Original Paper

Application Of Lean Manufacturing Tools To Improve The Efficiency Of A Manufacturing Company's Laboratory, Lima, 2025

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Abstract: The objective of this study is to assess the impact of Lean Manufacturing tools on the efficiency of a laboratory within a production company located in Lima. To this end, a total of 16 weekly records from the pre-test stage (from November to February) and an additional 16 records from the post-test period (from July to October 2025) were reviewed. The research was characterized by its applied nature, employing a quantitative approach, an explanatory level, and a pre-experimental design. Information was collected using record formats and checklists. The findings indicated significant enhancements after the implementation of the 5S and Poka-Yoke methodologies. The total efficiency of the system increased from 56%. The percentage increased from 45% to 86.41%, indicating a substantial rise of 53.06%. Concurrently, there was a 15% increase in the efficiency of material usage. 24% of the labor force by 15. The efficiency of the teams was found to be 87%, which is a 14% increase from the previous year. The observed discrepancy, which amounted to 10%, was primarily attributable to a reduction in downtime. The hypothesis was analyzed, yielding a significance value of 0.00. This finding serves to reinforce the conclusion that the implementation of Lean Manufacturing practices is conducive to enhancing the efficiency of the laboratory.

Keywords: Lean Manufacturing, Efficiency, 5S, Poka-Yoke, Laboratory

How to cite this article: Janeth SFM, Yajaira RPL, Laguna Dávila RF. Application of Lean Manufacturing Tools to Improve the Efficiency of a Manufacturing Company's Laboratory, Lima, 2025. Int J Drug Deliv Technol. 2026;16(13s): 109-126. DOI: 10.25258/ijddt.16.13s.12

1 INTRODUCTION

In the contemporary business landscape, particularly within the industrial sector, organizational effectiveness has emerged as a pivotal element in ensuring sustainability and competitiveness. This is particularly pronounced in a global environment characterized by escalating expectations for quality, expeditiousness, and the optimization of resources. The enhancement of efficiency not only facilitates augmented productivity but also contributes to the reduction of operating costs, fosters continuous improvement, and fortifies internal processes. These principles align with SDG 9, which pertains to Industry, Innovation and Infrastructure, emphasizing the modernization of processes through technological advancements, sophisticated methodologies, and the establishment of orderly and safe work environments. In this manner, a well-organized, clean, and standardized workplace not only circumvents issues in production procedures and pattern control, but also ensures immediate access to essential tools, facilitating compliance with the requisite quality standards (UN, 2024). This approach is especially relevant in key areas such as quality laboratories, where any deviation or delay can directly affect the production chain.

On an international scale, the packaging sector has undergone consistent expansion, propelled by robust demand from the food, pharmaceutical, cosmetics, and consumer goods industries. This growth has led to a substantial increase in the sector's value, which reached a staggering 1.24 trillion dollars in the year 2024. Projections indicate that by 2034, it will exhibit a growth rate of 3.16% annually, underscoring the imperative for enhanced efficiency, adaptability, and sustainability in operational processes (Statista, 2025). Companies with a global reach, such as Pepsi, have begun to apply redesign strategies in the production and use of recycled materials. For instance, they have incorporated 50% recycled plastic in their premium packaging, with the aim of improving sustainability and optimizing efficiency in critical processes (El Empaque, 2024). Concurrently, the global plastic packaging market, propelled by novel regulations, the pursuit of biodegradable alternatives, and escalating industrial demand, is anticipated to expand from 6.220 million in 2024 to 7.300 million by 2025, exhibiting a compound annual growth rate of 17.4% (The Business Research Company, 2025). This trend underscores the importance of companies optimizing their internal processes to ensure quality, traceability, and a rapid response to market challenges.

In Latin America, several economies have demonstrated consistent development in the manufacturing sector. Mexico and Brazil are salient examples that demonstrate the region's capacity to cope with variations in the global economy, as evidenced by their growth figures. In particular, Mexico reported a 5% increase in the second quarter of 2024 compared to the previous quarter (TLC Magazine Mexico, 2024). This growth can be attributed to several factors, including the consolidation of supply chains, the relocation of factories, and the adoption of automated technologies. In Peru, the manufacturing sector demonstrated a year-over-year growth of 2.7% in September 2024, signifying a transition towards more technical and effective methodologies (ANDINA, 2024). Furthermore, policies have been implemented with the objective of reducing the use of single-use plastics. For instance, the Plastic Law promoted the import and production of biodegradable packaging between 2021 and 2022. However, research has demonstrated significant variations in the operational efficiency of certain companies within this sector, including one factory with an efficiency rating of 71. The data indicates that 67% of the population requires the implementation of continuous improvement strategies (INEI, 2022).

In the local context, the company, which has over three decades of experience in the production of sustainable plastic packaging, faces challenges in its Quality Laboratory in the injection area. This area is responsible for the manufacture of standard performance. These performances play a pivotal role in ensuring that production aligns with the standards set by customers. However, a progressive decline in the efficiency of this laboratory has been observed, attributed to the following factors: inadequate classification, disorganization of inputs, and incorrect arrangement of the standards. These issues result in downtime, reprocesses, control errors, and delays in deliveries to production. The laboratory constitutes a pivotal component within the value chain, and any failure at this stage has the capacity to exert a direct and substantial impact on the entire production line. This underscores the imperative for the implementation of systematic improvement tools.

To identify the underlying causes of this inefficiency, root cause analysis techniques were implemented, leading to a comprehensive understanding of the contributing factors. The brainstorming technique was initially employed to elicit a range of concepts associated with the challenges identified by the area team. Subsequently, the Ishikawa Diagram was implemented to categorize the root causes according to the 6M, thereby offering a comprehensive understanding of the genesis of the discrepancies. Subsequently, the Vester Matrix enabled the assessment of the interactions and influence of each factor, yielding a score of 149 in the active variables. These findings enabled the formulation of a frequency table and the development of a Pareto chart, which revealed that 80% of the observed low efficiency was attributable to 20% of the factors, including insufficient drawers, inadequate classification, and errors in the placement of patterns. This analysis enabled the identification of a particular group of critical causes that required immediate attention. Conversely, stratification revealed that the Quality Laboratory, with a score of 498, was the primary domain where issues were concentrated, thereby designating it as the suitable experimental group for the intervention.

Pursuant to the findings of the diagnostic evaluation, a range of alternative solutions was contemplated through the utilization of a matrix that facilitated a comparative analysis of engineering tools. This analysis determined that Lean Manufacturing was the most suitable methodology to address the issue of low efficiency, due to its emphasis on the elimination of waste and the enhancement of processes. This approach enabled the delineation of both the overarching problem and its constituent elements, with a particular emphasis on the evaluation of Lean's impact on efficiency metrics such as overall, material, labor, and equipment efficiency within the context of the manufacturing company's laboratory.

The rationale underlying the study is found upon three pivotal aspects. From a pragmatic standpoint, the objective is to address a genuine problem by implementing novel methodologies that enhance quality and standardize processes (Romero et al., 2023, p. 7). In the methodological domain, the objective is to develop instruments that facilitate precise measurement of variables, thereby establishing the interrelationships between them within the context of research (Romero et al., 2023, p. 6). In terms of their social impact, the findings will directly benefit laboratory staff by improving accessibility, order, and availability of patterns, which will reduce unnecessary time and alleviate the operational burden (Romero et al., 2023, p. 9). Consequently, this study enhances operational efficiency, fosters employee well-being, and strengthens organizational culture.

