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Applying Lean Manufacturing in the Production Process of Rolling Doors: A Case Study

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Abstract: The lean manufacturing seeks to ensure the quality of the service and the supplier's products by the companies that implement this methodology, through the improvement of the research environment and the elimination of the classic wastes present in any process. The research was developed in a metalworking company which presents as main problem the delay in the delivery of the finished product (rolling doors), generating complaints and nonconformities. For this reason, the need arises to make a proposal for improvement in its production process which allows to reduce the delivery time of the product to its customers and to guarantee its efficiency and productivity, using the tools and techniques of lean manufacturing. The methodology assumed in the study, corresponds to the philosophy of lean thinking to develop an improvement proposal where the following tools were used: value stream mapping, 9'S, single minute exchange of die, total productive maintenance, Kanban which provided the following possible results: total production process time would improve by 6.10%, value added time by 2.13%. The production increases from 24-26 doors per month, giving an improvement of 7.4% and mainly, the delivery time would decrease 590-554 min with a reduction of 6.10%, all these results lead to faster and more efficient deliveries to the customer. A case study was carried out in the metalworking company in Ibarra, Ecuador. The results also indicate that lean thinking contribute substantially to the operating performance of company is decreased about 7% of the time in operational performance.

Key words: Lean manufacturing, production process, rolling doors, productivity, production capacity, improvement proposal

INTRODUCTION

According to researchers (Singh *et al*., 2015) companies are continually striving to increase productivity and output of their operations. Lean has been originally created and defined as the process of eliminating waste Toyota along with the support a system to reduce or eliminate waste and non-value added activities from various processes. Value stream is all the steps, both value added and non-value added required taking a product or service from raw material to the customer. On the other hand, Bamber and Dale (2000) discussed the application of lean production methods to a traditional aerospace manufacturing organization. They found that there are two main stumbling blocks to the LM application: the redundancy programme and a lack of employee education in the concept and principles of lean production (Gurumurthy and Kodali, 2011).

The lean approach has been applied more frequently in discrete manufacturing than in the continuous/process sector, mainly because of several perceived barriers in the latter environment that have caused managers to be reluctant to make the required commitment (Abdulmalek and Rajgopal, 2007).

There is consensus that lean techniques can eliminate waste and reduce risk to manufacturing and services sectors including construction (Howell and Ballard, 1998), aerospace (Hines *et al*., 2004), services (Bortolotti and Romano, 2012; Suarez-Barraza *et al*., 2012), tourism (Vlachos and Bogdanovic, 2013) hospitals (Reijula and Tommelein, 2012; Young and McClean, 2008) and public administration (Radnor and Walley, 2008; Vlachos, 2015).

Despite the lack of a universal definition of lean thinking (Shah and Ward, 2007), there is consensus that the adoption of lean thinking has a twofold impact on the

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way companies do business: at the strategic level, lean thinking helps companies to define value and at the operational level, lean thinking provides a set of tools and techniques to eliminate waste (Hasle *et al.*, 2012). Implementing lean thinking needs a clear understanding of what lean is and what constitutes a successful lean action plan (Vlachos, 2015).

Lean thinking focuses on the removal of waste that hinder the unremitting flow of research processes (Liker, 2004). According to lean thinking, there are seven types of waste: Overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion and defects. Womack and Jones (1996) developed the "The five steps model" which assumes that there are five consecutive sets of actions from value to perfection which transform problematic, operational practices into well-organized flows of goods and services. Where the value can only be defined by the ultimate end customer (Vlachos, 2015). The elimination of waste gives the possibility for process re-engineering and the creation a continuous flow. Companies are then able to develop a "pull" system in which the customer, not the company is the one who triggers the production; thus, goods and services reach the customer only when asked for neither before nor after requested (Vlachos, 2015). In many cases, lean transformations are radical changes that need a supportive organizational culture to be successful (Tsasis and Bruce-Barrett, 2008).

