

# Development of improvement measures for Fenesteves' production system using Lean Manufacturing principles

Vasco Antunes Oliveira  
vascooliveira@tecnico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal  
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## Abstract

The increasing complexity of the global market combined with the national lack of investment force the industrial sector to find new production models capable of producing more, with the highest quality and at the lowest cost possible. This way, comes up the Lean Manufacturing philosophy aiming to maximize the production capacity through the reduction of any waste, or inefficiencies, in the processes involved.

According to its fundamental concepts, an early diagnosis is performed covering the 6 floating floor's production lines of Fenevestes company, which is located in Portalegre. The data used in this analysis was collected using different approaches – for instance, the methods and times studies – as well as a quite wide performance indicator: the Overall Equipment Effectiveness (OEE).

From the several types of waste identified, specific corrective measures are suggested for each inefficient production line along with their implementation results, some of which are supported by methods such as *Kanban* or *Poka-Yoke*. An approach that, ultimately, will increase significantly the efficiency of Fenesteves' production system and, above all, add value to the products produced.

**Keywords:** Lean Manufacturing; Overall Equipment Effectiveness; 5 Whys; *Kanban*; *Poka-Yoke*; Production Management.

## 1 Introduction

The increasing competitiveness of the global market coupled with the national investment deficit impose, subsequently, the need for the industry to find practical production models capable of producing more and more, with better quality and lower cost.

It is precisely in this context that the Lean Manufacturing philosophy emerges, providing a sustainable performance maximization and, above all, increasing the productive capacity by eliminating eventual waste or inefficiencies in manufacturing processes.

This way, the purpose of this work is based on the application of the fundamental tools of the

Lean Manufacturing philosophy to the case of the company Fenesteves, established in Portalegre and dedicated to the manufacture of floating floors. Hence, this work aims to improve the overall efficiency of the 6 sectors of floor manufacturing, according to the '5 Whys' method and the Overall Equipment Effectiveness (OEE) forecast.

Finally, this indicator allows a comparative performance analysis of the various manufacturing sectors against their maximum capability, as well as the verification of possible improvement measures for each operation. These measures are based on methodologies such as *Kanban*, *Poka-Yoke*, Visual Management, or even on the suggestion of other control and

production management indicators, for instance, the Key Performance Indicators (KPIs).

## 2 Theoretical Review

### 2.1 Historical Background

Although the origin of manufacturing processes is often associated with the time of the great Greek, Egyptian or even Roman craftsmanship, the term industry gained significance only in the late eighteenth century with the industrial revolution and, of course, the introduction of the steam engine. Launching thus an era of strong economic prosperity and a significant increase of the living standards that, with its highs and lows, still runs until the present day [1][2].

In the early twentieth century, the founder of Ford Motor Company, Henry Ford, designed the first Model T assembly line based on its new mass and series production systems, in order to meet the growing market needs. This system, based on Ford's modest factory in Highland Park, had become a world benchmark not only for the industrial sector, but also for modern thinking itself. Aiming at the production of as many products as possible, with a simple design and above all at the lowest cost [3].

Nevertheless, the mass production system introduced by Henry Ford presents some flaws, among them, its incapacity to produce diversified products. This fact led Taiichi Ohno, chief engineer of Toyota Motors Company, to develop a new Japanese production system between 1948 and 1975, the Toyota Production System (TPS) [4]. In order to promote the production of a wide range of products, at a competitive cost and, above that, in relatively small quantities compared to the mass production system.

### 2.2 Lean Manufacturing

Based on TPS, the philosophy of Lean Manufacturing emerged as a production management system whose aim, it should be noted, is to develop procedures and processes through the continuous reduction of waste at all stages. Therefore, it enforces the differentiation between value-added activities and activities

with no added value, according to the requirements specified by the client [5].

According to the Lean Manufacturing philosophy, any activity or process that does not add value to the customer is considered wasteful - in Japanese: *muda* – hence, as all waste only adds costs and time, these are the symptoms of a particular problem to eliminate.

