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Application of 5S and SMED to Reduce Defective Products in a MYPE of the Metal- Mechanic Sector

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Abstract

The purpose of this work is to reduce the number of defective burners in a small metal-mechanic company. For this purpose, the implementation of continuous improvement tools was used, making use of Lean Manufacturing. In particular, the 5S methodology was applied to promote order and cleanliness in the production area, while SMED was used to shorten changeover times between processes. The proposal was validated through two approaches: a one-month pilot test to evaluate the application of 5S, and a simulation with Arena software to analyze the impact of SMED. Overall, the adopted strategy emerges as an effective and adaptable option for organizations seeking to minimize waste, raise the quality of the final product and optimize their production performance.

Keywords
Lean Manufacturing, SMED, 5S

1. Introduction
In the metal-mechanic sector, variables such as defective products, the 5S methodology and the SMED technique have gained great relevance to improving operational efficiency and quality in production processes. Globally, concern about defective products has intensified, as evidenced by the European Commission proposing in 2022 an update of Directive 85/374/EEC to adapt to new technological realities, recognizing that unsafe products can arise at any point in the supply chain, whether due to human failure or systemic errors (European Commission, 2022). In the Americas, these problems have driven the adoption of continuous improvement tools, such as 5S and SMED, which allow reducing errors and downtime, thus increasing the competitiveness of the sector (Ni, Tang and Pyke, 2014). In Peru, the situation is no different; in 2022, the manufacturing industry recorded more than 7,000 occupational accidents, which has motivated many metalworking companies to apply methodologies such as 5S, whose impact has been documented in studies that evidence significant improvements in order, cleanliness and productivity (Santos Guerra, 2023; Universidad César Vallejo, 2022). Likewise, the application of SMED has proven to be highly effective in

reducing machine changeover times, as revealed by recent research indicating an increase of up to 44% in the availability of equipment in metalworking companies in Lima after its implementation (Romero Torres, 2023). These strategies not only make it possible to control the generation of defective products, but also to optimize the production chain, guaranteeing continuous improvement that translates into greater competitiveness and sustainability for the sector. Thus, the analysis of these variables in the year 2022 shows that both quality management and operational efficiency are fundamental pillars for the development of the metal-mechanic sector in global and regional contexts, and particularly in the Peruvian case. In this context, small enterprises (MSEs) in the metal-mechanic sector face challenges such as the scarce standardization of their production processes and a limited implementation of continuous improvement tools. This situation increases the incidence of rework and defective products, which has a negative impact on the company's image and, above all, on its profitability. The improvement of these companies in the metal-mechanic sector is essential for industrial competitiveness, considering their weight in the national productive structure. Multinegocios Vulcano SAC, located in the district of Ventanilla, is an example of an MSE in the metal-mechanic sector in Peru. The company's interest in continuous improvement and process optimization leads to the application of SMED and 5s methodologies, methodologies aimed at mitigating the main problem in the company, which is the amount of defective products. Their effective implementation can generate concrete benefits such as a better use of resources and the promotion of an organizational culture based on order and continuous improvement. This research is located in the area of industrial engineering, adopting an empirical approach that analyzes the application of consolidated methodologies within local realities. At a practical level, it seeks to demonstrate the benefits of incorporating these tools in smaller scale companies so that they can be replicated in organizations of the same sector.

1.1 Objectives

- To implement improvements in the manufacturing process of stove burners in a metal-mechanic company, using the 5S and SMED tools, with the purpose of reducing the incidence of defective products and increasing operational efficiency.
- -To examine the current state of the company, identifying the main failures or inefficiencies that cause defective products.
- -Analyze the effects of the improvements applied on key indicators such as the number of defective products, reprocessing times, total production time, and the number of defective products.

