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Application of Lean Manufacturing to Increase Productivity of a Company in the Metalworking Sector

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Abstract. The application of lean manufacturing seeks to reduce waste and increase productivity, a problem faced by SMEs in the metal-mechanic sector in Peru, due to the lack of knowledge of the tool and the organizational culture. This investigation was carried out in a mype of the metalworking sector in which, after making a diagnosis using VSM, the low productivity (47%) of the hinge manufacturing process was found as the main problem. The main inputs found in the data collection were high waiting time in the assembly process (52 min), material transportation time (5.85 min) and delay due to access to tools. For this reason, the objective of the research is the application of lean manufacturing to increase the productivity of the company. The selected tools were 5S to reduce disorder and delay in access to tools, SLP to reduce material transportation time, and JIT to reduce waiting time in the assembly process (circulation time). As a result of the application, a 10% increase in productivity and a 60% reduction in the cycle time of the hinge manufacturing process were obtained.

Keywords. Lean Manufacturing, 5S, SLP, Just in Time, Productivity

1. Introduction

The metal-mechanic sector in Peru represents 20% of the GDP of the manufacturing industry, in addition, it is made up mostly of micro and small companies (MiPymes). Likewise, these represent 99.5% while only 0.5% are medium and large companies [1]. One of the main problems in this sector is low productivity. In 2019, it could be observed that it is 28% below the average for the manufacturing sector [2] and, compared to other industries, the difference is greater; for example, with the food and beverage industry (-35%) or the paper industry (- 78%). In addition, in a study carried out [3], it was determined that the main challenges of Mypes in the manufacturing industry were related to the informality of companies, personnel training and access to financing, which negatively affected the productivity of all items at the same time. not having the necessary tools and conditions to adequately carry out their work. In this research, the problem that is sought to be solved is the low productivity of a metalworking company that manufactures hinges through Lean Manufacturing tools.

There are success stories of the Lean Methodology implemented in the Metalworking sector in Peru and in countries around the world. For example, in an Ecuadorian company that uses hydraulic presses and die -cutters to manufacture its products, and the machine preparation time is very long due to the constant change of dies [4], they achieved a reduction of 66.29% in the production time. machinery preparation and a 28.91% increase in production capacity applying the SMED technique and 5S's as support in the process of changing the matrix of its presses to produce its product "two-phase metal box" which represents 27.96% of Your profits. In this investigation, the SMED technology was applied in 3 stages: in the first, the internal and external activities of the process were separated, in the second, an attempt was made to convert internal activities to external ones, and finally, in the third part, both types of activities are perfected by implementing the 5S's as another lean tool that works as a support for SMED.

In addition to this and considering a closer example, in Peru [5] they applied different Lean Manufacturing tools in a non-ferrous materials transformation company where the main problems were related to low productivity and disorder in the workstations. The main tools that were used were the combination of tools such as SMED and 5S's in addition to Kaizen to improve teamwork and Value Streaming Mapping to map the process flow of one of your products. Finally, in the research they carried out, they achieved results such as a 42% reduction in machine set-up times, a 50% increase in daily production and machine availability from 45% to 62%.

On the other hand, the motivation of the work is oriented to reduce the gap in 5% [6] of knowledge between the past investigations on the problems of the metal-mechanic companies, since the diagnosis and design of solutions for the problems in a factory will be carried out. of hinges. In the same way, as a practical motivation, it seeks to increase productivity by 19 % [7] of the hinge manufacturing process to improve the competitiveness of the company. That said, the general objective of the research is to implement Lean Manufacturing in a company in the metalworking sector to increase the productivity of the hinge production process. In addition, the specific objectives are to identify the main problems in the production area through the VSM tool, implement the 5S's technique in the hinge production process, implement the JIT tool in the hinge production process and to apply SLP in the production process of hinges. Finally, the hypothesis of this research is that the application of Lean Manufacturing increases the productivity of a company in the metal-mechanic sector in Peru.

Exposed this situation, leads us to the following question: does the application of Lean Manufacturing increase the productivity of a company in the metal-mechanic sector?

