Identification and Characterization of Opportunities for Improvement in Industrial Processes by Lean Automation Method

Ana Carolina Guimarães de Oliveira

Dissertation presented to the School of Technology and Management of the Polytechnic Institute of Bragança to obtain the Master's Degree in Industrial Engineering, Mechanical Engineering branch, under the double degree with the Federal Technological University of Paraná.

Work oriented by:

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Dedication

I dedicate this work to the person who taught me to fly, my mom, Patricia Guimarães.

Acknowledgement

I would like to thank...

First to God for the opportunity to do the double degree and the exchange, they were moments of a lot of learning, which I will take with me for the rest of my life.

To my family, Mami, Val, Grandma Dete and Gutinho, for all the support they've given me throughout my life, and in all my choices. You are essential!

To my beloved boyfriend, Renan, to support with me throughout the development of the dissertation, and making this year of exchange (and covid) lighter and more special. Love you!

My nine best friends, who even far are present every day. 10/10 4ever!

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Abstract

Considering that the need to adapt industries to remain competitive is increasing, this research is being carried out with the objective of identifying and characterizing improvements in industrial processes, in order to improve them through resources and methods widely used in the industry, such as Lean Manufacturing (LM) and Industry 4.0 (I4.0). Therefore, it was necessary to analyze the LM and I4.0 methodology, resulting in Lean Automation tools, the process of a real company was also analyzed as a case study so that improvement suggestions could be provided. In addition, it was important to interpret the biggest losses that happen in industries with the objective of avoiding them. Finally, it was found that the application of Industry 4.0 in lean tools brings convenience and flexibility since the combination of the two methodologies can be done according to the needs of each industry. Regarding the suggestions for improvements found in the process, initially, it was the implementation of a dashboard as an aid to visual management. Furthermore, it is also suggested to apply the OEE together with the production notes, also in the form of a dashboard. The implementations already carried out were satisfactory in terms of facilitating the automated monitoring of the process. Therefore, it is possible to verify that Industry 4.0 helps with lean tools that can facilitate the visualization and monitoring of industrial processes.

Keywords: Lean Automation; OEE; Industry.

Resumo

Considerando que a necessidade de adaptar as indústrias para se manterem competitivas é cada vez maior, esta pesquisa está sendo realizada com o objetivo de identificar e caracterizar melhorias nos processos industriais, a fim de melhora-los por meio de recursos e métodos amplamente utilizados na indústria, como o *Lean Manufacturing* (LM) e Indústria 4.0 (I4.0). Portanto, foi necessário analisar a metodologia LM e I4.0, resultando em ferramentas de automação enxuta, também foi analisado o processo de uma empresa real como um estudo de caso para que sugestões de melhoria pudessem ser fornecidas. Além disso, foi importante interpretar as maiores perdas que acontecem nas indústrias com o objetivo de evitá-las. Por fim, verificou-se que a aplicação da Indústria 4.0 nas ferramentas enxutas traz comodidade e flexibilidade, visto que a combinação das duas metodologias pode ser feita de acordo com a necessidade de cada indústria. No que diz respeito às sugestões de melhorias encontradas no processo, inicialmente foi a implementação de um dashboard como auxilio de gestão visual. Além disso sugere-se também a aplicação do OEE juntamente com o apontamento de produção também em forma de dashboard. As implementações já realizadas foram satisfatórias em termos de facilitar o monitoramento automatizado do processo. Portanto, é possível verificar que a Indústria 4.0 auxilia nas ferramentas enxutas que podem facilitar a visualização e o monitoramento dos processos industriais.

Palavras-chave: Lean Automation; OEE; Industria.

Contents

Acronym

The next list describes nomenclatures that will be later used within the body of the document.

AR	Augmented Reality
CPS	Cyber-Physical Systems
DMAIC	Define, Measure, Analyze, Improve and Control
GE	General Electric
I4.0	Industry 4.0
IoT	Internet of Things
IPB	Polytechnic Institute of Bragança
JIT	Just In Time
KPI	Key Performance Indicator
LCD	Liquid Crystal Display
LM	Lean Manufacturing
NC	Nonconforming Circuit
OEE	Overall Equipement Effectiveness
PPC	Production Planning and Control

QCS	Quality Control Systems
R&D	Research and Development
RFID	Radio Frequency Identification
SWOT	Strengths, Weaknesses, Opportunities and Threats
TPM	Total Productive Maintenance

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Motivation

The social and economic situation is constantly changing, creating in companies the need to adapt to remain competitive in the field in which they operate. In addition, the world is increasingly competitive, looking for good practices, efficiency and solutions that optimize production and distribution, so it is important to unite the practical universe with the academic world to enable the discovery of new paths for new solutions. These solutions are leaner in the area of waste, but highly effective.

Flexibility in responding to demand has become the greatest challenge today. To achieve customer expectations, organizations need to be flexible enough to offer a wide range of products and services that are available at any time to the customer.

Delays in deliveries and services are no longer tolerated. Furthermore, the increase in the production mix and delivery speed is inversely proportional to the decrease in costs. And it is not enough that companies produce a wide range of products at low cost and quickly, it is also necessary that the products are of high quality.

Lean Manufacturing (LM), or Lean Production, as it is also known, is a tool used to carry out the dynamic process and constantly seek improvement, it depends on the understanding and involvement of all company employees. It gives manufacturers a competitive advantage, reducing costs and improving productivity and quality. It improves production, processing, cycle, and setup time, as well as reducing inventory, defects and waste [1].

Larry Culp, president and CEO of General Electric, which in 2017 was ranked in the Fortune 500 as the third-largest company in the United States by gross revenue, says he doesn't know any other way to run a company than through lean principles. And the results are:

- GE Medical Systems diagnostic imaging scanner developed using lean methodology has reduced diagnostic time from 3 minutes to 17 seconds.

- GE Plastics perfected a plastics production process that reached a volume of 1.1 billion pounds, which increased revenue and enabled them to close a contract with Apple.

- Betsy Bingham, lean and operations leader at GE Digital, noted that using value stream mapping, a tool that identifies individual steps in the business process and determines whether they add value, and employing new metrics, helped improve the contribution margin of the Digital Grid unit within GE Digital by 30% from 2019 to 2020 [2] [3].

As mentioned in one of the Lean Manufacturing principles, it is always possible to improve processes, with this observation, this dissertation also intends to show how Industry 4.0 (I4.0) can add improvements to the already consolidated LM tools. "The benefits of Lean have yet to reach their full potential. Today's technology, powered by the Industrial Internet, allows enterprises to drive even more value and reach new levels of performance to accelerate their competitiveness," according to the GE report titled, "Lean Manufacturing in the Age of the Industrial Internet" [2].

1.2 Main Objective

Based on the motivation presented, this dissertation, carried out in partnership with the company Techwelf, aims to identify opportunities for improvement in industrial processes in their different aspects: production, logistics and quality. Through descriptive and qualitative, with the use of resources and methods widely used in industry, such as Lean Manufacturing. Furthermore, it is intended to show how I4.0 techniques can help improve lean tools.

1.3 Specific Objectives

- Analyze Lean Manufacturing methodology with emphasis on Kanban;
- Analyze the influence of Industry 4.0 on Lean Manufacturing tools, resulting in Lean Automation;
- Examine the distribution process of a real industry and propose improvements based on Lean Automation;
- Interpret the big losses of the OEE and their consequences on industries in general.

1.4 Document Structure

This dissertation is divided into four chapters, where the first has as its function the contextualization of this work and the enumeration of the objectives of this project. The second chapter intends to frame the reader in relation to the Lean Manufacturing methodology and the contribution of Industry 4.0 in its tools (Lean Automation).

The third chapter has as its theme the distribution process of a large industry in the region of Bragança, Portugal and the proposals for improvement based on Lean Automation. The fourth chapter aims to bring together the results achieved and finally to list the final considerations about the proposals addressed, as well as their viability.

Chapter 2

Theoretical Foundation

2.1 Definitions of Lean Manufacturing

Lean is a methodology with the objective of generating an efficient and well-organized system aimed at continuous improvement and the elimination of all forms of waste [4].

Toyota identified seven major types of losses without adding value in administrative or production processes:

1. Overproduction: Producing items that were not ordered generates losses with excess staff and stocks, in addition to transport costs due to excessive stock.

2. Waiting (time without work): Employees who only watch automatic machines or who are waiting for the next step in processing, tool, part, or have no work to do due to lack of stock, processing delays, equipment downtime and capacity constraints.

3. Unnecessary transport or handling: Moving in-process stock over long distances, creating inefficient transport or moving materials, parts or finished goods into or out of stock or between processes.

4. Incorrect processing: Inefficient processing due to poor quality tools or design, causing unnecessary movement and producing defects. Losses are also generated when products with a higher quality than requested are manufactured.

5. Excess stock: Excess raw material, in-process stock or finished products, causing longer lead-times, obsolescence, damaged products, transport and warehouse costs and delays. In addition, the extra stock hides problems such as production not being compatible, late deliveries from suppliers, defects, equipment under repair and long setup times.

6. Unnecessary moves: Any unnecessary movement that employees have to make during work, such as looking for, picking up or stacking parts, tools, walking is also waste.

7. Defects: Production of defective parts or repair. Repairing or reworking, scrapping or replacing production and inspecting means wasted handling, time and effort.

