

Reduction of Baffles Manufacturing Times in a Metalworking Company through Lean Manufacturing and SLP

**Dorcas Shalom Guerrero-Cáceres, Daniel Alberto Ramos-Olivera and
Marcos Fernando Ruiz-Ruiz**

Carrera de Ingeniería Industrial, Universidad de Lima
Lima, Peru

20183981@aloe.ulima.edu.pe , 20184355@aloe.ulima.edu.pe, mruiz@ulima.edu.pe

Abstract

The objective of this research was to reduce the manufacturing times of baffles by simulating the application of Lean and SLP tools in a company of the metalworking sector. For this purpose, an experimental and simulated applied improvement design (pre-test and post-test) with a structure of four consecutive phases, strategically validated by experts, was used. The main findings revealed significant improvements in four key indicators, mainly in reducing baffle manufacturing time by 24.17% and increasing the percentage of orders delivered on time by 10%. The contribution of this research is focused on benefiting other companies in the metalworking industry that seek to improve their processes and increase their competitiveness. It serves as a basis for future lines of research in which other areas within the manufacturing process of industrial equipment can be explored, demonstrating the effectiveness of the tools mentioned above.

Keywords

Lean Manufacturing, 5S, SMED, SLP, Baffle, Heat Exchanger, Metalworking.

1. Introduction

The metalworking industry has experienced significant growth in recent years. It constitutes a fundamental sector for the global economy. Authors like Zea (2021) consider companies in this industry to be at the forefront of development because they manage to improve their processes and increase their production through the use of technology. In Peru, the metalworking sector has achieved greater growth since 2020 due to the variety of manufactured components that are exported, noting a 55.5% increase in 2022 compared to the aforementioned year. Additionally, it is a major job generator in the country, contributing around 148,000 direct jobs (Merzthal 2022). During 2022, the sector's progress was above that of 2019, due to the influence of mining companies and the increased focus on machinery repair in the agro-industrial sector.

Lean tools facilitate and serve as a guide for carrying out an improvement process, especially in reducing times. The impact of this methodology on the problem is that, thanks to the variety of tools it possesses, such as 5S, TPM, SMED, among others, it can effectively address all the causes of the problem to eliminate or reduce them in the best possible way. Similarly, it is important to note that Lean Manufacturing is not a closed-structure methodology; it promotes continuous improvement within companies. The effects of implementing Lean Manufacturing can be quickly seen. Therefore, this study also reviewed articles that emphasize the importance of monitoring indicators to evaluate this method and identify potential adjustments or alternative techniques.

This research was conducted at a Peruvian metalworking company located in the district of San Martín de Porres, Lima. Established in 1996, the company specializes in the design, manufacturing, and maintenance service of heat

exchangers, air coolers, pressure vessels, and other industrial equipment. The study focused on measuring the manufacturing times of baffles, critical components that ensure efficient fluid flow in heat exchangers. These pieces are assembled into tube bundles, which are then inserted into a cylindrical shell to complete the exchanger, underscoring their significance in the manufacturing process and operational functionality of the equipment.

The lack of production indicators in the company made it necessary to cross-reference information from multiple sources. Documents such as production records, Gantt charts, project dossiers, inventory management, and sales data were utilized. The analysis revealed that the company achieved an on-time delivery rate of 25%. In contrast, the Peruvian metalworking sector standard is approximately 35%, indicating a technical gap of 10% (Kishimoto et al. 2020). This highlights an improvement opportunity as the company frequently fails to meet delivery deadlines, falling below industry standards.

As part of the diagnosis, the most significant issue identified is the low percentage of on-time deliveries, currently at 25% compared to the sector standard of 35% (Kishimoto et al. 2020). This issue plays a critical role within the company, directly impacting customer satisfaction, as timely delivery is crucial for maintaining positive client relationships. It was essential to identify and understand the root causes and effects of this issue, as this understanding will be foundational for implementing proposed improvement tools (View Figure 1).