According to Vlachos (2015) there are many lean tools available for companies to use, including SMED (Single Minute Exchange of Dies) and value stream mapping (Shingo, 1993). A piecemeal, unsystematic application of a single lean tool or technique may reduce waste in business processes without obstructing business as usual (Sasikumar and Kumar, 2013). However, lean thinking is much more than implementing a lean tool: it is a set of principles and a business philosophy (Tsasis and Bruce-Barrett, 2008). The real influence of lean tools can be realized when they are implemented as part of a lean action plan. In this way, lean endeavours can bring systematic and sustainable results by reducing waste and increasing value to customers (Vlachos, 2015).

For many Ecuadorian Small and Medium-sized Enterprises (SMEs) located in the metalworking industry, the main obstacle is the lack of availability of funds which are required by the rapid evolution of industrial processes which it forces them to develop machinery and production lines that incorporate modern technologies into the company.

Since, ancient times man has worked metals, developing materials and tools which have marked the progress of people (Iici, 2012). The metal-mechanic sector has become one of the main economic activities of the world. The international trade of Metalworking products exceeds 4,000 billion dollars, representing more than 30% of the world total. Within this industry, almost 40% corresponds to the capital goods sector, 20% to the automotive industry and another to the electronic components and electrical appliances sector, the rest completing the other metal-mechanical sectors. In this sense, the most important exporting economies are the countries of the European Union, the United States, China, Japan and Southeast Asian countries (Mainly South Korea), (Burgos, 2010).

In Latin America, the countries with the greatest influence are Brazil, Argentina, Chile and Colombia. For 2012, the ECLAC (Economic Commission for Latin America and the Caribbean) forecast a growth of 3.7% in the metallurgical industry in the whole region including the Americas Latin America and the Caribbean, (Anonymous, 2000).

In Ecuador, the metal-mechanic industry constitutes a fundamental pillar in the country's production chain. In this way, its transversality is justified with the food, textile and clothing sectors, lumber, construction, etc. (Anonymous, 2005).

According to the National Institute of Statistics and Censuses, this sector has 65% of employment generation. The metal-mechanics sector accounts for 14% of GDP and has had an annual average growth of 7% from 2000-2011. An important indicator of this sector is the productive chain which results in intermediate steel consumption is 65%, higher than the manufacturing industry with 59%.

In recent years, many organizations both in India and other countries are implementing the principles and concepts of Lean Manufacturing (LM) with the objective of achieving superior competitive advantage over other organizations. Few companies have attained their objective while many of them did not. For instance, Dunstan *et al.* (2006) examined the application of LM in a mining environment. They described the implementation of certain LM elements that are applicable in such organizations and noted that health-and safety-related incidents were reduced from 154-67 7; absenteeism was reduced by 3.4-1.8% while about $2 million (Australian) were saved during the year 2006 (Gurumurthy and Kodali, 2011).

The metalworking-steelmaking sector is a fundamental pillar in the development of strategic projects and great generator of employment because it needs operators, mechanics, technicians, blacksmiths, welders, electricians, turners and engineers in their production chain. Thanks to this sector Ecuador is known for the quality of the products, coming from January to July of 2013 to export USD 70 million to Colombia, Venezuela, Peru, China and the United States (Institute of Promotion of Exports and Investments).

MATERIALS AND METHODS

Lean manufacturing materializes in practice through the application of a wide variety of tools which have been successfully implemented in companies of very different sectors and sizes (Liker, 2010). These tools can be implanted independently or jointly, according to the specific characteristics of each case. Your application must be the subject of a previous diagnosis that establishes the appropriate roadmap (Ramnath *et al*., 2010).

The types of waste that can be seen in the metalworking company under study they refer to suppliers waiting times that do not meet the established delivery time of raw material which does not allow the production process to start and unnecessary movements by the lockers, that lengthen the cycle time (Cuatrecasas, 2004).

Considering the analysis of the lean manufacturing methodology and its various approaches; It details the procedure that is used to make the proposal of improvement of the process. This procedure consists of 4 phases:

Phase 1; Collection and search: To get an overview of the lean manufacturing system and develop its methodology, the first step was to carry out relevant scientific and technical research on its philosophy, tools, applications, objectives, benefits which provided information necessary to start the investigative research.