Liker 2005, includes an eighth waste, the waste of employee creativity such as wasted time, ideas, skills, improvements and learning opportunities by not involving employees of organizations [5].

Lean production utilizes all of the skills of the workforce, assigning workers more than one task, integrating direct and indirect work, and encouraging continuous improvement activities. As a result, Lean Production is able to manufacture a greater variety of products, at lower costs and higher quality, with less of each input, compared to traditional mass production: less human effort, less space, less investment and less development time [6].

2.2 The History, Evolution and First Techniques of Lean Manufacturing

After World War II, Toyota decided to enter into large-scale commercial car and truck manufacturing, however, they encountered a lot of problems. With the Japanese economy devastated, Taiichi Ohno, Toyota's chief production engineer, defined seven types of waste and adopted a strategy to eliminate them. This concept became the basis of the Toyota Production System known in the West as Lean Manufacturing, it sought to combat unproductive times, disorganization, uncontrolled production, lack of quality standards and overproduction.

Artisanal production methods were a known alternative, but it was not worth it if the company wanted to manufacture products for the mass market, Ohno found ways to deal with this, such as producing small batches eliminating the costs of large inventories, producing a few parts before assembling them causing errors to appear instantly, making operators more concerned about quality and eliminating waste with large amounts of defective parts, repaired at a very high cost, or even thrown away.

Top management used to judge factory management by two criteria: production and quality. The production consisted of the quantity of cars produced in relation to the plan, and the quality in relation to "external consumption", after the defective parts had been repaired. Plant managers knew that failure to meet production targets meant big problems, and failures could, if necessary, be corrected in the rework area, after the end of the line, and before the cars reached quality control on shipment.

Ohno, considered this entire rework system at the end of the line full of waste, according to him, none of the specialists, apart from the assembly line workers, really add value to the car. He also estimated that assembly workers would likely be able to perform most specialized tasks, and much better, because of their familiarity with line conditions.

Ohno's next step was to assign cleaning tasks, small tool repairs and quality control to the team. As a last step, after the teams were up and running, he periodically set aside time for the team to jointly suggest measures to improve the process. This process of continuous and gradual improvement, in Japanese, kaizen, took place in collaboration with industrial engineers, who still existed, but in much smaller numbers.

If workers could not anticipate problems before they occurred and take initiatives to resolve them, all factory work could easily stop, but the key was not to stop the line unless absolutely necessary, Ohno argued that the practice from mass production of setting aside mistakes to keep the line running, it only increased them further. Once the defective part is incorporated into a complex vehicle, the repair work can be immense.

And since the problem would only be discovered at the end of the line, a large number of vehicles with the same defect would have been assembled until the problem was detected. Therefore, Ohno instructed each workstation to immediately stop the entire assembly line if a problem arose that they could not solve.

As in mass production factories, the idea was simply to fix the bugs and hope it didn't happen again, Ohno instituted a problem-solving system called "5 Whys". Production workers were instructed to trace each error back to its true cause, asking 'why?' on each level of the problem discovered and finding a solution to the problem does not occur again. As the work team gained experience in identifying problems and tracing them to the final causes, the number of errors began to drop.

At the end of the assembly line, as the Ohno system consolidated, the amount of repairs before shipping constantly decreased. The quality of the cars shipped has also constantly increased. All this for the reason that quality control, however careful, cannot detect all assembly defects in complex vehicles.

Ohno also developed a new way to coordinate the flow of parts in the supply system, the just-in-time or kanban system. The idea was to convert the huge group of suppliers and parts factories into one big machine, for which he determined that the production of parts would be restricted to each previous step, to meet the immediate need of the next step. The mechanism worked through containers, transporting parts from one step to another. As each container was emptied, it went back to the previous step, automatically signaling the need to produce more parts.

Some authors argue that Lean Manufacturing evolved from the Toyota Production System; these philosophies were associated with management concepts and tools that resulted in the development of the Toyota Production System to Lean Manufacturing. Today's businesses must operate with maximum flexibility and the lowest associated costs. Only then can a company become competitive. It can be said then, that the key to success is cost optimization/reduction [7].

2.3 Lean Manufacturing Principles

When waste reduction techniques are being used, it is expected that there will also be a reduction in costs, if this does not happen, it means that the implementation was done ineffectively. This must be because Lean techniques aim to eliminate all unproductive activities and unnecessary costs. In addition, it proposes changes that add value to the product or service.

There is a sequence of five concepts, which companies can adhere to improve their processes, with the objective of manufacturing high quality products, reducing production costs and satisfying the needs of their customers. The five concepts are:

1. Specify Value: The product value must always be defined by the end customer, how much he is determined to pay for a particular product. The company must meet these requirements only with tasks that add value to the final product, without waste.

2. Identify the Value Stream: The value stream is all operations that add value, from planning to product marketing. To create, it is necessary to define all operations, those that generate value, those that, despite not directly generating value, such as maintenance, are necessary to the process and those that do not generate value and are totally irrelevant. The VSM (Value Stream Mapping) technique performs the mapping and identification of the value stream.

3. Flow: Flow optimization is the fluid processing of a service/product, it only has activities that add value and minimize waste. An example of a large flow is the production of a monobloc flow, with no stops or waiting time between activities, no intermediate product stock and minimal delivery time to the customer.

4. Pull: The basis of the Pull methodology is that a product is produced after a customer order. With this request, the production requirement for a certain product is generated, in a certain quantity and on a certain delivery date. The customer order must trigger the entire value stream process, thus producing only what is needed, when it is needed. However, it is necessary in practice, a minimum stock so that the delivery time is as short as possible.

This system allows for the abandonment of the traditional push-flow planning system, with several associated advantages, such as less dependency on stock, small batch production, reduction and control of inventory of work in progress and finished products, synchronization along the value chain , shorter lead times, more continuous production and information flow.

5. Perfection: The elimination of waste and the creation of value must be continually pursued. This principle comes from the Kaizen philosophy that seeks perfection through "continuous improvement". Even though perfection does not exist, it is always possible to improve from the current situation. This principle is transversal to all the previous principles that aim, as a whole, to explore the best ways to create value [8].

2.4 Kanban

The emphasis given to Kanban in this dissertation is due to the case study that will be carried out later, which is based on the Kanban tool, so it is valid that it be explained in the best possible way for a better understanding of the reader.

2.4.1 Kanban Definition and Implementation

The objective of Kanban is to improve the productivity system and ensure the involvement and participation of operators in the search for high productivity. It was developed to balance the flow of products through the production process [9]. In the Kanban system, employees do not need to analyze whether or not material is missing, as with the identification cards, which will be explained later, the stock levels are visible, as well as the manufacturing orders to be processed.

The cards can be physical or virtual, usually in green, yellow and red, indicating if it is not necessary to produce, if the production is flowing well, or if it is necessary to produce more to meet the next process, respectively. As a rule, production must necessarily be started for cards that reach the yellow band. When cards reach the red band, it means consumption of a scaled safety stock [10].

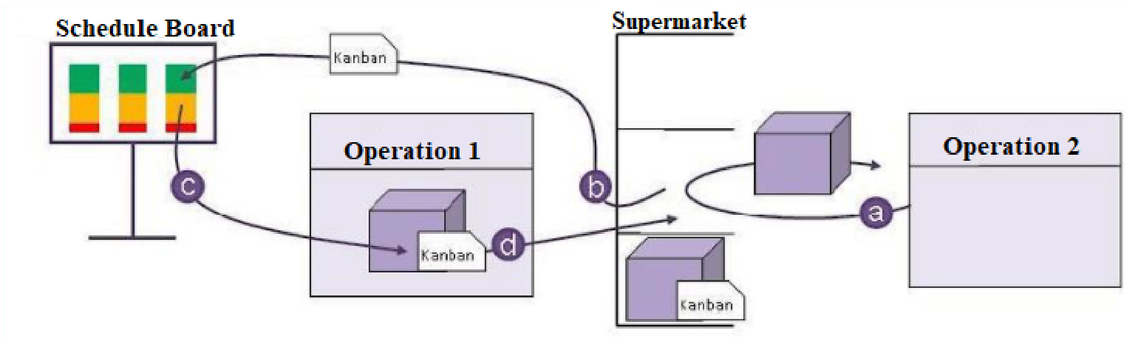

Figure 2.1: Kanban Scheme [11]

Is suggested the following sequential description of activities, improving understanding of the dynamics involved in a Kanban 2.1. [11]

a) A process from operation 2 needs an item from the previous process, operation 1, and removes this item from the supermarket between the two processes;

b) The Kanban card that accompanied the item in the supermarket is taken to the programming board of the previous process, signaling the need to replace that item;

c) The item is manufactured and the Kanban card put back together with it;

d) The item is taken to the supermarket that exists between the two processes.

The schedule board is an important source of information, as it is possible to visualize and identify the quantities that were produced and which ones will be produced during that shift. The operational dynamics of this framework is quite simple and carried out on the factory floor.

2.4.2 Kanban Advantages and Disadvantages

In general, the main advantage of the Kanban system in the industrial process is for the workers, who only follow the starting points and the sequence of cards. As in some processes a mix of products are produced in the same machine, a small stock is needed so that there is production flexibility, respecting the production schedule without sacrificing supplies and interrupting the line [12].

