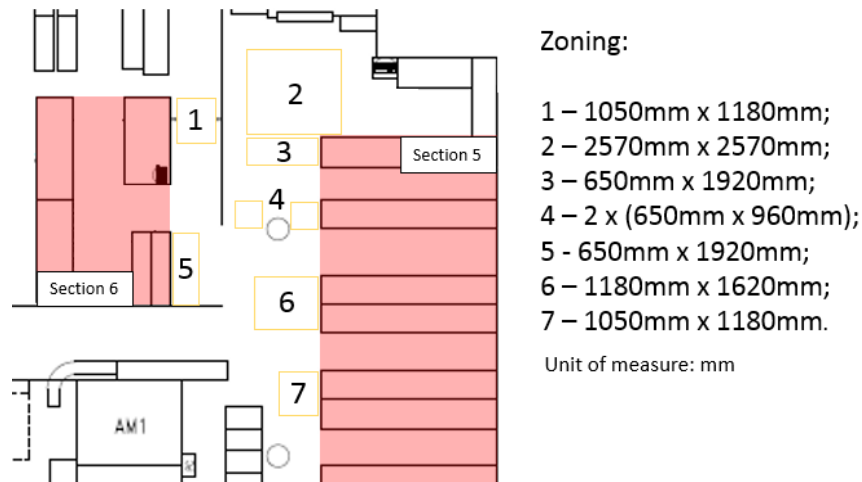


Figure 36: zoning layout.

Extra Storage Area

One of the key points to address during the project was the organization of the extra storage area (Figure 37), located on the opposite end of the facility where the logistics department is located. Since there were no identification mechanisms, and there was a considerable amount of palets left on the floor, movement and transportation were not efficient.



Figure 37: extra storage area.

Due to time constraints, the identification process and organization of the space within this area was not properly conducted. Instead, the focus of the previous initiatives was on reducing the amount of time spent in this area by repositioning the most used items near the respective worker. Additionally, this area was used as a temporary storage location for part of the least used items and materials that were occupying space inside the department itself.

Since most of the space used in this area was being occupied with obsolete or less frequently used items, which seldomly changed their position, a map of the storage area was created (Figure 38), with the help of worker 6. This was placed next to gate 1, as it was the access point to the central aisle that connected both areas. Whenever some of the workers left the department (mostly workers 4 and 5) the location of the searched items could be known. Since

worker 6 was assigned with storing goods across the facility, he was the only one who knew this information and was in charge of updating the document. This could be easily done using a marker since it was plasticized. Despite not being used very often, the map brought more transparency to the underlining process.

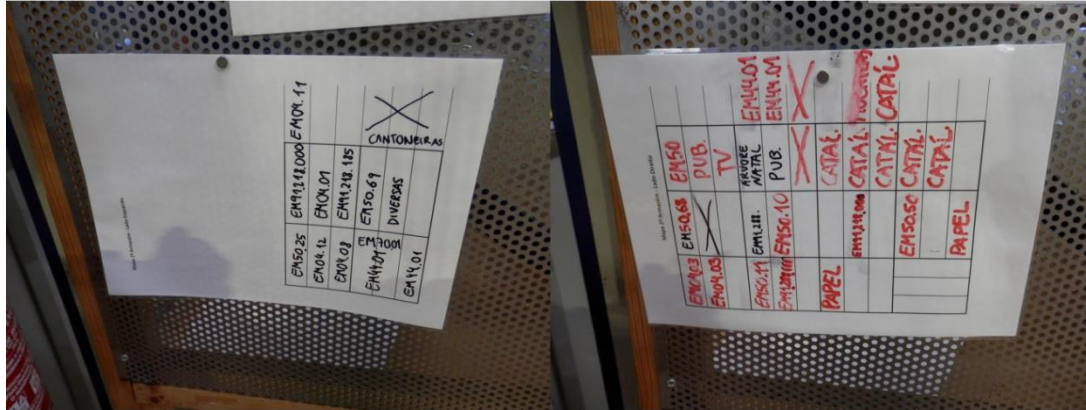


Figure 38: Extra storage area map (left and right sides).

Sustaining and Standardization

After addressing all of the previously mentioned topics, it was clear that without further monitoring and awareness, the effort and achieved improvements using the 5S methodology would be in vain. Sustaining and standardizing (last two S's) are often the most daunting parts as it was previously studied, since these are deeply rooted in the cultural spectrum of organizations.

In the hopes of tackling these issues, two new improvement tools were presented as follows:

- 5S Posters (Appendix D): in order to provide constant insight through an educational perspective, posters were created containing information about the different steps of 5S methodology, including their respective descriptions and benefits. As their visualization becomes part of the workers daily routine, they are expected to absorb the information and abide by its practices;
- 5S Audits: a template was created (Appendix E), encompassing the most critical aspects that concern each step of the methodology. A scoreboard was created to measure the global state of the department, under the previous terms. Since most of the evaluation process is observation-based, it might include a certain degree of subjectivity. As a result, audits should be possibly carried out on a monthly basis, by different workers (selected randomly), as a way to distribute responsibility and heterogenize the used criteria. Hopefully this will ease some of the tensions and develop a stronger sense of workplace ownership, especially in what concerns the least experienced individuals.

None of the previous tools were implemented. However, these are meant to be part of the department's near future, and since their elaboration constitutes an essential step towards this, it was important to include both in this work.

4.2 Graphic Work Instructions

Since the beginning of the project, it was clear that packing was a challenging task for the associated complexity. In particular, the packing of category 1 products was the hardest to be performed because it encompassed many product subcategories. The number of available items,

accessories and their related procedures; were too many to keep track of. Beyond understanding the intricacies of the packing process *per se*, workers assigned with this task were also responsible to monitor the available stock of the related products. Adding to the emerging wastes related with the time spent searching for the correct items or asking for guidance with the right procedures, there was the increasing number of external complaints pointing towards related problems. As a result, providing the needed information in a compact and understandable format was a challenge that had to be addressed.

Before elaborating the work instruction guides, all of the related product serial numbers were collected, including their dimensions and destined item sizes to be packed. During previously described labeling initiatives, most of this information had already been gathered. In order to address the most common mistakes, since there were many details involved, the most important guidelines and steps to be followed were prioritized and included in a highlighting format within the guides. In an attempt to make these more visual appealing and informative, photographic material illustrating the previous procedures was also included. Finally, both guides were placed on a visible location in the related workstation, as seen on Figure 39.



Figure 39: Work instructions (packing).

Adding to the previous, a guide on how to perform stock updates to the ERP was elaborated. This was asked by the workers who were struggling with it. Despite the apparent simplicity, there were still doubts hindering them from performing this task, which led to its neglect in some situations. Figure 40 displays the mentioned guide placed near the computer screen that was being used.

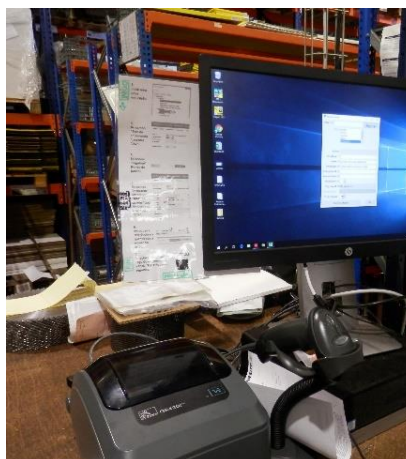


Figure 40: Work instructions (stock updates).

All of the elaborated guides (Appendix F) within this initiative had to be frequently updated due to mistakes or missing information. As these kept being used by the workers, the identification of the previous and the opportunity to include more knowledge about the underlining processes, kept increasing. Therefore, it is too ambitious to consider that this implementation was fully concluded, meaning that it must be closely monitored and updated.

