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Original Article

Enhancement of On-time Delivery Maintenance Services by Lean Manufacturing Tools in an Automotive Industry

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Abstract - *In recent years, the automotive industry has continued to develop exponentially. However, this has led to an increase in the demand for maintenance services that automotive repair companies are unable to provide (representing significant losses for automotive companies). Thus, to maximize the number of maintenance services performed each day and reduced the costs associated with penalties, automotive repair companies try to optimize maintenance service hours. According to the current analysis, the main problem that causes the greatest financial loss in a Peruvian auto repair company is the high percentage of maintenance services that are not performed. The company considers the issue to be crucial not only for the economy but also for the connection it maintains with its customers, as they are very likely to choose to travel to other auto repair centers if there are delays in deliveries. The company's assistance and data collection made it possible to identify the main causes of these delays. As a result, it is proposed to create a model based on the Lean Manufacturing technique, using the 5S tool, ABC analysis and standardized work, with the aim of optimizing the delivery times of the company's existing vehicle repair service. In the end, the approach reduced delivery time violations by 19.94%. In conclusion, the company was able to satisfy its customers and avoid delays as a result of the improvement made.*

Keywords - *Automotive, Lean manufacturing, Maintenance Service Optimization, Standardized work, 5S.*

1. Introduction

The automotive industry has expanded dramatically in recent years, year after year [1]. Due to mass production and significant demand for automobiles and replacement components, the automotive industry is now one of the most significant industries in the Peruvian economy [2]. Sales of light vehicles (cars, vans, SUVs and pickup trucks) are expected to increase by 43.1% in 2021 compared to 2020 [3]. In addition, due to the pandemic, maintenance repair times have been lengthened as a consequence of supply chain problems that make it difficult to locate replacement components for cars. Finding a new replacement component, for example, can take anywhere from one day to six weeks [4]. Also, domestic production increased by 3.47% in November 2021 compared to the same month in 2020 [5], mainly due to the good performance of most economic sectors.

Additionally, they found that the trade sector grew by 3.82%, mainly due to subsectors such as the automobile trade, which had an increase of 8.53% [6]. However, given that there are already 78,000 auto repair shops in Peru, serving some 2.9 million vehicles, this growth does not match the availability of auto repair businesses in the country [7]. Due to saturation problems and the resulting high demand for maintenance services that workshops are unable to provide, customer service waiting times are increasing. [8]. Therefore, companies in the automotive industry work to maximize maintenance service times in an effort to reduce the percentage of non-compliance and avoid economic losses.

Considering these factors, it is safe to say that, over time, service times will become an issue. Given the significant impact of this issue, a considerable number of authors have suggested solutions using various Lean technologies. First, according to the research presented by one of the authors, Masaki SAC is forced to improve its manufacturing processes to meet the demands of its customers due to the increased demand for maintenance services. The DMAIC technique and the five whys were the main tools used to meet this challenge [9]. Positive results were obtained: 39% to 23% fewer cars entering the workshop and not being removed on the same day. Positive results were obtained: 39% to 23% fewer cars entered the workshop and were not removed on the same day [10].

The second problem was the clutter of components, the accumulation of superfluous paperwork, and the lack of organization and cleanliness in the offices and corridors. Therefore, the main objective was to improve the structure and cleanliness of the warehouse in order to be able to find things more quickly [11]. The 5s technique was suggested as a strategy to address this problem. The organization increased compliance with the suggested objectives from 16.47% to 92.94% after applying the 5s technique [12].

To ensure customer satisfaction, the author proposes to reduce picking times and redesign the warehouse in research conducted in a warehouse of a high-end automotive repair company [13]. Using a flow chart, ABC approach and Monte Carlo method for space simulation, he offers a solution. In addition, it shows how picking times can be shortened by shortening the distances that spare parts must travel from their location in the warehouse to the delivery counter [14]. Another investigation describes the problem that a plastics manufacturing company had as a result of the Covid-19 pandemic.

The authors detected productivity and efficiency problems in this Small and Medium Enterprises (SMEs). The authors suggest applying a dual-approach optimization model that values both operational improvement and working conditions to address the problem that resulted in delays in delivering orders to consumers, leading to their dissatisfaction. This strategy makes use of lean tools such as Single Minute Exchange of Die (SMED) and 5S. Its main results include a 13.4% improvement in order fulfilment rate, a 62% decrease in operator effort, and a 57% reduction in setup time [15].

Although the Lean approach has been very successful in the industry, it has been observed that there is not much research focused specifically on the automotive sector. This study aims to improve the processes of a developing market, such as the automotive industry, by applying the lean manufacturing methodology, streamlining maintenance procedures, organizing the warehouse and improving purchasing management through the use of 5S tools to improve inventory management, order and cleanliness of the warehouse and work areas; standardized work which will help us to perform maintenance service processes faster and ABC analysis which will facilitate the management of spare parts purchasing [16]. The study will be carried out with the help of the 5S tools.

The structure of this project is as follows: Chapter 2 provides a literature review; Chapter 3 demonstrates the contribution of the case study; Chapter 4 demonstrates in detail the validation of the proposal; Chapter 5 presents the project discussions; Chapter 6 presents the conclusions; and the chapter concludes with the bibliographical references.

2. Literature Review

2.1. Lean Manufacturing in the Automotive Sector

To understand how lean manufacturing works, which is a set of tools of the lean philosophy aimed at streamlining a company's operations, it is necessary first to understand how it works.

