Design and Implementation of a New Layout in a New Production Area of a Cork Stopper Factory Following Lean Manufacturing Principles

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Abstract. The current market conditions and purchasing power put pressure on selling prices. In order to maintain the corporate profits, it is important to increase manufacturing efficiency and lower the costs. The industrial unit in this project was developed aims to increase the annual production of cork stoppers and by doing so, maintaining the high standards of the quality and accuracy in their processes. In order to respond to this growth, Lean Manufacturing was implemented, and it was decided to bet on the construction of a new lodge. The goal of this work is to create a new production area for cork stoppers capable of producing around half a million cork stoppers per day. The new required layout and with the aid of Lean Manufacturing tools, the aim is to avoid waste, achieving operational excellence with a reduced cycle time. The use of Total Flow Management (TFM) tools allows the design of the layout and to level of production. With the construction of a continuous flow between processes, the storage areas were gradually liberated, and the volume of intermediate stock decreased by 63%. The results have also shown a decrease in complaint rate of 3.5%, which was reduced under the established threshold of 5%, fulfilling the objectives proposed by the company for the project. It is hoped that all the improvements can serve as reference for future work to achieve stable processes, since they present real results of the Lean philosophy, as well as the critical factors for its practice.

Keywords: Kaizen; Total Flow Management; Layout; Levelling; Waste Elimination.

1 Introduction

The era of globalization has led to massive changes of manufacturing industries worldwide. Currently, consumer expectations are extremely high in terms of product quality and costs. Consequently, manufacturers must find solutions by implementing innovative strategies with continuous improvement as background [1, 2].

The food industry, as the majority of industries in 2020 decade, is confronted with complex challenges such as quality and hygiene standards in an international environment, falling margins, fluctuating raw material quality, high customer demands, employee turnover, requirements for food safety, and much more. As in the general industry, Lean Manufacturing can be applied, as a possible solution, to the food industry with the purpose of eliminating waste throughout the manufacturing process and maximizing efficiency [3].

Lean Manufacturing is a methodology that can reduce waste and improve quality. Besides Lean, other methods exist, such as Zero Defect Manufacturing, known to be a philosophy and/or methodology that strives to minimize, as much as possible, the occurrence of defects in manufactured products and service [4, 5]. The best Lean application is in conjunction with philosophies [6].

The beverage and food industry are considered essential industries since its end products are consumed by human beings. Therefore, it should be put under a more intense scrutiny through meticulous and rigorous regulations, as the safety and quality must be guaranteed in the product life cycle within the individual enterprise and in the product supply chain between different manufacturing sectors [7].

Within food and beverage industry, Lean Manufacturing applied to cork production industry has been a target of researchers for quite a while. In [8] it is proposed to reduce 3M by improved layouts and ergonomic intervention in a lean implementation in a cork production company in which distinct tools were applied, ones from ergonomics area while others are purely lean tools. In another study, the improvement of equipment is sought, in the cork industry, by introducing a variation, through the application of Lean methods, namely Single Minute of Exchange of Die (SMED) [9]. A study addressing the time reduction of drying process of natural cork stoppers process in lean improvement efforts is shown in [10] in which the value stream mapping (VSM) tool was used and the results have shown a shorter production lead time and increased efficiency. Finally, in [11] the warehouse operations logistics improvement through Lean Manufacturing tools in a cork stopper factory is proposed, and it was possible to identify non value added times and then reduce them. However, even though Lean Manufacturing tools were applied with relative success in these studies, safety is not addressed at all. The cork industrial process has also been studied from the environmental impact reduction point of view. In [12] the cork stoppers supply chain is addressed and its potential scenarios for environmental impact reduction while in [13] an environmental analysis of the production of champagne cork stoppers is made.

This study focuses on a company located in Portugal dedicated to the production of champagne cork stoppers, namely champagne sparkling wine cork stoppers, and Spark Top One corks stoppers, namely carbonated wines and beers.

With the increased demand for the Spark Top One cork, this company intended to increase annual production capacity from 600,000,000 to 720,000,000 cork stoppers. It continued to invest in its growth with a new pavilion. Approximately 5,200 square meters of facilities were intended to include production and logistics areas to support the company's previous facilities that could no longer meet market requirements.

