INCREASING EFFICIENCY IN THE PRODUCTION OF PLASTER MOULDS IN A CERAMICS FACTORY

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ABSTRACT

1 INTRODUCTION

The Kaizen Institute (KI) began its work at Company X with a Value Stream Analysis (VSA), a factory-wide waste analysis. Company X produces ceramic sanitary ware and had the objective of increasing productivity and production flow in all its factories in Europe and, in this sense, the two factories in Leiria were used as pilots. At the end of this VSA the most critical sections of the factory were determined, among them the plaster mould production section.

The function of this department is to produce plaster moulds which serve as moulds to form the ceramic pieces. In other words, the paste which will form the piece is inserted inside the mould and, after some time, the piece takes the desired shape. This section is one of the first stages of production, so lack of efficiency in the department generates less productivity in the whole process.

The tools and methodologies used by KI, being a continuous improvement company, are all associated to lean. The lean tools, methodologies and principles all converge towards the same result:

to create value by eliminating waste, and for this, the first step is to create flow efficiency.

In this sense, an in-depth analysis of plaster mould production was carried out to identify the main causes of inefficiencies

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2 DESCRIPTION OF THE PROBLEM

2.1 COMPANY X

In 1917 Company X was founded in Barcelona and was dedicated to the production of cast iron radiators. Twelve years later, in 1929, Company X began activity in what was to become its main market: bathtubs. With an excellent vision of the future, Company X realised that water was becoming a natural resource increasingly used for sanitary purposes and, a few years later, took up the challenge of focusing solely on the production of sanitary porcelain. It has done so up to the present day, where it has also included the manufacture of taps. At the beginning of the 90s, the company started its international expansion in some European countries, and even operating in China, Brazil and Morocco.

To solidify its presence in international markets, Company X acquired the Swiss group Y (the world's fourth largest manufacturer of sanitary ware), which also allowed the company to enter large markets such as the USA.

In 2006 Company X became the world leader in the bathroom space sector. Today, the company stands out as a leader in the production of products for the bathroom space sector, with more than 80 factories supplying more than 170 countries around the world.

2.1 GLOBAL PRODUCTION PROCESS

The production process (see Figure 1) begins with the arrival of raw materials at the factory where they are separated according to whether they are to supply factory Leiria I or factory Leiria II. In two distinct places the paste (composed by the raw materials) that will constitute the piece is prepared. At the same time glass inks are produced, which will serve to make the piece mirrored after leaving the oven. In another place, the plaster moulds that will give the desired shape to the piece are produced.

Once produced, the moulds and the paste are transported to the pottery section where the moulds are installed in production lines and filled with paste. After the piece is formed, it is reworked by potters to remove excess material, and then it is loaded into a drying zone. When dry, the piece is directly placed on a glazing carousel, where the last finishing touches are made, but essentially, where the piece is submitted to the glass paint. After this operation, the piece is taken to an oven at about 1000 ºC from where it comes out as the final product.

The piece still passes by the final sorting, where a quality inspection is made and where it is packed in cardboard boxes. Finally, the piece is transported to the finished product warehouse, ready to be shipped.

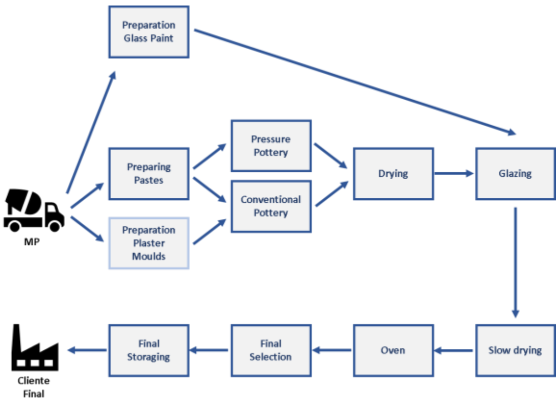

Figure 1 - Factory Production Process

2.2 PLASTER MOULDS SECTION

When analysing the factory's value chain, the Kaizen Institute identified that the monthly production plan was constantly not being met. This resulted in large amounts of stock being generated, which caused entropy in the factory; compromised customer service levels; lost efficiencies in all sections of the factory; and compromised production flow in the factory. In this way, it was concluded that the plaster mould production section could be critical to the factory's monthly production plan because it supplied both factories (Leiria I and Leiria II) and was one of the starting points of the process. The lead time to produce a mould line is approximately three weeks. This way, the Kaizen Institute explored and raised opportunities in this section and concluded that an increase in the efficiency of the plaster moulds production, would decrease the non-fulfilment of the monthly plan of the factory and, consequently, increase the productivity and the flow of the factory.