In relation to the above, some authors state that lean manufacturing is a strategy that, according to most research, produces efficient operations, manufacturing processes and logistics. Productivity, efficiency, decrease in the number of labour hours required, optimal use of space, and correct inventory records are the metrics that typically benefit [17-19]. The authors also include some of the most popular project management technologies, such as 5s, standardized work, SMED, Kanban, Andon and Heijunka, among others.

According to studies conducted by many authors, implementing lean manufacturing technologies has led to improvements in various processes in a wide range of companies around the world. One such study was the implementation of lean manufacturing in an automobile manufacturer in northern India, which led to a reduction in cycle time by 87.59%, WIP by 76.47%, production time by 95.41%, and value-added ratio by 66.08% [20]. The authors used the Value Stream Mapping (VSM) tool to design the Lean phases for project execution and suggested a future VSM perform a simulation and obtain the results described above [8][21][23].

In this sense, the objective of this project is to apply the best tools of the lean manufacturing methodology to challenging company operations related to the activities of the case studies mentioned above. In each of these examples, similar improvements can be observed in the processes examined, resulting in faster delivery of cars [24]. Despite the fact that some authors claim that this technique can be successfully used in any industry, it is of concern that there are so few studies on lean manufacturing methodology in the automotive industry.

2.2. Inventory Management

We are going to study the management of materials storage and purchasing in relation to inventory management. The ABC tool is perfect for achieving these objectives since it is responsible for creating a purchasing strategy by determining the value of each good that the company must purchase [5].

High operating and warehousing costs in supermarkets are a problem that causes low efficiency in the flow of goods, according to a case study conducted in a supermarket distribution center in China. The authors propose implementing a novel model to address the shortcomings of conventional distribution techniques using the ABC tool. The installation results, which resulted in a 34.72%

reduction in operating and warehousing costs, were as expected [26]. Moreover, other authors support the same point of view, noting that the ABC tool allows the segmentation of goods according to their consumption quantity and that reliable Key Performance Indicators (KPIs) must be managed for it is a pany that sells spare parts to national and global distributors. This company's main problem is delayed delivery times to its customers, so delays were reduced by 24.08% by using ABC analysis and prioritizing the most popular spare parts in advance [30].

The numerous case studies that have been previously evaluated have shown that the ABC tool allows for improving the management of spare parts purchases since the right supplies will always be available for preventive maintenance, which is crucial for this project [31]. In order to optimize the logistics procedures of the investigated automobile factory, ABC analysis will be employed as a technique in this research project. Furthermore, as seen in the case studies, many techniques will be applied throughout the phases of this tool to ensure the optimization of the mentioned procedures. To support the improvement of the research processes, it is crucial to validate and disseminate the use of ABC analysis and other complementary Lean tools in the automotive industry. [32].

2.3. Warehouse Management

Several authors argue that the 5s tool should be used to organize the warehouse, as it focuses on order and best practices in a well-established part of the company. The selection of items according to their relevance, the separation of those that are useful from those that are not, the physical arrangement of previously selected materials and, finally, the cleaning of workplaces and materials are some of the most commonly used techniques [33].

According to other authors, the 5S tool was implemented in hospitals as the main objective of the research conducted in Egypt in order to improve the work environment in terms of cleanliness, order and inventory management to decrease patient waiting times [34]. The results were favorable, as patient waiting times decreased by 25% and patient satisfaction increased by 43.5% [35].

Along the same lines, research conducted in a retail distribution company identifies that the high proportion of returns (12.45%) is the main problem caused by the following factors: orders arriving late, not complete or damaged when they do [36]. The drafters made the decision to apply various Lean tools, and the 5S system was selected to look at all aspects of the company's warehouse. First, red cards were used to identify all materials in the warehouse, as well as extraneous items. Second, colored ribbons and labels were used to identify shelves and floors. In addition, cleaning guidelines and product labels were established for the warehouse. Finally, the product rejection rate was reduced from 12.45% to 5.5% once the 5S tool was implemented [37].

The 5S tool works best when accompanied by another tool, such as VSM or Kanban, as it allows faster implementation, improves the processes to be performed and is more efficient, according to research that the authors have studied and analyzed [38]. The implementation costs of 5S can be quite significant for companies wishing to use them; hence there are not many studies that mix them with other technologies.

2.4. Standardized Work

The uniformity of the procedures used in the washing area is another crucial factor in reducing service times. In order to have clear production processes, standardized work is a method that aims to provide each employee with the same amount of work and time [39]. It also refers to the importance of assembly lines and how they are designed to follow a specific order to produce more uniform goods [40]; according to a case study conducted in a company engaged in the printing business, rejected orders due to delays and poor-quality products cost $4.3 million to the company's operations. To solve this problem, the cars proposed implementing standardized work and different lean manufacturing tools; when these improvements were completed, productivity increased by 30.7% [41]. Similarly, standardized work was used in similar research in a beverage company to increase the efficiency of manufacturing processes [42]. The company used this tool during batching, labeling, bottling and spraying operations. Finally, when the indicated processes were improved, the number of abandoned pouches decreased by 34% in the following months [7].

Since it is quite likely that operations in an automotive shop are standardized to maximize the optimization of work time, standardized work is well suited to our study project.

3. Innovative Proposal

3.1. Rationale

Figure 1 shows the proposed project model to meet the research objectives. For the development of this model, the model developed in a research study was taken into consideration developed in research [44], from which it was possible to extract the need to analyze the current situation of the company under study through different diagnostic tools and then use lean manufacturing tools to optimize the company's operational processes. As in this proposal, this model details the key elements to reduce service times to achieve the objectives set out in the research. Similarly, in another study, it was determined that by applying lean manufacturing tools, it is possible to increase the efficiency of processes to reduce service time.