2. Literature Review

2.1 Product defects in the metalworking industry

The problem of defective products in the metal-mechanic sector has been the subject of multiple investigations, showing the need to implement advanced technologies and continuous improvement methodologies to guarantee quality and efficiency in the production processes. In this context, several studies have addressed the detection and prevention of defects in metal-mechanical products, offering innovative and applicable solutions in industrial environments. For example, Kheir-Eddine et al. (2022) developed an artificial intelligence-based system to predict tool wear and detect defects in specialized milling machinery. Using low-cost acceleration sensors, they achieved effective machine condition monitoring, allowing them to identify conditions such as blade wear and assembly failures. This approach demonstrates the feasibility of implementing cost-effective and efficient solutions to improve quality in metalworking production. In the field of metal surface inspection, Alaa et al. (2024) proposed an automated defect detection model using Vision Transformers (ViTs). Their system achieved high accuracy in defect classification and localization, overcoming the limitations of traditional manual inspections. This breakthrough highlights the potential of deep learning techniques to optimize quality control processes in the metalworking industry. Similarly, Kaur et al. (2022) designed a sequential convolutional neural network, optimized using the Taguchi method, to classify defective fasteners. Their model achieved an accuracy of 96.3% in validation, demonstrating the effectiveness of combining experimental design techniques with machine learning to improve defect detection in critical components. On the other hand, Straat et al. (2022) implemented a real-time quality control system for mass steel production using noninvasive electromagnetic sensors and machine learning models. Their approach allowed predicting key mechanical properties and detecting deviations in material quality, helping to reduce the incidence of defective products and optimize production line efficiency. In the Latin American context, Quiroz-Flores and Collao-Díaz (2022) applied Lean Manufacturing tools, such as SMED, TPM and 5S, in a Peruvian metalworking company. Their operational efficiency model succeeded in reducing set-up times and improving machine availability, thus reducing the generation of defective products and increasing production capacity. Taken together, these studies evidence that the integration of advanced technologies, continuous improvement methodologies and artificial intelligence approaches can mean a significant improvement in the detection and prevention of defective products in the metalworking sector. The adoption of these solutions not only improves the quality of the final product, but also optimizes production processes, reduces costs and strengthens the competitiveness of companies in a globalized market.

2.2 SMED in the metal-mechanic sector

The SMED (Single Minute Exchange of Die) methodology has been widely applied in the metalworking industry to reduce tool changeover times and improve operational efficiency. Several studies have documented its implementation and results in different industrial contexts. Bidarra et al. (2018) conducted a case study in the automotive industry, demonstrating that the application of SMED enabled a 45% reduction in setup times in the metal component stamping process. This result was achieved through work reorganization, personnel training and standardization of procedures. Monteiro et al. (2019) implemented SMED in a metal-mechanical company, achieving a 40% reduction in setup times on a vertical milling machine and a 57% reduction on a horizontal milling machine. The application of SMED was complemented with Lean Manufacturing tools such as value stream mapping and process flow diagrams. Gómez et al. (2024) developed a simulation model using FlexSim software to optimize setup times in a metalworking industry. The implementation of SMED allowed a 48.5% reduction in setup times and a 33.8% increase in production, evidencing the effectiveness of the methodology in complex production environments. Balon and Buchtová (2016) applied SMED in a company engaged in the production of deep-drawn steel parts for the automotive industry. The methodology allowed significantly reducing tool changeover times by converting internal activities to external ones, standardizing procedures and training personnel. Cabezas et al. (2022) implemented SMED in a Peruvian metal-mechanical company, managing to increase the availability of a steel coil cutting machine by 17.36%. The reduction of set-up times and operating cycles contributed to improve the efficiency of the production process. Taken together, these studies evidence that the implementation of SMED in the metalworking industry contributes significantly to the reduction of set-up times, improvement of operational efficiency and increase in productivity. The methodology is adaptable to different industrial contexts and can be complemented with other continuous improvement tools to maximize its benefits.

2.3 5S in the metalworking sector

The 5S methodology, which originated in Japan, has been widely adopted in the metalworking industry to improve organization, efficiency and safety in work environments. Numerous studies have documented its implementation and results in different industrial contexts. For example, Costa et al. (2018) implemented the 5S methodology in a metal-mechanical company dedicated to the manufacture of cranes, achieving a significant improvement in the efficiency and safety of the work area. The reorganization of space and the standardization of processes allowed reducing search times for tools and materials, as well as minimizing occupational risks. In the Latin American context, Herrera-Vidal et al. (2019) applied the 5S methodology in companies of the metal- mechanic sector in Cartagena, Colombia. The results evidenced improvements in productivity, reduction of response times and increase in the level of customer service. The implementation of 5S facilitated the identification and elimination of waste, contributing to operational efficiency.