So, being the plaster moulds production a critical section in the factory production process and being this the section where this dissertation is contextualised, it becomes pertinent to make a more detailed and deep analysis of this stage. The plaster moulds production is divided in five sub-stages (see Figure 2).

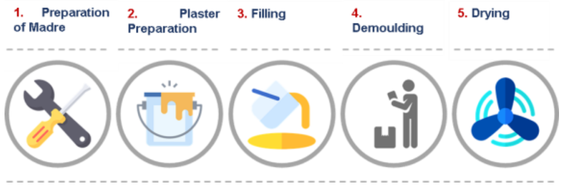

Figure 2 – Plaster Moulds Production Process

- **Preparation of Madre**: Preparation of Madre consists of installing (or changing if another is already installed) a set of moulds that will shape the components that make up a plaster cast. The change takes between 40 to 90 minutes (depending on the geometric shape that will be produced) and the workstation where this operation takes place remains stationary until the change is complete. The preparation of madre also requires the addition of accessories (pipes, fittings, etc.) that differ according to the madre.

- **Plaster preparation**: The operator takes a bucket to the plaster supply point, selects, on a digital system, which geometric shape he will produce and, automatically, a tank dispenses the amount of plaster and the respective percentage of water needed to produce the respective geometric shape. The operator puts the bucket into a mixer and after around 120 seconds the plaster paste is ready for use.

- **Filling**: The operator fills the set of purlins with the plaster paste and closes the top of each madre. While the paste is reacting and taking shape (about an hour), the operator finishes the last moulds that the last operator purposely left unfinished, so that the current operator is not left idle.

- **Demoulding**: When the plaster mould is already formed, the operator opens the madres and removes the moulds. Before starting the last finishing touches to the moulds, the operator repeats the filling process, in order to be more efficient. Only after the moulds are refilled does the operator finish the first mould that he produced.

- **Drying**: The finished plaster mould is transported to the drying area, where it is first strapped down and remains in the dryer for approximately 7 days. After that, the mould is ready to be installed on the lines of the conventional pottery.

2.3 CONTEXTUALIZATION OF THE PROBLEM

In general, the problems highlighted were: **quality and non-compliance with the plan**. In this sense, the objective is to guarantee that the production plan is fulfilled so that the time gained can be invested in quality controls and, in this way, effectively increase the quality and, consequently, the efficiency in the production of plaster moulds. In order to "gain" that time it's necessary to increase efficiency and eliminate waste from the most relevant causes, namely: mess in the section, displacement of operators, time to change madres, lack of standard in the sequence of work and lack of standards in production tasks.

3 LITERATURE REVIEW

In this chapter a bibliographical review of the essential topics for the theoretical foundation of this dissertation is made. Firstly, lean thinking is introduced, followed by a review of the main tools also used in the lean context. Then, the Total Flow Management (TFM) methodology and the respective tools that will be useful in the development of this dissertation are introduced. At the end of the chapter, some examples are described where the tools and lean methodologies were applied.

4.1. LEAN

Industrial production has been transforming over time and there has always been a focus on producing more efficiently, more quickly and with higher quality. In the west, production processes developed, incorporating more automation and new technologies. The East, aware of this growth, developed a production methodology focused on value for the client, known as Lean Manufacturing (LM). This methodological transformation was born after the Second World War, due to a lack of resources on the part of Japanese manufacturing companies, which found themselves on the verge of bankruptcy. Given this situation, Japanese industry was looking for low-cost alternatives that required few resources. On a visit to the United States of America, the leader of the Toyota Motor Company, Kiichiro Toyota, drank from the disruptive production ideas of the American automobile industry and created the LM methodology. (Womack & 15 Jones, 1992).Since the Japanese company Toyota Motor Corporation implemented this methodology and substantially increased productivity by reducing waste in the production process, major companies around the world have been incorporating the methodology into their production processes (Sanders, Elangeswaran and Wulfsberg, 2016).