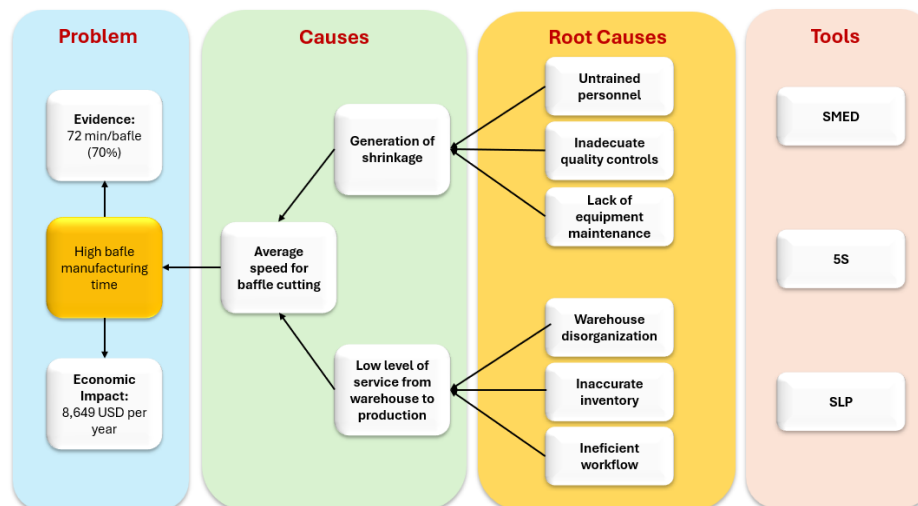


Figure 1. Root Cause Diagram

Regarding the economic impact of the problem, an operational surcharge per manufactured unit was identified, stemming from overtime hours that operators must work to meet agreed delivery deadlines. These overtime hours result from interruptions and delays during the manufacturing process. The cost per overtime hour is \$5.4 USD. With 10 operators in the plant, this amounts to approximately \$216.20 USD per unit. Annually, this cost totals \$8,649 USD, assuming four units are manufactured per year. Additionally, after a detailed review of contracts, it was determined that penalties averaged around 1% of the total cost per operational week (comprising five days) of delay in delivery. Applying these percentages to the values of the two mentioned units, it is estimated that the company incurs losses of \$216 USD per unit.

Based on the aforementioned information, the following research question was proposed: Is it possible to reduce the manufacturing times of baffles in a Peruvian metalworking company through the application of Lean Manufacturing and SLP tools?

1.1 Objectives

- Reduce the manufacturing time of baffles by simulating the application of improvement tools in a metalworking company.

- Perform an analysis and diagnosis of the problem in a metalworking company.
- Design and develop innovative solution proposals based on Lean Manufacturing and SLP tools in order to reduce unproductive time in the manufacturing process from 70% to 50%.
- Validate the proposed solution by assessing its economic feasibility and its impact on relevant stakeholders.

2. Literature Review

2.1 Lean Manufacturing tools

Through examples found in the literature review, it was determined that Lean Manufacturing tools are ideal for reducing manufacturing times. According to Rodrigues et al. (2019), companies that apply Lean in their work processes undergo changes in organizational and management rules, but in the short term, they start to achieve significant savings at a low cost. Lean tools are essential elements that organizations should implement to strengthen their competitive advantage, as they enable the identification of various forms of waste and, consequently, the elimination of activities that do not add value for the customer (Pinto et al. 2019). In this regard, Palaksha Reddy et al. (2018) demonstrate that manufacturing times (cycle times) can be reduced through the implementation of Lean tools, since their application allows for adjustments in production modes as well as in specific process parameters. Overall, Lean tools not only facilitate improvement initiatives but also serve as a guiding framework for reducing processing times and enhancing operational efficiency.

2.2 Metalworking sector

The research conducted by Anton (2022), the Peruvian metalworking sector has reported a 72% waste of time attributable to non-value-adding activities, which has led to an increase in delivery times from 30 to 42 days. According to Monteiro et al. (2019), as a critical observation, an additional form of waste that has gained prominence in this industry relates to the underutilization of operators' capabilities, as they are uniquely positioned to propose ideas for continuous improvement initiatives.

3. Methods

This research was categorized as an applied improvement case study using an experimental (and simulated) design with pre-test and post-test measurements. Its methodological design was structured into four consecutive phases.

