Proceedings of the 11th World Congress on Mechanical, Chemical, and Material Engineering (MCM'25)
Paris, France - August, 2025
Paper No. ICMIE 144
DOI: 10.11159/icmie25.144

Operational Model to Improve On-Time Delivery: A Peruvian Case Study in Metalworking SMEs Integrating Lean Tools and TPM

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Abstract **-** The Peruvian metalworking sector has historically faced delays in deliveries due to poor process standardization and inadequate equipment maintenance. While previous studies have addressed Lean tools separately, limited empirical evidence exists regarding their integrated application within a single model for SMEs in this sector. This research addressed key challenges—machine stoppages, production delays, and disorganized workspaces—through an operational model combining Standard Operating Procedure (SOP), 5S, Total Productive Maintenance (TPM), and Single Minute Exchange of Die (SMED), validated through simulation and pilot implementation. SOP was defined as a standardized set of instructions ensuring the correct execution of operational tasks. The 5S tool increased audit scores from 34.4% to 84.3%, TPM improved OEE from 24% to 67%, and SMED and SOP together reduced changeover time by 64.8 minutes. The findings demonstrated measurable gains in productivity and process organization. At the industrial level, the model provides practical implications for SMEs aiming to enhance operational performance in emerging markets with resource and time constraints.

Keywords**:** On-Time Delivery, Operational Efficiency, Process Standardization, Logistics Optimization, Voice Picking.

1. Introduction

The Peruvian metalworking sector has been key within the manufacturing industry, standing out as one of the most important economic activities in the country. As of 2022, it has shown sustained growth, with estimates projecting a value of 12.85 billion dollars by 2027, supported by an average annual growth rate of 3.9%. This outlook highlights the relevance of the sector for the national economy and its competitiveness in global markets. However, it has not been free of difficulties. International factors, such as the conflict between Russia and Ukraine, have posed serious challenges to the post-pandemic economic recovery, negatively impacting supply chains, increasing inflation levels and generating economic sanctions [1]. At the regional level, Latin America presents a talented outlook for the development of the metalworking sector, with projections of an increase in annual industrial production by 2024 in countries such as Uruguay, Colombia, Brazil, Mexico and Peru. In this context, Peru is expected to rank sixth in the manufacturing ranking in the region, achieving growth of 1.6%. In 2023, the Peruvian industry contributed 1.4% to the country's Gross Domestic Product (GDP) and reached 11.2% of GDP related to the manufacturing sector [2]. What makes one of the most important challenges of the metalworking sector in Peru is the delay in the delivery of finished products, which has an unfavorable impact on its competitiveness and its ability to remain financially stable [3]. These delays not only generate customer dissatisfaction, but also increase operating costs and reduce companies' profit margins. Internally, it has been identified that a large part of the operational inefficiencies in companies in the sector is due to the lack of standardization of processes and inadequate management of machinery maintenance. Recent studies revealed that 60% of the maintenance activities carried out in Peruvian companies are corrective, when the optimal international standard is approximately 38%. This unbalanced proportion indicates that the lack of adequate preventive maintenance generates equipment failures, affecting operational continuity and delivery times. Various studies have shown that the implementation of continuous improvement tools can significantly transform the operation of companies in the metalworking sector [4]. The set of improvement tools, which includes SOP, 5S, TPM and SMED, has the potential to address the main problems of the sector. The central motivation of this research lies in demonstrating how continuous improvement tools can optimize production processes, increasing operational efficiency and reducing economic losses associated with current inefficiencies. The general objective of the study is to implement an improvement model that combines SOP, 5S, TPM and SMED methodologies, in order to improve productivity and reliability indicators in deliveries.

2. State of the art

The search for scientific articles was carried out in 4 databases filtering them by keywords with an age of 5 years, obtaining a total of 40 articles of which 4 were essential for the development of this article.

2.1 5s tool in metalworking companies

The study carried out by the metalworking company was to implement lean manufacturing, such as the 5S methodology and total productivity maintenance techniques. As a result, in the last four months, the application of the first three phases of the 5S in a pilot area allowed to eliminate a total of unnecessary materials, which represented a large percentage of the wasted space in the area intervened by this method [5]. In this way, the implementation of the 5S methodology has a positive impact on working conditions, with notable improvements in different aspects. In particular, significant progress is observed in the identification and elimination of unnecessary objects, as well as in the organization and cleaning of the work area, especially in the area intended for the work station. This demonstrated the effectiveness of the best implements in the operating equipment [6].

