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Productivity Improvement in an Automotive Workshop through Lean Manufacturing Methodology

Geovanna Noemy Galo Bruner[1], Paola Michelle Pascua Cantarero[2]
[1]Universidad Tecnológica Centroamericana/UNITEC Boulevard Kennedy,Tegucigalpa, Honduras geova12@unitec.edu; paola.pascua@unitec.edu.hn[2]Universidad Tecnológica Centroamericana /UNITEC Boulevard Kennedy,Tegucigalpa, Honduras

Abstract – This research study focused on improving the productivity of an automotive workshop in Tegucigalpa, Honduras, by analyzing and identifying the causes of delays and implementing process improvements by applying the tools and principles of the LeanManufacturing methodology using a quantitative approach with a descriptive scope. The problem for the automotive workshop lies in the long maintenance service times for the engine oil change, from the time the vehicle enters the workshop until it is delivered to the customer. The first step was to analyze the company's current situation and identify opportunities for improvement. Analyzing a probability sample of 3 employees in the maintenance department. The activities with the greatest negative impact on the process were analyzed, including unnecessary materials in the work area, the accumulation of waste, unnecessary transfers, and the fact that there is noperson in charge of maintaining order and cleanliness in the area. The operation of the workshop was then described using indicators to improve the overall performance of the company. Seven activities were reduced in the current analysis using process diagrams and flowcharts. The duration of the maintenance service was reduced by 36 minutes, identifying a 40.6% opportunity to improve the serviceand standardize the process. Finally, socialization was carried out with the company, where information was shared about the project andpossible implementation and execution.

Keywords: Productivity, VSM, Systems Improvement, Automotive Shop Floor

1. Introduction

The current environment of the automotive industry in Honduras, Central America, is characterized by competitiveness, speed of change, and instability of demand, which is due to an increase in the number of customers who demand products that meet their requirements and have the quality required to satisfy specific needs.

In Honduras, with the arrival of the Banana Transnationals, most of the elements of modernity were introduced to the country through companies such as the United Fruit Company, the first automobile that arrived in Honduras in 1905 in San Lorenzo [1]. The automobile was increasingly used in countless activities such as war, politics, entertainment, commerce, and of course, as a means of popular communication by families, the introduction of the automobile caused profound transformations in the Honduran society of the twentieth century, in 1910 the first transportation companies were installed in Honduras which were enacted a series of agreements and regulations.

The company where the research was conducted, Tecniwash and Autolote Fredys, located in Tegucigalpa, has observed this problem since its beginnings in the maintenance service. Previously, the company had less demand, but over the years there has been an increase in the number of vehicles in the country and therefore in the city, leading to an increase in demand and a growth in competition, therefore it becomes necessary to propose an improvement in the productivity of the workshop for greater competitiveness in the area. Considering the above-mentioned, the general objective of this research is to propose improvement methods for the productivity of the automotive workshop in the maintenance service using Operations Improvements Systems tools.

2. Methodology

The approach of the study was defined as quantitative because the results can be measured and, in this way, the data processing is carried out. The scope determined for this research is descriptive since the study of the processes of the automotive workshop and the measurement of productivity without manipulation of variables were carried out [2].

The study population was defined as the 3 employees who work in the workshop, specifically in the vehicle maintenance service area, as well as the sample. Their working days are Monday through Saturday from 9:00 am to 5:00 pm. The sampling used is probabilistic because the population that makes up the sample has an equal probability of being selected. The following research variables were considered: time, waiting time, total time, and productivity.

The tools used for the first objective were flowcharts, a process analysis diagram, and a Pareto chart. The process diagram is a visual representation of the operations that take place during the creation and delivery of a product or service and involves the various people responsible for fulfilling the process, it favors the knowledge of the real functioning ofthe process. [3]. The flowchart shows each step, order, and decision in a workflow or process [4]. The Pareto Diagram is a very powerful tool for showing the relative importance of problems [5].

Key performance indicators were used to meet the second objective. These were described to ensure measurement within the automotive shop as they previously did not have these metrics. We used indicators, a method or way that allows us to quantify or measure things, every day in our daily lives.

