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Application of Lean Tools to Improve Productive Times in Workers of a Company in the Automotive Sector, Lima, 2024

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ABSTRACT
The automotive sector plays a critical role in economic development, but service companies face efficiency challenges that limit their competitiveness. This study aimed to apply Lean tools to optimize production times in a company dedicated to vehicle technical inspections in Lima. The research was applied, with a quantitative approach and a pre-test-posttest experimental design, developed during an observation period of four months. The data were obtained through chronological records and direct observation, implementing the 5S, Work Standardization (EdT) and Just-in-Time (JIT) tools. The results showed a significant reduction in standard care time, from 20.90 to 17.42 minutes, representing an average improvement of 3.48 minutes. The difference was statistically significant according to the Wilcoxon test (p = 0.003). It is concluded that the application of Lean tools effectively contributes to the improvement of productivity and operational efficiency in the Peruvian automotive sector.

Keywords: 5S, Lean, Work Standardization, JIT, non-productive times.

1. Introduction

In today's landscape of globalization and increasing competitiveness, companies are faced with the challenge of sustaining and improving their position in markets that demand more and more. Several studies have underlined the strategic importance of industries, not only for their contribution to economic growth, but also for their ability to create employment and improve social welfare (González et al., 2023). In this situation, productivity is established as a key indicator of competitiveness, since it allows the efficiency and effectiveness to be evaluated in relation to production volumes and the quality of the services provided (Ortiz et al., 2022).

The search for greater efficiency has encouraged the implementation of management philosophies such as Lean Manufacturing, which focuses on improving processes and reducing waste in various operational areas. Its application has shown positive results in different industrial contexts, both in developed nations and in developing economies (Arlinghaus and Knizkov, 2020). In this way, Lean is configured as a holistic approach that facilitates the optimization of the value chain, allows for a rapid response to changes in demand, and promotes an organizational culture based on efficiency and continuous improvement (Mora-Chávez et al., 2022).

The automotive sector, specifically, acts as a key driver of economic growth globally. In 2023, global car sales reached 92 million units, representing an increase of 12.3% compared to the previous year; however, a small contraction is expected in 2024, with 88.3 million units sold (Pérez et al., 2024). In Latin America, the application of Lean tools in companies in the automotive sector has produced improvements in service levels of up to 15% and a reduction in non-productive times of close to 25%. However, factors such as economic instability, cultural resistance to change, and lack of technical

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training have limited its effectiveness (Agustini et al., 2023). In addition, there are challenges related to the sustainability of advances over time, given that staff turnover and lack of continuity in Lean practices often negatively impact results (Gelves et al., 2022).

In the case of Peru, the Automotive Association of Peru (2023) reported that vehicle sales grew by 4.82% in 2022, driven mainly by the demand for pickup trucks, minibuses, and tractor-trailers. However, sales of spare parts and accessories experienced a reduction due to the increase in import and international freight costs. These data show that, despite the dynamism in the sector, there are limitations that affect the productivity and competitiveness of automotive companies in the country. Additionally, the implementation of Lean tools faces barriers derived from organizational culture, the absence of specialized training, and the financial constraints suffered by many small and medium-sized companies (Guevara et al., 2021).

In this context, a company dedicated to technical inspections of vehicles in Metropolitan Lima faces significant challenges that affect its performance. Although its theoretical capacity would allow up to 2. 880 vehicles each month, the data indicate a real average of 1. 607 monthly inspections, showing a lack of 44.2% in the service. This poor performance impacts not only profits, but also customer satisfaction, since the average service time exceeds 27 minutes, while the company's goal is 15 minutes. The observed inefficiency results in long lines, discontent, and loss of customers, highlighting the existence of wasteful internal processes, such as unnecessary waiting, duplicate activities, and lack of standardization.[5]

Faced with this situation, the need arises to address the following formulation of the problem:

General problem: How can the implementation of Lean tools improve productivity times in the employees of an automotive sector company in Lima, 2024?

Specific problems:

- What is the current situation in terms of productivity times for a company in the automotive sector in Lima, 2024?
- How would the implementation of Lean tools be carried out in a company in the automotive sector in Lima, 2024?
- What is the effect of Lean tools on worker productivity times in a company in the automotive sector in Lima, 2024?

The relevance of this study lies in the fact that it helps to fill a gap in research on the application of Lean in automotive companies in Peru, a sector where its use is still scarce. At the same time, it provides a practical proposal to improve operational efficiency, raise service quality and increase competitiveness in a growing market.

2. Theoretical framework

1. Lean philosophy and conceptual foundations

The Lean philosophy has established itself as one of the most relevant methodologies in the modern management of industrial operations. Its origin dates back to Toyota's production system, whose central focus lies in eliminating waste and optimizing production processes. As Paredes et al. (2023) point out, *"Lean tools are used to detect and suppress activities that do not add value to the production process or provision of services"*. This approach involves a deep analysis of workflows with the aim of eliminating overproduction, unnecessary wait times, redundant movements, excessive inventories and defects in products or services.

Similarly, Miranda et al. (2021) argue that *"by implementing these tools, companies can reduce costs and production times, improve product quality, and increase customer satisfaction, aligning with the main objective of maximizing customer value by minimizing the resources used."* This means that Lean is not limited to an operational methodology, but is a comprehensive management philosophy applicable to both manufacturing and service companies.

2. Principles of Lean Thinking

Lean thinking is based on five fundamental principles: defining value, identifying the value stream, optimizing the flow, allowing the customer to pull the flow, and striving for perfection. Vaca (2020) states that *"these principles are developed in a logical sequence that seeks not only operational efficiency, but also to meet the specific needs of the customer with the highest possible level of satisfaction"*.

The first principle is to understand what the customer values and ensure that the products or services offered meet those expectations. The second is oriented to process mapping to distinguish those activities that generate value from those that do not. The third seeks to optimize the fluidity in the operation by eliminating interruptions or redundancies. The fourth emphasizes production on real demand, avoiding overproduction. Finally, the fifth establishes continuous improvement as a permanent process. Together, these principles form a framework for the efficient and sustainable management of operations.

