# Continuous Improvement Model to Increase Productivity using Lean Manufacturing Tools in an SME in the Plastics Industry

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## Abstract

Nowadays, companies face strong competition worldwide, so there is great pressure to increase productivity and reduce production costs. Low productivity is reflected in a high amount of waste, unproductive times, and returns in the extrusion process of an SME in the plastics industry. Therefore, a model focused on continuous improvement is proposed to increase productivity using Lean Manufacturing tools such as Standard Work, SMED, and TPM. Through a simulation of the extrusion process using the Arena software, it was possible to validate an increase in the productivity of the extrusion process by 4.97%, going from 0.21 to 0.22. Likewise, the Standard Work tool reduced wastage by 30.44%, the SMED tool reduced extruder machine setup times by 9.76%, and finally, the TPM tool, focused on its fourth pillar of quality maintenance, was able to reduce defective products by 28.38%.

## Keywords
Continuous improvement, key performance indicators, plastic industry, productivity, lean manufacturing.

## 1. Introduction
In a highly competitive business environment, productivity is a key factor for success. The pressure to increase productivity and reduce production costs has become a necessity for companies (Almeida and Cunha 2017). Product quality, order delivery times, and production costs are important factors that influence productivity. However, there are other factors that affect productivity, such as long manufacturing times, high amounts of waste, and unproductive times due to machine downtime during setup (Becerra et al. 2019; Aldea Molina 2021; Karam et al. 2018).

Therefore, it is necessary to implement tools and strategies to address these challenges and improve productivity in companies. Identifying and solving specific problems in production processes can have a significant impact on productivity. Managers and business leaders must be aware of these factors and work to improve the efficiency and effectiveness of their operations to achieve greater success in an increasingly competitive business environment.
Based on the aforementioned, it can be concluded that the majority of companies in the manufacturing sector face low productivity issues, especially those in the plastic industry. For this reason, a research study was conducted focusing on a specific company with low productivity due to various problems in its plastic extrusion process. These problems were reflected in high product return rates, high waste quantities, and unproductive times, which not only justified the mentioned issues but also incurred costs for the company, representing 8% of gross profit. In order to solve the problem, a continuous improvement model was proposed using certain Lean Manufacturing tools, namely Standardized Work, SMED, and TPM. It should be noted that the research work was supported by similar models, which resulted in increased productivity in similar process lines. Similarly, previous research has shown the success of implementing Lean Manufacturing tools to achieve increased productivity in manufacturing companies (Canahua 2021; Costa et al. 2017; Rosa et al. 2017). However, there is a lack of research that has implemented a similar continuous improvement model in a small and medium-sized plastic industry, both nationally and internationally, which adds differentiated value to this investigation.

This scientific article is divided into: Introduction, Literature Review, Methods, Validation, Results and Discussion, and Conclusions.

### 1.1 Objectives
The main objective of the research is to increase the productivity of an SME dedicated to the manufacture of heat-shrinkable foils in the plastics industry by 10%. To achieve this result, a continuous improvement model is proposed, which is made up of three Lean Manufacturing tools: Standardized Work, SMED and TPM, and which in turn, will be delimited within the extrusion process of the company only; likewise, specific objectives were proposed to reduce the amount of wastage by 20%, setup times by 15% and the rate of returns by 20%.
In addition, this study presents a model whose tools adhere to the principles of Lean Manufacturing and are developed in harmony with the production line, which allows achieving the established objectives.

## 2. Literature Review

### 2.1 Standard Work
The use of standard work tools allows minimizing waste and maximizing performance by establishing the best methods and sequences for each activity and worker, which reduces cycle time variations and improves quality, safety and the environment (Ribeiro et al. 2019). Standardized work is subject to continuous improvement through Kaizen (Marinelli et al. 2021). This is important because manual operations can cause human errors and quality problems that affect productivity and economy (Torres-Medina 2020). By implementing these tools, it has been shown that company productivity can be improved and economic losses minimized (Torres-Medina 2020; Ribeiro et al. 2019).

### 2.2 SMED (Single Minute Exchange of Die)
The use of SMED in lean manufacturing reduces machining time, which increases line flexibility and enables faster production changeovers (Godina et al. 2018). Classifying operations into internal and external and converting internal operations to external helps to simplify all operations and reduce setup times (Ribeiro et al. 2019). The successful implementation of SMED in a case study resulted in a 15% improvement in setup times reduction and an increase in productivity by changing some work methodologies (Brito et al. 2020). In conclusion, SMED is an effective tool to increase productivity in manufacturing.

