5th Conference on Production Systems and Logistics

Improving OEE in a Peruvian SME: A Case Study on the Application of Lean Manufacturing Tools in the Metalworking Sector

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Abstract

In Peru, SMEs have been affected by the crisis that caused the COVID 19 pandemic. Likewise, the hard competition with Asian countries like China has been a reason for Peruvian SMEs deciding to work with high-quality products. However, poor machine and maintenance management, high percentage of rework, and excessive downtime are frequent problems faced by SMEs in the metalworking sector. For this reason, the bending area was identified as the most critical. In this study, the case of a Peruvian SME that produces air conditioning products was studied. In this case, the bending area was the most critical. Therefore, the main objective of this study is to prove how the use of lean manufacturing tools can impact the productivity of the bending area, thereby improving indicators such as OEE, cycle time, unnecessary routes, and space reduction.

Keywords: Lean Manufacturing; 5S; SLP; TPM; Standardized Work, OEE, Metalworking Sector.

1. Introduction

At present, SMEs are important in our economy because they represent 90% of all formal companies. In addition, they provide jobs to many people since they generate approximately 70% of employment. [1]. In 2021, approximately 2.1 million SMEs Will be registered in Peru. These SMEs represent a significant percentage (99.5 %) of all registered companies [2]. One of the most important sectors in Peru is the manufacturing sector, which accounts for 12.7 % of the country´s GDP. In addition, it generated a large number of jobs for people, accounting for 8.8% of the national employment. Similarly, the manufacturing sector registered 15.4 % of the total tax collection in 2021[3]. The metalworking sector is one of the most important branches of the manufacturing sector. In 2022, this sector registered more than $ 264 million in exports between January and May. This sector began to expand worldwide, with sales in 89 markets. Among the countries to which exports were made in 2022, Chile, Australia, and Argentina [4].

The main problem of low production is the low availability of machinery. Likewise, It is also due to poor machine maintenance management and poor quality products that generate low profitability for the business [5]. Most companies in the metalworking sector suffer drastic problems related to the poor use of resources, which decreases the productivity and quality of products due to poor process management [6]. Peruvian companies from the metalworking sector suffer from low production due to high set-up times and low machine availability [7].

DOI: https://doi.org/10.15488/15320
ISSN: 2701-6277

It is very important that Peruvian companies in the metalworking sector improve their productivity to meet national and international demand. For this reason, this case study chose the problems of this sector in terms of low productivity and low machine availability. Because of this problem, an improvement model has been implemented using tools such as SMED, inventory control, and work standardization [8].

This scientific article is divided into the following parts: State of the Art, Which Will show the background to the problem from the perspective of different authors. Contribution: The theoretical basis of the model is presented, and the proposed model is described with the indicators used. Validation, which describes the results before using the model, implementation of pilots and simulation, and results. Finally, conclusions are presented.

2. State of the Art

2.1 Metalworking sector

There is a lot of competitiveness in the metalworking sector, which motivates companies to use tools to increase efficiency and continually improve competitiveness [9,10]. Quality is one of the most important factors to be more efficient because consumers seek high-quality products to feel safe and satisfied [11].

For this reason, it's important to apply a tool to achieve the objective of increasing efficiency and reduce costs in the production process for SMEs in metalworking sector, therefore a new model of operational efficiency has been implemented using tools from lean manufacturing such as the 5S, SLP, Standardized Work and TPM [12, 13, 14, 15].

In agreement with the foregoing, the application of these tools in this sector results in better efficiency. However, it can sometimes be improved by a large percentage or just a small percentage, so it is not always possible to reach an acceptable percentage. [16, 17]. In addition, lean tools are not the only way to improve efficiency; there are other case studies that apply DEA (), which have achieved positive results. [18].