The background analysis supports the implementation of Lean Manufacturing as an effective strategy to increase efficiency in several production areas. Hinojosa and Cabrera (2022) demonstrated an increase of 144. A survey of microenterprises in Guayaquil revealed that 21% of them were affected. Manzano and Ramos (2024) reported a growth of 23.55%, while Malavé et al. (2024) demonstrated an increase of 28%. Seventy-seven percent of the subjects in the diesel injection laboratory reported that they had done so. In the industrial field in Ecuador, Espinales et al. (2024) achieved 86% efficiency after the tests, and Ganesan et al. (2023) demonstrated an increase of 31%. The application of Lean practices resulted in a 71% increase in productivity. In Peru, Bruce (2025) documented significant improvements of 28%, while Campos et al. (2024) reported increases of 12%. The extant research demonstrates an increase of 62%, as evidenced by Olivares et al. (2023) and Bravo (2023), with further increases of 22.95% and 26%, respectively. 92%, respectively. Finally, Delgado and Esquen (2021) achieved an increase of 5. The evidence that Lean Manufacturing can be applied in various sectors with effective results is further strengthened by the finding that 42% of the respondents were in the opinion that Lean Manufacturing is effective. These studies contribute to the contextualization and validation of the efficacy of Lean tools within the laboratory under investigation.

From a conceptual standpoint, Lean Manufacturing is defined as "a management philosophy whose primary objective is to reduce waste and maximize value for the customer" (Rajadell, 2021). The Toyota Production System (TPS) was developed in the aftermath of World War II and has since gained international recognition for its competitive advantages (Rahardjo et al., 2023, p. 6). Cerro (2022) characterizes this methodology as an approach focused on waste management, while Vargas and Camero (2021, p. 2) see it as a philosophy focused on eliminating activities that do not add value. As Munive et al. (2022, p. 2) emphasize, this approach is pertinent to economic growth and continuous improvement, with a view to sustainable development. The identification of waste, otherwise known as "mute," is of crucial importance in the Lean framework, as any activity that consumes resources without adding value must be reduced or eliminated (Rajadell, 2021). The eight types of shedding—defects, overproduction, waiting, untapped talent, transportation, inventory, movement, and overprocessing—form the foundational operational framework upon which improvements are structured.

The theory of the five zeros aims to establish ambitious goals to achieve complete waste elimination (Ariza & Martín, 2025). Consequently, several foundational principles such as VSM, 5S, Poka-Yoke, Kaizen, SMED, JIT, Andon, TQM, Heijunka, and Kanban are integral components of the Lean Manufacturing methodological approach (Hinojosa & Cabrera, 2022, p. 4). In this study, the 5S and Poka-Yoke tools were the only ones implemented. The 5S methodology prioritizes the classification, organization, cleaning, standardization, and maintenance of discipline in the work environment, with a focus on enhancing efficiency, safety, and the reduction of errors (Gómez, 2020; Hernández et al., 2023; Aldaz, 2022; Palomino & Vásquez, 2023; Juárez et al., 2021; Jaén et al., 2020). Concurrently, Poka-Yoke functions as an "error-proof" system, emphasizing the prevention of human errors from the initial stages of the process (Olivares, Salas, & Gil, 2023, p. 1). The integration of these tools fosters an environment characterized by order and resilience, thereby mitigating the risk of operational failures.

Conversely, efficiency is defined as "the appropriate use of resources" to achieve goals or generate results with minimal inputs (Ruffier, 1998). This concept may also be interpreted as the optimal relationship between the cost of the resources utilized and the results obtained (Olivera, 2022, p. 10). Efficiency can be categorized into two distinct dimensions: technical and economic. The technical dimension pertains to a firm's capacity to optimize production by leveraging available resources. In contrast, economic efficiency focuses on minimizing costs through the most efficient utilization of those resources (Ruiz et al., 2022). In the industrial sector, efficiency is paramount to ensure the continuity of operations, the quality of the final product, and competitiveness in the market.

In consideration of the theoretical and contextual underpinnings, the study posits a general hypothesis that the implementation of Lean Manufacturing tools enhances the efficiency of the Quality Laboratory of a manufacturing company in Lima. Furthermore, specific hypotheses are formulated related to improvements in material, labor, and equipment efficiency. The evaluation of these hypotheses will be conducted using a pre-experimental design, which will enable the measurement of the intervention's effect before and after its implementation.

2 METHOD

The research presented is considered applied, as it is conducted with the objective of providing an immediate solution to a specific problem that has been identified in the Quality Laboratory of a manufacturing company. This type of study, also known as empirical or practical, aims to generate knowledge that is useful and that can be transferred to improve specific processes within organizations. It aligns with the need to optimize operational efficiency using Lean Manufacturing tools. As Vizcaíno et al. (2023, p. 9737) have noted, the objective of applied research is to identify viable solutions that can be implemented in various industrial contexts. In this case, an intervention was developed that employs 5S and Poka-Yoke to address root causes that had been previously identified through Pareto and Ishikawa analysis.

The approach that was adopted was a quantitative paradigm, which is characterized by the objective collection of data, the use of standardized tools, and the implementation of strict statistical methods for the analysis of the variables under study. This methodological approach facilitates the attainment of reliable results, which can be replicated and comparatively analyzed, particularly in cases where the objective is to measure variations between two distinct moments—before and after a specified intervention. Vizcaíno et al. (2023, p. 9726) emphasize that quantitative research is predicated on the collection of numerical data and the application of statistical techniques, rendering this type of design appropriate for assessing the observed changes in the dimensions of efficiency: inputs, labor, and machinery.

The research is explanatory in nature, as it not only delineates the problem but also endeavors to comprehend the relationship between cause and effect concerning the use of Lean Manufacturing tools and alterations in efficiency. This analytical level enables us to investigate the underlying causes of the phenomenon and ascertain the impact of specific variables on the observed behavior (Vizcaíno et al., 2023, p. 9740). Consequently, the study's scope extends beyond the mere assessment of efficiency, encompassing an evaluation of whether the Lean-based intervention has contributed to its enhancement. This evaluation is meticulously executed through a systematic quantitative process, encompassing a pre-intervention and post-intervention assessment.

The selected design is a pre-experimental design, specifically the type that performs a pre-test and post-test with a single group. This design is commonly used in applied research when it is not feasible or not considered appropriate to have a control group. The design of the study involves the evaluation of the same group before and after the intervention to ascertain the effect that the application of the strategy (Lean Manufacturing) has had. According to Vizcaíno et al. (2023, p. 9731), this design incorporates a single group (G), an initial measurement (O1), the implementation of the intervention (X), and a subsequent measurement (O2). In the present study, the group is constituted by the company's Quality Laboratory, where the 5S and Poka-Yoke tools were implemented, enabling a direct comparison between the initial state and the final state.

From a pragmatic standpoint, the independent variable, Lean Manufacturing, was examined through two lenses: The 5S and Poka-Yoke methodologies were implemented, with the objective of utilizing quantifiable metrics to assess the degree of adherence to the 5S and Poka-Yoke principles. The evaluation framework encompassed the 5S Compliance (C5S) and Poka-Yoke Compliance (CPY). The evaluation was conducted using registration forms and checklists, employing a ratio measurement scale, given that the values obtained have an absolute zero and permit mathematical calculations to be made. The determination of compliance with the 5S was achieved through the implementation of the formula.

$$C5S = \frac{PO}{PI} \quad (1)$$

while for Poka-Yoke the relationship was used:

$$CPY = \frac{EA}{EH} \quad (2)$$

These indicators enabled the objective assessment of the implementation level of each tool within the laboratory.

Conversely, the dependent variable, Efficiency, was operationalized in three dimensions: Material efficiency, labor efficiency, and equipment efficiency are measured using percentage indicators that are frequently employed in industrial process studies. The following formula was utilized to ascertain the efficiency of the materials:

$$PEM = \frac{TMAP}{TMUP} \quad (3)$$

which determines the amount of material used versus the amount allocated. Labor efficiency was measured by:

$$PEMO = \frac{THUP}{THP} \quad (4)$$

and equipment efficiency was assessed by:

$$PEE = \frac{THOE}{THPE} \quad (5)$$

The evaluation of these dimensions was conducted through the analysis of weekly operation records and checklists, employing a ratio scale to ensure the validity of the results from both mathematical and comparative perspectives in the two instances examined.

