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# Improvement Design to Increase Productivity in the Finishing Area Through the Use of Poka Yoke, Value Stream Mapping and SMED in a Company of the Plastics Business

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***Abstract*– The present research aims to conduct an analysis and diagnosis of issues using Lean Manufacturing tools to reduce errors and lead times in the finishing department of a plastic products company.**

***In response to the identified issues, several improvement proposals have been formulated through the application of Lean Manufacturing tools. Therefore, by implementing Poka Yoke, VSM, and SMED technique, the anticipated outcomes include a reduction in processing times, improved task distribution, and a decrease in improperly assembled products.***

***Likewise, with the proposed designs and implementations, it will be possible to create a more organized work environment, leading to better resource management and, consequently, a more efficient product assembly.***

***On the economic side, a significant increase in income could be seen. The reduction in production costs, facilitated by improvements in efficiency, improves the company's profitability, increasing from 68.7% to 79%. Likewise, when more efficient processes are implemented, resource management is optimized and waste reduced, this allows us to operate more profitably. This not only directly impacts profit margins but can also offer the flexibility to adjust competitive prices in the market. Improving profitability through efficiency not only strengthens the company's financial position, but also provides additional resources that can be allocated to innovation, research and development, thus contributing to long-term competitiveness, improving in different areas.***

***In conclusion, following the implementation of all the improvements, there was a demonstrated improvement in the effective production time by 50.96%. Additionally, there was a notable enhancement in the non-conforming product rate in the polyurethane injection process by 90% and a significant improvement in the non-conforming product rate in the assembly process by 93%.***

***Keywords: Lean manufacturing, Poka Yoke, SMED, VSM, Plastic.***

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## I. Introduction

### *A. Background*

Nowadays, companies worldwide, due to intense competition across most sectors, find it imperative to continually enhance their processes, consistently reducing times and eliminating non-value-added activities to achieve better results [1]. The common goal of all companies making such improvements is to enhance efficiency and productivity, differentiating themselves from others.

To aid in process improvement, methodologies such as Value Stream Mapping, also known as lean production, have been developed. Originating in Japan and developed by Toyota's director after World War II [4], this methodology focuses on eliminating waste, defects, and inefficient processes to optimize all processes, ensuring they only involve value-adding phases.

Simultaneously, technology is progressing progressively and rapidly, prompting companies to take action to address challenges it poses. This includes staying competitive, optimizing time and money, and mass-producing efficiently. Technology is crucial for differentiation against competitors, providing a competitive advantage, positioning, and staying at the forefront to meet market needs with greater efficiency and economic profitability [2].

Poka Yoke is a continuous improvement method originating from Japan designed to make a company's production process more efficient and error-free by eliminating deficiencies [11]. It encompasses two other well-known and essential methods for eliminating deficiencies, namely 5S and Kaizen. Poka Yoke brings significant advantages, primarily aiming to improve the quality of produced products. Implementing this method helps minimize human errors, reduce costs due to defects in the production process, and enhance the quality of operations, providing customers with a better experience [13].

SMED, or Single Minute Exchange of Die, is a crucial tool within Lean Manufacturing aimed at reducing setup times, eliminating waste that increases time and costs in the production system [5]. The correct application of SMED in a company brings benefits such as more frequent changes, lower inventory, increased flexibility, and better product quality [6]. One of its main objectives is to transform as many internal tasks as possible into external ones to perform tasks without interrupting operations, benefiting from activities based on single-digit minute times.

As shown in Figure 1, all the study focuses on the Yeti 63qt cooler with wheels and a telescopic handle.

Fig. 1 Yeti 63 qt cooler with wheels and a telescopic handle

### B. *Objectives*

The objectives of the project are:

1) Prepare the background and state of the art of the project for a company in the plastic products sector.

2) Perform the analysis and diagnosis of the problem in the finishing area using industrial engineering tools.

3) Design and develop solution proposals that generate a reduction in costs, improve the efficiency and productivity of the processes.

4) Validate the solution and its impact on relevant stakeholders.

### C. *State of the art*

Regarding the state of the art, there are eight main articles of the forty that were previously chosen, because they are articles that are more linked to our problem and especially with our area to be touched, without leaving aside, which could be seen in better detail the tools used in these cases.

| Causes / Authors | Reduce excess time in production processes | Reduce the deficiency in production processes | Improve knowledge of production processes |
|---|---|---|---|
| De Oliveira, A., Da Rocha, W. (2019). | SMED | | |
| Nikolic, J., Dasic, M., Dapan, M. (2023). | SMED | | |
| Leksic, I., Stefanic, N., Veza, I. (2020). | | Six Big Losses | Poka Yoke Kaizen |
| Aparisi, M. (2019) | | Value Stream Maping | |
| Palma, J., Garay, E., Bernal, J. (2022). | SMED | | |
| Daniyan, I., Adeodu, A., Mpofu, K., Maladzhi, R., Grace, M. (2022). | | Value Stream Maping | |
| Martinelli, M., Lippi, M., Gamberini, R. (2022). | | | Poka Yoke |
| Leksic, I., Stefanic., N., Veza, I. (2020). | SMED | TPM | Kaizen Kanban |
| **Proposal** | **SMED** | **VSM** | **Poka Yoke** |

Fig. 2 Comparative matrix of the components of the proposal vs state of the art

As shown in Figure 2, in the first objective which is to reduce unnecessary transfers, the SMED has been chosen as a proposal, because in the main articles it is what the authors also implemented to solve this problem. The second objective is to reduce typing errors, and the chosen tool is the VSM, although there were 2 more options (Six Big Losses and TPM). Finally, the last objective which is to improve knowledge of the production process, Poka yoke was chosen as a proposal, however, Kaizen or Kanban could also have been used.