Phase 2; Analysis of the productive system: For the development of this phase an initial diagnosis was made in the metalworking company in study concerning the process of production of rolling doors, employee activities, supply of materials and supplies, sale of the finished product, machines and tools, etc., to determine the areas in which improvements are required in terms of order, cleanliness, timely deliveries and the seven-classic waste in an industry.

For this purpose, field observation, interviews with the manager, researchers and clients were taken as a basis to know their degree of satisfaction about rolling doors manufactured by the company. These investigative instruments provided important data and information for the development of this project and the use of quality management tools of which we highlight:

Value Stream Mapping (VSM): This graphic technique allowed us to visualize the whole process in detail and understand the flow of information and materials necessary for the rolling doors to reach the customer with this technique, we identified activities that do not add value to the process to later initiate the necessary activities to eliminate them.

Process diagram: It is the graphic representation of the process which provides a visual description of the activities involved in the production process of rolling doors, showing the sequential relationship between them, the number of steps in the process which facilitates the understanding of each activity.

Diagram cause-effect: This technique establishes what are the possible causes that generate an unwanted effect within the production process of rolling doors. This tool was used to provide solutions to the problems found in the production process whether machinery and equipment, economic resources, environment, people, management, materials and methods.

Flow diagram: It is a technique to visualize the process graphically, using symbols lines and connectors, indicating the sequence that carries this process in addition to, the interactions between each of the subprocesses.

Phase 3; Improvement proposal: This phase was aimed at finding the solution to the problem raised where we chose between the wide range of techniques and tools that groups lean manufacturing. This proposal had a rigorous and systematic approach to decide what solution had to be adopted to solve the problems encountered. This will require the following steps:

Stage 1; Prior awareness: A previous awareness was made with all the members of the metalworking company about the benefits that the implementation of the tools of the lean manufacturing philosophy in the company will bring.

Stage 2; Development of the proposal: At this stage, the tools that will be used for the implementation of the lean philosophy were determined, after having performed the initial diagnosis of the company.

Phase 4; Analysis of results: To determine the results that would be obtained in case the improvement proposal is implemented, the following analyzes by indicators or measures of performance will be necessary:

- By lean manufacturing tools (9'S, SMED, TPM, VSM)
- By production indicators

RESULTS AND DISCUSSION

The application of the described procedure is detailed. To carry out an analysis of the results of this proposed improvement it is necessary to perform the following calculations:

Results flow diagrams and VSM: As can be seen in the Table 1, the results of the times obtained by studying the different diagrams of each process and the VSM to produce rolling doors are as follows.

It is observed in Table 1, that there are 187.5 min that add productive value to the process but the time that does not add value is 82.5 min, a considerable amount of time of unnecessary activities within the productive process.

Table 1: Rkkrams and VSM

Process	Total time (min)	Time value added (min)	Time non-value added (min)
Supply	320	-	-
Strapping	140	110	30
Axis elaboration	19	12	7
Elaboration of angle and against-jack channel	16	11	5
Preparation of the base	13	11	2
Making ears	4	3.5	0.5
Development of rails and flags	13	9	4
Elaboration of roll-cover	7	6	1
Assembly and installation	58	25	33
Total	590	187.5	82.5

Table 2: Productivity data

Data collected	Values
Working days per month	20
Hours of work per day	8
Hours of work per month	160
Number of roll-up doors	24
Cycle time (min/roll-up door)	270
Total production time (min)	14160
Total production time (h)	236
No. of workers	2

Production calculations: Calculations were made of total production times, per unit, labor cost, installed production capacity, current production capacity to determine the current situation of the company.

Total production time: It is the time used for each operation of the process of elaboration of rolling doors:

$$\begin{aligned} &\text{Production time per unit} = \text{Time value added+} \\ &\text{Time non-value added} \\ &\text{Production time per unit} = 187.5\ \text{min}+82.5\ \text{min} \\ &\text{Production time per unit} = 270\ \text{min/roll-up door} \end{aligned} \quad (1)$$

About 270 min were used to make a roll-up door, i.e., 6480 min were used to produce 24 roll-up doors per month. The required time for the supply is 320 min, from 24 doors is required of 7680 min. Therefore, the total time to elaborate the 24 rolling doors taking into account the time of acquisition of raw material and the production time is as follows:

$$\begin{aligned} &\text{Total production time} = \text{Time supply+Time production} \\ &\text{Total production time} = 7680\ \text{min}+6480\ \text{min} \\ &\text{Total production time} = 14160\ \text{min} \end{aligned} \quad (2)$$

The total time to elaborate 24 doors to the month is of 14160 min, 236 h or 29.5 days where the supply time and the production time are added.