To propose improvements in the third objective, a VSM of the Current State and a VSM of the Future State were used, as well as a Muda Check to detect all the waste within the process. The VSM is a business method used to evaluate and improve the flow of information and resources needed to create a good or service. It is a planning tool to maximizeresults by eliminating waste [6].

The validation method of this study is carried out by comparing the time obtained in the current situation with the time obtained after the proposed improvement was made using a comparison table. The second verification was carried out through a meeting with the manager of the company under study, where the research was presented to him and possible improvement proposals for the workshop were evaluated. The main goal of validation is to demonstrate that the analytical method is fit for purpose [7].

3. Results and Analysis

A. Analysis of the company's current situation

In order to achieve the first objective of this research, we began with a diagnostic phase in which we observed andstudied the circumstances in which the primary processes of the workshop operate. With the help of some historical data and direct observation in the workshop area, several studies were carried out. With the help of the numerous tools suggested by an operational improvement system, proposals were made based on this knowledge to improve the internal processes of the workshop.

For the diagnostic phase, the direct observation technique was used for several weeks. The workshop performs different activities; among the main ones are vehicle maintenance service, painting, repair, as well as the acquisition, sale, or exchange of second-hand cars. The analysis was carried out specifically in the area of preventive maintenance of engine oil change, therefore this involves the mechanical personnel who perform the operation, the tools, and the materialresources that are used to carry out the service.

The first tool used for this research was the use of a flowchart to graphically represent the process, providing more information about the maintenance tasks of a car.

In order to understand the diagram, brief information about the processes is listed.

-Receiving: The consumer brings his car in the hope that, if the business has the necessary availability, he will be helped right away. If not, he will have to wait for the shop to make it available.

-Mechanical evaluation: Depending on the type of maintenance the vehicle requires; the technician evaluates the unit for the first time to confirm the need for replacement components.

-Unit maintenance: After receiving the customer's consent, the workshop manager assigns a mechanic to service the unit as soon as possible. The unit will be serviced as soon as possible.

-Delivery: Once the maintenance has been completed and the respective service inspections have been carried out,the vehicle is delivered to the customer. It happens that sometimes customers ask for their car to be washed before beingdelivered, however, it was not included in the diagrams since it is not part of the process since it counts as one more service.