### D. *Model components*

#### a. *SMED*

In order to implement SMED, the following steps must be taken:

1) Training on Lean Manufacturing and SMED: To improve the understanding of Lean Manufacturing principles and SMED methodology to reduce excess time in production processes, in addition to generating knowledge of these methodologies that can be used in any field.

2) Select the personnel in charge of performing the SMED: Evaluate and select individuals with a solid understanding of Lean Manufacturing principles and a willingness to participate in continuous improvement initiatives. Foster collaboration and effective communication within the team to maximize synergy in the implementation of SMED principles [9].

3) Record the change of workpieces or tools: Document in a systematic and detailed way the process of changing workpieces or tools for later analysis and improvement.

4) Perform time and motion study to find the standard time: Observe and record each movement and activity performed during the change of parts or tools. Use timing techniques to accurately measure the time spent in each phase of the process.

5) Eliminate unnecessary operations: Identify and eliminate all activities that do not add value to the product or service.

6) Monitoring of processes and results: Continuously monitor the processes implemented and evaluate the results obtained during and after the application of SMED.

*b. VSM*

In order to implement VSM, the following steps must be taken:

1) Collect data: This first step was the most important because the success of the implementation depended on the collection and reliability of this data. Information was needed on products and processes. In addition, it was important to analyze the effective demand for each product in order to evaluate the required production rate.

2) Train the personnel that will be part of the implementation: At this point, through training, the personnel were informed about the objectives and key aspects of lean manufacturing. They were also taught how to analyze operations and identify waste in order to represent the process by means of a value stream map [10].

3) Drawing the current value stream map: In this stage, the information collected and analyzed so far regarding the process before proceeding with the change was introduced.

4) Define and design the plant layout: the plant layout diagram was designed for the production of the product, determining the location of the machines and workplaces.

5) Standardize and implement improvements: Once it was verified that the model worked correctly, the process was standardized using 5s and proceeded with the final implementation.

6) Define control mechanism: Controls are established to ensure that changes are maintained and refined over time. In addition, improvements should be constantly evaluated and KPIs should be defined to monitor the efficiency of the process.

*c. Poka Yoke*

Poka Yoke methods are those that seek zero defect by using techniques and instruments that prevent errors from being made in the production process; they also help the operator to become aware of the error to correct it in time.

According to the theory, for the implementation of Poka Yoke, first the defect was identified and described; in addition, the degree of appearance it has had in the process was determined.

Then, the operations in which the error occurs were identified and the sequence of events was detailed. The next step was to carefully observe the operation and write down the steps in a format to identify the error conditions that may contribute to the defect. Once the root cause was determined, the type of Poka Yoke was selected according to the problem found and the instrument was designed. It is important to carry out tests beforehand to observe whether the chosen method works correctly in practice [7].

Finally, the operators were trained, and a control was also carried out to evaluate the improvements and show the efficiency of the work.

## II. SOLUTION DESIGN

*A. Linking root causes to selected solution tools*

As shown in Figure 3, the linkage of problem, root causes and tools can be visualized. As can be seen, it is the problem tree shown above, but with the difference that it is being fragmented according to its corresponding fields. The tools placed come from the best articles read and mentioned above. Based on this scheme it should be possible to establish the solution techniques.

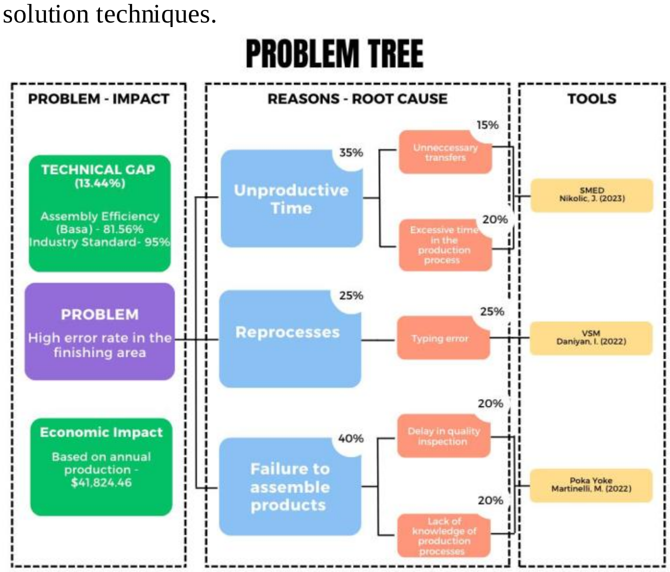


Fig. 3 Linking Problem - Reason – Tools

As can be seen in the graph, the problem found is the high rate of errors in the finishing area, followed by three reasons which are: unproductive time, reprocesses and errors in the assembly of products.

Then there are the root causes that are connected with the reasons found, the first reason has two root causes which are the lack of supply of inputs and unnecessary transfers, the second reason has a root cause which is the typing error, and the third reason has two root causes which are the delays in the quality inspection and ignorance of the production process.

Finally, there are the tools to be used, which are linked to the root causes found, the first two root causes would have SMED as a tool and the article that is more in line with our study would be that of Nikolic, J., the third root causes has Value Stream Mapping as a tool and the article that is more in line with our study would be that of Daniyan, I., finally the last 2 root causes have Poka Yoke as a tool and the article that is more in line with our study would be that of Martinelli, M.