In Peru, Luna Estelita and Zari Alday (2022) developed and implemented the 5S methodology in the warehousing system of a metal-mechanical company, achieving increased productivity and optimizing the parts supply process. The standardization of procedures and the improvement in the disposition of materials reduced delays in the production process. Globally, Sa et al. (2018) carried out the implementation of 5S in a metalworking company, focusing on improving efficiency and safety in the work area. The application of the five stages of the methodology allowed an effective reorganization of space, reduction of operating times and improvement in staff morale. In addition, Solis Núñez et al. (2024) conducted a systematic review of the literature on the effectiveness of continuous improvement methodologies, including 5S, in the metalworking industry. The study concluded that the implementation of 5S contributes significantly to process optimization and increased production efficiency in the sector. Taken together, these studies demonstrate that the 5S methodology is an effective tool for improving organization, efficiency and safety in the metalworking industry. Its systematic implementation, adapted to the specific needs of each company, can lead to significant improvements in productivity and process quality.

2.4 SMED, 5S to reduce defective products in the metalworking sector

The integration of lean manufacturing tools, such as 5S and SMED, has proven to be an effective strategy to reduce defective products in the metalworking industry. These methodologies allow optimizing work environments, reducing changeover times and eliminating sources of waste, thus contributing to a more efficient and higher quality production. In this sense, Silva et al. (2019) analyzed in a Brazilian metalworking company the implementation of 5S and SMED as part of a lean program, achieving a 60% reduction in changeover times and a 35% drop in quality defects, highlighting the synergistic effect of both tools in process improvement. González et al. (2020) studied a Peruvian metal-mechanic company that applied 5S to organize the work environment and SMED to optimize mold changeover, observing a 22% improvement in productivity and a significant reduction in rejected parts. Likewise, in a comparative research, Hernandez and Ramirez (2021) identified that metalworking companies in Mexico that applied both methodologies showed lower rework and waste rates, compared to those that only applied one of them, which reinforces the effectiveness of their joint use. (2022) conducted a pilot implementation in a Colombian metalworking plant and reported that the systematic use of 5S allowed the identification of root causes of defects, while SMED contributed to eliminate frequent errors during machine adjustments. Finally, a study by Fernandez et al. (2023) in an Argentinean company in the sector showed that after applying these tools in an integrated manner, defect levels dropped from 8.5% to 3.2% in three months, concluding that the combined approach has a direct impact on the quality of the final product. Overall, the studies reviewed agree that the synergy between 5S and SMED not only improves efficiency and order in the workplace, but also drastically reduces the probability of errors resulting in defective products, making it a highly recommended practice for metalworking companies seeking to improve their competitiveness.

3. Methods

The present case study, which was carried out in the company Multinegocios Vulcano SAC, located in the district of Ventanilla, Lima, Peru, has as its main purpose to reduce the number of defective products through the joint implementation of the 5S and SMED methodologies, key tools of the Lean Manufacturing system. The analysis is focused on the machining and adjustment activities of metal parts, where recurring problems such as quality defects, reprocesses and loss of time in operation changes have been identified. The proposed model begins with a detailed diagnosis of the production area. For this purpose, various instruments will be used, such as quality indicators, a Pareto diagram to prioritize problems, an Ishikawa diagram to detect root causes, and a problem tree that summarizes the operational effects of the current situation. Based on this analysis, an improvement proposal will be designed that incorporates both the 5S methodology (focused on the order and cleanliness of the work environment) and SMED (aimed at reducing tool preparation and changeover times). To measure the impact of the proposal, tools such as checklists, direct observations and time measurements using a stopwatch will be applied, both before and after implementing the improvements. Finally, the Arena software will be used.

The intervention will be structured in three stages:

a. **Process diagnosis:** evaluation of the operating environment, detection of the main sources of defects and measurement of unproductive times.
b. **Design and implementation of the proposal:** gradual application of the 5S and SMED methodologies in the most critical areas.
c. **Evaluation of results:** comparison of the main indicators before and after the intervention, such as the rate of defective products, changeover time, equipment availability and overall productivity using Arena software.

