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Application of Lean Manufacturing to Increase Productivity in an MSE in the Metalworking Sector

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Abstract

The application of Lean Manufacturing in any manufacturing sector aims to eliminate waste in the processes. In this sense, the metalworking industry in Peru, even though it has a very important role since it supplies raw materials to other sectors. This research aims to increase productivity in a metalworking company; After the diagnosis, the main causes of low productivity were found to be disorder in the production areas, the lack of standardization of processes and machine stops. The 5S was implemented to improve order and cleanliness, the TPM to increase the reliability and maintainability of the equipment, and the Standardized Work to standardize operations in the different processes. After the implementation, the following results were found: increase in productivity by 17.02%, decrease in waste from 46.57% to 39.79%, a decrease of 14.56%, decrease in defective products (47.06%), decrease in maintenance time from 129 minutes to 80 minutes.

Keywords

5S, Standardized Work, TPM, Metalworking Industry, Lean Manufacturing

1. Introduction

In recent years, the metalworking sector has faced challenges such as large amounts of waste, a lack of production planning, and poor production control. These challenges also include human factors and substandard conditions, such as occupational accidents during production, which have hindered the sector's development (Jara et al., 2023) (Medina-Chacón, 2020). In Latin America, the metalworking industry is a pillar of the regional economy, accounting for up to 10% of manufacturing output, with Argentina, Brazil, and Mexico accounting for almost 4% of total production (Metalmecánica, 2023). The region is expected to grow by 2025: Uruguay at 3.4%, Colombia at 2.9%, Brazil and Mexico at 2.5%, Peru at 2.4%, and Argentina at 2.3%. (El Peruano, 2022).

In Peru, the metalworking industry is important to its economy, with an Economically Active Employed Population (EAP) equivalent to approximately 382,385 workers. Similarly, it represents significant percentages in the following economic indicators. It can be observed that the sector has an EAP of 2.2% of the national EAP, which is equivalent to 22.9% of the EAP of the manufacturing sector. Furthermore, it represents 11.4% of the GVA (gross value added) of the manufacturing industry (73.51 billion soles) and 1.5% of the national GDP (Ministry of Production, 2024). However, regarding exports in this market, it can be observed that in January and February 2024, compared to 2023,

the sector has shown a negative growth rate of -3.8% (Ministerio de Producción, 2024). This information allows us to understand that the metalworking industry in Peru faces certain difficulties, which is reflected in the slowdown in business growth.

In the context of the emergence of COVID-19, the Peruvian metalworking sector experienced an annual decline of 4.2% between 2017 and 2020 (Ministerio de Producción, 2022); between 2017 and 2022, production increased by 7% annually, recovering mainly in 2021, which had grown by 48.3% following the resumption of economic activities. (Ministerio de Producción, 2024).

After searching for information on this sector, it was found that this industry largely uses recycled non-ferrous metals, such as aluminum and bronze, as raw materials. Furthermore, as observed, the majority of companies dedicated to this sector are SMEs and partially formal, lacking the necessary resources for expansion. Furthermore, many companies focus solely on accumulating revenue, rather than increasing their income through continuous improvements in the production line (preventive maintenance, good layout designs, process standardization, etc.). Thus, companies' most sought-after objectives are to improve profitability and reduce waste generated in production, which leads to reduced economic losses and improved production processes.

Ribeiro et al. (2019) point to the philosophy of Lean Manufacturing and TPM as the main tools for increasing efficiency in manufacturing lines. Despite this, many companies still struggle to successfully transform into a Lean company (Buer et al., 2018).

1.1 Objectives

The aim of the article is to demonstrate that applying Lean Manufacturing and engineering tools in a metalworking factory reduces defectives products, improves the efficiency of the process and reduces the downtime due to maintenance.

2. Literature Review

Today's business environment is constantly changing, and agile methodologies are important because they allow companies to adapt to this environment. Therefore, it is necessary to integrate these methodologies.