3.1 Phase 1: Identification of causes, problems, and measurement of baseline indicators

A comprehensive diagnosis of the company was carried out to evaluate its initial situation and performance. Following this evaluation, the study was focused on the manufacturing of a specific piece of equipment and its associated process. This allowed the identification of the research problem, its root causes, and the relevant associated variables. Simultaneously, a literature review was carried out to gain a deeper insight into the problem. This phase was validated by three academic experts through the evaluation of root cause analysis tools, including the Ishikawa diagram. As the company lacked indicators for its production line, new metrics were developed based on direct observation and historical data, which were subsequently validated with organizational representatives.

3.2 Phase 2: Design of the current and proposed simulation models

In this second phase, the simulation design is carried out. For this purpose, creating a sketch or conceptual diagram of the baffle manufacturing process was of utmost importance. This step was essential for visualizing and planning the model. Subsequently, in the Arena software, the model itself is created, following a series of general steps. In addition, it is essential to highlight that during the implementation of each of the improvement proposals derived from the three tools (components), a first simulation was carried out using the current situation of the company as a reference point (pre-test), followed by a second simulation after the implementation of the proposals (post-test). Before starting with the simulation in the Arena software, a series of steps are carried out in order to develop the model that integrates each of the three tools.

First, SLP is a tool used for the proper design of plant layout. This technique allows the efficient use of resources, improves organization between work areas and optimizes production processes. A collection of data related to the current layout of the company is carried out, including information about the dimensions of the work areas and the flow of processes. Subsequently, using the information obtained, a preliminary design of the current design of the company is prepared, in order to identify areas requiring improvement through data analysis and observation of the processes. Considering the criteria required to implement the SLP tool, a new optimized distribution model is developed that includes the layout of workstations, equipment, machines and corridors.

The SMED (Single-Minute Exchange of Die) methodology is a process improvement tool. Its main objective is to reduce tool and setup changeover times in production, leading to greater efficiency, flexibility and competitiveness in the industry. As part of the tool, the duration of the process is measured. Aspects such as the time required to move tools and materials from the warehouse or external areas to the production site were analyzed. Then, the relevant data collection is carried out, including the tasks and elements involved in the process. Based on the above, the activities that are suitable for the application of SMED were identified, specifically those areas in which the implementation of this method is considered feasible.

The 5S methodology is a management system of Japanese origin that promotes organization, cleanliness and efficiency in the work environment. Based on five principles (Classification, Order, Cleanliness, Standardization and Discipline), 5S helps to optimize processes and improve productivity in any company or organization. Prior to using Arena Version 16.2 software for the simulation, a series of steps were followed to adapt the information collected to the needs required by the 5S methodology. Based on this, relevant data, such as time sampling, were collected and the process steps to be intervened were selected. Subsequently, the 5S components were reviewed, considering that they have specific applications and can be useful in various situations, adapting them to a specific activity of the process.

3.3 Phase 3: Development of implementation manuals

In this third phase, after validating the simulation of the processes in which the engineering tools are applied, the implementation of the manuals intended for the baffle process begins. These guidelines aim to ensure the correct application of improvement tools in the work areas, as well as to familiarize personnel with Lean Manufacturing techniques, which are essential for their training and development. Therefore, to achieve these changes and improvements, the preparation of the aforementioned manuals is fundamental.

3.4 Phase 4: Evaluation of the project's impact on society

The analysis of a project's impact on society is a fundamental element in business management and in the promotion of sustainable development. In this context, during the fourth phase, a systematic evaluation of the effects generated on the stakeholders was carried out. The process began with the development of a list of potential impacts, covering both positive and negative aspects. This analysis served as the basis for recognizing all relevant stakeholders, including both internal and external actors. Subsequently, a power-interest matrix was developed to categorize stakeholders according to their influence and level of engagement. This classification made it possible to determine which actors hold the greatest relevance for the project and, consequently, to prioritize the relationships that require focused management. Also, this phase was supported by experts who evaluated and validated the prioritization of stakeholders in accordance with the criteria established in the power-interest matrix.

4. Data Collection

The initial state of the metalworking workshop was characterized by a lack of systematic organization, which negatively impacted workflow efficiency. Machines and equipment, including lathes, welding stations, and workbenches, were positioned without a coherent spatial arrangement, leading to suboptimal material and personnel movement (see Figure 2). Furthermore, the presence of excessive scrap materials and empty containers occupying floor space contributed to workplace clutter, reducing operational efficiency and hindering the implementation of standardized work processes.