4.3 Circular saw blade Kanban

Allowing the customers to buy directly from the front office, was disrupting the flow of the operations inside the logistics department. Despite the smaller size of the orders and the fact that these were of mainly standard products, the marking and packing steps of category 2 products had to be frequently interrupted because most of these products were stored without being marked and packed. Contrary to this, category 1 products were always marked before the proceeding steps, and the packing process was less time consuming and physically demanding. As a result, the productivity of workers 5 and 9 was being negatively affected, when compared with the others.

In order to tackle this problem, a Kanban solution was envisioned for the top-selling category 2 product series. The data that was analyzed encompassed all the records for this products' category that had been sold during the past year to local customers, through the front office. For confidentiality reasons, it was not possible to disclose further information on this analysis' conclusions. The placement of the Kanban had to be the closest possible to the exterior to minimize the traveling distance of the picking process. After organizing the shelved area in Section 7, the necessary space requirements were fulfilled, and this area was designated for meeting the previous criteria.

After labeling the selected shelves, these were accommodated with the required quantities and Kanban cards were placed in between the product stacks. Worker 5 was responsible for the replenishment process of the stacked quantities since his main tasks included packing and picking category 2 products. As the units were being retrieved from the Kanban, usually by worker 1, who was processing the invoices as the orders came through, the Kanban cards were placed next to the keyboard of the computer that served Section 6, to inform worker 5. As can be seen in Figure 41, saw blades were ready to be delivered as soon as they were placed in this area.



Figure 41: Circular saw blade Kanban.

In order to facilitate the communication and task prioritization of worker 5 during the replenishment process, a visual aid was created. This document, displayed on Figure 42, contained information about each product's storing position (by serial number) in Section 5,

including the defined quantities for the safety stocks and reorder points of the Kanban system. It also included the respective serial numbers translated into barcodes, so that worker 5 could quickly introduce them into the software when printing labels, which was not always the case with normal orders. A visual language was created to inform the same worker on two key aspects: if any of the products needed to be replenished, and if there were enough in stock, marked and ready for packing. Worker 5 did not have any control over the marking process, as a result, every week during the first three days, it was the most important task to be carried out. Since nearly all the front desk orders were destined to local customers, products were engraved with the company's logo. This allowed worker 9 to use the robot more often, saving more time and effort.



Figure 42: Kanban system visual management aid.

Lastly, a visual prototype of a simple queue management system for the front desk orders was elaborated (Figure 43). This was inspired by the wastes related with movement and communication adjacent to the Kanban system. Instead, the information could possibly flow through a digital application which is meant to be a future suggestion.

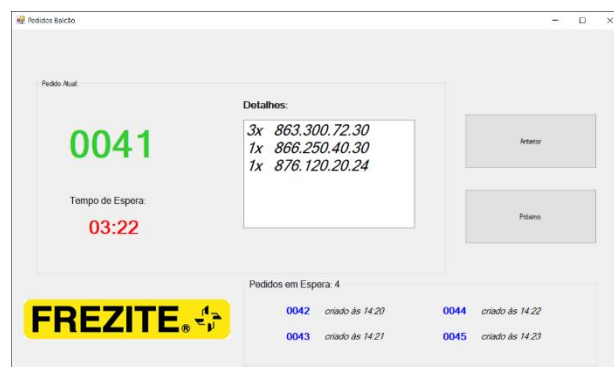


Figure 43: Queue management system (mockup).

4.4 Autonomous maintenance

During the time while the project was being developed, most of the newly readjusted departments of the SBU were undergoing an autonomous maintenance program. This started with a set of workshops that were being given by the maintenance personnel. Since the logistics department isn't immediately connected with production-related activities, there was still the opportunity to act in this field. Inside, there were two types of machines that have been previously mentioned: the cutting machine, near the automatic warehouse (Section 3); and the laser engraving machines (Section 2). The first machine started to be used more often by different people, including workers with insufficient experience, and was already showing signs

of deterioration, becoming more vulnerable. Consequently, it was the priority of this implementation within the logistics department.

The result of the previous was the elaboration of an autonomous maintenance guide (Figure 44). Information was displayed of the most critical parts and functions of its components. The procedures to ensure their operating conditions were briefly described, including the preferred method of inspection, and its frequency. The document was also enriched with a set of symbol language with predefined colors and shapes, that was being used across the SBU, to be more easily recognized by the workers (Appendix G).



Figure 44: Autonomous maintenance guide (cutting machine).

4.5 Results

After the implementation phase, the outcomes of the project needed to be accessed. The evaluation phase was carried out during the last two weeks of the project and was targeted at the most impactful transformations that have occurred.

Space Utilization

Space decongestion was one of the most significant achievements with the application of the 5S methodology. The most prominent changes can be summarized in Table 1. With more room available, the organization of the layout was greatly improved, resulting in more freedom of movement and a cleaner work environment, which besides being more visually appealing, became safer for all workers. The gained area was directly measured.

Table 1: Space utilization improvements.

Description	Gained Area (m ²)
Section 4	4,6
Section 5	1,2
Storage Equipment	7,7
Total	13,5

External complaints

The considered period for analysis of this indicator was narrowed down to the 1st of April until the 1st of June and compared with the previous year. This choice was made to match the timeframe that followed the implementation phase. It is important to mention that there was a

significantly inferior amount of data when compared to the analysis that was made on the third chapter, where one year was considered. For this reason, the causes for the external complaints were also grouped in a different way, according to their description, in order to be more specific.

The instability lived during the project, with the absence of various collaborators for several consecutive weeks caused a severe disruption of the regular flow. For this reason, part of the project's action plans had to be postponed, while the remaining ones had to be reviewed. However, the associated costs to the analyzed complaints were nearly six times inferior, meaning that their financial impact was considerably lowered. Figure 45 shows the percentage distribution for each of the new groups. The number of damaged items/package was greatly reduced due to the reorganization of the packing material used with category 1 products since these started to be better accommodated. Missing or wrong accessories in the same category of products were more frequent during the first weeks of April due to the replacement of worker 4, who had left the company. The remaining complaints referred to cases that were mostly caused by distractions, which were common during the chosen period due to the beforementioned reasons.

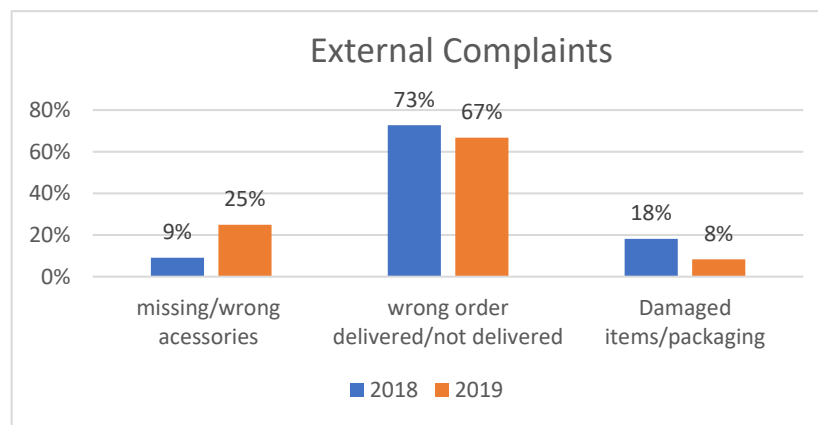


Figure 45: External complains analysis.

Productivity Gains

Using the data acquired from the methods described in the third chapter, it was possible to estimate the average total productivity gains, expressed in both time and currency units. The results are summarized In Table 2.

Table 2: productivity gains summary.

