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Improving On-Time Order Fulfillment through SOPs, 5S, and Standard Work in a Peruvian Metalworking Company

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Abstract

The research analyzes frequent delays in order fulfillment within a Peruvian metalworking company. Based on production records, time studies, and root-cause analysis, three main contributors to additional operating time were identified: inefficient material handling, inadequate workplace organization, and rework associated with quality issues. These factors were used as operational drivers to design an improvement model integrating Standard Operating Procedures (SOPs), 5S, and Standardized Work, aiming to reduce variability in key processes such as cutting, internal transport, and assembly. The study was conducted using a mixed-methods approach, combining time studies, value stream mapping, regulatory compliance analysis, and root cause identification through Lean tools. The findings reveal non-productive time associated with disorganized routes, unnecessary search activities, and inconsistent work sequences. The model proposes reorganizing the operational environment through 5S, establishing standardized sequences for critical activities, and formalizing tasks through SOPs aligned with national technical standards. Validation demonstrated a reduction in cycle variability and a projected improvement in OTD performance. This work provides a methodological framework applicable to metalworking companies in emerging markets, offering practical tools to strengthen reliability, operational discipline, and responsiveness to customer demands.

Keywords
SOP, 5S, Standard Work, Order Fulfillment, Metalworking Industry

1. Introduction
The Peruvian metalworking sector is a key supplier for mining, construction, and infrastructure projects, where delivery reliability is essential to maintaining customer trust and operational continuity. However, many companies face recurring delays in On-Time Delivery (OTD), primarily due to inconsistent work methods, inefficient material flow, lack of formal procedures, and disorganized work environments. In the company under study, production records and time studies showed chronic deviations in On-Time Delivery, with an OTD of 87.64% compared with a target of 95%. The operational diagnosis associated this gap with additional operating time generated by material handling, workplace organization, and rework in the habilitado area.

International literature shows that Lean-based tools such as 5S, Standardized Work, and Standard Operating Procedures (SOPs) significantly improve flow stability and task repeatability. However, empirical applications in

Peruvian metalworking operations remain limited, particularly those that integrate engineering standards such as AWS D1.1, ISO 12944, Law 29783, and NTP 334.040 as operational constraints to ensure consistent quality.

This article is structured as follows: Section 2 presents the literature review; Section 3 describes the methodology; Section 4 details the data collection process; Section 5 presents the results and improvements; and Section 6 provides the conclusions.

1.1 Objectives

- Improve the company's on-time order fulfillment performance through the implementation of SOPs, 5S, and Standardized Work, reducing operational variability in key production stages.
- Diagnose the current operational situation by identifying the main inefficiencies affecting OTD performance based on the company's most relevant productivity and service indicators.
- Design an integrated improvement model to optimize workflow, workplace organization, and process standardization in the metalworking operations under study.
- Validate the proposed improvement through cycle time analysis and projected OTD performance, verifying feasibility and the enhancement of the targeted indicators.

2. Literature Review

Lean Manufacturing has become a key approach for improving operational efficiency through waste elimination, workflow stabilization, and variability reduction in production processes. Garza-Reyes et al. (2022) emphasize that Kaizen events and Lean initiatives require structured managerial support to sustain continuous improvement in manufacturing environments. Similarly, Makwana and Patange (2022) show that the strategic implementation of 5S can improve productivity when workplace discipline and operational control are maintained.

Among Lean tools, the 5S methodology is widely recognized for its impact on workplace organization, accessibility, cleanliness, and visual control. Gupta (2022) explains that 5S supports workplace management by improving organization, safety, and productivity. Shahriar et al. (2022) demonstrated that 5S can reduce waiting and motion wastes in a manufacturing setting, while Costa et al. (2018) documented the implementation of 5S in a metalworking company, showing its usefulness for improving workplace organization and visual control in this sector. In addition, Pombal et al. (2019) showed that Lean tools and visual management can reduce search time and improve the organization of consumable materials in industrial environments.

Standard Operating Procedures (SOPs) represent another fundamental tool for ensuring process repeatability. De Treville et al. (2005) argue that SOPs can improve production outcomes by reducing process variability in repetitive manufacturing contexts. In this study, SOPs were used to document operational sequences, safety guidelines, and quality checkpoints for critical habilitado activities.

Similarly, Standardized Work is positioned as a key element for defining the optimal work sequence by establishing standard times, production rates, and expected performance levels. Mor et al. (2019) show that standardization of work can eliminate non-value-added activities and improve productivity in manufacturing operations. Its proper implementation creates the necessary conditions to stabilize processes, enhance operational flow, and sustain higher levels of efficiency.