The main benefits associated with implementing the Kanban system are:

- Inventory reduction, resulting in more physical space available between workstations and easier inventory management;
- Improves production flow;
- Prevents overproduction;
- Puts control on operators;
- Creates visual management and process management mechanisms;
- Improves responsiveness to changes in demand;
- Simple operating system;
- Information between workstations is faster when problems arise in the processes (breakdowns and non-conforming parts);
- It benefits the adaptation of the pull system, because it is only produced according to demand needs;
- Shortening of delivery times to customers. [13]

This mechanism attacks one of the main reasons that lead companies to accumulate inventory: the fear of not recognizing the moment when it is necessary to start production again. The amounts of Kanbans, calculated under current conditions of the process, without implementing other improvements, it is common to obtain an inventory reduction between 25% and 75%. This reduction is important, especially from a financial point of view, since in addition to allowing a reduction in the cost of capital invested in inventory, it also allows for a reduction in space [13].

The Kanban system also has some disadvantages, such as not being used in all types of raw materials, components with large quantities to transport, which are physically too fragile to be handled, with small quantities to transport but with large dimensions taking up space on the production line.

Besides that, requires strict discipline, demand should already be stabilized, does not respond quickly to product change. Kanban physical cards are easily frayed, wet, torn, and placed in the trash by accident. Also, changing the bill of materials for products requires recalculate the number of Kanbans [14].

2.4.3 Visual Management

The Kanban system allows visual control throughout the entire production process, allowing the identification of failures or waste that must be corrected immediately. Allows anyone, who is in your workplace, to understand everything that is around them. This tool also makes it possible to increase the efficiency and effectiveness of operations, making all employee procedures visible, logical and intuitive [15].

When information is immediately seen by those who need it, there are a number of benefits. They allow operators to do their job more easily, more motivated, and even a lot of ineffective controls and planning are eliminated. Information boards containing standard work methods, objectives, performance indicators, together with communication boards, are tools that facilitate work on the shop floor and increase employee pride and satisfaction [16]. In the Kanban board, analogous to the card system, magnets and plastic chips are used as a sign. Contains all production processes, and as soon as the product is moved, the flag is moved on the frame according to that move. When this product is consumed, the signal representing the product is moved to the Kanban board production queue [17].

With the light indication, the operator activates a light command at his workstation every time he consumes a product. This signal is transmitted to the production cell of that item, where a light will be lit for each unit to be used. The worker at the supply station triggers a command for each unit he produces, which causes the lights to go out.

Look-see is a form of Kanban that is based on visual systems, such as marks on the floor that signal when an item needs to be stocked. The components themselves can be used as signals to production when the content starts to empty and is removed from the

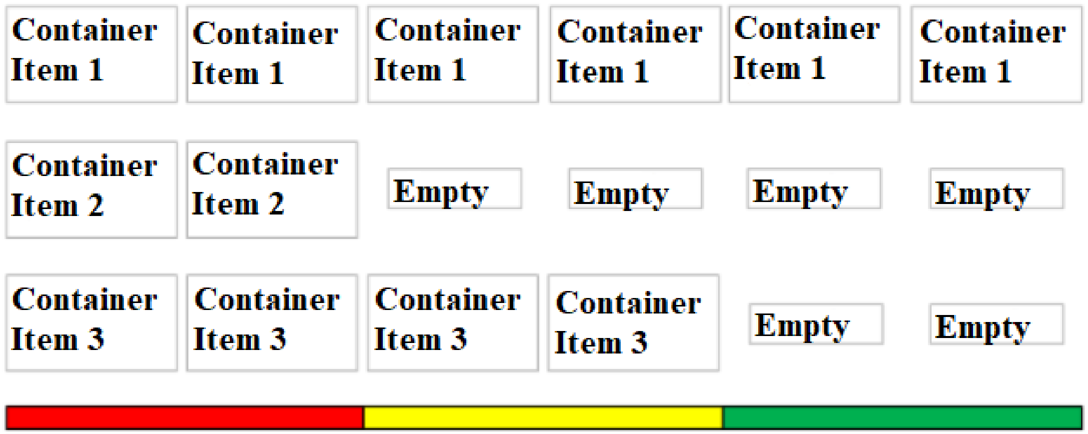

Figure 2.2: Kanban visual management - look see [13]

queue for production, the operator gets the knowledge when it has to be supplied or have a certain material or component produced 2.2 [17].

2.4.4 Kanban Pull System

This production system is driven by the customer, that is, by the output of the process, as opposed to the classic push system, which is characterized by production based on forecasting the demand of the final consumer. The pull concept is integrated into the Toyota Production System philosophy.

It was mainly developed to combat the inefficiencies of the push production system. Its operation consists of a flow of information parallel to the flow of materials, but in the opposite direction, in the form of some kind of visual symbol, the Kanban [18].

The main objectives are:

- Minimize in-process inventory;
- Minimize the fluctuation of in-process stock, in order to simplify its control;
- Reduce production lead time (metric that represents the time it takes for a product to be produced);

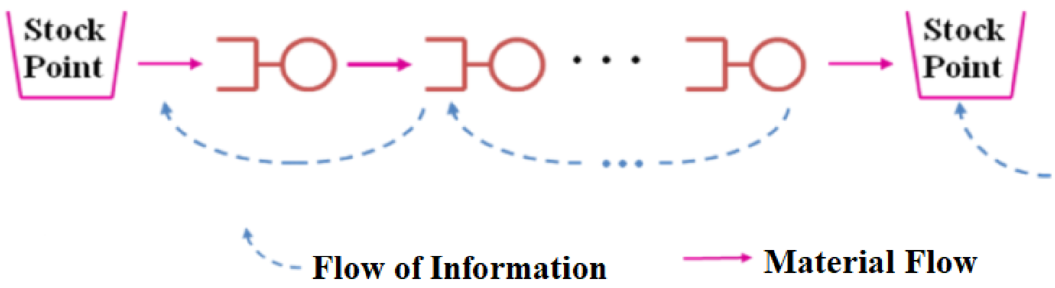

Figure 2.3: Diagram Representing a Pull System [18]

- Raise the level of factory control through decentralization: give area operators and supervisors a role of production and inventory control;
- React faster to changing demand;
- Reduce defects [19].

The advantages perceived by companies that have implemented a Lean Manufacturing system (pulled) are presented in table 2.1:

Competitive Advantages	Advantage Perceived by the Company
Delivery Lead Time Reduction	63%
Price Reduction	63%
Increased Market Share	61%
Reduction of Time to Launch a New Product	39%
Increasing Product Diversity	24%

Table 2.1: Advantages of Lean Production

It can be seen in figure 2.3, in a pure Pull system, each station pulls the previous station, in a chain effect, until the beginning of the process.

It is important to highlight that inventories generate high costs for many reasons, such as quality defects, long lead times, and consequent lack of flexibility with customers. Using the Pull principle, not only production, but also logistics, are only activated in the value chain when the customer is carried out, thus managing to synchronize production with logistics and with the customer's "pace".

In addition, the introduction of transparent and self-regulated systems can be considered an advantage of this system, thus facilitating production planning and control, avoiding “fire fighting” and opting for intuitive visual management systems.

2.5 Lean Automation (LM + I4.0)

Digitization and Industry 4.0 have a strong impact on today’s production environment. Established lean production methods are also affected and can be improved through new technologies as it is considered a complement to automation. Any digitization must deal with waste and reduce it more effectively than a classic lean approach could [20].

Lean Manufacturing and Industry 4.0 are concepts with different origins and moments of appearance, but they seek the same goals: reduce waste and improve companies’ production. However, they are executed in different ways, LM through waste reduction and I4.0 through exploring new technologies powered by the IoT.

These approaches can be completed, as the implementation of LM will lead the company to train thinkers [21] that will be critical to the change required by Industry 4.0. It is hoped, however, that new technologies can also help in this training and in making the right decisions through collaborative work platforms, teaching platforms and "learning factories" [20].

The process flow in Lean Automation is simple and helps humans and machines collaborate rather than work independently. When compared to conventional automation, Lean Automation spaces are smaller, system prices are cheaper, inventory is lower and energy use is lower. The system designer and operator, however, must have higher skills and knowledge. Failure can come from not following the right steps and not understanding that lean is not just about applying lean tools, but also changing the culture of companies and developing people [22].

2.5.1 Lean Automation Applications

Next, the main lean techniques will be explained along with the automation of Industry 4.0 and the improvements that this union can cause in the processes.

Continuous Flow

Raw material, semi-finished and finished products must have a continuous flow and according to the customer's request. In this way, it is possible to guarantee that the necessary information and materials are delivered to the production system in the right time and in the exact quantity. With the development of flexible production systems, it is possible to achieve a continuous flow. This system seeks to balance the use of people and equipment, always seeking to add value to the end customer and ends up simplifying operations.

Common mistakes such as inventory counting, insufficient capacity and centralized control systems can lead to interruptions in flow and, consequently, delays in decision making. Industry 4.0 uses a technology where "smart" products are automatically identified and work by issuing radio signals, capable of accessing information such as location, history, status and flows present on the tags, known as RFID [23], aiming to eliminate errors associated with stocks, as it can monitor them in real time. With this monitoring, it is possible to reduce the maintenance of stocks for long periods, generating cost savings in the products [24].

Horizontal integration, which are optimized real-time networks that allow for integrated transparency, offering a high level of flexibility to respond more quickly to non-compliances [25] [26], is enabled by I4.0 and can connect network companies using clouds, thus facilitating outsourcing. With integrated planning, subcontractors will have less difficulty managing the lack of capacity.