2. Methodology

2.1. Input

In this investigation, the design of a case study is developed in the company "Industrias Melo SAC" of the metal-mechanic sector in Peru, where various data related to cycle times (processing, transport and waiting time) were collected for the diagnosis of the problems, the design of the solution proposal applying Lean methodologies and finally the pilot of the implementation of the proposal. On the other hand, it has a descriptive and explanatory scope. It is descriptive since an analysis of the current situation will be carried out to specify the main problems of the production area. Likewise, it is of an explanatory type since it will seek to explain how the application of lean tools has an impact on the productivity of the company. Based on this, the proposal for an improvement model was prepared, where inputs were identified in the diagnosis stage through the preparation of the VSM and plant inspection, such as disorder in the workstations, high inventory waiting time. in process, especially after automated operations and before manual ones, productivity of 0.06018 hinges per minute, disorder in workstations (mainly those where operations are manual) and lack of PPE for operators. According Figure 1, based on this, 3 lean tools were chosen to address these specific problems. The 5S to reduce the delay time in search of tools and disorder in the workstations. The SLP tool to reduce transportation time and finally, the JIT tool to reduce the amount of inventory on hold as well as the time it sits without adding value.

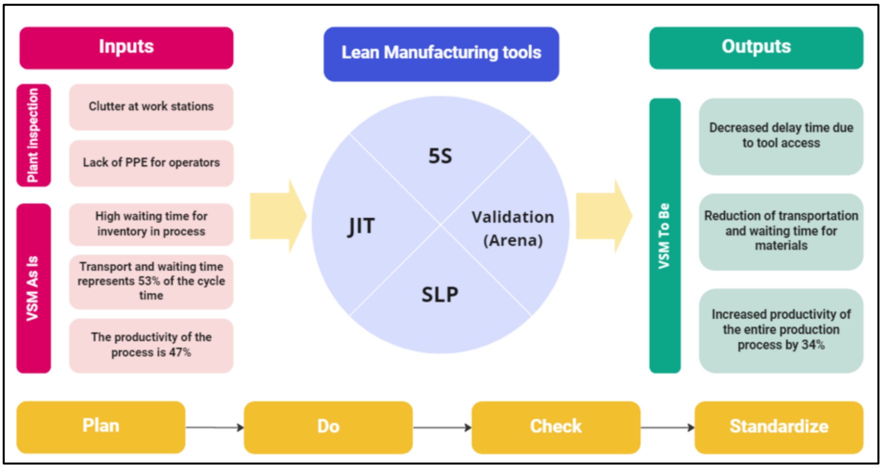

Figure 1. Solution proposal template

2.2. Methodology planning

To better explain the methodology to be followed in this research, the following flowchart was prepared, Figure 2 details the entire process from data collection to the validation of the Hypothesis.

As it shows on Figure 2, in the first place, the process will begin with the diagnosis and analysis of mype problems. For this, visits to the plant will be made to carry out preliminary time studies, 5S audit and collect information to diagram processes, in addition to making a photographic record. After the preliminary study, the sample size will be defined through the student t distribution since the number of times taken per task is not greater than 30 samples. The following will be to diagram the processes through a DAP to identify the processes, analyze the travel times and distances for the raw material. After the initial collection stage, the data validation phase will begin in Minitab with Cronbach 's alpha to ensure that our collected data is adequate. Then we will proceed to identify the root causes of the problems through an Ishikawa diagram and validate these root causes through a survey of the plant's experts to perform a pareto and prioritize the root causes. Once the data collection and analysis stage are over, we will continue with the solution design stage, in this case it will be based on 3 lean tools: 5S, Standardized

Work and Plant Redistribution. Then the deployment and implementation of the solutions will be carried out and finally, a new time study will be carried out to validate whether the proposed hypothesis was fulfilled.