With respect to the population, it was defined as the aggregate of weekly records pertaining to the fabrication of standard preforms executed in the Quality Laboratory. A total of 16 records were identified for the pre-test period (from November to February), and an additional 16 records were selected for the post-test period (from July to October 2025). These records were meticulously defined to include only those occurring from Monday to Saturday, excluding Sundays and activities deemed unrelated to the identification of patterns. Given the population's accessibility and manageable size, the sample encompassed the entire population, thereby eliminating the necessity for probability sampling. The unit of analysis was each of the weekly pattern creation records, which ensured consistency and comparability in the measurements.

The efficacy of methods such as document analysis and on-site observation in obtaining data was demonstrated, particularly in the context of reviewing operational records and assessing compliance with procedures within the laboratory. The instruments employed in this study encompassed efficiency record forms, 5S and Poka-Yoke lists, in addition to official checklists and formats stipulated by the company for the governance of laboratory tasks. These instruments enabled the collection of quantifiable and consistent data throughout the process.

The validity of the instruments was of a contained type, as assessed through the judgment of experts who examined the instruments in terms of clarity, relevance, and relevance. The instruments were evaluated by three specialists from the Faculty of Engineering and Architecture, who confirmed their suitability for evaluating the established dimensions (see Table 3). Conversely, the reliability of the data was substantiated by the calibration certificates of the equipment utilized for time measurement, along with a formal endorsement from the company, which attested to the accuracy of the collected information.

With regard to the analysis of data, both descriptive and inferential statistical techniques were employed. The descriptive analysis encompassed measures of central tendency (mean, median, mode), dispersion (standard deviation, variance), and shape (asymmetry and kurtosis). These statistics offer a detailed characterization of the behavior of each dimension of the efficiency variable in both contexts. Subsequently, the normality of the data was evaluated using the Shapiro-Wilk test, given that the sample size was 50 units or less. The distribution found necessitated the implementation of the Student's T-test, a statistical test used to compare the general and specific hypotheses. This approach enabled the determination of statistical significance between the observed differences in measurements before and after the intervention (Ibáñez et al., 2023).

In conclusion, the fundamental ethical principles were addressed, including the promotion of well-being, the prevention of harm, equity, and privacy. The intervention was meticulously designed to ensure that it offered advantages to staff, while also taking measures to avoid any form of harm or danger. Furthermore, it was implemented with the objective of ensuring that all parties had equitable access to the resulting benefits. In a similar way, the information provided by the company was treated confidentially. This approach was taken to safeguard the identity of the collaborators and to ensure that the data was used exclusively for academic purposes. This protocol was in accordance with the guidelines established by Reyes et al. (2020) and Gonzáles et al. (2024).

3 RESULTS

In relation to the general objective for Total Efficiency, the average for the two evaluation stages is detailed, as can be seen in Fig. 1.

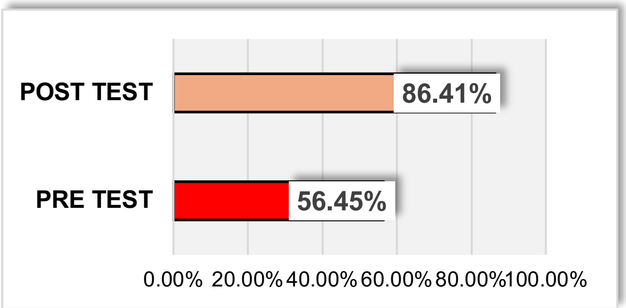


Fig. 1. Variation in Total Efficiency

As illustrated in Fig. 1, the mean percentage for the pre-test was recorded at 56.45%, while for the post-test, it was recorded at 86.41%. This discrepancy can be attributed to the standardization of laboratory procedures. According to the data, the calculation was performed to determine the variation in the increase using the formula:

$$\%\ of\ Improvement\ variation = \left(\frac{Post\ test - Pre\ test}{Pretest}\right) x100\% \quad (6)$$

Recording the data in the figure, the following formula was obtained:

$$\%\ of\ Improvement\ variation = \left(\frac{86.41 - 56.45}{86.41}\right) x100\% \quad (7)$$

$$\%\ of\ Improvement\ variation = 53.06\% \quad (8)$$

Consequently, the total efficiency exhibited a marked increase of 53.06%, attributable to the effective utilization of designated resources, including materials, labor, and equipment, within the laboratory sector of the study company.

With regard to the initial specific objective concerning material efficiency, the mean for the two evaluation stages is illustrated in Fig. 2.

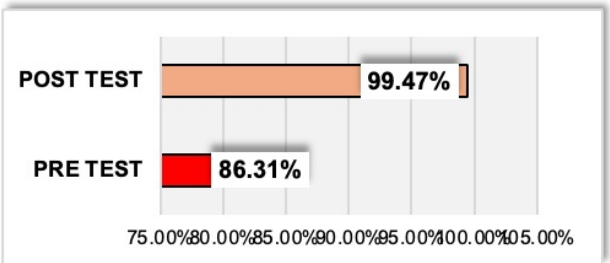


Fig. 2. Varying Material Efficiency

The Fig. indicates an average pre-test score of 86.31% and a post-test score of 99.47%. This improvement can be attributed to the standardization of the material necessary for the creation of a pattern, in accordance with the order programming. According to the data, the calculation was performed to determine the variation in the increase using the following formula.

$$\%\ of\ Improvement\ variation = \left(\frac{Post\ test - Pre\ test}{Pretest}\right) x100\% \quad (9)$$

Recording the data in the figure, the following formula (4) was obtained:

$$\%\ of\ Improvement\ variation = \left(\frac{99.47 - 86.31}{86.31}\right) x100\% \quad (10)$$

$$\%\ of\ Improvement\ variation = 15.24\% \quad (11)$$

Consequently, Material Efficiency exhibited an augmentation of 15.24%, attributable to the effective application of materials, a development that proved advantageous for the study company.

In regard to the second specific objective for labor efficiency, the mean for the two evaluation stages is illustrated in Fig. 3.

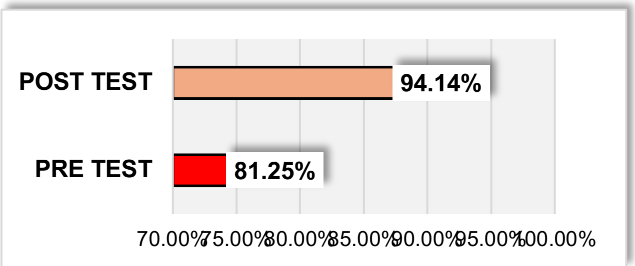


Fig. 3. Labor Efficiency Variation

From Fig. 3, it is indicated that the average for the pre-test was 81.25% and for the post-test it was 94.14%, this is because it was possible to reduce unnecessary times where the staff did not comply with their work activities. According to this, an attempt was made to ascertain the extent of the variation in the increase by employing the following formula:

$$\%\ of\ Improvement\ variation = \left(\frac{Post\ test - Pre\ test}{Pretest}\right) x100 \quad (12)$$

Recording the data in the figure, the following formula was obtained:

$$\%\ of\ Improvement\ variation = \left(\frac{94.14 - 81.25}{81.25}\right) x100\% \quad (13)$$

$$\%\ of\ Improvement\ variation = 15.87\% \quad (14)$$

Consequently, Labor Efficiency exhibited an augmentation of 15.87%, with the eradication of downtime from 0.3 hours to 0.1 hours, thereby facilitating an escalation in patterns, adhering to the stipulated schedule, and ensuring client satisfaction.