### 2.3 Lean Tools and Methods

#### 2.3.1 5 Whys

The '5 Whys' is a tool for analyzing, detecting and solving defects or problems in any process and operation, aiming to identify its 'root cause' through the sequence of cause and effect relationships. Its application is based on asking the 'why?' question enough times- usually 5 - until it is explicitly found the reason for the problem subject to analysis.

The great advantage of the '5 Whys' face to any other analysis tool must be, above all, its ability to differentiate between the symptoms that produce the problem and its real causes, which effectively should be eliminated for the benefit of the process or operation in study [6].

#### 2.3.2 Poka-Yoke

The *Poka-Yoke* is based on a simple but powerful technique to eliminate human failures, using accessible and economical devices to prevent possible errors, including visual and sound signals [7]. Its designation comes from the Japanese terms '*poka*' and '*yoke*' which, combined, refer to the 'error-proof' translation of this system, initially developed by Shigeo Shingo in the early sixties and later included in the TPS.

Thus, a *Poka-Yoke* is therefore any mechanism that, in addition to preventing the occurrence of a certain error, also allows it to be detected more easily. Acting directly in the error origin, this type of device contributes to the zero defects goal in the products produced and, ultimately, allows a drastic reduction in the need for inspection after manufacture [7].

#### 2.3.3 Visual Management

Visual Management - also known as Visual Control - is a tool that enhances the development and continuous improvement of organizations through sound or visual devices that immediately

inform employees about the procedures to be performed, execution periods, possible errors and any support required. This allows the worker to understand everything that is going on around him without necessarily being familiar with the production processes. This way, the Visual Management systems should be simple and intuitive, and may present the following features [8]:

- Indicate how the work should be performed;
- Show how materials and tools are used;
- Show how resources are stored;
- Present the control levels of the inventory;
- Show the status of the processes;
- Indicate when someone needs support;
- Identify hazardous areas;
- Support error-proof operations.

### 2.3.4 Kanban

The *Kanban* is a strategic and operational management tool developed by Taiichi Ohno in the 1960s based on the JIT concept [9]. Its designation comes from the Japanese language, in which it literally refers to the terms ‘visible plaque’.

Therefore, this technique is based on a philosophy of production exclusively adjusted to customer needs, being used to control the production, inventories and supply of raw material. In practice, the *Kanban* operation has become a major landmark of the pull system, presenting the shapes of a card or a box with all the information required for the execution of the intended operation, including the batch code, part number, date, quantity, etc. [8].

### 2.3.5 OEE

The Overall Equipment Effectiveness (OEE) is a performance indicator introduced by Seiichi Nakajima in the 1960s to evaluate the efficiency of any production system. It allows the detection of eventual losses in the production sectors in comparison to its maximum potential, as well as the verification of possible improvement measures for its operation. In this context, the OEE is based on three fundamental cornerstones [10].

- 1) Availability: losses for adjustments and repairs that correspond to setup times and other stops due to mechanics;
- 2) Performance: reduced speed losses in the regular operation of the production equipment;
- 3) Quality: losses due to defects that include rejections, rework or even cases demanding the restart of the production processes.

Although there are other performance indicators, most of them do not have the same scope as the OEE, often focusing only on efficiency or on the available production time [11]. Hence, based on the three cornerstones already discussed, it can be considered that the OEE represents the percentage of overall effectiveness of a given system, resulting from the following equation.

$$OEE = Availability \times Performance \times Quality \quad (1)$$

## 3 Case Study

### 3.1 Description

The purpose of this paper is based on the application of the concepts established in the Lean Manufacturing philosophy to the particular case of Fenestevés. This allows the characterization of the current state of its production system so that, afterwards, can be presented the appropriate solutions for the possible operational problems identified.

Fenestevés is a family business based in Portalegre that operates in the market of wood processing and floor production. Currently, it has 26 employees and is one of the few companies that produces floating wooden floors in Portugal.

