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Implementation of Lean Manufacturing to Increase Productivity in the Manufacture of Kitchen Sinks in a Metal-Mechanical Company

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Abstract. The application of the lean manufacturing strategy aims to reduce waste and increase the productivity of the organization in which it is applied; however, in Peru many companies in the metal-mechanical industry do not know how to implement it. The objective of the research is the application of lean manufacturing tools to increase productivity in the manufacturing of washing machines. We implemented 5S to reduce time and route waste, Kanban to standardize production based on demand and lead time, as well as the use of MRPII for its execution. In addition, it was complemented with the Jidoka philosophy to eliminate defective products. The study was carried out in a SMEs company of the metal-mechanic sector that after performing the diagnosis using VSM, productivity (0.1858 washers/H-H), defective products (9.06%) and delivery time compliance (64.67%) of stainless teel washers were identified as the main problems. The imputs found in the data collection were low delivery reliability, high defective rate and low productivity. After the application of Kanban, 5S and Jidoka, an improvement was obtained in the percentage of washers delivered on time to 100% of the orders, a reduction in the percentage of defective products to 3.23%, and an increase in productivity of 5.02%.

Keywords. Lean manufacturing, 5s, Kanban, Vsm, Jidoka, Productividad

1. Introduction

The metal-mechanic industry is an important sector in the productive structure of the global and national economy, however, in Peru the increase in productivity is five times lower compared to developed countries (2%) [1] while the metal-mechanic sector in Peru grows between 8% and 9% annually [2]. The global problem of the sector is the shortage of supplies and materials worldwide, the high costs of raw materials and energy [3] while the national problem is the lack of investment in new projects and the few that exist have a long time in development and fail to be completed, i.e. there is a lack of productivity and efficiency [4] in metal-mechanical projects.

The company under study is a small Peruvian SME oriented to the production and commercialization of kitchen sinks and has identified as one of its main problems around 35.33% of non-compliance with delivery dates and 9.06% of defective products, reducing productivity and increasing the company's expenses due to the fact that each error represents a loss of approximately 425.09 dollars per month. According to [5], non-compliance generates revenue losses due to the non-rotation of the product as well as deterioration of the company's image, while in [6] it is pointed out that the manufacture of defective products generates waste of material, movement and storage, rework and re-inspections, productive labour time and low product quality, Therefore, the importance of this research focuses on making efforts to improve productivity standards in a small company dedicated to the metal-mechanics sector and that this can be replicated in many other Small and Medium-sized Enterprises (SMEs) in the same field and thus boost the growth of a sector that has a high demand. With respect to success stories in SMEs in the same sector, in [7] the application of VSM to analyze data and 5S and Total Productive Maintenance (TPM) increased machine efficiency by 5%, productivity by 16.23% and the number of defective parts was reduced from 217 to 42, while in [8] using 5S and Kaizen it was possible to reduce defective parts from 11 to 0 and production time by 25. 5% on the first production line and 20.9% on the second, and in [9] using Single Minute Exchange of Die (SMED), 5S and Poka Yoke, production efficiency increased by 6.4% and productivity by 12%.

The motivation of the article is to apply lean manufacturing tools (5'S, Kanban and Jidoka) in a metal-mechanical SME and generate a considerable improvement in the production of stainless steel sinks, to contribute to the achievement of operational excellence of processes in small companies by identifying and eliminating losses, contributing to knowledge management, creating a culture of continuous improvement.

The general objective of this research is to increase productivity in the manufacture of kitchen sinks in a metal-mechanical company by 5% using a lean process strategy. The specific objectives are as follows;

- To reduce cycle time by up to 4% in a metalworking company using the lean manufacturing tools descripted.
- To reduce defective products in the production of kitchen sinks by up to 5% in a metal-mechanical company by using the lean manufacturing tools descripted.
- To increase delivery reliability of kitchen sinks in a metal-mechanical company by up to 95% by using the lean manufacturing tools descripted.

In accordance with the aforementioned objectives, the research question is as follows: Does the application of a lean manufacturing process strategy increase productivity in the manufacture of kitchen sinks in a metal-mechanics company?

The hypothesis of the research is that the application of a lean manufacturing process strategy increases productivity in the manufacture of kitchen sinks by more than 5%.