### *B. Design of the proposed solution model*

As shown in Figure 4, the graphic will explain in a summarized form what is planned to be done according to the objectives proposed in the objectives tree.

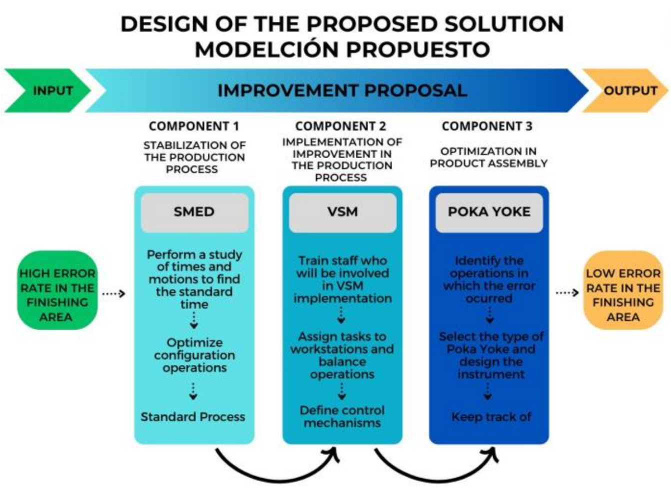


Fig. 4 Design of the proposed solution model

This model is divided into two parts: the first part would be the Input and Output, which are found in the problem tree, the Input would be the problem of the tree and the Output would be the antithesis of the Input, i.e., it is what is expected to be obtained after implementation. The second part is composed of the components and the tools to be used, the components are the minimum conceptual definitions of what is needed for the construct to walk, and the tools are the methodologies or mechanism to carry out the components.

In the presented construct it is organized as follows:

- Input: High error rate in the finishing area.
- Output: Low error rate in the finishing area.
- Component 1: Stabilization of the production process.
- Component 2: Implementation of improvements in the production process.
- Component 3: Optimization in the assembly of products.
- Component 1 Tool: SMED
- Component 2 Tool: VSM
- Component 3 Tool: Poka Yoke

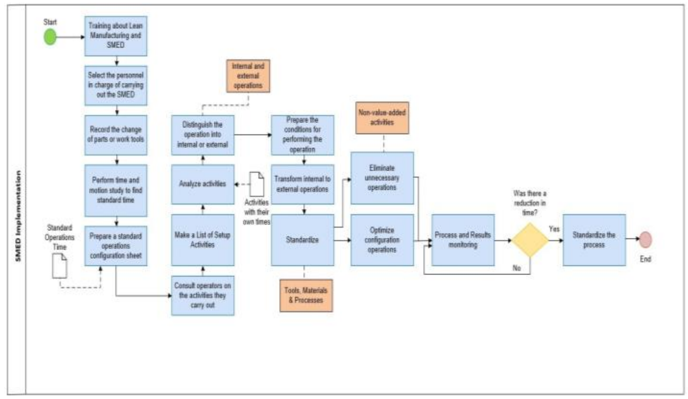


Fig. 5 SMED implementation

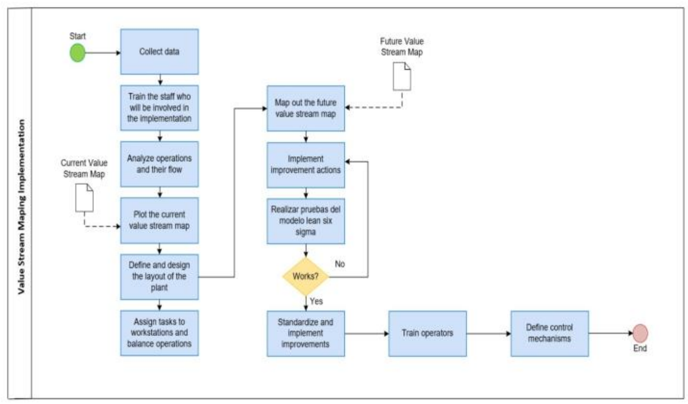


Fig. 6 Value Stream Mapping implementation

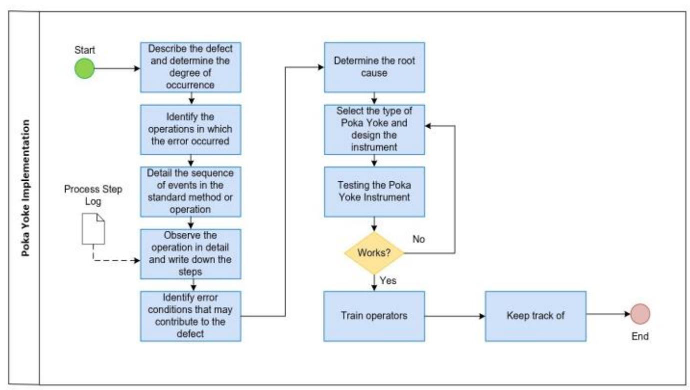


Fig. 7 Poka Yoke implementation

## III. DEVELOPMENT OF THE PROPOSAL

### A. *Development of the validation methodology*

Component 1 - Stabilization of the production process:

The validation method used for the stabilization of the production process is the implementation. Our methodology to be used in this component is the SMED, as explained above is the taking of times of all activities throughout the production process, in which in this case no activity was eliminated since all were necessary for it to be completed. That is why some internal activities were changed to external ones, in order to reduce time and make the process more efficient.

As shown above, the times were taken before the implementation in order to have an average of how long it usually takes the operators to perform each activity and to define actions together with the head of finishing, in order to reach the goal set.