### 3.2 Methodology

The present work intends to study the construction of floating floors, which includes a set of manufacturing processes that not only determine the geometry and functionality of the final product, but also require the greatest working effort from the Fenestevés’ human resources. Therefore, these processes are: wood cutting (LP Machine Sawing), manual (LP 1) and automatic (LP 2) layering, size calibration (LP 3), finishing (LP 4) and, finally, the profiling of the fittings of each floor (LP 5).

In the scope of this work several analysis techniques are applied, aiming to understand the procedures and latent operations in each production sector. Thus, the qualitative study of the production lines is based on two methods, the visual analysis and the casual interviews. Regarding the quantitative study of the same workstations, two techniques to study the

relevant times were used: the instantaneous observations and the timekeeping. Therefore, it allows the evaluation of its performance based on obtaining the production times as well as the stops of each sector.

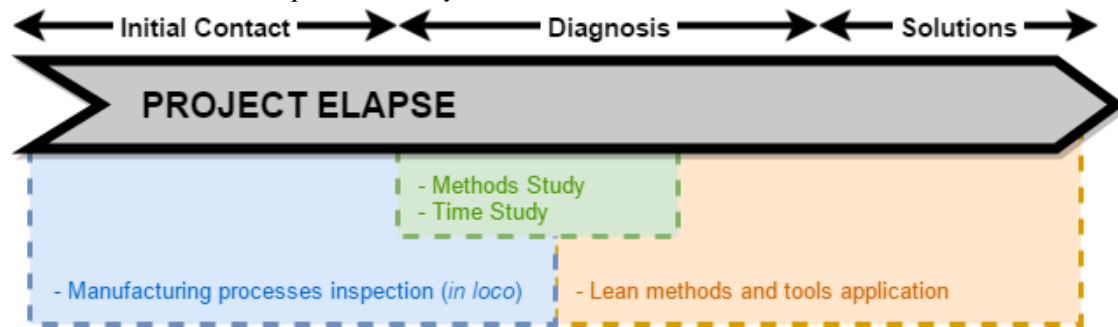


Figure 1 - Production system analysis methodology.

## 4 Diagnosis

In order to identify more accurately the root cause of the wastes measured in each of the production sectors and, above that, to evaluate their overall efficiency, it was preferable to characterize Fenestevés' production system based on the OEE calculation.

### 4.1 OEE Results

By calculating the OEE for each production sector, it is observed an accumulation of productivity losses referring to the three indicators considered, in particular, the Availability, Performance and Quality. This way, the following conclusions about its productive performance can be already taken:

- The sector that has the worst performance is the manual layering (LP 1), presenting an OEE below 50% due to the abrupt reduction of its Performance to 53.1%. This fact is related to the handcrafted nature of the operations involved, as well as the waiting time associated with pressing in this sector;
- The results corresponding to the Quality of each production line are above 90% in most cases, except for LP 4 (71.4%). This value is justified by the quantity of defective finished products registered in this sector, having a direct impact on the

OEE, which is below 60% and represents the second worst performance;

- The Availability of each production line registered results above 95% for all cases, with a small decrease in LP 3 (calibration) to 91.4%. This register comes mainly from the number of mechanical stops accounted in this particular sector, which, combined with a performance of 71%, presents the third worst performance with an OEE of close to 63%;
- The remaining workstations (LP Machine Sawing, LP 2 and LP 5) present OEEs above 70%, a value considered positive for their performance when compared to LP 1, LP 3 and LP 4. Hence, there is no need of major improvement measures for the performance of these particular lines.

### 4.2 Analysis of the Production System Losses

Following the analysis of the OEE of each workstation, it is presented a graphic and detailed evaluation about their performance, based on the root cause of the verified stops. Since the OEE calculation ultimately represents an accumulation of multiple occurrence losses, it differs from line to line, given the total time available for production (corresponding to 100% in the graph).