Alternative manufacturing improvement approaches, such as TPM, SMED, predictive maintenance, Poka-Yoke, and production scheduling models, have also been used to improve delivery reliability and operational performance. TPM and SMED are especially useful when machine availability, preventive maintenance, and setup reduction dominate the problem, as shown in a metalworking case study by Delgado et al. (2022). Predictive maintenance is more appropriate when machine failure prediction and data-driven reliability are central issues, as discussed by Dalzochio et al. (2020). Poka-Yoke, in contrast, focuses on error-proofing and defect prevention, including newer digital approaches discussed by Romero et al. (2022). In the present case study, the diagnosis showed that the dominant sources of additional operating time were material handling, workplace organization, and rework. Therefore, SOPs, 5S, and Standard Work were selected because they directly match the operational drivers identified through the Pareto analysis.

3. Methodology

The research is applied, quantitative, and uses an explanatory case study in a Peruvian metal-mechanical company operating under a Make-to-Order (MTO) strategy, focused on the profile cutting/preparation ("habilitado") area. The evaluation design follows a pre–post approach by comparing two scenarios: AS-IS (current condition) and TO-BE (improved condition), assessed through discrete-event simulation (DES) in Arena.

Before defining the TO-BE scenario, an operational diagnosis was conducted using production records, time studies, shop-floor observations, and root-cause analysis. The diagnosis quantified 119.24 annual additional operating hours in the habilitado area. The main contributors were inefficient material handling, inadequate workplace organization, and rework due to quality issues. These factors were prioritized using a Pareto analysis and then translated into the intervention components of the improvement model (Table 1).

Table 1. Prioritization of annual additional operating time causes

Cause	Annual additional hours	Share	Cumulative share
Inefficient material handling (includes loading-transfer-unloading)	63.33	53.11%	53.11%
Inadequate workplace organization	32.05	26.88%	79.99%
Rework due to quality issues	23.86	20.00%	100.00%
Total	119.24	100.00%	—

To visually clarify the relative importance of the causes affecting production time, a Pareto chart was developed from the annual additional operating time identified in the operational diagnosis. As shown in Figure 1, material handling and workplace organization account for approximately 80% of the identified additional time, supporting the prioritization of these drivers in the improvement model.

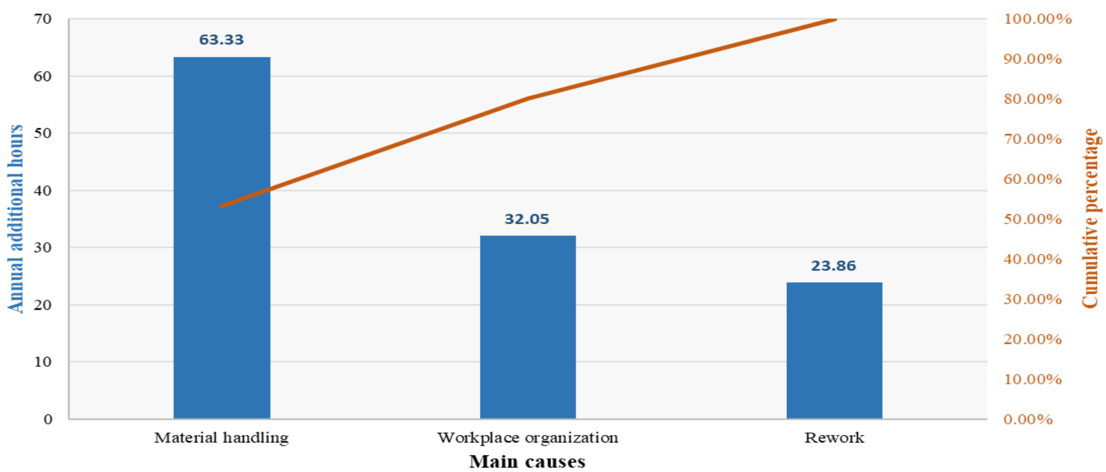


Figure 1. Pareto chart of annual additional operating time causes

The conceptual design (Figure 2) states that the intervention (SOP, 5S, and Standard Work) acts on operational drivers within the habilitado process (crane operating time, cleaning/organization time, and rework), which in turn affect the total process time and on-time delivery (OTD).

Variables:

- Independent variable (X): implementation of the TO-BE scenario (SOP + 5S + Standard Work).