As shown in Figure 8, the first thing that will be done after taking the time, after implementation, will be to choose the 5 activities with the longest time, see the problem which caused these last so long and affect the process, then with someone in charge of the area to analyze what would be the best solution to this problem in order to have a shorter time. Finally, together with the person in charge, estimate an expected time that could be reached by implementing the improvement and see if it provides a solution to the problem found.

| N° | Operations | Time before improvement | Problem | Improvement | Expected time |
|---|---|---|---|---|---|
| 5 | Inject polyurethane. | 194.08 | 4 of the 6 injectors were used due to a failure in 2 mandrels | Perform maintenance on the 2 chucks | 100 |
| 7 | Place wheels and secure. | 38.28 | Difficulty could be observed in carrying out this activity | Train staff | 30 |

Fig. 8 Problem Table - Improvement

The table shown is an example of a scheme that can be used to better organize the SMED in order to have a more adequate procedure and be able to meet the objective, which is to be able to minimize production time.

Finally, time will be taken again in different productions to see if it has been successful. However, if the analysis of the time taking has been successful, the process should be standardized so that all operators know the steps and times taken for each activity.

Component 2 - Implementation of improvements in the production process:

For the second component, Value Stream Mapping, different data had to be collected from the entire production process and then analyzed in order to reduce inefficiencies. First, a current value stream mapping (VSM) was performed, which includes the formulation, molding, process warehouse, assembly and distribution areas. The data used for this flow map were the kg of raw materials required for production, the number of parts produced for a production order, production times, waiting times and fixed times. With this, it was possible to obtain the lead time and value-added time in hours and days that allow us to know the time that elapses from the moment the purchase order is issued until the product is shipped to the customer. Also, with this map an improvement could be identified, which is to assemble the coolers in the molding area in order to avoid waiting time, reduce unnecessary travel and reduce costs.

On the other hand, to complement the VSM and to have a better view of the movement of materials in the areas involved, a current route diagram was drawn up. Therefore, for this component, it was decided to make a pilot on reorganizing the production process, eliminating the transfer to the process warehouse and assembling the coolers in the molding area.

Component 3 - Product assembly optimization

In the case of the Poka Yoke method, the main objective is to eliminate errors when assembling the coolers through different techniques and instructions. First of all, it was necessary to have a clear knowledge of the assembly process, so the steps that the operators perform according to the production order were noted. Then, when analyzing the data and the errors that were most frequently made, it was possible to identify that it was recurrent that the coolers had some defect in the assembly of the telescope handle and the wheels. Therefore, at the time of doing the research, it was determined that placing a sequential and physical poka yoke device would allow to have a more orderly and clear work area when placing the parts. The proposed device is a Mitsubishi Electric poka yoke work table; however, since this is a table that is currently out of the company's budget, a pilot test was conducted with containers labeled and ordered according to the assembly sequence.

### B. *Experimentation and validation*

Component 1 - Stabilization of the production process:

As shown in Figure 9, the first step is to select the 5 activities that take the most time in the process.

| N° | Operations | Time before improvement | Problem | Improvement | Expected time |
|---|---|---|---|---|---|
| 5 | Inject polyurethane. | 194.08 | 4 of the 6 injectors were used due to a failure in 2 mandrels | Perform maintenance on the 2 chucks | 100 |
| 7 | Place wheels and secure. | 38.28 | Difficulty could be observed in carrying out this activity | Train staff | 30 |
| 8 | Install telescopic handle (6 bolts). | 44.93 | The operator could not find the drill or it was out of battery | Give the drill a specific place where it can be loaded at the same time | 35 |
| 12 | Bag x2. | 33.89 | The operator was not clear about how to correctly place the cooler | Train staff | 23 |
| 13 | Tie bag with raffia. | 122.26 | Personnel without training in how to tie with raffia | Train staff | 61 |

Fig. 9 Problem Table - Current Improvement.

As shown in Figure 10 and 11, The process should then be time-tested again to verify that the proposed actions have solved the problem or, if not, the improvement should be reconsidered.

| N° | OPERATION | T1 (s) | T2 (s) | T3 (s) | T4 (s) | T5 (s) | To prom (s) | S (s) | CV (s) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Disburse body. | 15.23 | 15.76 | 15.55 | 15.87 | 15.33 | 15.55 | 0.27 | 0.02 |
| 2 | Glue metal sheets x2. | 10.42 | 10.35 | 10.84 | 10.61 | 10.12 | 10.47 | 0.27 | 0.03 |
| 3 | Place handle and safety x2. | 10.97 | 10.65 | 10.33 | 10.39 | 10.23 | 10.51 | 0.30 | 0.03 |
| 4 | Place white body. | 2.55 | 2.34 | 2.72 | 2.94 | 2.49 | 2.61 | 0.23 | 0.09 |
| 5 | Inject polyurethane. | 96.35 | 96.42 | 96.51 | 96.13 | 96.46 | 96.37 | 0.15 | 0.00 |
| 6 | QA. | 10.86 | 10.36 | 10.34 | 10.44 | 10.12 | 10.42 | 0.27 | 0.03 |
| 7 | Place wheels and secure. | 23.84 | 23.32 | 23.55 | 23.09 | 23.73 | 23.51 | 0.30 | 0.01 |
| 8 | Install telescopic handle (6 bolts). | 30.87 | 30.56 | 30.91 | 31.08 | 30.33 | 30.75 | 0.30 | 0.01 |
| 9 | Insert cover. | 6.88 | 6.53 | 6.82 | 6.94 | 6.38 | 6.71 | 0.24 | 0.04 |
| 10 | Paste label. | 6.36 | 6.81 | 6.75 | 6.77 | 6.43 | 6.62 | 0.21 | 0.03 |
| 11 | Paste barcode. | 5.13 | 5.49 | 5.42 | 5.66 | 5.78 | 5.50 | 0.25 | 0.05 |
| 12 | Bag x2. | 20.88 | 20.97 | 20.76 | 20.59 | 20.24 | 20.69 | 0.29 | 0.01 |
| 13 | Tie bag with raffia. | 30.53 | 30.41 | 30.64 | 30.22 | 30.83 | 30.53 | 0.23 | 0.01 |
| 14 | Complete multipackage label. | 8.59 | 8.76 | 8.34 | 8.65 | 8.86 | 8.64 | 0.20 | 0.02 |
| 15 | Paste multipack label. | 5.78 | 5.12 | 5. 41 | 5.87 | 4.54 | 5.33 | 0.62 | 0.12 |
| 16 | Palletize. | 5.24 | 5.75 | 5.33 | 5.58 | 5.95 | 5.57 | 0.29 | 0.05 |
| | | | | | | | | Máx: | 0.12 |