### 2.3 TPM (Total Productive Maintenance)
Total Productive Maintenance (TPM) aims to optimize equipment efficiency and has been widely used in the industry with excellent results. TPM has eight pillars aimed at proactively improving machine reliability and requires the active participation of operators and their continuous training. Many studies have shown the improvements that the TPM tool can bring in different fields and it can be used in all industries as a management and continuous improvement tool (Pinto et al., 2019; Canahua 2021; Lopes et al. 2020)..

## 3. Methods

### 3.1. Basis
During the literature review, different models have been found that aim to increase productivity. These models have allowed the identification of the tools related to the problems that cause low productivity in an SME in the plastics industry.

Table 1. Comparative Matrix

| Authors/Components | Operations standardization | Setup time optimization | Maintenance plan |
|---|---|---|---|
| Flores et al. (2020) | Trabajo Estandarizado y Kanban | | |
| Pena, R., Ferreira, L.P., Silva, F.J.G., Sá, K.C., Fernandes, N.O. & Pereira, T. (2020) | Kaizen, 5S, Trabajo Estandarizado | | |
| Brito, M., et al. (2020) | | SMED | |
| Godina, R., Pimentel, C., Silva, F.J.G., & Matias, J.C.O. (2018) | | SMED | |
| Canahua Apaza (2020) | | | TPM |
| Pinto, G., Silva, F.J.G., Baptista, A., Fernandes, N., Casais, R. & Carvalho, C. (2020) | | | TPM |
| Proposal | SMED | Standard work | TPM |

### 3.2. Proposed model
A continuous improvement model was proposed based on Lean Manufacturing tools, such as Standardized Work, SMED and TPM. It should be noted that each tool focuses on a specific process: mixing, extrusion and rewinding, respectively.

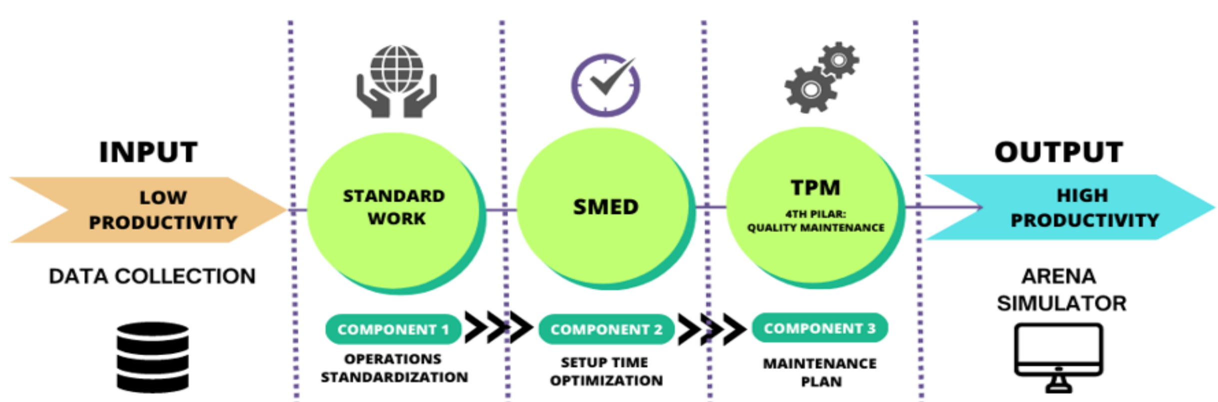


Figure 1. Proposed model

This model contains three main components: operations standardization, setup time optimization and maintenance plan. Apart from the components, there are the inputs of the model, which are low productivity supported by data collection, and the output of the system that will be validated with the simulation software. The main value of this model is the combination of different Lean Manufacturing tools in the plastic extrusion process of an SME, which can bring new methodologies to this type of companies in order to achieve an improvement in their processes.

## 3.3 Components

For the development of the proposed model, three components are included, which are directly related to the proposed tools.

### 3.3.1. Component 1: Operations standardization

In the first component, the Standardized Work tool was developed, which followed a series of planned steps aimed at performing certain activities more efficiently, thus improving operational quality.
This tool allowed a better performance of the mixing of the polymers used as main inputs. It should be noted that this problem was the one that had the greatest impact on the waste presented by the company under study. Next, the steps to be followed for the development of the standardized work proposal were detailed.