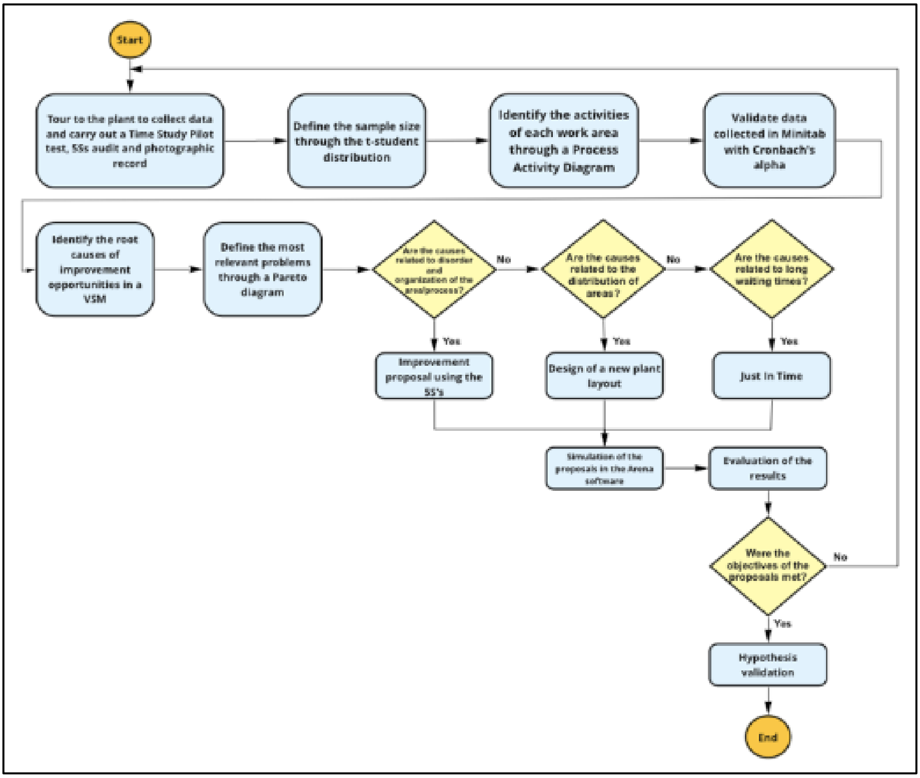

Figure 2. Study methodology flowchart [1]

2.3. Materials, technique, and instruments

To carry out the data collection, the timing method of the activities that are part of the hinge manufacturing process. Also, it You will use the technique of observation, survey and audit of 5S. By utility, the Instruments that will be used will be the stopwatch and the questionnaire.

2.4. Variables, population, and sample

The independent variables of this investigation are the following:

- Waiting time in the assembly process
- Material transport distance
- Material transport time
- Tool access delay time

On the other hand, the dependent variables are productivity and circulation time in the hinge manufacturing process, which will be impacted by the first 4 variables. Regarding the population and sample, in this case the population is the hinges produced in the company while the sample will be defined based on the preliminary time study that was carried out. Since the preliminary samples per element were not greater than 30, the student's t test was used for the calculation.

2.5. Data collection

With the objective of defining the working conditions and organization, cleanliness and order of the company, an audit of 5S's was carried out following the format of the 5S Verification Sheet for Laboratories, Workshops and Warehouses. In this audit the following results were calculated.

Figure 3 shows the results for the first S: Classification. The assembly area with 65% obtained higher compliance than the other areas and the Rolling area with 25% was the one that obtained the lowest percentage of compliance along with the cutting area has compliance Below average. Here it was observed that around many of the stations there are unnecessary items on shelves such as plastic bottles, cardboard, and bags. On the other hand, there are also shelves with matrices that belong to other areas and should be close to them.

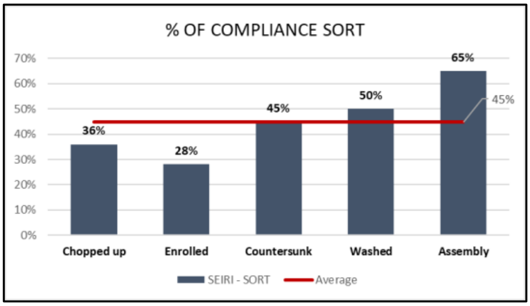

Figure 3. Classification Compliance.

Figure 4 shows the results for the second S: Organization. The assembly area also obtained the highest percentage, and the Rolling, Cutting and Countersinking areas were the lowest since in general the machines were not identified and the tools and instruments did not have a given site, this made the operators take time to find their tools to carry out their tasks.

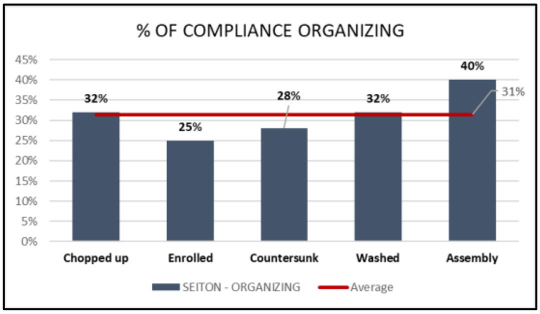

Figure 4. Organization Compliance.