In regard to the third specific objective for team efficiency, the mean for the two evaluation stages is illustrated in Fig. 4.

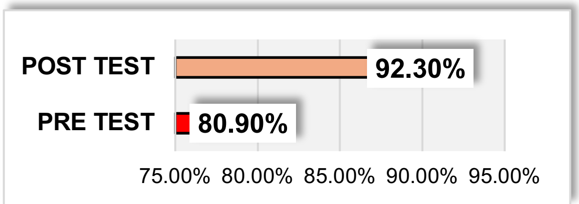


Fig. 4. Variation in Equipment Efficiency

Fig. indicates an average of 80.90% for the pre-test and 91.94% for the post-test. This improvement can be attributed to the effective programming of the equipment by the personnel of the area, who utilized the equipment in an orderly and programmed manner. According to the data, the calculation was performed to determine the variation in the increase using the formula:

$$\%\ of\ Improvement\ variation = \left(\frac{Post\ test - Pre\ test}{Pretest}\right) x100\% \quad (15)$$

Recording the data in the figure, the following formula was obtained:

$$\%\ of\ Improvement\ variation = \left(\frac{91.94 - 80.90}{80.90}\right) x100 \quad (16)$$

$$\%\ of\ Improvement\ variation = 13.65\% \quad (17)$$

Then, Equipment Efficiency achieved an increase of 13.65%, using the equipment according to the schedule, allowing the evaluation of the patterns in time to be sent to production and their manufacture according to the customer's request.

3.1 Descriptive analysis of Total Efficiency

Then, the descriptive statistical analysis of the Total Efficiency was carried out, as detailed in Table 1.

Table 1. Descriptive type of central trend of Total Efficiency

Central trend		
	ET_PRE	ET_POST
Stocking	56,45	86,41
Median	55,78	86,53
Fashion	46.89a	79.07a

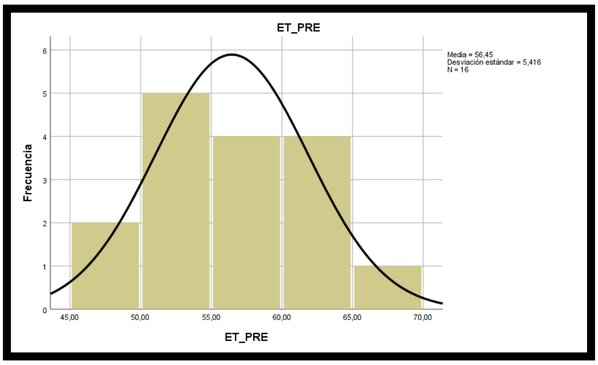
According to the central trend, the average value exhibited a substantial increase, surpassing 30%. This finding is the most significant evidence of a substantial positive impact of the intervention. The median value also showed a substantial increase. The distribution of the data is relatively balanced around the mean in both cases, as evidenced by the proximity of the median to the mean in both the PRE and POST analysis. The most common value (mode) also increased; however, it is considerably lower than the mean and median in the two states. This finding suggests that the data may still indicate a concentration of low values.

Table 2. Dispersion type description of the Total Efficiency

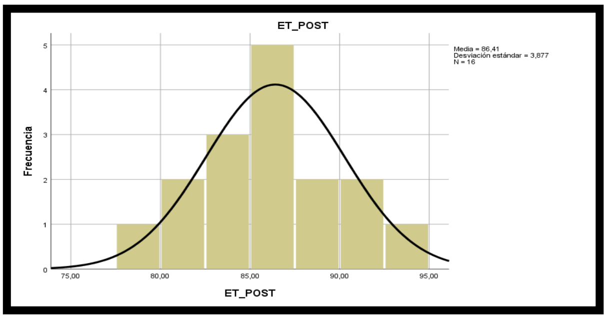
Dispersion		
	ET_PRE	ET_POST
Desv. Deviation	5,42	3,88
Variance	29,33	15,03

The standard deviation of the data increased substantially following the intervention, indicating a significant increase in the variability of the data points relative to the pre-intervention levels. This increase in variability suggests that, while the mean value has increased, the individual data points are less consistent and more dispersed than before. To calculating variance, the standard deviation squared was multiplied by a factor of three. This calculation yielded an approximate result of 3.46. This finding indicates that the variability of total efficiency data has increased considerably in conjunction with the implementation of Lean Manufacturing.

Table 3. Labor Efficiency Description



ASYMMETRY	KURTOSIS
PRE (+0.54): The distribution shows a bias to the left of moderate intensity. This means that in the distribution, the queue is on the left and the data is mostly on the right (the values are higher).	PRE (-0.93): Being close to zero (platicurtic), indicates a distribution with peaks similar to normal.



KURTOSIS	ASYMMETRY
POST (0.058): A positive (mesocurtic) value, indicating a distribution with high-density tails and a high, accentuated peak. This indicates that there is a high concentration of values around the center, but also that there are extreme outliers.	POST (0.00): The distribution being zero, indicates that it is symmetrical, there is no dispersion in the data.

3.2 Descriptive Analysis of Material Efficiency

Then, the descriptive statistical analysis of the Efficiency of Materials was carried out, as detailed in Table 4.

Table 4. Descriptive type of central trend of Equipment Efficiency

Central trend		
	EE_PRE	EE_POST
Stocking	80.90	92.79
Median	80.00	92.84
Fashion	75.00	91.93a

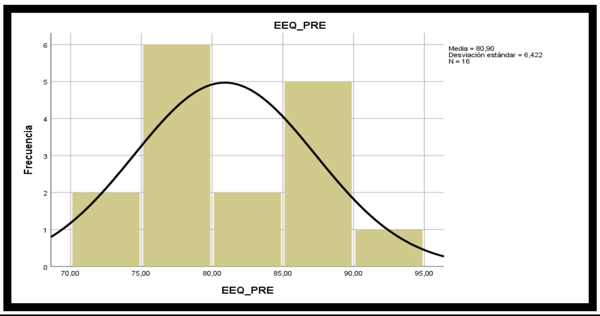
According to the central trend, the average value exhibited a substantial increase, surpassing 37. This finding is the most significant evidence of a substantial positive impact of the intervention. The median value also showed a substantial increase. The distribution of the data is relatively balanced around the mean in both cases, as evidenced by the proximity of the median to the mean in both the PRE and POST analysis. The most common value (mode) also increased; however, it is considerably lower than the mean and median in the two states. This finding suggests that the data may still indicate a concentration of low values.

Table 5. Description of the dispersion type of the Equipment Efficiency

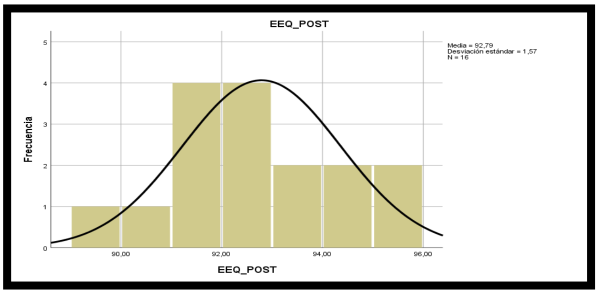
Dispersion		
	EE_PRE	EE_POST
Desv. Deviation	6.42	1.57
Variance	41.24	2.47

The standard deviation of the data increased substantially following the intervention, indicating a significant increase in the variability of the data points relative to the pre-intervention levels. This increase in variability can be attributed to the intervention, as it has been observed to result in a notable shift in the data distribution, characterized by reduced consistency and increased dispersion of the individual data points. For the purpose of calculating variance, the standard deviation squared was multiplied by a factor of three. This calculation yielded an approximate result of 3.46. This finding indicates that the variability of data has increased considerably in conjunction with the implementation of Lean Manufacturing.