In addition, through CPS, cyber-physical systems, where intelligent machines, products and devices are used that exchange information autonomously, working in collaboration with the physical world around them, being able to negotiate cycle times and, thus, find the best possible usability per workstation in a continuous flow of goods. The transfer to a decentralized structure will transform production into autonomous and dynamic systems capable of adjusting to updated production schedules [27].

Just in Time (JIT)

Determines that the products are manufactured on time and in the exact quantity, eliminating the need for unnecessary stocks. For this to happen, it is extremely necessary that the logistical system is impeccable, as any interruption in the flow of information can cause changes in the search for requests and generate excess or lack of products.

The IoT has several communication devices capable of providing the necessary information about the products and their respective location. This is possible through the use of RFID tags, which can know the identity, real location, condition and trajectory of a product without human intervention. [28]

Real-time data capture at every step of the process synchronizes the flow of products with the flow of information, reducing or eliminating errors. Tracking each item ensures the correct product to the correct destination, at the time it was ordered. In the event of some unforeseen congestion or any other obstacle, a "smart" task allocator initiates a simulated negotiation process, redirecting as requirements to meet time constraint requirements [29].

Total Productive (TPM) and Predictive Maintenance

In addition to the applications presented above, it is also possible to make maintenance processes lean. TPM, for example, aims to improve the overall efficiency of machine equipment, which includes reducing wasted time, speed and quality [30]. What causes the loss of time are mainly machine settings and failures. Failures can be avoided with self-maintenance and replacement of parts, improving the condition of machines and reducing their degradation.

Augmented Reality can be used to guide operators during maintenance activities. In addition, sensors that monitor vibration, noise and heat help operators detect abnormal

	RFID	CPS	IoT	Cloud	Big Data	AR
Continuous Flow	X	X	X	X	X	
JIT	X		X	X	X	
Kanban Pull System	X			X	X	
TPM and Predictive Maintenance			X	X	X	X

Table 2.2: Industry 4.0 and Lean Integration Summary Table

conditions before failure.

For predictive maintenance, condition monitoring, data analysis and early failure prediction increase uptime and overall equipment efficiency. Data collected by sensors is transmitted to a time series database via a web service. Data in the database is analyzed using predictive algorithms and when a critical measurement level is detected, maintenance is scheduled [30].

E-Kanban

The digital version of the traditional Kanban card system is e-Kanban. It is able to reduce the probability of errors by eliminating the problems of human error in filling cards, bureaucratic tasks and excessive paper circulation.

When using Information Communication Technology, lost Kanban no longer causes errors in production control as long as the stock in the manufacturing execution system matches the actual stock. Another advantage over the old system is related to visualization, e-Kanban displays the flows of all production sectors on panels or monitors that can be viewed anywhere in the company, inside or outside the production units [24].

Table 2.2 presents a summary of the main applications of Industry 4.0 and Lean Manufacturing integration.

Big Data corresponds to the amount of data that exceeds the capacity of traditional processing. It can be defined as large volumes of data available at different scales of complexity, designed at high speed and that do not fit the data structures of current architectures [31].

Cloud is the term used to describe a global network of servers, each with a unique role. The cloud is not a physical entity, but rather a vast network of remote servers across the world that are interconnected and must function as a single ecosystem. These servers are designed to store and manage data, run applications or deliver content such as streaming videos, webmail, productivity software or media. Instead of accessing files and data from a local or personal computer, it is possible to access them online from a device with internet, the information will be available wherever you are and at any time [32].

With this, the convenience of using these two I4.0 methodologies in lean tools is explicit, and how comprehensive they are, since it is possible to apply them in practically all tools already consolidated in order to automate them.

2.6 Production Note

The sectors responsible for production planning and control (PPC) carry out the planning of production activities that must meet the company's needs. This planning is based on tools and calculations that have good results, but are not perfect and, therefore, there is a need to check what was executed, to compare it with what was planned.

This process is called production control, and is intended to provide information back to planning, allowing a historical basis for future planning and also allowing new plans to be made to cover errors or deviations from past or running plans.

The production control provides data on events that occurred in production, such as parts and quantities executed, the number of production stops and the reason for them, start and end times of activities, among others, exemplified in the figure 2.6

These data can be obtained in several ways, the most widespread being manual recording. This consists of notes that are made in the production environment, and that are passed on to planning, in order to control production. [34]

Research has shown that one of the key areas for all manufacturing companies is the production control function. This is due to the fact that it is the data-generating function needed in many other business functions, such as lean tools [35].

PRODUCTION NOTE																	
Operator:____						Equipment:____						N°____			Local:____		
Start of the 1st shift				1st stop			2st stop			3st stop			4st stop			Journey End	
Data	Initial Hourmeter	Hour Start	Hour End	Reason	Start	End	Reason	Hour Start	Hour End	Reason	Hour Start	Hour End	Reason	Hour Start	Hour End	Hour	Final Hourmeter

Reason:
1- Preventive Maintenance
2- Corrective Maintenance
3- Fuel
5- Operator
6- Transport
7- Lunch

Figure 2.4: Modified Production Note template [33].

Thus, the combination of lean with production control is essential in companies, since for a better application of lean tools it is ideal to have a thorough control of production to understand where the bottlenecks and main problems are.

One of the most important datasets for control is knowing what production activities have been carried out, what the end dates and times are, and the quantities produced. The collection of this data in production environments in batches or with high volumes of production, is usually done at the end or during the operation. Except in cases where this collection is done automatically, the operator must write down or enter this data.

This manual note is functional, but it has a number of problems. One of these is the fact that all human activity is subject to error. Another problem is the reliability of the indicated data, as this depends on the precision with which the operator makes counts, measurements, calculations, timing and other observations. The frequency with which this annotation is made can also be a problem, as the smaller it is, the longer it will take for the data to be known.

The correct thing would be for manual annotation to consider all the data necessary for the control, but this would imply a large extra workload for the operators, in addition to their normal productive tasks. In this way, some data are selected that will then be collected in the note. It is worth saying, however, that this is a simple process to be implemented and that it requires little investment.

Due to the problems presented, situations where there is no absolute confidence in the data collected and made available by the production control are common. This causes parallel and individual controls to be used, in addition to requiring an effort to confirm existing data or to collect missing data.

With this, the planning works with inaccurate or even incorrect data, causing the next production plans and programs to be distorted, which generates a cycle of inaccuracies. These inaccuracies are felt at all levels of the production planning and control hierarchy.

An alternative to manual notation is data collection equipment, such as bar code readers, keyboards and computers, which do not require manual writing of note data, for example, the identification of a material or a production order.

Other information such as operator identification, products, codes and locations can also be obtained this way. Computers also allow information to be collected using easy-to-use features such as buttons and data lists, thus eliminating the need for typing.

The use of this category of appointment through collectors still depends on the operator. This requires a diversion of attention from the productive activity itself, indicating that the frequency of production control data collection cannot be high, as it would affect the productive activity. However, the reliability of data obtained in this way is superior to the reliability of data obtained through manual notation.

In this case, the implementation of these data collection equipment does not require a large investment, as these equipments are widely used in various applications, according to QS, which for 27 years has been providing integrated business management system services on demand [36].

2.7 OEE

Due to the current market, which is totally globalized, competitive and demanding, companies need to find ways to survive and meet the demands that are imposed, always seeking to increase productivity, efficiency and quality of their products and processes. For this to happen, it is necessary to correctly control and manage your data in order to generate indicators capable of monitoring your production processes.

The KPI (Key Performance Indicator) is a highly relevant metric for measuring the performance of a strategy and management processes. With KPI indicators, managers can analyze the numbers correctly and decide if projects are progressing satisfactorily, or if a change of direction is necessary.

The importance of the KPI is to encourage the exchange of information between employees at all levels within an organization. With this, employees feel important and are aware of how their performance can help or not for the company's growth.

Based on this, this chapter seeks to analyze the OEE, as it is an indicator that encompasses three important factors, availability, performance and quality, which will be better explained later, thus making it possible to know the reality of an organization's production processes, in order to interfere where there is a higher failure rate. [37].

An ideal equipment, totally efficient, would work for as long as necessary at maximum speed, without causing quality problems. However, most equipment is subject to the occurrence of minor variations such as small downtimes, and there is also the possibility of causing defective parts, causing a reduction in the efficiency of the equipment [38].

The original definition of OEE that was developed by Nakajima [39] comprises the so-called "Six Big Losses", divided into three categories, as well as the degree of variation of these over the time available for production, as can be seen in Figure 2.5.

Nakajima excludes from its definition of losses planned equipment stoppages such as operator meal breaks or mandatory breaks; planned maintenance (autonomous, preventive, inspection or corrective); periods without production between other stops as long as they are provided for in the production plan [40].

With the identification of losses, it is possible to know the reason for the low performance of the equipment [41]. To record the time, data, reason for the stop and the time of occurrence, this for all production losses, thus making it possible to identify the factors with more stops, this data can be recorded with the aid of a production note. Complement that the loss identification phase must always be in constant improvement, since what is not measured cannot be improved [42].