LM is then based on eliminating the waste associated with the process, minimising the consumption of resources and the activities that do not add value to the final product (Abdullah, 2003). To this end, there needs to be a criterion to identify which activities are actually value-added or not. According to Imai (1997), value-added activities (VA), are all those that the customer will be willing to pay for; in contrast, muda (waste in Japanese) are all those activities that do not add value to the product that the customer will buy. The main objective of the lean concept is to eliminate muda.

4.2. LEAN CONCEPTS AND TOOLS

The lean tools are structured approaches that facilitate the implementation of the methodology and lean philosophy in an organisation. After characterising the fundamentals and basis of this methodology, the lean tools considered potentially relevant for this dissertation will be addressed, namely: Visual Management and 5S, Value Stream Mapping and the PDCA Improvement cycle.

3.2.1 VISUAL MANAGEMENT AND 5S

In lean environments, Visual Management is the vehicle to interpret work performance. In other words, it is a communication strategy that seeks to facilitate the interpretation of results and indicators. Once problems are made visible, solving them becomes easier (Tezel, 2016).

One of the main standards of Visual Management is the application of the 5S: a concept aimed at creating habits that improve the organisation and tidiness of the workplace (Imai 2012). The 5S correspond to five Japanese words beginning with "S" and implying an action in an established order:

1. **Seiri (Sort)** - Separate materials that add value from those that do not;

2. **Seiton (Organise)** - Place Value-Added materials in strategic positions according to their characteristics (frequency of use, size, etc.);

3. **Seiso (Clean)** - Clean the workstation;

4. **Seiketsu (Standardise)** - Create the necessary standards to support the three previous steps;

5. **Shituke (Sustain)** - Ensure that the norms are executed and sustainable and make them a habit.

The application of the 5S can bring surprising and disruptive results. In fact, many studies point out that this tool is not only useful in production environments, but it can have impact in other areas of society (Gapp, Fisher and Kobayashi, 2008). Its advantages are essentially to make the organisation's problems visible (Singh et al., 2013) and, incorporated with other lean tools, to reduce waste leading to reduced process time, costs and improved safety conditions (Buesa, 2009).

3.2.2 VALUE STREAM MAPPING (VSM)

he Value Stream Mapping tool (VSM) is based on the Toyota Production System and allows a perspective of the value chain of a production process, facilitating the projection of a future vision (Teichgräber and De Bucourt, 2012). VSM provides an overview of all activities in the process, making it easier to identify non-value-adding activities, the waste associated with those activities and its causes. The application of VSM will not allow reducing waste, production times or costs, but identifying improvement opportunities in a visual way (Lacerda, Xambre and Alvelos, 2016).

The five steps are:

1. Gather Information - Collect information and observe the initial state of the processes and distinguish what adds value from what is waste;

2. Mapping the Current Situation - Treat the information collected and draw the current situation of the process;

3. Mapping the Future Situation - Based on the current situation and the problems found, design a future vision;

4. Definition of the Work Plan - Design the work plan for the implementation of the future vision;

5. Execute the Work Plan

3.2.3 PDCA IMPROVEMENT CYCLE

The PDCA (Plan, Do, Check, Act) improvement cycle is a continuous improvement tool that proposes to categorise improvement actions into planning, execution, confirmation and normalisation (Corinne Johnson, 2016). The objective is to create an improvement dynamic with defined goals and thus generate a spirit of evolution in the organisation. In this model it is necessary to involve all employees, so that everyone is available to perform these actions and thus improve and solve problems in an effective and quality way (Ren et al., 2017). This cycle is composed of four steps (which the acronym itself suggests), described below (Moen and Norman, 2009):

1. **Plan** - Gather information about the current situation and identify improvement opportunities and their causes; develop an action plan, always allocating a responsible person and a completion date to the action;

2. **Do** (execute) - Execute the proposed solution;

3. **Check** - Verify the results

4. **Act** - Standardise the new standard and disseminate the results obtained.