2.1. Lean manufacturing

Lean manufacturing is the identification process that seeks to eliminate activities that do not add value and instead generate costs (Socconini, 2019). Lean manufacturing is based on several principles, including waste elimination, continuous improvement, customer focus, value stream mapping, and single-piece flow; its philosophy is effectiveness, doing more with less. (Weber, 2004).

In a case study, various lean manufacturing tools were applied to reduce lead time, achieving a 10% reduction in lead time and a 20% increase in production. (Nallusamy, 2016).

In another study, using lean tools such as Valuable Stream Mapping (VSM), a 41.66% increase in production was achieved, as well as a 29.41% reduction in time. (Chaudhary et al., 2020)

2.2. TPM

The Total Productive Maintenance (TPM) tool seeks to maximize productivity by eliminating waste, involving everything from the administrative to the production areas (Singh et al., 2022). This tool establishes “autonomous maintenance, which includes a set of inspections, cleanings, replacements, and planned repairs to prevent compromising failures and control machine deterioration” (Pinto et al., 2020), which reduces the occurrence of machinery failures and prevents unexpected production downtime.

Likewise, by implementing TPM, "it is possible to identify six sources of losses that reduce efficiency: process defects, reduced operating speed, time losses, adjustment and downtime, losses due to minor stoppages, and equipment failures" (dos Reis et al., 2019). Thus, by identifying these losses, the necessary measures are taken to avoid them and reduce the amount of waste on the production line. Furthermore, the importance of this tool is to guarantee equipment availability; however, it must be applied in conjunction with other Lean methodology tools to obtain optimal results in reducing waste.

2.3. 5S

It is a system for reducing waste and optimizing productivity and quality through maintenance and organization (Rizkya et al., 2019) (Nallusamy & Adil, 2017).

Furthermore, in other studies, combining Lean Warehouse and 5S has resulted in an efficiency increase of at least 40% in warehouse operations. (Coronel-Vasquez et al., 2022).

With the above, it can be noted that the 5S tool, when used in conjunction with another tool, can generate great benefits for production and significantly increase the management of the area in which this tool is implemented.

2.4. Standardized work

Lean principles don't work well when everyone is allowed to choose their own job, method, or the sequence in which they perform their operations. Thus, in a work environment where products and processes are highly standardized, the fundamental role of continuous improvement is to ensure that processes remain within prescribed tolerances and closely follow standard operating procedures. (Chan & Tay, 2018).

Standardized work methodology research can be implemented in 5 stages: 1) Diagnosis, which is understanding how the company works and what needs to be done; 2) Action planning, which consists of proposing a table that combines process information and its visual representation; 3) Standard action table, which provides standard operating times for a work section; 4) Evaluation; and 5) Specification learning. (Barrientos-Ramos et al., 2020).

On the other hand, the implementation of this methodology has generated significant improvements in production efficiency, as was the case with "a car radio manufacturing company that experienced a 30% increase in productivity through the use of standardized work." (Monteiro et al., 2019).

Thus, it can be seen that a successful implementation of work standardization in SMEs in the metalworking sector would yield positive results in achieving significant improvements in the production area, as it would create an orderly and specific process.

3. Methods

This study is a practical case, as it focuses on solving a problem with theoretical knowledge. Regarding the manufacturing of brass rods, a high percentage of defective products was observed. This results from various factors such as a lack of maintenance planning, a lack of order, and poor standardization in processes. Therefore, after identifying the main problems, a root cause diagnosis was conducted through the development of a problem tree. The analysis identified the main causes as machinery failures and the lack of a properly organized and clean workstation. After identifying the key causes and issues, various solutions and tools were evaluated to enhance the indicators that significantly influence the process. It is expected that through the application of lean methodologies and engineering tools, downtime will be reduced, and process productivity will increase. The variables identified are the reduction in maintenance time, the ratio of defective products, and the amount of waste in the process. Therefore, the Figure 1 below shows the improvement proposal.