2.2 5S Methodology

5S is a Japanese methodology derived from 5 word: Seiri (sort), Seiton (set in order), Seiso (clean), Seiketsu (Standardise) and Shitsuke (Sustain) [19]. The 5S tool has the objectives of cleanliness and order of the workplace and standardization of the area. The integration of 5S motivates employees and improves process efficiency [20].

On the other hand, the implementation of the 5S tool and other lean tools has improved efficiency, reduced operating costs, and substantially increased quality in the metalworking sector, as they address common industry problems such as long production times, late deliveries, and low productivity, highlighting the relevance of the 5S tool in this sector [21].

However, not always 5S brings impressive results; as expected, sometimes the company has little or no improvement. For example, a Peruvian company did not achieve its goals using the 5S tool because the performance was affected by the human factor focused on organizational culture and the standardization of its processes [22].

2.3 SLP – Systematic Design Planning

Systematic design planning (SLP) is a methodology that allows the observation and identification of different scenarios to determine the one that best fits the requirements of the plant. This tool contributes to reducing the bottleneck rate, reducing the cost of material handling, reducing downtime, and optimizing labor to reduce costs and optimize the plant [23,24].

Likewise, the application of the SLP tool provides positive results, such as a decrease in the flow of material, cost reduction with respect to material handling, shortening the effort of the operators, and reducing the time to search for materials, since everything was assigned in the correct place [25, 26, 27].

On the other hand, the SLP tool is very versatile and can be applied not only in the manufacturing sector, but also in other sectors such as the textile and food industries. [28, 29, 30].

2.4 TPM – Preventive Maintenance

The objective of Total Productive Maintenance (TPM) is to improve the productivity and quality of products, as well as increase employee satisfaction at work. It reduces breakdowns, eliminates losses, and thus reduce costs [31]. One of the pilars of TPM is preventive maintenance, which consists of not waiting for failure to occur but performing maintenance to avoid it [32].

In addition, the implementation of the TPM methodology led to the recognition of the importance of good maintenance management and the continuous improvement of production processes to reduce breakdowns, increase availability, and improve operational performance, supporting the effectiveness of this tool in the industrial sector for global competitiveness [33, 34].

However, this tool has also been applied to the metalworking sector in other countries. A Brazilian company implemented TPM practices and increased the MTBF indicator by more than 700%, had an MTTR reduction of more than 40%, and increased availability by more than 5% [35].

2.5 Standardized work

Standardized work is a tool for lean manufacturing that seeks to reduce variability and waste based on three elements: talk-time, sequence of operations, and work-in-process [36].

Likewise, Standardized work allows procedures and operations to be produced efficiently, seeking a minimum amount of waste. For this purpose, efficient methods and standards are used. [37].

On other hand, the application of this tool resulted in improvements in an SME in the manufacturing industry, because the percentage of reprocessing was reduced from 20.14% to 2.1% and the talk time indicator was reduced from 5.64% to 3.84%. [38].

3. Contribution

3.1 Fundamentals of the contribution

The proposed model is developed based on work management. It can be validated through its use in different studies that sought organized practice but had limited application in companies specialized in ventilation systems, contributing to the state of the art or knowledge by validating its success in increasing efficiency. Figure 1 shows the proposed model.

In this case, the 5s tools of lean manufacturing methodology were considered to focus on the organization and cleanliness in the workstation, contributing to the PDCA (PLAN-DO-CHECK-ACT) improvement cycle. These tools allow diagnostic control with different formats, 5S sequences, standard audits, and continuous improvements [39]. In addition, work standardization improves the training of operators to optimize and formalize work methods by identifying and analyzing activities that do not generate value [40].

Furthermore, it is important to consider the proposed structure when implementing the Total Productive Maintenance (TPM) strategy. It seeks the main definition of maintenance and coordination for intervention at critical points by applying the preventive maintenance plan to control and evaluate different phases [41].

Finally, the systematic layout planning (SLP) tool is of great importance as it contributes to identifying different scenarios to choose the correct sequence for the areas and optimal material transportation, storage, and operational services [42].