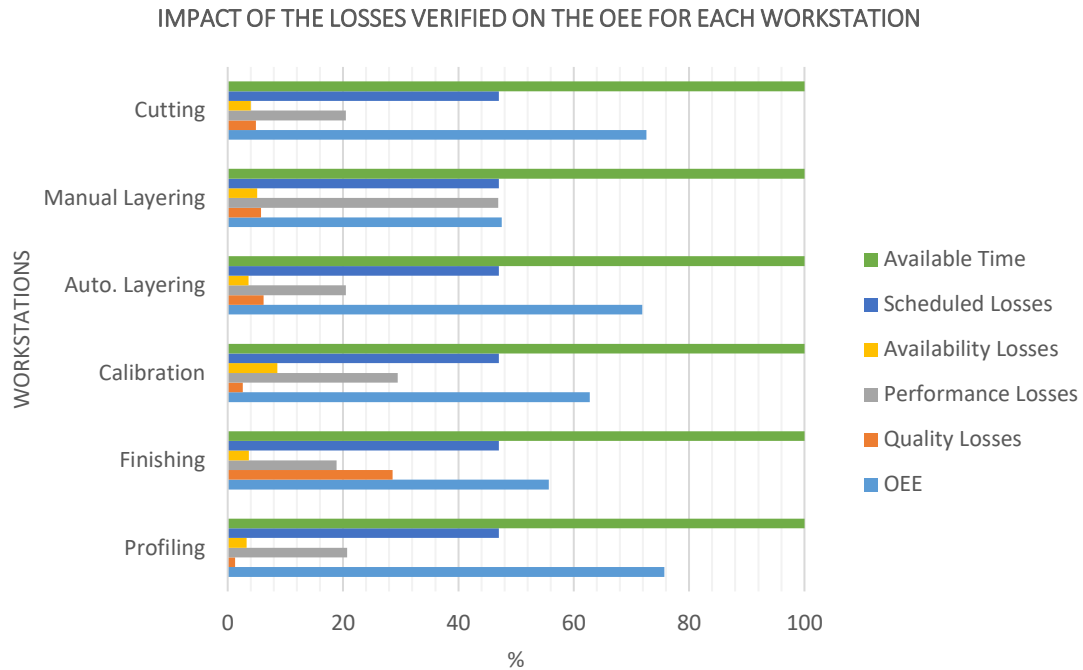


Figure 2 - Graph depicting the impact of the losses verified on the OEE for each workstation.

#### 4.2.1 Performace Losses

The decrease in Performance recorded in the manual layering sector (LP 1) is directly related to its reduced speed losses. This is related to the fact that both layering and assembly operations are mostly handmade and, unlike LP 2, the pressing is not automated in this sector. For this reason, the human action assumes a strong impact on the performance of LP 1 and, particularly, on the waiting time verified in the pressing operation.

Neglecting the mandatory permanence time of the floors in the presses to let the glues solidify, it is possible to verify that the main factor of production congestion is the delay in the manual collection of the pressed batches and the introduction of the subsequent ones. Since this operation requires at least two operators at the same time, the auxiliary operator and one of the layering machine operators, who are often engaged in other activities such as the initial moisture register or the manual assembly.

#### 4.2.2 Quality Losses

The Quality reduction verified in the finishing sector (LP 4) is due to the high quantity of defective products registered in the Quality Control.

In agreement with the observations made in this particular sector, it can be concluded that the main cause of finishing defects is based on successive varnishing operations. Since, in most cases, the surface of defective floors presents non-varnished areas or even encrusted residues, which are mainly due to the presence of impurities obstructing the feed pipes of the varnishing machines.

Although the varnishing is done by two rollers - an applicator and a dispenser - which should turn the varnishing of each floor uniform, that situation wasn't verified due to the lack of cleaning procedures, as well as the scarce filtering of the pipes in this sector.

#### 4.2.3 Availability Losses

Although not as significant as in the previous cases, it was registered an Availability decrease in the calibration sector (LP 3) related with its mechanical stops losses. This fact is due to the corrective maintenance operations on the calibrator and the multi-saw. Since the corrective maintenance is the only type of maintenance applied in this sector, tools such as the abrasive belts, the steel brushes and the cutting blades are not only far away from LP 3, but also without any assembly instructions or descriptive labels. This impairs the work of the operator responsible for

its maintenance and, above all, the productive performance of this sector.