4.3. TOTAL FLOW MANAGEMENT (TFM) TOOLS

3.3.1 LINE DESIGN AND LAYOUT

When flow in production is desired, the first tool to use, according to TFM, is Line Design and Layout. The objectives of its use are to create a line design that allows the elimination of tasks that do not add value to the product and to create a unitary flow through the value-added operations. Lines can be designed in series, parallel, U-shaped and have a two-sided assembly (Saif et al., 2014).

3.3.2 BORDER OF LINE

The border of line provides flexibility and efficiency in production by creating structures for supplying the workstations. The objective of a well-dimensioned line side is to supply as many consumables as possible to the workstation in order to minimise operator movements. Therefore, the material that is supplied must be ergonomically accessible to the operator, avoiding being more than an arm's length away (Coimbra 2009). The dimensioning of the line border follows three steps:

1. Defining the priority of the consumables supplied

In the first step, you must define which consumables have priority at the line border. The ideal situation would be to have all consumables at the line border simultaneously, however due to the space limit, it is necessary to classify the consumables according to priority.

2. Define a position at the line side

This step consists of defining positions at the line side (identifying them with labels for example), i.e. every position where boxes of consumables can enter should be identified with a number. Afterwards, each box must be associated with a position at the line side.

3. Defining the number of consumables per position

After each component is associated with a position at the line side, it is necessary to define the number of boxes of each component to be filled. In this step you must take into account the speed at which each component is consumed so that the logistics team never runs out of that component during the supply cycle. To do this, the supply cycle time must be defined.

3.3.3 STANDARD WORK

Standard Work (SW) means the execution of procedures in a standard way. The standard is established through the best combination between the actions of the operator and the specificities of the equipment, in order to find the most efficient, productive, safe and highest quality way to perform a task (Pereira et al., 2016).

Once SW is implemented in a given task, it becomes easier to control and improve its execution. That is, if the standard way has already been defined, i.e. the best way to perform a task, whenever the productivity of the task does not match what is expected, it is only necessary to observe the operator and identify when it "escapes" the established procedure. In addition, it is possible to slow down or speed up the pace of work according to demand (Sundar, Balaji and Satheesh Kumar, 2014).

In the scope of this dissertation, the application of SW at the workstations would make the working methods homogeneous to all operators. Thus, it would be easier to control the tasks and compare the efficiency between operators and whenever a better way to perform a task is found, the standard is updated.

In order to create a SW eight steps are suggested (Johansson et al., 2013): form an improvement team, identify the takt time (production rate to meet demand), identify the target cycle time, determine the sequence of operation execution, identify the amount of standard WIP, prepare the standard workflow, determine the standard for each task and finally continuously improve the existing standards.

3.3.4 MIZUSUMASHI

The mizusumashi is a logistics train that supplies only the necessary components, in the right quantities and at the right time. This logistic operator (normally aided by a logistic train) is the one that supplies the line edges and Supermarkets, characterized above. Therefore, the efficiency of the mizusumashi is a critical aspect in the functioning of the production flow and strongly affects the productivity of the workstations supplied by it (Ichikawa, 2009).

The mizusumashi follows a certain predefined route, going through all the stations that it must supply and following a previously established schedule. This logistical train allows a reduction in operational costs allied with the high productivity of a standardised job. In addition to being economically advantageous, mizusumashi allows production to be more flexible and increases its quality.

4 CURRENT SITUATION ANALYSIS

This chapter aims to portray and analyse the initial state of the section, based on the analysis of the main performance indicators. This chapter also intends to present the principles for solving the main problems and to define the objectives to be achieved. In this way, chapter 4 is divided into five sub-chapters, the first one being the preliminary assessment, where it is described how the diagnosis phase was carried out and where the main problems are summarised again. The second sub-chapter shows the performance indicators to be taken into account in this analysis and their initial status. Then, in subchapter three, the solution principles to overcome the identified problems are described. In subchapter four, the objectives to be achieved with the implementation of the proposed solutions are defined and, finally, the general conclusion of the chapter is made.