3. Lean tools applied to production management

Among the most widespread tools within the Lean philosophy are 5S, Just in Time (JIT) and Work Standardization (EdT). According to Mosquera and Allauca (2022), *"by applying JIT, inventory levels in the production process are minimized, which contributes significantly to cost reduction and improved worker efficiency and productivity."* This approach allows organizations to respond quickly to fluctuations in demand and decrease the risk of unnecessary inventory buildup.

For its part, the 5S methodology promotes the organization, cleanliness and standardization of the workplace, reducing search times and promoting a safer and more efficient environment. Work Standardization (EoT), on the other hand, ensures that all activities are carried out uniformly, avoiding excessive worker autonomy that can lead to inconsistencies in processes. Together, these tools enable not only operational improvement, but also the consolidation of a culture of discipline and quality.

4. Lean Problem-Solving Methodology

An essential component of the Lean approach is the eight-step methodology for problem solving, which is a structured process of analysis and improvement. Miranda et al. (2021) explain that this methodology *"begins with the delimitation and detailed analysis of the problem, followed by the identification of potential causes and the investigation of the main cause"*. Subsequently, corrective measures are formulated and applied, the results obtained are verified and preventive strategies are designed to avoid recidivism.

This process encourages planning, critical analysis and reflection, reducing improvised responses and promoting sustainable solutions. Thus, Lean not only seeks immediate results, but also promotes a cultural change that privileges discipline and continuous improvement at all levels of the organization.

5. Improved uptime

Improving uptime is one of the main objectives of lean management. According to Ortiz et al. (2022), *"companies are striving to implement various strategies and technologies that optimize their operational processes and improve their overall performance."* Reducing non-productive times implies increasing the company's response capacity and, consequently, increasing its competitiveness in dynamic markets.

Muñoz (2021) complements this idea by arguing that *"improving production times can be seen as a key strategy to reduce operating costs"*. By reducing the time needed to produce each unit, the use of resources is optimized and significant savings in energy and materials are obtained. Likewise, from a sustainability approach, the reduction of non-productive times contributes to a lower environmental impact, aligning with current demands for corporate social responsibility (Zambrano et al., 2021).

6. International empirical evidence

Various international research has validated the effectiveness of Lean in improving productivity. Zainal et al. (2022) demonstrated in Malaysia that *"the implementation of lean manufacturing resulted in an increase in the manufacturing plant performance index from 0.75 to 0.78, representing a 4% increase in total factor productivity."* In Brazil, Santos et al. (2021) reported improvements in logistics efficiency through process standardization in the agricultural machinery industry.

Rajput et al. (2020), in a study applied in an automotive plant in Pakistan, observed that the reduction of takt time allowed for an increase in daily production, while Kishimoto et al. (2020) reported that the implementation of Lean in a metalworking company in China increased the rate of on-time deliveries from 35% to 80%. These findings confirm that Lean is not limited to advanced manufacturing contexts, but can be adapted to various sectors and regions.

7. Empirical evidence in the national context

In Peru, empirical evidence also supports the effectiveness of Lean. Trujillo and Pasapera (2023) reported that the application of Kaizen and Craft in an automotive company improved order processing time by 36.6% and efficiency in the use of space by more than 45%. Flores (2023), in a study on the operational management of vehicles, documented a 55.36% reduction in corrective repair costs thanks to the implementation of Lean.

Likewise, Cruzado and Pozo (2023) showed that the 5S methodology significantly reduced rework in the maintenance area, improving organization and performance by 86.67%. Gonzales and León (2023) verified that Lean Logistics decreased the percentage of delays in tricycle assemblies, from 45% to 27%. Finally, Izquierdo and Torres (2022) showed that the standardization of processes reduced travel distances and operation times, in addition to generating positive profitability indicators, such as a favorable Net Present Value and an Internal Rate of Return higher than the opportunity cost.

8. Theoretical synthesis

Overall, the literature reviewed shows that the application of Lean tools has a positive impact on reducing non-productive times and improving productivity, both in international and national contexts. However, the challenge of ensuring the sustainability of these improvements remains, as cultural, economic, and organizational factors can limit their permanence over time. This theoretical and practical gap justifies the relevance of studies that analyze the effectiveness of Lean in Peruvian companies, particularly in the automotive sector, where limited academic evidence is still reported.

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3. Objectives

3.1 General objective

Applying Lean tools to improve productive times in workers in a company in the automotive sector, Lima, 2024.

3.2 Specific objectives

1. Determine the current state in terms of productive times of a company in the automotive sector, Lima, 2024.
2. Designing the implementation of Lean tools for a company in the automotive sector, Lima, 2024.
3. Measuring the impact of Lean tools on productive times in the workers of a company in the automotive sector, Lima, 2024.

4. Hypothesis

The application of Lean tools in a company in the automotive sector in Lima, in the year 2024, results in a significant improvement in workers' productive times.

The study is theoretically justified the implementation of Lean tools in the automotive sector has been revealed as a highly effective strategy to enhance operational efficiency and reduce costs. This philosophy focuses on the eradication of waste and the optimization of processes, in order to achieve a more agile and superior quality production. Numerous studies have demonstrated the benefits of Lean in various industries around the world, but its specific application in automotive companies in Peru has not yet been widely explored. This study seeks to fill that gap, providing a solid theoretical basis for the implementation of Lean in the local context and generating knowledge about its effectiveness in improving productive times in the automotive sector of Lima in the year 2024.

In addition, it is justified from the methodological perspective, to carry out this study, two complementary methodological approaches will be used: analysis of the company's productivity and direct observation of work processes. The productivity analysis will allow a detailed view of the current state of production times in the selected automotive company, identifying areas of opportunity and possible sources of waste. Direct observation of work processes will provide qualitative information about work practices and behaviors that could be contributing to inefficiency. By combining both approaches, a complete picture of the current situation will be obtained, which will facilitate the design and implementation of specific and effective Lean solutions.