#### 4.2.4 Production Management

In addition to the losses identified through the OEE for each LP, the diagnostic of the problems in the productive system in study is only concluded with the analysis of the current control and production management practices.

This way, it is possible to identify a huge disarticulation between the various productive sectors regarding not only the data acquisition and control, but also the capacity for overall improvement of Fenestevés' results. The lack of common manufacturing indicators of control and management has several negative consequences for the production system, including:

- Delays in the production and dispatch of orders against the pre-established deadline (4 weeks);
- Delays in the delivery of materials by suppliers;
- Deficit of tangible medium- to long-term productive targets by the production managers;
- Cost deviations in the selection of materials and components;
- Need for rework or development beyond scheduled.

## 5 Solutions

Considering the productivity losses evidenced in the diagnostic phase as opportunities to improve the Fenestevés production system, it is thus possible to make a resolution plan to solve them according to the Lean philosophy.

### 5.1 Improving the Press Operator Response Time

According to the analysis of the reduced speed losses performed previously, the human action assumes a strong impact on the performance of LP 1 and, in particular, the waiting time verified during the pressing operation. Therefore, the current function distribution model promotes the over-occupation of the press operators (the auxiliary operator and one of the layering machine operators) overloading the flow of pressed and unpressed batches that, chaotically, are accumulated in the

work area. This situation, if properly diagnosed, can then be solved by implementing a new working dynamic based on the visual *Kanban* and the auxiliary operator support system.

Being a visual production and inventory control system, the *Kanban* aims to standardize the input and output procedures of the floors in the press, avoiding an overload of the work area. In addition, the auxiliary operator support system is designed to simplify the transport and lift of the lots, enabling the execution of the pressing operation exclusively by this operator, based on the acquisition of 6 mobile lifting tables - one per each *Kanban* - properly equipped with roller mats.



Figure 3 - Visual *Kanban* placement in the LP 1.

Based on the application of both the visual *Kanban* and the auxiliary operator support system, it is then possible to establish a new operational dynamic for the manual layering sector. It aims to prevent the overload of the work area, as well as the over occupancy of the pressing operators, through the assignment of specific jobs and standard functions for each worker.

Ultimately, the new operational dynamics allow a reduction of around 10 percent in Human Stops accounted in LP 1, enabling the implementation of the visual *Kanban* and the proposed support system. Although the support system requires a total investment in equipment acquisition of around 2.274,00€, this amount is then justified by the addition of 50 m<sup>2</sup> of daily production that, in the short term, validate its application to the manual layering sector.

## 5.2 Preventing Obstructions in the Varnishing Tubing System

According to the analysis of the quality losses previously made, the main cause of defects in the finished product lies in the varnishing operation and, in particular, in the feed pipes of the varnishing machines. Considering the origin and dimensions of the fouling observed on defective pavements, it is suggested the implementation of a *Poka-Yoke* preventive filtering system, which consists on Y-type filters strategic positioned in the feed pipes of varnishing machines.

By using the Y-type filter - also known as Angle Valve - in the varnishing pipes, the varnish is then deflected to a punctured filtration screen, which has an easy-fitting lid for its washing and replacement. Thus, it allows the removal of solid particles with larger dimensions (up to 2 mm) existing in the fluid - such as raw material residues, oxidation residues or even sands. Contributing to the protection of the hydraulic pumps of varnish flow, as well as both varnishing rollers, against casual obstructions and wear associated its usage.

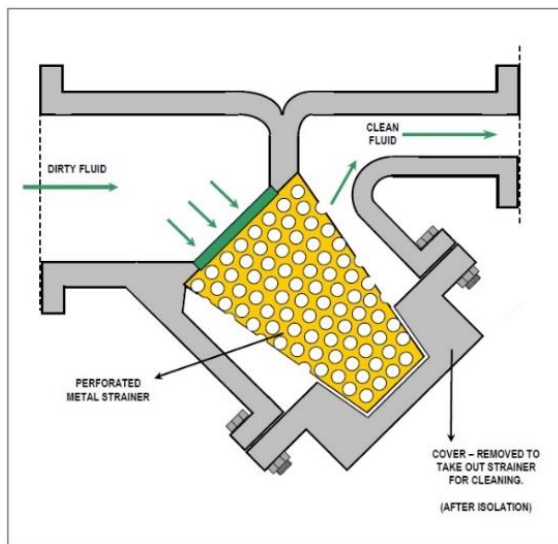


Figure 4 - The Y filter system operation [12].