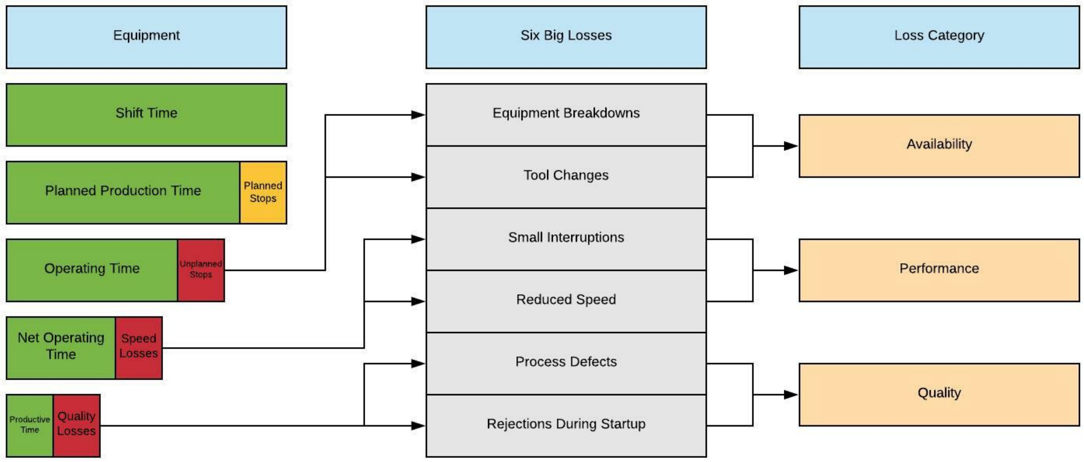

Figure 2.5: Modified Relationship between the Six Big Losses and OEE Factors [39]

The ideal goal of the OEE indicator for companies is 85%, but for this it is necessary to reach 90% availability, 95% performance and 99% quality in the equipment [39]. The OEE, must be classified as: unacceptable index less than 65%; between 65% and 75% is good; 75% to 85% is very good [43].

OEE is increasingly used in series production lines as its results allow us to assess the levels of productivity of the lines, the effects of improvement actions and consequently generate economic benefits for the organization [44].

Chapter 3

Improvement Plan

As previously mentioned, this research aims, in addition to showing the improvements of lean tools with the help of Industry 4.0, also to propose new solutions, and make them applicable to any type of industry.

In this chapter, the ideas for applying OEE and production note in a production and distribution process of a large industry in the region of Bragança, Portugal will be discussed. Also, discuss the OEE and its relationship to big losses.

One of the focuses of this work is to identify and characterize improvements in the distribution system of a large industry, but suggest improvements that can be applied to industries of all sizes and segments.

For this process to be effectively improved, the improvements must start in the previous process, in production with the production note and the OEE.

The implementation of production note in production will help to quickly identify stoppages and production deviations, thus reducing the chances of wrong or damaged products reaching the distribution process, or even worse, reaching end customers.

In addition, the OEE as a productivity indicator in the form of a dashboard is of great value because employees will be able to see in real time the consequences and results of their work, facilitating quick decision-making.

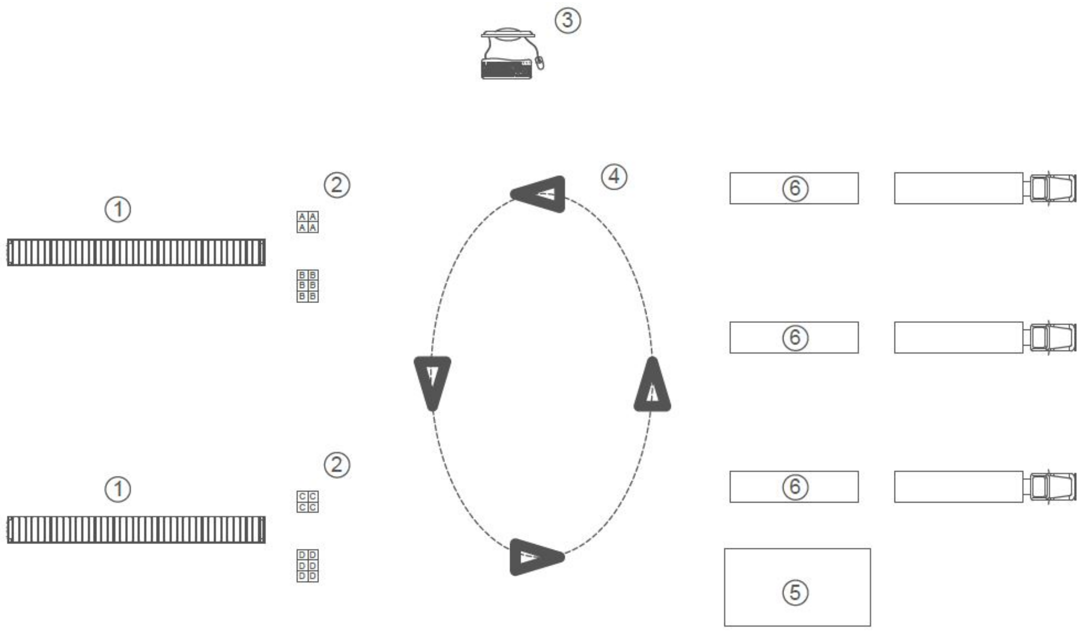

Figure 3.1: Industrial Distribution Process

A visual aid to control the distribution process was implemented, the initial improvement was carried out through a dashboard that will be presented in the next topics, developed by Techwelf, company with the objective of applying the knowledge and experience acquired in several national and European R&D projects to companies and institutions, through the innovation of processes and products, with the main objective of being an informative panel to facilitate the efficient monitoring of operations of the factory.

3.1 Internal Industrial Distribution Process

In figure 3.1 the points means:

1- Production Line;

2- Containers;

3- Outbound Logistics System;

4- Employee Path;

5- Stock;

6- Product Distribution to Trucks and Delivery.

Figure 3.2: Kanban Card Example

The distribution process of an industry in the region of Bragança begins when the Production Planning and Control (PPC) is made by the factory managers, who are part of the central system and carry out production forecasts for the next two weeks, these forecasts are passed on to the outbound logistics system, which will be explained later.

From there, the PPC can be started, all products go through the production line (1), as seen in the figure 3.1, in this line the employees divide the products into segments and place them in containers, which are batches of a given product, as represented in figure A, B , C and D (2).

From this point on, another process starts, the distribution process itself, at point 3 is the outbound logistics system, where the kanban cards are printed, there are three logistics possibilities: the goods leave the containers (2) for the stock (5), out of containers (2) to the delivery point (6) or out of stock (5) to delivery points (6). Figure 3.1.

This information is present on the Kanban card, in addition to other material data, such as code, name, quantity, description, barcode for identification, date and time, as in the example in figure 3.2

With the Kanban card in hand, and through an self-guided vehicle, the employee picks up the goods where the card indicates and takes them to the final destination also indicated on the card. After leaving the products at the final destination, the employee goes back to the computer (3) and informs the system that everything is fine, so a second Kanban is generated, this time a production Kanban, which is taken to the employees of line 1, entering to the mechanism of accumulation of containers, thus being possible to define the formation of the container for the next hour, with the objective of reducing the exchange of tools.

All programming is made to occur uniformly, if something goes wrong, the employee goes to the outbound logistics system and informs that it is not OK (NOK) and the reason for the problem, which is usually related to the line production (1) or with stock (5), depending on the severity of the problem, the NOK alert passes through the company hierarchy until the problem is resolved.

In the first analysis carried out in the distribution process, it was observed that some steps were already done electronically, such as printing the kanbans already filled in and the OK and NOK system. To complement the process, it was first suggested to implement a dashboard to help employees visualize what has been done, what is in progress and what is scheduled to be done, the implementation of this improvement will be better explained in the next topics.

3.1.1 Dashboard

Dashboards are commonly displayed on large LCD screens in operational departments so that, following the performance indicators, all professionals feel more integrated into the organization's processes. This transparency process is called spot management.

Another great objective of a dashboard is to enable each company to build their dashboard with their indicators in a customized way. Thus, it is not a standard interface, but a customized tool for the specialties of each business.

Through the grouped and available data, it is possible to plan and implement improvements in processes, correct failures and think of new strategies. With the dashboards, it is also possible to display data on production processes and various industrial performance indicators, such as raw material waste rates, machinery reports, among others.

In addition, the manager can choose to view this data in general or with information segmented by categories. It can also monitor updated indicators in real time (near-real-time) or periodically consolidated. It is noted that, in the case of a selection of indicators, it is necessary to list the most important ones, as the excess of little or no relevant information obstructs the quick analysis and decision-making by managers.

In this work, the dashboard was as a complement to the already consolidated distribution system, without too drastic intervention, so that employees feel comfortable with the improvements.

3.1.2 Dashboard Pilot Version: Implemented Improvement

The first version of the implemented dashboard is available in the 3.3 and 3.4 images, and the output logistics system can be seen in the figure 3.5. The kanbans represent materials that are already available and are relative to the local distribution system previously.

The vertical red line indicated on the 3.3 image is the current time position, which is updated every 15 minutes. It serves as a basis for operators and managers to understand what has already been done, what is in progress, and what the next forecasts are.

In the left part of the images, it is possible to visualize the customers, where each line represents the distribution status of their products. The green color represents the kanbans already relocated OK, the orange ones, the kanbans that are currently being relocated, and the blue ones, the kanbans that are scheduled to be relocated. Gray bands signify programmed operator stops, at which times the lines are stopped.

In figure 3.4 there are some yellow cards, to the left of the red vertical line, this means that at the time of the exit logistics there was some problem, and NOK (not OK) was given in the system, so it turns yellow at the time of NOK and it is reprogrammed, remaining yellow until the issue is resolved and the system is OK.

