UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

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Servicio de Post Venta Esbelto: Implementación de Metodología DMAIC en Procesos Post Venta de un Taller Automotriz.

.

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RESUMEN

Con el fin de brindar al cliente la oportunidad de experimentar un servicio postventa diferenciador en la ciudad de Quito, capital de Ecuador; un taller automotriz local presenta el servicio personalizado como una proeza de profesionalismo, cero defectos y calidad. Sin embargo, la mejora de los procesos de posventa a través de la metodología DMAIC no ha sido ampliamente estudiada en la industria. Este artículo examina cómo optimizar los procesos para disminuir el tiempo promedio de servicio del taller y aumentar la agilidad de sus actividades y procesos Se utilizó análisis estadístico para determinar los procesos más relevantes desde el punto de vista del cliente, con el apoyo de la base de datos del Contact Center. Asimismo, se utilizó la metodología circular DMAIC con el apoyo de herramientas Lean. Los principales resultados obtenidos muestran una reducción del tiempo en el proceso de servicio de toda la cadena de postventa, una disminución del desperdicio de insumos y materiales del taller y un aumento de la satisfacción del cliente evidenciado en las llamadas de seguimiento de calidad. Adicionalmente, se aplicó simulación y programación lineal.

Palabras clave: Postventa, Taller automotriz, DMAIC, Lean Six Sigma, Grado Lean.

ABSTRACT

In order to offer the customer the opportunity to experience a differentiating after-sales service in the city of Quito, capital of Ecuador; a local automotive workshop introduces personalized service as a feat of professionalism, zero defects and quality. However, the improvement of lean post-sales processes through the DMAIC methodology has not been widely studied in the industry. This paper examines how to optimize processes in order to decrease the average service time of the workshop and increase the leanness of its activities and processes Statistical analysis was used to determine the most relevant processes from the customer's point of view, with the support of the Contact Center database. Likewise, the circular DMAIC methodology was used with the support of Lean tools. The main results obtained show a reduction in time in the service process of the entire after-sales chain, a decrease in the waste of workshop supplies and / or materials and an increase in customer satisfaction evidenced in quality follow-up calls. Additionally, simulation and linear programming were applied.

Key words: After-sales, Automotive Workshop, DMAIC, Lean Six Sigma, Leanness Degree.

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1. INTRODUCTION

In the automotive industry, specifically in after-sales service, the quality of service makes the difference between the success or failure of the entire firm. Generally, once a customer purchases a car, it will represent a single sale to the dealership. On the contrary, this same customer will return multiple times to the service shop for either corrective or preventive maintenance, so the profit generated by after-sales is greater than that obtained from sales; with the service market being larger than the sales market, generating at least three times the turnover of the original purchase during the product life cycle (Bundschuh and Dezvane 2003).

Arroyo and Buenaño (2017) made an observation on the quality of after-sales service as an opportunity for the automotive sector in Ecuador and concluded that when a vehicle is sold, the brand acquires an ethical obligation and therefore is directly responsible for the customer service process, basing quality in service as a critical variable to increase competitiveness in the market.

Furthermore, nationwide there are 29.068 economic establishments dedicated to automotive trade activities, of which 70% correspond to establishments dedicated to the maintenance and repair of automotive vehicles (Pro Ecuador 2017). In this way, the after-sales service, apart from generating economic sustenance for the country, generates an important number of jobs with around 90.012 people (Arroyo and Buenaño 2017). However, despite significant market share, research on quality and efficient optimization in after sales processes has received less attention compared to efficient manufacturing (Arlinghaus and Knizkov 2020).

Under the above context, the present study was developed in a company dedicated to the provision of maintenance services, repair; and marketing of automotive parts and accessories in the cities of Quito and Santo Domingo, Ecuador. The automotive repair shop is defined as a multi-brand shop catering to the automobile, sport utility vehicle (SUV), VAN and pick-up truck market mainly. In order to manage the quality of the service provided, the contact center conducts a telephone satisfaction survey. In the last year, several complaints have been received related to quality and delay issues, affecting the returnability of the customer to the workshop. Considering the benefits of Lean Service in similar industries, it will be used to achieve the objective of the study.