2.2 Total productive maintenance in the Metal-mechanical Industry

Total Productive Maintenance is implemented in the metalworking industry with the aim of maximizing the effectiveness of equipment, optimizing its availability, performance and the quality of manufactured products. Its main focus includes two key pillars: autonomous maintenance and planned maintenance. On the one hand, autonomous maintenance trains operators to perform basic equipment care tasks, such as cleaning, lubrication and periodic adjustments, strengthening the life of the machines and improving the quality of the final products. On the other hand, planned maintenance focuses on periodic interventions carried out by specialized technicians, in order to preserve the equipment during its life cycle and prevent unexpected failures [7].

2.3 Application of improvement tools in the metalworking sector

The aspects that metalworking companies fall back on are the quality, control and inspection of the processes. Therefore, detecting and eliminating the causes is essential to increase the efficiency and productivity of the processes [8]. Using TPM, it was possible to increase the OEE by 3.5% in the 3 areas evaluated and thus increase the availability, quality and performance of the machines [9]. With the application of the 5s tool reductions in waste and idle time were obtained by 5.26% and 5.13% respectively [10]. Using the SMED and SOP tools they achieved a reduction in processing time to a time of 607.5 seconds from an initial time of 848.6 seconds, which represents a reduction of 28.41% [11].

2.4. Metallurgical sector

The metalworking industry in Peru has been evolving since 2020, when this sector fell significantly due to the pandemic, which was recovering until 2022 reaching a value of 8,268 million PEN and having a slight drop of 6.9% in 2023 due to the decrease in construction activities [12]. In order for the metalworking sector to face challenges and continue to strengthen itself exponentially, the implementation of process improvement tools together with investment in new technologies is necessary, which will not only improve productivity and efficiency in the production of a product, but will also allow reducing costs and increasing the profit margin. In this way, the company will be able to cover and serve the products requested in the market.

3. Problem

As can be seen in Figure 1, the reasons for the general problem of late order handling are detailed. Each of the reasons was evaluated and analyzed using data collected in 2023 in the metalworking company. The first reason for the delay in order handling is the stoppage of machinery, which represents 47.62% of the general problem. To solve this point, the TPM tool was implemented, focused on the pillars of autonomous and predictive maintenance, and SOP (Standard Operating Procedure) to seek to reduce unexpected failures or stops either by the machine or by poor handling by operators. For the second reason, which represents 33.33%, which is the delay in the production chain, the SMED tool was used to identify the type of activity carried out by the operator, which are divided into internal and external, with their respective time measurements and in this way reduce it and obtain an adequate average time for each activity. As a last reason, there is the disorganization in the warehouse area, which will be worked on with the 5s tool, which aims to optimize the work area by eliminating non-useful components and assigning locations for the necessary objects or materials.

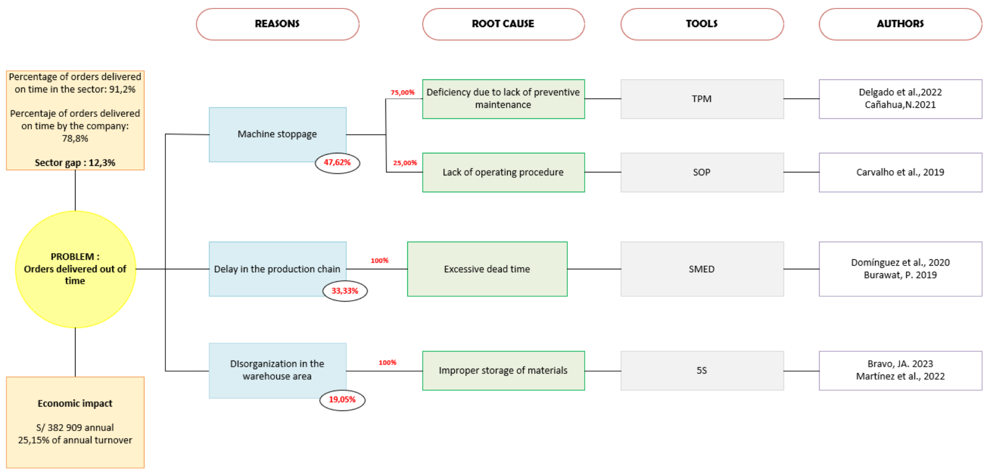

Fig. 1: Root cause diagram - tools

3. Methodology and implementation

Figure 3 presents the proposed model, designed based on the analysis of the literature. In particular, it is based on the success stories of companies that have implemented the methods mentioned, obtaining favourable results, as detailed in chapter. Therefore, the SOP, 5S, SMED and TPM tools were used with the aim of reducing downtime and inefficiencies related to the use of machinery.