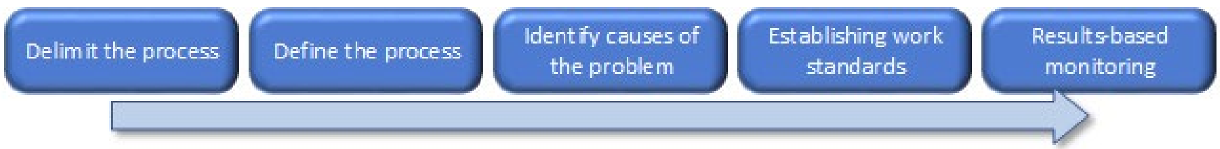


Figure 2. Operations standardization

### 3.3.2. Component 2: Setup time optimization

In the second component, the SMED tool was proposed to reduce setup times or preparation times. This tool was focused on the extruder machine, since this is where the machine preparation activity is performed.

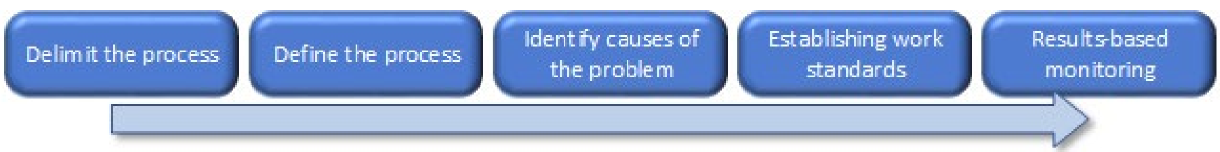


Figure 3. Setup time optimization

### 3.3.3. Component 3: Maintenance plan

The third component consists of proposing the use of the TPM tool to achieve higher quality in the extrusion machines. The fourth pillar of TPM or quality maintenance was used, which aims to maintain high quality standards in the extrusion process. This component focuses on reducing the amount of defective rolls present at the end of the rewinding activity. The tool was focused specifically on the rewinding operation of heat-shrinkable film.

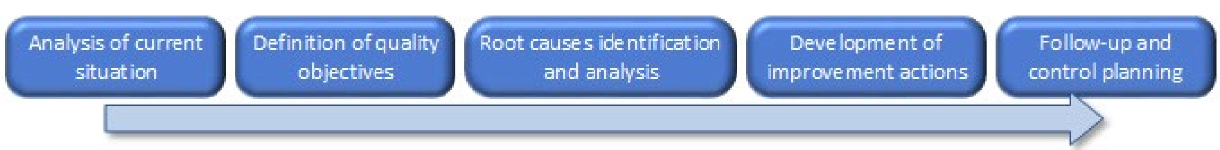


Figure 4. Maintenance plan

## 3.4 Indicators

The indicators of the proposed model are shown below. With this it was possible to calculate a variation between the current system and the optimal one.

Table 2. Indicators

| Indicator | Formula |
|---|---|
| Productivity | $$Productivity = \frac{kg\ of\ units\ produced}{input\ costs}$$ |
| Waste quantity | $$Waste\ Quantity\ (\%) = \frac{(Final\ waste\ quantity\ in\ kg - Initial\ waste\ quantity\ in\ kg)}{Initial\ waste\ quantity\ in\ kg}$$ |
| Setup times | $$Setup\ times\ (\%) = \frac{(Final\ setup\ time - Initial\ setup\ time)}{Initial\ setup\ time}$$ |
| Defective plastic rolls | $$Defective\ rolls\ quantity\ (\%) = \frac{(Final\ quantity\ of\ defective\ rolls\ (kg) - Initial\ quantity\ of\ def.rolls\ (kg}{(Initial\ quantity\ of\ defective\ rolls\ (kg))}$$ |

## 4. Validation

The proposed model was validated using Arena Simulation software, this section aims to evaluate the proposed tools at each stage of the extrusion process. First, the process limits were defined in order to proceed with the simulation of the extrusion process. The beginning of the extrusion process was delimited as the arrival of the polymers in the mixing area and the end, as the output of the produced heat-shrinkable rolls. Secondly, the input variables that are involved in all the activities of the process were defined and classified into controllable and not controllable variables in order to provide a more complete view of the system to be simulated and, consequently, to have a deeper analysis of the expected results.