4.1. DATA COLLECTION AND DEFINITION OF PERFORMANCE INDICATORS

Two main performance indicators were defined, which measure the effectiveness of the solutions that will be implemented: reprocessing time at the Pottery section and compliance with the plan. Besides these indicators, other indicators were also defined which, despite not being main indicators, influence and allow monitoring the main ones in greater detail.

Reprocessing time at the Pottery section

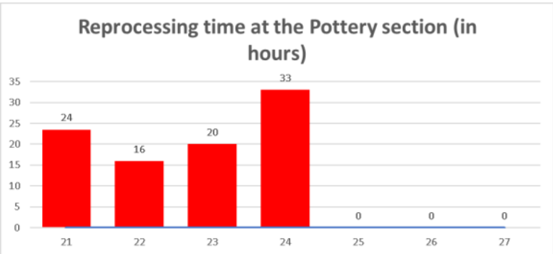

Figure 3 - Reprocessing time at the Pottery section

After the moulds are produced in the respective section, the flow goes to the Pottery section, where their quality is evaluated. It is interesting to follow this indicator, because it represents the hours that were wasted in reworking the moulds due to their lack of quality. Reprocessing time in Pottery reduced to zero hours, would mean that the quality in the production of moulds could not be better.

The indicator started to be measured since May and is updated weekly. Figure 3 represents the first month of measurement of the indicator and, as we can see, the reprocessing hours vary a lot from week to week, which reflects the quality oscillation in the production of moulds. This is due not only to the absence of a standard work sequence as well as work instructions and operational methods.

Compliance with the plan

The compliance with the monthly plan is one of the two most important indicators to measure the evolution of efficiency and productivity in the mould section. All the other indicators that measure the productivity of an operator, the failures or the time lost changing moulds, are reflected in the compliance with the plan. This indicator will mirror if the new initiatives and solutions implemented in the section translate into numerical results.

The graph in Figure 4 shows the compliance with the production plan of the mouldmaking section in the first four months of the year 2021. This analysis is done weekly, because upon receiving the monthly plan, the foreman builds a weekly plan to be able to allocate his human resources more easily. In addition, a weekly analysis allows for better traceability of problems and their correction. The data for week 4 was not available to us. As we can see, compliance with the plan is on average 84%, which is critical. That is, if one of the first sections of the production chain only meets 84% of the plan, then the overall compliance of the factory will always be less than this value. KI has stipulated that the aim will be to reach 95% compliance with the plan, with the vision of increasing the efficiency of the section and consequently of the factory.

Figure 4 - Compliance with Plan in Plaster Mould Production

Changeover time of madres

In order to control the time lost in the changeover time of madres, it is pertinent to keep a record of these exchanges. As this indicator is represented weekly, it is possible to see which purlins are more complex and need more hours.

On Figure 5 (representing the month of May 2021) it is possible to see that the number of hours wasted on the changeover time of madres varies a lot during the weeks. This is due to the number of exchanges that can exist in a day (discussed in chapter 2 and that can vary between 0 and 7 exchanges), the variety of complexity of the madre, as well as the position of the madre in the warehouse.

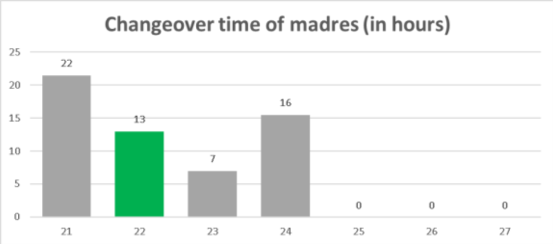

Figure 5 - Changeover Time of Madres

4.2. SETTING OF GOALS

The proposed objectives for each indicator were set until the end of 2021. According to the Kaizen philosophy, objectives should always be ambitious, because it is preferable to set a high objective and then narrowly miss it, than to have an easily attainable objective and then miss it. By raising the bar and setting a high (but achievable) goal, KI believes that results will be better, even if the goal is not achieved.