Figure 2. Initial workshop layout of the company

Therefore, as part of the preliminary analysis, a sketch of the layout of the work area was developed in order to improve the visualization of the production process and facilitate the evaluation of a possible reorganization of the workstations. This representation made it possible to identify opportunities for optimization in the spatial distribution and operational flow.

Data were collected through direct time measurement of the manufacturing process of baffles used in shell-and-tube heat exchangers. These components were selected due to their critical role in directing fluid flow and ensuring thermal efficiency. Measurements were conducted on a sample of 12 baffles, a number constrained by the low production frequency of this component within the facility. The study employed systematic time recording using standardized data collection instruments. Each operational and non-operational activity was documented from the reception of steel plates to the perforation stage. To reduce observer-induced bias, operators were not informed in advance about the timing procedure. Additionally, all recorded data were reviewed and validated by industry experts to ensure accuracy and reliability. As part of the process, Figure 3 presents the drilling operation, which constitutes one of the most time-consuming stages because of the high level of accuracy and precision demanded (Figure 3).



Figure 3. Drilling of a baffle

5. Results

The unit of analysis in this study is the carbon steel sheet, a fundamental element in the baffle manufacturing process. This sheet undergoes various production stages, such as cutting, drilling, and machining, before becoming the final product. For process analysis, time studies were conducted through direct observation to identify the most time-consuming and complex activities. Based on the production supervisor's recommendation, measurements focused on the stages between the receipt of the steel sheets and the drilling process.

One of the main limitations of the study was the limited data collection, consisting of 12 baffles, due to the low production frequency of heat exchangers at the company. To ensure representative process data, operators were not informed about the time studies, and both operational and non-operational activities were recorded.

Given the absence of historical production records, the data obtained were extrapolated to 54 units to increase the accuracy of the simulation model. Normality tests performed in Minitab indicated that the initial dataset did not significantly deviate from a normal distribution ($p > 0.05$). Based on this result, the sample mean and standard deviation were used as estimators of the process parameters. Assuming statistical stability and process homogeneity, additional observations were generated using the identified distribution to reach a sample size of 54 units.

The decision to approximate a sample size of 50 observations was validated by simulation specialists using Arena 16.2 software, who indicated that it was necessary for an adequate representation of the system. This approach ensured that the generated data maintained the original process variability while reducing sampling error. As part of the simulation model validation, a detailed analysis of each process activity was performed, ensuring an accurate representation of the operations and, consequently, the generation of reliable and realistic results. Furthermore, goodness-of-fit tests were used to identify the probability distributions corresponding to each activity, considering p-values greater than 0.05 as the acceptance criterion. Table 1 presents a summary of the activities included in the simulation model developed in Arena 16.2 software, along with the probability distributions used to model the variability associated with the duration of each activity (Table 1).

Table 1. Probability distributions of activities in the validation model

Activity	Probability distribution	P-value
Marking out	Triangular (3, 4.5, 6)	$p = 0.447$; $p > 0.05$
Cut of ironing board	Beta (0.552, 1.35)	$p = 0.434$; $p > 0.05$
Deburring	Exponential (6.18)	$p = 0.053$; $p > 0.05$
Hole tracing	Triangular (88.5, 99.1, 112)	$p = 0.721$; $p > 0.05$
Welding	Normal (9.67, 0.765)	$p = 0.488$; $p > 0.05$
Drilling and machining	Triangular (33, 46.3, 59)	$p = 0.736$; $p > 0.05$
Breaking weld points	Normal (9.07, 0.737)	$p = 0.542$; $p > 0.05$
Final machining	Normal (4.65, 1.55)	$p = 0.731$; $p > 0.05$

Based on the model presented (view Figure 4), we proceeded to build the simulation of the validation model using Arena version 16.2 software, focusing on the case study of the baffle manufacturing process. In this simulation, both basic and advanced modules available in the tool were used. After carrying out both simulations, the original and the proposed scenario, a comparative analysis of the results obtained was made through the report presented by the Arena 16.2 software (View Table 2).