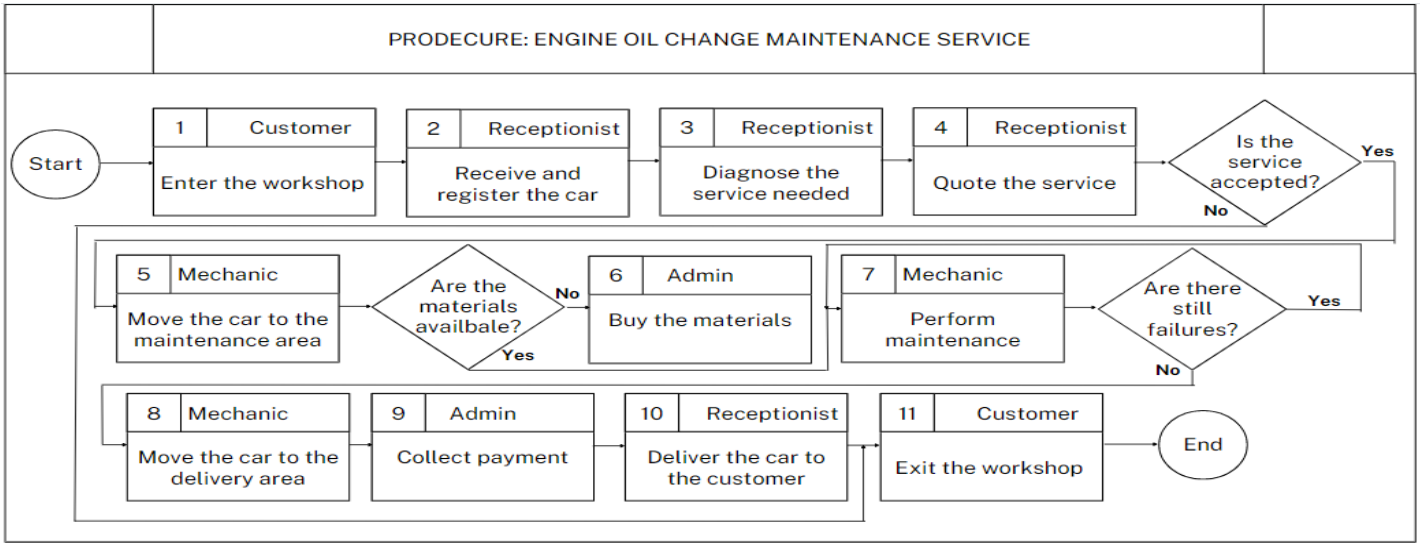

Fig. 1: Flowchart- Maintenance

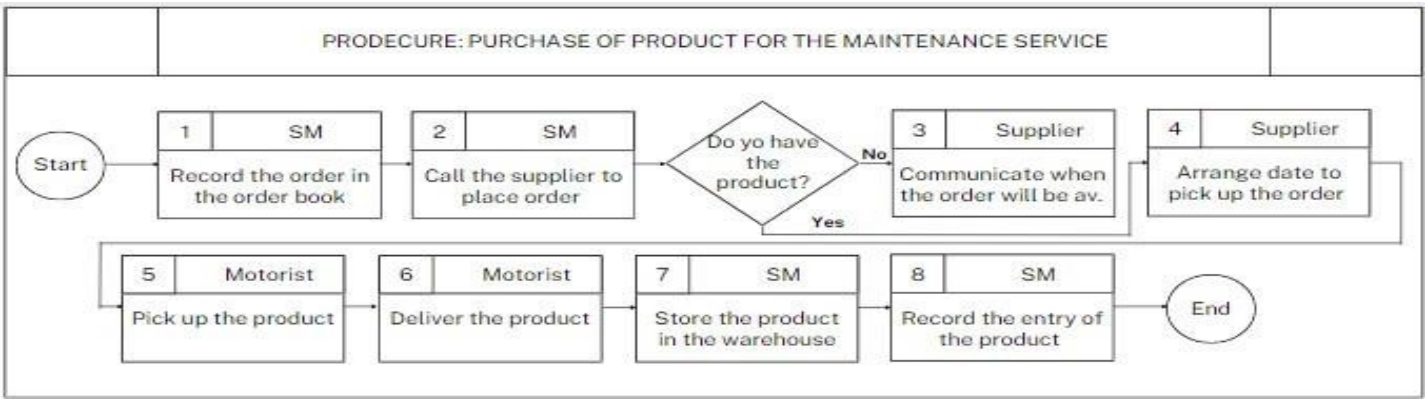

Fig. 2: Flowchart- Purchasing

The sequence of all activities, transports, inspections, delays, and taming that take place in each process are represented in the process diagram. The diagram was created with the intention of making it easy to distinguish between the actions that contribute to engine oil maintenance and those that do not. using a stopwatch and a visualization of the process.

Subprocess	Description	Symbol	Time (sec)
Reception	Receipt of vehicle		540
	Simple inspection		720
	Diagnosis and quotation		240
Maintenance	Vehicle entry to the maintenance area		36
	Placement of elevator clamps		105
	Lifting the vehicle		78
	Vehicle condition check		39
	Transfer of burnt oil collector under the vehicle		21
	Search for tools		135
	Remove oil filter cover		35
	Waiting for oil filter drainage		76
	Remove crankcase tap		12
	Waiting for crankcase tap emptying		218
	Place tap		7
	Transfer of burnt oil collector to its original place		19
	Tighten the tap		22
	Look for new filter and oil		87
	Open filter and install it		19
	Tighten the filter		15
	Lower the elevator		67
	Uninstall lift clamps on vehicle		53
	Open the bonnet and uncover the oil tank.		9
	Place the funnel		16
	Pour the oil		101
	Remove the funnel and cap the tank.		9
	Check oil level by starting the car		56
	Verify with dipstick		41
	Air filter cleaning		23
	Returns tools to their place		93
	Close bonnet		13
	Move vehicle to delivery area		139
Delivery	Verify that the service has been performed		200
	Invoicing and delivery of vehicle		125
	TOTAL		3369

Fig. 3: Oil Change Maintenance Service Analysis Diagram.