Table 6. Description of Equipment Efficiency



ASYMMETRY	KURTOSIS
PRE (0.53): The distribution shows a bias to the left of moderate intensity. This means that in the distribution, the queue is on the left and the data is mostly on the right (the values are higher).	PRE (-1.03): Being close to zero (platicurtic or mesocurtic), indicates a distribution with peaks similar to normal.



KURTOSIS	ASYMMETRY
POST (-0.21): A high and positive value (leptocurtic), indicating a distribution with high-density tails and a high and accentuated peak. This indicates that there is a high concentration of values around the center, but also that there are extreme outliers.	POST (-0.61): The distribution has a marked bias to the right, with a significant positive skew. This indicates that the right side of the queue is on the right and that the data is mostly on the left (the lowest values compared to the average).

Inferential Analysis

General Hypothesis Test according to Total Efficiency

According to this, this analysis was carried out in two stages that were normality and the hypothesis test of total efficiency, detailing the following:

Normality test

According to the number of samples studied, which were 16 weeks of total efficiency recording, Shapiro Wilk was analyzed, which complies when it is less than 50 data, as shown in Table 7.

Table 7. Description of Equipment Efficiency

	Statistical	Gl	Gis.
ET_PRE	,972	16	,872
ET_POST	,986	16	,994

Therefore, as a result of the sig (p-value) that for measurement stages were 0.872 and 0.994 greater than 0.05 (5%), then it is indicated that the results present parametric behavior. Therefore, T-Student is applied for hypothesis testing.

Hypothesis testing

From the formulation of the general hypothesis, the following sub-hypotheses are included:

Ho: The application of Lean Manufacturing tools "does not" improve the Efficiency of the laboratory of a Manufacturing Company, Lima 2025

Ha: The application of Lean Manufacturing tools "if" improves the Efficiency of the laboratory of a Manufacturing Company, Lima 2025

Table 8. T-Student of Total Efficiency

		Paired differences							
					95% difference confidence interval				
		Stocking	Desv. Deviation	Desv. Average error	Inferior	Superior	t	Gl	Sig. (bilateral)
Par 1	ET_POST ET_PRE	29,95688	7,35400	1,83850	26,03821	33,87554	16,294	15	,000

According to the result of the sig (p-value) was 0.00, which is less than 0.05 (5%), it means that the Ha is affirmed, rejecting the Ho. In other words, applying Lean Manufacturing does improve overall efficiency.

3.3 General Hypothesis Test According to Material Efficiency

According to this analysis, this analysis was carried out in two stages that were normality and the hypothesis test of material efficiency, detailing the following:

Normality test

According to the number of samples studied, which were 16 weeks of total efficiency recording, Shapiro Wilk was analyzed, which complies when it is less than 50 data, as shown in Table 9.

Table 9. Material Efficiency Normality Test (Shapiro-Wilk)

	Statistical	Gl	Gis.
EM_PRE	,972	16	,872
EM_POST	,986	16	,994

Therefore, as a result of the sig (p-value) that for measurement stages were 0.872 and 0.994 greater than 0.05 (5%), then it is indicated that the results present a parametric behavior. Therefore, T-Student is applied for hypothesis testing.

Hypothesis testing

From the formulation of specific hypothesis n°1, the following sub-hypotheses are included:

Ho: The application of Lean Manufacturing tools "does not" improve the Material Efficiency of a Manufacturing Company, Lima 2025

Ha: The application of Lean Manufacturing tools "if" improves the Material Efficiency of a Manufacturing Company, Lima 2025

Table 10. T-Student Material Efficiency

		Paired differences							
					95% difference confidence interval				
		Stocking	Desv. Deviation	Desv. Average error	Inferior	Superior	t	Gl	Sig. (bilateral)
Par 1	EM_POST - EM_PRE	29,95688	7,35400	1,83850	26,03821	33,87554	16,294	15	,000

According to the result of the sig (p-value) was 0.00, which is less than 0.05 (5%), it means that the Ha is affirmed, rejecting the Ho. In other words, applying Lean Manufacturing does improve material efficiency.

3.4 General Hypothesis Test according to Labor Efficiency

According to this, this analysis was carried out in two stages that were normality and the hypothesis test of the efficiency of Labor, detailing the following:

Normality test

According to the number of samples studied, which were 16 weeks of labor efficiency recording, Shapiro Wilk was analyzed, which complies when it is less than 50 data, as shown in Table 11.

Table 11. Normality Test of Labor Efficiency (Shapiro-Wilk)

	Statistical	Gl	Gis.
EMO_PRE	,972	16	,872
EMO_POST	,986	16	,994

Therefore, as a result of the sig (p-value) that for measurement stages were 0.872 and 0.994 greater than 0.05 (5%), then it is indicated that the results present parametric behavior. Therefore, T-Student is applied for hypothesis testing.

Hypothesis testing

From the formulation of specific hypothesis n°2, the following sub-hypotheses are included:

Ho: The application of Lean Manufacturing tools "does not" improve the Labor Efficiency of a Manufacturing Company, Lima 2025

Ha: The application of Lean Manufacturing tools "yes" improves the Labor Efficiency of a Manufacturing Company, Lima 2025

Table 12. T-Student Labor Efficiency

		Paired differences							
					95% difference confidence interval				
		Stocking	Desv. Deviation	Desv. Average error	Inferior	Superior	t	Gl	Sig. (bilateral)
Par 1	EMO_POST - EMO_PRE	29,95688	7,35400	1,83850	26,03821	33,87554	16,294	15	,000

According to the result of the sig (p-value) was 0.00, which is less than 0.05 (5%), it means that the Ha is affirmed, rejecting the Ho. In other words, applying Lean Manufacturing does improve labor efficiency.

3.5 General Hypothesis Test according to Equipment Efficiency

According to this, this analysis was carried out in two stages that were normality and the hypothesis test of the efficiency of Equipment, detailing the following:

Normality test

According to the number of samples studied, which were 16 weeks of total efficiency recording, Shapiro Wilk was analyzed, which complies when it is less than 50 data, as shown in Table 13.

Table 13. Equipment Efficiency Normality Test (Shapiro-Wilk)

	Statistical	Gl	Gis.
EE_PRE	,972	16	,872
EE_POST	,986	16	,994

Therefore, as a result of the sig (p-value) that for measurement stages were 0.872 and 0.994 greater than 0.05 (5%), then it is indicated that the results present parametric behavior. Therefore, T-Student is applied for hypothesis testing.

Hypothesis testing

From the formulation of specific hypothesis n°3, the following sub-hypotheses are included:

Ho: The application of Lean Manufacturing tools "does not" improve the Equipment Efficiency of a Manufacturing Company, Lima 2025

Ha: The application of Lean Manufacturing tools "yes" improves the Equipment Efficiency of a Manufacturing Company, Lima 2025

Table 14. T-Student Team Efficiency

		Paired differences							
					95% difference confidence interval				
		Stocking	Desv. Deviation	Desv. Average error	Inferior	Superior	t	Gl	Sig. (bilateral)
Par 1	EE_POST - EE_PRE	29,95688	7,35400	1,83850	26,03821	33,87554	16,294	15	,000

According to the result of the sig (p-value) was 0.00, which is less than 0.05 (5%), it means that sex affirms the Ha, rejecting the Ho. In other words, applying Lean Manufacturing does improve the efficiency of Equipment.

4 DISCUSSION

The findings of this research indicate that the implementation of Lean Manufacturing tools, specifically 5S and Poka-Yoke, has resulted in substantial advancements in the efficacy of the Quality Lab. This finding aligns with the findings of previous studies that have demonstrated substantial improvements in operational performance following the implementation of Lean methodologies in analogous contexts. The 53.06% increase in overall efficiency, as measured by the difference between the pre-test (56.45%) and the post-test (86.41%), provides substantial evidence that the elimination of waste, the organization of the workspace, and the standardization of procedures have a direct and significant impact on the productivity of the system.