Figure 1 shows the value proposition which explains the research process as well as the inputs and outputs.

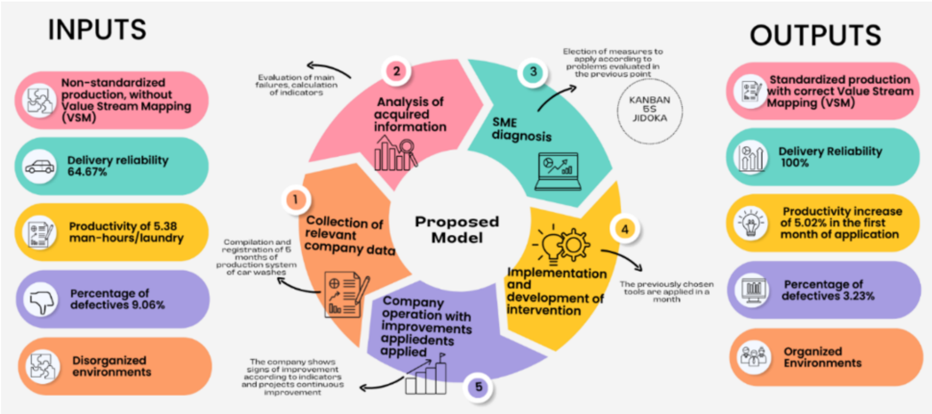

Figure 1. Proposed Model.

2. State of the Art

2.1. Lean Manufacturing

The expression lean manufacturing can be defined as a management model focused on a flow created to be able to deliver to the customers of a company the maximum added value on a product [10]. It is a management model of excellence and continuous improvement whose main objective is the elimination of waste that does not add value to the product and is made up of various tools for the realization of this objective. The Lean philosophy is relevant for many small and medium-sized companies, because it allows the optimization of production processes, which generates a significant improvement in the economy and resource savings in the organization [11].

2.2. VSM

The Value Steam Map is a valuable tool used for the diagramming of manufacturing processes, from the flow of raw materials to the finished product. At the same time, it allows to add to the diagram the relevant data in an organization, such as lead time, productivity, among others. This diagram does not allow to solve problems in the organization directly, but through the arrangement of data, it allows to visualize the initial state of the company and thus apply tools for its solution. The VSM is mainly used to compare the state before and after the application of a solution tool and then facilitate the process of analyzing the information [12].

2.3. 5'S

"Five S's" is a technique that derives its name from the initials of a logical, phased process whose words are in Japanese and begin with the letter ese(s): seiri (eliminate unnecessary), seiton (order), seiso (cleanliness and inspection), seiketsu (standardize), shitsuke (discipline) [13].

Companies, especially small and medium-sized ones, often do not consider internal influencing factors such as the cleanliness and orderliness of the work areas and/or the discipline of the work to be done; however, maintaining a clean and ergonomic space can make a big difference in efficiency, as well as the application of different operational practices in any manufacturing-focused company [14]. It has 5 phases: organization, order, cleanliness, visual control, and discipline and habit [15].

2.4. Kanban

Kanban is an information system that allows control over the production of products in the time and quantity required in all processes, with multiple benefits such as inventory reduction and improved operator satisfaction [16].

2.5. Jidoka

The word "jidoka" means automation with a human touch. It is based on the implementation of a self-monitoring system whose purpose is to prevent the production of defective parts with the aim of not producing defective items [17].

3. Methodology

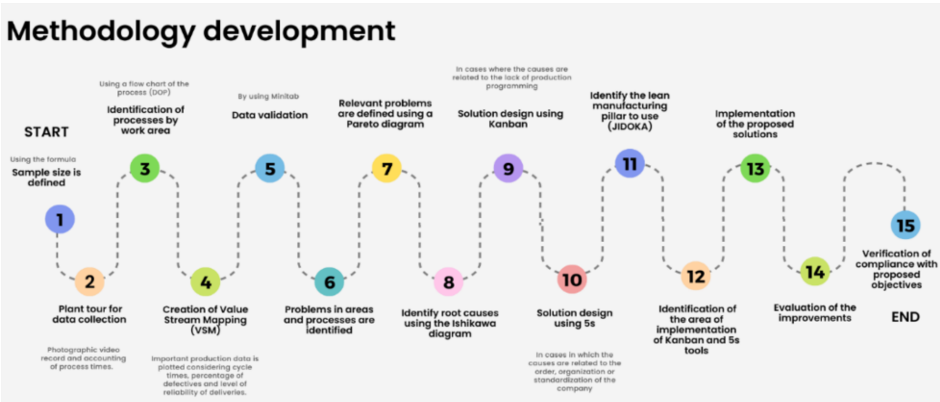

Figure 2. Methodology development.