Figure 5 shows the results for the third S: Cleaning. The Assembly area has the highest percentage of compliance with 40% followed by the Cutting area with 30%. In these areas, brooms and flannels were found for cleaning, unlike the other areas where many cleaning elements were not found. On the other hand, in general there is no cleaning plan in the factory, so the average compliance with this S is very low.

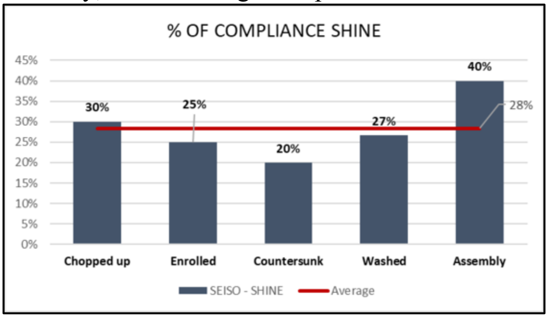

Figure 5. Cleaning Compliance.

For the diagnostic of the fourth S that relates to Standardization, only the first 2 questions were qualified since it was considered that the last 2 questions did not apply since the minimum requirements to be applied were not met and the results are as follows from the audit following. Figure 6 shows these results.

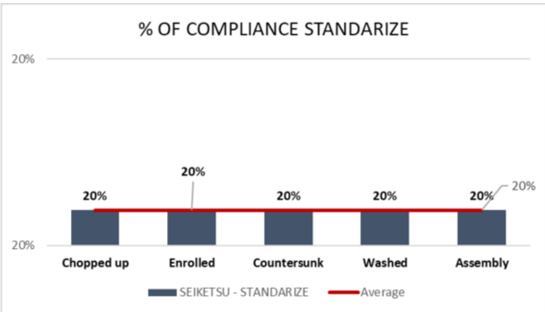

Figure 6. Standardization Compliance.

Finally, the diagnosis of the S of Discipline was not considered since the questions of the questionnaire do not apply in the Work areas since a 5S Program has not been implemented previously, so there is no defined 5S coordinator, Follow-up Report, among others.

After having carried out the 5S audit, the following proposal for the implementation of this tool was prepared. The proposal contains 7 stages that are carried out in a pilot test of 1 week.

Stage 1: Planning

Those responsible for the implementation of the 5S Methodology in the Workshop were defined, as well as those responsible for Documenting, controlling, and monitoring the 5S System. Likewise, a talk was held for the operators with the aim of informing and educating about the 5S methodology, how it would be implemented in the workshop, the benefits it would bring to improve productivity and meet the company's objectives.

Stage 2: Calculation of the delay time for access to tools or materials

An initial delay time was calculated for access to tools and/or average materials of 7.95 minutes from the cutting, rolling, countersinking, washing, assembly and assembly stations. No delay times due to access to tools and/or materials were found at the other stations.

Stage 3: Deployment of the 5S tool – Seiri (Ranking)

All the objects found in the different workstations are identified to classify them into the following 3 categories:

- Necessary: those that are used constantly or occasionally to perform the tasks of the workstation.
- Unnecessary: those that are not required to carry out the activities or functions corresponding to the workstation.
- Damaged: those objects that are damaged and cannot be used successfully to perform the tasks.

After the objects are categorized, they go through the following flow shows on Figure 7, to know which ones to keep for organizing, discarding, or giving them a second use outside of the operation. tasks.

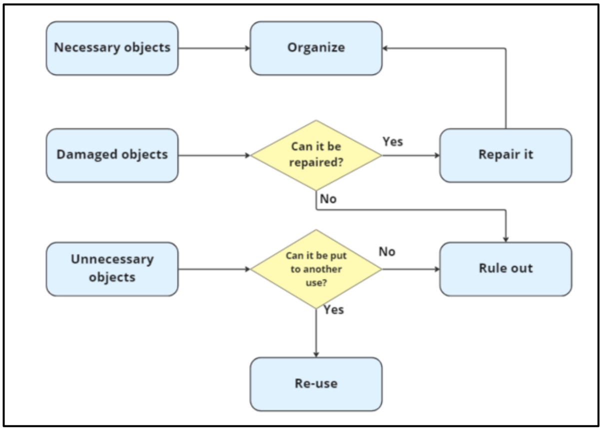

Figure 7. Flowchart to classify objects.

Stage 4: Deployment of the 5S tool – Seiton (Organization)

After classifying and identifying the objects to be kept, they are organized by giving them a suitable place in visible places and where they can be easily found by the operators and close to the workstations where they will be used to reduce the time of delay due to access to tools or materials. In addition, tools and materials are labeled so that they can be easily identified and prevent operators from taking the wrong objects.