Productivity: It is the relation between the quantity of products obtained by a productive system and the resources used to obtain such production. It can also be defined as the relationship between the results and the time taken to obtain them: the shorter the time it takes to obtain the desired result, the more productive the system is (Gutierrez, 2010).

Current productivity: It refers to the efficient use of resources (inputs) when producing goods and/or services (products). Productivity in terms of employees is synonymous with performance. In a systematic approach we say that something or someone is productive with a quantity of resources (inputs) in each period of time and obtains the maximum of products (Gutierrez, 2010) (Table 2).

General productivity: Productivity is calculated considering the input time used to produce 24 rolling doors and the total production time:

$$\begin{aligned} &\text{Productivity} = \frac{\text{Units produced}}{\text{Total time}} \\ &\text{Productivity} = \frac{24\ \text{rolling doors}}{236\ \text{h}} \\ &\text{Productivity} = 0.20\ \frac{24\ \text{rolling doors}}{236\ \text{h}} \end{aligned} \quad (3)$$

Production capacity: It is the production potential or maximum production volume that a company can achieve over a given period of time, taking into account all available resources such as: production equipment, facilities, human resources, technology, experience/ knowledge, etc. (Gutierrez, 2010).

Installed production capacity:

$$\text{Production capacity} = \frac{\text{Number units or pieces}}{\text{Time}} * \text{Available time}$$
$$\text{Monthly production capacity} = 0.20\frac{\text{Doors}}{\text{Hours}} * 8\frac{\text{Doors}}{\text{Day}} * 20\frac{\text{Days}}{\text{Month}}$$
$$\text{Production capacity} = 32\frac{\text{Doors}}{\text{Month}} \quad (4)$$

The expected production capacity is 32 doors a month, considering the 8 h a day that employees research and 20 days a month of research, concluding that the company has an installed capacity of 384 doors per year.

Current production capacity:

$$\text{Production capacity} = \frac{\text{Number units or pieces}}{\text{Time}} * \text{Available time}$$
$$\text{Current production capacity} = 0.20\frac{\text{Doors}}{\text{Hours}} * 7\frac{\text{Doors}}{\text{Day}} * 20\frac{\text{Days}}{\text{Month}}$$
$$\text{Production capacity} = 28\frac{\text{Doors}}{\text{Month}} \quad (5)$$

The actual production capacity is 28 doors a month, since it must be considered that the employees research 7 h a day, 1h is used in the lunch time which is subtracted from the available time per day. This means that the current annual capacity is 336 doors. Therefore, it is shown that there is a monthly difference of four doors and annual of 48, indicating that its installed capacity is being used in an 87.5%.

Lean manufacturing times: The calculation of lead time, order lead time and takt time was carried out to determine the current situation of the company.

Lead Time calculation (LT): Lead Time is the time that elapses between the initiation of a request for the supply of raw material and supplies to suppliers or a factory of a certain product until the finished product is delivered to the customer. Lead time is composed of three factors:

Lead-time supply: It is the time that elapses from the purchase order until the materials and supplies are delivered to the factory.

Lead-time production: Average time of permanence of a product in the production process.

Lead-time transportation: It represents the time spent on calendar days, since, the loading of a vehicle until the download occurs at the point of destination:

$$\text{Lead time} = \text{LT supply+LT production+LT transportation}$$
$$\text{Lead time} = 320+212+58 \text{ min}$$
$$\text{Lead time} = 590 \text{ min} \quad (6)$$

The lead time of the metalworking in study is 590 min where the lead time of supply, lead time of production and lead time of transport are considered for the elaboration of each rolling door.