Figure 2 shows the methodology process. The sample size was determined in order to obtain the specific value of kitchen sinks that would need to be studied. The calculation was made on the basis of the sample size formula using a finite population since the data obtained was from a period of time of the company's production, the sampling was stratified because the company produces various types of products but the research was focused exclusively on the production of kitchen sinks. The data used were as follows:

- n = Sample size sought
- N = Population size or finite universe: 150 laundries.
- Z = Statistical parameter that depends on the confidence level: 1.96.
- e = Maximum accepted estimation error: 4%.
- p = Probability of occurrence of the studied event: 10.67%.

- q = (1 - p) Probability that the studied event does not occur: 89.33%. With these values, the sample size formula is calculated as follows

By applying the values in the formula, a sample of 90,839 was obtained. This means that a survey will have to be carried out for 90 laundries.

After determining the sample size, a tour of the plant was carried out in order to design a DOP of the production process of the stainless steel kitchen sink. Once the generalized form of the process diagram had been designed, a VSM was applied to better visualize the production processes, thus identifying the percentage of defective products (%), cycle times, waiting times, lead time and laundries delivered on time (%). In this way the indicators can be sorted more efficiently and the future results can be organized after the implementation of the following lean manufacturing tools.

The information collected both from the study prior to and after the implementation of the lean process strategy is plotted in the VSM shown in Figure 4. It shows indicators on the percentage of defective products by part and machine, as well as data on cycle time, lead time and total useful time. These data were validated using the Minitab tool by using the P matrix, which indicates that the defective products are not within the expected limits (from 0 to 2 defective products per day), which generates problems in the delivery of the products as shown in Figure 3, and CPk (0.68) to determine that the process is out of control.

Subsequently, a formulation was made of the frequent problems in the organization, which were captured in a Pareto diagram in order to select the most frequent problems and, therefore, the ones with the greatest impact on the company. After the graph was drawn up, the main problems identified were late deliveries, defective products and confusion of plates for production. With these identified values, three Ishikawa diagrams were made to determine the root causes and thus be able to know where to focus the implementation of the tools.

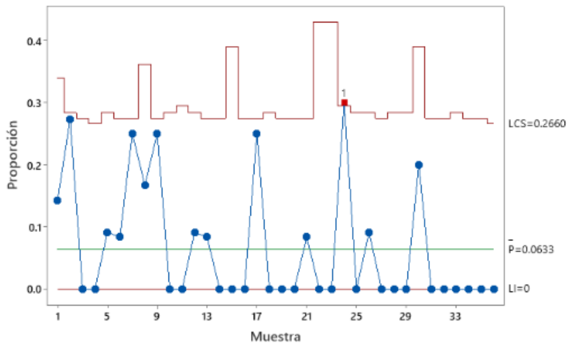

Figure 3. P chart of defectives.

With these root causes we were able to determine the best tools to use to solve them. The 5'S for the organization and standardization of the plant's processes in order to solve the confusion of plates. Kanban to be able to improve the fulfilment of the orders for the established times. Finally, the Jidoka philosophy was used to stop the operations in the process where the error occurred and thus avoid dragging it to the following processes.

Once the tools and the area in which they were to be applied had been identified, they were implemented and at the end of the research period an evaluation of the improvements made was carried out.