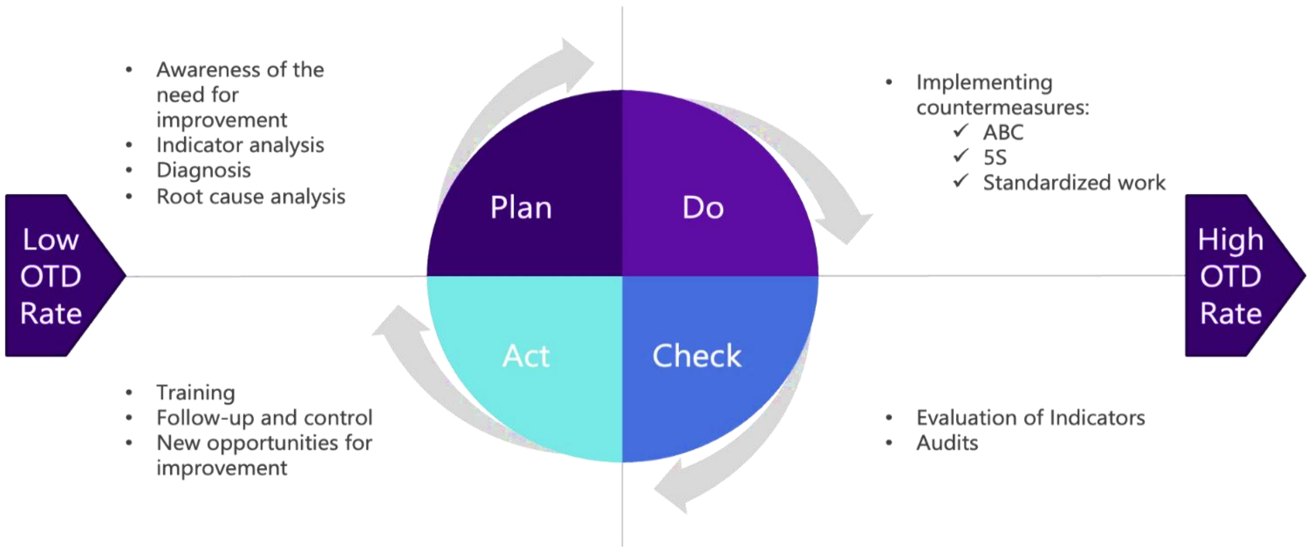

Fig. 1 Proposed Model

On the other hand, the value generation of this proposal is based on the tools mentioned in state of the art, integrating each of them into the proposed model, which is developed based on a PDCA continuous improvement model, which aims to reduce the cycle time of the maintenance service. This model consists of four phases and has as its main reference the lean manufacturing philosophy [11, 45]. Also, ABC, 5'S, and standardized work tools were combined to improve the same problem.

The root causes of this problem are poor purchasing management (with an impact of 17.43% on the problem), products without specific location (with an impact of 15.07% on the problem), inefficient final inspection of the vehicle (with an impact of 13. 19% impact on the problem), the disorder in the warehouse (with an impact of 12.24% on the problem), error in the purchase of spare parts (with an impact of 11.15% on the problem) and absence of washing process activities (with an impact of 9.89% on the problem).

Taking the previously mentioned diagnosis as a starting point, the present research project has developed the management model under the lean manufacturing approach detailed in Figure 1 to mitigate non-compliance in maintenance service deliveries. The purpose of this study is first to validate and then disseminate the implementation of the lean manufacturing methodology in a practically new scenario and little studied by the literature, with the objective of leaving a precedent that can help to optimize the service times of the automotive sector and thus, counteract the low supply of automotive workshops that exists in the market, seeking to increase revenues and thus improving customer satisfaction. Consequently, it is necessary to highlight this model that integrates in a novel way the ABC tools, 5S and standardized work with the objective of optimizing the delivery times of the vehicle maintenance service in an automotive company.

3.2. Proposed Model

The diagnosis made to the processes of a Peruvian company in the automotive sector determined that the main problem is the high ratio of non-compliance in the delivery time of the vehicle maintenance service. After performing the analysis of this research, it was found that preventive vehicle maintenance services are the ones with the highest ratio of failure to deliver on time, with 30.2% in the year 2021. As a result of this diagnosis, it was possible to know. The root causes of this problem are deficient purchasing management (with an impact of 17.43% on the problem), products without specific location (with an impact of 15.07% on the problem), inefficient final inspection of the vehicle (with an impact of 13.19% on the problem), lack of coordination (with an impact of 15.07% on the problem), inefficient final inspection of the vehicle (with an impact of 13. 19% impact on the problem), the disorder in the warehouse (with an impact of 12.24% on the problem), error in the purchase of spare parts (with an impact of 11.15% on the problem) and absence of washing process activities (with an impact of 9.89% on the problem).

Taking the previously mentioned diagnosis as a starting point, the present research project has developed the management model under the lean manufacturing approach detailed in Figure 1 to mitigate non-compliance in maintenance service deliveries. The purpose of this study is first to validate and then disseminate the implementation of the lean manufacturing methodology in a practically new scenario and little studied by the literature, with the objective of leaving a precedent that can help to optimize the service times of the automotive sector and thus, counteract the low supply of automotive workshops that exists in the market, seeking to increase revenues and thus improving customer satisfaction. Consequently, it is necessary to highlight this model that integrates in a novel way the ABC, 5S and standardized work tools with the

objective of optimizing the delivery times of the vehicle maintenance service in an automotive company.