Improvement Action (Location: Description)	Affected Workers	Average time P/ frequency (secs)		Average Total Productivity Gains		
				Time Reduction		Annual Savings - labour costs (€)
		Before	After	P/ Day (mins)	P/ Year (hrs)	
Section 4: Labeling	1, 2, 3, 4, 6	72	22	74	311	4413
Section 7: Shelf Layout	1, 2, 3, 4, 5	9	4	33	140	1988
Section 6:	Tools Shadowboard	5	2	4	17	236
	Shelf & Wooden Separators	114	114	15	64	907
	Cardboard Drawers	5	2	5	23	325
	Extra Storage: Area Map	32	22	7	30	428
		Total		139	584	8297

Each improvement action directly or indirectly affected each one of the workers, depending on their tasks. The “Time Reduction”, presented under the “Average Total Productivity Gains” tab, represents the total time reduction, considering all of the involved workers. The average daily amount of time devoted per task and per worker, was estimated from the work sampling data. In the case of the fourth initiative, the time of completing the associated task was not lowered, instead, the frequency in which it was performed changed from 10 times a day to only 2. Lastly, it was assumed that there were 252 working days per year, and the average Portuguese labour cost per hour was 14,2 euros, in order to calculate the annual savings (in https://ec.europa.eu/eurostat/statistics-explained/index.php/Hourly_labour_costs).

The productivity gains associated with the introduction of the circular saw blade Kanban were not effectively measured due to time constraints.

Human Potential

There were a number of subjective benefits associated with lean implementations which cannot be objectively evaluated due to their intangible nature. The amount of time spent inside the department, working closely with the collaborators, providing them with feedback on their activity while advocating for waste reduction, contributed for an invaluable transmission of knowledge, in a reciprocal manner. As there was more transparency through the more well-documented procedures, teamwork, job-facilitation and autonomy were leveraged considerably. With more organization embedded in the daily routine, workers were provided with the right tools at the right time, developing a sense of care for their workplace. Involving the same people in improvement decisions and actions resulted in a more acute sense of ownership, motivation and loyalty towards their peers.

5 Conclusions

Supply chain management encompasses a wide array of fields of expertise, where logistics and warehousing are obviously incorporated. The work presented in this thesis was developed inside a logistics department which, in practice, was not exclusively dedicated to this type of activities. As it was analyzed before, flexibility is an important characteristic for modern organizations, including the one where the project was elaborated. Despite the variety and overwhelming complexity of details in the associated procedures, this allowed more freedom and appeal to the creative capabilities that are commonly linked with the implementation of continuous improvement initiatives.

The nature of Frezite's core activity justifies the application of Lean methodologies. As most of its production is engineered-to-order, the underlining processes become subjective to the emergence and impact of the seven known wastes. In fact, producing highly customized products demands a substantially high level of know-how, experience and attention to detail; hindering the possibility of automation, producing accurate forecasts and leveraging economies of scale.

Technology has been a pervasive and cost-effective mean to transform organizations and tackle modern pitfalls. However, issues related with bureaucracy and privacy frequently constitute a barrier for data-hungry and capital demanding implementations, inhibiting innovation and continuous improvement. The ever-changing nature embedded within these practices require a level of adaptability and commitment that is often absent, which has also been the cause for growing pains inside the SBU where the project was developed, for being the oldest. Contrary to this, Lean tools allow for a smoother transition with minimal investment, when paired with the right mindset and involvement among participants. Despite there hadn't been any formal training, Frezite's collaborators were familiar with some waste reduction practices, which was crucial in aligning them with the followed methodology.

The course of the project was marked by several absences that disrupted the ordinary flow of the work inside the department. Even though this hindered the possibility to perform a thorough and detailed analysis on part of the most critical processes, there was still the opportunity to study and evaluate solutions for several of the encountered problems. Despite the mildly simplistic approach, there was a distinctive focus on the sustaining of the improvements by facilitating the dialogue with the workers who make a daily use of the implemented initiatives. Some resistance to change was present, however, the willingness to learn was an essential driver for success in defeating the previous. Overall, beyond the increased productivity, organization and savings; workers were able to achieve more transparency, autonomy, collaboration, empowerment and sense of ownership, when comparing with the initial situation.

In a more personal perspective, the project allowed a different and more holistic learning approach, incited by the immersion in a complex and unique industrial setting. As a result, the objective of going through an enriching and more practical learning experience, which could provide an insightful understanding of the "real world", was completed with success.

Future Work

Even though some of the future suggestions have already been presented, others are also to be considered.

Over the course of the project, when working with the packing process, it was noted that in some situations, the number of steps was excessive. For these cases, optimization could undergo a different approach by considering new items which could introduce more streamlined and quicker procedures. As an example, Figure 45 depicts a specific type of plastic cases, that could be used to protect drill heads, instead of foaming. This is because the foam must be measured

and cut before being placed. Even the placement process is rather meticulous, making it slower. With the new plastic equipment, the worker would only need to select the right one according to the tool's diameter and directly apply it. These are also being used by the metal cutting tools SBU, presenting an opportunity to exchange information that could avoid the need to search for a new supplier or making an initial investment to test this product.



Figure 46: substitute plastic cases.

In order to tackle the mentioned mobility issues, workers whose activities are closely related with the reception or storage of merchandise could be using more advanced means of exchanging information. A mobile computer with an embedded scanner, designed in a gun format, was envisioned for this matter (Figure 46). Ideally, these should be integrated with the adopted software solutions, namely the ERP. This could open the possibility for more efficient identification systems inside the logistics department, such as barcode or QR code-based ones, which could make the storing and picking processes more efficient.

Still within the technological spectrum, it could be beneficial to study more advanced communication means such as queue management systems. Instead of processing the orders and managing their preparation using the printed invoices, a display could show the most relevant information, keeping it organized and constantly updated; in a clearer and more visually appealing way. This would prevent occasional mistakes related with its misinterpretation and speed up the feedback loop. Lastly, this would turn out to be a more environmentally friendly approach, since the use of paper could be greatly reduced, as well as its associated waste.



Figure 47: mobile computer example.

During the elaboration of this project, a set of productivity related KPI's were created and measured. However, this was later discontinued due to the conclusion that the chosen methodology was not providing enough accuracy, among other external factors which have already been mentioned. Besides, for most cases, the departments' collaborators were asked to update a physical record of the previous, which was negatively affecting their productivity, since most of their activities involved manual labor. In other situations, it was found that there was the possibility to obtain valid information through the used software. However, for mainly

bureaucratic reasons, this information was not broadly and easily accessible, as the systems were not also properly integrated.

This is an important aspect to prioritize since without valuable insights, the process of exchanging information with the collaborators will not be as transparent and fruitful. Additionally, using a more centralized tool, the task of gathering and processing the same information can be more efficient and less prone to errors.

According to the collaborators of the department, daily Kaizen meetings used to be conducted for a period of approximately ten minutes during the morning shift, in the presence of a management supervisor. With the recent readjustments in the organizational spectrum of the SBU, these ceased to exist. Without a clear venue for communication inside and outside the department, some of the staff members felt voiceless and outcast, which also explains some of the tensions within the department. Similarly to what was already happening in other departments of the same SBU, these meetings should be focused on joint problem-solving, goal and priority definition, and provide constructive discussions on the measured KPI's. Most importantly, before formalizing this initiative, it is suggested that a new hierarchy inside the department is studied, in the hopes of restoring healthy working relationships and leadership.

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Appendix A: Work sampling

A.1: Worker 1.