- Dependent variables (Y): the operational indicators defined in Table 2 and the macro-level outcomes (total process time and OTD, when applicable).

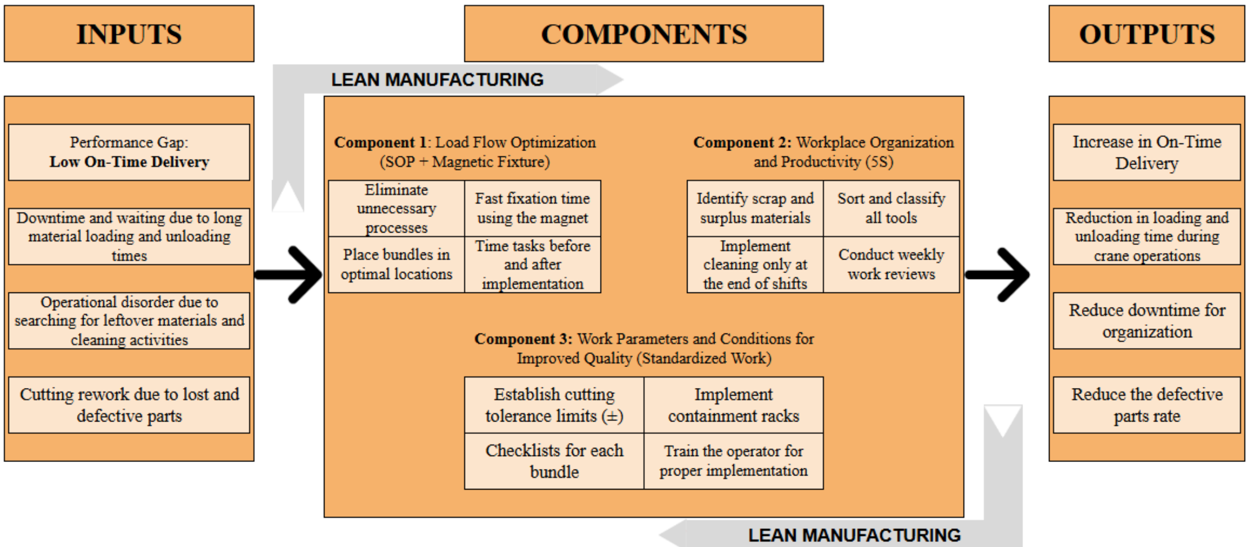


Figure 2. Conceptual Design of the Proposal

The unit of analysis is the processed part within the habilitado process. To represent maximum-demand conditions, the highest-load day within the analyzed period was selected as the reference frame, defining an operational population of N = 50 parts (peak day), as shown in Figure 3.

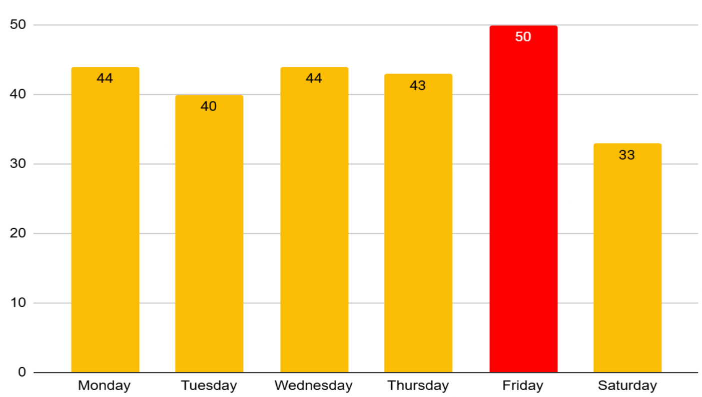


Figure 3. Record of Parts Processed in One Working Day

The sample size was estimated using the finite population equation with 95% confidence and 5% error, yielding n ≈ 30 parts, selected via simple random sampling from the peak-day work order list. The sample was restricted to parts following the standard habilitado flow.

$$n = \frac{N * Z^2 * p * q}{E^2 * (N - 1) + Z^2 * p * q}$$

Where:
n = Sample size (29.91 ≈ 30)

N = Population size (50)
Z = Value for 95% confidence (1.96)
p = Event occurrence proportion (0.05)
q = Complement of p, i.e., 1-p (0.95)
E = Margin of error(0.05)

Inclusion criteria: parts processed under the standard habilitado flow during regular operations.
Exclusion criteria: non-representative events (major stoppages, trials, or extraordinary rework due to causes external to the typical process).