The diagram shows the average time taken on days of high demand for the process where it is shown that the engineoil change takes place. It was observed that for the development of the process, there are 22 operations, 7 transfers, 2 inspections, and 2 combined activities. The average service time is 56.15 minutes.

The analysis of the process revealed the following:

- Operating personnel: The company's management encourages teamwork. The personnel are familiar with the company's operations and the functions they perform, identifying their responsibilities and the positions for which they have been hired; however, the mechanics do not use any personal protective equipment. There is also no one responsible for cleaning the workshop.
- Tools: Although the tools they use are in excellent condition, there seems to be no order or designated place for them, and time is wasted when it is generally needed, slowing down the procedures being carried out.
- Methods: Since the status of the vehicle maintenance process is not visualized or regulated from incoming to outgoing, the organization lacks adequate techniques to improve the efficiency of the procedures performed.

In addition, the order of the process flow is not uniform, which occasionally causes bottlenecks for fast service.

- Material: Although the process requires a minimum amount of stock, occasionally work is stopped due to a shortage of supplies.

Overall, with the help of the expert, it was easy to determine that the approach is technically sound, and the observations also show which tasks are redundant and which can be eliminated to improve the method. It is essential to emphasize that the process analysis will make it possible to determine whether changing some activities will increase the productivity of the service by reducing the time required for its creation.

The automotive workshop handles different types of services, depending on the needs of the client and the needs of the unit. According to the Workshop Management Control Board and its evaluation, the most required types of

services can be obtained, as shown in the Pareto diagram, it should be noted that for the following diagram, the non-routine services have been eliminated.

Board is from 06/02/2023 to 16/02/2023 were cut as research subjects. The objects that do not change at all the result ofthe most demanded service are:

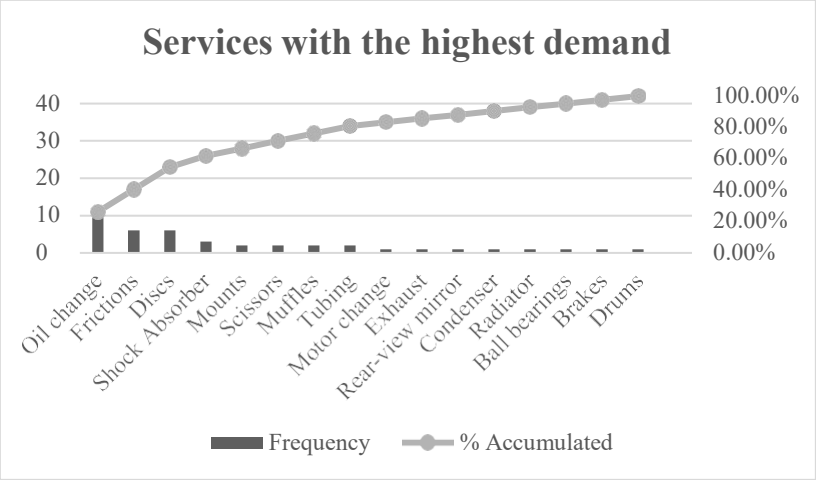

Fig. 4: Pareto diagram analysis of automotive workshop demand.

B. Description of KPIs for the workshop

The automotive workshop did not have established key performance indicators, therefore two key KPIs were proposed for the standardization of the process, such as customer waiting time at the reception, duration of the maintenance service, and the use of cycle times. It was observed that the employees did not pay attention to a sequence of activities, they focus on doing a quality job, but without keeping in mind the customer experience. By establishing indicators in different areas, the automotive shop can identify areas where improvement is needed.

Table 1: Key Performance Indicators

Indicator	Frequency	Formula	Goal
Waiting time at the reception	Every two weeks	Waiting time at reception= (Total waiting timeof customers/total number of customers)	8 min
Maintenance time	Every two weeks	Maintenance time= (total repair time/total number of repairs)	30 min

-Waiting time at the reception desk: the time that customers wait to be served at the business' reception desk was measured. This evaluated the quality of customer service and the competence of the reception staff. In order to establish a KPI for waiting time at the front desk, a specific goal in terms of time was defined. The waiting time at reception can be measured and monitored on a daily, weekly, or monthly basis to evaluate the performance of the business and take measures to improve customer service. This goal was established based on the creation of a prior appointment by the customer with the management for the attention of their vehicle, therefore, there should not be a long wait, an amount of 8 minutes was estimated in case the area is obstructed and proceed to clear the area for the entry of the next vehicle to be attended as scheduled.