	Tempo (min)	Tempo (%)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/ Unidade	Tempo (min) P/ Frequência
Registo no Kardex (Entrada/Saída de Stocks)	77,9	31,4%	1,3	1	35	1,4	77,9
ERP - Emissão (Faturas)	50,5	20,4%	0,8	6	40	1,3	8,4
ERP - Emissão (Notas de Crédito)	47,5	19,2%	0,8	1	8	5,9	47,5
Comunicação útil (verbal + telemovel + e-mails)	20	8,1%	0,3	14			1,4
Inspeção (física)	9,5	3,8%	0,2	2			4,8
Inspeção (ERP)	8	3,2%	0,1	2			4,0
ERP (Entrada/Saída Stocks)	6,5	2,6%	0,1	2			3,3
ERP - Mudar estado material 66 (só mercado nacional)	5	2,0%	0,1	1			5,0
Deslocação (Mesa Bruna e Rafael)	5	2,0%	0,1	4			1,3
Rework - Refazer pedidos	4,5	1,8%	0,1	2			2,3
ERP - Emissão (Orçamentos)	3,5	1,4%	0,1	1	1	3,5	3,5
ERP - Mudar estado material 66 (pedidos urgentes)	2	0,8%	0,0	1			2,0
Inspeção (guias e faturas)	2	0,8%	0,0	1			2,0
Emissão - Guias Transportadoras	1,8	0,7%	0,0	1	4	0,5	1,8
Deslocação (Balcão)	1,75	0,7%	0,0	3			0,6
Emissão - Ordens Compra	0,7	0,3%	0,0	2	3	0,2	0,4
Deslocação (Kardex)	0,5	0,2%	0,0	2			0,3
Limpeza/Arrumação	0,5	0,2%	0,0	1			0,5
Troco Balcão	0,5	0,2%	0,0	1			0,5
Deslocação (Gravação)	0,35	0,1%	0,0	1			0,4
Total	248						

A.2: Worker 2.

	Tempo (min)	Tempo (%)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/Unidade	Tempo (min) P/ Frequência
Embalamento (paletes - inclui cintar, pesagem e descarregamento)	31,0	13,1%	0,5	3	3	10,3	10,3
Embalamento serras (ajudar Rafael)	29,0	12,2%	0,5	2	63	0,5	14,5
Embalamento (volumes - inclui cintar, pesagem e descarregamento)	26,0	11,0%	0,4	7	7	3,7	3,7
Picking/Inspeção (física - listagem para embalamento)	20,0	8,4%	0,3	12			1,7
Limpeza/Arrumação	19,0	8,0%	0,3	10			1,9
ERP - Emissão - Carta de portes	18,0	7,6%	0,3	10	10	1,8	1,8
Comunicação (verbal + email)	14,0	5,9%	0,2	15			0,9
Espera	13,0	5,5%	0,2	5			2,6
Deslocação (2º armazém)	11,0	4,6%	0,2	1			11,0
Testar nova máquina cintar	10,0	4,2%	0,2	1			10,0
Deslocação (Gravação/Mesa Bruna)	9,0	3,8%	0,2	3			3,0
Etiquetar (ajudar Rafael)	7,0	3,0%	0,1	1	30	0,2	7,0
Ajudar Bruna	7,0	3,0%	0,1	1			7,0
Rework - Refazer embalamento	5,0	2,1%	0,1	1	1	5,0	5,0
ERP - Inspeção	4,0	1,7%	0,1	2			2,0
Deslocação (montagem)	4,0	1,7%	0,1	1			4,0
Deslocação (Kardex)	4,0	1,7%	0,1	5			0,8
Impressão etiquetas	3,0	1,3%	0,1	6			0,5
ERP (kardex) - saída de material	3,0	1,3%	0,1	3			0,5
Total	237,0						

A.3: Worker 3.

	Tempo (min)	Tempo (%)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/ Unidade	Tempo (min) P/ Frequência
Embalamento (volumes - inclui cintar, pesagem e descarregamento)	53,0	22,5%	0,9	14	8	6,6	3,8
ERP - Emissão - Guia Transporte	39,0	16,5%	0,7	25			1,6
Reposição Stocks	37,0	15,7%	0,6	8	8	0,5	4,6
Deslocação (2º armazém)	26,0	11,0%	0,4	2			13,0
Picking/Inspeção (física - listagem para embalamento)	18,0	7,6%	0,3	9			2,0
Limpeza/Arrumação	17,0	7,2%	0,3	7			2,4
Comunicação (verbal + email)	14,0	5,9%	0,2	8			1,8
Pausa/Espera	12,0	5,1%	0,2	1			12,0
Deslocação (Mesa Bruna)	4,0	1,7%	0,1	5	2	2,0	0,8
Deslocação (Kardex)	4,0	1,7%	0,1	5			0,8
Impressão etiquetas	3,0	1,3%	0,1	5			0,6
Deslocação (Gravação)	3,0	1,3%	0,1	4			0,8
Rework - guias transportadoras	3,0	1,3%	0,1	2			1,5
ERP (kardex) - saída de material	3,0	1,3%	0,1	5			0,6
Total	236						

A.4: Worker 4.

	Tempo (min)	Tempo (min)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/ Unidade	Tempo (min) P/ Frequência
Embalamento (fresas)	34,4	14,1%	0,6	16	25	1,4	2,2
Colar etiquetas serras diamante	29	11,9%	0,5	1	80	0,4	29,0
Deslocação (Expedição/Prateleiras Vendedores)	23,5	9,6%	0,4	27			0,9
Preparação (reunir embalagens suficientes)	18,5	7,6%	0,3	10			1,9
Deslocação (2º armazém)	18	7,4%	0,3	3			6,0
Embalamento (serras)	17,0	7,0%	0,3	6	22	0,8	2,8
Embalamento (brocas)	13,4	5,5%	0,2	9	18	0,7	1,5
Embalamento (SP)	13	5,3%	0,2	2	10	1,3	6,5
Rework - Refazer embalamento	11	4,5%	0,2	4			2,8
Guardar/Retirar Stock + deslocação (serras)	9	3,7%	0,2	2			4,5
Deslocação (1º armazém)	9	3,7%	0,2	6			1,5
Limpeza/Arrumação	5,2	2,1%	0,1	3			1,7
Embalamento (fresas grandes)	5,0	2,0%	0,1	1	2	2,5	5,0
Impressão etiquetas	5	2,0%	0,1	3			1,7
Comunicação útil (verbal)	4,2	1,7%	0,1	4			1,1
Espera	6	2,5%	0,1	2			3,0
Deslocação (Mesa Tiago)	3,3	1,4%	0,1	4			0,8
Deslocação (Kardex)	2,7	1,1%	0,0	3			0,9
Retirar Stock + deslocação(serras)	2	0,8%	0,0	1			2,0
Deslocação (Gravação)	1,5	0,6%	0,0	4			0,4
Inspeção (física)	1,5	0,6%	0,0	1			1,5
Deslocação (fábrica serras)	1	0,4%	0,0	1			1,0
Deslocação (Tapete)	0,8	0,3%	0,0	3			0,3
Pausa	10	4,1%	0,2	1			
Total	244,0						

A.5: Worker 5.

	Tempo (min)	Tempo (%)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/ Unidade	Tempo (min) P/ Frequência
Embalamento	41	21,6%	0,7	22	78	0,5	1,9
Retirar Stock + deslocação(serras)	40	21,1%	0,7	28			1,4
Preparação (reunir embalagens suficientes)	20	10,5%	0,3	20	36	0,6	1,0
Desembalamento	16	8,4%	0,3	2	36	0,4	8,0
Guardar em Stock + deslocação (serras)	16	8,4%	0,3	24	150	0,1	0,7
Impressão etiquetas	12	6,3%	0,2	7			1,7
Deslocação (Expedição/Prateleiras Vendedores)	10	5,3%	0,2	13			0,8
Deslocação (fábrica serras)	8	4,2%	0,1	4			2,0
Deslocação (Gravação)	6	3,2%	0,1	8			0,8
Carregar/descarregar "fábrica"	5	2,6%	0,1	3			1,7
Deslocação (2º armazém)	5	2,6%	0,1	1			5,0
Limpeza/Arrumação	4	2,1%	0,1	3			1,3
Rework - Refazer embalagem	2	1,1%	0,0	1	4	0,5	2,0
Inspeção (listagem de embalagem)	2	1,1%	0,0	2			1,0
Deslocação (Kardex)	2	1,1%	0,0	3			0,7
Comunicação útil (verbal)	1	0,5%	0,0	4			0,3
Total	190						

A.6: Worker 6.