1.1 Objectives

Although, research has been done considering lean implementations in service industries, this study aims to address the gap between applicability of Lean Service tools based on Lean Six Sigma approach and the optimization of quality process and time through a DMAIC methodology in the context of after sales services, focusing specifically in after-sales maintenance in the automotive industry.

2. LITERATURE REVIEW

The Lean implementation methodology has its roots particularly in the manufacturing automotive sector through Toyota Production System (Monden 2012). Levitt in 1992 was the first author to study the transfer of organizational principles from production lines to services in the article "Production Line Approach to Service", using McDonald's as a clear example that manufacturing operations can be used to improve the design and management of services (Dos et al, 2015; Seddon et al. 2011). Under this premise, in the last decade, the "Lean" methodology was silently expanding beyond manufacturing to become an improvement methodology for service industries (Ahmed et al. 2015), being the publication of the book "Lean Thinking" by Womack and Jones (1996) as a preamble of the Lean philosophy to other sectors different from the industrial one, triggering the first article where the word "Lean Service" was mentioned for the first time (Arango and Rojas, 2017).

Progressively, several Lean Service case studies were taking action, such as the research of Portioli-Staudacher (2014), who implemented Just in Time (JIT) improvement in a financial service company to streamline the banking and insurances processes. The same results were obtained by Rexhepi and Shrestha (2011) in the implementation of Lean tools such as Value Stream Mapping, 5'S, Kanban and red tag techniques for the elimination of waste in the operations of the rheumatology department in Kosovo. The result was the standardization of processes evidenced in the increase of patient's satisfaction and work efficiency in the department (Rexhepi and Shrestha 2011). Dragomir and Surugiu (2012) used the four step-model of Lean Implementation applied to three universities in the United States and the United Kingdom, obtaining results such as budget and cost reductions, elimination of obsolete administrative processes, and increased employee job satisfaction and productivity levels. Flores et al. (2018) used Takt Time and the 6M tool to propose indicators in a Shared Service Center (SSC), additionally stability and capacity studies were held to verify the metrics for each process were reached.

Among most of the literature, it is shown that the implementation of Lean tools has allowed the improvement of process effectiveness in quality, cost and time by standardizing and simplifying activities, reducing time and increasing commitment and job satisfaction. Additionally, Arango and Rojas (2017) conducted a systematic literature review through Scopus in order to identify the contributions made on Lean Service, providing an analysis of the main tools used in Lean Service from the literature reviews of Dos et al. (2015); Gupta et al. (2016) and, Hadid and Afshin Mansouri (2014). Additionally, they analyzed that the main benefits of a Lean

Service implementation lie in the release of personal time; identification and elimination of waste; improvement in capacity, operational efficiency, internal and external customer satisfaction; reduction of cycle times and human errors (Arango and Rojas 2017).

However, despite the steady increase in Lean Services research, the core of the articles focusses on healthcare or education services (Arlinghaus and Knizkov 2020), and very little research has been done on quality improvement in after-sales services using a Lean Thinking approach, despite the deep roots of the lean approach in this sector. One of the few cases that respects the measurement of a lean degree is the study by Overboom et al. (2010) in the logistics service industry. And in the automotive industry, one of the few application cases corresponds to Venkat and Wakeland (2005), who used discrete event simulation to understand and optimize a lean automotive workshop service process obtaining as results the reduction of the average time to appointment, average repair competition and delay in parts delivery. Finally, the simulation allowed to take actions regarding the number of technicians, work bays and the standardization of the scheduling process.

3. METHODOLOGY

The Six Sigma methodology focuses on measuring and improving the quality of processes, which juxtaposed with Lean Service allows eliminating waste, resulting in time and productivity optimization (Jensen et al. 2017). Thus, to analyze the application of Lean Six Sigma in after-sales processes, the DMAIC methodology established as a five-step sequence (Define, Measure, Analyze, Improve and Control) will be used. The motivation for the use of this methodology is due to several successful case studies in services, such as Bargerstock and Richards (2015) case study of DMAIC to Academic Assessment in Higher Education, showing that DMAIC led to organizational improvement recognizing inputs, outputs and feedback loops targeted for continuous process improvement efforts.

