Operations management improvement through the application of Lean Kaizen methodologies – TecnoSPIE

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Abstract

Given the current economic climate and the increasing globalization of the economy, market's competitiveness has been growing significantly. Therefore, it is essential that companies analyze their supply chain and seek alternatives that allows them to achieve reductions in costs and waste. Therefore, the importance of Lean methodologies has been increasingly recognized when applying corrective or preventive actions when facing obstacles encountered by companies.

This paper arises in this context and has several solutions in order to overcome the wastes found in materials supply process, as well as command and control panels (QCC) and transformer stations (PTF) production processes in the Manufacturing Production (FAB), from SPIE Group. The lack of culture in continuous improvement, organization and communication were the origins of these wastes.

Regarding the studies discussed in Literature Review, it was developed a Value Stream Mapping (VSM) and was collected and analyzed data concerning the two processes. Then, by implementing tools like SMED, Kobetsu Kaizen, 5S, Standardization, Visual Management and Kanban, it was possible to achieve the desired results.

After these implementations, there was an increase of about 30% of the Overall Equipment Effectiveness (OEE) and about 33 hours of production time throughout the PTF and QCC production processes (approximately 13% and 22%, respectively). Considering the investment, the return will be approximately 1 year and 4 months.

Keywords: Lean, Continuous improvement, Command and control panels, Transformer stations, VSM.

1. Introduction

After the end of Second World War there was a technological explosion that dictated the opening of the business market across borders, revolutionizing the entire world economy. Currently there is an open economy of capitalist type in a globalized market, constantly evolving and consumers increasingly informed and demanding (Castells, 1999).

Changes in globalization markets led to an increase in global competitiveness in today's markets, which means that organizations are under constant pressure to achieve excellence and improve their performance in order to reduce their costs and offer high quality products with reduced lead times (Garza-Reyes et al., 2014). In this context, Womack and Jones (2003) indicate Lean Thinking as a way to perform more with less resources, meaning less human effort, equipment, time and space, aiming full satisfaction of the end customer. However, the Lean concept is still a major challenge for organizations, since their implementation requires changes in both technical and management systems, as well

as changes in attitudes and culture (Marodin and Saurin, 2013).
It is in this context that arises the motivation for this paper with a proposed methodology based on the integration of multiple Lean tools required to achieve efficiency improvements and sustainability in processes similar to the control and command panels (QCC) and transformer stations (PTF) production processes, at TecnoSPIE. Also, this will be the present paper case study that will be used to illustrate the applicability of the methodology.
In section 2, a brief literature review will be made to the available bibliography about Lean methodologies applied to manufacturing industries. In section 3 it will be carried out a detailed framework for TecnoSPIE and for the case study on analysis. In section 4, it will be analyzed the data and indicators collected during monitoring of production processes, as well as the steps taken in the implementing process. In sector 5 it will be analyzed the results obtained after the implementation of the tools. Finally, in section 6 it will be presented the main conclusions of this paper, as well as possible future work.

2. Literature Review

In this section there will be presented the origin and evolution of Lean (2.1), its principles (2.2), wastes (2.3) and tools (2.4).

2.1. The origin and evolution of Lean

From 1945, after the end of World War II, Japan was a country with a lack of resources and as such, had to adapt to the industry, because otherwise, they could not compete with the low prices of western industries (Jacobs and Chase, 2008). Consequently, it has become essential to develop a production system able to accomplish much with little, since the demand was varied and reduced. It was after the perception of these scenarios, that the Toyota Production System (TPS) was developed by Taiichi Ohno and Eiji Toyoda. TPS is based on two core philosophies in Japanese culture: elimination of waste and respect for people (Jacobs and Chase, 2008). According to Melton (2005), the method that was beginning to be developed in Japan was the exact opposite to what was used in the Western world, where production took advantage of economies of scale, by mass producing. According to Hallfren and Olhager (2009), Lean production concept first appeared in an article written in 1988 by the current CEO of TrueCar company, John Krafcik, entitled by "Triumph of the Lean Production System". It was from this date that the paradigm that Lean methodologies could be applied to manufacturing industries began to be exceeded (Bowen and Youngdahl, 1998). Later, Womack et al. (1990) described the concept in the book "The Machine That Changed the World" and six years later, in "Lean Thinking" book. Womack and Jones (2003) continued to develop the concept and approached the Lean Thinking applicable to all industries. From the beginning of the XXI century, Hines et al. (2004) argued that Lean Thinking focuses on customer perception.
The ideas of Jayamaha et al. (2014) corroborate the way of thinking described so far, arguing that by structure of the Toyota Way (book published in 2004 by Jeffrey Liker), there were two major pillars: continuous improvement and respect for people. These two pillars are divided into challenge, kaizen (meaning continuous improvement in Japonese), Genchi genbutsu (go and see in English), respect and teamwork.