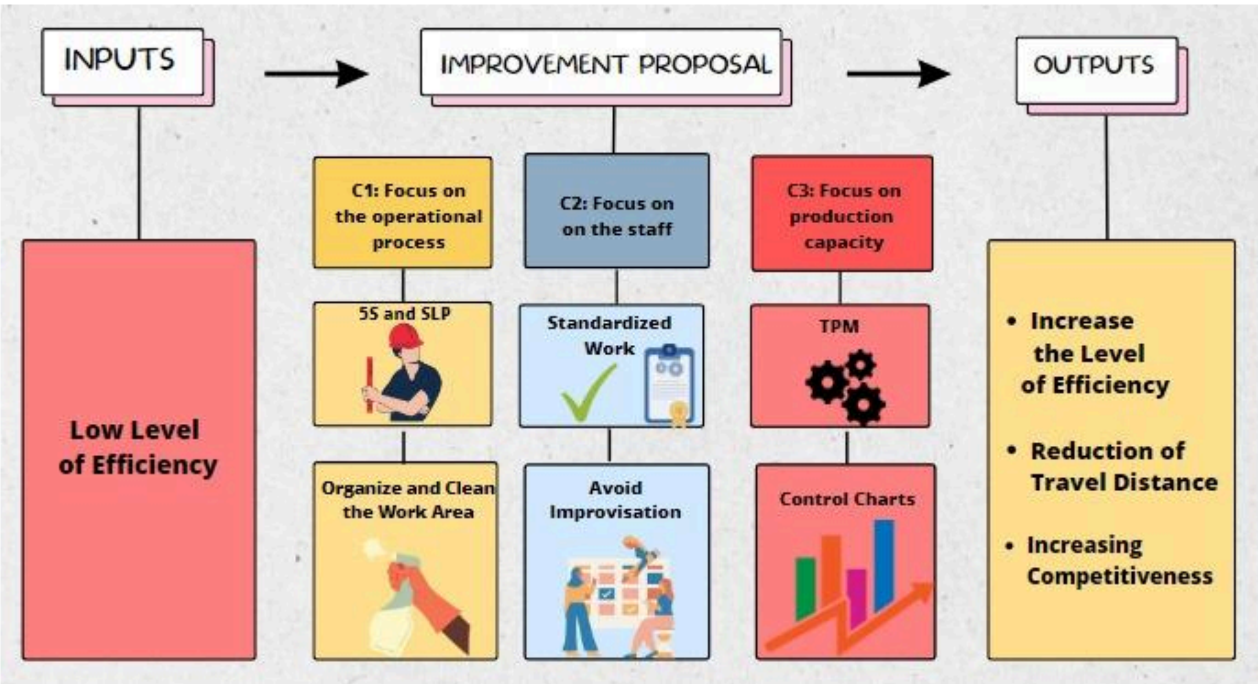

Figure 1: Basis of the Model

3.2 Proposed model

The study revealed that a singular Peruvian company in the metal-mechanical sector had the main issue of low efficiency. This situation was primarily caused by the impact of unproductive time, where the analysis showed that there were three root causes of these problems: machine failures, stoppages due to the absence of operators, and unnecessary displacements.

The first component of the model was problem analysis. In this section, the identification of different problems in the current situation is possible by applying value stream mapping to identify the operational efficiency, performance, cycle times, and others. Additionally, the structure of the layout diagram is used to record the proposed plant layout in the initial situation. Moreover, a route diagram was created to verify all activities involved in the process and find the best way to reduce time and distance. Finally, specific indicators are proposed for the four tools:5S, standardized work, SLP, and preventive maintenance, with the purpose of identifying the necessary methodologies for making the necessary changes (Figure 2).