Maintenance time: this metric measured the time required to complete a repair from start to finish. It is important to track the time taken for each service to get a clear picture of the company's productivity in this area. A specific goal in terms

of time was used; it is important to remember that the length of service time can vary depending on the type of service provided, the complexity of the service, the number of customers served, the personnel available, and other factors. The goal was set at 30 minutes based on the time of the sum of the service activities studied through the process analysis diagram, considering that some activities are eliminated, and others are improved.
With the proposed inclusion of these metrics, it was possible to reduce the operating times and service indicators, making the process more efficient and transmitting a culture of customer satisfaction.

C. Identification of process improvements.

The value stream map (VSM) was used as a tool to gain an in-depth understanding of processes, both within the company and in the supply chain. The value stream map was developed considering 6 macro-processes carried out in the automotive workshop: Reception, simple inspection, diagnosis, maintenance, payment, and delivery of the vehicle, maintenance, payment, and delivery of the vehicle.

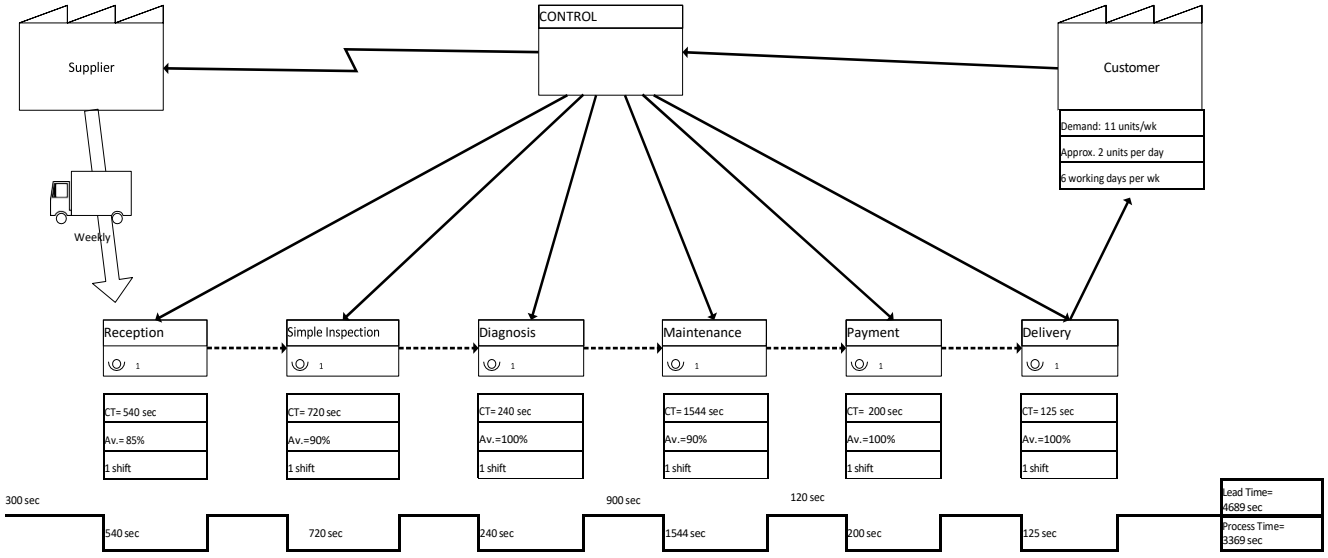

Fig. 5: Current VSM

In the current VSM, a slow, ambiguous process was observed, with many delays and long processes, which is whythe lead time obtained is quite high, 4689 seconds, which is a little more than 78 minutes, and a process time of 3369 seconds, it should be noted that this is an average, and often creates discomfort in the customer since it is a higher timefor the type of service.
Obtaining a Takt Time in minutes for the current flow: 405 min/2 units = 202.5 min.