2.2. Lean Principles

The application of Lean production in Western companies generated several cases of failure (Hines et al., 2004).
Womack and Jones (2003) argue that Lean Thinking allows companies to specify value, line up value-creating actions in the best possible sequence, coordinate these activities without interruption whenever they are requested and make them more efficient.
In this follow-up, there are five principles that serve as the foundation to Lean Thinking, namely (Womack and Jones, 2003):

- Value, since any organization must have a profound knowledge of what is value to its customers;
- Value Stream, as the set of all actions necessary to guide a product (and / or service or combination of both);
- Flow, as the ‘smooth’ route made by products and / or services.
- Pull, because it allows the client to trigger flow value;

- Perfection or zero defects, meaning no inventory and without any waste.

Beside this sequence, the Comunidade Lean Thinking (CLT) (2008), through research and development, suggested adding the two following Lean principles: Knowing the stakeholders, where there is a need to focus on the end consumer and innovate always.

2.3. Wastes

Waste means any activity that the customer is not willing to pay, in other words, any activity that does not add value to the end consumer (Bergmiller and McCright, 2009). In this context, Taiichi Ohno (decade of 80/90), ranked the following seven types of waste (Imai, 2012):

- Overproduction: Generates larger lots, which result in higher delivery times and storage;
- Excessive inventory: Raw materials held in inventory, and finished or "semi-finished" goods without any value to the end user;
- Unnecessary transport: Unnecessary transport of parts in production;
- Waiting: Waiting time for unnecessary features or approval decisions to proceed with the next production step;
- Excessive Processing: Processes that do not add value to the product;
- Unnecessary Movement: Refers to all the unnecessary movements performed by an operator to transport a product;
- Defects: They are considered as errors or failures that occur during the process.

Other authors, such as Dolcemascolo (2006), add an eighth waste as the lack of use of the ideas of employees.

2.4. Lean Tools

Based on published examples, in this section, it will be presented the tools with the greatest impact on a continuous improvement project in manufacturing sector. These tools are:

2.4.1. Value Stream Mapping (VSM)

VSM identifies and evaluates the company's value stream, analyzing the activities that add value or not in the handling of information or materials during the process in order to identify this waste in the same (Hettler, 2008).

2.4.2. 5S

Kaoru Ishikawa developed 5S as a simple application which has the benefits of creating a clean, safe and healthy environment, increasing employee's motivation and revitalize gemba. 5S stands for Seiri (sort), Seiton (straighten), Seiso (shine) Seiketsu (standardize) Shitsuke (sustain) (Imai, 2012).

2.4.3. Visual Management

Tjell and Bosch-Sijtsma (2015) consider Visual Management as a tool that works as a system through visualization allowing employees, a better understanding of their role and contribution to the perception of the company's values and needs.

2.4.4. Kanban

Kanban is a material flow control tool via a visual indicator that informs the operator about how and when to produce (or order), therefore "pulling" production (Gross and McInnis. 2003).

2.4.5. Single Minute Exchange of Die (SMED)

SMED it is a tool that can reduce the time for setup operations in order to perform preparatory operations in less than ten minutes, meaning that the reduction is always to achieve a time whose duration in minutes is less than one digit (Shingo, 1985). Shingo (1985) argues that SMED is based on four steps: Mapping the current situation, identification of the internal and external operations; conversion of internal operations to external operations; and reducing the execution time of the internal and external operations.

2.4.6. Kobetsu Kaizen

Kobetsu Kaizen is mainly focused on the identification and elimination of losses that occur at the level of equipment and processes, in order to achieve efficiency improvements (Sütőová et al., 2012). Sütőová et al. (2012) also confirm that the tool deployment process proceeds to the following seven steps: Problem selection and training of the working team; identification and classification of losses; prioritization of losses (Pareto charts); analysis of the causes (Ishikawa diagram); improvements planning; implementation of improvements; and results.