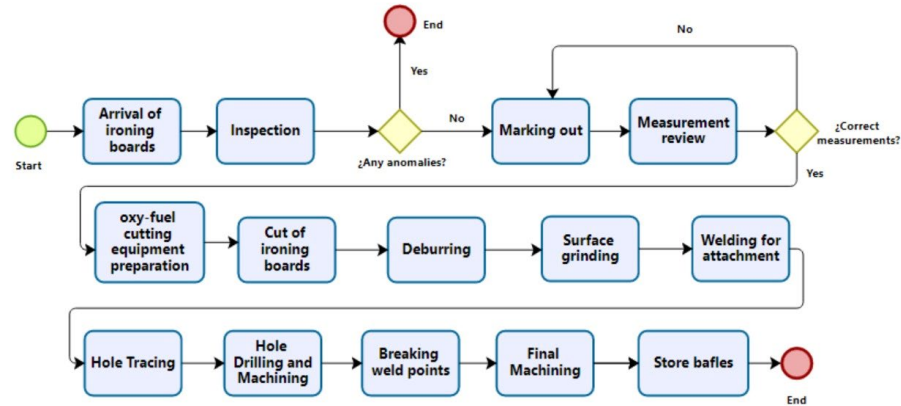


Figure 4. Diagram process in BPMN

Table 2. Comparison between indicators of the original and proposed scenario

Indicator	Original Scenario	Proposed Scenario
Average machine availability	73.23 +/- 0.32 %	75.25 +/- 0.34%
Average time per baffle	77.30 +/- 5.15 minutes	54.60 +/- 4.48 minutes
Percentage of shrinkage produced	30 %	30%
Average transfer time	18.03 +/- 5.57 *10 ⁻⁵ minutes	2.3 +/- 2.98 *10 ⁻⁵ minutes
Average cycle time per batch of baffles	367.75 +/- 10.49 minutes	243 +/- 6.42 minutes

The average manufacturing time was significantly reduced, as was the average cycle time per batch and transfer time. On the other hand, a slight increase in average machine availability was observed in the proposed scenario. These results presented in the improved scenario indicated progress; however, this comparison between the data shown is not sufficient to reach a definitive conclusion. Therefore, it was necessary to use the Output Analyzer tool (View Figure 5 and Figure 6), which made it possible to visualize and analyze the results with greater precision and reliability.

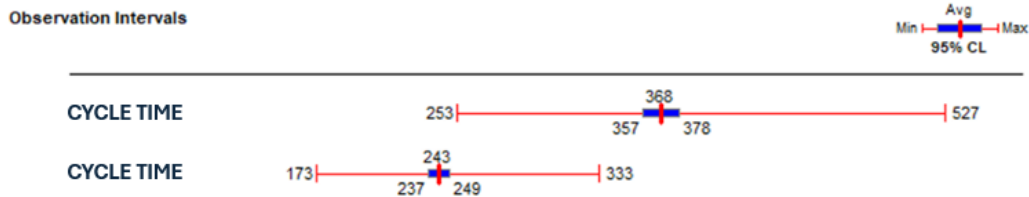


Figure 5. Cycle Time

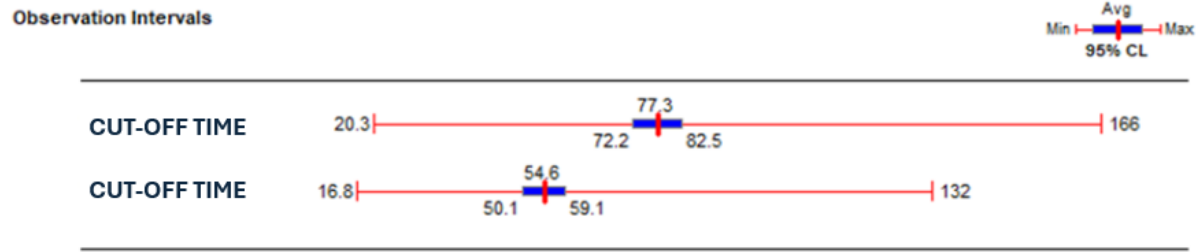


Figure 6. Cut-off Time

The figure shows the comparison of the confidence intervals generated for both indicators. Furthermore, it can be seen that in both cases the intervals do not overlap significantly; that is, they are completely separated, as are the corresponding means. Therefore, it can be concluded that there are significant differences, the value in the original model being higher. In order to evaluate and analyze the functional impact of the proposed scenario, it is important to consider the verification of the technical gap presented in previous sections. Table 3 below shows a comparison of the indicators for the current scenario, the proposed scenario, and the industry standard.