The DMAIC methodology resembles Deming's continuous learning and process improvement model PDCA (Plan, Do, Check, Act) and aims to eliminate those non-value-added steps, focus on new measurements and applies technology for continuous improvement (Mohamad et al, 2019), which is directly connected with customer satisfaction. It is important to emphasize, that for the implementation of a Lean Six Sigma project, a more flexible framework on the DMAIC cycle should be established (Villacís and Burneo 2020). The adaptation of the methodology for the present project can be visualized in **Table 1.**

Table 1: DMAIC Methodology adaptation for project execution.

Universal Problem Solving Process	**DMAIC Methodology**	**DMAIC Activities required**	**Deliverable**
Problem	Define	Define Measure Analize	* VOC analysis * SIPOC diagram * Historic information analysis * CTQ tree diagram * Process Flowcharts * Project Charter
	Measure	Measure Analize	* KPI definition from CTQ * Leanness Service Degree * Six Sigma Degree * Analysis of hypotheses tests
Cause	Analize	Analize Measure	*Capability Analysis *Pareto Diagram * Cause and Effect Diagram *Vester Matrix * 5 Why's chart
Solution	Improvement	Improvement Measure Analize (re)Define	* 6'S * Kanban *Andon *TPM * Standardization of processes * Linear programming for assembly line * Discrete event Simulation
	Control	Measure Analize (re)Define	* Kobetsu Kaizen Board * Process Monitoring Plan

The first phase of the Lean Six Sigma framework is the define phase, in which an analysis of customer satisfaction surveys was performed to recognize the voice of the customer (VOC) and identify the substantial customer requirements (Swarnakar and Vinodh 2016). Once these requirements were identified, a Critical to Quality Tree was performed in order to convert customer requirements into metrics and set targets based on historical data analysis. It should be noted that additional tools such as the SIPOC diagram and flowcharts were used to have a more general view of the after-sales process (Swarnakar and Vinodh 2016). To finalize this phase, a Project Charter was drawn up to communicate key project information and objectives to after-sales managers.

The Measure phase of DMAIC, consisted of establishing reliable metrics to help monitoring progress towards the goal (Rahman 2017). Particularly for this project, the Measure phase meant the definition and selection of metrics to clearly identify the Six Sigma and Lean levels that the aftermarket preventive maintenance process possesses. Additionally, historical data analysis was used to measure the process capability based on the processes that add value to the customer.

The Analyze phase was performed in synchrony with the Measure phase, in order to identify the gap between the current performance of the processes and the desired goal (Garza Reyes et al, 2010). For this, data analysis was used, followed by research to determine and understand the root cause of the problems (Breyfogle III, 2001). Several brainstorming sessions with process users were conducted to identify possible causes and even possible future improvements.

Continuing with the Improve phase, all plausible causes identified in the previous phase were taken and improved thanks to the Lean Service perspective. Lean tools such as 5'S, Kanban, Standarization and Poka Yoke were implemented. As complement, linear programming and discrete events simulation were applied during this phase.

Finally, in the control phase new data was collected to measure the implemented improvements, as well as the updated Lean and Sigma grades of the after sales process. In order to establish a control plan, periodic policy meetings were held. According to Swarnakar and Vinodh (2016), it is important that all meetings and improvements are documented, so a Kobetsu Kaizen board was developed to encourage communication and visibility of improvements or new objectives.

It should be noted that during all phases, hypothesis testing was continuously used to determine whether the current metric is statistically significant to the proposed one.

The paper is structured as follows: In Sections 1 and 2, the research design chosen based on a systematic literature review (SLR) and a multi-case study on Lean Service implementation is briefly described. In section 3, the adapted DMAIC methodology to be used considering the case study is described. In section 4, metrics and pre-implementation Lean Six Sigma information about the company and a post-implementation analysis are provided. In section 5, the results obtained considering previous studies will be discussed. Finally, in section 6, it concludes with the main results on the Lean Six Sigma application, and offers recommendations for future research.