3. Case Study

The third section presents TecnoSPIE (3.1) and its processes (3.2). Finally, there will be presented the proposed tool integration (3.3).

3.1. TecnoSPIE

TecnoSPIE is part of the SPIE Group, a French multinational company. The company offers its experience in various labor markets, namely (SPIE Portugal, 2015): Technical maintenance (MMT), energy and technical installations (EIT), industry (IND) and manufacturing production (FAB), the latter area the focus of this paper.

The main activities of FAB are related to the production of switchboards (QE) and those can be of several types, but our main focus it is going to be on command and control panels (QCC) and transformer station (PTF).

In its production areas, the plant is divided into two distinct areas: Metalworking and Electricity. For example, in the case of QCC, its chassis may be produced in Metalworking area or may be purchased to a supplier. Then it needs to be assembled and tested on the Electricity area.

3.2. Materials supply and production process

Before starting the production of QCC and PTF, there is a pre-production complex and bureaucratic process that needs to be done, denominating by materials supply process (Figure 1), that is divided into 7 steps.

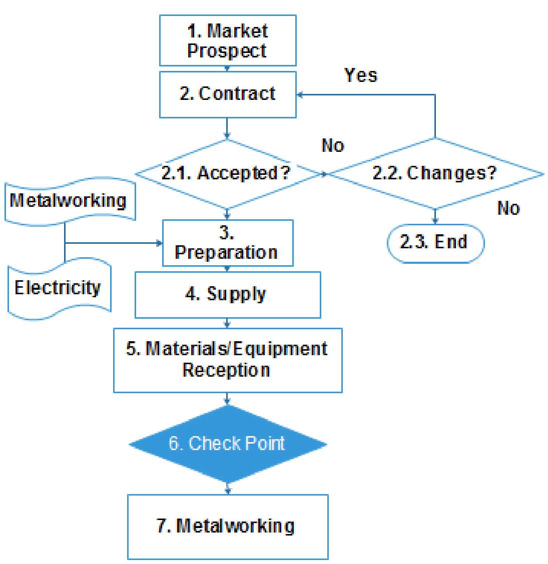

Figure 1 –Materials supply process.

This steps are as follows: Market prospecting (step 1); Later, after the submission of the contract (or proposal) (step 2), it can be accepted (2.1), changed (2.2) or rejected (2.3); considering that the contract has been accepted, it will be started the preparation process (step 3); supply (step 4); reception of materials and / or equipment (step 5); check point (step 6); finally, there follows the possibility of sending the materials to the area of Metalworking (step 7).

For this process, it is intended to analyze and improve the step 4, in order to better control the stock levels of materials / equipment for daily use in the production, such as copper or circuit breakers, for example.

The production process is divided on the two area already mentioned: Metalworking and Electricity. The steps of this process are: regarding Metalworking, are cutting, drilling, bending, welding, structure assembly and surface treatments (like painting, for example); in Electricity, there could be done assembly, electrification, final tests and expedition.

3.3. Proposed tools integration

Figure 2 proposes a methodology based on the integration of multiple Lean tools (main tools in blue color and complementary tools in dark blue color), allowing achieve efficiency improvements and sustainability in processes similar to the PTF and QCC production processes in TecnoSPIE.

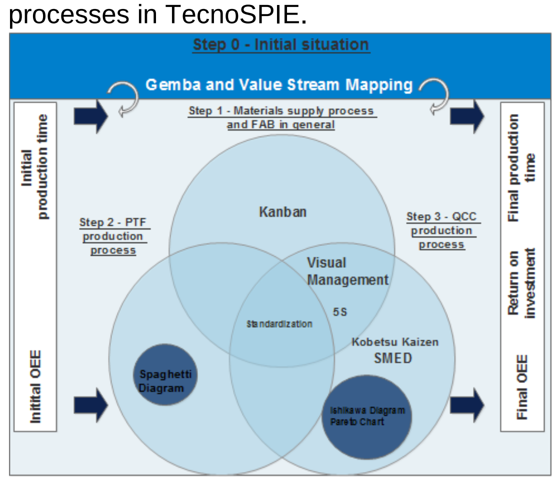

Figure 2 – Proposed tools integration

The proposed integration involves four steps: Mapping of the initial situation developing VSM tool (Step 0); Materials supply process and FAB in general with the implementation of 5S,

Standardization, Kanban and Visual Management (Step 1); PTF production process with the implementation of several strategies and tools like Standardization and complementary tool Spaghetti Diagram (Step 2); QCC production process, where it were implemented SMED, Management Visual, 5S, Standardization, Kobetsu Kaizen and used complementary tools like Pareto chart and Ishikawa Diagram (Step 3).
With a view to assessing the improvements implemented, there will be evaluated indicators like OEE and production times of various essential tasks in the process.