Data were collected through continuous time study and recorded on time sheets for the critical habilitado activities. System resources included the gantry crane and the main process stations. Observed times were fitted using Input Analyzer to parameterize the simulation model in Arena, enabling comparison between AS-IS and TO-BE scenarios. For each observation, crane operating time, cleaning/organization time, and rework were recorded, along with basic metadata (machine, operator, and shift) to control for variability (Table 2).

Table 2. Indicators and calculation method

Indicator	**How to compute**
Crane operating time	$\frac{\text{Transport + loading + unloading hours}}{\text{Total cutting/preparation hours}} \times 100 = \%$ of cycle
Cleaning and organization time	$\frac{\text{Cleaning and organization hours}}{\text{Shift hours}} \times 100 = \%$ of shift
Average rework rate	$\frac{\text{Reprocessed tons}}{\text{Total tons processed}} \times 100 = \%$ of cycle

The study followed a replicable procedure:

1. Scope definition of the profile cutting/preparation ("habilitado") process and identification of the critical activities to be measured.
2. Definition of the operational population (peak day) and calculation of the sample size (finite population).
3. Random selection of 30 parts/work orders (WO) and preparation of data collection sheets.
4. On-site data collection through continuous time study (stopwatch timing) and recording of control variables.
5. Data cleaning (consistency checks and removal of non-representative records caused by extraordinary events).
6. Fitting time distributions for each activity using Input Analyzer.
7. Development of the AS-IS model in Arena, incorporating entities, resources (crane and workstations), queues, and the actual flow logic.
8. Development of the TO-BE model, incorporating SOP + 5S + Standard Work improvements (changes in method, order, sequence, and variability).
9. Simulation runs and AS-IS vs. TO-BE comparison, reporting the indicators in Table 2 and aggregated results (total process time and OTD, if applicable).

4. Data Collection

Data collection was conducted through a continuous time study using a sample of 30 observations, recording the total time per operating cycle as well as part- and process-related attributes. Based on the observed data, probability distributions and their corresponding expressions were identified (Table 3), which were subsequently used as input parameters for the discrete-event simulation model.

Table 3. Identified activity-time distributions in the shop-floor area

Activity	**Distribution**	**Expression**
Crane transfer	Triangular	TRIA(19, 26, 33)
Steel cutting	Normal	NORM(15.4, 3.84)
Drilling and punching	Weibull	9 + WEIB(4.97, 1.86)
Bending and forming	Normal	NORM(12.9, 1.66)
Piece collection and sorting	Triangular	TRIA(7.31, 12, 14)
Area supervision	Triangular	TRIA(2, 3.58, 6)

These parameters are essential to define the mean processing times and variability assumptions for the AS-IS model developed in Arena Simulator, enabling a reliable representation of the operational process, as illustrated in Figure 4.