The construction of the new plant, pavilion F3, began in May 2018 and was completed in November of the same year. So, in order to begin the production in the new pavilion the layout of the new space needed to be defined, including defining the equipment, storage areas and workstations for the jobs, transportation systems, as well the production levelling.

Through Total Flow Management (TFM) methodologies [11], it was expected that all F3 production costs to be minimized, including all material handling and information that occurs from receipt of the raw material until delivery of the finished product to final customers.

Several objectives were proposed. A production process without high lead times and high stocks, and reduce unnecessary movement of materials. It was also intended to ensure the leveling of production. A contribution to scientific community with the application of Lean Manufacturing tools in the cork stopper industry was also an objective of the study, since this industry has peculiar and uncommon characteristics.

This paper is structured as follows: in section 2 the methodology used in this research is presented as well as a brief contextualization of Lean practices; section 3 is dedicated to the problem under investigation, the creation of the company plant layout; in section 4 the results obtained area analyzed; and finally, in section 5, the main conclusions are drawn.

2 Lean manufacturing and Continuous Improvement

At the beginning of the project, the initial situation and the associated problem were studied. After completing the research on the problem and the theoretical knowledge that supports the selection of tools, the Layout of the new pavilion was defined through the implementation of the Production Flow pillar and Flow in Internal Logistics in TFM.

During the creation and operation of the new pavilion, it was essential to analyse the quantitative and qualitative results to see if the measures implemented were going as intended and whether the objectives were to be achieved. In carrying out the research of this project, a qualitative method was used. An action-research was carried out to understand the problem and a change of action was achieved through the improvement of the methods analysed in scientific articles and books. The tools resulting from decision making were all adapted according to the interpretation of the obtained experience and knowledge.

Being a project in the scope of continuous improvement, it was fundamental to ensure the constant search for excellence and optimization of results.

2.1 Lean manufacturing practices

Lean Manufacturing can be based on following management philosophies focused on eliminating waste and adjusting to customers' needs and requirements, focusing on value-generating activities and value chains, in search for perfection, ensuring continuous process improvement [5]. Lean Manufacturing is employed to identify the causes of waste and to combat them, in order to reduce their negative effects [15]. Therefore, this improved production is based on the logic of eliminating activities that do not add value to the production systems, that is, by eliminating waste from the process. This management philosophy bases its foundations on several approaches, such as Kaizen (continuous improvement) [16, 17], Just-in-Time (on time) [18], Production Levelling (*Heijunka*) [19, 20]; *kanban* system [21–23]; SMED [24–26]; Cycle Time (CT), lead time and Takt Time (Tk) [27, 28], Standardized Work, among other fundamental concepts [29].

One of the most important philosophy behind Lean Manufacturing is Kaizen. Kaizen's success comes from the actions developed by employees. In order to increase productivity, the involvement of all is essential in implementing improvements in the *Gemba* [30–32].

In Lean practices, the term "*Gemba"* refers to "the location where value is created,", for example, the shop floor in manufacturing. Therefore, after understanding the tools necessary to respond to the problem identified, the section 3 presents the implementations made in *Gemba*.

The company in which Kaizen is implemented must be able to motivate and encourage its employees so that it is possible to achieve the maximization of its potential [33].

3 Creation of the plant layout

The layout of the Pavilion F3 was developed with the goal of creating an optimized production process and minimize costs, ensuring an efficient performance of all employees and equipment.

3.1 Machinery selection and production levelling

It can be seen in Table 1 that the chosen machines had to meet the objectives proposed by the Management. They must ensure the continuous flow of production to produce 120,000,000 Spark Top One cork stoppers per year. In the line of Mechanical Finishing (ACAM), it counts with the objective of annual production of 40,000,000 agglomerated cork stoppers.

It is important to note that the values presented correspond to the cadence of the F3 machines (the expected production value taking into account the processing speed of the references). After its implementation, it was essential to verify that the actual values correspond to those expected, to ensure that this resource is being used most efficiently and the objectives are being met. For reference, 22.5 hours of work per day and 227 working days per year were considered.