For each indicator an objective was set by Company X in conjunction with KI. The indicator "Reprocessing time at the Pottery section" has the objective of decreasing up to 10 hours per week. This objective is very ambitious, since the indicator mirrors the quality in mould production, which is one of the most critical aspects of the section. For the compliance with the plan, a high objective was also established (9% increase in the compliance with the monthly plan), since this indicator reflects the results of the other indicators and, consequently, the productivity of the section. The "Changeover time of madres" has as a goal the reduction of 50% of the time in the changes.

5 IMPLEMENTATION OF IMPROVEMENTS INITIATIVES

In this chapter the implementation of each initiative is described in detail. The objective is to understand all the steps of the implementation of the solutions and how they are sustained. Thus, chapter 5 is divided into seven sub-chapters, the first five corresponding to the five initiatives that will be implemented, a sub-chapter on their sustainability and, finally, the general conclusion of the chapter.

5.1 NORMALISED BORDER OF LINES

Step 1 - Define pilot station

In order to make the workstations organised and tidy, with all materials in specific places at all stations, the first initiative will be to standardise the border of line. This initiative aims to solve one of the section's main problems: time lost looking for material at the station.

The first step is to choose a pilot post and define the standard border of line. Then, it is necessary to understand what material the operator will need to produce (the ideal situation is that the operator never leaves the station). Thus, we will have to define a specific location for each material, using boxes marked with labels indicating the material that corresponds to the box. A very important aspect when implementing a new line side is the accessibility of the materials by the operators, so it is crucial to ensure that all the boxes are in easily accessible locations, which do not obstruct production and do not put the ergonomics of the worker at risk. That said, the standardised border of line of the pilot station should be replicated for the other stations, thus creating a standard border of line transversal to the section.

5.2 MIZUSUMASHI AND REPLACEMENT STANDARD

The mizusumashi is a logistics operator that supplies all the stations on a predefined route. In other words, the logistics operator takes a trolley with all the materials necessary for all the stations. At a set time, the mizusumashi supplies the stations so that the production operators do not have to travel outside their workstation.

The logistics operator can be any worker in the section, but preferably not one who is producing (so as not to lose productivity). After defining who will be the mizusumashi and when they will supply the materials, it is necessary to define the supply route and the level of replenishment of the materials. That is, define which stations will supply first, how long the route will last and the minimum level of each material that the station must contain. To do this, it is essential to calculate how much of each material is necessary to "hold" the daily production of the station. With the new standardized line border and the use of boxes to place the material, the mizusumashi's task is made easier. For example, if for the daily production of station 1 ¾ of a box of material A is needed, if the logistics operator supplies the stations once a day, he will only have to fill the box up to the top (to have safety stock) so that it lasts until the next supply cycle.

5.3 ORGANISE THE WAREHOUSE OF THE MADRES

Knowing that the changing of madres is frequent and whose times are very extensive due to warehouse disorganisation, the simple tidying and organisation of this space will bring quick benefits.

To do this, it is necessary to divide the madres into categories of use. The madreswill be subdivided into three categories: category A - purlins from the best-selling references, that is, madres with the greatest use; category B - madres with medium use; category C - madres with little use, as they are rarely produced. Next, the zones of the warehouse with greater and lesser accessibility are defined. In this warehouse, the purlins are stacked and distributed along aisles (with no space between them). This means that to use a madre at the end of the aisle, it is necessary to remove all the madres that precede it with a forklift. Zone 1 will be the area of the first positions of the most accessible aisles; Zone 2 will be the second positions of these aisles and other less accessible aisles; and Zone 3 will be the area of the least accessible aisles, including the last positions of all aisles. Thus, category A madres will be allocated to zone 1, category B madres will be in zone 2 (if there is no more space in zone 1) and so on.

5.4 MONITORING OF PRODUCTION SCHEDULE AND COLLECTION OF REASONS FOR DEVIATIONS

So that each operator has a defined work sequence when he is producing, a production schedule will be monitored. That is, the operator will know at what exact time he will have to do each task, in order to reach the desired daily production.