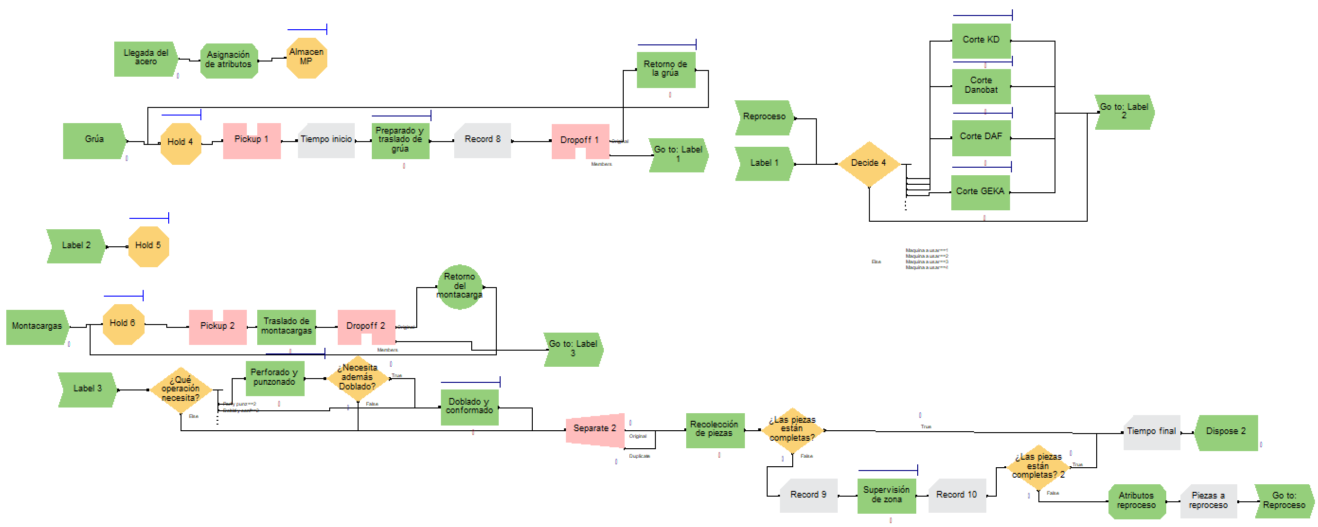


Figure 4. Proposed AS-IS scenario

5. Results and Discussion

5.1 Numerical Results

Statistical validation of operational performance was conducted by comparing the AS-IS and TO-BE scenarios through discrete-event simulation in Arena. The simulation outputs were processed using 74 replications and 95% confidence intervals in Output Analyzer. This procedure allowed the study to quantify the simulated performance effect of the improvement proposal based on SOPs, 5S, Standard Work, and improved material handling conditions in the habilitado area.

To address statistical significance, paired t-tests were used to evaluate whether the reductions observed in the TO-BE scenario were significant. The null hypothesis stated that there was no difference between the AS-IS and TO-BE mean values, while the improvement hypothesis stated that the TO-BE scenario reduced the corresponding time-based indicator. A significance level of $\alpha = 0.05$ was used. Table 4 summarizes the mean values, 95% confidence intervals, reductions, percentage improvements, t-test results, and statistical decisions for each evaluated indicator.

Table 4. Numerical comparison of performance indicators (AS-IS vs. TO-BE)

Indicator	Main operational driver addressed	AS-IS mean (95% CI)	TO-BE mean (95% CI)	Reduction	Improvement (%)	t-test result	Statistical decision
Rework Time (hrs)	Rework and quality-related variability	0.542 [0.495 ; 0.589]	0.447 [0.409 ; 0.484]	0.095	17.50%	$t = 3.91$, $p < 0.01$	Reject H_0
Cleaning Time (min)	Workplace organization and 5S discipline	2.62 [2.54 ; 2.69]	2.35 [2.32 ; 2.37]	0.27	10.30%	$t = 2.88$, $p < 0.05$	Reject H_0
Transport Time (min)	Material handling and crane operation	2.35 [2.34 ; 2.37]	2.25 [2.24 ; 2.27]	0.1	4.20%	$t = 2.31$, $p < 0.05$	Reject H_0
Total Process Time (hrs)	Integrated effect of SOPs, 5S, and Standard Work	0.827 [0.809 ; 0.846]	0.622 [0.601 ; 0.642]	0.205	24.80%	$t = 5.47$, $p < 0.01$	Reject H_0

Table 4 shows consistent reductions across all evaluated indicators under the TO-BE scenario. Rework time decreased from 0.542 to 0.447 hours per part, representing a 17.5% improvement. This result is consistent with the expected contribution of SOPs and Standard Work to reducing process variability, improving task repeatability, and minimizing errors associated with cutting and dimensional control. The t-test result ($t = 3.91$, $p < 0.01$) indicates that the difference between the AS-IS and TO-BE scenarios is statistically significant.

Cleaning time decreased from 2.62 to 2.35 minutes per part, equivalent to a 10.3% improvement. This reduction is associated with the implementation of 5S practices, particularly sorting, set-in-order, cleaning routines, and visual organization of tools and remnants. Although the magnitude of the improvement is moderate, the result was statistically significant ($t = 2.88$, $p < 0.05$), supporting the operational relevance of workplace organization in reducing non-productive time.

Transport time showed a smaller reduction, decreasing from 2.35 to 2.25 minutes per part, equivalent to a 4.2% improvement. This result is linked to improved material handling conditions, more organized routes, and the use of the magnetic lifting yoke to support crane-related movements. The effect is less pronounced than in the other indicators, but the t-test result ($t = 2.31$, $p < 0.05$) indicates that the reduction is still statistically significant within the simulated environment.

The strongest improvement was observed in total process time, which decreased from 0.827 to 0.622 hours per part, representing a 24.8% reduction. This result suggests the combined effect of the three improvement components: SOPs reduced operational uncertainty, 5S improved workplace organization and accessibility, and Standard Work helped stabilize the sequence of critical activities. The statistical evidence was also stronger for this indicator ($t = 5.47$, $p < 0.01$), confirming that the overall process-time reduction is significant in the AS-IS versus TO-BE simulation comparison.