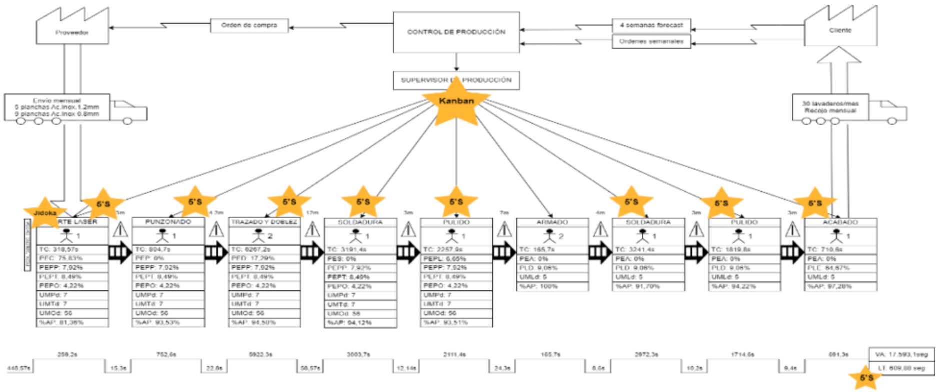

Figure 4. Value Stream Mapping

4. Results

With the data obtained in the period of data collection from the previous state of the company, a new operations diagram of the kitchen sink manufacturing process was implemented by adding combined operations (process and inspection). Quality control cards were added to the laser cutting, welding and polishing processes in order to verify that the previous processes have been carried out correctly. The cards are filled in by the same operators before starting the manufacturing process (in the previous state of the product) and at the end of the process.

Following the implementation of the new DOP, action was taken on the root causes analyzed in the period February to July 2022. These were as follows in table 1.

Table 1. Actions on identified root causes

Root causes	Tool	Actions
Lack of order in the company.	5's	Delimitation of areas for materials and work areas.
Lack of system and delimited area for the use of tools..	5's	Drive registration system, tool coding and delimited area.
Uncalibrated tools.	-	Purchase of certified instrument.
Lack of production order system.	Kanban	MRP II System Application.
Lack of error stop system.	Jidoka	Purchase of remote control for CNC laser machine.
Lack of process control.	5's	Implement quality control sheets.
Lack of training for new staff.	-	Training plan for management and plant manager.
Lack of input and output system for raw material from the warehouse.	5's	Recording and storage system through drive. Measured and coded plates.
Operators with distractors.	5's	Policy setting.

With these measures implemented, the evaluation of the level of compliance with the 5'S was carried out again at the end of October for greater precision, obtaining 81% compared to the 20% obtained before the actions were taken, showed in figure 5.

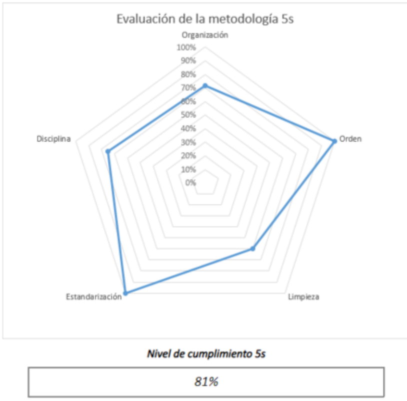

Figure 5. Level of compliance of posterior 5's

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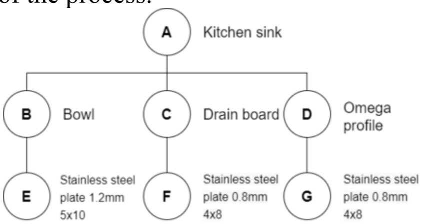

Figure 6. Gozinto diagram

The application of the Jidoka philosophy represented an investment to the company of $159.00. It was able to stop the process in the event of an error almost instantaneously and without affecting the following cut products.

With the actions taken in the month of August (implementation period), data collection was carried out for the following three months to determine the final state (E1) of the organization through the application of lean manufacturing tools and compare them with the initial state (E0), as well as to analyze whether the objectives presented in the research were met. The results are shown below:

Table 2. Indicators

Indicator	E0	Goal	E1
Productivity kitchen sink/HH	0.1858	0.1951	0.1954
Circulation time (h)	5.2159	5.0007	4.9943
Defective kitchen sink (%)	9.06	5	3.23
Deliveries on time (%)	64.67	95	100

In the period of implementation of lean manufacturing tools in the small metal-mechanical company, an increase in productivity and on-time deliveries was obtained, being 5.02% and 100% respectively. As well as a decrease in circulation time and defective washeries, being 4.25% and 100% respectively, and the CPK was improved to 1.35. With respect to the defective ones, the P graph after the implementation is shown below in figure 7, which indicates that after the implementations carried out, the number of defectives was considerably reduced and is within the specified limits.