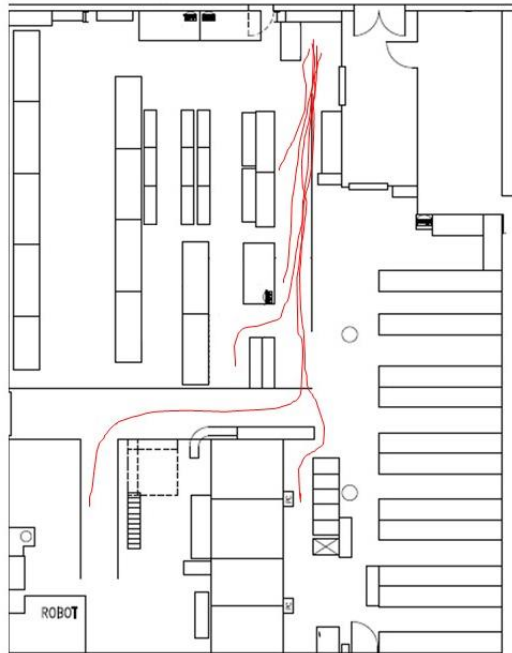
	Tempo (min)	Tempo (%)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/ Unidade	Tempo (min) P/ Frequência
Desempacotar	102	21,7%	1,7	11	23	4,4	9,3
Registo no ERP (Entrada/Saída de Stocks)	95	20,2%	1,6	8			11,9
Guardar em Stock (Kardex)	43	9,1%	0,7	4	26	1,7	10,8
Guardar em Stock (2º armazém)	38	8,1%	0,6	1	4	9,5	38,0
Deslocação (empilhador)	27	5,7%	0,5	5			5,4
Descarregar (empilhador)	24	5,1%	0,4	3	8	3,0	8,0
Inspeção (física)	22	4,7%	0,4	8			2,8
Emissão - Guias Transportadoras	19	4,0%	0,3	8			2,4
Comunicação útil (verbal + telemovel + e-mails)	16,5	3,5%	0,3	18			0,9
Inspeção (M3)	16	3,4%	0,3	4			4,0
Descarregar matéria prima (armazém serras - empilhador)	15	3,2%	0,3	1	1	15,0	15,0
Registo no Kardex (Entrada/Saída de Stocks)	12	2,6%	0,2	3			4,0
Descarregar ("Stacker" - 2º armazém)	9	1,9%	0,2	2	3	3,0	4,5
Transporte ("porta-paletes")	6	1,3%	0,1	1			6,0
Limpeza/Arrumação	6	1,3%	0,1	4			1,5
Assinaturas (receção de envios)	5,5	1,2%	0,1	14			0,4
Transporte (carro)	4	0,9%	0,1	1			4,0
Deslocação (produção: soldadura)	3	0,6%	0,1	1			3,0
Deslocação (stock laminas)	3	0,6%	0,1	1			3,0
Guardar em Stock (zona atrás da fábrica)	3	0,6%	0,1	1	1	3,0	3,0
Impressão Etiquetas	1	0,2%	0,0	3			0,3
Total	470		1				

A.7: Worker 7.

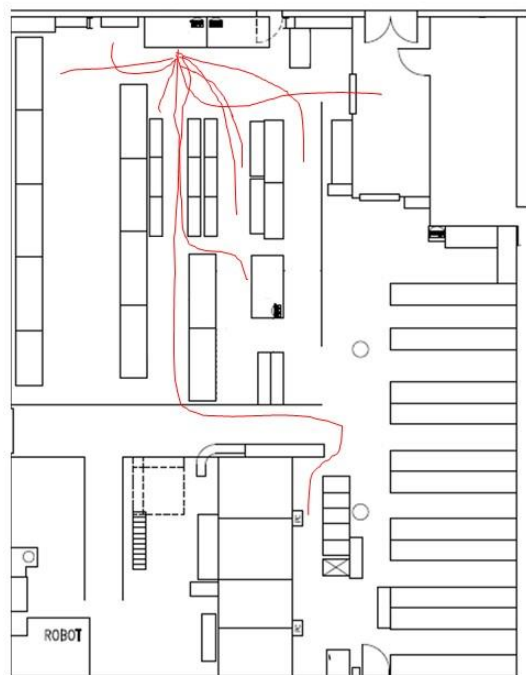
	Tempo (min)	Tempo (%)	Tempo (horas)	Frequencia	Unidades	Tempo (min) P/ Unidade	Tempo (min) P/ Frequência
Kardex (Entrada/Saída de Stocks)	63,7	26,6%	1,1	30			2,1
Kardex (Verificar "Pedidos")	35,3	14,7%	0,6	28			1,3
Inspeção (física)	23,2	9,7%	0,4	14			1,7
Deslocação (fábrica serras)	20	8,3%	0,3	1			20,0
Retirar do Stock (serras)	19,2	8,0%	0,3	8	31	0,6	2,4
Limpeza/Arrumação	19,1	8,0%	0,3	14			1,4
Máquina Corte	14,3	6,0%	0,2	9			1,6
Carregar/Descarregar (faisca)	10,1	4,2%	0,2	6			1,7
Deslocação (Helicoides/Diamante/Soldadura /tornos/serrote)	9,2	3,8%	0,2	2			4,6
Impressao Etiquetas	7,2	3,0%	0,1	23			0,2
Comunicação útil (verbal)	7	2,9%	0,1	10			0,7
Deslocação (fora expedição)	5	2,1%	0,1	1			5,0
Deslocação (mesa Costa)	4	1,7%	0,1	5			0,8
Deslocação (gravação)	1,7	0,7%	0,0	4			0,4
Deslocação (gab. produção)	0,8	0,3%	0,0	1			0,8
Total	239,8						

Appendix B: Spaghetti diagrams

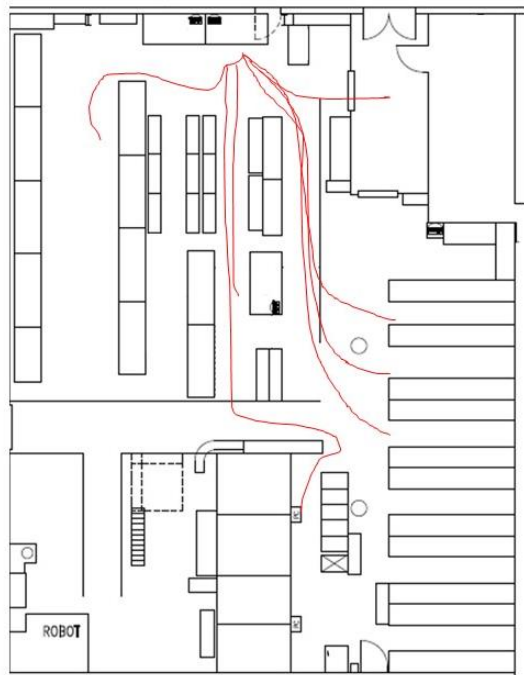
B.1: Worker 1 (logistics department).