For that, a sheet can be printed for each post indicating the hours at which the operator will have to execute each task. This way, the operator will always know when he is behind in his production. For example, the operator of station 1 receives the Excel sheet printed at the beginning of his shift. Looking at it he realizes that in one hour he will have to fill a mould. That is, if the shift starts at 8 o'clock, at 9 o'clock and a half, at 11 o'clock, at 12 o'clock and a half, etc., he will have to fill the mould. If you do not do so, you will not meet the objective and you will have to write the reasons for this on the sheet.

Based on the operators' justifications for missing the target, a weekly analysis will be done by the department head to solve the main reasons for deviations.

5.5 WORK INSTRUCTIONS AND THERMOMETER FOR DEMOULDING

In order that there are no discrepancies between operators and that all moulds are produced with the desired quality, work instructions will be created to support the workers when producing.

For each reference a standard will be created with all the most relevant indications that guarantee the quality of the mould. For more complex references more detailed standards can be built with a detailed description of the step-by-step of each task.

One of the tasks that causes more broken moulds is the demoulding of the mould. The timing of demoulding is not the same for all operators, so the quality also varies. Therefore, a thermometer that measures the temperature of the mold will be instituted. The temperature at which the moulds have to be demoulded will be defined and in this way the quality will be similar for all operators. The temperature at which the mould should be demoulded is an example of an indication that the work instruction contains.

6 PRESENTATION AND ANALYSIS OF THE RESULTS OBTAINED

This chapter presents and analyses the results obtained with the implementation of the initiatives. The results presented in this chapter refer to the beginning of October and are therefore not the final result of the initiatives (objectives were defined until the end of the year). However, this analysis allows us to observe the evolution trend of the indicators and establish countermeasures for the difficulties and deviations that existed.

Reprocessing time at the Pottery section

One of the initiatives with the greatest impact on this indicator are the work instructions that allow operators to produce in a standard way and alert them to the main difficulties of each reference. However, not all work instructions have been produced yet (only 50%, due to the lack of availability of the person in charge), i.e. there are still references without a defined work standard. Therefore, it is not possible to perceive the final benefit of this initiative in the indicator of reprocessing time in Pottery. Even so, we reached the value of seven minutes in week 40, a value that is below the defined target (Figure 6).

Although the value of the last week is within the target, we know that this result is not constant and tends to oscillate (based on the history of previous weeks). With the production of the remaining work instructions, we believe that the results will be consistently within the target, until the end of the year.

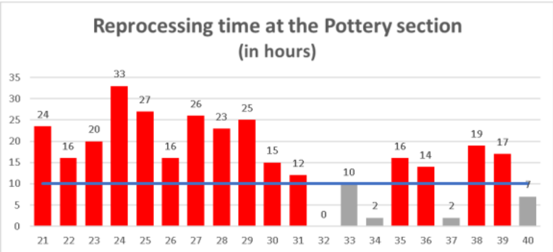

Figure 6 - Result of Reprocessing Time at the Pottery Section

Compliance with the plan

Compliance with the plan, as can be seen in Figure 7, has seen a 9% increase from 84% to 92% in the last week. As we can also see the values are quite stable and have not varied in the last three weeks. The target by the end of the year is 95% compliance with the plan and the trend of this indicator is very promising. As defined throughout this dissertation, this indicator is (along with the reprocessing time in the Pottery section), the one that most reflects the efficiency of the moulds section. Thus, we conclude that we are on the right track to achieve the final objective.

As this indicator is directly influenced by the others, we will have to analyse them to understand the reason why we haven't reached the objectives yet.