The main objective of the solution model design is to reduce the company's current cost overruns by eliminating all activities that do not add value to the vehicle maintenance service.

Having said this, the first component of the model is the Plan phase, which seeks to organize the project, define the main problem of the company and define the objectives of the project, which refers to raising awareness of the top management of the company in order to facilitate the development of the proposal, implementing work teams that will be trained The project also includes the implementation of work teams that will be trained on the tools to be implemented, which will make it easier to monitor each of the implementation stages. The stages to consider for the implementation of this phase are the following:

- Generate management commitment.
- Implement teamwork.
- Train the work team.

The second component of the model is the Do phase, where the solution tools that will help achieve the implementation objectives are applied, which refers to the implementation first of the ABC analysis in order to determine the spare parts needed in the warehouse, then the implementation of the 5'S tool, which seeks to reduce delays in the dispatch and finally, to implement the standardized work to improve the washing process. The stages to be considered for the implementation of the tools in this component are as follows:

3.2.1. ABC

In this first stage of phase C, the aim is to identify those essential spare parts belonging to class A that should not be missing in the warehouse to avoid delays generated by the lack of stock of spare parts. To this end, the following activities are carried out:

- Data collection.
- Classification of spare parts.
- Define safety stock.

3.2.2. 5S

In this second stage, the aim is to increase the efficiency in dispatch times, reducing the delay in the search for spare parts. In order to implement this tool, it was decided to divide it into three phases:

Planning and analysis
- Reach an agreement with the company.
- Establish objectives.
- Drawing up a timetable.
- Train personnel.

Execution of the Model
- Seiri implementation.
- Seiton implementation.
- Implementation of Seiso.
- Implementation of the Seiketsu.
- Implementation of the Shitsuke.

Follow-up and improvement
- Evaluate and follow up on the improvements implemented.
- Establish an improvement plan.

Standardized Work

In this last stage, what is sought through the implementation of the tool is to mitigate delays in the washing service, thus improving the washing process by reducing the cycle time and eliminating those activities that do not add value to it. To this end, the following activities are carried out:

- Planning and analysis.
- Execution.
- Carry out proposed WTP.
- Carry out a final inspection.

The third component of the model is the Check phase, where the objective is to perform a detailed comparative analysis after implementing the solution tools. This is done by means of periodic audits together with some measurement indicators.

The fourth and last component of the model is the Act phase, where some reports will be made based on the data collected from the audits and indicators that will allow having first feedback that will help to develop continuous improvement.

3.3. Design of the Proposed Method

Figure 2 shows in detail the complete sequence of activities to be followed to develop the implementation of the proposed model. This starts with the execution of the first component, where the commitment with the company's top management is generated, and work teams are formed; then follows the execution of the second component, where the improvement tools are implemented (first the ABC analysis, then the 5'S methodology and finally the standardized work); followed by the execution of the third component where the indicators are compared, and improvement audits are performed, and finally the fourth component is executed where the implementation of continuous improvement is sought.