This approach seeks to demonstrate how the integrated application of these tools contributes to improve operational efficiency and significantly reduce defective products within the company Multinegocios Vulcano SAC (Figure 1).

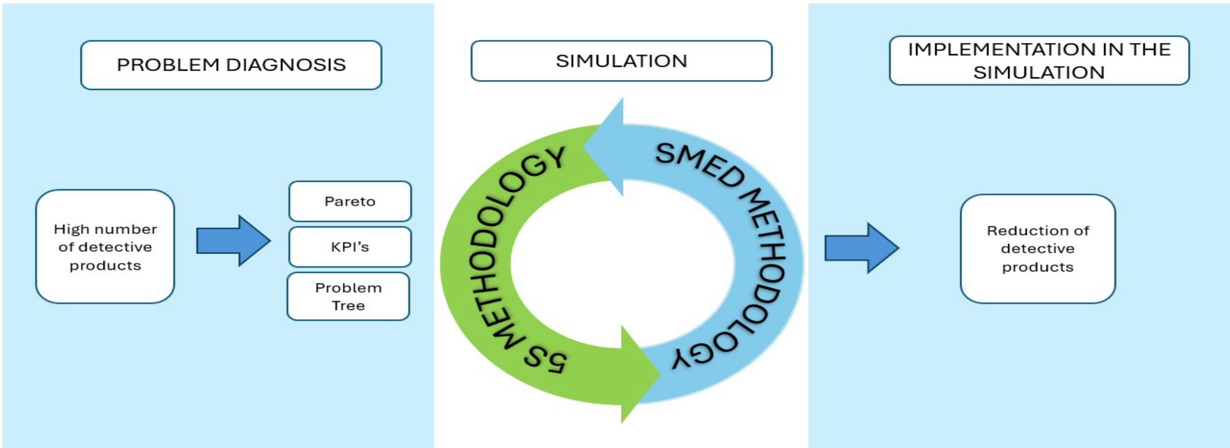

Figure 1. Proposed model

4. Data Collection

For the preparation of this study, both primary and secondary sources were used. First of all, several bibliographic materials were consulted, such as scientific articles, specialized books and previous research related to the use of Lean Manufacturing tools, specifically 5S and SMED, within the metal-mechanical field. In addition, direct visits were made to the facilities of **Vulcano SAC**, located in the district of Ventanilla, in order to observe the actual conditions in which production activities are carried out. These observations made it possible to identify more precisely certain critical points in the process. To complement this information, interviews were conducted with workers and people in charge of different areas, focusing on the most frequent problems, the times used in each operation and the indicators used to control their performance. Once this information was collected, a **Pareto diagram** was drawn up to determine the processes that most influence the generation of defective products, especially in the machining area. Based on this analysis, an **Ishikawa diagram** was drawn up to examine the possible causes of defects, taking into account aspects such as methods, labor, materials and environment. Finally, a **problem tree** was structured to relate the above findings and understand the impact of these factors on product quality and production line performance. Thanks to this data collection process, it was possible to confirm that the application of methodologies such as 5S and SMED is relevant to intervene in the identified causes, promoting a comprehensive improvement of efficiency and reduction of errors in the production processes. Figure 2 shows the process modeling in the production of the company's kitchen burners.