Order Lead Time (OLT): Order Lead Time (OLT) is a characteristic parameter of a logistics network. It is the time that takes place from the time an order is placed in the system (Order Entry Date) until the customer wishes the material on his site (Desired Date):

$$\text{Delivered to time (\%)} = \frac{\text{Orders delivered to time}}{\text{Orders received}}$$
$$\text{Delivered to time (\%)} = \frac{43}{68} \quad (7)$$
$$\text{Delivered to time (\%)} = 63.23\%$$

The level of fulfillment of orders delivered on time is 63.23% and that of non-compliance is 36.77%, the days of delay of the rolling doors in the last 6 months were a total of 29 days, reflecting an inadequate compliance rate.

OLT calculation: It is the sum of the multiplications between the quantity of product delivered and the Order Timeout (OLT) divided by the number of orders entered into the system in the period of time that the analysis takes place in a specific location (Cuatrecasas, 2004). In other words:

$$\text{OLT} = \frac{\Sigma \text{Quantity delivered} * \text{Waiting time}}{\text{Orders numbers}} \quad (8)$$
$$\text{OLT} = 10.42 \text{ days}$$

Obtaining this number allows the company to find the volume-weighted ratio between the amount of required material for each order and the time taken for delivery. The result obtained from this operation represents the average number of days it takes, since, entering an order to the system and the desired day for delivery considering the historical data and the volumes of each order.

Calculation of takt time: It is the pace at which products must be completed or completed to meet the needs of demand, this time is defined by the customer and not the engineer or company policies given that this time is defined by the demand and the time available for meet this demand for the particular case under study this pace is the necessary to calculate it to be able to ensure that the plant will meet customer demand.

- Time available: 8 h = 480 min
- Average working days per month: 20
- Lunch time: 1:30 h = 90 min
- Break: 12 min

Real time:

$$\text{Available time-lunch time-break} = 480\text{-}90\text{-}12 = 378 \text{ min/day}$$

$$\text{Market/customer demand: } 24 \text{ doors}/20 \text{ days} = 1.2 \text{ door/day}$$

$$\text{Takt time} = \frac{\text{Required time}}{\text{Customer demand}} = \frac{378 \text{ min/day}}{1.2 \text{ door/day}} = 315 \text{ min/door} \quad (9)$$

With the data analyzed, it is possible to establish the “takt time” that expresses the rate at which the whole process moves at what speed the product needs to be produced to satisfy the demand of the customer. In this case you have “takt” of 315 min to get 1.2 doors a day. If it is not possible to elaborate 1.2 doors to the day will not be fulfilled with its demand and will be late in its shipments.

Takt time is different from cycle time, since, this is constant until demand changes and cycle time will depend on your process as incidental research, value added and waste (Liker, 2010).

Calculation of efficiency: It is the ability to achieve goals with the least amount of resources possible, this involves “doing things right” without having to spend time on unnecessary activities (Rajadell and Sanchez, 2010). In the case study, the following efficiency calculation was performed where the following results were obtained:

$$\text{Efficiency} = \frac{\text{Time value added}}{\text{Time value added+Time non value added}} *100$$

$$\text{Efficiency} = 69.44\% \quad (10)$$

It means that the process of manufacturing rolling doors is at 69.44% efficiency. There is a 30.55% waste on the resource time.

Indicators for the evaluation of the level of Service “NS” provided

Cycle time delivery order: It is the time between the reception of the order and the delivery of the order. To determine this, many samples (orders that are requested) must be obtained that meet the appropriate confidence levels and observe the time it takes to complete them (an order may consist of a single product or several products):

$$\text{Cns} = \text{X} + \text{Z}\varsigma$$

$$\text{Cns} = 16 + 1.96 = 17.96 \text{ days}$$

It is considered that the time of the ordering cycle-delivery of the process of elaboration of rolling doors is of 18 days.

Reliability of the order-delivery cycle: In this case you can use the deviation of the duration of this cycle, you can also analyze the delay time in the delivery of the order:

$$\text{FC} = \frac{\text{Number of orders delivered in the period}}{\text{Quantity of orders}} *100$$

$$\text{FC} = 63.23\% \quad (11)$$

Availability of the product or reliability of the inventory: It can be measured by evaluating the ratio of complete delivered orders and ordered orders.