In the same way, it is justified from a practical perspective, since the application of Lean tools to improve productive times in a company in the automotive sector in Lima, in the year 2024, has important practical implications for both the company and the sector as a whole. By optimizing production processes and reducing cycle times, the company will be able to increase its competitiveness, improve the quality of its products, and better meet market demands. In addition, implementing Lean could also lead to tangible benefits for workers, such as reduced work stress, increased job satisfaction, and career development opportunities. Ultimately, this study will contribute to strengthening the automotive industry in Lima by promoting more efficient and sustainable management practices.

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5. Methodology

5.1 Research Design

The study was applied, with a quantitative approach and a pre-test-posttest experimental design.

According to Hernández and Mendoza (2018), experimental design allows for the deliberate manipulation of an independent variable—in this case, the implementation of Lean tools—to observe its effect on a dependent variable, workers' productive times.

Applied research seeks to generate practical solutions to real problems, using theoretical principles of continuous improvement and process management. The quantitative approach made it possible to objectively measure changes in service times before and after the application of Lean tools.

The procedure was carried out in two phases:

1. Pre-test phase, in which the average attention times of the production processes before the intervention were recorded.
2. Post-test phase, in which the times after the implementation of Lean tools (5S, JIT and EdT) were measured again.

The results of both measurements were compared using Wilcoxon's nonparametric test for related samples, since the data did not follow a normal distribution. This method made it possible to determine the existence of significant differences in productive times after the intervention.

5.2 Population and sample

The population to be studied was made up of the operations of the first 4 months of 2024.

The sample in this study was also the operations of the first 4 months of 2024, specifically, the attention time related to the attention of vehicles for vehicle inspection.

5.3 Data collection techniques and tools

The data collection techniques used to carry out this research are described below: Direct observation was used in a review of the technical and scientific literature for the application of continuous improvement For Arias (2020), this consists of observing the event, event, or context that occurs, depending on the research purposes.

The instruments used included the registration form to collect data to determine the effectiveness of the service process in the vehicle technical review company (Arias & Covinos, 2021).

6. Results

Current status in terms of company uptime

For the initial identification of the activities to be carried out in the workshop, the following DAP has been designed, which is presented below:

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CURSOGRAMA ANALÍTICO DEL PROCESO					
Hoja N° 1 De: 1 Diagrama N° 1	Operar. (X) Mater. ( ) Maqui. ( )				
Proceso: Inspecciones técnicas vehiculares	RESUMEN				
Fecha:	SÍMBOLO	ACTIVIDAD	Act.	Pro.	Econ.
Método: Actual (X) Propuesto ( )	○	Operación	7		
Nombre del trabajador:	⇨	Transporte	2		
	□	Inspección	1		
	D	Espera	1		
Elaborado por: Jorge Quispe	▽	Almacenaje	0		
	Total de actividades realizadas		11		
	Valor del flujo		0,64		
	Tiempo min/hombre		200		

Número	DESCRIPCIÓN DEL PROCESO	Cantidad	Distancia (m)	Tiempo (min)	Símbolos procesos: ○ (Operación)	⇨ (Transporte)	□ (Inspección)	D (Espera)	▽ (Almacenaje)
1	Recepción de vehículo	1	5	10	•				
2	Traslado al área de pre-inspección	1	1	10		•			
3	Espera en el área por asignación de turno	1	2	25				•	
4	Inspección inicial	1	1	15	•				
5	Inspección técnica completa	1	3	45	•				
6	Inspección de seguridad	1	5	25	•				
7	Control de emisiones	1	5	15	•				
8	Registro de resultados y evaluación	1	2	30			•		
9	Comunicación de resultados	1	3	10	•				
10	Traslado del vehículo fuera del área de inspección	1	1	10		•			
11	Entrega del vehículo a cliente	1	15	5	•				
Total		11	43	200					

Figure 1. DAP of the technical inspection process. In original Spanish language

As evidenced in the figure, there are 11 activities in total that complete the cycles of attention in 200 minutes of duration; identifying various processes such as transfers or delays during care. This flow allows us to obtain a value of 64% currently. Accordingly, the collection of incident reports was carried out between the first 4 months of 2024, in order to compile the base information that would allow us to know the types of interruptions that were constantly incurred. Among these, there were those associated mainly with technical failures, equipment adjustments and electrical interruptions; whose stops added between 5 and 10 minutes of waiting. Given this, a time was taken from 10 observations to estimate the average times and calculate the standard operating time, using the Westinghouse method for the calculation of supplements and rating factors

Supplements	
Constant	
Fatigue	5
Variables	
a) NORMAL POSTURE	
Uncomfortable (body tilt)	4
b) LIGHTING	
Well below	2
c) VISUAL TENSION	
Precision work	2
d) NOISE	

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Intermittent and loud sound	5
e) MENTAL MONOTONY	
Very monotonous work	4
TOTAL	22

Table 1. Calculation of supplements

No.	***Operation***	***Prom***	***Fac. Califi***	***Normal Time***	***Supplements***	***T. Std.***
01	Vehicle reception	9,36	0,8	7,49	0,22	9,14
02	Transfer to the pre-inspection area	9,82	0,9	8,84	0,22	10,78
03	Waiting in the area by shift assignment	23,92	0,8	19,14	0,22	23,35
04	Initial inspection	15,23	1,2	18,27	0,22	22,29
05	Full technical inspection	42,55	1	42,55	0,22	51,92
06	Safety Inspection	25,99	0,8	20,79	0,22	25,36
07	Emission control	15,02	1,1	16,52	0,22	20,16
08	Recording of results and evaluation	33,67	0,8	26,94	0,22	32,87
09	Communication of results	12,58	0,8	10,07	0,22	12,28
10	Moving the vehicle out of the inspection area	11,42	0,9	10,28	0,22	12,54
11	Delivery of the vehicle to the customer	9,45	0,8	7,56	0,22	9,22
		Total Normal Time		17,13	0,22	20,90

Table 2. Standard Time Estimate Summary (Initial)

The result of the initial analysis yielded a standard time of 20.90 minutes for the cycle of the 11 processes. Considering this, the following Ishikawa was designed to identify the root causes of the problem of non-productive times based on 6M:

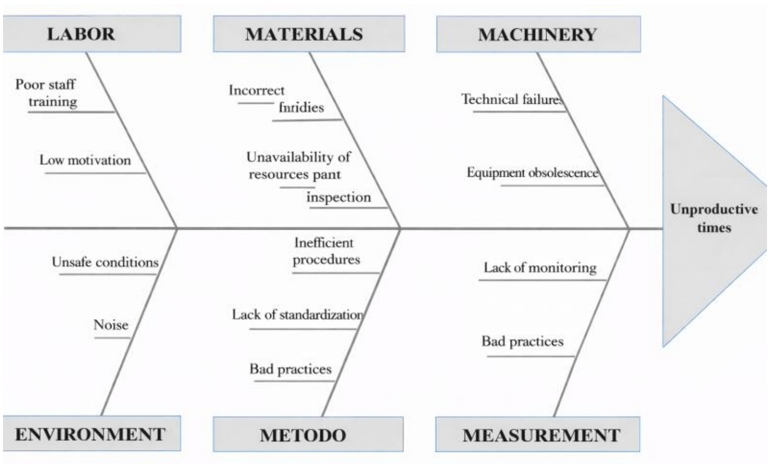

Figure 2. Ishikawa of unproductive times

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Based on the description of each cause, they were compared by means of a Vester matrix, in order to obtain the frequency and perform the weighting, which allowed the construction of the Pareto:

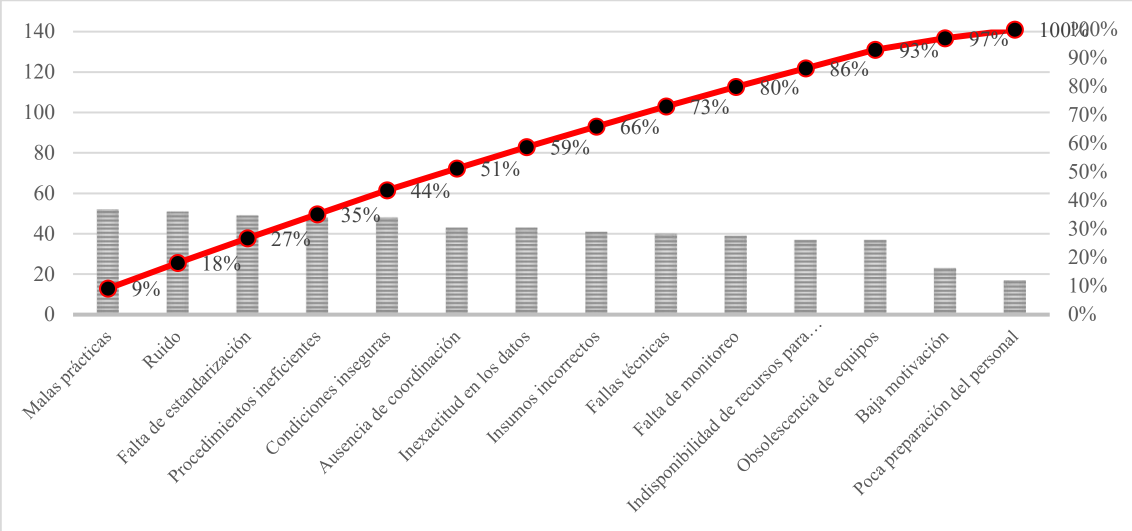

Figure 3 Pareto of nonproductive times. In original Spanish language

In accordance with the results, the 80-20 ratio is set among the first 10 activities that generate the greatest impact on the problem, these being the ones that should be prioritized in the result of the solution, so that each assignable cause has been disaggregated by each area to which it belongs.

AREA	FREQUENCY	PERCENTAGE
Labor	83	15%
Materials	78	14%
Measurement	82	14%
Method	149	26%
Machinery	77	14%
Environment	99	17%
TOTAL	568	100%

Table 3. Grouping of cases by each area

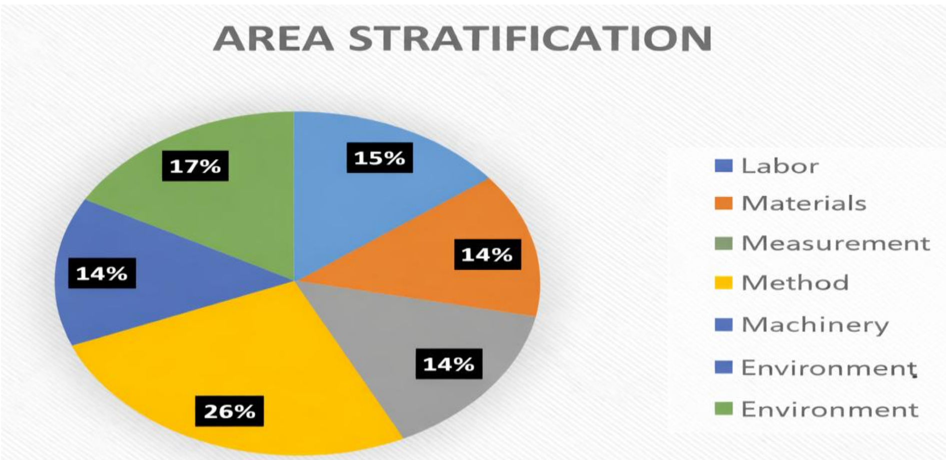

Figure 4. Area stratification chart

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The priority causes to be solved are encompassed in important areas of the process, such as the method (26%), followed by environmental conditions (17%) and problems associated with labor (15%). For this reason, it is necessary to know which types of Lean tools could cause a significant change and a sustainable result over time, so the following table of decision criteria has been made for three tools to be implemented: 5S, Work Standardization (EdT) and Just In Time (JIT).