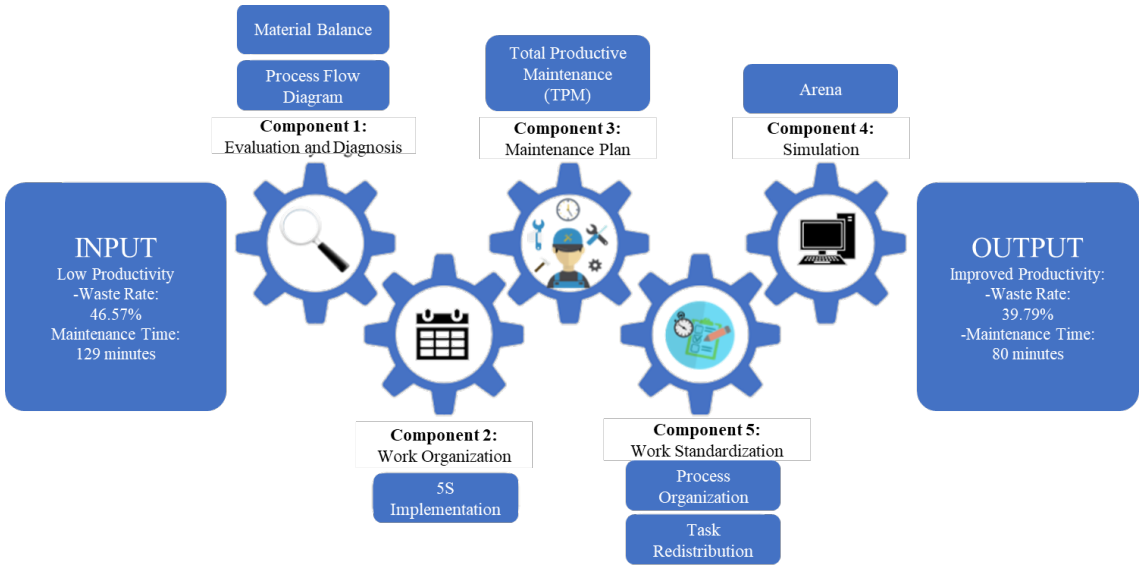

Figure 1. Tentative model

4. Data Collection

The data was collected based on the entire brass rod production process. One method was the collection of past time studies and the verification of recorded times. Another method used was the collection of data related to machinery maintenance and maintenance downtime. Brief interviews were also conducted with workers involved in the production process. After collecting the data, a The Pareto chart helped in identifying the most impactful problems, and then the causes were identified using the problem tree. Once the information was obtained and the literature reviewed, it was concluded that the appropriate tools for the current problem were 5S TPM and Standardized Work.

4.1. TPM

The number of operators and machinery used in the production process was determined. Then, the workers were instructed in the correct use of the machinery and how to carry out maintenance properly. A pilot test was then conducted to demonstrate how the process worked after the improvements were made, and a simulation of the process with the improvements implemented was also conducted.

4.2. 5S

Before implementing the 5S, an Audit was carried out, where the company's current status with respect to the methodology will be evaluated.

The initial results obtained were:
Classification 35%, Organization 40%, Cleaning 40%, Standardization 25%, Discipline 25%
a. Classification: the tools, safety equipment, documents, dies, and other materials found on the shelf and regularly used for extrusion were classified using a control sheet. Likewise, items that are not frequently used or that do not belong in the area in question were identified.
b. Organization: the shelf was organized according to the frequency and type of tools or items used. The PPE items were placed first so they were visible, followed by high-use and turnover tools. Other less frequently used items, such as dies, sandpaper, and other tools, were then placed. Finally, documents were placed to show the specifications and instructions for some items and prevent them from being damaged or soiled.
c. Cleaning: The shelf, its surroundings, and the tools within the area were cleaned. The workers were also informed about the importance and benefits of cleanliness and order in the work area; a record sheet was also created to keep track of cleaning schedules.
d. Standardization: A cleaning and ordering plan was developed for operators to follow daily and posted on a wall near the rack for visibility. The daily cleaning schedule for the extrusion area was also recorded, allowing for an assessment of the first three S's.

e. Discipline: workers were informed about the benefits of implementing the 5S tool and how order and cleanliness make their work more efficient and faster. Reminder boards for improvements were created and posted on the walls of the area to raise awareness and establish a routine for daily work (Figure 2).