Table 1. Cadence of the F3 machines

Sector	Machine	Hour	Day*	Sector	Year*
Halting	1	13200	297000	594 000	134 838 000
	2	13200	297000		
Collage	1	5000	112500	630 000	143 010 000
	2	5000	112500		
	3	9000	202500		
	4	9000	202500		
ACAM	Agglomerated	8640	194400	194 400	44 128 800
	1	10800	243000	729 000	165 483 000
	2	10800	243000		
	3	10800	243000		

Assessing the Takt Time allows verifying if the productive process can satisfy the demand of the client. Determines the number of parts to be produced per minute. As mentioned previously, the T_K is given by the following equation [16].

$$T_K = \frac{T_a}{D} \tag{1}$$

where T_K is the product assembly time required to meet demand, T_a is the net time available to work customer demand and D is the customer demand. However, in this context, T_a corresponds to the total time without stops and D corresponds to the number of units required within a defined period.

To determine the time available for production in one year, it was necessary to analyse the following information:

The pavilion works in three shifts, scheduled as follows:

- 1st shift from 6:00 to 14:00;
- 2nd shift from 14:00 to 22:00;
- 3rd shift from 22:00 to 6:00;

However, only 22.5 hours were recorded. The remaining time corresponds to production breaks (for example, lunch break). Converting 22.5 hours in minutes, we have 1 350 minutes. After accounting for 227 business days in 2019, the time available for production was: Available time = 227 × 1 350 = 306 450 min.

The established goal for this pavilion is 120,000,000 Spark Top One cork stoppers per year. Therefore, in the calculation of T_K this production value can be considered for the demand.

It was then possible to calculate the desired pace to achieve the stated objectives. Since 1,000 cork stoppers correspond to 1 ML, Takt Time resulted in 2.55 min/ML. It can be assessed that, in order to achieve the objectives defined by company, it is necessary to produce 1ML (1000 cork stoppers) every 2.55 minutes. This confirms the values discussed.

3.2 Choice of the transport system

The layout was developed with the objective of eliminating all activities that do not add value for the customer. Thus, it was considered that the machinery related to production should directly supply the following sector lines, eliminating the transportation of work in process. The use of automatic conveyor systems ensures the transport of cork and cork stoppers between sectors, eliminating the movement of containers by forklift.

However, the chosen layout has some limitations. By being interdependent processes, stopping a machine can lead to stopping the entire production line. It became essential to ensure the supervision of the flow and timing between sectors. As a preventive action, supply towers were positioned to allow the production to continue even if previous machines stop.

During the process of planning the layout, in addition to the previously mentioned, conveyor belts were selected as methods of low-cost automation. In the packaging sector, a pallet lift system was implemented in order to replace the forklift.

The chosen machines allowed to respond effectively to multiple production scenarios, ensuring a good performance of the layout in the long run. It was also necessary to reverse the direction of the production flow to produce agglomerated cork stoppers. So, a line of Mechanical Finishes was defined and was able to be powered independently of the other machines in the lodge.

3.3 Future expansion

Management has set a rise of annual production of 120.000.000 Spark Top One cork stoppers in response to market demands. The project was also developed with an angle of future expansion of the equipment. So, the growth of production lines can be seen shaded on the layout (Figure 1). The use of common support structures on the machines in the same sector will allow a decrease of future costs.

3.4 Safety

In the literature, there are numerous methods developed to investigate human risk factors during the production process [34]. For safety reasons, it is also extremely important that the locations are well signposted so that no accidents can occur at work. For the success of the project it was necessary to ensure all the requirements of occupational safety, health and hygiene. Thus, points of access were developed to all machines, especially to those that have a greater need for maintenance. As can be seen in Figure 1, the layout was marked with clear paths for people and forklifts in order to prevent work accidents.

The definition of the areas of passage and storage of containers and material was fundamental to ensure the safety and organization of jobs. This project was developed after the analysis of the General Regulation of Occupational Safety and Health in Industrial Establishments.

Improvements according to Article 11 (occupation of floors) resulted in the space around the elements of production being reserved and properly marked in order to allow its normal operation and possible maintenance of the machinery or storage material of the raw product to be manufactured.