Overall, the numerical results support the effectiveness of the proposed improvement model in reducing operating time and process variability. However, these findings should be interpreted as statistically validated simulation results rather than full-scale plant implementation results.

5.2 Graphical Results

The graphical results of the TO-BE scenario are presented in alignment with the study's thematic axes and research objectives—namely, improving On-Time Delivery (OTD) and reducing operating times and rework. The improved model diagram represents the updated process flow logic in the habilitado area, integrating the use of a magnetic lifting yoke, 5S, and Standard Operating Procedures (SOPs) (Figure 5 and Figure 6). This is consistent with prior evidence reporting improvements in workplace organization, visual control, and flow stability when Lean tools such as 5S and Standard Work are applied in manufacturing and metalworking environments (Costa et al., 2018; Makwana and Patange, 2022; Mor et al., 2019). The magnetic lifting yoke component is also technically aligned with the use of electromagnetic and electro-permanent lifting systems for ferrous material handling (Oliva and Faranda, 2023).

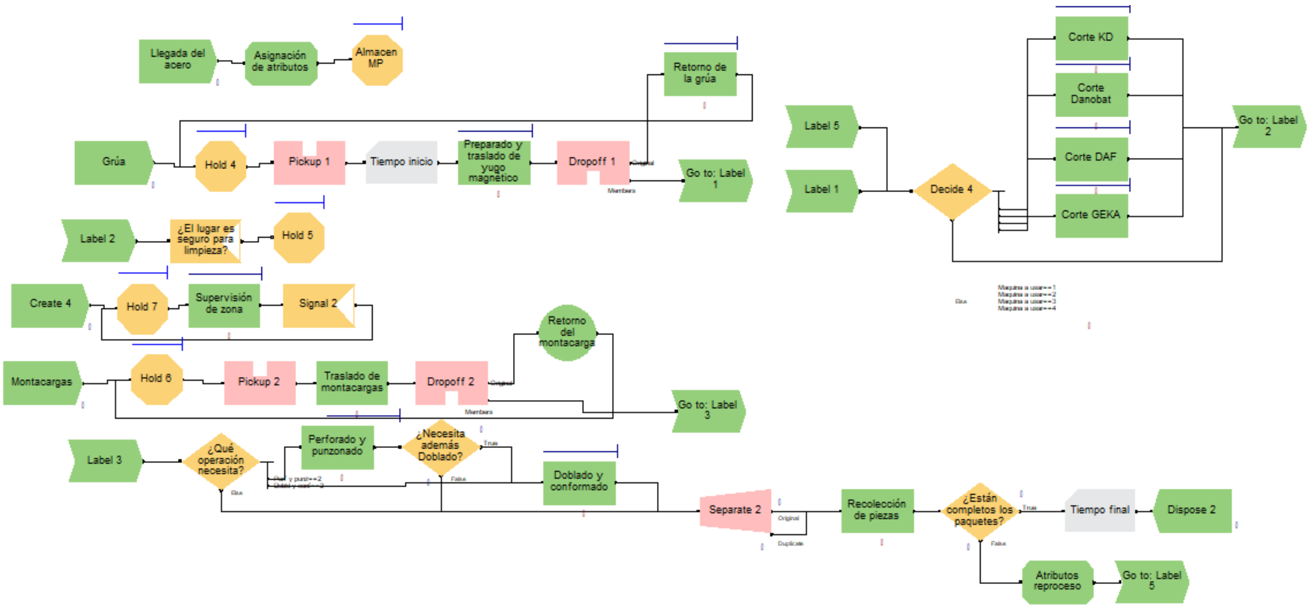
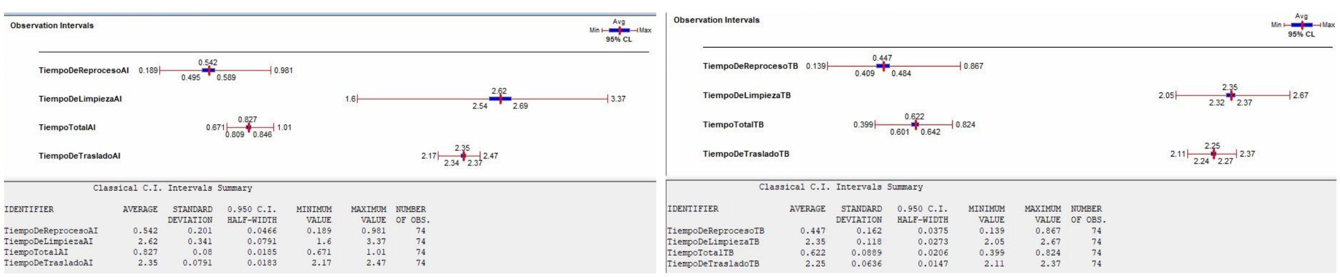


Figure 5. Proposed TO-BE scenario.