This indicates that our available hours of work are above the "touch" or what the customer wants in time, which iswhy we must reduce the number of available hours, as it shows that there are many waiting times in the process. It is important to note that the total time available was based on the working day and the demand was taken only based on oil changes, considering that the workshop performs other types of service.
The following observations can be obtained from the VSM diagram:

The cycle time for the first two processes indicated is minimal. At the beginning of the activities, sometimes customers are already queuing outside the workshop to be attended, which varies the service time during the reception of vehicles. On the other hand, three processes (simple inspection, maintenance, and payment) have waiting time because

the car must be moved to another area to be attended to. It is proposed to reduce time by redesigning processes and eliminatingactivities that do not add value.

- Dead times were identified within the processes. This is mainly due to time spent searching for tools to start work, the transfer of vehicles between different areas, and time wasted by the workers themselves, among others. For this reason,it is proposed to eliminate waste in the process.
- In the maintenance area, tools, machines, and materials are disorganized. When the vehicles are inspected, the personnel place the parts wherever they see fit, creating a tripping hazard for the workers and increasing maintenance time. In addition, it was detected that the objects are not returned to their respective places after being used, even though there is a shelf to organize the work tools. To avoid this, it is necessary to create a logical sequence of the activities of the process.

It is also proposed to establish the Gemba walk philosophy, in which an employee performs periodic walks in the workplace to observe and keep records of the process times, review the lean aspects, review the standards, and observe the key indicators of the process.

MUDA CHECK

Table 2: 7 wastes of Lean

Wastes	Description
Waiting	Loss of time while waiting for the arrival of material or for the availability of maintenance personnel. maintenance personnel. The supply of tools is slow, so it is possible that some of them are being used by technicians or are in disuse.
Transportation	Unnecessary transfers of the same cars, parts or maintenance personnel do not add value to theservice.
Duplication	More work than necessary, such as performing maintenance services at too short intervals or changing parts that do not yet need to be replaced.
Inventory	In the absence of a safety inventory in the company's warehouse, if any spare part is missing, it will have to be obtained immediately, completely delaying operations.
Motion	Operators often move around the facility sporadically in search of the equipment they need to complete tasks, such as tools or spare parts.
Talent	The company lacks a strategy to capture the inventiveness of its employees. The company's manager usually finds solutions to the problems that arise.
Defects	Performing improper repairs, using low-quality parts, or installing incorrect parts that cause the vehicle to fail and, therefore, require additional repairs.

The workshop has a collector for burned oil; however, for other waste there is no specific place to place the other waste; they use garbage bags. It is suggested to use a container specifically for these toxic materials. Use a suitable, corrosion- resistant container, such as a plastic or metal container, to store burned oil waste without spills, thus avoiding any accidentsor spills in order to avoid any accidents and damage to the environment.

When detecting the moults that influence the process, the most effective measure to improve the process is to eliminate them. This can be achieved by reorganizing the processes, implementing more advanced technologies, optimizing the workflow, reducing waiting times, among other measures.

Once best practices have been identified and moults have been eliminated, work standards can be established to ensure process consistency and quality. It is important that workers are trained in the new processes and work standards. It is also necessary to implement monitoring and control systems to ensure that the process continues to function properly, and that possible future shedding can be detected.

FUTURE VSM

The future state VSM shows how the process will look after implementing the proposed improvements. A waste reduction has been included, thanks to the MUDA Check performed, proposing measures to eliminate or reduce them in the future state. Reduced times in the areas that generate waiting times in the current process, and propose measures to reduce or eliminate them, as well as an improvement in productivity and quality by identifying the areas in which errors or problems are generated and the areas in which rejects, or rework are generated in the current process. A better sequence of the workflow has been proposed to achieve a clear optimization.