4. Lean implementation

In this section, it will be presented all the data collected, as well as, its analysis. Initially there were identified the main wastes on FAB in general and on both production processes in study (4.1). Finally there will be shown all the implementing process (4.2), on materials supply process and FAB in general (4.2.1), PTF (4.2.2) and QCC (4.2.3) production processes.

4.1. Data collection and analysis – waste identification

This paper started with an observation of the current state in order to identify muda and improvement opportunities. For this, there were identified, on the three processes, the following wastes and improvement opportunities:

<u>Step 1 - Material supply process and FAB in general</u>

- Identification failures (unnecessary movement);
- Lack of organization and cleanliness (unnecessary movement and defects);
- Waiting for the material (waiting).

<u>Step 2 – PTF production process</u>

- Inappropriate loading / unloading equipment and means of transport (unnecessary movement and waiting);
- Differences in rigid bars production times (waiting and defects);
- Isolation bars production time (unnecessary movement and excessive processing).

<u>Step 3 – QCC production process</u>

- Slow placement of tips and terminals (excessive processing);
- Improper transport of QCC (waiting and defects);
- Inappropriate QCC doors loading and transportation (waiting and defects);
- Setup times and problems in Computer Numerical Control (CNC) machine (excessive processing, waiting and defects).

4.2. Tools implementation

In this subsection, there was presented the various applications of Lean methodologies, with a view to eliminating waste and problems detected in the subsection 4.1. This sub-section functions as the practical part of this paper with a view to improving the FAB processes under study.

4.2.1. Step 1 – Materials supply process and FAB in general

- <u>Identification failures</u>

The identification of the various working areas and tools helps to reduce waste, in particular, the unnecessary movement of employees. As such, there were used the Visual Management tool in order to achieve improvements in identifying the layout and handling trucks, as in Figure 3.

Figure 3 – Before (1) and after (2) Visual Management.

- <u>Lack of organization and cleanliness.</u>

In order to reduce the various existing wastes as potential defects due to dirt (for example) or the movement of people and materials, improve the well-being of employees in daily operations, and consequently reduce setup times, there was implemented 5S tool (Figure 4).

Figure 4 – Before (1) and after (2) 5S.

- <u>Waiting for the material.</u>

The constant lack of materials resulted in the construction of Kanban cards, allowing greater control of the warehouse stock.

4.2.2. Step 2 – PTF production process

- Inappropriate loading / unloading equipment and means of transport.

Regarding this waste, it was proposed to purchase a mechanical arm with suction cups and a platform hand truck. With the implementation of these two measures is expected to reduce from 3 operators to 1 on the Guillotine and from 2 operators to 1 in the plates transport and handling. Finally, it is also important to mention, that the payback period of this investment is about 16 months.

- Differences in rigid bars production times.

In order to avoid the difference in production time, there was built production standards, so it can allow each operator to follow specific instructions in the various production processes, working in a standardized way rather than intuitive one.

- Isolation bars production time.

In order to improve the duration of these tasks, there were built molds, avoiding the task of Drawings and Measures (waiting and unnecessary movements).

4.2.3. Step 3 – QCC production process

- Slow placement of tips and terminals.

As to make this fast and easy for the operator, it was proposed the use of electric crimping machines that perform all the three tasks (striping, placement and crimping) in one operation, passing the task to take from almost 2 minutes to a few seconds per wire.

- Improper transport of QCC.

After a few conversations and meetings with operators, there were discovered 4 hydraulic trucks in obsolete materials, with little use. This alternative allows overcoming the disadvantages of the forklift in terms of duration, availability, cleanliness and fuel.

- Inappropriate QCC doors loading and transportation.