With respect to efficiency in the utilization of materials, the observed increase of 15.24% indicates a more efficient use of raw materials. This outcome is associated with the "Classify" pillar (1S), which facilitated the elimination of superfluous materials, and "Order" (2S), which promoted the effective management of inputs. Concurrently, the implementation of Poka-Yoke technology averted errors in the manipulation and utilization of the standard preforms. This finding aligns with the conclusions of Piedra et al. (2021), who assert that the judicious utilization of the material leads to a reduction in variability and enhances the efficacy of production processes. A reduction in waste and greater accuracy in the amount of resin used is also observed, which is crucial in sectors where raw material represents a high percentage of the total cost.

The increase of 15.87% in efficiency among the workforce indicates that the elimination of unproductive time and the reorganization of activities can result in a substantial enhancement of employee productivity. Prior to the intervention, periods of inactivity were observed due to the search for equipment, tools, or patterns that were in suboptimal locations. Following the intervention, the standardization of space facilitated the execution of tasks by workers, resulting in enhanced efficiency. This phenomenon aligns with the assertions put forth by Ramírez et al. (2022), who contend that efficiency is contingent upon the effective utilization of human resources. Furthermore, the training component of the fifth S (Discipline) served to fortify the organizational culture, thereby enabling staff members to embrace and perpetuate operational practices that are in alignment with the principles of Lean.

The enhancement of 13.65% in the efficiency of the equipment can be ascribed to the judicious scheduling of its utilization, the assurance of its availability in a timely manner, and the mitigation of waiting times that were attributable to inadequate internal coordination. Prior to the intervention, the absence of standardization resulted in the temporary inoperability of certain equipment, thereby causing delays in the quality control process. Following the implementation of Lean, the equipment was made accessible in accordance with the demand of the process, as suggested by the continuous flow principles of Lean Manufacturing. This phenomenon aligns with the observations reported by Malavé et al. (2024), who documented substantial enhancements in diesel injection laboratories following a restructuring of equipment and work cycles.

A comparison of the findings with the literature reviewed reveals that the behavior exhibited by the laboratory analyzed displays a trend analogous to that observed in previous studies, including those conducted by Hinojosa and Cabrera (2022), who documented an increase of 144. The findings of this study demonstrate that, following the implementation of the Lean methodology, there was a 21% increase in the specified outcome. This observation aligns with the results reported by Espinales et al. (2024), who documented an increase of 26%. The research indicates that 47% of the population is affected by the issue. Despite the variability in the percentages observed across different production processes, a consensus has emerged that Lean Manufacturing consistently yields substantial improvements, particularly in cases where root causes are associated with disorder, improper sorting, rework, or downtime. In a similar vein, the outcomes of this study are analogous to those reported by Bruce (2025) and Olivares et al. (2023). These researchers observed enhancements in efficiency following the implementation of 5S and Poka-Yoke in the domains of quality control and production.

A salient finding is that the outcomes not only mirror enhancements in operational procedures but also shifts in staff conduct. As posited by Aldaz (2022), the discipline stage of the 5S methodology represents the most arduous phase, necessitating the modification of established practices and the cultivation of a culture that fosters order and perpetual enhancement. The findings of this research indicate an advancement in average scores from 54% to 70% and beyond, reaching levels above 90%. This outcome suggests that the intervention had not only a technical impact, but also a cultural one. This is imperative to ensure the continuity of the change and to prevent the laboratory from reverting to its previous state.

Furthermore, the congruence between the findings of the descriptive analysis and the statistical test conducted (T-Student) serves to substantiate the reliability of the results obtained. The statistical significance value of 0.00 indicates that the observed differences are not random but rather are directly attributed to the implementation of Lean Manufacturing. This statistical behavior lends support to the robustness of the pre-experimental design, despite the absence of a control group.

A thorough economic analysis demonstrates that the intervention is not only effective from an operational perspective but is also financially sustainable. The positive net present value (S/ 5,169.35), the benefit/cost ratio above 1 (1.28), and the return on investment in 8 months and 28 days validate that Lean Manufacturing represents a profitable strategy for the organization, especially in contexts where waste of materials and time generate significant losses.

The evidence collected indicates that Lean Manufacturing is an effective tool for improving laboratory efficiency, increasing staff productivity, optimizing material usage, and ensuring equipment availability. This finding underscores the relevance of the subject in analogous industrial contexts and establishes a foundation for subsequent research endeavors. These future studies might encompass more intricate experimental frameworks or the integration of additional Lean principles, such as Kaizen, SMED, or VSM.

5 CONCLUSION

The implementation of Lean Manufacturing resulted in a substantial and quantifiable enhancement in the overall efficiency of the Quality Lab, with the efficiency rate increasing from 56.45% to 86.41%, representing a 53.06% increase. This increase indicates that the Lean methodology, when employing only two of its tools (5S and Poka-Yoke), can substantially transform processes characterized by high variability, clutter, and downtime. The statistical outcomes ($p = 0.00$) substantiate that the intervention exerted a direct and substantial influence on performance, thereby validating the general hypothesis. These findings indicate that the organization of the environment, the standardization of processes, and the elimination of waste are pivotal in enhancing performance in quality control activities.

Material use efficiency exhibited an increase of 15%. The utilization of raw materials was optimized, resulting in a 24% reduction in waste generation during the fabrication of standard preforms. This achievement signifies a substantial enhancement in the effective management of resources and a notable decrease in the environmental impact of the manufacturing process. This advancement was facilitated by the effective separation, classification, and organization of supplies, which enabled the identification of excesses, the prevention of losses, and the assurance of expeditious access to the requisite resources by workers for each task. Moreover, the implementation of Poka-Yoke has been shown to reduce errors in material handling and control, thereby enhancing the traceability of material usage. The evidence presented herein demonstrates that Lean offers benefits not only in terms of productivity, but also in terms of sustainability and cost reduction.

The efficiency of work increased by 15%. The data indicates that the performance of the human team is significantly enhanced when the work environment is well-organized, marked, and standardized, with an observed improvement rate of 87%. Prior to the implementation of the new system, employees experienced periods of downtime due to the time-consuming nature of locating misplaced tools or patterns. The implementation of the 5S methodology resulted in several notable improvements. A more efficient workflow was achieved, characterized by a reduction in the number of superfluous trips and an enhancement in concentration on assigned tasks. Concurrently, there was a decline in operational errors. The enhancement in personnel further corroborates the notion that Lean exerts a significant impact on organizational culture, cultivating attributes such as discipline, responsibility, and a sense of belonging. These elements are indispensable for the sustenance of enduring change within an organization.

The equipment's utility experienced a 13% increase. The result, indicating an availability rate of 65%, underscores the significance of ensuring adequate availability, fundamental maintenance practices, and effective organization of laboratory equipment. The intervention successfully addressed the issues of prolonged wait times due to the search for devices, the absence of order, and the lack of clear procedures for their use. Consequently, work cycles became more efficient, and the performance of the equipment demonstrated greater stability. This finding underscores the notion that Lean does not merely impact human behavior or materials, but also the manner in which technological resources are integrated into the workflow.

The findings support the hypothesis that Lean Manufacturing is an effective, versatile, and highly relevant approach for comparable industrial environments, especially in those where problems such as clutter, the need for rework, unnecessary movements, and lack of standardization are frequently encountered. The extant literature suggests that even a partial intervention, i.e., one that does not encompass the full implementation of Lean tools, can generate significant impacts in a relatively brief timeframe. This adaptability renders Lean a viable option for a range of manufacturing entities seeking to enhance their efficiency without the necessity of substantial investments.