Ultimately, the implementation of the *Poka-Yoke* preventive filtering system may represent, in the short term, a decrease of 7,14 percent of the Quality Losses registered in the diagnosis of LP 4.

## 5.3 Reducing the Maintenance Time of the Calibration Equipment

In agreement with the analysis of the losses caused by mechanical stops previously performed, the maintenance time of the equipment assumes a strong impact on the performance of the calibration sector. Taking into account that, due to the lack of preventive maintenance procedures, the delays in the replacement of parts in the calibrator and the multi-sawing machine result from the operators difficulty of access to them.

Properly diagnosed, this situation can be mitigated by setting up an immediate supply counter of replacement parts for those machines. This measure can be also complemented through the implementation of Visual Management procedures for the cataloging of some of these parts, as well as the periodic inspection of LP 3 equipment.

Therefore, the counter for immediate supply of abrasive belts and steel brushes, used for the maintenance of the calibrating machine, should be positioned as close to both machines as possible without obstructing the work area. This will allow the operators responsible for their maintenance to be quick and efficient.

Finally, the implementation of the proposed preventive maintenance measures could mean, in the short term, a decrease of approximately 5 percent of Mechanical Stops, in comparison to the actual numbers verified in the LP 3 diagnosis. These measures could represent an increase up to 20 m<sup>2</sup> in the daily production of the calibration sector, at a relatively low cost.

## 5.4 Network Production Management (Future Work)

Through the analysis of the production management and control practices carried out in the final stage of the diagnosis, it was verified that the diverse productive sectors are not articulated in obtaining and sharing data. This situation, combined with the short-term tangible productive targets deficit, has a direct influence on the overall improvement capacity of the company's results.

In this context, it is suggested as a future work the implementation of production management indicators that allow a continuous performance evaluation of the manufacturing system in study, the Key Performance Indicators (KPIs). KPIs consist of several variables that an organization can use to access, analyze and control its production processes regarding defined goals and targets [13].

The KPIs proposed in this work allow a non-financial evaluation, but oriented to each different operational areas around, in this case, the Production Department. It also seeks to satisfy the customer's quality standards as shown in the following table, where the KPIs are presented along with their purpose, method of calculation and frequency of measurement.

Process/Area	Indicator	Formula	Target	Frequency
Production Management	Count	$\sum Produced\ Orders$	$\geq 10$	Daily
Production Management	Production Rate	$\frac{\sum EProduced\ Orders}{\sum Orders}$	$\geq 95\%$	Daily
Production Management	Disturbances per order	$\frac{\sum Disturbances}{\sum Orders}$	$\leq 5$	Weekly
Production Management	Rejection Ratio	$\frac{\sum Rejections}{\sum Orders}$	$\leq 5$	Weekly
Supply Management (Procurement)	Waiting Time in Warehouse	$\frac{\sum (Output_{warehouse} - Input_{warehouse})}{\sum Components}$	$\leq 2\ weeks$	Monthly
Logistics and Shipping	Waiting Time for Shipping	$\frac{\sum (Output_{shipping} - Input_{shipping})}{\sum Orders}$	$\leq 3\ days$	Monthly
Research and Development	Customer Complaints Ratio	$\frac{\sum Complaints}{\sum Orders}$	$= 0$	Semesterly

Table 1 - Suggested KPIs for Fenestevés

## 6 Conclusions

Based on the OEE of each workstation, it was possible to verify the losses, limitations and, above all, any improvement aspects to be implemented. The diagnosis was concluded with the study of the possible causes for the losses in Availability, Performance and Quality identified in these sectors through the '5 Whys' method, followed by the suggestion of some resolution measures to be taken.