Table 3. Technical gap closure

Indicators	Current	Proposed	Industry standard
Percentage of orders delivered on time	25%	35.49%	35%
Penalty Rate	16.70%	11.76%	-
Warehouse to production service level	50%	75.25%	70%
Percentage of shrinkage produced	30%	30%	-
Average manufacturing time	72 minutes/baffle	54.6 minutes/baffle	-

To obtain the values for the proposed scenario, the indicators previously evaluated in the Arena 16.2 software were correlated. On the one hand, the percentage of orders delivered on time in the proposed scenario is 35.49%, while the industry standard is 35%. This slight improvement is due to the reduction in cycle time and in the cutting stage, which is above the standard level, as indicated by Kishimoto et al. (2020) for the Peruvian metalworking industry. As for the level of service from warehouse to production, it initially performed poorly; however, the value reflected in the proposed scenario indicates a percentage of 75.25%. Therefore, the gap between the two indicators was completely eliminated, as the sector's results revealed a service level of 70% (Leon Andia et al. 2021).

6. Discussion

In order to evaluate and analyze the functional impact of the proposed scenario, it is important to consider the verification of closing the technical gap. On one hand, the percentage of orders delivered on time in the proposed scenario is 35.49%, whereas the sector standard is 35%. As indicated for the Peruvian metal mechanical sector, this slight improvement is attributed to the reduction in cycle time and cutting stage, positioning it above the standard level (Kishimoto et al. 2020). Regarding warehouse-to-production service level, initially showing unfavorable performance, the value reflected in the proposed scenario indicates a percentage of 75.25%. Therefore, the gap between both indicators has been eliminated, as sector results revealed a service level of 70% (Donamai et al. 2023).

Regarding the implementation of the 5S methodology in the Baffles manufacturing process, a 10% reduction in the total cycle time of all activities was achieved, positively impacting the delivery service level of these products. This result coincides with a study showing a 46% increase in delivery time in a metal-mechanical company, concluding that the 5S methodology serves as a foundation for implementing other Lean tools (Kishimoto et al. 2020). Furthermore, the results of this research are consistent with findings from other authors who applied this methodology in an industrial assembly company similar to the study's subject, resulting in improvements in productivity efficiency

and activity standardization (Donamai et al. 2023). While in this study the methodology was applied to a specific process, its effects can be seen across all company operations (Barbosa et al. 2021).

Regarding the application of SMED in the cutting stage, an average reduction of 23 minutes was achieved. These results align with research where setup time decreased from 44 minutes to 8.1 minutes through SMED implementation (Singh et al., 2018). This achievement was made possible by reorganizing internal resources of the company without requiring significant investment. Similarly, another study related to the present work achieved a 50% reduction in mold changeover time using this Lean tool, benefiting production flow between stations (Huang et al. 2022)

According to Seminario et al. (2023), the application of SLP tools yielded satisfactory results in a metal-mechanical company, such as a 14.54% cycle time reduction resulting from a 75.64-meter process route reduction. This observation aligns with our research results, as optimization of the process flow with SLP methodology led to a significant 33.79% reduction in cycle time. Additionally, an optimal reorganization of workstations significantly contributed to process efficiency improvement. Likewise, the impact achieved with this tool coincides with findings from an improvement project where a similar SLP implementation procedure was used to propose an optimized plant layout (Campos et al. 2020).

Process simulation emerges as an effective tool for mitigating uncertainty by allowing exploration of various potential scenarios without committing the real system to costly modifications or early investments (Zarza 2021). This assertion is reflected in the current study, as process simulation was conducted using Arena Version 16.2 software, especially considering the inherent limitations of our project mentioned in previous sections. Similarly to Seminario et al. (2023) and González et al. (2017), a similar procedure was applied to simulate the process in the mentioned simulation program, which included validation of both the current process and the proposed improvements in the enhanced model.