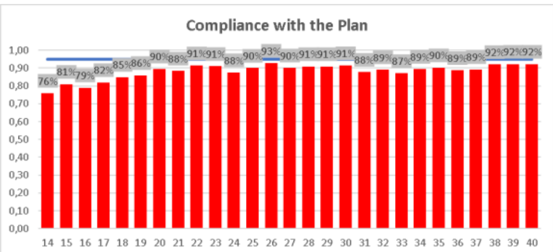

Figure 7 - Result of Compliance with the plan

Changeover time of madres

As the layout of the purlins is not yet fully completed (only sorting was done), due to the large size of the warehouse, the figures in Figure 8 do not yet translate the final benefits of this initiative. However, just the sorting of obsolete madres allowed a much easier access to some purlins, and therefore some results can already be seen. Since week 28 we can already observe a decrease in the number of hours, never reaching more than 12 hours per week. The significant increase from week 32 to 33 and also from week 36 to 37, is naturally due to the variation in the change of madres that took place in those weeks. Even so, the tendency is that the time spent exchanging madres is less than seven hours and, implementing the new layout in its entirety, we believe that by the end of the year the objective will be reached in a consistent manner.

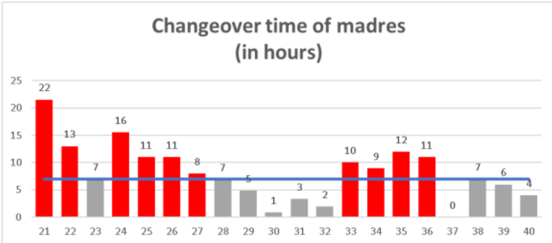

Figure 7 - Result of Changeover time of madres

7 FINAL CONCLUSIONS

This project aimed to present a theoretically grounded methodology whose application is illustrated in the characterized case study. In this sense, this master's dissertation is divided into a more theoretical part, where all relevant concepts, methodologies and tools are grounded, exposed and described, and which subsequently serves as support to the practical part, where these tools and methodologies are applied in a real case. In order to achieve the objective of this dissertation, we proceeded in such a way that the whole development had a common thread and purpose.

After defining the structure that would guarantee the guiding thread of this dissertation, the framework of Company X and the KI was made. It was also described the productive process of the factory and, in more detail, the production process of the plaster moulds. With a more detailed characterisation and analysis, the main problems of the plaster moulds production section were exposed, showing the causes that originate those problems. This analysis was important to make evident the problems of this section, but essentially to serve as a theoretical basis for the numbers presented later, regarding these problems.

The revision chapter has an added weight in this work, since the proposed solutions are based on the theoretical analysis of each one of these tools. In this sense, all the tools discussed in this chapter, would contribute to the development of this work. Besides, it is also exposed, in this chapter, real cases where the tools and methodology were already applied, thus showing the possible benefits of applying them and giving credibility to the theoretical review.

The following chapter, the preliminary assessment, serves as a connection between the theoretical and practical part. That is, it quantifies the problems that were described in chapter 2, showing with numbers their evidence. This chapter is important because it allows the comparison of the initial state of the mould section with the final state (or the state after the initiatives are implemented). For that, the main indicators that best mirrored the efficiency level of the moulds section were chosen. Only in this way could we evaluate if the implemented tools had an impact on the solution. At the end of this preliminary analysis of the section, the initiatives that would be implemented are proposed, based on the tools and methodologies based on the review chapter.

Following the main thread of this dissertation, chapter 5 describes in great depth the implementation procedure of the five initiatives presented in the previous chapter: standardised line edges, mizusumashi and standard replenishment, tidying up the moulder warehouse, monitoring the production schedule and collecting the reasons for deviations and work instructions and thermometer for demoulding. In addition to these initiatives, a short sustainability analysis of them is made. This chapter is the core of this dissertation, as it analyses the implementation of lean tools and methodologies in practice, which is the major objective of this study. Thus, for each initiative, the step-by-step of its implementation was described.

The last chapter of analysis aims to expose the results and benefits of the solutions implemented and described in the previous chapter. Although the objectives were set until the end of 2021, it was already possible to understand and quantify the partial benefits of the initiatives. Namely, the reduction of about 60% in the reprocessing time at the Pottery Shop that, despite still being at 40% in relation to the established goal until the end of the year, already reflects the benefits of the implemented tools and methodologies; the increase in the compliance with the plan that was initially at 84% and is now at 92% (final goal is 95%), showing that this indicator has a tendency to reach or even surpass the defined goal; and a reduction of almost 50% in the changeover time of madres, surpassing the goal stipulated for the end of the year.