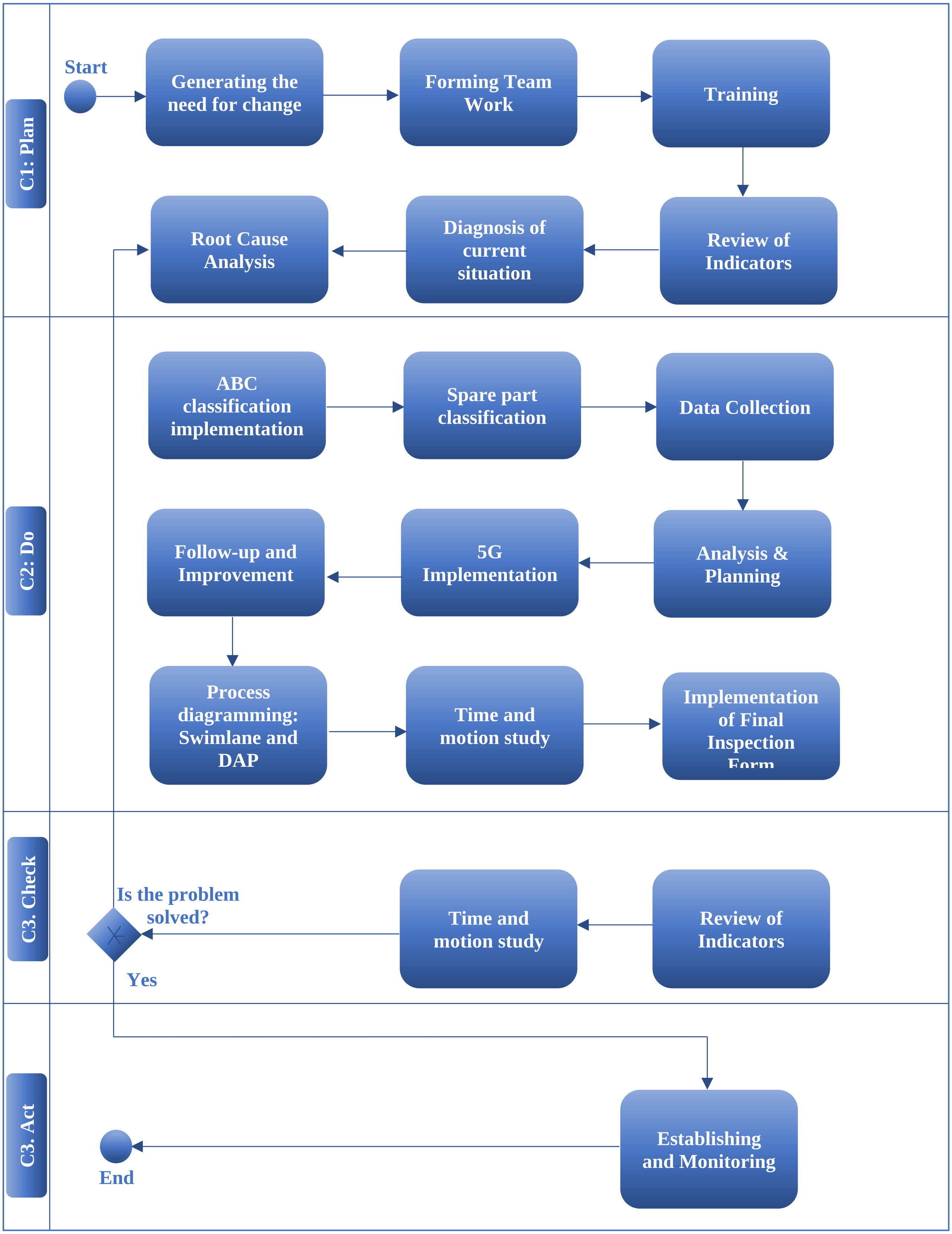

Fig. 2 Proposed method

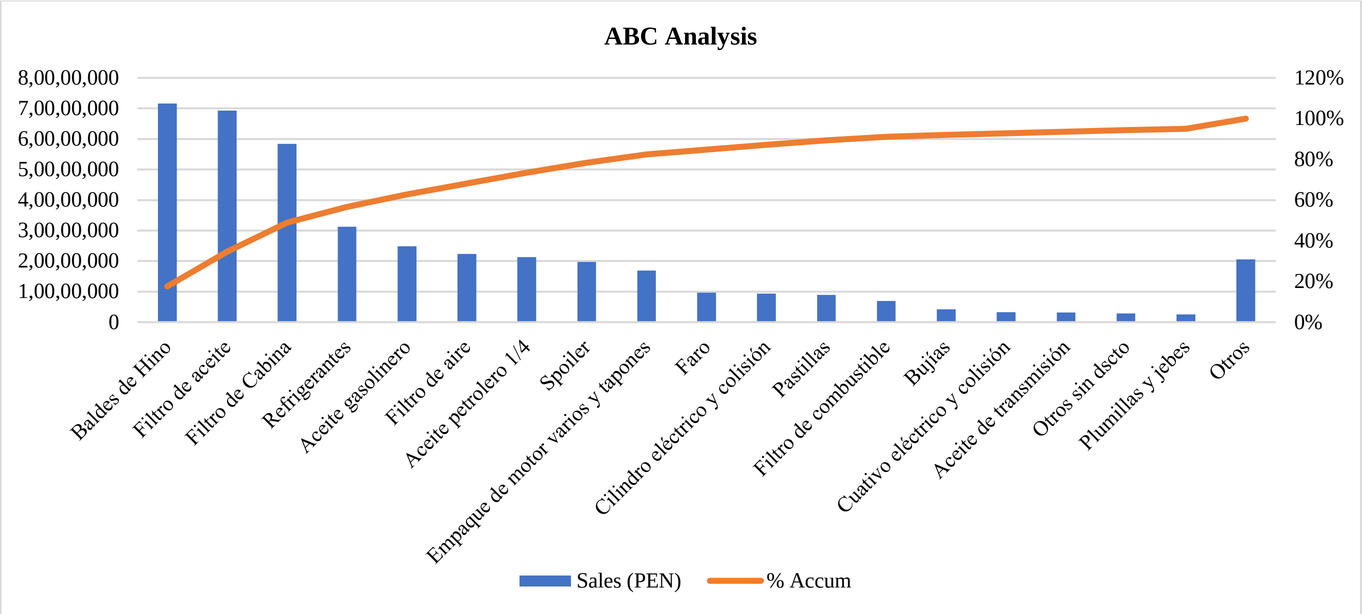

Fig. 3 ABC analysis

3.3.1. Component 1: Plan

Generate Commitment from Top Management

For this first phase, a meeting is held with the management of the company under study to generate awareness about implementing the solution model that will mitigate the impact generated by the main problem identified (high ratio of non-delivery of maintenance service). This creates commitment on the part of the hierarchy to facilitate the implementation of the solution tools.

Implement Work Teams

In this phase, the people who will make up the work team overseeing and monitoring the implementation are selected, and their roles are defined as shown in Table 1.

Table 1. Positions of team members

Member	Position in the company	Functions
Team Leader	Head of services	Organize the work team Follow-up of implementation activities
Team Coach	Administrator	Train workers involved in the implementation Ensuring the proper performance of each of the activities
Team Assistant	Spare parts assistant	Documentation of the implementation steps Providing assistance to internal staff

Training of Work Teams

In this phase, the respective training on the PDCA model and the solution tools used throughout the implementation will be carried out. Likewise, the solution schedule and its following sequence will be explained in detail.

It should be noted that all proposals made by the workers will be taken into consideration and will serve as feedback for improvement.

3.3.2. Component 2: Do

Conduct data collection

In this phase, the first thing to do is to collect information from the company's system, which will identify all the spare parts available in the warehouse and then proceed to classify them.

Perform ABC Classification of Spare Parts

In this phase, the classification of spare parts is carried out to identify those that are the most important during maintenance services, so they are the ones that should never be missing in the warehouse since they are also the ones that have the highest rotation. Once the first general classification of all the spare parts has been made, they are separated according to the family to which they belong to make the ABC classification as shown in Figure 3 finally.