The procedure was the construction of acrylics to line the bases of handling trucks. This implementation significantly reduces the transport time of the doors of QCC, since it avoids the detailed cleaning or removal of rust provided by the base of the truck and facilitates the doors loading and unloading.

- Setup times and problems in CNC machine.

It was found that there is a great waste in doors setup times, which significantly affects the production time. To reduce the high setup times, there were used SMED tool. In what regards the errors detected during the drilling process, as well as losses associated with the CNC machine, it was used Kobetsu Kaizen tool.

As already mentioned and according to Shingo (1985), SMED is composed by four steps. In the step 1, through a meeting with machine operators, it was possible to discriminate all tasks to perform this operation, managing to map the current situation of about 36,2 minutes. In the second and third step, given all of the tasks are internal, meaning, all tasks are performed with the machine in work mode, it was decided to group the step 2 and 3. In these two steps, there have become some internal tasks in external. It proceeded further to the identification and reorganization of internal and external tasks in order to reduce setup times. With the implementation of steps 2 and 3, there was possible to reduce the number of movements and transportations comparing with the initial situation. In the last step (step 4), was made use of engineering, by technological solutions applications or Lean tools implementation, in order to eliminate or reduce the time of internal and external tasks. Regarding internal tasks, there was created problem solving standards which contains rules to check the oil level before the start of drilling. Thus, the oil replacements become sporadic and not successively performed. Also, was created production standards to avoid time consumption. On external tasks, through the application of 5S tool, it was possible to reduce the duration of a few tasks of cleaning the doors.

Regarding Kobetsu Kaizen, initially (step 1) the tool was introduced and explained to the employees responsible for CNC machine, as well as, showed the number of hours lost with errors (102 hours) during the last quarter of 2015 and its impact on OEE indicator in this operation. On step 2 it was organized a meeting with the CNC machine operators, where it has measured what types of errors were detected during drilling. The types of errors identified were: lack of oil, inadequate tool distance, safety zone invasion, broken tool and computer errors. Then in step 3, there was a prioritization of those, as the focus was just on the first three errors. On step 4, through an

Ishikawa Diagram there were analyzed the main root causes of the three main causes. The most likely causes for the 'lack of oil' were: start drilling without checking the oil level; lack of knowledge of oil replacement method; and lack of signaling a lack of oil. For ' inadequate tool distance' the most likely causes are: lack of parameterization standards of appropriate distances from tool and lack of identification and organization tools. Finally, for the 'security zone invasion' the probable causes are: lack of signage in the surrounding environment; and that the safety bars have too much range of security zone. On step 6 and 7 there were planned and implemented the improvement for each root cause. The main implementation were: i) The creation of production and problem solving standards and minimum oil level signaling to 'lack of oil'; ii) The creation of parameterization rules and implementation of 5S and Visual Management for 'inadequate tool distance' error; iii) Restriction of passage to 'safety zone invasion' (Figure 5).

Figure 5 – Before (1) and after (2) restriction of passage.

Finally, on step 7 the verification proved that the improvements were significant and the number of hours lost was reduced.

5. Results of the implementation

This section presents the results obtained with the implementation of the proposed improvements in materials supply process and FAB in general (5.1), PTF (5.2) and QCC (5.3) production processes.

5.1. Step 1 – Materials supply process and FAB in general

In this step there was some difficulty in quantifying the results obtained from the application of Kanban, 5S and Visual Management. However, there was received a very positive feedback from the operators, considering a 'cleaner and more organized' environment, with 'more intuitive' tools choices. Also, that was not registered any type of stock out consequent waiting for materials due to the use of Kanban card.

5.2. Step 2 – PTF production process

In this production process there were considered the following improvements: a) purchase of a mechanical arm with suction cups and a platform hand truck; b) the establishment of production standards; and finally, c) creation of molds for the isolation bars. As such, the results were (Table 1):

Table 1 – Savings in PTF production time.