The second component focuses on the operational process, proposing the implementation of tools that reduce no-value activities in production. For this situation, the 5s methodology will be sequentially implemented, involving sorting, organizing, cleaning, standardizing, and sustaining to improve the working conditions. Additionally, systematic layout planning will help reduce the workflow by eliminating unnecessary movements during productive activities. The main tools in this component are summarized in the next section.

- Red card to identify useless items.
- 5S schedule.
- 5S Waste notification report.
- Process for 5S audits.

- Code for reasons and order of proximity.
- Correlation and thread diagrams.
- Procedure for implementing Standardized Work (SLP).

In addition, the focus on personal will be maintained, utilizing a standardized work tool to enhance their performance and capacity by primarily selecting methods, procedures, and work practices to reduce variability. The main tools in this component are summarized in the next section.

- Standard Work Diagram.
- Standardized Work Combination Table (SWCT).
- Training Record.
- Standardized Activity Plan.

Then, the focus on production capacity will be to implement Total Productive Maintenance (TPM), primarily through preventive maintenance, to solve critical points within the production areas by conducting maintenance activities on each machine and defining the times, resources, and frequencies involved in reducing operational issues. The main tools in this component are summarized in the next section.

- Failure mode and Effects Analysis (AMEF)
- Maintenance control for continuous improvement
- Preventive maintenance training plan

Finally, the third component verifies objective compliance to ensure that the developed model achieves increased operational efficiency. Additionally, audits will complement it to maintain activities according to the production standard by comparing before and after implementation. Figure 2 illustrates the implementation of the proposed model.

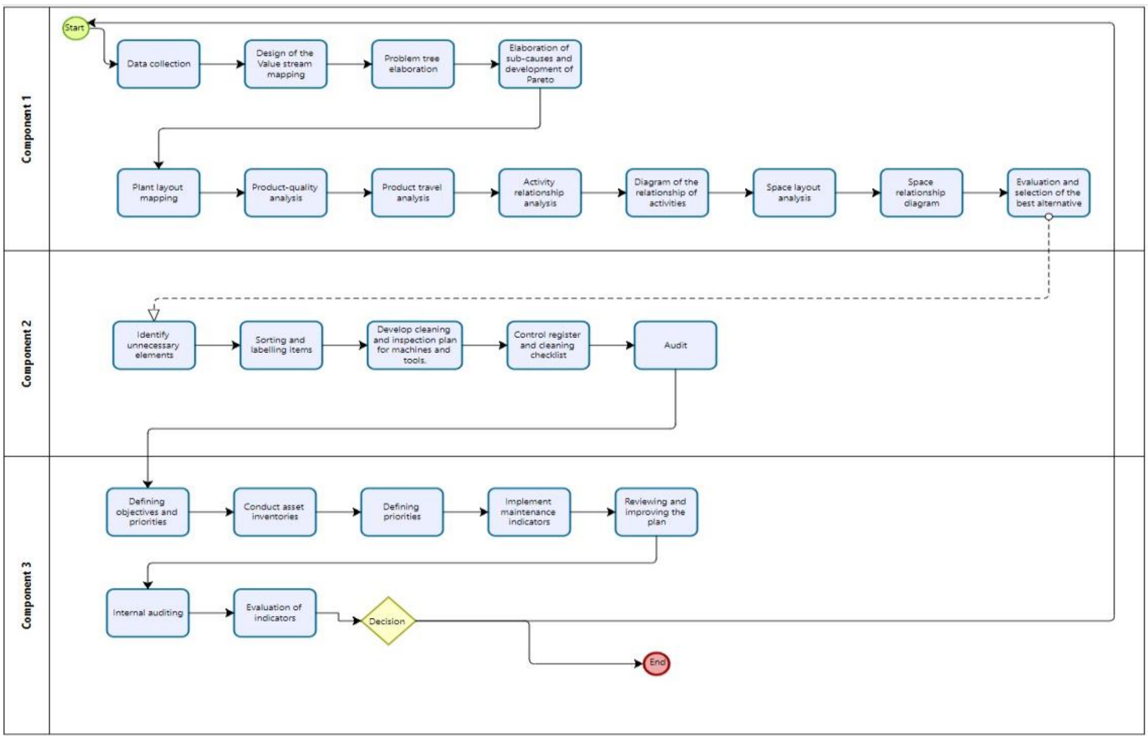

Figure 2: Proposed Model

3.3 Model indicators

To evaluate the enhancements brought about by the proposed model, the following indicators must be used:

Overall Equipment Effectiveness (OEE)

These investigations indicate that lean manufacturing tools can increase the OEE indicator by 3.75% [43].

$$OEE = A\ x\ P\ x\ Q$$

$$Availability\ (A) = \frac{Run\ Time}{Planned\ Production\ Time}$$

$$Performance\ (P) = \frac{Ideal\ Cycle\ Time\ x\ Total\ Count}{Run\ Time}$$

$$Quality\ (Q) = \frac{(Units\ Produced - Defects)}{Units\ Produced}$$

Mean time between failures (MTBF)

A study demonstrated that a 15% increase in MTBF can be achieved by improving the level of availability [44].

$$\beta = \frac{Operating\ Time}{Number\ of\ faults}$$

Cycle time

Several studies have mentioned that the implementation of standardized work can improve the cycle time indicator by 9% [45].

$$\gamma = \frac{Available\ Work\ Time}{Units\ of\ work}$$

Unnecessary travel routes

Many studies have indicated that the implementation of SLP can lead to an approximately 22 % reduction in unnecessary travel [46].

$$\delta = \left(\left(\frac{Final\ Total\ Distance}{Initial\ Total\ Distance}\right) - 1\right) x\ 100$$

Tool search time

Using the 5S tool, the search time indicator was reduced by 30.27% [47].

$$\theta = \left(\left(\frac{New\ Area}{Current\ Area}\right) - 1\right) x\ 100$$

4. Validation

4.1 Initial Diagnosis

The case study presents a technical gap related to low operational efficiency in production, which is below the 85% standard. This is because the current production model achieved only 64% efficiency. In this structure for the diagnosis data collection, it was found that the main cause of the problem was machine breakdown, representing 86.38%. The primary causes arise from machine issues (51.41%) due to a lack of maintenance plans, downtime due to the absence of operators (15.14%) as the company undergoes personnel changes that are inexperienced in machine operation, and unnecessary displacements (6.62%) as the layout of the machinery results in long travel distances due to a lack of organization and cleanliness. Figure 3 summarizes the problem tree based on the technical diagnosis conducted during 2022.