Table 3. System variables

| Controllable | Not controllable |
|---|---|
| Raw materials | Demand |
| Materials and equipment | Activity times |
| Number of operators | Percentage of defective products |
| Company machines | Percentage of waste |

Thirdly, the times and distributions of all activities were calculated; and the entities, attributes and resources used within the process were defined based on the previously defined limits. Finally, we proceeded with the simulation of the current and optimal model.

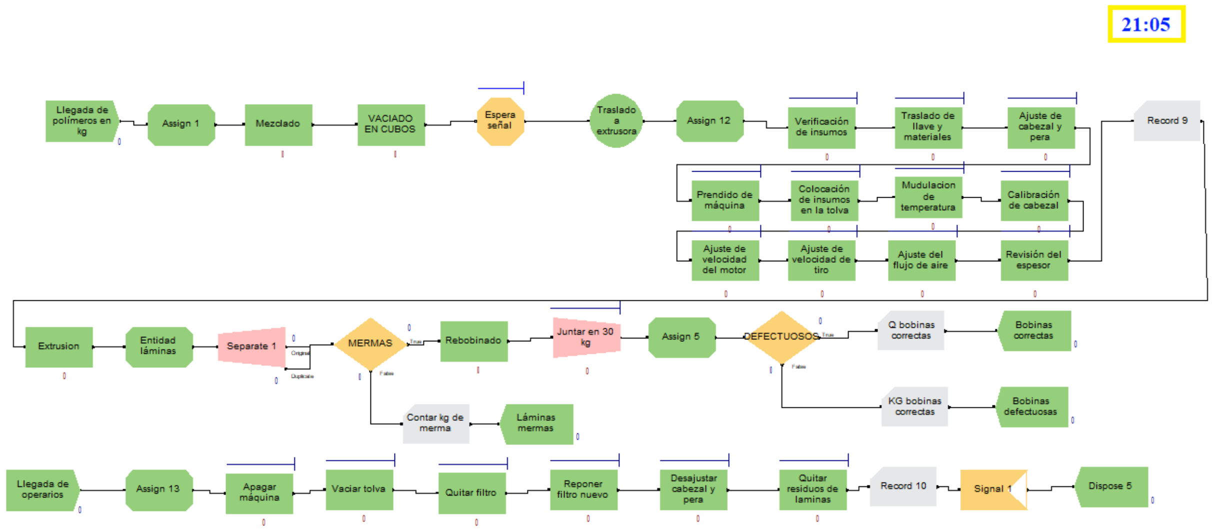


Figure 5. Simulation of the current model

As can be seen in the current model, the polymer extrusion process starts with the input of the polymers for subsequent blending. As mentioned above, the setup activities were simulated, which are carried out in series. After that, extrusion is performed, which is the most time-consuming process, and once the mixture is extruded, the sheet produced is rewound to finally produce the rolls, which are the final product of the process. Finally, the system presents the entity as the kg of incoming polymers and the resources as the two workers who perform the setup of the machine.