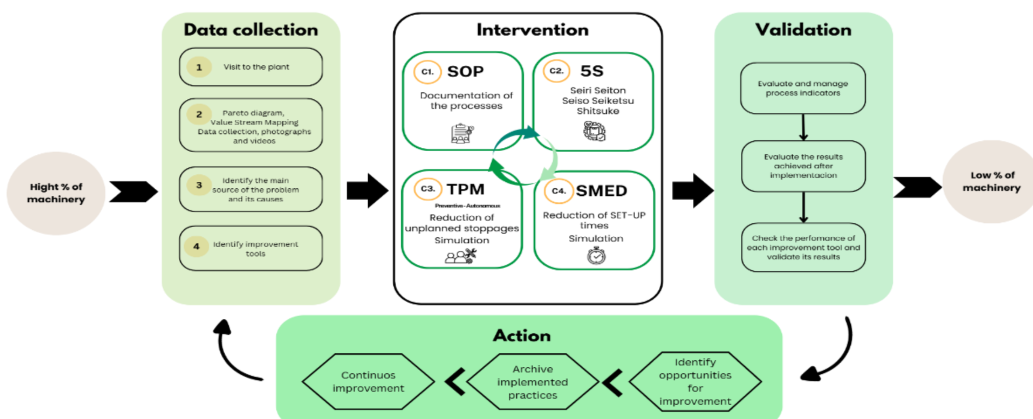

Fig. 2: Conceptual model and its components

Component 1:

According to Alhaj [13] Standard operating procedures (SOP) describe step by step work instructions that carry out operations correctly. They are also written documents or work instructions that detail all the steps involved in a procedure or process. Standard operating procedure development services include mapping processes from start to finish and formatting standard operating procedures into organizational templates and structures.

Component 2:

According to Manzano & Gisbert [14]. 5S is a Lean Manufacturing tool that seeks to establish and standardize a series of order and cleanliness routines in the workplace. As illustrated in Figure 4, this tool establishes a structured process for continuous improvement. First, a diagnostic audit is carried out to assess the current status, followed by the development of an action plan based on the 5S principles: Seiri (Classification), Seiton (Order), Seiso (Cleanliness), Seiketsu (Standardization) and Shitsuke (Discipline). Once these practices are implemented, a final audit is carried out to assess progress and ensure the effectiveness of the improvements.

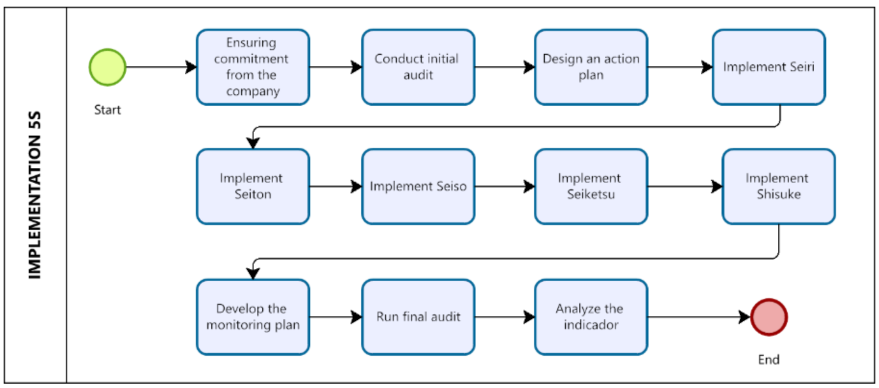

Fig. 3: 5s flowchart

Component 3:

According to Logesh et al [15] defines and develops the pillars of the TPM tool and the main indicator which is the OEE (Overall Equipment Effectiveness) which is expressed in percentage as a result of the product of the availability, performance and quality of a machine.

Component 4:

According to Trombeta et al [16], the SMED tool allows increasing work rates, which consequently has a positive impact on the productivity and efficiency of the machines. It is also mentioned that the main error in the implementation of this tool is the lack of differentiation between external activities, which are carried out simultaneously when the machine is running, and internal activities, which are carried out when the machine is stopped.

It is worth mentioning that for component 2 a pilot plan was carried out in which an area was taken as a basis, and the other components were tested in a simulation software called arena. The simulation carried out in the aforementioned program will be presented below. As mentioned, the tools used for this simulation were SMED, TPM and SOP. In which SMED and SOP were used to determine the times required for each activity considering the sum of the times of the internal and external activities. In the case of TPM, each resource was assigned a preempt or wait failure module depending on the nature of its work, in addition to the respective maintenance downtime for each machine.