Previously there were 6 macro-processes, but by eliminating repetitive operations, unnecessary transfers, rejects, or rework in the current process, a better workflow sequence has been proposed to achieve clear optimization. By eliminating repetitive operations, unnecessary transfers, duplication of activities, inventory errors, idle time, and waste,among others, it was possible to reduce the customer's waiting time when requesting an engine oil change. The changes proposed to improve service productivity are detailed below:

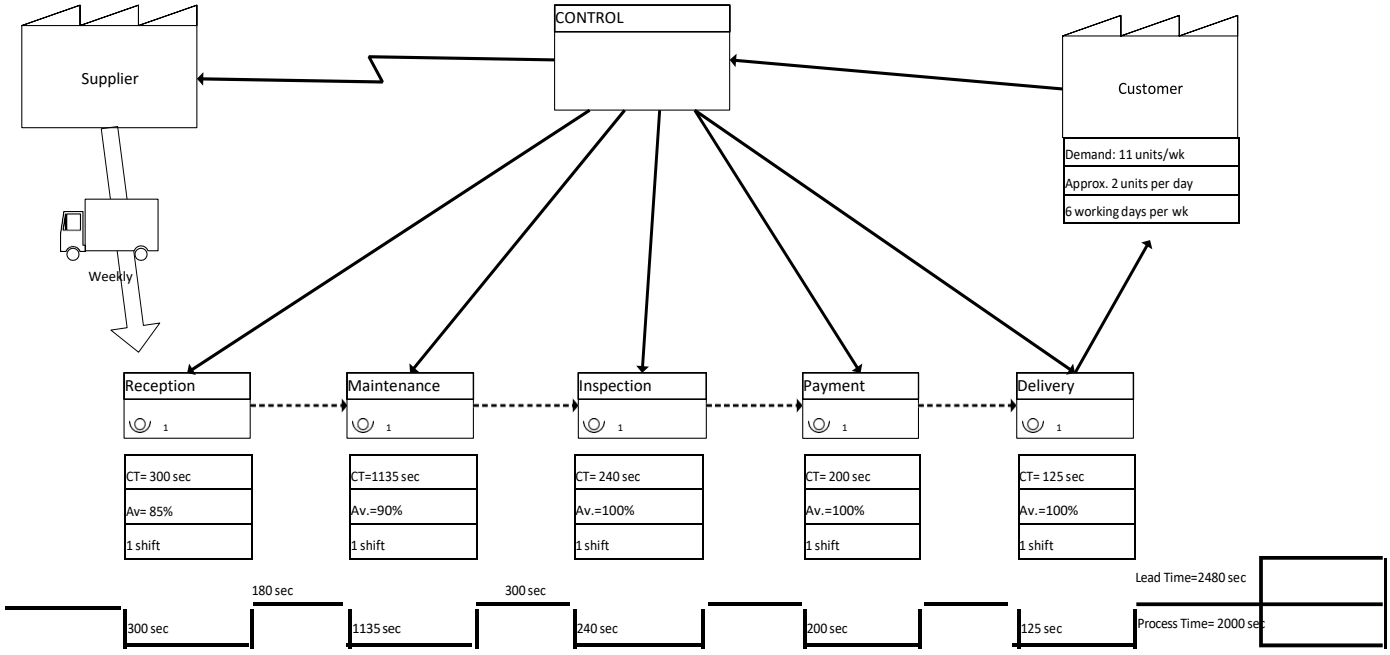

Fig. 6: Future VSM

Vehicle reception: This operation cannot be eliminated; however, it can be improved because the organization must verify the condition in which the vehicle enters the shop. In addition, the workshop manager should assign the work according to the volume of service. To reduce this, organization and planning are necessary; having a well-defined andorganized plan for the reception can help reduce the time it takes to serve customers. For example, having a well- organized reservation system and a checklist for preparing tools and materials before customers arrive. For customers who visit the workshop for the first time and do not have an appointment scheduled, it is important to ask a series of questions at the end of the service that can provide information regarding their satisfaction in the expected time, also mention that for a next visit, you can make an appointment so that the attention is much faster and effective reducing approximately 55% of the time they normally wait.

Simple inspection, diagnosis, and quote: Once the oil change is scheduled, the customer will be able to quote the price of the service through a message or phone call to the workshop, as well as provide details of the car model, type of filter, and the oil he wants for his vehicle in case he has a preference. It was decided to eliminate both operations to reduce these waiting times for the customer.