The horizontally colored bar indicated in the figure 3.3 identifies the criticality level of

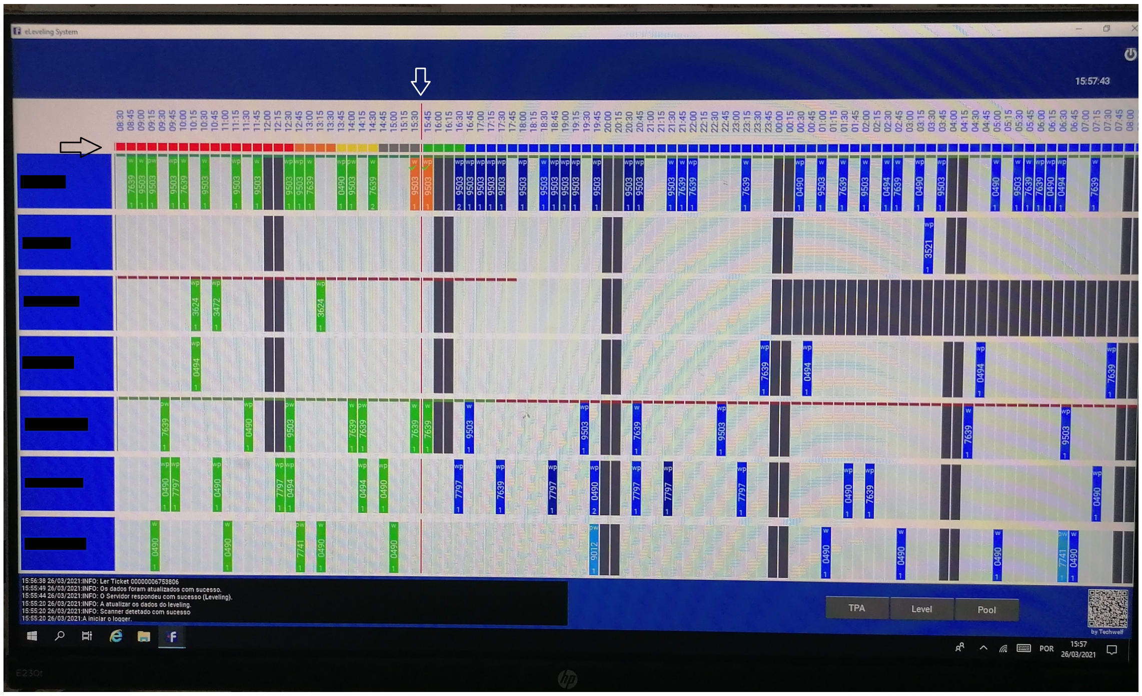

Figure 3.3: Dashboard Kanban 1

the delays of unregistered cards or registered as NOK to the left of the vertical red line. If a blue card is to the left of the red vertical bar it has not been counted, if it is an hour late it is not critical, represented by the gray color.

If it takes 2 hours, it starts to be critical, represented by the yellow color, if it reaches 4 hours it reaches the orange line and the hierarchy requested to solve the problem increases, if it reaches the red part the problem arrives at the level of the factory directors.

In future versions, it is also expected to include alerts of production stops and deviations from production note information, in addition to monitoring production according to availability, performance, and quality through the OEE.

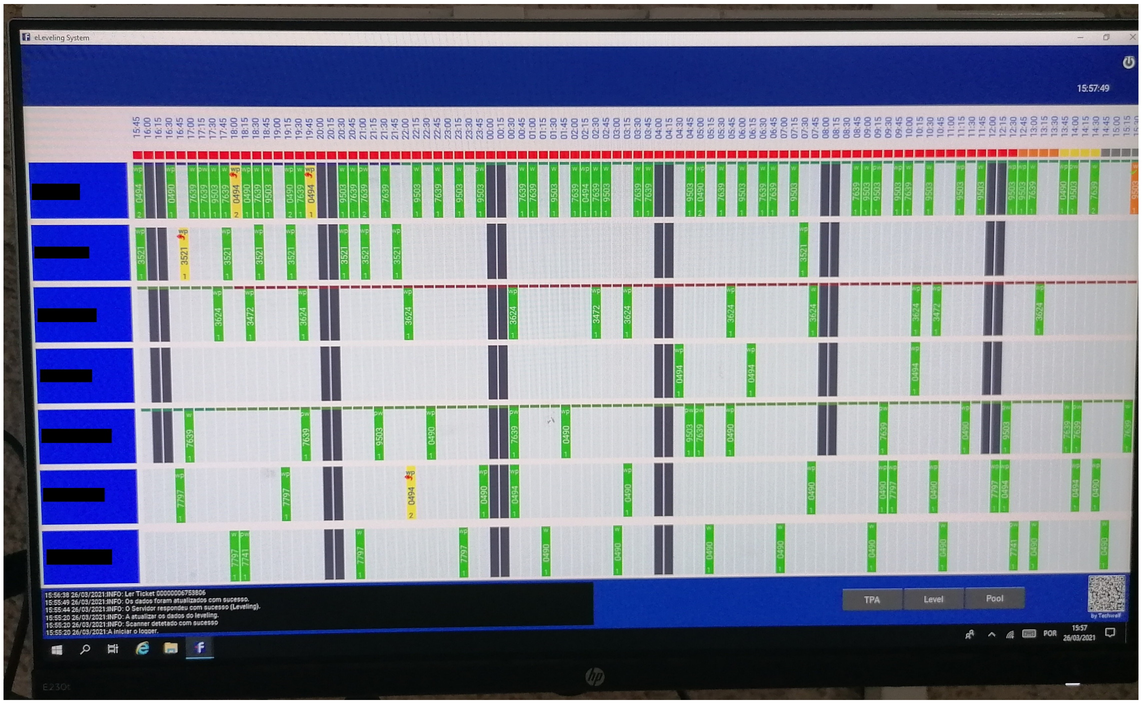

Figure 3.4: Dashboard Kanban 2

3.2 Improvements in the Production Process

3.2.1 Quality Control Systems

Quality control in production is a set of techniques and operational activities used to make the products produced controlled and organized. It also certifies that the customer's requirements have been met.

In the company of the previous case study, this control is carried out by the operators during the production process. The damage would be greater if the failures were only detected after the end of the production process, with the increase of NOK parts (not OK), it would also increase the number of tools needed for rework.

It would be even worse, if a quality problem is detected by the consumer, which can cause the loss of the manufacturer's good reputation, which often leads to irreversible damage. This is, therefore, a process that aims to reduce the variance so that, in this way, all products comply with the agreed standards.

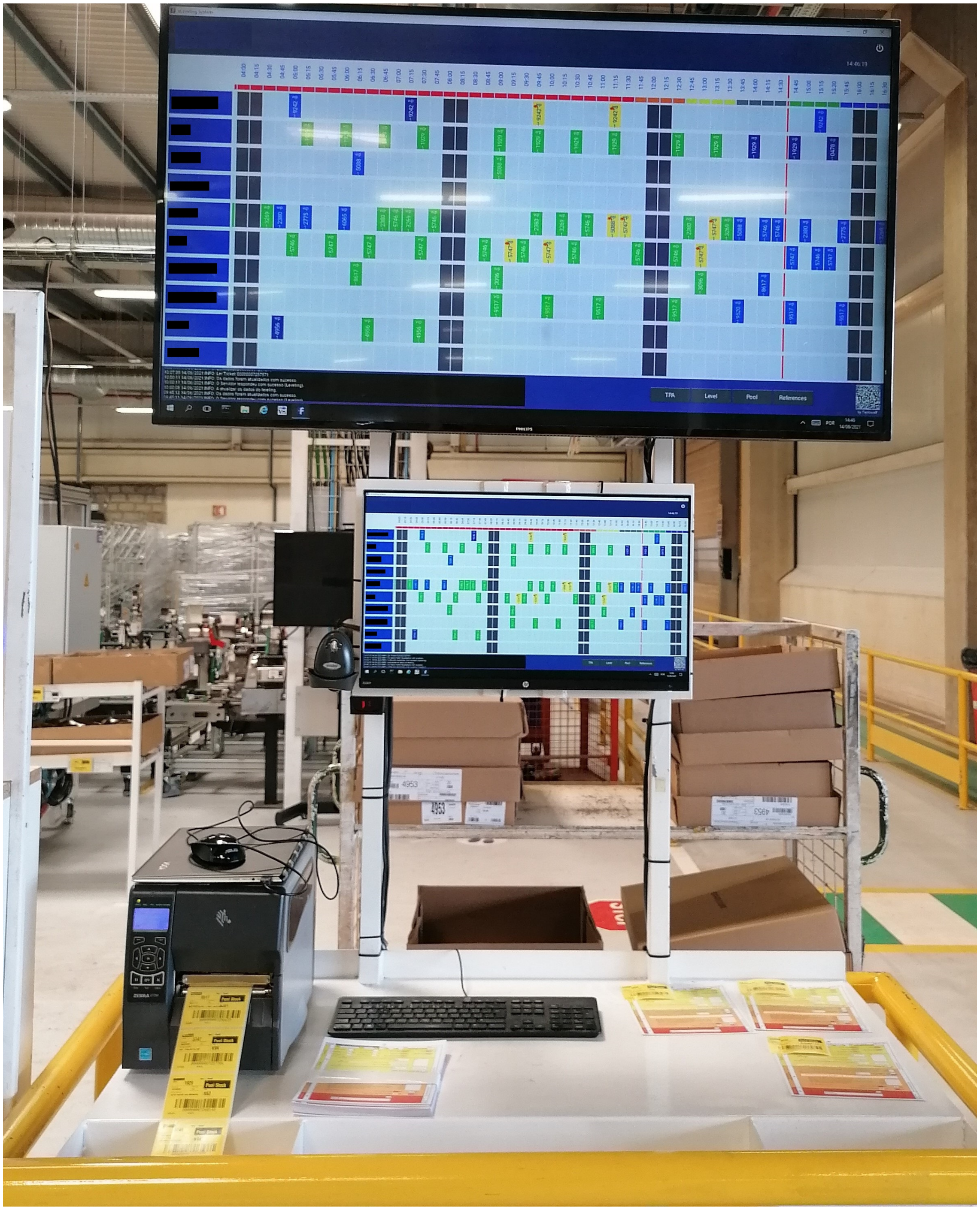

Figure 3.5: Outbound Logistics

The OK 1st Part is a procedure carried out in the company of the case study of this research and it happens as follows: whenever there is a shift start, tool change, any type of break or quality problem, the employees responsible for it must respond to a checklist to ensure that everything is properly correct for production return.