The graphical comparison between the AS-IS and TO-BE scenarios reports transfer/transport time, cleaning time, rework time, and total cycle time along with their 95% confidence intervals, showing clear reductions and lower dispersion under the proposed scenario. These results are consistent with other studies using discrete-event simulation to quantify the impact of Lean-based interventions on process time performance and service level in Latin American industrial contexts (Ramírez-Cruz et al., 2023; Campos-Villanueva et al., 2023).



Classical C.I. Intervals Summary

IDENTIFIER	AVERAGE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS.
TiempoDeReprocesoAI	0.542	0.201	0.0466	0.189	0.981	74
TiempoDeLimpiezaAI	2.62	0.341	0.0791	1.6	3.37	74
TiempoTotalAI	0.827	0.08	0.0185	0.671	1.01	74
TiempoDeTrasladoAI	2.35	0.0791	0.0183	2.17	2.47	74

Classical C.I. Intervals Summary

IDENTIFIER	AVERAGE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS.
TiempoDeReprocesoTB	0.447	0.162	0.0375	0.139	0.867	74
TiempoDeLimpiezaTB	2.35	0.118	0.0273	2.05	2.67	74
TiempoTotalTB	0.622	0.0889	0.0206	0.399	0.824	74
TiempoDeTrasladoTB	2.25	0.0636	0.0147	2.11	2.37	74

Figure 6. Confidence intervals for the AS-IS and TO-BE indicators.

The discussion of these graphical findings is contrasted with the literature on improvements in metal-mechanical companies, where the application of Lean tools has enabled reductions in waste, setup/preparation times, and delivery delays (Cárdenas, 2018; Delgado et al., 2022).

5.3 Proposed Improvements

The improvement proposal consists of an integrated implementation of SOPs supported by a magnetic lifting yoke, 5S methodology, and Standard Work in the habilitado area, aimed at reducing the 119.24 h/year of additional time associated with handling/transport, cleaning/organization, and rework. Under the improved TO-BE scenario, simulation results indicate that the total cycle time per part decreases from 0.827 h to 0.622 h (−24.8%), rework time drops from 0.542 h to 0.447 h (−17.5%), cleaning time decreases from 2.62 min to 2.35 min (−10.3%), and transfer/transport time is reduced from 2.35 min to 2.25 min (−4.2%).

As a consequence, the TO-BE model projects an improvement in On-Time Delivery (OTD) from 87.64% to approximately 94.8%, virtually closing the gap relative to the corporate target of 95%. Therefore, it is proposed to formalize this operating scheme as the standard for the habilitado area by incorporating the new SOPs into the management system, maintaining periodic 5S audits, and implementing a Standard Work training program to ensure the sustainability of improvements over time.

5.4 Validation

To validate the effectiveness of the proposal, a pilot was conducted in the habilitado and cutting area, aiming to assess feasibility and direct impact on workspace organization and residual material (remnants) management.

A baseline 5S diagnostic assessment was performed using the organization's institutional inspection and workplace organization checklist. The initial results (Figure 7) revealed several deficiencies, including the accumulation of unidentified remnants, tools stored out of place, and a work environment with low levels of order and visual signage. Material layout in the cutting area showed inefficient space utilization and generated long search times, which justified the proposed intervention.