Fig. 10 Timetable according to operations – Post improvement

| N° | OPERATION | To prom (s) | Valoration (105 - Bueno) | Tn (s) | Frequency | Supplements | Ts (s) |
|---|---|---|---|---|---|---|---|
| 1 | Disburse body. | 15.55 | 1.05 | 16.33 | 0.17 | 1.15 | 3.13 |
| 2 | Glue metal sheets x2. | 10.47 | 1.05 | 10.99 | 0.50 | 1.15 | 6.32 |
| 3 | Place handle and safety x2. | 10.51 | 1.05 | 11.04 | 0.50 | 1.15 | 6.35 |
| 4 | Place white body. | 2.61 | 1.05 | 2.74 | 1.00 | 1.15 | 3.15 |
| 5 | Inject polyurethane. | 96.37 | 1.05 | 101.19 | 0.17 | 1.15 | 19.40 |
| 6 | QA. | 10.42 | 1.05 | 10.95 | 1.00 | 1.15 | 12.59 |
| 7 | Place wheels and secure. | 23.51 | 1.05 | 24.68 | 1.00 | 1.15 | 28.38 |
| 8 | Install telescopic handle (6 bolts). | 30.75 | 1.05 | 32.29 | 0.17 | 1.15 | 6.19 |
| 9 | Insert cover. | 6.71 | 1.05 | 7.05 | 1.00 | 1.15 | 8.10 |
| 10 | Paste label. | 6.62 | 1.05 | 6.96 | 1.00 | 1.15 | 8.00 |
| 11 | Paste barcode. | 5.50 | 1.05 | 5.77 | 1.00 | 1.15 | 6.64 |
| 12 | Bag x2. | 20.69 | 1.05 | 21.72 | 0.50 | 1.15 | 12.49 |
| 13 | Tie bag with raffia. | 30.53 | 1.05 | 32.05 | 0.50 | 1.15 | 18.43 |
| 14 | Complete multipackage label. | 8.64 | 1.05 | 9.07 | 0.50 | 1.15 | 5.22 |
| 15 | Paste multipack label. | 5.33 | 1.05 | 5.59 | 0.50 | 1.15 | 3.22 |
| 16 | Palletize. | 5.57 | 1.05 | 5.85 | 0.50 | 1.15 | 3.36 |
| | | | | | | TOTAL STANDARD PRODUCT TIME | 150.95 |

Fig. 11 Table for Standard Operating Time - Post Improvement

For the SMED carried out, it was only possible to take the time of 5 different productions as shown in the table, due to the time available and also due to the demand for products in the company, which causes a high turnover of these products.

Component 2 - Implementation of improvements in the production process:

As shown in Figure 12, once the areas in which the improvement can be made were identified, a future value stream mapping was performed, showing the process with the implementation of the improvement, in other words, the process warehouse area was eliminated, thus reducing the waiting time and eliminating the storage time.

As shown in Figure 13, compared to the current value stream mapping, there is a reduction in lead time and value-added time, which shows that if this improvement is implemented, the process will be more optimal since a sub-process that does not add value has been eliminated [8].

On the other hand, to continue improving productivity and to have a better visualization of the new process, a future route diagram was drawn up, which will also help operators to know the movements that will no longer be performed. It also clearly shows how the implementation will allow the finished product to be moved to the distribution warehouses, eliminating waiting time, reducing the number of meters of travel and the number of operators, as well as allowing the finishing area to attend to other priorities.