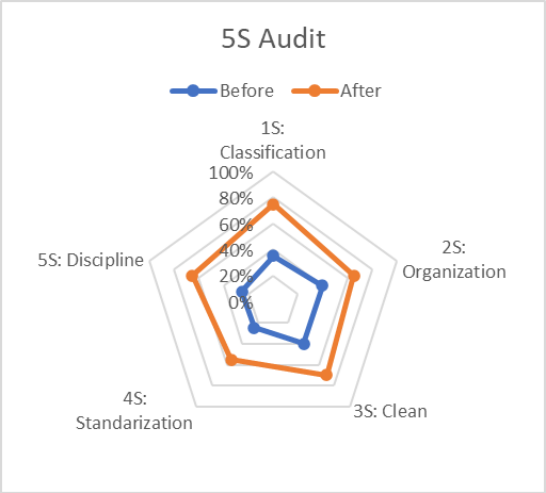

Figure 2. Assessment of the 5's

5. Results and Discussion

The improvement initiative to decrease defective products in the brass rod production at the metalworking plant was executed over six months. During this period, the company's employees were provided with the necessary information and work techniques for each task through various training sessions.

5.1 Numerical Results

Below are the results of the simulation (Table 1).

Table 1. Results of the simulation test

Indicator	Unit	As-Is	To-Be	Variation
Corrective Maintenance Time	minutes	103.2	0	100.00%
Preventive Maintenance Time	minutes	25.8	80	210.08%
Total Maintenance Time	minutes	129	80	37.98%
Machine Failure	percentage	13.33%	0%	100%
Waste Rate	percentage	46.57%	39.79%	14.56%
Rods produced	unit	47	55	17.02%
Defective Rods	unit	8	0	100%
Cycle Time	minutes	656	598	8.84%

As shown in the table, all results were favorable, with significant reductions in all indicators. In fact, in the case of machinery failure, the reduction reached 100%.

5.2 Graphical Results

Below are the results of the pilot (Table 2).

Table 2. Improvement of the 5's

S	Before	After
1S: Classification	35%	75%
2S: Organization	40%	65%
3S: Cleaning	40%	70%
4S: Standardization	25%	55%
5S: Discipline	25%	65%
Total	**33%**	**68%**

As shown in the previous graphic, a 40% increase was achieved in Classification, 25% in Organization, 30% in Cleaning, 30% in Standardization, and 40% in Discipline. The results were obtained from a one-month trial period at the company, where the outcomes were measured once a week. During this period, operators were instructed to follow the recommendations of the 5S methodology.

5.3 Proposed Improvements

For the improvement proposal, the activity generating the highest amount of waste was identified, which is the extrusion process. The process was observed 240 times, during which the probability of failure and the probability of machinery breakdown were determined. For the improvement, the appropriate number of processes before preventive maintenance was determined (Figure 3- Figure 4).