Maintenance: The operator was asked which activities he considered could be performed in less time, he commented that the installation and uninstallation of the elevator, but this operation cannot be eliminated because, due to health and safety issues at work, the mechanic must ensure that the car is well secured in the elevator and the engine cover. However, 3 activities are eliminated, including one operation and two unnecessary transfers, which are covered by preparing all the necessary tools for the service. The two waits of burn oil were merged with one operation, removing the crankcase tap, because when the mechanic is waiting for the oil to be drained, he can also be performing anotheractivity, either removing the tap or preparing the filter to be installed, and he can even clean his hands with the rag in any case that it has been spilled. There are several operations that are indispensable within the process since they were performed in the correct time, therefore, they were standardized in the same value. It is always recommended that the activities are not carried out with eagerness and that they are performed prudently.

A new activity is integrated at the end of the maintenance, and inspection, the mechanic performs it in two ways, by means of the measuring rod the dipstick, and when starting the vehicle, but this new inspection would be performed after the maintenance has been done so that the management can make sure it is delivering the customer's vehicle in proper conditions,thus avoiding future complaints or claims.

The payment of the service and delivery of the vehicle were standardized as they were in the current situation since normally the customer prefers to pay when the service has been completed and they can see that their vehicle is in good condition, and the keys are handed over so that the customer can leave the workshop.

In the Future VSM, all the proposed improvements were considered, leading to a notable decrease in the oil change, achieving a lead time of 2480 seconds when before it was 4689 seconds, thus increasing productivity by 47.1%; the process time went from 3369 seconds to 2000 seconds, improving by 40.6%. The number of operations was reduced from 22 to 19,from 7 transfers to 4, and one inspection was reduced. The improvement in the reception area was the key to the increase inproductivity, representing a significant time saving, as well as the standardization of the sequence of maintenance steps, alsoallowing the inclusion of activities such as inspections that add value to the service.

D. Validation by time comparison

The research study was facilitated to the management of the automotive workshop, through socialization with the objective of better understanding its operation, organizational culture, processes, and indicators, among other relevant aspects. This type of socialization was carried out in order to obtain valuable information for the research and to enrich the analysis of the results obtained, and an evaluation of the possible suggestions for improvement of the workshop was offered so that it can fulfill its purpose, which is to increase productivity in the workshop. Below is Table 3 as a summary of the before and after.

Table 3: Comparison of the current and improved process.

	Current	Future
Operations	22	19
Inspections	2	1
Transfers	7	4
Process Time	3369 s	2000 s
Lead Time	4689 s	2480 s

Table 3 was discussed in order to be able to state which were the proposals of improvements taken to obtain such data, eliminating 3 operations at the time of providing the service, eliminating the inspections that they made before the process

and establishing a new one for the review of the process carried out, the reduction of transfers by avoiding the operator is moving unnecessarily since 2 of the 4 replacements that remained in the improved state include what is the entry and exit of the vehicle which means that the operator as such only moves 2 times for the collection of the burnt oil.

Turnaround times let us know how long it takes to manage the maintenance of a vehicle. By reducing this metric, both in process time and lead time with 1369 seconds and 2209 seconds, respectively, the company will gain greater flexibility and a better ability to cope with higher demand and thus obtain good customer references. The company is considering taking the suggestions into account, as they do not involve an initial cost, but rather a commitment between the company and its employees to comply with them and thus be able to implement the improvement suggestion and prevent future imperfections within the processes.

4. Conclusion

A diagnosis of the company's current situation was made through which the main activities with opportunities for improvement were identified and analyzed, and those with the greatest negative impact on the productivity of the automotive workshop were selected.

Specific measurements were established in front of the team, aligning the individual objectives with those of the workshop, and achieving the company's 2 KPIs, waiting time at reception which would take 8 minutes, and service time which would be 30 minutes. Understanding the automotive shop's objectives around these KPIs is the best way to achieve success in the service department.

A proposal was made to improve the activities that caused delays in the automotive workshop by using the value flow map and waste detection. Seven activities were reduced within the current analysis carried out by using process diagrams and flowcharts. The duration of the maintenance service has been reduced by 36 minutes difference, identifying a 40.6% improvement in the service and achieving standardization of the process.

The analysis in the use of Lean tools was crucial to help drive a culture of continuous improvement in the work teams and maximize available resources. The times of the productive process of the workshop were analyzed by comparing the state the company was in when the data was collected and how implementing the improvement proposal can significantly benefit the company's success.

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