4. RESULTS

4.1 Define

This section made an overview of the after-sales maintenance process using SIPOC diagrams (Supplier, Inputs, Process, Outputs and Customers) and flowcharts that enabled the identifying and centralizing of product requirements and process capabilities in relation to project specifications and target customers (Arlinghus and Knizkov, 2020). In the face of this panorama, it was possible to define the scope of the project, which will understand the service in the field, that is, from the time the client enters the workshop until the customer leaves the premises, understanding the activities from "Routing" to "Billing" visualized on **Figure 1.**

Figure 1: Stylized process of maintenance in the automotive workshop.

Obtaining a clear scope of the process to be covered, a customer voice analysis (VOC) was conducted based on satisfaction surveys conducted to customers by telephone in the months of October to December 2020. This analysis was conducted in order to understand customer perceptions, judgments, attitudes, intentions, and behaviors towards the maintenance service provided (Vikas 2017). Of the 373 surveys analyzed, it was obtained that 24.66% of clients submitted any request, complaint or demand. RCDs were subsequently classified into categories to quantify which of them had the greatest impact on customer dissatisfaction (Silva et al. 2009).

A pareto analysis was held, revealing that 80% of customers dissatisfaction was related to delays, inefficient service and bad attention of service customer center. Performing a category analysis for each problem, it was obtained that in the dissatisfaction by "Delay", 26.32% belonged to delays per wash, 23.68% to delays for spare parts, 21.05% to delays in mechanical service, and 28.94% delays related to payment, scheduling and on-site care processes. Similarly, as dissatisfaction with "Inefficient Service", 55% dissatisfaction was obtained for poorly done jobs, 20% for rework (i.e. the customer had to enter the workshop a second time), 10% for process quality, and 10% for the quality of care of the mechanical technician. Finally, of the "Bad attention of service customer center" category, about 56% of customers showed their nonconformity by claiming the staff attitude.

Consolidating the information, it was obtained that customer loyalty to the service of the workshop is summarized in an average Net Promote Score (NPS) of 82% for customers who were served during the months of October to December 2020. When assessing the NPS, following Reichheld, those companies with a positive two-digit NPS are profitable in their growth (Krol et al. 2014). However, to know the extent to which the customer has a positive view of the business, you need to know the results of its direct competitors. A studio carried out by Condor (2020) regarding the development of a complaint management model generated in the after-sales area-workshops of the company CASABACA S.A. in the city of Quito, demonstrated an NPS of 80% for its line of business. Which places the multi-brand workshop of this studio on a highly competitive level.

Compared to the 3 nonconformities listed above, there was a need to decode the customer language (needs, expectations, requirements) into service specifications. CTQs are internals quality parameters that relates customer's needs with technical requirements (Knop 2016). In this way, a CTQ Tree shown on **Figure 2** allowed the general concepts of the VOC to be transferred to metrics and objectives of the automotive workshop based on a base survey.