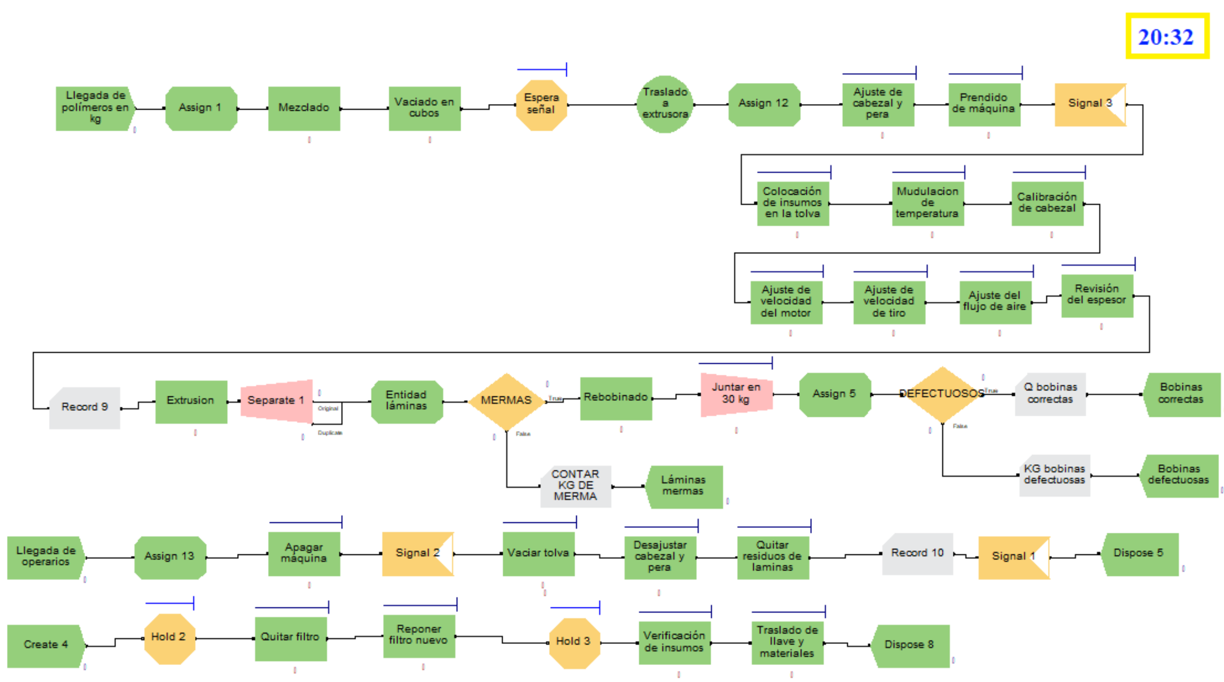


Figure 6. Simulation of the optimal model

With respect to the optimal model, the extrusion process was simulated by applying the proposed tools and substantial reductions in waste and defective products were obtained. In addition, an additional worker was added in order to consolidate the change of certain activities from internal to external setup, which reduced the time of the extrusion process as shown in the figure.

In order to have the optimal number of replicates for both the simulation of the current and the improved model, the output analyzer analysis was performed. For this purpose, a sample of 30 replicates was taken in both systems so as to hopefully arrive at a tighter confidence interval. The following data were obtained:

Table 4. Output analyzer

| IDENTIFIER | N0 | HALF WIDTH | H0^2 | EXPECTED HALF WIDTH | H^2 | N |
|---|---|---|---|---|---|---|
| Current system time | 30 | 4.2279 | 17.875 | 2.1 | 4.41 | 122 |
| Improved system time | 30 | 2.4536 | 6.02 | 1.5 | 2.25 | 81 |

With the output analyzer analysis, it was obtained that it is necessary to perform 122 replications for the current system, and 81 replications for the improved system.
Once the simulation of the current and improved model was performed, the output indicators or outputs of the system were identified, as shown in the following table.

Table 5. Outputs

| IDENTIFIER | CURRENT SYSTEM | IMPROVED SYSTEM | UNITS |
|---|---|---|---|
| Total system time | 1263.5 | 1219.6 | Minutes |
| Setup time | 82.43 | 74.38 | Minutes |
| Correct plastic rolls | 422 340 | 448 050 | Kilograms |
| Defective plastic rolls | 8 880 | 6 360 | Kilograms |
| Waste | 13 270 | 9 230 | Kilograms |
| Number of correct plastic rolls | 14 078 | 14 935 | Units |
| Number of defective plastic rolls | 296 | 212 | Units |

As can be seen in the table, the main indicators of the current and improved system are related to total and partial times, number of shrinkage and defective leaks, and number of correct rolls produced, both in kilograms and units.

## 5. Results and Discussion

### 5.1 Numerical Results

Taking into consideration the simulation of the improved system, a traffic light table has been created that shows the results obtained by using Lean Manufacturing tools. The current results column shows the data obtained at the beginning of the investigation, which reflect a productivity problem. The "Objective" column shows the values that were expected to be reached. Finally, the "Improvement" column shows the results validated by the simulation. In this last column, the yellow color indicates that the objective has not been reached, although an improvement in the indicators has been achieved. On the other hand, green indicates that the proposed objective has been exceeded.

Table 6. Model results

| MODEL RESULTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Problem** | **Current** | **Objective** | **Improved** | **Cause** | **Indicator** | **Current** | **Objetivo** | **Mejorado** |
| Low productivity | **0.21** | **0.231** | **0.22** | Inefficient polymer blending | Waste quantities (kg) | **12 896.4** | **10 317.2** | **8 970.2** |
| | | | | Inefficient setup process | Setup time (min) | **78.0** | **66.3** | **70.4** |
| | | | | Non compliance with quality standards | Defective plastic rolls quantities (kg) | **10 957.8** | **8 766.2** | **7 848.2** |

## 5.2 Graphical Results

Comparative bar graphs of current data, targets and improved results are shown below.