In order to ensure that production starts well and ends well, here is a checklist with a set of important aspects, which must be checked at each validation:

5s: related to the cleaning and organization of the workstation;

Versatility: check if they are able to do the intended job;

Health and Safety Executive (HSE): check safety points, how safety instructions are posted, test safety systems. If personal protective equipment is available and is being used?

NC: All parts in the Nonconforming Circuit are identified. There are no out-of-flow parts;

Process: Ensure that the process parameters are in accordance with the reference to be produced, check the critical points of the tools and that the protectors of the functional zones are present;

Product Characteristics: Carry out and check all the controls of the final inspection, check the absence of burrs, loose particles, and mass in the part, for example;

Identification Ok 1st Part: Identify the ok 1st part with date, shift, time, reference and operator ID and place it in the support identified for this purpose;

Final Result: After confirming all the points of the OK 1st Part.

All aspects are validated by the intervening functions. Within the Final Result aspect, the production result can be:

OK: All aspects have been checked and are in compliance. Production can start without any restrictions.

NOK: There are aspects that are NOK and that, due to their critical nature, production cannot be started. Until corrective actions are implemented, production must remain stopped.

By identifying the NOK aspects, necessary containment and/or correction actions can be carried out quickly. Therefore, the importance of the initial validation activity and subsequent error/problem control is given, also avoiding non-quality/productivity costs

3.2.2 Production Note

In addition to the options mentioned in the previous chapter for capturing data, there is also the option to automatically collect production control data. In this process, there are equipment installed in production resources that generate information without the need for operator intervention.

This equipment can be controllers, actuators and sensors, among others used for automation and control of the production process. For example, the same equipment used for loading can generate control information about how many parts were loaded into the equipment and the times of those events.

Likewise, various other control data can be obtained, such as number of parts produced, production and set-up times, number of rejected parts and material and product identifications.

With the use of these equipments, the frequency of data collection is very high, as most of them generate several pieces of information per minute. This generates the need for processing this data, as its volume and detail are large, which makes it impossible to make it available in the way it is collected. The data obtained in this way is highly reliable and available immediately after collection. The implementation of this category of data entry requires high investments and specific qualifications, according to QS, which for 27 years has been providing integrated business management system services on demand [36].

Regardless of the process used, the data must be treated correctly after collection, so that the necessary corrections or improvements can be carried out. Furthermore, due to the importance of recording production, it must be constantly reviewed to ensure that the necessary data is obtained with due frequency and accuracy.

3.2.3 OEE

Availability Indicator

This index is nothing more than the availability of the equipment, expressed as a percentage of the time the equipment actually operated and the time it should have operated. Also according to the authors, this index should answer the following question: "Is the machine working?" [45].

As an example of machine availability, consider that the company has three shifts, out of the 24 hours available, the planning foresees 1 meal hour for each shift, leaving 21 hours available for work.

At 21 hours, there was an unexpected stop, this stop was due to problems found by the quality control system (QCS). As can be seen in figure 3.6, inspections are carried out in certain periods of time, when a NOK happens, there is a time delta 1, until the problem is identified, some parts still continue to be produced, only then the line stops for maintenance.

After the maintenance is finished, the line starts to operate again, but with reduced speed, until an inspection is made again and a new OK 1st part is given, in this delta 2 time, during the turn of the line the machine loses in performance, which will be talked about in the next topic.

The stop lasted 4 hours. Then, from the 21 hours planned, subtract 4 hours from the unplanned downtime for a total of 17 hours available. So this machine had 80.9% availability, and the indicator is calculated by dividing the operating time by the planned operating time (17/21).

In general, which could be applied in any industry, in relation to the ways to obtain this data, it is understood that by accessing the PPC it is possible to obtain data on planned time and planned shutdowns, and for the part of unplanned shutdowns ideally, get this data through the production note.

Figure 3.6: OK 1st Part - QCS

Performance indicator

The performance index involves the following aspects: equipment production capacity in a given time, quantity of parts that can be produced in a period and, finally, the time in which production took place. Furthermore, according to the authors, this indicator should answer the question: "Is the machine running at full speed?" [45].

Performance losses are more difficult to observe manually or visually due to very short cycle times and small variations in the process. As mentioned in the previous topic, the 3.6 image shows that in delta 2, the machine produced less than expected due to previously unplanned downtime.

At this time, this machine, which should have produced 1000 pieces, only produced 882, transforming the number of pieces into hours, 15 net hours were left, of the 17 available, the other 2 hours were lost due to the machine working at a speed below the specified speed. Its performance was then 88.2%, as this index is calculated by dividing the units actually produced by the number of theoretical units that could have been produced.

For performance, obtaining data can be more complex, as to obtain the number of units produced it is necessary to know the time produced and the real time of the cycle, in addition to planning the number of units to be manufactured, it is necessary to know the time of standard cycle of the equipment.

It is possible to obtain the standard cycle time of the equipment by referring to the technical manual that describes its capabilities. The actual production information is possible to be obtained by the production note, once well filled, it can truly provide the units of parts produced by the equipment per hour.

Quality Indicator

Quality is composed of the number of parts that can be produced in a given period, parts that cannot be recovered (rejection) and defective parts that can be recovered. Therefore, this index tends to be easier to see and should answer the question, "Is the machine producing to the correct specifications?" [45].

Continuing the example, after the end of the day, 58 parts failed in quality, corresponding to approximately 1 hour of production, leaving 14 hours of production of good parts, with a quality of 93.4% dividing the number of good parts (882-58), for the total amount of production (882).

Regarding the parts being rejected or sent for recovery, in the QCS checklist there are questions that collaborators must answer regarding product quality, these questions can be eliminatory or limiting. In the eliminatory questions (yes or no) for the NOKs the pieces are rejected. In the limiting questions, where the answer is a number, there are limits, so if a certain part is within the established limit it is OK, there is also a determined limit where the part can still be retrieved and if it is outside that, it will be rejected.

In relation to product quality, the total planned number can also be obtained by PPC, and the number of good parts will also be present in the production note.

In this example, the OEE is 66.6%, the result of multiplying the indicators of availability (80.9%), performance (88.2%) and quality (93.4%). With the final representation of the 3.7 figure.

The OEE has different definitions and circumstances, making comparisons between companies difficult, as its objective is not the search for the perfect measure, but one that shows production employees where to act with improvements. they add that, “by improving the process and reducing waste, financial returns and increased productivity and product quality will be obtained” [42].

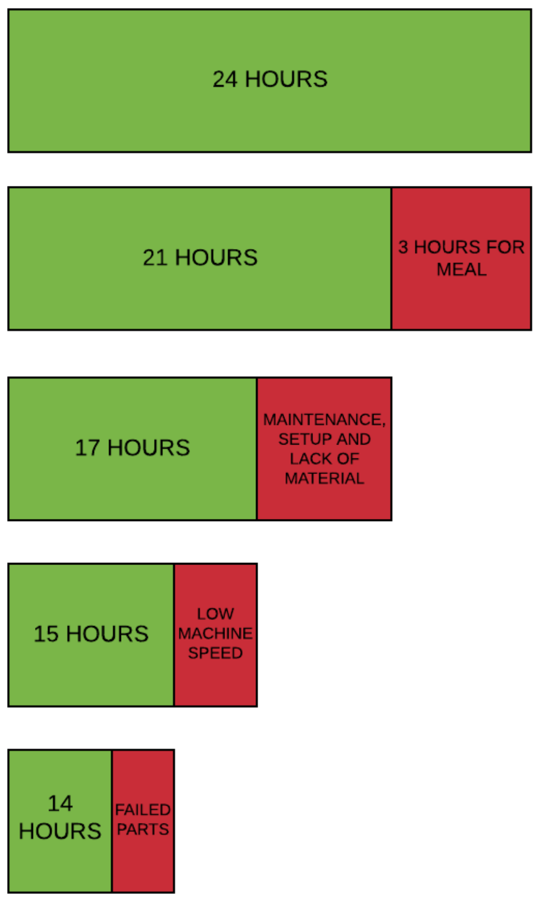

Figure 3.7: OEE example

3.2.4 Suggestions for Improvements in the Production Process

After the information presented on the production notes and OEE, explained their operations, ways of obtaining data and practical examples, it is suggested that the production notes of the automatic collection be used in the production area of the company, so that this collected information serves as a database for the OEE indicator. Furthermore, it is also suggested to implement dashboards on production lines, so that employees can see in real time the consequences of your work and efforts.