On the other hand, the workstations are also limited by zones and the machines and/or equipment are labeled.

Stage 5: Deployment of the 5S tool – Seiso (Cleanup)

After classifying and ordering, at this stage a transversal cleaning protocol is established where the person responsible according to the workstation is indicated, this protocol designates the activities to be carried out as well as their frequency.

Stage 6: Deployment of the 5S tool – Seiketsu (Standardization)

Here visual controls are used to facilitate the organization, classification and cleaning adapted to the different seasons and thus the staff can interpret it properly.

Stage 7: 5S Tool Deployment – Shitsuke (Discipline)

At this stage, a very important document was prepared for the application and durability of the implemented measures. This is a monthly checklist to verify compliance with cleaning activities and protocols.

On the other hand, regarding the preliminary study of times that shows the Table 1, it was possible to calculate the productivity of 0.06 hinges per minute. Likewise, it was determined that 28% of the time spent is spent on transportation.

Table 1. Summary table of preliminary study.

Task	Element	Average T.O (seconds)	St Desv	Relative Error	Confidence level	Number of preliminary observations	Number of samples calculated
Chopped up	Cutting of the coil in a cutter	2.11	0.15	0.05	0.95	25	9
Selection	Group 40 hinges	29.34	3.03	0.05	0.95	5	18
Enrolled	Enrolling of 2 hinges at the same time	1.34	0.05	0.05	0.95	25	2
Countersunk	Countersunk	4.9	0.38	0.05	0.95	25	10
Washed	Loading hinges to washing machine	9.9	3.13	0.05	0.95	25	170
Washed	Washed	71.5	11.21	0.05	0.95	5	42
Assembly	Assemble hinge with axis	13.52	1.23	0.05	0.95	25	14
Armed	Assemble plates of 80 hinges	320	0	0.05	0.95	1	0
Painted	Place hinge plates on the painting table	11.36	1.82	0.05	0.95	4	44
Painted	Paint plates with a gun	41.45	3.51	0.05	0.95	6	12

For this table, only operations that have a significant impact on the hinge manufacturing process were considered. After obtaining the average time observed per element, an adjustment of 15% was made.

Just in Time tool was as follows. In the first place, the data in relation to the Processing Time, Transportation Time and Waiting Time were collected in order to calculate the Cycle Time of the process. Second, the factor of safety (alpha) was determined by calculating the average demand and operating time along with their standard deviation. Finally, the Kanban number was found using the previously collected data.

In the first place, through the study of times, the time data on the manufacturing process of hinges were collected. As can be seen in the tables below, 53% of the cycle time represents T. Transport + Waiting while processing time only represents 47% as it shows on the Table 2.

Table 2. Circulation time.

Circulation Time (seconds)	1	2	3	4	5

Processing Time	9637	9413	9337	9419	9265
Transportation time + waiting time	10698	10069	10674	10325	10495
Circulation Time (seconds)	20334	19483	20011	19744	19760

Secondly, the alpha (safety factor) was determined by applying the following formula, through which a value of 3.32% was obtained:

$$Alfa = Z\sqrt{(desv\ D/Prom\ D)exp2 + (Desv\ t/Prom\ t)exp2}$$

For the Assembly Area, the following times were determined on Table 3.

Table 3. Assembly area time.

Assembly Area Times	Seconds
Processing	13.13
Wainting	8.50
Transportation	0
Cycle time	21.6
Cycle time (hours)	0.01

Finally, the following formula was applied to find the Kanban number for the assembly station, from which a result of 13 cards was obtained for the 3 main types of hinges as it shows the Table 4 and 5. Each container can store 80 hinges.

Table 4. Kanban Number Calculation.

Kanban Number Calculation	1	3
Demand (units/ hour)	69.23	173.08
Container Size	80	80
Circulation time (hours/unit)	5.52	5.52
Coef. Security	3%	3%
Kanban Number	5	13

Table 5. Container Ratio.

Type	Dairy Production	%	Cantity
Hinge 3"	554	40%	32
Hinge 3 1/2"	277	20%	16
Hinge 4"	554	40%	32
Container Size	1385	100%	80

3. Results

For the validation of the SLP tool, a matrix analysis was carried out on the effort tons - meter that was carried out when applying the new plant distribution. For which a new travel distance of the materials of 156 meters was determined, an effort of 1029 tons - meter per month and an increase in productivity of 10%. These results are shown on Table 6.