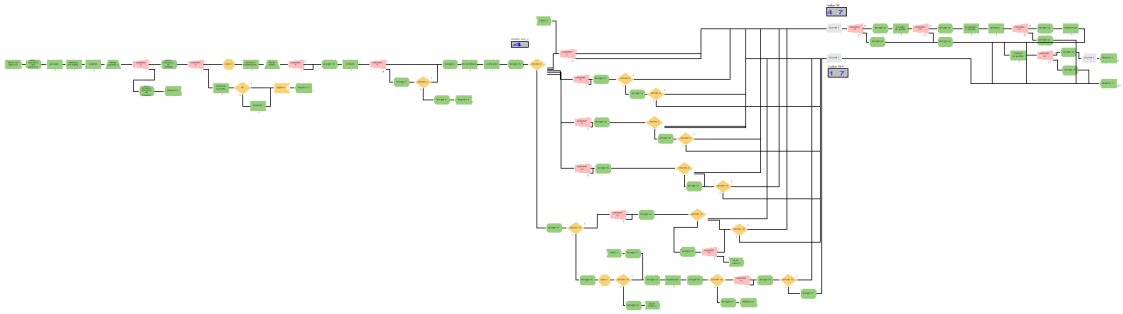

Figure 3. Simulation Aa Is

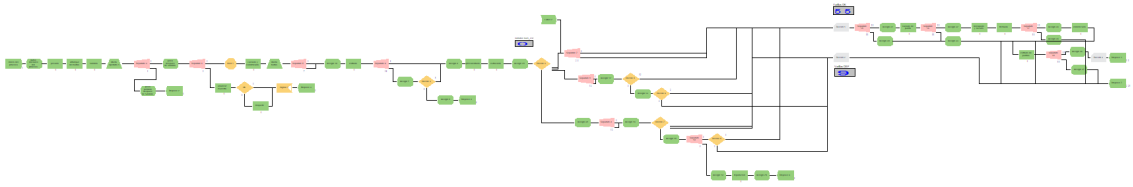

Figure 4. Simulation To Be

5.4 Validation

The proposed model was validated by conducting a one-month pilot test and running a simulation. Tools like 5S were applied to enhance the plant's organization and cleanliness, as well as to improve the preventive maintenance of the machines. These activities were carried out during February and March of 2025.

The following results were obtained from the improvement:

The production increased from 47 to 55 metal rods, a 17.02% increase in productivity.

The waste percentage relative to raw materials was reduced from 46.57% to 39.79%, having an improvement of 14.56%

The defective product ratio decreased from 36.17% to 16.36%, having an improvement of 54.8%

The maintenance time were reduced by 49 minutes, from 129 to 80 minutes, thanks to the order, cleanliness, and standardization, having an improvement of 37.98%

The machine failure decreased from 13.33% to 0%, thanks to the implementation of TPM, having an improvement of 100%

6. Conclusion

It can be seen that the use of Lean tools, in this case 5S, TPM, and Standardized Work, in an SME in the metalworking sector has a positive impact on productivity, increasing it by 17.02%.

By performing a material balance for the entire process, it was determined that the process was generating considerable waste. After this, the causes of the problem were identified using the Pareto Chart, and then a problem tree was developed. Thanks to the aforementioned tools, the causes of the problem were identified and the company was diagnosed.

After implementing the 5S tool, it was evident that the company had several items that did not add value. Furthermore, the average for each S was increased by 35%, making the production process more organized. Regarding the implementation of Total Productive Maintenance (TPM), which was only applied up to preventive maintenance, a reduction in corrective maintenance time was achieved from 103.2 minutes to 0 minutes and an increase from 25.8 minutes to 80 minutes in preventive maintenance was implemented on the extruder, achieving a reduction in maintenance time by 49 minutes.

By implementing Standardized Work through a simulation in the Arena program, a 17.02% increase in productivity was achieved; that is, an increase from 47 to 55 metal rods. Furthermore, the percentage of waste decreased from 46.57% to 39.79%, a decreased of 14.56% and the number of defective rebars decreased from 8 to 0 units (100%).

Thus, this leads to the conclusion that the implementation of Lean Manufacturing tools has shown positive results in improving productivity in an MSME in the metalworking sector. It is hoped that this research will serve as a guide for other MSMEs in this sector to implement Lean-TPM methodologies to increase their productivity.

Future studies could focus on expanding the implementation of Lean Manufacturing tools to other production areas and evaluating their long-term sustainability. It would also be valuable to integrate digital technologies, such as real-time monitoring systems and predictive maintenance, to enhance the effectiveness of TPM. Additionally, future research could include economic analyses to quantify cost reductions and profitability improvements resulting from Lean practices in small and medium-sized metalworking enterprises.

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Biographies

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