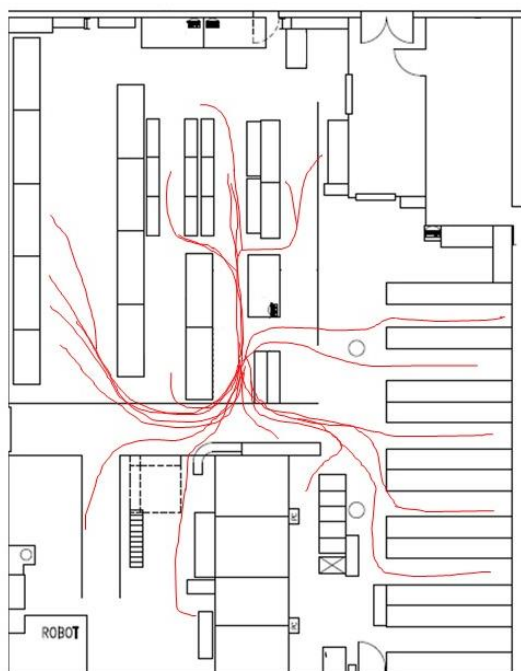
B.2: Worker 2 (logistics department).



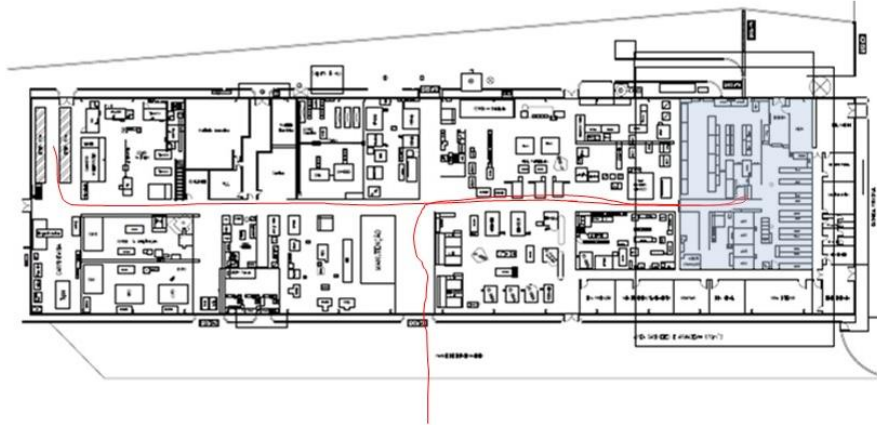
B.3: Worker 3 (logistics department).



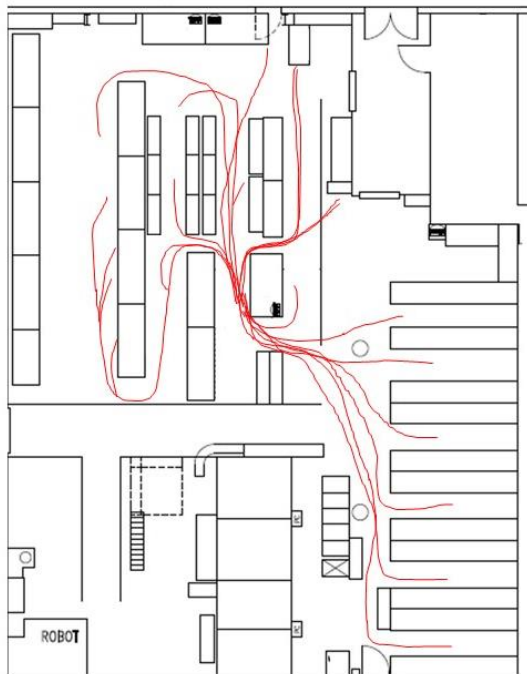
B.4: Worker 4 (logistics department).



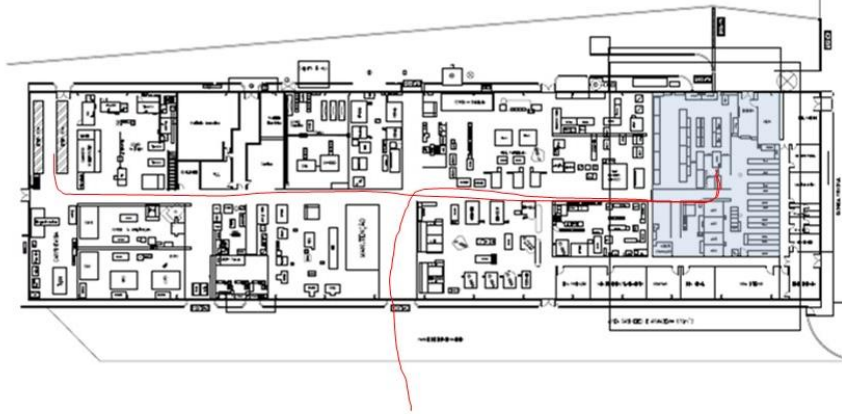
B.5: Worker 4 (entire facility).



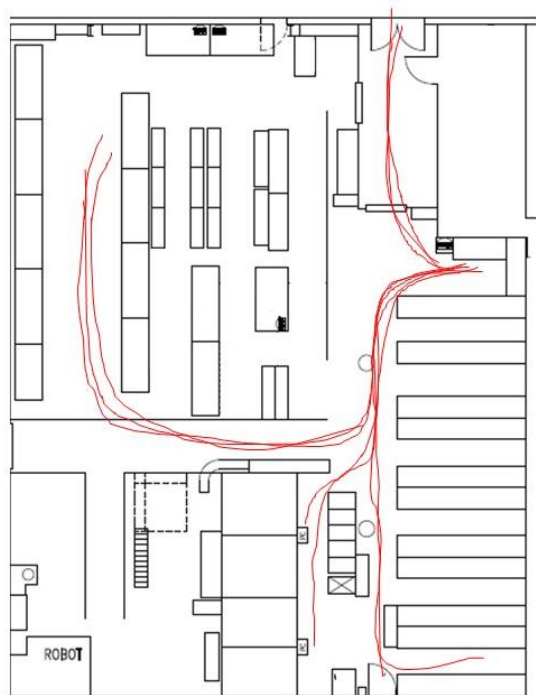
B.6: Worker 5 (logistics department).



B.7: Worker 5 (entire facility).



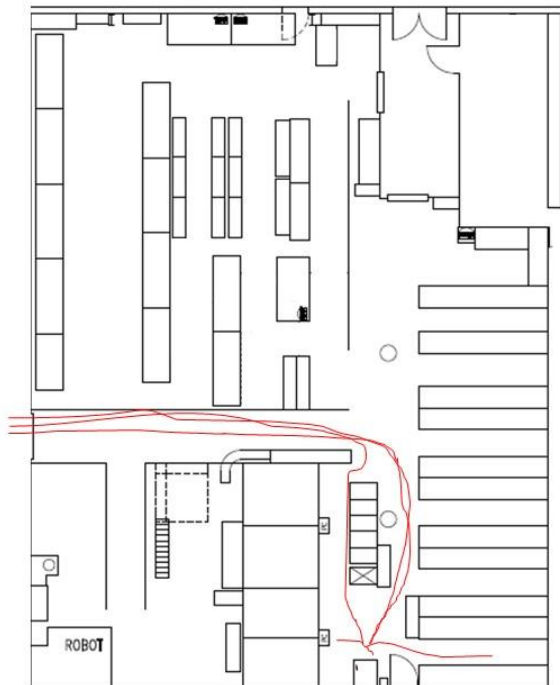
B.8: Worker 6 (logistics department).



B.9: Worker 6 (entire facility).