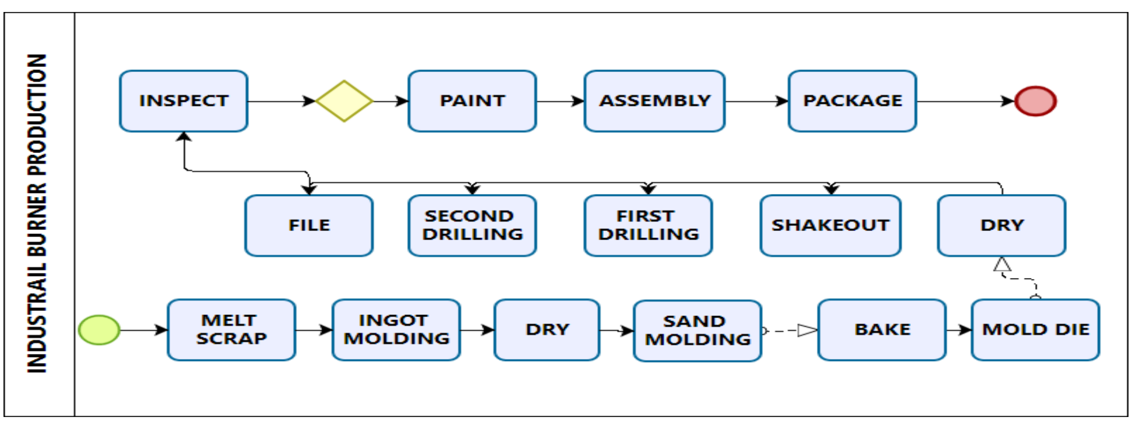

Figure 2. Bizagi Diagram

4.1 Implementation of 5S and SMED

In this step, the 5S and SMED methodologies are put into practice. First the application of 5S to maintain an orderly environment in the company and SMED to reduce unnecessary time. In the following, each methodology will be described:

- For the 5s tool, an internal audit was conducted to determine the current state of the organization and improvement measures. First, the necessary tools and materials that provide value for the production of cooking burners of a model were classified, also materials that are worn and in poor condition were separated. Secondly, all the molds and tools to be used were labeled according to the size of the stove burner, assigning a place to each one. Thirdly, the places that get the most dirty due to sand, scrap metal and paint were detected in order to generate a daily cleaning plan to mitigate the accumulation of dirt. In the fourth place, the previous processes were standardized and there are visual instructions where the personnel already know about the continuous improvement plan. Finally, there is ongoing training on the implementation and a final audit was conducted with the changes made.

- For the application of the SMED methodology, the main activities involved in this process were identified and classified according to whether they were internal or external. Each of these activities was manually timed to obtain the times for each of them. With these results, the process was analyzed and improvements

were proposed to reduce these times without generating excessive costs for the company. In this way, we sought not only to make production more efficient, but also to reduce the number of defective parts generated.

5. Results and Discussion

In order to improve the level of organization and efficiency in the kitchen burner production area, an initial audit was carried out under the 5S methodology. This assessment yielded a result of 20%, which showed a clear opportunity for improvement. In response, a one-month pilot test was implemented to apply 5S and optimize the work environment. During this process, several key actions were taken:

First, a detailed sorting of tools and materials was carried out, separating those actually useful for burner production and discarding those that were in poor condition or unnecessary. Subsequently, molds and tools were labeled according to the type of burner and assigned a specific place, facilitating their quick location.

Another important step was to identify the areas that were most dirty, due to the constant presence of sand, scrap and paint. Based on this analysis, a daily cleaning plan was established to reduce the accumulation of dirt and keep the area in optimal conditions.

The processes implemented were then standardized. Visual instructions were designed and staff were trained to ensure that everyone understood and consistently applied the improvements introduced.

As a final part, discipline and commitment were promoted through ongoing training, tracking of individual compliance and the installation of an information wall with the team's progress. This approach fostered personal responsibility and self-discipline, which was key to achieving the objectives.

Thanks to this collective and structured effort, a 76% result was achieved in the final audit, reflecting notable progress in the organization of the area and a significant reduction in production defects (Figure 3).