According to orders:

$$\text{DPP} = \frac{\text{Number of completed orders delivered}}{\text{Numbers of orders delivered}} *100$$

$$\text{DPP} = \frac{43}{68}*100 \quad (12)$$

$$\text{DPP} = 63.23\%$$

According to quantities:

$$\text{DPC} = \frac{\text{Number of unitsdelivered}}{\text{Numbersof unitsorders}} *100$$

$$\text{DPC} = \frac{99}{145}*100 \quad (13)$$

$$\text{DPC} = 68.27\%$$

The level of general service of the company is given by the multiplicative integration of selected private meters:

$$\text{NS} = f\,(\text{quantity, quality, term, cost, variety, opportunity})$$

It translates into the reliability indicator which responds to a multiplicative model:

Table 3: Lean indicators

Indicator	Frecuency	Whithout lean	Whith lean
Maintenance control of machinery	Monthly	Eventual	Planned
Work areas	Daily	Not established	Signs
Handling tools	Daily	Inadequate	Suitable

$$FS = \Pi\left(\frac{1-N_f}{N_0}\right)$$

Where:

N_f = Number of faults

N_0 = Total

This indicator is no more than customer satisfaction; therefore, its calculation is made from gathering information from customers through surveys, interviews, complaints, phone calls and mailbox; That is look for information about customer satisfaction. It is considered that there is an average of 12 orders per month with this data we proceed to the calculations of the cycle and level of customer satisfaction.

Customer Satisfaction Cycle (CSC):

$$\begin{aligned} C_{SC} &= \bar{X}+Z\sigma \\ C_{SC} &= 15.33+1.96*1.03 \\ C_{SC} &= 17.35 \approx 18 \text{ days} \end{aligned} \quad (14)$$

The maximum customer satisfaction cycle is approximately 18 days with a NS of 95%.

Level of service provided:

$$\begin{aligned} LS &= \left(1-\frac{Nf}{OLT}\right)_{,\ term} \\ LS &= \left(1-\frac{6}{10}\right) \\ LS &= 0.6*100\% \\ LS &= 60\% \end{aligned} \quad (15)$$

The level of service provided is 60% considering that it is very low.

Comparative analysis: After the diagnosis to the company, it is necessary to carry out a comparative analysis that indicates the percentage of improvement in case of implementation (Table 3).

By lean indicators

By production indicators: Below is the comparative production data in case this improvement proposal is implemented (Table 4).

Table 4: Production indicators, comparison production calculations and lean manufacturing

Description	Current	Proposed	Improvement(%)
Working days per month	20	20	-
Hours of work per day	8	8	-
Hours of work per month	160	160	-
Number of roll-up doors	24	26	8.33
Cycle time minutes/rolling doors	270	238	11.85
Cycle time minutes	14160	13776.8	2.71
Cycle time hours	236	229.6	2.71
No of workers	2	2	-
Labor productivity (doors/hour-worker)	0.10	0.11	9.09
General productivity (doors/hour)	0.20	0.22	14.28
Monthly production capacity	28	31	10.71
Lead time minutes	590	554	6.10
Takt time minutes	315	316	7.40
Efficiency	69.44%	77.31 %	7.87

CONCLUSION

The proposal of improvement the process production of rolling doors, allows to reduce the time of delivery of the product to its clients and to guarantee the efficiency and productivity by using the lean thinking tools. With the initial diagnosis of the process of rolling doors, the lack of organization and cleaning of the company was carried out, the lack of a preventive maintenance program, inadequate plant management and supply management, generators that the final product is not delivered in the agreed time to the client.

IMPLEMENTATIONS

With the application of this proposal, these tools (9'S, Kanban, TPM, VSM, SMED) were used in the lean manufacturing methodology, achieving the improvement of the productive process, eliminating the activities that do not generate value, times for repair of machinery, waiting for raw material and supplies, resulting in greater customer satisfaction and shorter delivery times for the finished product. With the implementation of this proposal, a total production time of 554 min is obtained, time adding 184 min, takt time of 316 min to produce 26 doors per month, two above those that were being produced and mainly lead time decreased to 554 min with a reduction of 6.10%, guaranteeing that the product will be delivered in a suitable time to the customer.

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