Table 6. Matrix Analysis.

Variable	Unity	As Is	To Be	Variation %
Tons Transported	Tons	85	85	0
Distance Traveled	meters	170	159	6%
Effort (productivity)	(t-m)	1127	1029	0.1

Figure 8 shows the proposal for the distribution of the plant is presented applying the SLP tool.

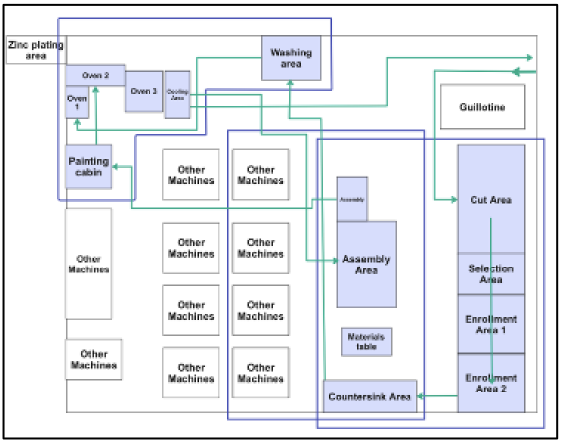

Figure 8. Plant redeployment.

Then, for the validation of the Just in Time methodology, a simulation was carried out in the Arena software. The simulation parameters were 8 hours per day, 20 replications, and the base time unit in minutes. The proposed scenarios will be detailed below. Figure 9 shows the arena simulation model with the stages of the process where the data was collected.

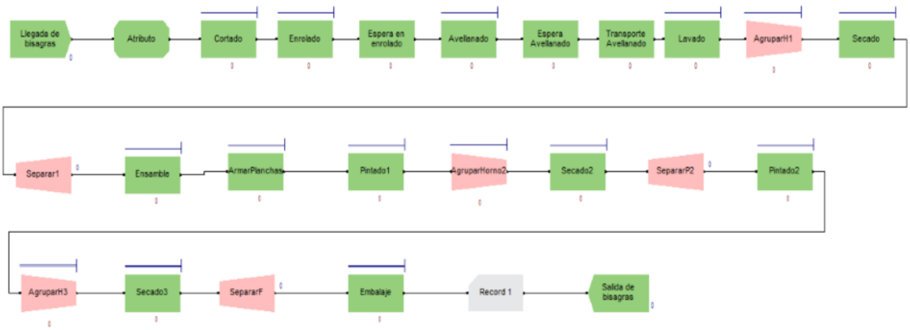

Figure 9. Arena Simulation Model.

Current situation of the company

This shows the result of the preliminary analysis of the time study, the improvement opportunities found, and the inputs collected in the 5S audit. In addition, it will be the one used to compare the proposed scenarios.

Scenario A: In this scenario, the application of the JIT tool will be simulated assuming continuous production of the main type of hinge that is manufactured (3"). Likewise, it will be simulated with a Kanban number of 5.

Scenario B: In this scenario, the application of the JIT tool will be simulated assuming continuous production of the 3 main types of hinges manufactured in the company (3", 3 ½ " and 4") with a 40% proportion, 20% and 40% respectively in the production batch. It will also be simulated with a Kanban number of 9.

Scenario C: In this scenario, the application of the JIT tool will be simulated, assuming continuous production of the 3 main types of hinges manufactured in the company (3", 3 ½ " and 4") with a 40% proportion, 20% and 40% respectively in the production batch. Also, it will be simulated with a kanban number of 13.

Table 7. Scenario comparison

Scenarios	As Is	A	Var %	B	Var %	C	Var %
Kanban Number	0	5		9		13	
Assembly Waiting Time	61.2	12	-0.81	21.9	-0.64	34	-0.44
Total Waiting Time	176	126	-0.28	137	-0.22	149	-0.15
Cycle time	331	281	-0.15	292	-0.12	304	-0.08
Productivity	0.47	0.55	0.08	0.53	0.06	0.51	0.04

Table 7 shows that in all scenarios there is an increase in productivity between 6%-8%. Scenario A is the one with the highest increase with 8%, mainly due to the reduction in waiting time in 81% of the assembly area. In this sense, we observe that as the number of Kanban increases, the percentage increase in productivity decreases.