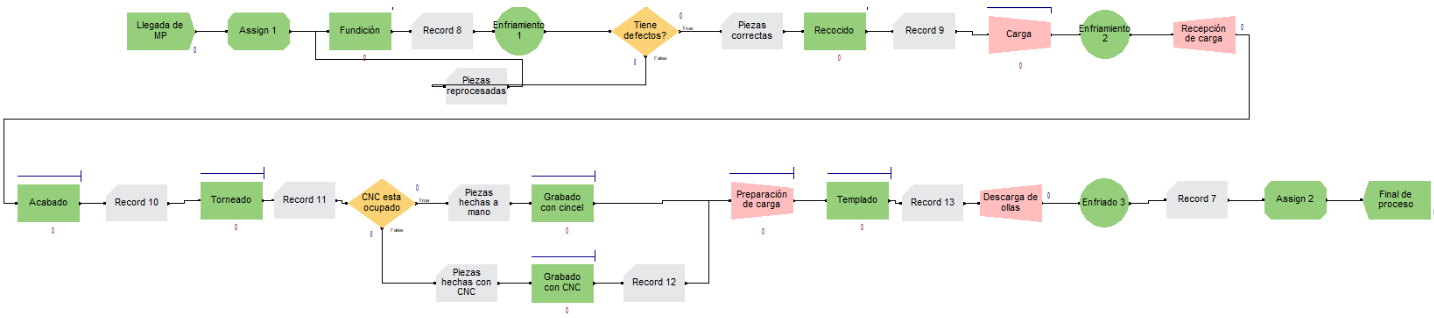

Fig. 4: SOP, SMED and TPM simulation model

4. Results

The implementation of the 5S tool was carried out by developing each of the previously defined "S" during the established test period. As shown in Figures 5 and 6, photographs were captured as evidence of the implementation process and the improvements achieved, comparing the initial situation with the results obtained after the intervention.

Fig. 5: Before and after implementation Seiri and Seiton

Fig. 6: Before and after implementation Shitsuke

Following the completion of the final audit, outstanding results were obtained, which are presented in Table 1. These data indicate a total score of 105 and a performance index of 84.3%. The results show a significant improvement compared to the values obtained in the initial audit, which demonstrates the sustained commitment of the work team.

Table 1: Initial audit- Final audit

	Initial Audit		Final Audit	
5s	**Score**	**Indicator**	**Score**	**Indicator**
Seiri	9	36%	21	84%
Seiton	8	32%	24	96%

Seiso	7	28%	19	85%
Seiketsu	6	24%	18	85%
Shitsuke	10	40%	23	86%
Total	40	34.4%	105	84.3%

As regards the economic results, as detailed in Table 2 a comparative analysis of the economic indicators was carried out before and after applying the tools. This analysis made it possible to demonstrate the improvements in monetary terms and the profitability achieved by the project.

5. Discussion

In order to demonstrate an improvement and economic impact, the analysis must focus on the number of units produced. It should be noted that the price for each pot is 950 dollars, so the economic impact would be 83,600 PEN.

Table 2: Comparison of economic evaluation indicators

Improvement tools	KPIs	Unit	Poor	Appropriate	Optimal	As-Is value	To-Be value
General	Production	unit	**390**	**410**	**440**	372	460
TPM	MTBF	minutes	**100**	**300**	**500**	115	581
TPM	OEE average	%	**<20%**	**<50**	**>60**	24%	67%
SMED y SOP	Time out	minutes	**110**	**50**	**30**	95	37
5S	Auditorias	score	**<1.5**	**3**	**>3**	2.4	4.8

Finally, the economic evaluation of the company's project was an NPV of 39,368.36 PEN, IRR is 32%, BCR 4.32 and the payback is 1 year and 1 month.

6. Conclusion

The study demonstrated that the combined implementation of SOP, 5S, TPM, and SMED significantly improved operational efficiency and on-time delivery in a Peruvian metalworking SME. Among the most relevant outcomes, the Overall Equipment Effectiveness (OEE) increased from 24% to 67%, the 5S audit score improved from 34.4% to 84.3%, and changeover time was reduced by 64.8 minutes. These measurable results reflected tangible progress in workplace organization, efficient resource utilization, and process reliability. The importance of this research lies in showing that, even in resource-constrained environments, substantial improvements can be achieved through a structured continuous improvement model. The integrated approach addressed multiple inefficiencies in a coordinated and effective manner. The main contribution of this study was the development of a replicable model that could be adapted by other small and medium-sized enterprises facing similar operational challenges. As a final observation, future research should examine the long-term sustainability of the improvements and explore the use of digital tools to strengthen indicator monitoring and process control. Additionally, it would be valuable to assess how organizational culture and workforce training influence the success of such improvement models, contributing to more resilient and adaptable industrial operations in emerging economies.

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