The intervention proved to be financially lucrative, demonstrating its economic viability. The analysis yielded a positive net present value (NPV) of S/ 5,169. The cost-benefit ratio is 1:35, the recovery time is less than one year (8 months and 28 days), and the cost-benefit ratio is 1.28. This finding suggests that the implementation of Lean not only yields operational advantages but also generates quantifiable economic benefits, thereby underscoring its value in strategic decision-making within the organization.

A notable finding of the analysis was the reinforcement of the organizational culture concerning order, cleanliness, and discipline—fundamental elements in guaranteeing the sustainability of the transformation. The consolidation of the fifth S (Discipline) enabled employees to adopt new practices, decrease initial resistance to change, and adopt more systematic and responsible behavior. This cultural aspect is crucial, as Lean requires continuity and consistency to prevent methods from reverting to their previous state after intervention.

The research enabled the empirical verification of both the general and specific hypotheses, thereby confirming the significant impact of Lean Manufacturing on total efficiency as well as on the efficiencies of materials, labor, and equipment. These confirmations serve two primary functions. First, they serve to reinforce the study's methodological framework. Second, they provide useful evidence for future research seeking to replicate or extend the intervention across different sectors or functional areas.

The study's findings underscore the efficacy of Lean Manufacturing as a sustainable strategy for continuous improvement, paving the way for the implementation of additional tools such as Kaizen, SMED, Kanban, or VSM in subsequent stages of optimization. The initial intervention's success establishes the foundation for the organization to transition towards a more efficient, competitive management model that aligns with international quality standards.

ACKNOWLEDGMENTS

The authors would like to thank all participants and authorities who allowed this study to take place.

REFERENCES

[1] Al-Khatib M, Al-Khazraji E, Al-Mulla A, Kasi R, Al-Maadheed S, Al-Khatib W, et al. Waste to energy and resource recovery of plastic packaging waste. *J Clean Prod* [Internet]. 2021;46(1). [Consulted 2025 Abr 22]. Available from: https://www.sciencedirect.com/science/article/abs/pii/S2214785320398783

[2] Andina.pe. Digitalización: tendencias y oportunidades en la industria manufacturera peruana [Consulted 2025 Abr 10]. Available from: https://andina.pe/agencia/noticia-digitalizacion-tendencias-y-oportunidades-la-industria-manufacturera-peruana-1000509.aspx

[3] Ayeni MO, Ebohon OO, Akerele TM. Lean manufacturing and its impact on production efficiency. *J Res Int Bus Manag* [Internet]. 2024;2(5):093–097. [Consulted 2025 Abr 22]. Available from: https://www.interesjournals.org/articles/lean-manufacturing-and-its-impact-onproduction-efficiency.pdf

[4] Bravo J. Aplicación de herramientas Lean Manufacturing (5S, Andon y Tiempo Estándar) para el aumento de la productividad en el área de producción de una empresa metalmecánica. *Rev Ind Data* [Internet]. 2023;26(1):217–245. [Consulted 2025 Abr 22]. Available from: http://dx.doi.org/10.15381/idata.v26i1.24580

[5] Bruce S. Mejora de la eficiencia en el proceso revisión de estado de envases aplicando herramientas de Lean Manufacturing. *Rev Ing Invest Tecnol* [Internet]. 2025;XXVI(1). [Consulted 2025 Abr 22]. Available from: https://www.journalingeniar.org/index.php/ingeniar/article/view/205/292

[6] Campos C, Palomino J, Montoya G. Metodología 5S para incrementar de la productividad en el almacén de una empresa ferretera en Lima. *Rev Investig Cient Tecnol Llamkasun* [Internet]. 2024;5(1). [Consulted 2025 Abr 22]. Available from: https://llamkasun.unat.edu.pe/index.php/revista/article/view/127/184

[7] Castillo-Cárdenas LF, Rojas-Vallejos PC, Oropeza-Arce LV, García-Albornoz JH. Análisis de viabilidad de una cadena de suministro circular para residuos de plástico y vidrio. *Rev Fac Ing Ind* [Internet]. 2021;24(2):e249. [Consulted 2025 May 29]. Available from: http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S1810-99932021000200249

[8] Cerro Á. *Gestión industrial y Lean Manufacturing.* [Consulted 2025 Abr 22]. Available from: https://www.google.com.pe/books/edition/Gesti%C3%B3n_Industrial_y_Lean_Manufacturing/KXvpzgEACAAJ?hl=es-419

[9] Chamorro R, et al. Evaluación de procedimientos para determinar la población y muestra: según tipos de investigación. *Desafíos*. 2023;12(1):50–7.

[10] Chen Z, Jiang K, Lu J, Zhu Z, Li X. Circular economy and supply chain resilience: from the perspective of industrial symbiosis. *Processes* [Internet]. 2023;11(1):72. [Consulted 2025 May 29]. Available from: https://www.mdpi.com/2075-1702/11/1/72

[11] Córdova-Alvarado JM, Rojas-Quispe DA. Evaluación de los indicadores de circularidad en la cadena de suministro en el sector confecciones para su sostenibilidad. *Rev Investig Cient Univ Le Cordon Bleu* [Internet]. 2023;13(2):152–167. [Consulted 2025 May 29]. Available from: http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S2223-25162023000200008

[12] Delgado Huamán M, Esquén Pisfil O. Logística inversa: factores que influyen en la gestión de residuos sólidos plásticos para su reintroducción a la cadena de suministro en el distrito de Chiclayo, 2021. Chiclayo: Universidad Señor de

Sipán; 2022. [Consulted 2025 Abr 22]. Available from: https://repositorio.uss.edu.pe/bitstream/handle/20.500.12802/10735/Delgado%20Huaman%20Melissa%20%26%20Esquen%20Pisfil%20Oscar.pdf?sequence=1&isAllowed=y

[13] El Empaque. PepsiCo lanza empaques con 50% de plástico reciclado. México: El Empaque; [Consulted 2025 Abr 12]. Available from: https://www.elempaque.com/es/noticias/pepsico-lanza-empaques-con-50-de-plastico-reciclado

[14] Espinales J, et al. Manufactura esbelta para la mejora del proceso operacional: un caso de estudio en la industria de plástico. *Rev Cient Int* [Internet]. 2024;11(2). [Consulted 2025 Abr 22]. Available from: https://www.journalingeniar.org/index.php/ingeniar/article/view/205/292

[15] Ganesan J, et al. Implementation of lean manufacturing to improve production efficiency: a case study of electrical and electronic company in Malaysia. *Rev J Sustain Manuf Transp* [Internet]. 2023;3(2). [Consulted 2025 Abr 22]. Available from: https://publisher.uthm.edu.my/ojs/index.php/jsmt

[16] Gómez J, et al. Eficiencia de los sistemas productivos de las pequeñas y medianas empresas en el departamento de Bolívar-Colombia. *Rev Saber Cienc Lib* [Internet]. 2023;17(2). [Consulted 2025 Abr 22]. Available from: https://revistas.unilibre.edu.co/index.php/saber/article/view/9298/8524

[17] Gonzáles J, et al. Carácter ético de la investigación científica: la mirada de futuros doctores en educación. *Veritas* [Internet]. 2024;27(1). [Consulted 2025 Abr 22]. Available from: https://www.scielo.cl/pdf/veritas/n57/0718-9273-veritas-57-37.pdf

[18] Guamán Maza JL, Chachalo Caiza DB. Desarrollo de nuevos productos ecoamigables a partir de un enfoque de economía circular en el barrio La Florida, Ambato. *FIPCAEC* [Internet]. 2024;9(1):317–340. [Consulted 2025 May 29]. Available from: https://www.fipcaec.com/index.php/fipcaec/article/view/921/1553

[19] Guimarães PF, Dantas E, de Almeida TL, de Abreu PM. A logística reversa de embalagens plásticas pós-consumo: um estudo de caso. *Eniac Pesquisa* [Internet]. 2024;13(1):26–44. [Consulted 2025 May 29]. Available from: https://ojs.eniac.com.br/index.php/EniacPesquisa/article/view/858

[20] Hernández-Cuellar JF, Fernández-Nodarse L, Lezcano-Ferrera LR. Caracterización de la investigación científica en las ciencias médicas de Pinar del Río. *Rev Cienc Méd Pinar del Río* [Internet]. 2023;27(3):e0147. [Consulted 2025 May 29]. Available from: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1815-59362023000300147

[21] Hinojosa C, Cabrera R. Impacto del Lean Manufacturing en la productividad de las microempresas de Guayaquil. *Rev E-IDEA J Eng Sci* [Internet]. 2022;4(9). [Consulted 2025 May 10]. Available from: PDF.