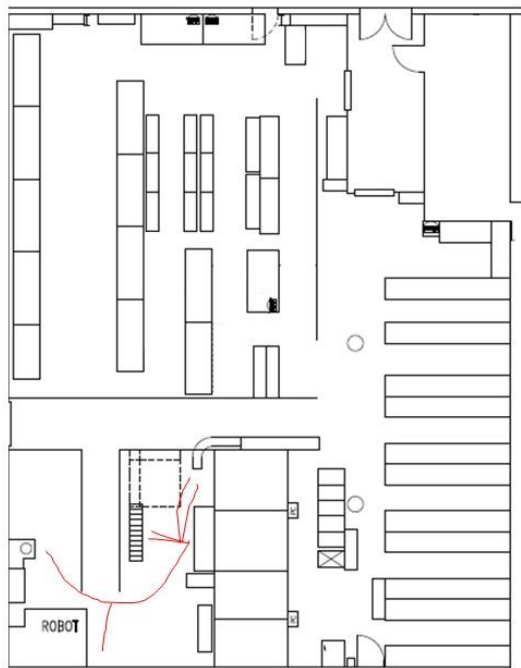
B.10: Worker 7 (logistics department).



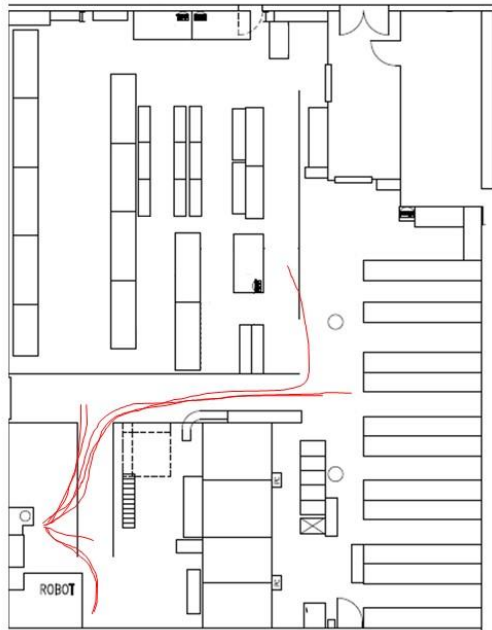
B.11: Worker 7 (entire facility).



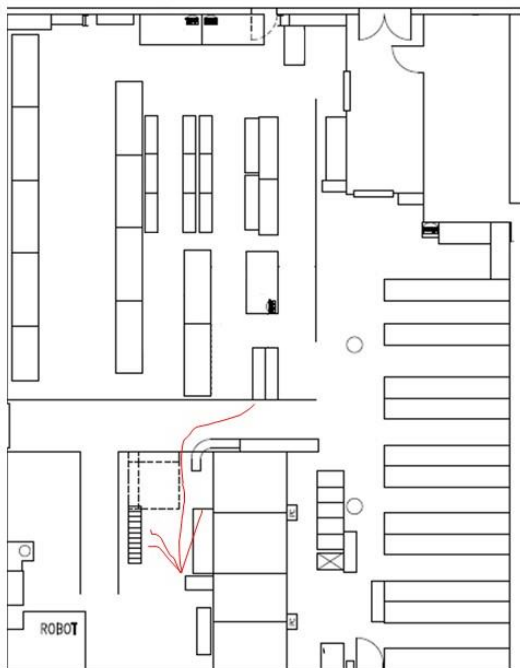
B.12: Worker 8 (logistics department).



B.13: Worker 9 (logistics department).



B.14: Worker 10 (logistics department).



Appendix C: Section 4 labels (examples)

C.1: cardboard boxes labels.

FREZITE Armazém / Logística Madeira 	EM9X.XXX.XXX	
	P/ DIÂMETRO $\emptyset$ XX DIMENSÕES XXX x XXX	
FREZITE Armazém / Logística Madeira 	EM9X.XXX.XXX	
	P/ DIÂMETRO $\emptyset$ XX DIMENSÕES XXX x XXX	

C.2: cardboard filling labels.

FREZITE Armazém / Logística Madeira 	EM9X.XXX.XXX	
	P/ DIÂMETRO $\emptyset$ XX DIMENSÕES XXX x XXX	
FREZITE Armazém / Logística Madeira 	EM9X.XXX.XXX	
	P/ DIÂMETRO $\emptyset$ XX DIMENSÕES XXX x XXX	

Appendix D: 5S Posters

D.1: Sort.

Guia dos 5S

1. Arrumar (*Sort*)
2. Organizar (*Set in Order*)
3. Limpar (*Shine*)
4. Padronizar (*Standardize*)
5. Manter (*Sustain*)

FREZITE Group

Arrumar (*Sort*)

Remoção de todos os materiais que não são úteis na estação de trabalho onde se encontram.

Antes



Depois



Benefícios:

- Menos Obstáculos;
- Mais Espaço;
- Maior Segurança;
- Localização facilitada.

D.2: Set in Order.

Guia dos 5S

1. Arrumar (*Sort*)
2. Organizar (*Set in Order*)
3. Limpar (*Shine*)
4. Padronizar (*Standardize*)
5. Manter (*Sustain*)

FREZITE Group

Organizar (*Set in Order*)

Organização dos materiais em locais de fácil acesso, com a respetiva identificação. Alguns exemplos:

Etiquetas



Marcações



Separadores



Benefícios:

- Melhor organização;
- Melhor orientação;
- Maior consistência;
- Melhor informação.

D.3: Shine.

Guia dos 5S

1. Arrumar (*Sort*)
2. Organizar (*Set in Order*)
3. Limpar (*Shine*)
4. Padronizar (*Standardize*)
5. Manter (*Sustain*)

FREZITE Group

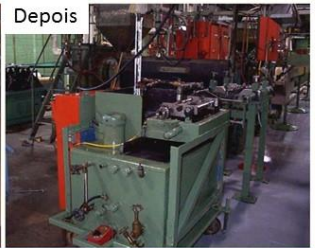
Limpar (*Shine*)

Limpeza de todo o equipamento e do local de trabalho, no final do turno. Tudo o que for movido deve regressar ao local de origem.

Antes



Depois



Benefícios:

- Mais higiene e segurança;
- Maior durabilidade do equipamento.

D.4: Standardize.

Guia dos 5S

1. Arrumar (*Sort*)
2. Organizar (*Set in Order*)
3. Limpar (*Shine*)
4. Padronizar (*Standardize*)
5. Manter (*Sustain*)

FREZITE Group

Padronizar (*Standardize*)

Os princípios dos 5S têm de ser realizados diariamente.

Cada funcionário é responsável pela organização do seu local de trabalho, no entanto, deverá cooperar no sentido de ajudar a manter a organização de outros espaços.





D5: Sustain.

Guia dos 5S 1. Arrumar (<i>Sort</i>) 2. Organizar (<i>Set in Order</i>) 3. Limpar (<i>Shine</i>) 4. Padronizar (<i>Standardize</i>) 5. Manter (<i>Sustain</i>) FREZITE Group	Manter (<i>Sustain</i>) O sucesso desta empresa depende da participação e envolvimento de todas as pessoas na organização do seu local de trabalho. Para que os 5S tenham o efeito desejado, todos têm de estar envolvidos e ser consistentes na realização das suas tarefas! 
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Appendix E: 5S audit template