No.	ALTERNATIVES	CRITERIA						TOTAL
		COST	APPLICATION TIME	COMPLEXITY	SUSTAINABILITY	COMPLETE	REGULATIONS	
1	5S	2	2	2	2	2	2	12
2	Standardization of work	2	2	1	1	0	1	7
3	Just in time	2	1	2	2	1	2	10

Table 4. Evaluation criteria for Lean tools

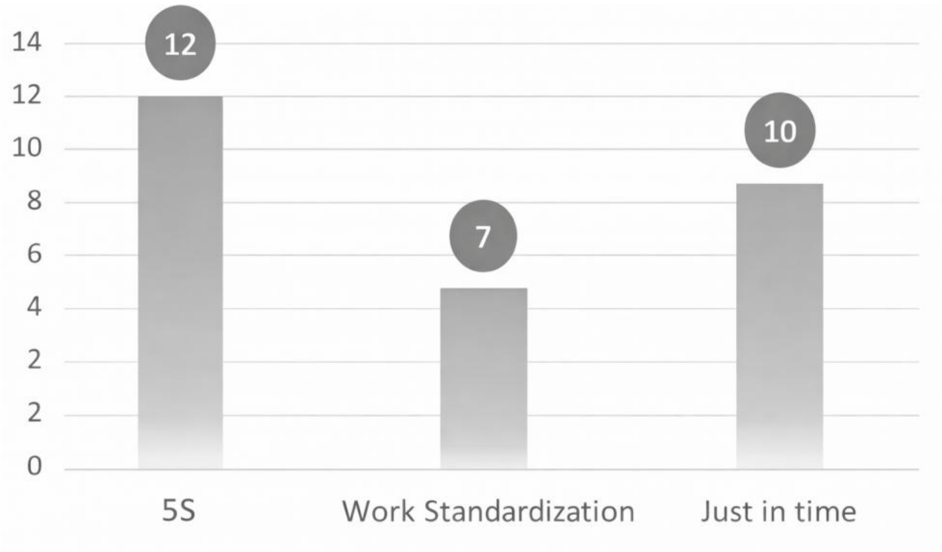

Figure 5 Evaluation Chart of Criteria for Tool Selection

Based on the evaluation of criteria such as costs, implementation times, sustainability or regulatory factors that may affect compliance, it has been obtained that the three tools have good characteristics for their implementation; the order of its implementation is also specified according to the scores obtained.

Design of the implementation of Lean tools for a company in the automotive sector

In order to draw a timeline for the implementation process, the following periods were considered for the execution of the improvement:

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Activity	Duration	My 1				My 2			
		S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Phase 1: 5S	2 weeks								
Phase 2: JIT	3 weeks								
Phase 3: Standardization of work	3 weeks								

Table 5. Deployment timeline

An estimated time of eight weeks was stipulated for the achievement of each phase and, as follows, the actions carried out in each one are described:

Phase 1: 5S

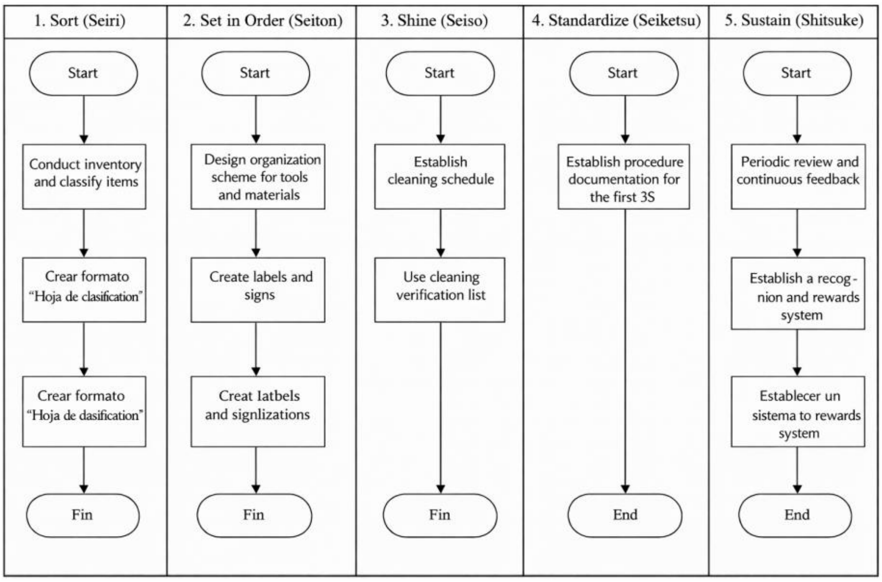

Figure 6. Evaluation chart of criteria for tool selection

In the first stage, a complete inventory of all equipment, tools, and materials present in the inspection area is made. Each item is evaluated to determine its need and usefulness. Unnecessary items are removed to free up space and reduce clutter, facilitating a more efficient work environment. In accordance with this, a specific format is developed where all the classified items are recorded, specifying which are necessary and which are not. This helps keep an organized record and facilitates future audits of the process. The classification is concluded once all the items have been evaluated and the correct documentation of the process has been made.

In the second stage, a specific plan is developed for the optimal organization of the tools and materials that have been determined as necessary. This includes designating specific locations for each item, which reduces search time and improves efficiency. To ensure that each item has a designated and easily recognizable location, clear labels and signage are created and placed. This makes it easier for any worker to find and return tools and materials to their respective locations.

Following this, in the third stage, a regular cleaning schedule is established to keep the work areas clean and tidy. This not only improves safety but also work efficiency. To ensure that all areas and equipment are cleaned as scheduled, a checklist is used. Each cleaning task is marked once completed, ensuring consistency in cleaning.

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In the fourth stage, a set of standard procedures for sorting, tidying and cleaning activities is created and documented. This ensures that all employees follow the same standardized practices, which improves the consistency and quality of the work environment.

Finally, regular process reviews are carried out and continuous feedback is provided to ensure compliance with established standards. This helps to identify areas for improvement and maintain discipline in the long term. To encourage and recognize continued compliance with 5S procedures, a system of incentives and rewards is implemented. This motivates staff to adhere to established practices and promotes a culture of continuous improvement.