[22] Ibañez F, et al. Manual de supervivencia básico para los análisis estadísticos descriptivos. *Espiral* [Internet]. 2023;16(32). [Consulted 2025 May 10]. Available from: https://ojs.ual.es/ojs/index.php/ESPIRAL/article/view/9134

[23] INEI. Industria del Plástico en Perú. [Consulted 2025 May 29]. Available from: https://www.inei.gob.pe/media/MenuRecursivo/boletines/industria-plastico-peru.pdf

[24] Lezcano-Ferrera Y, Lezcano-Ferrera Y, García-Rívera LA. La innovación en el contexto universitario: consideraciones desde la dirección de procesos. *Rev Cienc Méd Pinar del Río* [Internet]. 2023;27(1):e0003. [Consulted 2025 May 29]. Available from: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1815-59362023000100003

[25] Malavé A, et al. Niveles de eficiencia del post uso de manufactura esbelta en la reducción de tiempos de servicios en laboratorios de inyección a diésel del Cantón Quevedo. *Rev Cient INGENIAR* [Internet]. 2024;7(13). [Consulted 2025 Abr 22]. Available from:

https://www.journalingeniar.org/index.php/ingeniar/article/view/205/292

[26] Manzano J, Ramos Y. Incremento de la productividad en Metrológica Instrumentes S.A. mediante herramientas Lean Manufacturing. *Rev Ing Ind* [Internet]. 2024;XLIV(3). [Consulted 2025 Abr 22]. Available from: http://scielo.sld.cu/pdf/rii/v44n3/1815-5936-rii-44-03-147.pdf

[27] Olivares A, et al. Caso de aplicación: herramienta Poka Yoke en la micro y pequeña empresa Bohemian Brew Peru. *Rev Ing Ind* [Internet]. 2023;XLIV(1). [Consulted 2025 Abr 22]. Available from: http://scielo.sld.cu/pdf/rii/v44n1/1815-5936-rii-44-01-3.pdf

[28] Olivera J. La relación entre la eficiencia y el desempeño organizacional. *Rev Cient An-fibio* [Internet]. 2022;5(1). [Consulted 2025 Abr 22]. Available from: https://www.revistaanfibios.org/ojs/index.php/afb/article/view/100

[29] Palange A, Dhatrak P. Lean manufacturing a vital tool to enhance productivity in manufacturing. *Mater Today Proc* [Internet]. 2021;46(1). [Consulted 2025 Abr 22]. Available from: https://www.sciencedirect.com/science/article/abs/pii/S2214785320398783

[30] Piedra M, Dutto M, Stimolo M. Análisis de la eficiencia en el uso de recursos de las empresas del sector industrial manufacturero de Ecuador. *Rev SaberEs* [Internet]. 2021;13(2). [Consulted 2025 Abr 22]. Available from: https://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S185242222021000200213

[31] Quispe Galarza JC, Cotrina-Aliaga EW, Povis-Guillermo JM, Valdivia-Martínez ER. Evaluación de los criterios de la gestión de la calidad bajo el enfoque de la economía circular: el caso del sector metalmecánico en Perú. *Rev Fac Ing Ind* [Internet]. 2023;26(1):e217. [Consulted 2025 May 29]. Available from: http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S181099932023000100217

[32] Rajadell M. *Lean Manufacturing herramientas para producir mejor.* Alfaomega; 2021. [Consulted 2025 Abr 22].

[33] Ramírez G, et al. Productividad, aspectos que benefician a la organización. *Rev Trascender Contab Gest* [Internet]. 2023;7(20). [Consulted 2025 Abr 22]. Available from: https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S244863882022000200189

[34] Reyes Perez JJ, Cardenas Zea MP, Plua Panta KA. Consideraciones acerca del cumplimiento de los principios éticos en la investigación científica. *Conrado* [Internet]. 2020;16(77):154–161. [Consulted 2025 May 29]. Available from: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1990-86442020000600154

[35] Revista Global Trade. Futuro del mercado de envases de plástico: tendencias, crecimiento y oportunidades. Miami: Revista Global Trade; [Consulted 2025 May 29]. Available from: https://www.globaltrademag.com/future-of-plastic-packaging-market-trends-growth-and-opportunities/

[36] Romero R, et al. Implementación de guía teórico-práctica para la realización de proyectos de investigación como objeto de aprendizaje para entornos virtuales. *Rev Est Interdiscip Cienc Soc* [Internet]. 2023;25(1). [Consulted 2025 May 10]. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=8761310

[37] Rueda-López AC, Morales-Castaño AP. Evaluación de la sustentabilidad en la cadena de suministro de palma de aceite: un enfoque de economía circular. *Rev Anfibios* [Internet]. 2023;6(2):270–282. [Consulted 2025 May 10]. Available from: https://www.revistaanfibios.org/ojs/index.php/afb/article/view/100

[38] Ruffier J. *La eficiencia productiva* [Monografía en línea]. Montevideo: OITCinterfor; 1998. [Consulted 2025 Abr 22]. Available from:

https://www.oitcinterfor.org/sites/default/files/file_publicacion/ruffier.pdf

[39] Ruiz M, et al. Eficiencia técnica de las empresas del sector calzado de la zona 3 del Ecuador. *Rev Venez Gerencia* [Internet]. 2022;27(7). [Consulted 2025 Abr 22]. Available from: https://produccioncientificaluz.org/index.php/rvg/article/view/38081/42065

[40] Statista. Valor de mercado global de los envases. Nueva York: Statista; [Consulted 2025 Abr 12]. Available from: https://www.statista.com/statistics/1535934/global-market-value-of-packaging/

[41] The Business Research Company. Informe del mercado global de envases alternativos al plástico Informe/Monografía en línea]. The Business Research Company; 2025. [Consulted 2025 Abr 12]. Available from: https://www.thebusinessresearchcompany.com/report/plastic-alternative-packaging-global-market-report

[42] Velasteguí-Camacho JL, Cabezas-Marizalde RC, Castillo-Navas RE. El diseño circular del producto como estrategia competitiva para las empresas del sector del mueble de madera. *M+A Rev Electrónica Multidiscip* [Internet]. 2022;(1):20–37. [Consulted 2025 May 29]. Available from:

https://dialnet.unirioja.es/servlet/articulo?codigo=8430234

[43] Vizcaino P, Cedeño R, Maldonado I. Metodología de la investigación científica: guía práctica. *Rev Cienc Latina* [Internet]. 2023;7(4). [Consulted 2025 Abr 22]. Available from: pdf.

[44] Zapata-Molina S, Palacio-Villa CA, Bustamante-Montoya JW. Evaluación de los impactos de la economía circular: una revisión sistemática de la literatura. *Rev CEA* [Internet]. 2022;9(19):1–17. [Consulted 2025 May 29]. Available from: https://revistas.itm.edu.co/index.php/revista-cea/article/view/1800