FREZITE Group		Auditoria dos 5S		Data:	
Critério verifica-se? 0 - Nunca; 1 - Por vezes; 2 - Sempre;		Pontuação*			
Categoria	Critério	0	1	2	
Arrumar (Sort)	1. Equipamento/material não essencial ocupa espaço necessário?				
	2. É fácil encontrar todas as ferramentas/equipamento úteis no dia-a-dia?				
	3. Zonas de armazenamento contém apenas o necessário?				
	4. Movimentação dificultada por objetos desarrumados?				
	5. Instruções/posters/procedimentos antigos ocupam espaço?				
	Observações:				
Organizar (Set in Order)	1. Zonas de armazenamento organizadas e identificadas?				
	2. Zonas destinadas a equipamento/materiais definidas e identificadas?				
	3. Marcação no solo adequada ao equipamento ou à atividade a realizar?				
	4. Mecanismos de controlo de inventário organizados?				
	5. Equipamento em uso, totalmente operacional?				
	Observações:				
Limpar (Shine)	1. Zonas de armazenamento e equipamento limpos?				
	2. Lixo dentro do local apropriado?				
	3. Marcação no solo visível/ não danificada?				
	4. Material de limpeza visível e acessível?				
	5. Tarefas de limpeza estão definidas e são realizadas regularmente?				
	Observações:				
Padronizar (Standardize)	1. Mecanismos de controlo de inventário em funcionamento?				
	2. Mecanismos de gestão visual atualizados regularmente?				
	3. Todos compreendem as suas tarefas e procedimentos a cumprir?				
	4. Sugestões de melhoria são geradas e apresentadas com regularidade?				
	5. Standards dos primeiros 3S atualizados e perceptíveis?				
	Observações:				
Manter (Sustain)	1. Todos os procedimentos, mapas e guias estão atualizados?				
	2. Quadro de indicadores atualizado diariamente?				
	3. Quadro dos 5S e posters atualizados diariamente?				
	4. Todos estão aptos à realização do seu trabalho/tarefas diárias?				
	5. Todos percebem e conseguem explicar os benefícios dos 5S?				
	Observações:				
*0-17: Melhorias urgentes ; 17-34: Pode melhorar ; 34-50: Organização ideal					Total

Appendix F: Graphic work instructions (examples)

F.1: Packing process – Category 1 products.

FREZITE

Embalamento Ferramentas - Embalagens Cartão

1 Seleccione a Caixa

1.1 Utilize a tabela desta folha como referência. Comece por identificar o **diâmetro da ferramenta**. As referências das caixas seguem o **seguinte código**: Neutras - [EM92].[L].[H] ou FREZITE - [EM90].[L].[H]

2 Seleccione o Preenchimento

2.1 Utilize a **tabela desta folha**. O preenchimento adequado à caixa que escolheu anteriormente ocupa na mesma linha da tabela, na respetiva coluna. Os preenchimentos podem ser de dois tipos: **bases** quadradas, ou **interiores** (com ou sem furo a picotado).

2.2 As referências dos preenchimentos seguem o seguinte código: Bases - [EM91].[L].[000] e Interiores - [EM91].[L].[øfuro]

3 Embalamento



1. Dar Forma



2. Preencher: colocar primeiro uma base no interior.



3. Acessórios
Atenção: devem ir acondicionados devidamente!



4. Fita cola
No caso de H > L, esta deve ser aplicada desde o topo.



5. Colar Etiqueta
Visível do lado esquerdo de uma das faces laterais (de preferência a do logótipo).

Acessórios!

Fresas de afinação e jogos:
incluir respetivo jogo de anilhas.

Aperto mecânico: incluir chave de aperto e calibrador de lâminas (Ver catálogo geral/desenho de produção).

diâmetro	Embalagens (EM92/EM90)		Preenchimento (EM91)	
	L	H	L	øfuro
145	175	40	173	145
145	175	60	173	145
145	175	210	173	145
185	220	50	218	185
185	220	90	218	185
185	220	180	218	185
250	290	60	288	250
250*	290	160	288	250
335	370	60	368	335
335*	370	160	368	335
370*	400	160	398	370

*só existe versão neutra

L – Comprimento lateral da base (quadrada) da caixa; H – Altura;

F.2: Packing process – Category 1 products.

FREZITE

Embalamento Ferramentas - Embalagens de plástico

1 Seleccione a Caixa

1.1 Utilize a tabela desta folha como referência. Comece por identificar o **diâmetro da ferramenta**.

3 Preparação e Embalamento






Utilizando a furadora, remover do rolo de espuma a forma desejada, **consoante a embalagem escolhida**.

Retirar ambas as formas. Devem sempre ser duas: uma para a base e outra para a tampa. **Aproveitar o máximo de espaço!**

Não esquecer de introduzir as formas anteriores nos respetivos fundos. Esta operação condiciona melhor a ferramenta.

Antes de introduzir a tampa e colar etiqueta, verificar se a ferramenta não se movimenta lateralmente para máxima segurança!

Embalagens plástico preto (EM60)

Diâmetro recomendado	Referência	Diâmetro furo	Altura
16	EM60.01	16	80
20	EM60.02	20	20
30	EM60.19	30	120
30	EM60.03	30	200
45	EM60.06	45	60
45	EM60.20	45	120
65	EM60.07	65	80
65	EM60.08	65	120
80	EM60.05	80	80
80	EM60.09	80	120
80	EM60.10	80	200
105	EM60.21	105	120

Localização do equipamento necessário para utilizar a furadora manual

F.3: Instructions on how to perform stock requisitions in the ERP.

Início

1. Inicie uma nova requisição.
 

3. No campo "Tipo de encomenda", escreva "SSC".
 

4. Selecione "Seguinte" (fundo da janela).
 

5. No campo "Armazém" introduza "007". No campo "tipo de processo" introduza "172".
 

6. Introduza a referência e a quantidade a mover do artigo.
 

7. Selecione "Seguinte", seguido de pressionar a tecla "F3" três vezes seguidas.
 

Fim

Appendix G: Autonomous maintenance guide





Máquina de Corte
WIMMER TM 374

Responsável:

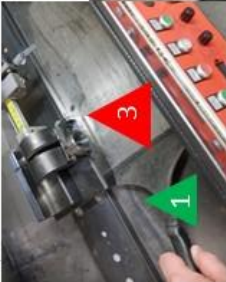
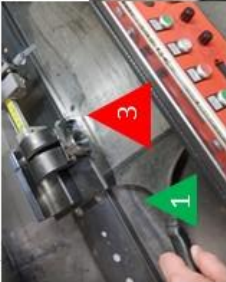
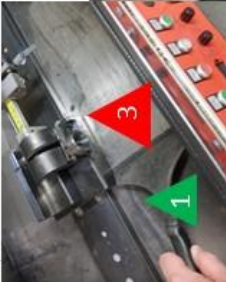
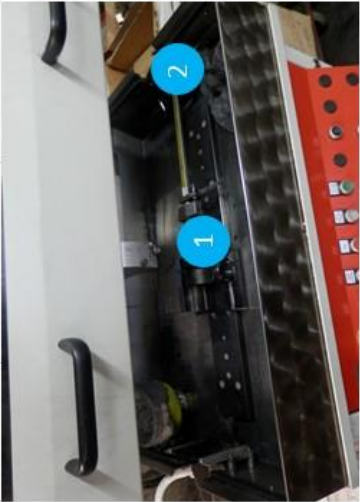
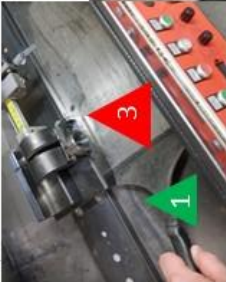


Nome

Sector: Armazém/Logística

Manutenção Autónoma

Número	Componente	Inspeção	Descrição	Ferramentas	Periodicidade
1	Unidade de aperto e régua	Visual/Auditiva	Procurar folgas e danos	Inspeção Visual	Diária
2	Saída	Visual	Verificar se existem fugas na saída	Inspeção Visual	Diária
3 e 4	Interior	Limpar	Depositar resíduos no filtro e esvaziar no final do turno	Equipamento 1	Diária
5	Painel de controlo	Limpar	Manter painel limpo	Pano macio	Semanal
6	Depósito do fundo	Limpar	Esvaziar depósito	-	Diária
7	Mangueiras	Visual	Procurar fugas e danos na tubagem	Inspeção Visual	Semanal



Legenda: ▲ Limpeza ● Inspeção ▲ Equipamento

ATENÇÃO! Detetando alguma anomalia: comunicar à Manutenção!