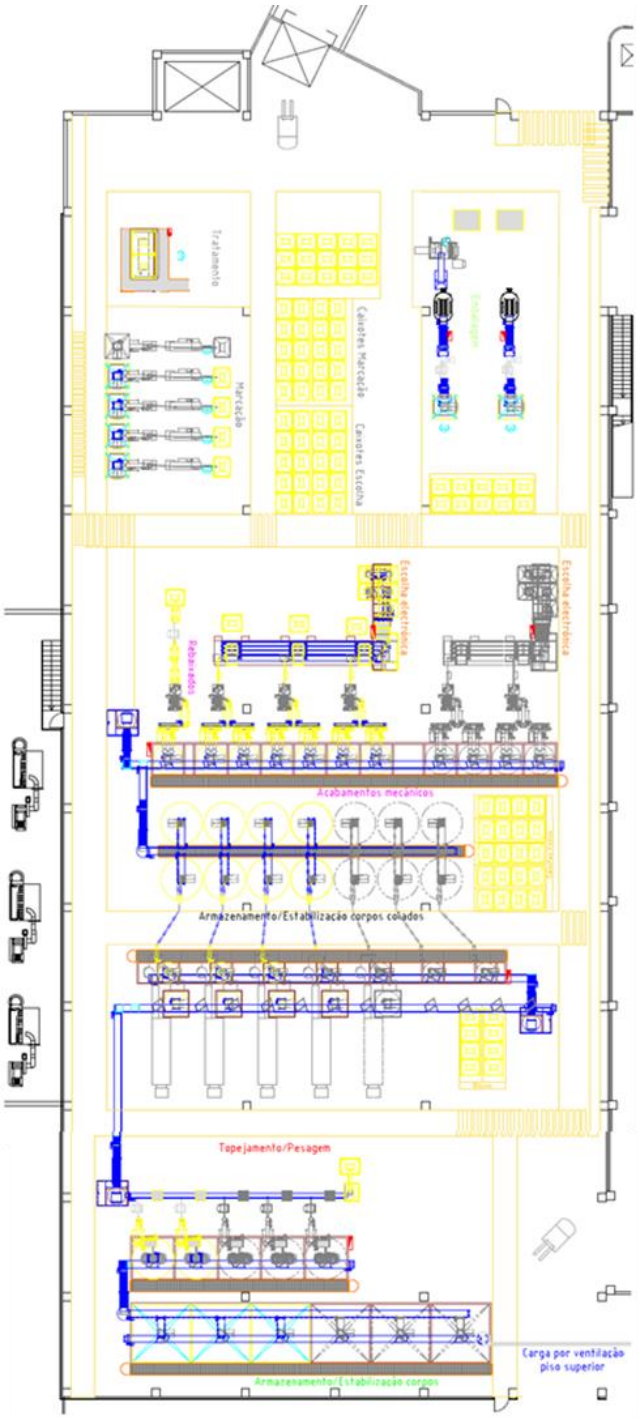

Fig. 1. Layout of the safety marks (in light brown).

Improvements according to Article 10 (Traffic lanes, communications and exits) and 12 (Openings on floors and walls) have shown that all transit areas intended for the simultaneous transit of vehicles and persons ensure safe traffic, as well as the rapid and safe evacuation of the building in case of emergency. As for Article 14 (Quality of pavements), floors intended for the movement of vehicles and persons became free of obstacles. Finally, improvements related to Article 79 (Rolling lanes and railways), resulted in sharp angles and curves, ramps with a steep slope, narrow passages and reduced height ceilings being avoided on the roads intended for vehicle traffic. The marking was performed on each side and throughout its length by a visible line. The lanes show the width of the vehicles for which they are intended (Forklifts with a width of 1.30 m) or the loading material increased by 0.6 m.

Improvements regarding Article 85 (Lifting and transport of materials), led to the employees being trained to ensure that the transportation and lifting of the containers is safely executed.

After understanding all the necessary requirements for the shop floor, the representation of the marking lines was carried out with the aid of a design software, AutoCAD. This program, widely used in architectural and engineering projects, allows its user to elaborate pieces or plans in two dimensions (2D) or three-dimensional (3D) models. The main advantage during the development of this project in AutoCAD was the ability to change, eliminate and redesign the marking lines in different proposals to achieve the ideal solution for the company.

The use of the Pavilion-wide measurements made it possible to analyse the width of the passageways in order to ensure that all safety restrictions were met. The ink marking was completed by an outsourced company. However, a follow-up was carried out during the painting, in order to ensure that all measurements were respected, as shown in Figure 2.

At the location of information boards, areas with good brightness, easy access, and complying with the defined markings for the passage of people were chosen. Also, special attention was given to the height of the nameplates suspended from the ceiling, to ensure that the path is clear and to avoid accidents with forklifts.