Operation	Initial time	Actual time	Savings
Cutting, drilling, bending	12 dias e 5:05	11 dias e 0:32	12:33
Guillotine	04:14	03:36	00:38
Transportation and handling	00:53	00:15	00:38
Press	05:11	04:30	00:41
Transportation and handling	02:11	01:30	00:41
Máquina CNC	08:12	07:56	00:16
Transportation and handling	00:46	00:30	00:16
'Corners' cutting	04:14	03:34	00:40
Transportation and handling	01:30	00:50	00:40
Bending machine	1 dia e 2:26	07:28	02:58
Transportation and handling	03:58	01:00	02:58
Welding, retifiying, assembling	8 dias e 4:48	7 dias e 05:28	07:20
Transportation and handling	3 dias e 7:20	3 dias	07:20
Platines, accessories and isolation bars	06:06	05:34	00:32
Isolation bars	01:48	01:16	00:32
Measurements	00:27	00:05	00:22
Drawings	00:12	00:02	00:10
Supports, 'toros', accessories and copper	1 dia e 7:06	1 dia e 04:37	02:22
Isolation bars	03:36	02:32	01:04
Measurements	00:49	00:05	00:44
Drawings	00:22	00:02	00:20
Rigid bars	06:45	05:27	01:18
Cut, drill and bend	03:20	02:02	01:18
Isolation bars	02:02	01:07	00:55
Measurements	00:43	00:05	00:38
Drawings	00:19	00:02	00:17
		TOTAL	16:22

The rows with black color represent the name of the main operations, at dark grey color there is represented the selected operation and at light grey color are represented the tasks from each operations. There is a need to mention that at orange color there are identified the envisaged improvements if the responsible for the FAB decide to move forward with the purchase of the mechanical arm with suction cups and a platform hand truck. Considering all the results, there is obtained a total reduction of 16 hours and 22 minutes (approximately 13%).

Regarding the investment on the mechanical arm with suction cups and platform hand truck, there were conclude that: i) the purchase of the mechanical arm with suction cups prevent the presence of 3 operators on the Guillotine, requiring only 1 operator resulting in a saving of € 330 per month or € 3,960 per year. Also, the return on investment will be approximately 1 year and 4 months or about 16 months (considering 22 working days in a month); ii) Buying the platform hand truck allow the allocation of only one operator in handling the plates in each operation, once the platform is adjustable to the height of the machines, it is possible to raise the same, to facilitate loading and unloading. It was also considered that handling would become much faster and require less effort from the operator. As such, given the difficulty in quantifying the reduction without the operations can be carried out, were considered approximate reductions for Guillotine operations, CNC machine, press, 'Cut corners' Bending and joinery (Table 1) .

5.3. Step 3 – QCC production process

In Step 3 there was proposed the following improvements: a) the use of electric crimping machines for placement of tips and terminals; b) QCC transport with hydraulic trucks; c) acrylic in handling trucks to transport QCC doors; d) SMED and Kobetsu Kaizen.

Figure 6 shows the results of SMED implementation.

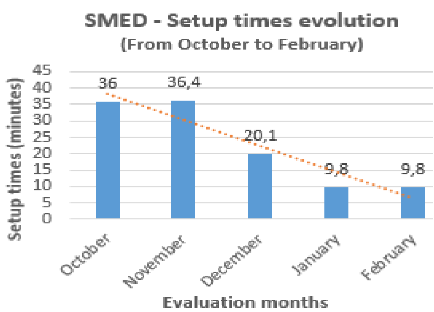

Figure 6 - Setup times evolution (10/15 - 02/16).

In short, with the implementation of SMED it was possible to reduce 72.9% in the change of time due to the initial situation, having been able to reduce this time to less than a two-digit number as suggested by Shingo (1985).

By implementing Kobetsu Kaizen, it was possible to reduce the number of hours lost due to major errors detected in the CNC machine – inadequate tool distance, safety zone invasion and lack of oil. As can be seen from Figure 7, there were achieved some significant reductions in lost hours with errors. Parameterization standards allowed a reduction of 80% (from 35 to 7 hours lost), with restriction passage to the machine, there was a reduction of about 93% (from 29 to 2 wasted hours) and the establishment of production and problem solving standards, as well as signaling the oil level allowed a reduction of 100% in the problem of lack of oil from October to February.

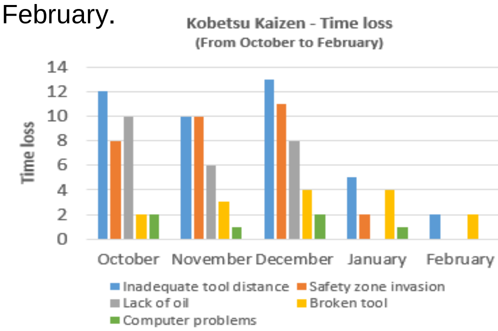

Figure 7 – Time loss (10/15 - 02/16).