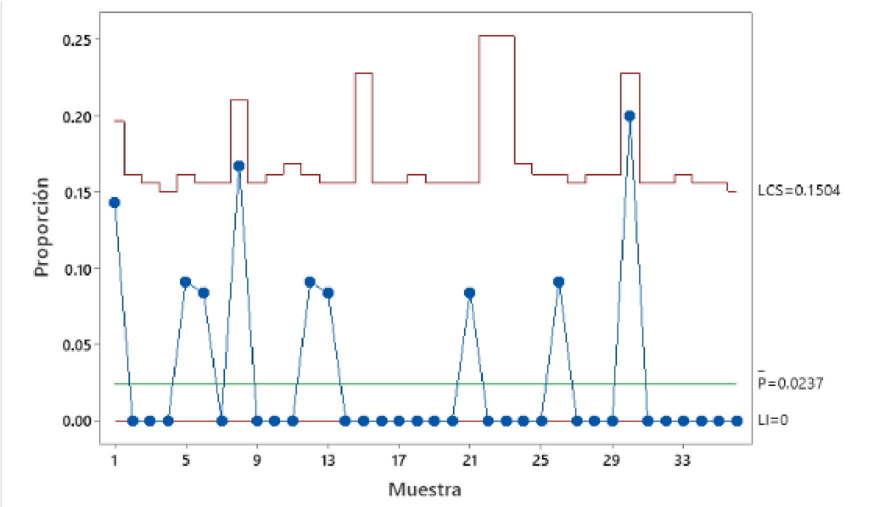

Figure 7. P chart of defectives

5. Discussion

Regarding the findings of the research, the most important was the possibility of implementing changes in short periods of time that generate long-term benefits in a small metal-mechanical company; this same implementation procedure can be replicated for other manufacturing processes of stainless steel products within the company, as well as for other small companies in the same industry. Likewise, the standardization of the process through the application of Kanban can cause immediate improvements in the short term, as demonstrated in the research conducted by Marinas and Vejarano [7] where the use of Kanban increased production efficiency from 93% to 98%. Having defined procedures can have a great effect on production, since it allowed the identification of problems to be carried out more effectively as in the case of Chávez [9] in which, as in the present research, initially a DOP and later a VSM were performed for the diagramming of processes and data respectively, in addition the application of the 5S (as a support tool together with SMED) was carried out, increasing productivity by 7% (from 55% to 62%).

Another finding was that the best way to improve production is to start with the organization, order and registration of all processes; small manufacturing companies do not have much experience and therefore generate disorder by not having a correct record and description of the processes to be carried out. Unlike Chavez's research, the 5s were not used as a support tool, but as the main tool, but it takes into account the research of Gonzales [8], which shows that the application of the 5s has a positive impact on small companies that have problems of productivity and organization of production.

Below is a table comparing the similarities of the three success stories explained above with the present research.

Table 3. Comparison with successful cases

Factors / Case studies	Marinas and Vejarano [7]	Gonzales [8]	Chavez [9]
Increase of productivity	X	X	X
Application of lean manufacturing tools	X	X	X
Use of analysis and diagnostic tools	X	X	X
Use of VSM	X		X
More than one lean manufacturing tool is applied	X	X	X
There is no correct procedure defined	X	X	X
There is disorder and lack of cleanliness	X	X	X
There is an economic benefit after application	X	X	X

The limitations of the study were the short time to perform the tests and implement the improvements, so it is highly recommended to have enough time to develop the intervention, especially in small companies that require greater efforts since each error or problem represents large monetary losses for them, while each solution to these problems can represent not only cost reduction, but contribute to the knowledge of the company and drive it to a culture of continuous improvement.

6. Discussion

The result of the application indicates a 5% increase in the total value of productivity in the manufacture of stainless steel kitchen sinks through the application of the actions proposed in table 1. In turn, the expected values in the indicators shown in table 2 were exceeded, thus proving that the initial hypothesis was correct.

Furthermore, after the development of the value proposition shown in figure 1, it was possible to increase reliability up to 100%, reduce circulation time by 4.25% and reduce defective times by more than 5%.

It is concluded that the implementation of a lean process strategy allows small companies, despite the lack of capital, to be competitive in the market without having to invest large amounts of money to achieve increased efficiency, gain experience in process analysis and orient their company towards growth and continuous improvement.

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