Fig. 2. Steps to implement the layout of the safety marks.

4 Results

After the implementation of the described actions, the results obtained were analysed. The starting of the new pavilion and the productivity of Spark Top One cork stoppers were studied.

4.1 Starting the F3 pavilion

Figure 3 shows the relevant steps and dates of the pavilion construction and the defined layout.

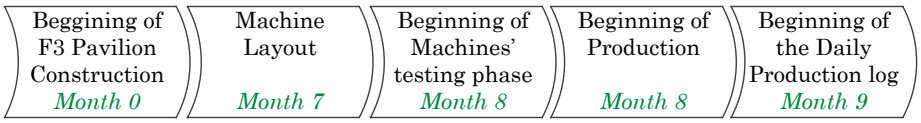

Fig. 3. Steps from the beginning until the full operation of the pavilion.

By observing Figure 3, during the project there were limitations regarding the scheduled implementation dates of the presented Lean tools. There was a delay of three months compared to the construction deadline of F3 pavilion, thus accelerating the project execution process and reducing the time available for data collection and analysis of results.

When the new pavilion started operating, the initial concern of the company was to ensure that the facilities and machines were in the best condition and that employees had the appropriate training for their operating location. Soon there was noticeable a lack of organization in the jobs. The practice of *Kaizen* methodologies was undeveloped. After the implementation, several improvements were reached as a result, such as reaching a complaint rate of 3.5%, which dipped below 5%, fulfilling the objectives proposed by the company for the project. The evolution of the factory floor, or *Gemba*, can be seen in Figure 4.

Due to the initial disorganization of the processes, space was high. With the creation of a continuous flow between processes, the storage areas were released gradually, and the volume of intermediate stock decreased by 63%.

Fig. 4. Observable improvement in Gemba evolution.

4.2 Productivity of Spark Top One

By comparing the production records with the 2020 Scheduled, presented in Table 2, it is possible to analyze the compliance rate of the operating sectors.

According to these data, the sectors have a compliance rate lower than expected by the company. However, meanwhile the causes responsible for the low production values of the pavilion was studied and it is expectable to increase the compliance rate and to achieve the foreseen at the end of the May.

Table 2. Weekly production summary.

Daily Production	Production			2020 Day Total Scheduled	2020 Scheduled	Compliance Rate %
	Week	Month	Year			
	14/01/2020 20/01/2020	01/01/2020 20/01/2020	01/01/2020 20/01/2020			
Moldeling	1057650	2301810	2301810	3171086	60000000	↓72,60
Collage	1725756	3335105	3335105	4229075	80000000	↓78,90
Mechanical Finishes	1890065	4168213	4168213	6343612	120000000	↓65,70
Spark Top One	1620428	2918980	2918980	4229075	80000000	69,60
Agglomerates	677880	1249233	1249233	2114537	40000000	59,10

4.3 Limitations

During the project there were limitations regarding the implementation dates for the presented *Lean* tools. There was a three-month delay compared to the F3 construction deadline, speeding up the project's execution process and reducing the available time for data collection and result analysis.

The postponement of the start of production in several sectors made it impossible to proceed with recording times for mapping the value chain, thus being challenging to analyze in detail these processes. However, in view of the objectives defined at the beginning, the majority of them were achieved and the obtained results were considered satisfactory.

5 Conclusions and suggestions for future research

These results obtained from the implantation of Lean Manufacturing tools (5S, Standardized Work, VSM, SMED, Kanban among others) in this study led to an increase in efficiency at the company, reaching all the objectives defined by the Management: increasing level of customer satisfaction, increased productivity index and reduced stocks.

The layout defined had a positive impact on reducing lead time and eliminating waste. However, there was a need for the implementation of others Kaizen improvements to ensure compliance with the intended Takt Time. In the end, the entire team

involved in this project became more capable in preventing and detecting errors, the production flow was more fluid and the stations were more organized. The results have shown that storage areas were gradually liberated and the volume of intermediate stock was reduced by as much as 63%. Also, a decrease in complaint rate of 3.5% was observed, which was reduced under the set threshold of 5%, and thus, fulfilling the objectives. The management became more transparent and the exchange of information clearer and objective.

As a future research it is recommended to strictly implement the five pillars of total flow management in order to reduce costs even further, increase productivity and raise levels of consumer satisfaction.

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