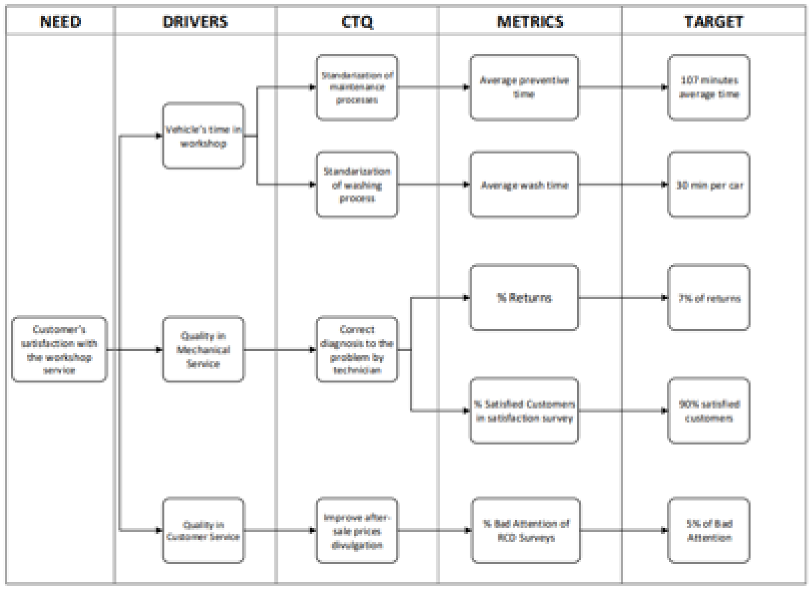

Figure 2: Critical to Quality Tree.

For the baseline of the first drive, vehicle's time in workshop, the workshop's historic database was used, from July to December 2019. In this way, it was obtained that the average time of the preventive maintenance service is 117.09 minutes. In constant communication with the head of the area, it is determined that the standard for preventive maintenance of a vehicle is 100 minutes, i.e. 1 hour with 40 minutes. In view of this, it was established to reduce the average preventive maintenance time to 10 minutes, having a target of 107 minutes (1 hour and 47 minutes). In order to analyze whether 117 minutes are statistically different from the proposed 107 minutes, a hypothesis test was performed in Minitab software, obtaining a p-value of 0.034. This indicated that the proposed objective was statistically significant and justified implementing the corresponding improvements in order to achieve it.

It is identified that the lack of standardization in the washing area has an impact on the driver of the vehicle time in the workshop. Since there was no data for this process, a total of 15 cars were timed up based on **Equation 1.**

$$n = \frac{z_{\alpha/2}^{2} \times \sigma^{2} \times N}{z_{\alpha/2}^{2} \times \sigma^{2} + e^{2}(N-1)}$$

Equation 1: Sample size by means with finite population.

Where, N is the average of vehicles served per month, e the maximum permissible error of cars, $Z\alpha/_2$ will correspond to the deviation of the average value that is accepted based on a level of confidence, and σ^2 ,is the variance of cars per month (Fuentelsaz 2014). Taking into account the number of work orders served in 2019, it is determined that the average number of vehicles (for preventive service) served per month is 199 vehicles, with a permissible error of 5 cars. The level of reliability chosen was 95% since it is the most used in market studies (Aguilar 2005), and the variance corresponds to 10 cars per month.

A random measurement plan was made using Kanban formats throughout February 2021, and a sample of 102 washes was obtained. According to the Lean management philosophy exhibited by Toyota in 1950, Kanban allows you to visualize the workflow and measure the lead time (i.e., the time it takes to finish one item) (McLean and Canham 2018). In this way, a variation of the traditional Kanban tag to a much simpler tag which consisted of a travelling leaf located on the car board was elaborated. Operators were informed that before any washing, the name of the washer, the date and time of start of washing should be registered; and end-of-wash date and time.

As a result, it was obtained that 80.39% of the time the washes were carried out individually, while 19.6% of the process was carried out by two washing machines. Of the time the washing was carried out in a shared way, operator 1 performed 40% external washes (body) and 60% interior washes (inside the car), and of course, operator 2 performed 60% outdoor washes and 40% interior washes.

As for the average washing time, it was obtained that the average washing with a single operator is 35.26 minutes, while the average washing time between two washers was 33.75.

In the face of the obvious lack of standardization and balancing of work in the washing process, it was established to achieve a target of 30 minutes per wash (according to competitive market standards). Since it was questioned whether the existence of 2 washers, instead of 1, was justified, "t-tests" were performed. Minitab resulted in a significant difference between the average time of a single washer with the 30-minute goal. However, the average time between two washers is not significantly different from the target 30 minutes. Still, since the process is not standardized, and if there is a significant difference between 35 and 30, the existence of 2 washers is justified and it is proposed to improve the process through line balancing.