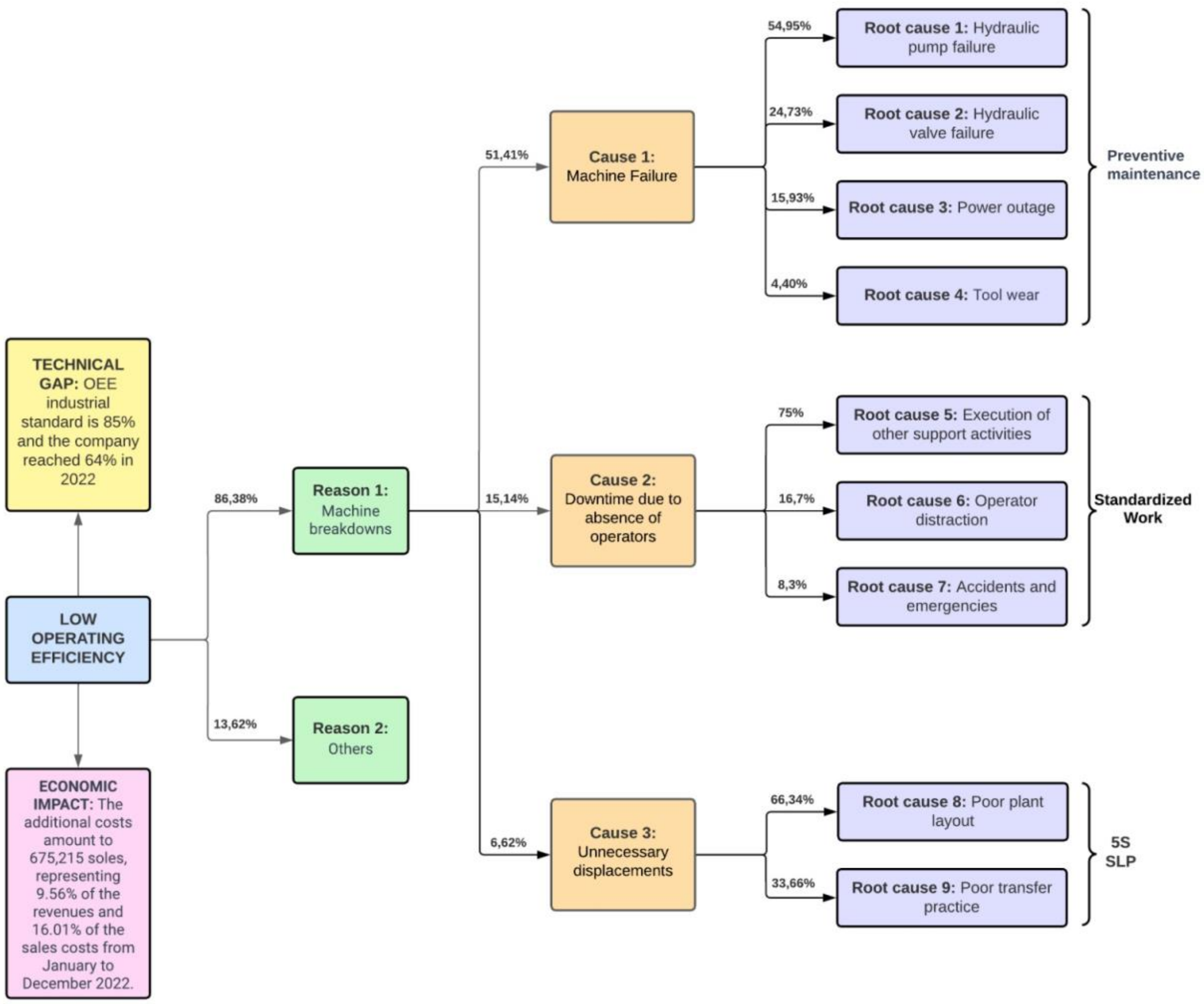

Figure 3: Problem Tree

4.2 Implementation for the pilot plan in 5s and SLP

First, the tools were classified using a control card to group all objects in the warehouse, count them, identify their respective purpose, frequency of use, necessity in production, and observation of their condition. Additionally, unnecessary items were removed if they were damaged, non-functional, or not in the warehouse.

Second, signs were placed on the shelves and labels were attached to each item. These items were grouped based on their frequency of use, with those used most frequently being placed closer to the main door.

Third, the entire warehouse and the instruments or tools inside were thoroughly cleaned. To establish better cleanliness control, a brief talk was given to explain the benefits of cleanliness, and a registration form was created for each operator to complete on the day they performed the cleaning.

Next, the number of maintenance inspections was monitored to confirm the effectiveness of the work. Subsequently, a procedure was implemented to maintain order in the warehouse, which was posted outside the main door for all employees.

Finally, a daily cleaning control sheet was developed. It is important to remind all company employees about the philosophy of the 5S tool and strive to achieve its objectives. Therefore, a panel was placed on the wall, indicating the meaning of the 5S, the objectives, and the steps to follow in this philosophy. These actions were undertaken to motivate operators and enable them to perform their tasks correctly. Table 1 shows the initial 5S audit.