The overall results of Step 3 is present in Table 2:

Table 2 – Savings in QCC production time.

Operation	Initial time	Actual time	Savings
Cutting, drilling, bending	2 dias e 2:01	1 dia e 7:09	02:52
CNC machine	09:46	06:54	02:52
Setup times	01:49	00:29	01:20
Errors	01:42	00:10	01:32
Assembly (structures, accessories and equipment)	2 dias e 4:04	2 dias e 3:22	00:42
Doors transportations	00:15	00:06	00:09
Doors cleaning	00:33	00:00	00:33
Eletrification	4 dias e 7:01	3 dias e 2:17	12:44
Wiring strip	04:42	00:32	12:08
Placement and crimping of terminals and tip	07:58		
Transportation	00:54	00:18	00:36
		TOTAL	16:18

As can be assessed, it was obtained a total saving of 16 hour and 18 minutes (approximately 22%).

As conclusion, in Figure 8 follows the evolution of the OEE indicator.

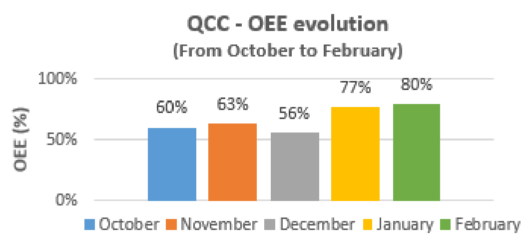

Figure 8 - OEE evolution (10/15 - 02/16).

The implementation of SMED and Kobetsu Kaizen allowed to achieve considerable increases in OEE. This increase of about 30% from October to February, was due to the reduction of the changing times and wasted time with errors during the drilling process, which enabled the increasing number of parts produced with quality, as well as production capacity. Should also be noted that if the sense of discipline, when it comes to Lean Thinking, is acquired by the FAB, the trend of OEE is to increase.

6. Conclusions

This case study aimed to propose several solutions so that was possible to reduce waste and increase the efficiency of procurement and production processes, such as QCC and PTF in TecnoSPIE. Also, it was tried to make the environment work of FAB - one of the working areas of TecnoSPIE - more appealing, organized and clean. In fact, FAB proved to be a work area where the working methods and procedures applied have proved significantly to be disorganized and archaic. In order to attain this goal, there were implemented various strategies and Lean tools, which allowed not only increase efficiency and improve the organization in the FAB, as well as reduce costs for the company.

Initially, in order to know with more detail the various FAB processes (including supply and production), all the data needed to build the VSM (Step 0) for two production processes analysis - PTF and QCC, was monitored throughout the manufacturing cycle in FAB. As such, there was analyzed FAB in general (Step 1), PTF (Step 2) and QCC (Step 3) in order to identify the various waste and opportunities for improvement.

Then, the intervention method in the FAB and the consequent implementation of Lean tools in order to solve the problems identified, was scheduled. The improvements accomplished were the following ones: in Step 1 (FAB), it was implemented Visual Management for solving FAB identifying faults, 5S (and Standardization) to overcome the lack of organization and cleaning and Kanban to better control stock, avoiding unnecessary waiting; in Step 2 (PTF) the purchase of a mechanical arm with suction cups and a platform hand truck was suggested in order to improve loading / unloading process and subsequent handling and transport. It was implemented Normalization so it was possible to surpass differences in production times and problem solving. Also it were developed molds for the isolation bars to prevent excessive processing; finally in Step 3 (QCC) the use of electric crimping machine for placement of tips and terminals was established, avoiding excessive processing. The use of acrylics on handling trucks and hydraulic trucks, improved the transport of QCC doors and of QCC, respectively. Finally, it was implemented Kobetsu Kaizen and SMED, to reduce (or eliminate) the errors obtained in the QCC doors drilling operation and in order to reduce the setup times.