With the OEE information available, it is easier to make the necessary corrections both in the equipment and in the processes performed. These improvements would also be reflected in the distribution process, as with a more organized production, consequently, the logistics process will also improve.

3.3 OEE's Big Losses

In Table 4 the three aspects of the OEE are classified and which major losses are related to them. It is important to carry out this type of analysis, because, with the knowledge of which losses are linked to which aspects, it is possible to investigate into each one of them to find the root causes of all losses, and take appropriate actions to correct the errors, or even prevent them.

Availability: Downtime Losses	**Performance: Speed Losses**	**Quality: Defects Losses**
Failures	Minor Stoppages	Scrap and Rework
Setup Time	Reduced Operating Speed	Startup Loss

Table 3.1: Examples of Occurrences of the "Six Big Losses" and Respective Consequences [38].

Next, each loss and its consequences on OEE results within an industry will be analyzed in a generalized manner.

1. Breakdowns: Losses related to breakdowns and tool changes generate consequences on availability, which end up reducing the time available for the equipment to operate. The reduction or even elimination of unplanned downtimes is the main point for OEE improvements, since any other point cannot be improved if production is stopped.

In addition to knowing the real time of stops, it is important to understand why the stops happen and at what times. Here comes the importance of the production note, whose main function is to obtain information such as stop time, reason, duration, so that a later analysis can be made and the process optimized.

Some occurrences that generate consequences on availability and end up reducing the time available for the equipment to operate are tool failures, malfunctions that cause equipment interruption and general system failure.

2. Change of Tools: The losses related to tool changes are the time spent between the last piece produced with quality until the production of the next unit produced with the new tools, respecting the quality criteria, after a new start-up/adjustment.

These losses are mostly due to the non-standardization of the process, where operators carry out tool changes in the way they prefer, and not in the quickest and most adequate way. The implementation of Lean methodology SMED (Single Minute Exchange of Die) techniques can be an excellent approach to minimize these losses.

Tool change, machine preparation, lack of material or operator and equipment start-up are some occurrences that also generate consequences on availability and end up reducing the time available for the equipment to operate.

3. Minor Interruptions: Short stops that are solved by the operator himself are losses related to speed reduction, which consequently decrease the machine's performance. This happens, for example, when there is an obstruction of the flow, lack of materials or tools, material stuck, wrong settings in the equipment, blocked sensors, employees busy on other machines, dependence on the assembly line or a temporary breakdown. If the problem is not detected, it can become recurrent and negatively impact the process over time.

4. Loss of Speed: Anything that causes the equipment not to be operating at its full capacity, that is, at its theoretical maximum speed, is considered a loss of speed. Situations such as material wear or equipment misuse can lead to loss of speed and consequent performance. Like the previous point, speed affects cycle duration and the performance indicator that goes into the OEE calculation.

One reason for slower operation is unstable product quality at design speed. Speed losses (lost performance) are measured in production units of the product. For the OEE, the difference between the actual output and the potential output is observed if the machine ran consistently at the projected speed or at the default ideal speed for each product, as it may happen that the projected speed is not ideal for a given product. [38]

5. Process Defects and Rework: When there are products that are identified as defective or in need of rework, during a production process, they must be classified as defective/rejected. Occurrences such as poor equipment configuration or operator error may be some of the causes for the loss of quality.

Tracking down a defective product can help identify the real causes or even identify a pattern. This information helps define improvements to implement in the process to eliminate the cause of the defect. Process defects lead to product defects, while reworks take into account parts that can still be reused and reworked.

6. Defects on Startup: At the start of production, until the equipment reaches a stable and adequate performance, there may be defective parts that are commonly rejected. Misconfiguration of the equipment in a new production or even rejections inherent to the start-up process itself are some of the situations that can lead to reduced performance, which also affects the quality parameter. But it also ends up reducing the machine's operating time, generating losses in terms of performance.

Chapter 4

Results and Conclusions

This chapter will address the results, conclusions, limitations and suggestions for future work of the dissertation, whose main objective was to identify opportunities for improvement in industrial processes in areas such as production, logistics, and quality with the use of resources and methods widely used in industry, such as such as Lean Manufacturing and Industry 4.0.

Topics such as Lean Manufacturing definitions were discussed to support the relationships to be studied later, in addition, the theoretical foundation had an emphasis on Kanban as it is one of the most significant tools in the analyzed distribution logistics process, a real industry as a case study.

Thus, Lean Automation was introduced, bringing together Lean Manufacturing and Industry 4.0. To complete the fundamental theoretical part of the study, the production notes and the OEE were presented, tools that aim to monitor production and measure the performance of equipment and machines, respectively.

In Lean Automation, all lean production techniques presented here are supported by cloud and big data tools to further improve your results. This shows the utility and flexibility of Lean Manufacturing and Industry 4.0 integration. It is also understood that these tools are not mutually exclusive but can be integrated for successful production management.

Integrating innovative automation technology together with Lean Manufacturing is an up-to-date and promising topic, as I4.0 is unlikely to solve the problems of poorly organized or poorly managed manufacturing systems. Also, your tools must be applied to lean activities that are successful even before automation.

The ideal is to mature the lean tool in the industry and use automation as a complement to improve the flow and adapt to it. It should also be noted that, after implementing lean improvements, automation has the potential to add value and reduce human variability.

In addition, the habits and behaviors of employees who are used to waste are adversities, since it is difficult to change people's mindsets and habits. In this context, the strategy should be to show employees how important their work is and how reducing waste can greatly improve individual and overall results.

After analyzing the internal distribution process in a case study of an industry in the Bragança region, some points for improvement were suggested, including the implementation of a dashboard as a visual management tool. The first version of the panel that helps the factory in the distribution process has a display divided by customers, the kanbans already made, those that are in progress and those that are scheduled to be made. In addition to showing non-compliances, delays and what are their critical points.

The panel brought improvements to the factory in terms of visual management, as operators' activities became simpler. The idea is that the next version of the panel will be implemented in the process before distribution, in production. The intended improvements in the panel are related to the OEE and supported by the production report, since these two tools are interconnected within the production scope.

The production report will provide information about production stoppages and problems for the OEE, which will be demonstrated in its three aspects, the diagnosis of availability, performance and quality.

To carry out these implementations, there must be some preparations by the company, such as general training of employees in production appointments, and OEE this training aims to introduce basic notions on methodologies and new equipment that will be part of the day-to-day life of the industrial zone.

Training will be required related to the software that will be deployed, it is important to inform the areas about its operation, from adding information, interacting with the system, updating and changing information.

In addition, also in relation to the OEE, its six main losses, their occurrences and their consequences were presented, in terms of availability, performance and quality. Here, the production note is also important, as the downtime has as a consequence a decrease in the availability of machines, which ends up reducing the time available for the equipment and, consequently, the production quantity also decreases. Standardization is also a key element in this area, as any standardized process tends to save resources, reduce variability, and increase productivity.

Defective products are a loss in terms of quality and reduce the quantity of products that meet specifications, tool changes and startup defects can generate two types of losses, both in terms of availability and quality, as the time available is reduced machine and generates a loss of materials related to the production of defective materials.

Again, these losses can be avoided by reducing variation through standardization. For this to happen, it is important to establish and implement more accurate definitions and modes of operation for the equipment.

The dissertation identified opportunities for improvement in the distribution process of an industry in the areas of production, logistics and quality using Lean Manufacturing tools supported by Industry 4.0. The results presented in this study are of great value to any industry segment, and of any size, since the dissertation was prepared with the objective of making Lean Automation tools more accessible, understandable and applicable in general.

The work was satisfactory in the area of industrial process improvement, because as much as each industry needs to be analyzed individually, the suggestions made in this dissertation as the implementation of the OEE and the production grade in the form of a panel can be used in different sectors of different sectors, thus improving their processes.

4.1 Limitations

Some limitations found during the dissertation were related to the practical implementation of the suggested improvements, these limitations were mainly due to the short execution time of the thesis, since the improvement suggestions are for the long term, with several necessary subsequent adaptations. In addition, the dissertation was carried out in the midst of the coronavirus pandemic, which limited visits to the industry and to anticipate the necessary implantations.

4.2 Future Works

For future work, it will be interesting to monitor the post-implementation of the current panel, and assist in the implementation of the panel with OEE information and production notes, enabling confirmation of improvement results. It is important to instruct management on how to work with data coming from the panel, providing support in the Lean Automation suggestions area.

Then, make a study of which tools would be ideal to improve problems arising from production, such as 5 whys, DMAIC (Define, Measure, Analyze, Improve and Control) and SWOT (Strengths, Weaknesses, Opportunities and Threats). After applying the appropriate tools, monitoring can be carried out weekly, fortnightly or monthly, making comparisons in the production report itself, checking if the number of downtimes has decreased, or even if the downtimes were resolved more quickly.

It is also possible to carry out a comparison work between before and after the implementation of the improvements suggested in this dissertation, being able to carry out a survey with the employees themselves and also to compare the company's monetary gains, thus carrying out a quantitative survey.

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