Phase 1: Planning and Analysis

In this phase, a detailed warehouse study is carried out to determine the factors that intervene in the delays in the search for spare parts generated by the disorder in the warehouse and the products without a specific location. Likewise, a chronogram will be implemented where the phases and the progress of the 5'S methodology will be reflected.

Phase 2: Execution of the 5S Model

In this phase, the 5'S methodology is implemented in the warehouse. To do this, we begin with the implementation of the first "S", which is Seiri (Select), and its main objective is to separate the necessary materials from the unnecessary ones, for which red cards will be used to represent the frequency of use of each of these as shown in Figure 4.

Then, the second "S" is implemented, which is Seiton (Organize), and its main function is to organize the previously selected elements to reduce spare parts search times and reduce operator movements. Figure 5 shows the implementation in the company.

Next, implementing the third "S" Seiso (Clean) is performed, which consists of cleaning to remove dust, dirt, and any contaminants found in the work area.

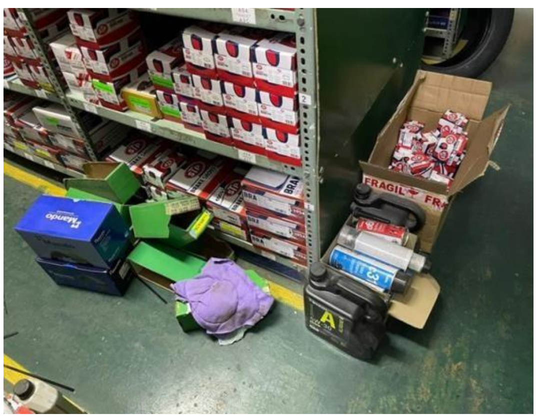

Fig. 4 Seri implementation

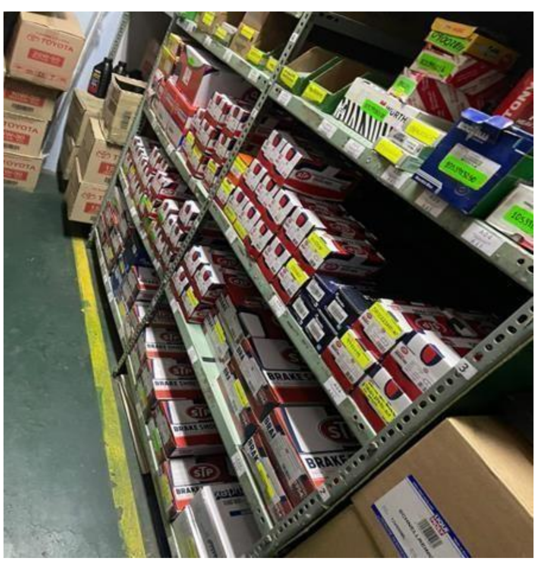

Fig. 5 Seiton implementation

Then, the fourth "S" Seiketsu (Standardize) is used, whose main function is to improve the 3 "S" previously mentioned; otherwise, the 5s methodology will not be implemented successfully.

Finally, the fifth "S" Shitsuke (Self-discipline) has as its main objective that the methods and standards mentioned in the rest of the "S" become a habit for the operators and adopt Deming's circle to obtain a continuous improvement in the work.

Create a Process Flowchart

During this phase, the implementation of the standardization of the washing service, whose main objective is to eliminate the reprocesses generated in the washing of the vehicle, causing delays in the final delivery time of the car.

Perform Final Inspection Form

At this stage, a new final inspection form is made so that the operators can verify if the car is delivered in perfect condition to avoid reprocessing that may cause delays in the final delivery of the vehicle. Table 2 shows the inspection form.

Table 2. Final car inspection sheet

Responsible	Task/Activity	Good	Bad	Observations
JC	Clean car interior	X		
JC	Tires clean and siliconed	X		
JC	Engine clean and siliconed	X		
JC	Rinsing process	X		
JC	Drying process		X	Bad drying
JC	Good internal vacuuming	X		
JC	Shiny vehicle		X	Lack of shampoo

3.4. Model Indicators

The indicators proposed to measure the model's performance are detailed below.

- Non-compliance ratio in maintenance service delivery times.
- Work orders were delayed due to a lack of stock of spare parts.
- Time spent searching for tools.
- Audit compliance.
- Washing cycle time.
- Productive activities in the washing process.

4. Validation

To demonstrate the effectiveness of the designed solution, the pilot plan was chosen as a validation method. The pilot plan system was developed taking into account the processes of vehicle maintenance management, purchasing management and washing in an automotive company.

4.1. Description of the Scenario

To demonstrate the effectiveness of the designed solution, the pilot plan was chosen as a validation method. The pilot plan system was developed, taking into account the processes of vehicle maintenance management, purchasing management, and washing in an automotive company.

4.2. Diagnosis of the Company Under Study

The preventive maintenance service presents a high ratio of non-delivery in the company under study throughout the year 2021, which was 30.2%, representing an economic loss of PEN 166,500.00 for penalties, equivalent to 5.7% of the total income generated in that year.

In relation to the study division, 36.2% of the work orders were delayed due to a lack of stock of average spare parts search time of 7 minutes per work order, a wash cycle time of 63.4 minutes and 77.33% of productive activities in the washing process.

4.3. Validation Design and Results

Initially, an analysis of the company's current situation is carried out to determine each company's processes and identify the main problem. Once identified, we proceed to determine the causes that are generating it and then identify the most appropriate solution tools to implement in order to reduce the impact generated by it.