The first one is the implementation of a new operational dynamics in the manual layering sector based on the visual *Kanban*, as well as the auxiliary operator support system, aiming to improve the operators' response in the press operation. This solution ultimately represents a decrease of the batch replenishment time from 14,6 to 2,9 minutes and, consequently, an increase in the performance of this sector of around 12%.

In order to reduce the amount of rejected product in the finishing sector, it was recommended to prevent any obstructions in the varnishing pipes by applying a *Poka-Yoke* filtering system. This allows a reduction of around 20 m<sup>2</sup> per day of rejected product in this sector, which, according to its OEE, represent a decrease of approximately 10 percent in its quality losses.

Regarding the improvement in the maintenance time of the calibration equipment, it was chosen both the creation of an immediate counter for replacement parts, as well as the implementation of simple and intuitive Visual Management procedures for the prevention of eventual stoppages mechanically originated. Thus, it enables reducing the maintenance time of the equipment in this sector from 29,9 to 11,9 minutes and, consequently, increasing about 5 percent its Availability.

In addition to the proposed solutions for short-term implementation in the company, it



was also suggested the future introduction of Key Performance Indicators (KPIs). It aims, this way, the control and network management of the production in all sectors of the industrial unit, as well as the definition of tangible productive objectives by the Fenesteves' managers.

At last, it should be referred that the solutions specifically presented for the manual layering, calibration and finishing sectors allow an improvement of their OEE of 10,7%, 3,3% and 5,6%, respectively. Nevertheless, it is noted that, above the quality of the results obtained, the present work certifies the Lean philosophy and its tools as means for analysis and problem solving in the industrial sector.

## 7 References

- [1] R. Lucas, *The Industrial Revolution Past and Future*, 2003.
- [2] R. E. J. Lucas, *Lectures on Economic Growth*, Cambridge: Harvard University Press, 2002.
- [3] Ford Motor Company, "A Evolução da Produção em Série," [Online]. Available: <http://www.ford.pt/ExperienciaFord/SobreFord/InformacaoSobreEmpresa/Heritage/TheEvolutionofMassProduction>.
- [4] T. Ohno, *Toyota Production System: Beyond large scale production*, Productivity Press, 1988.
- [5] A. B. R. S. K. R. Sundar, *A Review on Lean Manufacturing Implementation Techniques*, Tamilnadu: Elsevier, 2014.
- [6] R. A. W. J. M. T. J. Santos, *Improving Production With Lean Thinking*, John Wiley & Sons, 2006.
- [7] P. P. Elsa Henriques, *Gestão da Produção, Secção de Folhas*.
- [8] J. P. Pinto, *Lean Thinking: Introdução ao pensamento magro*, Comunidade Lean Thinking, 2008.
- [9] S. B. N. G.-G. V. G. Aguilar-Escobar, "Hospital kanban system implementation: Evaluating satisfaction of nursing personnel," *Investigaciones Europeas de Dirección y Economía de la Empresa*, 2015.
- [10] D. H. Stamatis, *The OEE Primer – Understanding Overall Equipment Effectiveness, Reliability and Maintainability*, CRC Press, 2011.
- [11] J. P. Rodrigues, "OEE - A forma de medir a eficácia dos equipamentos," [Online]. Available: [http://www.freewebs.com/leanemportugal/OEE\\_forma\\_de\\_medir\\_eficacia Equipamento-Rev1.pdf](http://www.freewebs.com/leanemportugal/OEE_forma_de_medir_eficacia Equipamento-Rev1.pdf).
- [12] Volans, "Filtro y," [Online]. Available: <http://www.volans-filtros.com.br/filtro-y>.
- [13] Bresimar Automação, "Os 7 KPI's mais comuns para monitorização da produção," [Online]. Available: [http://www.bresimar.pt/Cache/binImagens/RedLion\\_WP-3524.pdf](http://www.bresimar.pt/Cache/binImagens/RedLion_WP-3524.pdf).