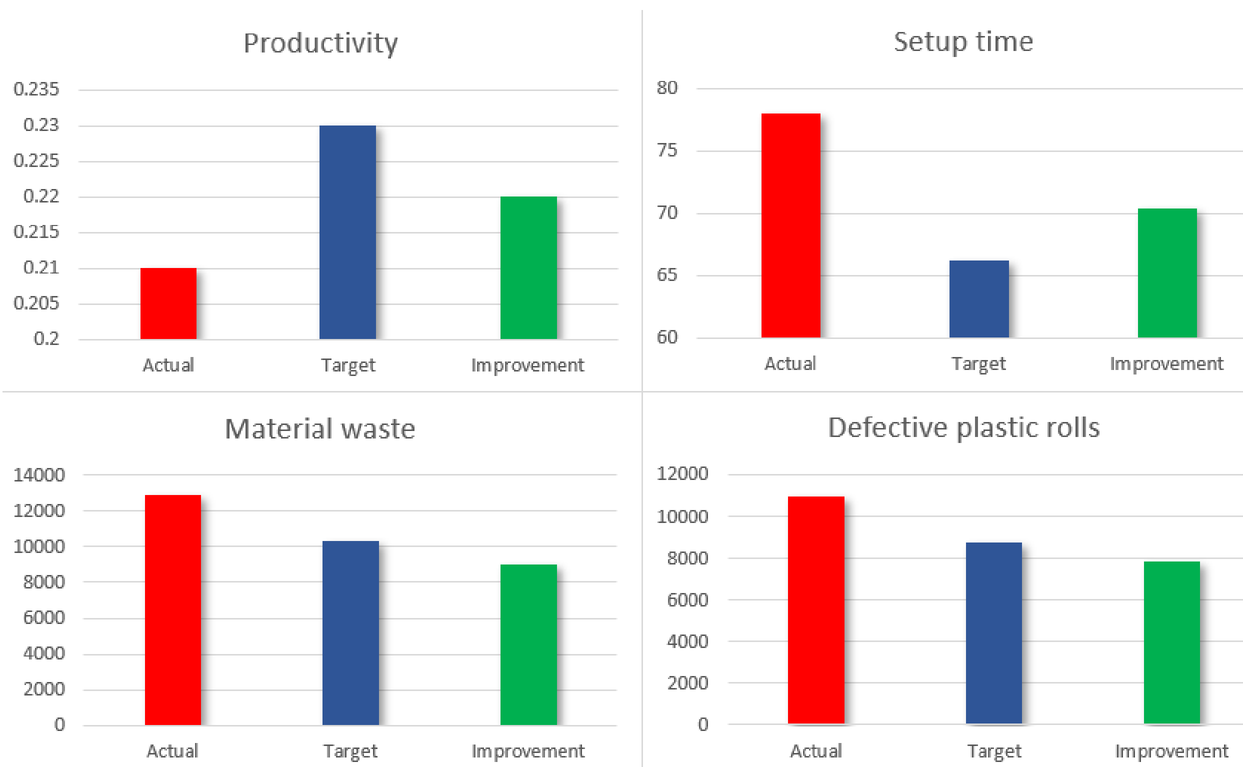


Figure 7. Graphical results

With the simulation it was possible to verify that productivity, setup time, waste quantities and production times showed an optimal variation.

## 6. Conclusion

With the proposed implementation of the continuous improvement model, it is possible to increase the productivity of the extrusion process of an SME in the plastics industry by 4.97% as shown in the results obtained; achieving an increase in productivity from 0.21 to 0.22, acquiring an increase in the overall efficiency of the company.
With the results obtained, it was possible to determine that with the use of the standard work tool it was possible to reduce the amount of wastage by 30.44%, which is the most significant improvement. Similarly, the SMED tool achieved a 9.77% reduction in setup time by converting part of the internal tasks to external ones, which in turn caused a reduction in unproductive times. Finally, with the proposal of the TPM tool based on the fourth pillar (quality maintenance) it was possible to reduce the number of defective rolls by 28.38%, which implies a reduction in the rate of returns in the company.

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