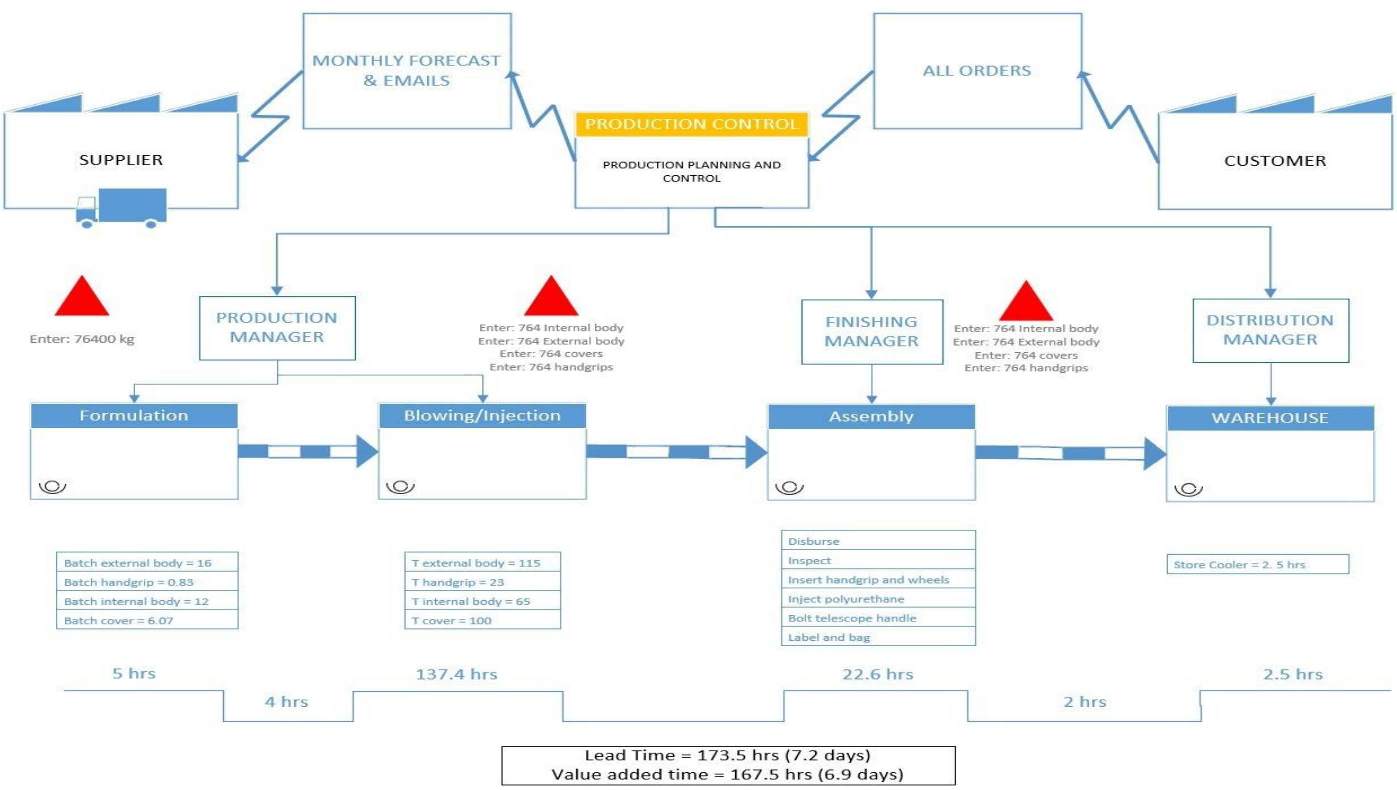


Fig. 12 Value stream map - Post improvement

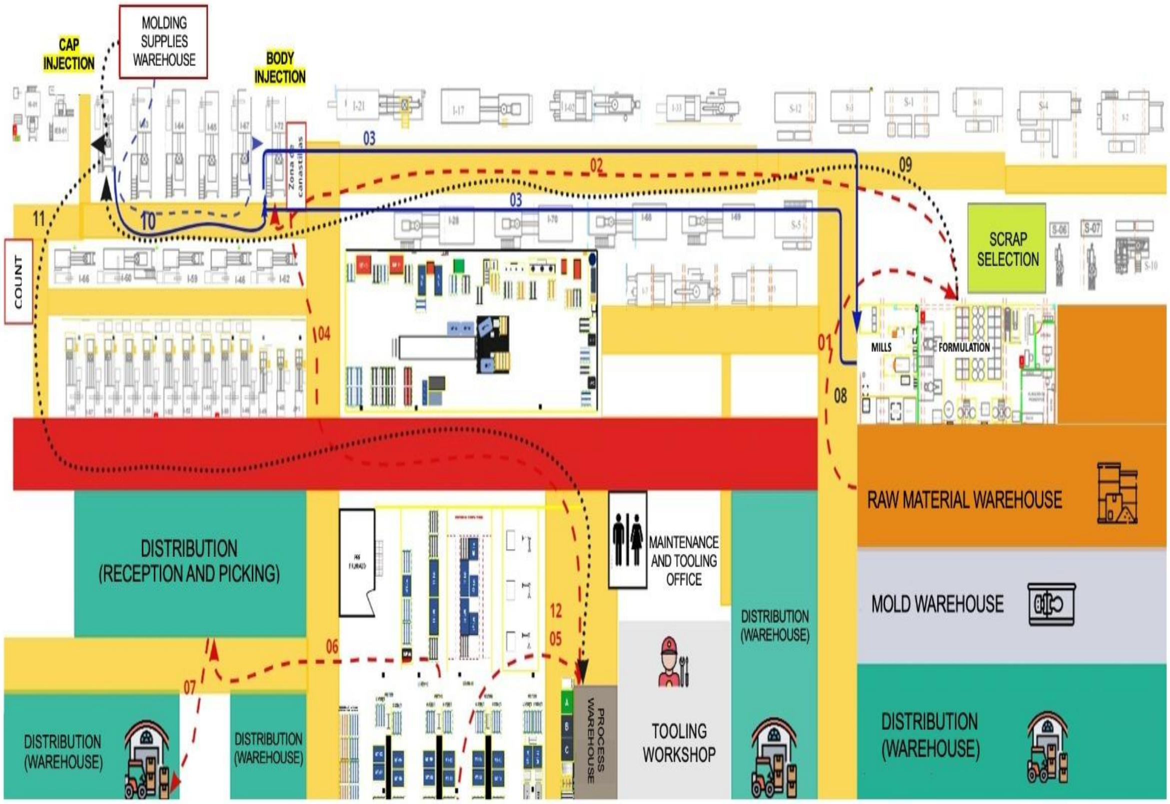


Fig. 13 Path diagram - Post improvement

Component 3 - Product assembly optimization

To begin with the pilot test, it was identified that the most convenient way was to arrange the work tables, placing containers with the materials and parts to be used sequentially. In addition, a label was placed on the outside of each container to identify the materials so that, at the time of filling, they would not get mixed up or disorganize the already established sequence. The control of this improvement was made through a new time taking at the time of the cooler assembly, which showed a reduction in time and also evidenced the reduction of errors, so that the operators were happy and comfortable with the poka yoke method chosen.

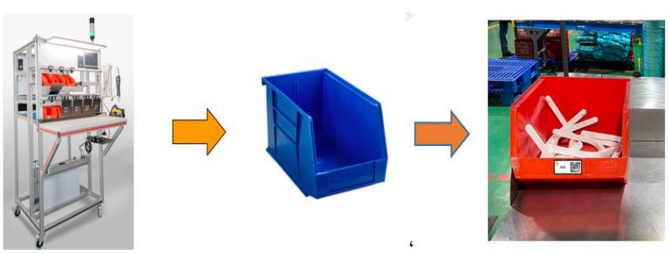

Fig. 14 Containers with materials

## C. *Analysis of results*

Component 1 - Stabilization of the production process:

When analyzing the tables shown above, it can be seen that there was a great decrease in the process and also an increase in productivity since with the improvement implemented, the number of products assembled per hour was doubled.

| N° | OPERATION | Ts 2 (s) | Ts 1 (s) |
|---|---|---|---|
| 1 | Disburse body. | 3.13 | 6.81 |
| 2 | Glue metal sheets x2. | 6.32 | 12.83 |
| 3 | Place handle and safety x2. | 6.35 | 8.27 |
| 4 | Place white body. | 3.15 | 3.27 |
| 5 | Inject polyurethane. | 19.40 | 58.59 |
| 6 | QA. | 12.59 | 20.12 |
| 7 | Place wheels and secure. | 28.38 | 46.22 |
| 8 | Install telescopic handle (6 bolts). | 6.19 | 9.04 |
| 9 | Insert cover. | 8.10 | 8.50 |
| 10 | Paste label. | 8.00 | 8.11 |
| 11 | Paste barcode. | 6.64 | 7.20 |
| 12 | Bag x2. | 12.49 | 20.46 |
| 13 | Tie bag with raffia. | 18.43 | 73.81 |
| 14 | Complete multipackage label. | 5.22 | 5.55 |
| 15 | Paste multipack label. | 3.22 | 3.11 |
| 16 | Palletize. | 3.36 | 4.36 |
| **TOTAL STANDARD PRODUCT TIME** | | **150.95** | **296.26** |
| **Standard production per hour in units** | | **24** | **12** |

Fig. 15 Comparative table of times before and after the upgrade