Once identified the problems and opportunities to improve, as well as strategies and Lean tools to implement, it was possible to evaluate the results obtained with such implementations. The evaluation of the results was carried out through three main indicators: production times, OEE and return on investment. On PTF production process (Step 2) it was achieved saving of about 16 hours and 22 minutes (approximately 13%) with the largest reduction achieved with the construction of molds for the isolation bars, reducing about 45% its manufacturing time. Also in Step 2, it was proposed an investment to cutting, drilling and bending operations of € 5,398 and with a return on investment of about 1 year and 4 months. In the production process of QCC (Step 3), the savings was about 16 hours and 18 minutes (approximately 22%), having the greatest reduction on the electrification operation with the use of electric crimping machines, achieving a reduction of about 33%. These savings resulted in increased OEE indicator about 30%.

7. References

- Bergmiller, G. G. e McCright, P. R. (2009). *Parallel models for lean and green operations*. *Industrial Engineering Research Conference*. Routledge (6).
- Bowen, D. E. e Youngdahl, W. E. (1998). *“Lean” service: in defense of a production-line approach. International Journal of Service Industry Management*, 9 (3), 207-225. doi: 10.1108/09564239810223510.
- Castells, M. (1999*). Information Technology, Globalization and Social Development*. Geneve. UNRISD Discussion Paper No.114.
- Comunidade Lean Thinking (CLT), 2008. A criação de valor através da eliminação do desperdício - XV EDIÇÃO PORTO.
- Dolcemascolo, D. (2006*). Improving the extended value stream: lean for the entire supply chain*. New York: Productivity Press, Inc.
- Garza-Reyes J. A., Belekoukias I. e Kumar V. (2014*). The impact of lean methods and tools on the operational performance of*

manufacturing organisations. International Journal of Production Research, 52 (18), 5346 – 5366, doi: 10.1080/00207543.2014.903348.

- Gross, J. M. e McInnis, K. R. (2003). *Kanban Made Simple: Demystifying and Applying Toyota's Legendary Manufacturing Process*. New York: Amacon.
- Hallfren, M. e Olhager, J. (2009). *Lean and agile manufacturing: external and internal drivers and performance outcomes*. *International Journal of Operations and Production Management*, 29 (10), 976 - 999. doi: 10.1108/01443570910993456.
- Hettler, N. (2008). *Lean Means Business. Manufacturing Engineering Magazine.*
- Hines, P., Holweg, M., e Rich, N. (2004). *Learning to evolve: A review of contemporary lean thinking. International Journal of Operations e Production Management*, 24 (10), 994–1011. doi: 10.1108/01443570410558049.
- Imai, M. (2012). *Gemba Kaizen: A Commonsense Approach to a Continous Improvement Strategy* (2nd Ed.). New York: McGraw-Hill.
- Jacobs, F. R. e R. B. Chase (2008). *Operations and Supply Chain Management: The Core.* New York. McGraw-Hill Education. P.226.
- Jayamaha, N. P., Wagner, J. P., Grigg, N. P., Campbell-Allen, N. M. e Harvie, W. (2014). *Testing a theoretical model underlying the 'Toyota Way' – an empirical study involving a large global sample of Toyota facilities. International Journal of Production Research*, 52 (14), 4332 - 4350. doi: 10.1080/00207543.2014.883467.
- Marodin, G. A. e e Saurin, T. A. (2013). *Implementing lean production systems: research areas and opportunities for future studies. International Journal of Production Research,* 51, (22). doi:10.1080/00207543.2013.826831.
- Melton, T. (2005). The Benefits of Lean Manufacturing. Chemical Engineering Research and Design, 83 (6), 662–673. doi: 10.1205/cherd.04351.
- Shingo, S. (1985). *A Revolution in Manufacturing: The Smed System*. Cambridge: Productivity Press.
- SPIE Portugal (2015). SPIE Portugal – Ambição partilhada.
- Sütőová, A., Markulik, Š. e Šolc, M. (2012). *Kobetsu Kaizen - its value and application. Electronic International Interdisciplinary* Conference. Žilina (108 – 110).
- Tjell, J. e Bosch-sijtsema, P. M. (2015). *Visual management in mid-sized construction design projects. Procedia Economics and Finance*, 21 (2014), 193 – 200. doi: 10.1016/S2212-5671(15)00167-7.
- Womack, J. e Jones, D. T. (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* (2nd Ed.). New York: Free Pass.
- Womack, J., Jones, D. T. e Roos, D. (1990). *The Machine That Changed the World*. New York: Free Pass.