Regarding the limitations of the study, it is important to highlight that it focused on a specific aspect of the heat exchanger manufacturing process: the production of baffles. It is acknowledged that a comprehensive analysis of the entire process would have required greater investment of resources and time. This approach is similar to the methodology employed in an improvement project at a metal-mechanical company, where the authors also chose to concentrate on a specific process, specifically the assembly process of metal parts kits (De Mello et al. 2017).

7. Conclusion

This study successfully achieved its primary objective through simulation using Arena 16.2 software. The manufacturing time of baffles, represented by the cycle time, was reduced by 24.17%, demonstrating that the implemented improvements were effective in optimizing this key performance indicator. The application of the SMED tool resulted in a 10% increase in the on-time delivery rate, mainly due to improved machine availability. Additionally, the redistribution of facility areas using the SLP tool reduced unnecessary material flows between workstations, leading to a 25% improvement in the warehouse-to-production service level. Overall, these findings confirm the effectiveness of the proposed solution, as the obtained results exceeded both industry benchmark values and the objectives established at the beginning of the study.

A critical analysis of the baffle manufacturing process was fundamental to identifying the most influential stages and their respective time contributions. This detailed examination revealed key factors that contributed to extended manufacturing times, including inadequate warehouse-to-production service levels, inefficient material handling, high scrap rates, and insufficient process standardization.

In conclusion, this study demonstrates that the integration of simulation using Arena 16.2 software with Lean Manufacturing and SLP tools constitutes an effective and replicable approach for reducing unproductive time in low-frequency metalworking environments. The proposed framework not only provides practical guidance for operational management but also represents a significant methodological contribution for future research aimed at the optimization and continuous improvement of manufacturing systems.

Despite the positive outcomes, the findings also highlight the need for further research. It is recommended that future studies examine the effect of external variables, such as market demand variability and raw material price fluctuations,

on the sustainability and robustness of the improvement strategies. Understanding how these external conditions influence operational performance will support the development of more resilient systems. Furthermore, exploring additional stages of the industrial equipment manufacturing process may uncover other opportunities where Lean Manufacturing and SLP tools can generate measurable benefits.