Phase 2: JIT

For the development of this phase, it was taken into account that the company has a current service capacity of up to 60 vehicles per day, so a calculation of the WIP ("Works in Progress") admissible for each activity has been considered in order to mitigate the incidence of bottlenecks in the service process. To this end, it has been established that the regular working day is 8 hours/day, which allows a total time of 28,800 seconds to be defined:

$$Takt\ time\ (real) = \frac{Available\ time/day}{Demand\ for\ vehicle\ service} = \frac{28800\ seg}{60\ veh} = 480\ sec/veh$$

Process Stages	Global Average Time (min)	Global Average Time (sec)	Suggested WIP Limit (Takt Time/TPG)
Vehicle reception	9,14	548,13	1,14
Transfer to the pre-inspection area	10,78	646,91	1,35
Waiting in the area by shift assignment	23,35	1400,71	2,92
Initial inspection	22,29	1337,41	2,79
Full technical inspection	51,92	3114,96	6,49
Safety Inspection	25,36	1521,81	3,17
Emission control	20,16	1209,37	2,52
Recording of results and evaluation	32,87	1971,93	4,11
Communication of results	12,28	736,81	1,54
Moving the vehicle out of the inspection area	12,54	752,37	1,57
Delivery of the vehicle to the customer	9,22	553,47	1,15

Table 6. Identification of the WIP for each vehicle technical inspection process

Regarding the WIP analysis, a clearance of up to 28 vehicles has been identified that can remain in line in the service processes during the working day, whose clearance allows workers to develop dedication in each activity and guarantee customer satisfaction, as well as the fulfillment of goals without incurring bottlenecks. In addition, it is suggested to use the following Kanban board, in order to execute a visual management that guarantees the monitoring of each stage of the service process:

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Figure 7. Visual management with Kanban board. In original Spanish language

Phase 3: EoT

For this last phase, the information has been collected, as well as the respective documentation within the company's information system, so that all workers can have access to this. An informative email has also been issued to ensure the consultation and verification of reading by all workers. The purpose of this procedure is to achieve the standardization of activities and avoid autonomous procedures that may lead to deviations in production times.

PROCEDURE DESCRIPTION

Company name: Company in the automotive sector [Company name and RUC] p. 1 (rev01)

Name of the unit: Area of Vehicle Technical Inspections (Headquarters: Lima)

Name of the procedure: Cycle of vehicle technical inspections

Objective (for each activity):

1. **Vehicle reception**
   - **Suggested Time:** 7.80 minutes
   - **Control Point:** Verification of documentation and registration in the system.
   - **Description:** The vehicle is met at the entrance of the inspection center, where the necessary documentation is checked and recorded in the system.
2. **Transfer to the pre-inspection area**
   - **Suggested Time:** 8.18 minutes
   - **Control Point:** Confirmation of arrival at the pre-inspection area.
   - **Description:** The vehicle is moved to the pre-inspection area where it is prepared for the initial inspection.
3. **Waiting in the area by shift assignment**
   - **Suggested Time:** 19.93 minutes
   - **Control Point:** Assignment of shift number.
   - **Description:** The vehicle waits in a designated area until it is assigned a turn for inspection.
4. **Initial inspection**

- **Suggested Time:** 12.69 minutes
- **Control Point:** Completeness of visual inspection.
- **Description:** An initial visual inspection is performed to identify any obvious issues that may require immediate attention.

5. **Full technical inspection**
    - **Suggested Time:** 35.46 minutes
    - **Control Point:** Review of all the vehicle's technical systems.
    - **Description:** The vehicle undergoes a series of detailed technical tests to verify its operation and overall safety.
6. **Safety Inspection**
    - **Suggested Time:** 21.66 minutes
    - **Control Point:** Verification of active and passive security systems.
    - **Description:** Specific safety tests are carried out to ensure that the vehicle complies with all current safety standards.
7. **Emission control**
    - **Suggested Time:** 12.52 minutes
    - **Control Point:** Measurement of emissions and comparison with permitted standards.
    - **Description:** The vehicle is verified to meet the permitted emission standards.
8. **Recording of results and evaluation**
    - **Suggested Time:** 28.06 minutes
    - **Control Point:** Data entry and report generation.
    - **Description:** All inspection results are recorded in the system for evaluation and for the creation of the final report.
9. **Communication of results**
    - **Suggested Time:** 10.49 minutes
    - **Control Point:** Delivery and explanation of the inspection report to the customer.
    - **Description:** The results of the inspection are communicated to the customer, detailing any problems encountered and recommendations.
10. **Moving the vehicle out of the inspection area**
    - **Suggested Time:** 9.52 minutes
    - **Control Point:** Exit of the vehicle from the inspection area.
    - **Description:** Once the inspection is complete, the vehicle is moved out of the inspection area.
11. **Delivery of the vehicle to the customer**

- **Suggested Time:** 7.88 minutes
- **Control Point:** Confirmation of receipt of the vehicle by the customer.
- **Description:** The vehicle is delivered to the customer along with an inspection report detailing the findings and recommendations needed.

Table 7. Description of the procedure for attention in vehicle inspections

Impact of Lean tools on productive times on the company's workers

To verify compliance with production times, a new time taking of 10 random observations has been made, allowing the normal and standard time of the process to be calculated again, resulting in the following:

No .	***Operation***	***Pro m***	***Fac. Califi***	***Norm al Time***	***Suppleme nts***	***T. Std.***
01	Vehicle reception	7,80	0,8	6,24	0,22	7,61
02	Transfer to the pre-inspection area	8,18	0,9	7,36	0,22	8,98
03	Waiting in the area by shift assignment	19,93	0,8	15,95	0,22	19,45
04	Initial inspection	12,69	1,2	15,23	0,22	18,58
05	Full technical inspection	35,46	1	35,46	0,22	43,26
06	Safety Inspection	21,66	0,8	17,32	0,22	21,14
07	Emission control	12,52	1,1	13,77	0,22	16,80
08	Recording of results and evaluation	28,0 6	0,8	22,45	0,22	27,39
09	Communication of results	10,49	0,8	8,39	0,22	10,23
10	Moving the vehicle out of the inspection area	9,52	0,9	8,57	0,22	10,45
11	Delivery of the vehicle to the customer	7,88	0,8	6,30	0,22	7,69
		Total Normal Time		14,28	0,22	17,42

Table 8. Description of the procedure for attention in vehicle inspections

In this way, it is specified that the new standard time is 17.42 minutes. Likewise, the following comparative table is presented where the differences between the initial and final times of the process are established:

Process	**T. Std. (Pretest)**	**T. Std. (Postest)**	**DIF**
Vehicle reception	9,135	7,613	1,523
Transfer to the pre-inspection area	10,782	8,985	1,797
Waiting in the area by shift assignment	23,345	19,454	3,891
Initial inspection	22,290	18,575	3,715
Full technical inspection	51,916	43,263	8,653
Safety Inspection	25,363	21,136	4,227
Emission control	20,156	16,797	3,359
Recording of results and evaluation	32,866	27,388	5,478

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Communication of results	12,280	10,233	2,047
Moving the vehicle out of the inspection area	12,540	10,450	2,090
Delivery of the vehicle to the customer	9,225	7,687	1,537
Average Time	20,90	17,42	3,48

Table 9. Comparison between standard initial and final time in technical inspection processes

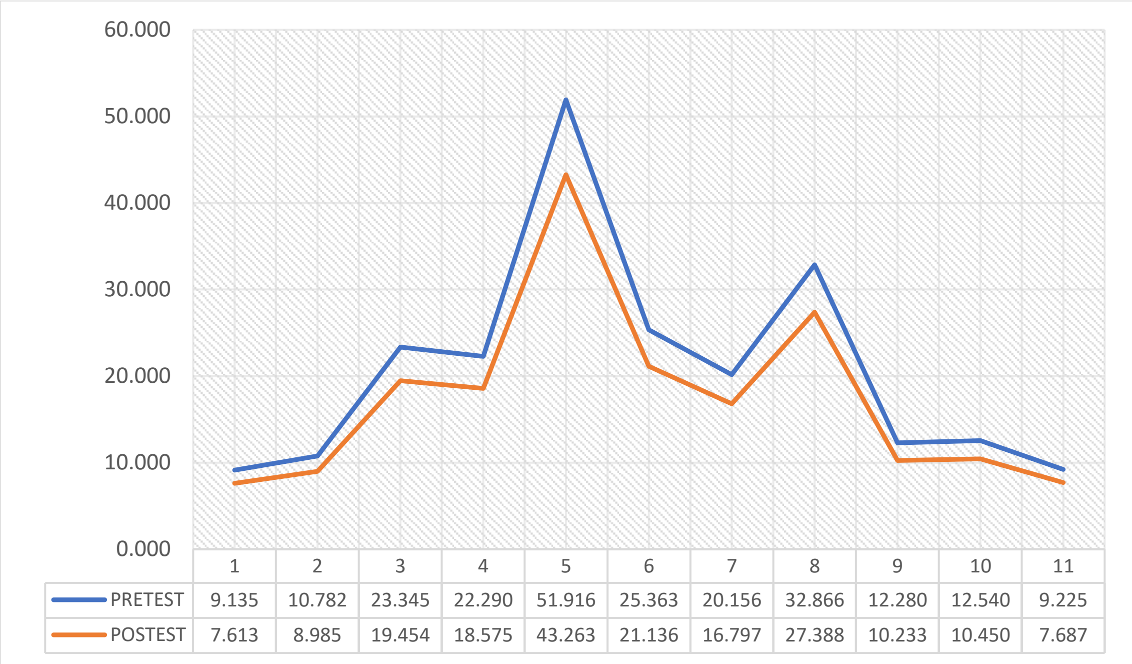

Figure 8. Uptime Comparison Chart

According to the descriptive analysis of the table and figure above, there is evidence of a decrease trend in the final measurement phase, after implementing the Lean tools, which allowed a reduction of 3.48 minutes of difference.

Hypothesis testing

Normality test

	Shapiro-Wilk		
	Statistician	gl	Say.
PRETEST	,843	11	**,035**
POSTEST	,843	11	**,035**

Table 10. S-W Normality Test

For these purposes, a normality test given by Shapiro Wilk has been performed, whose significance turned out to be $0.035 < 0.05$, which allows us to conclude that the data handle a non-normal behavior and, therefore, it was decided to use a non-parametric test such as Wilcoxon's for dependent samples.

Statistical hypotheses

H0: The application of Lean tools in a company in the automotive sector in Lima, in 2024, does not result in a significant improvement in workers' productive times.

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H1: The application of Lean tools in a company in the automotive sector in Lima, in the year 2024, results in a significant improvement in workers' productive times

Decision Rule:

p-value > 0.05 the null hypothesis (H0) is accepted

p-value < 0.05 the alternate hypothesis (H1) is accepted

		N	Average Range	Sum of ranks
POSTEST - PRETEST	Negative Ranges	11a	6,00	66,00
	Positive Ranges	0b	,00	,00
	Draws	0c		
	Total	11		
a. POSTEST < PRETEST				
b. POSTEST > PRETEST				
c. POSTEST = PRETEST				

Table 11. Descriptive Ranges Test

The analysis, at a descriptive level, shows a clear difference of 11 points in relation to the post-test, which validates that there have been significant changes between both evaluation periods.

Test statisticians	
	POSTEST – PRETEST
Z	-2,934b
Asymptotic sig. (bilateral)	,003
a. Wilcoxon Sign Range Test	
b. It is based on positive ranges.	

Table 12. Wilcoxon Test Statisticians

From the result of the test, there is a p-value = 0.003 < 0.05, so the alternative hypothesis is accepted, that is, the application of Lean tools in a company in the automotive sector in Lima, in the year 2024, results in a significant improvement in workers' productive times.

7. Discussion

The results of this research confirm the hypothesis: the implementation of Lean tools has a positive and significant effect on the improvement of production times in the automotive sector. The 3.48-minute reduction in standard service time (p = 0.003 < 0.05) is a significant improvement, representing a direct increase in responsiveness and customer satisfaction. This finding not only shows the potential of Lean to optimize processes, but also supports its applicability in service companies, a field less explored compared to the manufacturing field.

Compared to international studies, the results are consistent with those reported by Zainal et al. (2022), who identified a 4% increase in productivity after applying value stream and JIT mapping in a plant in Malaysia. Kishimoto et al. (2020) also observed notable improvements in China, increasing the rate of on-time deliveries from 35% to 80% after applying Lean. Similarly, Rajput et al. (2020) found that adjusting takt time allowed for a significant increase in production at an automotive plant in Pakistan. These coincidences reinforce the external validity of the results, by demonstrating that Lean generates consistent benefits in diverse productive and cultural contexts.