Table 1: Initial 5S audit

Phases of 5S	Start	Objective	Percent
Seiri - Sort	3	10	30%
Seison – Set in order	3	10	30%
Seiso - Shine	5	10	50%
Seiketsu - Standardize	4	10	40%
Shitsuke - Sustain	3	10	30%

An analysis of the current workshop layout and optimized plant layout design was proposed. The effort was then calculated to compare it with the current situation, previously determined during the company diagnosis, resulting in the measurement of the productivity variation. Figure 4 illustrates the proposed layout.

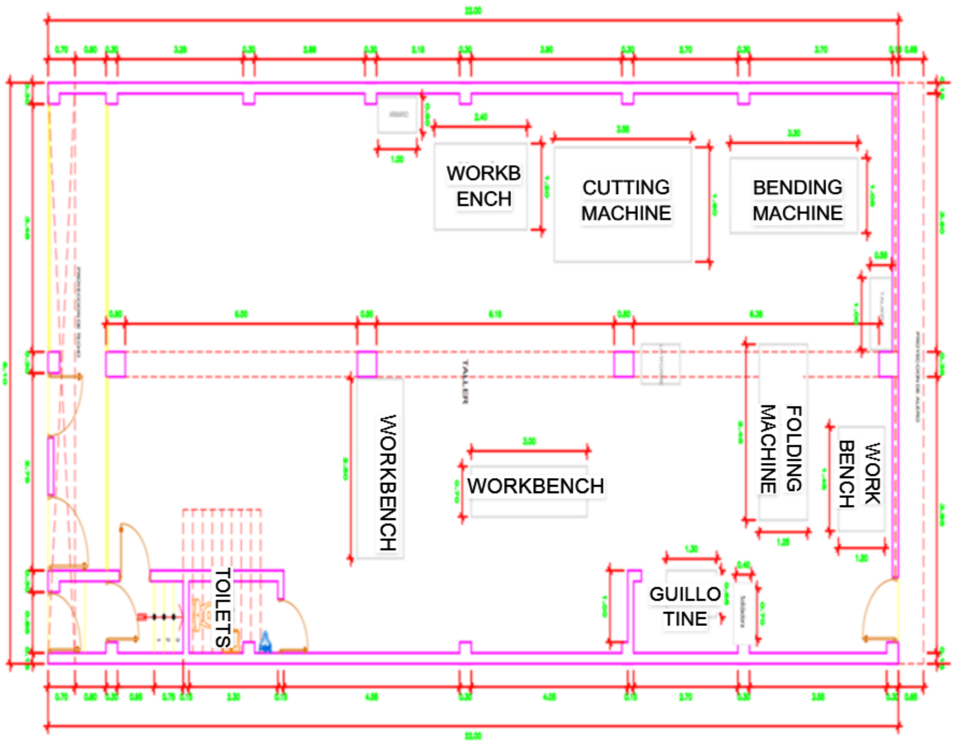

Figure 4: Improvement proposal for Workshop Layout.

4.3 Simulation improvement proposal

The simulation started after the 5S and systematic layout planning implementations using the Arena software, where the main problems identified were the excessive times in the bending activity and the different unproductive times owing to constant machine breakdowns. The figure shows the improved system, starting from order arrivals, where the ventilation system design was specified, to storage and dispatch. Changes were made by increasing resources with the support of an assistant in bending and shearing, specializing in work activities, and implementing a maintenance plan to reduce machine breakdowns and minimize downtime. An input of 40 samples was implemented to increase the accuracy of the values, considering a confidence level of 95% and margin of error of 5%. This resulted in an optimal value of 95 repetitions with confidence intervals of [1.94, 3.29]. The distributions were adjusted using the input analyzer, where only values with a chi-square greater than 0.15 were accepted. Figure 5 shows the simulation of the process using the Arena Simulator software.