References

- Anami Donomai, N., & Rocha Pinto, F, Application of methodology 5s in an industrial assembly company in the City of Manaus, AM. *International Journal For Innovation Education And Research*, 114-126. 2023.
- Anton, A., Roque, M., & Ramos, E, Lean Warehousing Model to improve the Order Fulfillment in a Metalworking Company. *ICIBE*. 2022. doi: <https://doi.org/10.1145/3568834.3568881>
- Barbosa, A., Morello, J., Campana, H., & Anjo, A, Implantação do programa 5s e ferramentas da qualidade: Um estudo de caso em uma empresa Metalúrgica de pequeno porte. *Revista Científica Multidisciplinar Núcleo do Conhecimento*, 4, 142-160.2021. Obtenido de <https://www.nucleodoconhecimento.com.br/engenharia-de-producao/ferramentas-da-qualidade>
- Campos, G. F., & Silva, A. L, Application of the SLP methodology in a company manufacturing household products. *Produção Online*, 422-448. 2020. Obtenido de <https://link.gale.com/apps/doc/A643043086/IFME?u=anon~3a55023&sid=googleScholar&xid=a51a8675>
- C. Huang, D. Lee, S. Chen, W. Tang, “A Lean Manufacturing Progress Model and Implementation for SMEs in the Metal Products Industry” *Processes*, 2022.
- De Mello, M. F., Cunha, L. A., da Sila, N. J., & Cardoso Araujo, A. , A importância da utilização de ferramentas da qualidade como suporte para melhoria de processo em indústria metal mecânica – um estudo de caso. *Exacta*, 15(4), 63-75. 2017.
- González Torres, A., Ramirez Castañeda, A., Ricardez González, D., Fernández López, S., & Martínez Muñoz, M. , Improvement of the production process through the application of the simulation technique. *International Journal of Trend in Scientific Research and Development*, 10-17. 2017. doi: <https://doi.org/10.31142/ijtsrd5821>
- Kishimoto, K., Medina, G., Sotelo, F., & Raymundo, C, Application of Lean Manufacturing Techniques to Increase On-Time Deliveries: Case Study of a Metalworking Company with a Make-to-Order Environment in Peru. *Springer Nature Switzerland* 952–958. 2020.
- Leon Andia, P. A., & Gonzales Camarena, L. P, Modelo para la optimización del proceso de abastecimiento de una MYPE del sector metalmecánico mediante la notación de procesos con el BPMN y la inspección de inventarios. Obtenido de <https://n9.cl/xnpip0> , 2021.
- Merzthal Toranzo, B., Third-party logistics as a competitive advantage in utilities spare parts management, *IFAC-PapersOnLine*, vol. 51, no. 11, pp. 600–605, 2018.
- Monteiro, C., Ferreira, L. P., Fernandes, N. O., Silva, F. J. G., & Amaral, I, Improving the machining process of the metalwork industry by upgrading operative sequences, standard manufacturing times and production procedure changes. *Procedia Manufacturing*, 38(2019), 1713–1722. 2019. <https://doi.org/10.1016/j.promfg.2020.01.106>
- Palaksha Reddy, K., Kumar, D., Venkatraman, R., & Vishweshvar, V. , Cycle time reduction studies in threading. *International Journal of Mechanical and Production Engineering Research and Development*, 8(2), 149–156.2018.
- Pinto, G. F. L., Silva, F. J. G., Campilho, R. D. S. G., Casais, R. B., Fernandes, A. J., & Baptista, A, Continuous improvement in maintenance: A case study in the automotive industry involving Lean tools. *Procedia Manufacturing*, 38(2019), 1582–1591. 2019. <https://doi.org/10.1016/j.promfg.2020.01.127>
- Rodrigues, J.; de Sá, J.C.V.; Ferreira, L.P.; Silva, F.J.G.; Santos, G. Lean management “quick-wins”: Results of implementation. A case study”. *Qual. Innov. Prosper*, 23, 3–21 . 2019
- Seminario Mestanza, C., Soto Araujo, A., Collao Díaz, M., Quiroz Flores, J., & Flores Perez, A, Production Model Based on Total Productive Maintenance and Systematic Layout Planning to increase Productivity in the Metalworking Industry. *Journal of Economics*. 2023. doi: <http://dx.doi.org/10.18178/joebm.2023.11.2.741>
- Singh, J., Singh, H., & Singh, I, SMED for quick changeover in manufacturing industry – a case study. *Benchmarking: An International Journal*. 2018. doi: <https://doi.org/10.1108/BIJ-05-2017-0122>
- Zarza Diaz, R, Simulación de mejora en el proceso de galvanizado. *Tema A2b Manufactura*. 2021.
- Zea Maridueña, Jorge Luis, Eliminación de las salvaguardias y su impacto financiero en el sector metalmecánico del Ecuador. *Revista Universidad y Sociedad*, 13(5), 621-627. Epub 02 de octubre de 2021. <https://n9.cl/mmjpv>

Biographies

Dorcas Shalom Guerrero-Cáceres holds a Bachelor's Degree in Industrial Engineering from the Universidad de Lima (UL). She is a Comercial Assistant in logistics area since 2025. She has specialized in Supply Chain Management, also at Universidad de Lima. Her experience focuses on managing logistics and operational processes related to the supply chain in the automotive sector.

Daniel Alberto Ramos-Olivera holds a Bachelor's Degree in Industrial Engineering from the Universidad de Lima (UL). He is a commercial Data Analyst of OXXO Perú since 2024. His research interests include pricing and promotion strategy, optimization, predictive analysis, data science and machine learning.

Marcos Fernando Ruiz-Ruiz holds a Degree in Industrial Engineering and a PhD in Education Sciences from Pontificia Universidad Católica del Perú (PUCP). He is currently Associate Professor of the Research Methodology Projects Area of the Faculty of Engineering at Universidad de Lima (UL). He holds a Postgraduate Certificate (Expert Diploma) in Future Studies from UNED (Spain). He is a Renacyt researcher accredited by the National Council of Science and Technology of Peru (Concytec). Additionally, he is a member of several professional organizations, including the Ibero-American Chapter of the World Futures Studies Federation (WFSF), the Peruvian Society for Educational Research (SIEP), the College of Teachers of Peru (CPP) and the College of Engineers of Peru (CIP).