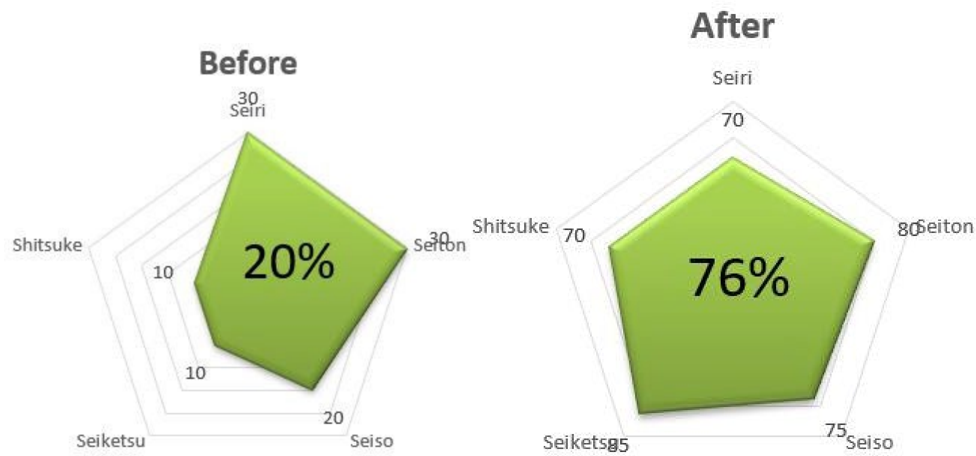

Figure 3. 5S Final audit results

After applying the 5S and SMED methodology in this work, the scenario was modeled in Arena Simulation software. Of the 9 working hours, 8 effective hours were taken into account. The time of each activity was measured with a stopwatch and this data was used in the Input Analyzer to know which distribution to use in each activity. The process starts at 8:00 a.m. with the arrival of the molten scrap ingots, which on average use 3 to 4 ingots per day (Figure 4). There are 9 employees in the company, one for each station.

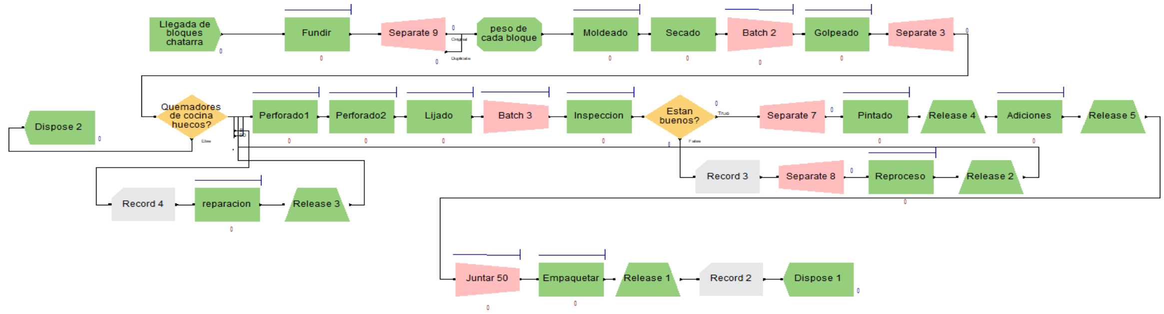

Figure 4. Process diagram

The indicators used in Arena were the following in Table 1:

Table 1. Current scenario indicators

Simulation indicators	Values obtained
Number of defective burners	7 units
total process time	7 h 52 min
total reprocessing time	16 min
Number of burners produced	345 units
average time to produce a burner	82 seconds

First pass yield	97%
Number of burners discarded	7 units

The 5S and SMED methodologies were applied as a fundamental part of the improvement process. The 5S tool significantly improved the work environment, promoting order, cleanliness, and standardization in the production area. On the other hand, the implementation of SMED contributed to the reduction of downtime and the elimination of unnecessary activities during production changeovers. As a result, a considerable decrease in the number of defective products was achieved, and shrinkage was reduced from 2% to 1%, reflecting an improvement in efficiency and final product quality. Regarding the application of SMED, it was detected that many of the main processes are internal, i.e., they require stopping production in order to carry them out. These idle times generated errors and therefore defective products. As a result, the number of defective burners was reduced from 7 to 3, the total process time was reduced and burner production increased by 11.88%.

5.1 Numerical Results

The indicators after the simulation are as follows in Table 2. During the simulation of the production process in the kitchen burner company, a total production of 386 units was obtained, of which 3 were defective. Although this number represents only 0.78% of the total produced, it is important to consider that each defective unit implies a direct loss and affects the overall efficiency of the process. The first pass yield (First Time Right) was 96.1%, a positive value indicating that most of the products were produced correctly on the first attempt. However, in industries where operational excellence is sought, it is recommended to achieve levels above 98%. The average time to manufacture a burner was 71 seconds, which reflects an efficient work rate. However, it is important to ensure that production speed does not compromise quality, as a fast pace can increase the risk of errors. The total process time was 7 hours and 38 minutes, and rework time was minimal, with only 8 minutes recorded, indicating that defective parts were not recovered, but discarded directly. Although this avoids unnecessary reprocessing, it also means a waste of materials and resources.