The expected times set in the first table were exceeded and this made it possible to achieve the objective, having a more efficient production process with better results. It was possible to double the production per hour, since before it was only possible to produce 12 units per hour, now it is possible to produce 24 units per hour. Also, if we analyze the other activities, we can see that there was also a decrease in them and this is due to the training that the operators have had and the commitment that they are putting into their work, to be more efficient each time.

Component 2 - Implementation of improvements in the production process:

With the future value stream map, it is shown that assembling the product in the molding area will reduce the number of operators working in the areas involved, save working hours as waiting time will be eliminated and there will be less meters traveled.

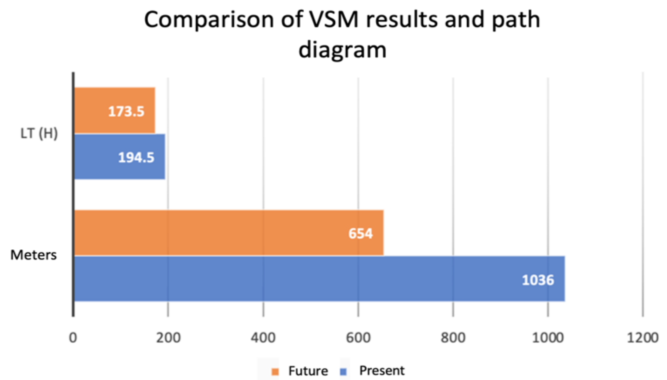


Fig. 16 Comparison of VSM and Path Diagram result

The analysis of results according to the route diagram was based on comparing the distances of the present and future route diagrams. The following is the route of the activities and their respective meters.

| N° | Activity Tour | Meters |
|---|---|---|
| 01 | From Raw Material to Formulation | 62 m |
| 02 | From Formulación to I-72 | 101 m |
| 03 | From I-72 to Mills (Round Trip) | 200 m |
| 04 | From I-72 to the Process Warehouse | 62 m |
| 05 | From Process Warehouse to Assembly | 18 m |
| 06 | From Assembly to Count (Distribution) | 12 m |
| 07 | From Count to Warehouse (Distribution) | 10 m |
| 08 | From Raw Material to Formulation | 62 m |
| 09 | From Formulación to I-61 | 133 m |
| 10 | From I-61 to Mills (Round Trip) | 264 m |
| 11 | From I-61 to Process Warehouse | 94 m |
| 12 | From Warehouse to Assembly | 18 m |
| Total Route | | 1036 m |

Fig. 17 Analysis of results according to the path diagram

By implementing the improvement, it is obtained that:

Variation of the path →1036 m-654 m=382 m

Component 3 - Product assembly optimization

As for the third component, the decrease in time is evidenced with a new time recording with the stopwatch, which indicated that, by having a more orderly work area with containers labeled according to the production sequence, a shorter assembly time is achieved and thus a greater quantity of finished products. On the other hand, a record has been kept of the errors in each month, and in the last production of coolers an optimum result was achieved.