Auditoría 5S: Formato de inspección y organización del área de trabajo

Área: Habilitado	**Auditor:** Francisco T.	
Responsable: Operario CNC	**Fecha y hora:** 24/09/25 11:57	
Escala de evaluación: de 1 a 5 (1 = no se cumple, 5 = se cumple totalmente)		
Criterio	Puntaje	Observaciones
Seiri - Clasificar Si: 1, No: 5		
¿Hay materiales/retazos/chatarra fuera de uso dentro del área?	2	Hallados debajo y alrededor del área
¿Existen herramientas duplicadas o dañadas en estaciones?	3	
Seiton – Ordenar		
¿Piezas en proceso están identificadas (orden, lote, responsable)?	2	Etiqueta poco detallada
¿Pasillos y zonas de seguridad están libres y demarcados?	3	
Seiso – Limpiar		
¿Residuos metálicos y viruta se gestionan sin acumulación?	2	Merma acumulada en volumen significativo
¿Se ejecuta limpieza luego de cada corte?	3	
Seiketsu – Estandarizar		
¿Existe "estándar visual" por estación (foto del estado ideal)?	4	
¿EPP obligatorio y herramientas críticas tienen codificación por color?	4	
Shitsuke – Disciplina		
¿Se cumplen las 5s sin necesidad de supervisión constante?	2	No hay aplicación de 5s
¿Se revisan métricas y acciones correctivas cada semana?	2	No se toman medidas
Puntos Posibles: 50	**Puntos obtenidos:** 27	
Observaciones generales del auditor: Desorden general, incluso en zonas de camino general. Falta de monitoreo y toma de medidas de solución		
Firma del responsible:	**Firma del auditor:**	

Figure 7. Results of the initial operational assessment.

Subsequently, a training session was delivered to shop-floor personnel to ensure a clear understanding of the 5S principles, the pilot objectives, and the importance of complying with the proposed standards (Figure 8). Practical examples were reviewed, specific actions associated with each "S" were explained, and responsibilities were defined to support sustained workplace organization. This stage was critical to secure active participation and proper implementation of the methodology.

Figure 8. Training sessions for shop-floor personnel.

Finally, after implementing the redistribution of remnants, visual signage, and classification of available material, a post-implementation 5S assessment was conducted using the same checklist (Figure 9). The results showed significant improvements in the dimensions of sorting, orderliness, and cleanliness, reflecting a more organized, accessible, and safer work environment. In addition, the new remnants layout reduced congestion at the cutting point and improved visibility of available material. The comparison between the baseline and post-assessment confirmed that the proposal is operationally feasible and generates measurable improvements in workplace organization.

Auditoría 5S: Formato de inspección y organización del área de trabajo

Área: Habilitado	Auditor: Francisco T.	
Responsable: OPERARIO CNC	Fecha y hora: 16/10/25 10:04	
Escala de evaluación: de 1 a 5 (1 = no se cumple, 5 = se cumple totalmente)		
Criterio	Puntaje	Observaciones
Seiri - Clasificar		
¿Hay materiales/retazos/chatarra fuera de uso dentro del área?	4	
¿Existen herramientas duplicadas o dañadas en estaciones?	5	
Seiton – Ordenar		
¿Piezas en proceso están identificadas (orden, lote, responsable)?	4	
¿Pasillos y zonas de seguridad están libres y demarcados?	5	
Seiso – Limpiar		
¿Residuos metálicos y viruta se gestionan sin acumulación?	5	
¿Se ejecuta limpieza luego de cada corte?	5	
Seiketsu – Estandarizar		
¿Existe “estándar visual” por estación (foto del estado ideal)?	4	
¿EPP obligatorio y herramientas críticas tienen codificación por color?	5	
Shitsuke – Disciplina		
¿Se cumplen las 5s sin necesidad de supervisión constante?	5	
¿Se revisan métricas y acciones correctivas cada semana?	4	
Puntos Posibles: 50	Puntos obtenidos: 46	
Observaciones generales del auditor:		
Firma del responsible:	Firma del auditor:	

Figure 9. 5S post-assessment results and shop-floor evidence.

6. Conclusion

The study’s conclusions support that the stated objectives were achieved: the current condition of the habilitado area was accurately diagnosed, an integrated improvement model based on SOP with a magnetic lifting yoke, 5S, and Standard Work was designed, and its impact was validated through simulation. The results show a consistent reduction in operating times and process variability, which translates into a higher capability to meet delivery deadlines and move closer to the target service level in a Make-to-Order (MTO) environment.

The proposed solution generates structural organizational benefits: it formalizes safe and repeatable work methods, strengthens discipline in the use of Lean tools, improves workplace organization, and aligns operations with national technical standards. This reinforces a continuous improvement culture, facilitates operational control, reduces reliance on improvised solutions—such as overtime or last-minute corrections—and creates better conditions to sustain results over the long term.

The distinctive contribution of this research lies in providing a replicable methodological framework that combines Lean tools, discrete-event simulation, and compliance with national technical standards for the analysis and improvement of processes in the metal-mechanical sector. This integrated approach not only quantifies the effect of the intervention on time performance and On-Time Delivery (OTD), but also provides a solid foundation for future studies to extend the same logic to other stages of the value chain or incorporate additional performance metrics, thereby contributing to the expansion of the state of the art in metal-mechanical process improvement.

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