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In Latin America, Santos et al. (2021) documented improvements in the logistics efficiency of the Brazilian agricultural machinery industry through process standardization, while Agustini et al. (2023) pointed out that the implementation of Lean in automotive companies in the region produced increases in service levels of up to 15% and reductions in non-productive times of close to 25%. This research adds to this evidence, by demonstrating that even in a Peruvian environment characterized by cultural and financial limitations, the Lean philosophy can be successfully applied.

In the national context, the findings are also closely related to previous studies. Trujillo and Pasapera (2023) reported that the application of Kaizen and Craft generated a 36.6% increase in dispatch efficiency in an automotive company, while Cruzado and Pozo (2023) showed that the 5S methodology significantly reduced maintenance rework. Gonzales and León (2023), on the other hand, verified that Lean Logistics decreased assembly times in the tricycle industry, going from 45% delays to 27%. This research shows that Lean is not only applicable, but highly beneficial in the Peruvian automotive sector, although with particular challenges.

One of the most relevant aspects of this study is the identification of the organizational barriers that limit the effectiveness of Lean: absence of standardization, excessive autonomy of workers and weaknesses in process control. Gelves et al. (2022) had already warned that "Lean results are often compromised by cultural and organizational factors that affect the sustainability of improvements over time." This approach is especially relevant, as it confirms that the simple adoption of tools does not guarantee lasting results, but that it is essential to accompany them with a cultural and leadership transformation.

From a theoretical perspective, these results reaffirm that Lean should not be understood as an isolated set of techniques, but as a comprehensive management philosophy. Mora-Chávez et al. (2022) argue that "Lean is more than a set of tools; it requires a systemic vision aimed at continuous improvement and commitment at all organizational levels." Consequently, the reduction in time achieved in this research constitutes an initial step towards the consolidation of a culture of operational excellence.

The practical implications are equally significant. An improvement of 3.48 minutes per service, in a company that processes more than 1,600 vehicles per month, is equivalent to recovering about 93 hours of operational capacity in the same period. This translates into the possibility of serving more customers, reducing queues and improving the perception of service, key elements to sustain competitiveness in a sector where speed and reliability are decisive for loyalty.

However, it is important to recognize the limitations of the study. The observation period was restricted to four months, which makes it difficult to assess the sustainability of the improvements over time. In addition, the research was conducted in a single company, which limits the generalizability of the results to other organizations in the industry. In this sense, future studies should include longer periods and representative samples of various Peruvian automotive companies, to determine the degree of replicability of the benefits obtained.

Finally, this research provides empirical evidence to a field that is still little explored in Peru: the application of Lean in automotive service companies. Although there are multiple studies in manufacturing and maintenance, the national literature on vehicle technical inspections is scarce. In this sense, the present study not only contributes to business practice, but also opens a path for new research that integrates Lean with other management philosophies, such as Six Sigma or Kaizen, to achieve even more sustainable and far-reaching improvements.

8. Conclusions

The research carried out showed that the use of Lean tools is an effective strategy to improve production times in a company in the automotive sector that performs technical inspections of vehicles in Lima.

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After reviewing the methodology suggested by the reviewers, it was determined that the study did not conform to a cross-sectional design, but should be considered a pretest-posttest experimental design, since it implied the intentional manipulation of the independent variable, that is, the application of Lean tools, and the subsequent evaluation of its impact on the dependent variable. which are the working times of the employees, at two different times. This adjustment in methodology ensured consistency between the research approach, the nature of the data collected, and the statistical analysis performed, which strengthened the internal validity of the study and the firmness of its conclusions.

The findings showed a notable decrease in standard service time, which dropped from 20.90 to 17.42 minutes, which equates to an average improvement of 3.48 minutes for each vehicle inspection process. This variation was statistically relevant ($p = 0.003$) according to the nonparametric Wilcoxon test for related samples, selected based on the non-normal behavior of the data verified by the Shapiro-Wilk test. These results show that the adoption of Lean tools, especially 5S, Just-in-Time (JIT) and Work Standardization (EoT) methodologies, directly affects operational efficiency and shortens non-productive times, by eliminating activities that do not add value, improving the organization of the workspace and establishing standardized procedures.

The redesign of the methodology allowed the causal effect of the intervention to be observed more clearly, since the experimental approach provided the opportunity to empirically compare two measurement moments, something that would not have been feasible with a cross-sectional design. This adjustment improved the scope of the research analysis, moving from simply describing the phenomenon to checking the impact of the intervention, which in turn strengthened the study's ability to provide empirical evidence that can be applied in similar contexts.

On the other hand, the adoption of Lean tools facilitated a comprehensive improvement in the company's process management, which was reflected not only in the reduction of service times, but also in the increase of operational capacity, the elimination of bottlenecks and the promotion of a culture of order. cleanliness and work discipline. Work Standardization helped to decrease the excessive autonomy of workers and to ensure that procedures were consistent; Just-in-Time improved the flow of care and avoided unnecessary accumulations; and 5S promoted a safer and more efficient work environment. These combined initiatives resulted in a more dynamic and adaptable production system, which aligns with the principles of continuous improvement.

From a practical approach, the results of the study show that the Lean philosophy, which was initially designed for the manufacturing sector, can be successfully implemented in automotive service businesses, producing concrete effects in terms of productivity and competitiveness. The company studied was able to increase its capacity without the need to make new investments in infrastructure or human resources, which shows that effectiveness can be achieved by optimizing the resources already available. This method not only favors the economic growth of the company, but also supports the operational sustainability of the field.

In conclusion, it is suggested that the company establish a system of continuous monitoring of performance indicators and carry out periodic 5S audits to ensure that the improvements achieved are maintained. In the academic field, future research should extend the period of analysis and include factors related to operating costs, quality of service and customer satisfaction, in order to evaluate the viability of the Lean model in the long term. In this way, the methodological correction carried out in this research not only guaranteed the scientific validity of the design, but also provided consistent and practical evidence on the effectiveness of Lean tools in the automotive context of Peru, contributing to the theoretical advancement in process management as well as to business practice focused on operational excellence.

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