Table 2. Improved scenario indicators

Simulation indicators	Values obtained
Number of defective burners	3 units
total process time	7h 38 min
total reprocessing time	8 min
Quantity of burners produced	386 units
average time to produce a burner	71 seconds
First pass yield	96.1%
Number of burners discarded	3 units

5.2 Graphical Results

The following (Figure 5) visual results were obtained during the implementation of the pilot test and simulation:

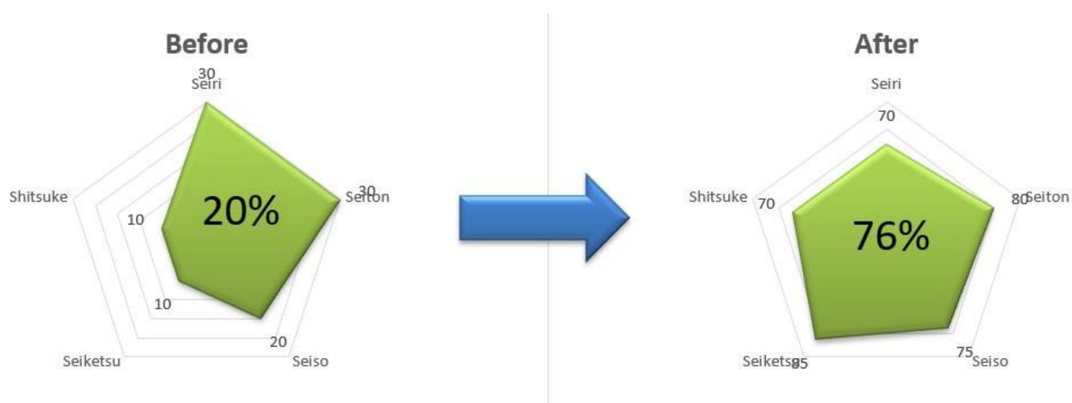

Figure 5. 5S Audit Comparison before and after

5.3 Validation

For the validation of the improvement model, a 4-week pilot test was conducted in which the improvement with the implementation of the 5S methodology was evidenced. The SMED methodology was applied in the Arena software. The results are shown in the following Table 3.

Table 3. Comparison of indicators results between scenarios

Indicators	Initial Situation	Final Situation	Percentage variation
Number of defective burners	7 units	3 units	-57.14%
total process time	7h 52 min	7h 38 min	-3.0%
total reprocessing time	16 min	8 min	-50%
Number of burners produced	345 units	386 units	11.88%
average time to produce a burner	82 seconds	71 seconds	-13.41%
First pass yield	97.0%	96.1%	-0.93
Number of burners discarded	7 units	3 units	-57.14%

From the results of the percentage variation in the indicators of the 2 scenarios, the company has made significant progress in optimizing its production process. A significant reduction of 57.14% in the number of defective and discarded burners stands out, which evidences a notable improvement in product quality and a considerable decrease in losses associated with defects. In addition, the total process time has been slightly reduced by 3%, while the time dedicated to reprocessing has been halved, showing greater efficiency and less rework. This progress is complemented by an 11.88% increase in the number of burners produced, along with a 13.41% reduction in the average time to produce each unit, indicating an improvement in production capacity and process speed. Although the first pass yield (FTR) showed a slight decrease of 0.93%, this small variation does not significantly affect the overall positive balance obtained. Overall, these results reflect a more efficient process, with better quality and higher productivity, positioning the company to better meet demand and reduce costs associated with defects and rework.

6. Conclusion

From the comparison between the original scenario and the improved scenario, it is observed that the number of defective burners decreased considerably. This improvement is related to the application of SMED and 5S methodologies, which helped to reduce variability and errors during critical operations. In numbers, the defective rate went from 2.03% to 0.78%, which validates the positive impact. As a result of optimizing set-up times and improving order at the workstations, daily production increased from 345 to 386 units. This increase represents an 11.88% improvement in the system's response capacity without requiring additional investment in machinery or personnel. The average production time per burner was also reduced, positively impacting planning and delivery. The changes made focus on standardization, order improvement and optimization of downtime. All modifications are easy to implement, do not require large resources and can be sustainable over time. Therefore, it is concluded that the proposal is feasible and useful for other organizations in the metal-mechanic sector with similar processes.

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