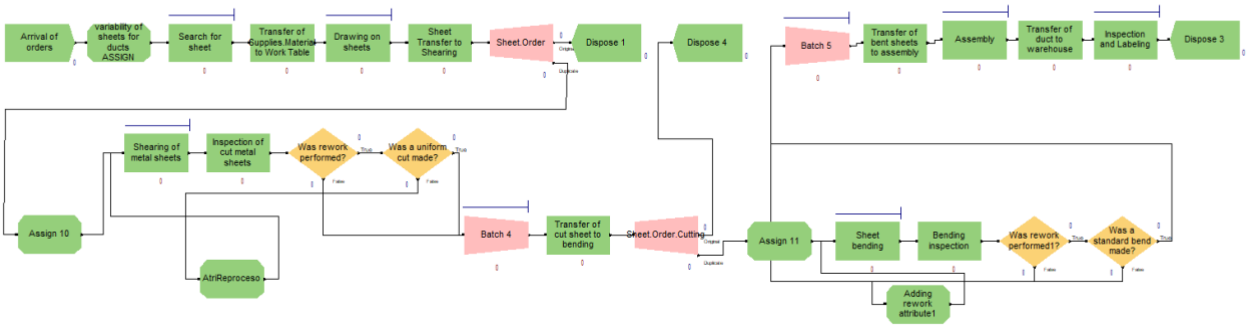

Figure 5: Simulation model in Arena

Table 2 lists the results of the in-house application and the simulation.

Table 2: Model Indicators

Problem	As is	Objective	Results	Cause	Indicator	Actual	Improved
Low Efficiency	64%	85%	72%	Machine Failure	MTTR	1.32 days	5.1 days
				Downtime due to absence of operators	Cycle time	2.69 hr	2.27 hr
				Unnecessary displacements	Unnecessary travel routes	43 m	21 m
					Tool search time	5 min	3 min

5. Results and Discussion

The proposed model, based on increasing efficiency in a company specializing in the production of industrial ventilation systems, utilized 5S, SLP, Standardized Work, and Preventive Maintenance tools. These tools address issues related to machine failures, operator absences, and unnecessary displacements. The results from Table 2 are interpreted in this section, starting with the company's efficiency not reaching the acceptable minimum of 85%; however, the trend shifted from poor to fair, ranging between 65% and 75%. In fact, the 5S tool enabled a 66.67% reduction in the tool search time by maintaining order and cleanliness in the work environment. The SLP achieved a 104% reduction in unnecessary displacements between different areas by redistributing the areas for better flow. The implementation of standardized work in machine operations resulted in a 15.61% reduction in cycle time, as the standardization of machine functioning was established owing to technical operator **inexperience.** Finally, the preventive maintenance program ensured that the Mean Time to Repair (MTTR) remained above the optimal level by approximately 200%. This was achieved by scheduling complete operation shutdowns on Saturdays for equipment repair and maintenance, allowing them to remain operational during the workweek. These methods have an impact on the standard deviation by reducing the variation compared with the others. However, it is important to note that the mean value indicates a different situation in terms of maintaining wide ranges, especially when compared to the results from the reviewed studies for MTTR (Mean Time to Repair) and SLP (Service Level Performance).

6. Conclusion and outlook

This study presents a model composed of the use of four tools (Standardized Work, 5S, SLP, and Preventive Maintenance), which achieved an efficiency level of 72%, an acceptable level when seeking improvement, although it has not reached the global standard. The improvement was achieved through the reorganization of work areas by reducing distances using SLP, where the organization and cleanliness provided by the 5S tool were key to maintaining commitment to the objective. Additionally, machine downtime was reduced owing to stoppages caused by poor maintenance, which was addressed through a structured preventive maintenance plan tailored to the type of industrial machinery. The variability in equipment handling by the staff was also reduced by maintaining standards in work activities. Future studies should delve deeper into this research to verify its long-term effectiveness as this is a prototypical review of the model.

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