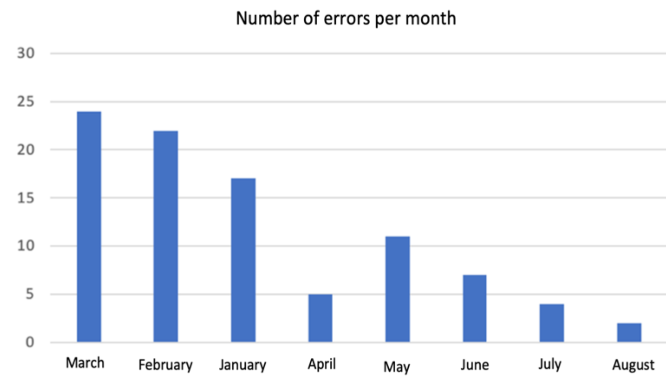


Fig. 18 Number of errors per month

## IV. CONCLUSIONS & DISCUSSIONS

It is concluded that the most important part of this work is to perform the pilot tests of the engineering tools since it allows perfecting the methods and instruments, as well as making the necessary adjustments or modifications so that the company can apply them directly without any problem. On the other hand, it allows us as students to analyze the data on the feasibility, acceptability and effectiveness of the procedures to prove that our research was successful. As shown in Figure 19, for this project it could be evidenced that there was an improvement in the effective production time of 50.96%, as well as an improvement in the rate of non-conforming products in the polyurethane injection process of 90% and finally an improvement in the rate of non-conforming products in the assembly process of 93%.

| Indicator | Formula | Unit | Traffic light protocol | | | As Is | To Be | Improvement |
|---|---|---|---|---|---|---|---|---|
| | | | Red | Yellow | Green | | | |
| Effective production time | Total sum of averages by activity | Minutes | > 210 | 210 - 160 | 160 > | 296.22 | 150.95 | 50.96% |
| Rate of non-conforming products in the polyurethane injection process | Sum of non-conforming products per shift | Unit | > 5 | 5 - 3 | 3 > | 10 | 1 | 90% |
| Rate of non-conforming products in the assembly process | Sum of non-conforming products per shift | Unit | > 5 | 5 - 3 | 3 > | 14 | 1 | 93% |

Fig. 19 Traffic light protocol

It can be concluded that the use of engineering tools such as SMED, Value Stream Mapping and Poka Yoke help to find opportunities for improvement in production processes, and thus make the work more efficient and optimal, avoiding errors, reprocesses and downtime. Also, with the implementation of the improvements, not only the company benefits, but also the customers, since they can receive their orders faster and without any type of complaint.

In conclusion, for the chosen tools to be implemented and work well in the company, it is necessary to involve the operators in the improvements and train them so that they have knowledge of how to use them so that their work will benefit. In addition, they are the ones who, through their experiences, can provide feedback on the improvement and turn the new way of working into a habit for other processes.

| Indicators | Monthly | Annual |
| --- | --- | --- |
| Defective Products | 3, 033.00 | 36, 396.00 |
| Unplanned Stops | 10, 658.84 | 127, 906.08 |
| **Totals** | 13, 691.84 | 164, 302. 08 |

Fig. 20 Indicators

By analyzing the results obtained, it can be validated that, if the company decides to implement the tools, the results will be favorable since there is economic viability and a positive impact on the stakeholders. In addition, the indicators of quality rate, assembly efficiency and screen printing were taken into account, which allow identifying defective products and unplanned stops in the blower.

As for defective products, waste and poorly assembled coolers are considered, which require reprocessing. By using VSM and Poka Yoke to improve this process, it is expected to obtain approximately S/ 3,033 more monthly. Likewise, regarding unplanned stops and downtime, only the SMED tool is being applied, which will achieve greater efficiency and this is reflected in a monthly income of S/ 10,658.84 for the Basa company.

## V. RECOMMENDATIONS

It is recommended to continue implementing the Poka Yoke, Value Stream Mapping and SMED methodologies, as these strategies have proven to be highly effective in improving operating efficiency and reducing waste in the various industrial processes. The combination of these methodologies allows to comprehensively address quality, efficiency and changeover time issues. The implementation of these methodologies will allow maintaining a constant focus on continuous improvement and process optimization, which in turn will contribute to maximizing the company's profitability and competitiveness in a constantly evolving business environment.

It is recommended to maintain an ongoing training program for all personnel, including operators, on the methodologies employed. Ongoing training is essential to ensure that all team members are fully aligned with the organization's continuous improvement objectives and processes. By investing in employee training and skills development, an increase in competency and understanding of these methodologies will result in more effective implementation and the ability to proactively identify improvement opportunities.

It is recommended that a dedicated team be established to conduct internal audits on a regular basis. This internal audit team can conduct regular assessments of processes and practices throughout the organization, identifying areas for improvement, verifying compliance with established standards and procedures, and proposing recommendations to optimize efficiency and quality.

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