Results of the 5S implementation

Seiri Implementation (Classification)

Following the proposed flow of classification of found objects, obsolete elements were found such as sandpaper in very poor condition, damaged hose replacements, and damaged wrenches. In addition, necessary objects such as keys, Allen keys, EPP Helmet, Screwdriver, Matrices, Hammers and hinges were found. Lastly, various unnecessary items such as empty plastic glasses and bottles, newspaper, empty paint bucket, empty lubricants, radio, among others, were discarded or eliminated.

Figure 10 shows the before and after the implementation of 5S at the Cutting station.

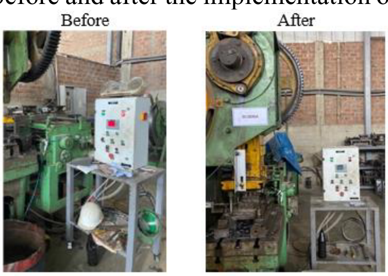

Fig. 10. Before and after the implementation of 5S at the Cutting station

Implementation of Seiso (Cleanup)

In this stage, the Plant Cleanliness Control shown in Figure 11 was implemented. It is a cleaning protocol applicable to all workstations. Also, it should be noted that a section for observations was added to this protocol so that operators can timely report cases such as losses, breakages, or failures in company equipment and/or tools and the employer can take action. In this way, the environments are kept clean without overloading the operators with cleaning activities.

PLANT CLEANLINESS CONTROL								
Area:								
Name and Surname of the person in charge:								
Cleaning frequency	Date							
Daily	11/11	11/12	11/13	11/14	11/15	11/16	11/17	11/18
Sweep the station floor.								
Clear surfaces collecting solid waste.								
Cleaning dust from horizontal surfaces.								
Degrease machine surfaces.								
Desengrasar las herramientas.								
Degrease the tools.								
Verify that the equipment and tools are in the right place.								
Weekly	11/11 - 18/11							
Wash garbage cans.								
Remove stains and dust surfaces.								
Clean and dust machines and tools.								
Monthly	Remark						Date	
Thoroughly clean tools and materials.								
Thoroughly clean surfaces.								

Fig. 11. Transversal Cleaning Protocol

Implementation of Seiketsu (Standardize)

At this stage, 5S visual standards adapted to the different workstations were implemented, such as the one shown in Figure 12.

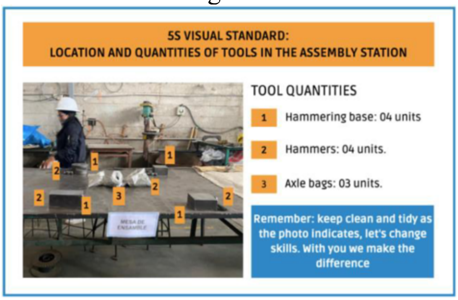

Fig. 12. 5S visual standard

Finally, after the implementation of the methodology, a second time measurement was carried out, which resulted in a delay time for access to tools and/or materials of 2.97 minutes, 63% less than the initial time.

4. Discussion

When making the comparison with [5], we can see that their scenario applying JIT with 5S obtained a productivity increase of 19%. The difference with this result is that his proposal focused on eliminating delays in material requirements while in this research the focus was on a manual production process. On the other hand, comparing the results of Lora Soto [8] where a reduction of unnecessary movement of 68% was obtained while in this investigation an improvement of 63% was obtained. This is justified because in the first investigation the implementation was carried out during a period of 3 months compared to the implemented pilot of 1 week. In addition, the implementation of the SMED tool was carried out at the same time, which also had an impact to achieve 68%.

5. Conclusion

The implementation of Lean Manufacturing tools in a metalworking company increases productivity by up to 10 % of the hinge production process. Likewise, the main problems identified in the production area were the high level of inventory in process, long waiting times and disorder in the workstations. This conclusion was reached after the study of times, preparation of the VSM and audit of 5S.

Regarding the implementation of the 5S's, it reduced the delay time for access to tools and/or materials by 60%. In addition, the area available for operators to work and move about has increased.

Regarding the application of the Systematic Layout Planning tool, this allowed us to identify the total distance that the materials have to travel (170 m) and the effort that the operators make when transporting them (1 127 ton-meters per month). Likewise, applying a matrix analysis, a distribution of the workstations was carried out with an increase in productivity of 10%, reducing the effort to transport the materials to 1029 tons-meter and the distance traveled to 156 meters.

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