For the execution of the proposal, the pilot plan is developed based on the continuous improvement model to reduce the initial indicators. To begin with, the number of samples needed to demonstrate the reliability of the implementation was established using the formula for finite population, concluding that the pilot test should be conducted in a minimum amount of 347.98 maintenance services, which is equivalent to 3 months.

4.3.1. ABC

The ABC classification of the spare parts in the warehouse was carried out, as shown in Table 3.

From this analysis, it was determined that the company has 291 types of spare parts, which represent 22.33% of the total inventory of inputs and, at the same time, represent 80% of its value. In this sense, efforts should be focused on optimizing the management and control of the inventory of this type of spare parts.

Table 3. ABC classification

Classification	Nº Spare Sparts (SKU's)	% Spare Sparts (SKU's) Acumulado	% Valued	Valued
A	291	22.33%	79.96%	1,300,924.90
B	390	52.26%	15.03%	244,465.51
C	622	100.00%	5.02%	81,631.08
	1303			1627021.49

In addition, policies were implemented to improve inventory management, as detailed in Table 4 below.

Table 4. Inventory management policies

Nº	Inventory management policies
1	Maintaining a safety stock of spare parts present in the A-Class
2	Warehouse will have to record all stock receipts to SAP.
3	Conduct a warehouse inventory in the months of April and November.
4	Meet ERI indicator >= 95%.
5	Performing a new ABC Classification after the last inventory of every year

Once the ABC methodology was implemented, in line with compliance with inventory management policies, it was possible to identify a reduction in the number of maintenance service work orders registered in the company's automotive management system (EMS) that were delayed due to a lack of spare parts in stock.

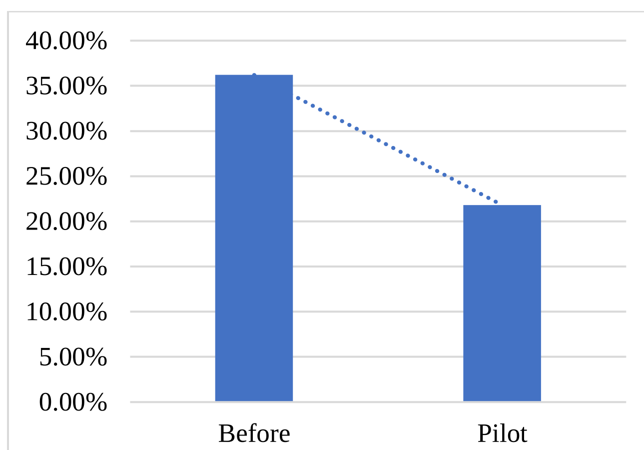

Fig. 6 Comparison of work orders delayed due to lack of spare parts in stock

4.3.2. 5S

We started with the planning and analysis phase and then implemented each one of the 5'S and carried out an audit on the compliance of the same, determining that there was an increase of 32%, as shown in Figure 7.

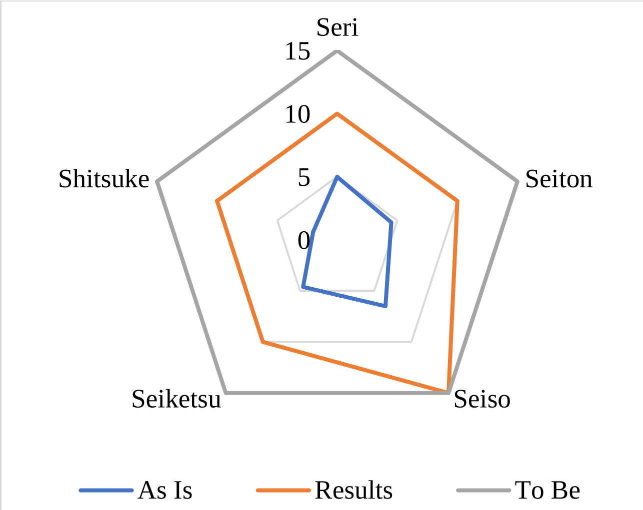

Fig. 7 5S Audit comparison

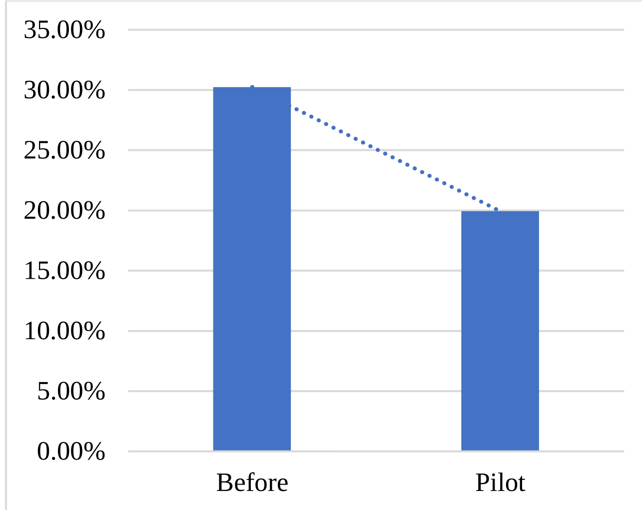

Fig. 8 Comparison of the rate of compliance in delivery times

The improvements obtained from implementing the 5'S methodology are reflected in the spare parts search time, which before was 7 minutes. After the improvements, a time of 4.11 is obtained, being 2.5 minutes as the ideal time. The improvement obtained is shown in Table 5.

Table 5. Comparison of spare parts search time before and after process improvements

	Formerly	Now
Spare parts search time	7 minutes	4.11 minutes

4.3.3. Standardized Work

It was used to correct two types of errors, the absence of activities in the washing process and the inefficient final inspection of the vehicle. To this end, a new flow of activities to be carried out by the person in charge of the washing process was created, and then a new activity diagram of the process was drawn up.

From this, it is determined that there is an increase in the percentage of productive activities by 11.29% compared to the activity diagram of the process before implementation. Likewise, the cycle time of the washing service was reduced by 11.9 minutes, and the improvement obtained can be seen in Table 6.

Table 6. Comparison of indicators before and after process improvement

	Formerly	Now
Productive Activities	0.7733	0.8462
Washing process time	63.4 min	51.5 min

Finally, it was possible to validate that the implementation of the management model under the Lean Manufacturing approach allowed a significant reduction in the ratio of non-delivery of the maintenance service, from 30.2% to 19.94% (a reduction of 10.26%), achieving the main objective set out in the research.

5. Discussion

5.1. New Potential Scenarios

Through the pilot plan, it was possible to determine the effectiveness of the proposed improvement proposal to reduce non-compliance in the delivery times of preventive vehicle maintenance services; this means that the results were satisfactory.

However, to demonstrate the reliability of the results, the implementation in other scenarios will be analyzed. That said, we will consider the services that have similarities with the preventive vehicle maintenance service, which are the corrective vehicle maintenance service and the bodywork and painting service.

5.1.1. Corrective Maintenance Service

With a longer service time than preventive maintenance, this type of service has a non-compliance ratio of 27.4%, the second with the highest non-compliance ratio. Like preventive maintenance services, this type of service also has the same causes that generate this non-compliance and the same indicators.

However, unlike preventive maintenance services, this type of service also has the same causes of non-compliance, as well as the same indicators. This service has spare parts with a lower frequency of rotation, so it is more likely that they are not in stock.

5.1.2. Results in Potential Scenarios

Based on the scenarios proposed for the vehicle corrective maintenance service, an evaluation of the improvements obtained is presented.

From the results presented in Table 7, it can be determined that the improvement model proposed in this project would achieve favorable results for the other types of services the company provides.

Table 7. Results

Indicator	Current Value	Final Result
Non-compliance ratio in delivery times	27.40%	18.36%
% of work orders delayed due to lack of spare parts stock	24.20%	15.83%
Audit compliance	46%	58%
Tool search time	7min	4.11min
Washing cycle time	63.4min	51.5 min
% productive activities	77.33%	95%

5.2. Analysis of Results

5.2.1. Economic Analysis

For the economic evaluation of this project, a 5-month projected financial cash flow was made, taking into account all the costs of the implementation of the improvement proposal, as well as the reduction of the maintenance service non-delivery ratio by 10.26%, which incurs a greater number of services performed during these months. Likewise, the revenues and investment involved in the same were taken into account.

Based on the cash flow, the financial indicators of Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback Period (DRP) and Benefit Cost (B/C) were identified (Table 6). It is determined that a net present value (NPV) of PEN is 48,707.30. In addition, the internal rate of return (IRR) for the same scenario is 63%, which means that being higher than the COK makes it viable, in addition to a payback period of 1.72 and a benefit/cost ratio of 1.51. For all these reasons, it can be concluded that the project is viable for the company. Table 8 shows the results of the economic evaluation.

Table 8. Economic results

Results	NPV (PEN)	48,707.30
	IRR	63%
	Payback	1.72
	B/C	1.51

5.2.2. Future work

After finishing the present investigation, to expand the limits of the acquired knowledge and seek to contribute to the different areas to optimize their processes, reducing the delivery times, the future works to be carried out are shown.

- Investigate, propose and validate a possible implementation of Lean Manufacturing to mitigate other problems related to process improvement in the automotive sector.
- To expand lean manufacturing knowledge in industries other than automotive; in other words, to investigate, propose and validate implementing a management model based on Lean Manufacturing in other industries.
- Investigate the compatibility of other Lean Manufacturing tools for possible future implementation in process optimization.

6. Conclusion

This research was able to diagnose that the high ratio of non-delivery of the maintenance service is the main problem presented by the company in the automotive sector and, at the same time, is the one that generates the greatest amount of economic loss. Likewise, it was determined that poor purchasing management, products without location, inefficient final inspection of the vehicle, the disorder in the warehouse, error in the purchase of spare parts and the absence of washing process activities, with an impact of 17.43%, 15.07%, 19.19%, 12.24%, 11.15% and 9.89% respectively, are the main root causes of the problem.

Recognizing the problem and its root causes from the beginning facilitated the use of the solution tools used in the project. Different companies from different industries have implemented the tools implemented, obtaining positive results, such as those reviewed in the success stories of this work.

The lean manufacturing management model applied to the processes of an automotive company can mitigate the ratio of non-delivery of maintenance services by 10.26%. Likewise, it was possible to reduce the spare parts search time and the washing cycle time by 44.7% and 18.8%, respectively, in addition to reducing the number of work orders with delays due to the absence of spare parts by 14.4%.

The project is economically viable with an NPV of S/. 48,707.30, an IRR of 63% and a B/C ratio of 1.51, which are positive values.

In addition, on the one hand, the present research allows expanding the literature referred to process optimization through the implementation of ABC analysis, the 5'S methodology, and standardized work. On the other hand, consider expanding the implementation of the proposed model in other services with similar characteristics to the preventive maintenance service to continue mitigating the non-delivery ratio.

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