Finally, as for the drives of "Quality in Mechanical Service" and "Quality in Customer Service", the satisfaction survey results outlined above were used, and together with service headquarters goals were agreed to reduce the percentage of rework from 20% to 7%, reduce the percentage of complaints for bad care from 20% to 5%, and increase the percentage of satisfied customers from 75% to 90%.

The information raised and projected was presented to Management through a Project Charter in order to transform the facts and agreements of the after-sales maintenance service to a documented project management approach and provide a baseline on which to base decisions on this project (Kusay-Merkle 2018).

4.2 Measure

In order to follow lean implementations, a base line for leanness degree developed by Amrani et al. (2016) and adapted by Villacís and Burneo (2020) was measured. Amrani et al.

raised for the first time in 2016 a key indicator to measure how lean a company is, this would be presented as a Leanness degree applied to aeronautical manufacturing companies. Following the same line, in 2020, Villacís and Burneo defined a mathematical approach to evaluate the three parameters of the Amrani Leanness degree: structural, organizational and implication grades. In addition to literature, a new mathematical definition of Leanness degree will be considered taking into account critical factors based on a lean literature review and analysis.

Over the years, a large number of definitions, tools and practices somehow related to the idea of lean approach. On the attempt to develop a leanness degree for logistic serviced in Overboom's et al. study (2010), it was stated that the lean philosophy can be summarized into bundles (Shan and Ward 2003), and based on quantitative analysis of literature, there were distinguished four internal-oriented bundles: Just-In-Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and, Human Resource Management (HRM); and two external-oriented bundles: Supplier Communication Management (SCM) and Customer Involvement (CI) (Overboom et al. 2010).

For their part, Vujica and Tonchia in 2014 conducted a study to determine a target instrument to measure the degree of lean implementation in manufacturing. Of 59 lean variables analyzed in studies and expert's questionnaires, 24 variables were built and tested statically using Cronbach's alpha test. These 24 variables solve lean issue such as: the value concept+customers, value stream mapping, Pull/Kanban + Flow, Waste elimination, Productive Maintenance, Just in Time, Employee involvement and Development of excellent (lean) suppliers.

Based on these two studies, it was decided to apply the variables identified by Vujica and Tonchia (2014) and classify them into the lean bundles acknowledged by Overboom et al. (2010).

It should be emphasized that the previous authors focused their work on Lean Manufacturing, so the additional goal of the degree read to develop will be to focus it on the needs of Lean Service.

In this way, the variables for measuring a leanness service degree in the automotive workshop are summarized in **Table 2.**

Table 2: Leanness degree for automotive workshop.

Lean Bundle (Overboom et al. 2010)	Lean Variable (Vujica and Tonchia 2014)	Lean service variable to the workshop	Mathematical approach
Customer Interaction (CI)	Value Concept + customers	Percentage of Customer satisfaction	$\frac{\sum_{n=1}^{1} N^{o}\ olf\ satisfied\ customers}{Total\ of\ attended\ customers} \times 100$
Total Preventive Maintenance (TPM) and Just in Time (JIT)	VSM	Cost reduction and Waste evidence	$Value\ Stream\ Ratio = \frac{Value\ Added\ Time}{Total\ lead\ time} \times 100$
	Pull/ Kanban + Flow	Customer involvement during service process	$Customer\ follow-up = \frac{\sum_{n=1}^{1} N^{o}\ of\ contacted\ customers\ during\ service}{Total\ of\ attended\ customers} \times 100$
		Flexible response in customer's demands	
		Standarization of the service	Takt time + Work sequence+ Standard process stock =100%
	Waste Elimination	Inventory management	$\frac{\sum_{n=1}^{i} Entered\ cars\ delivered\ the\ same\ i\ day}{Total\ of\ vehicles\ entered\ on\ i\ day} \times 100$
		Capacity utilization	$\%Calendar\ utilization \times \%Avg.Shop\ Proficiency \times hours\ per\ station\ per\ week \times weeks\ per\ year$
Total Quality Management (TQM)	Productive Maintenance	Effectiveness of the Service	$OSE = Quality \times Performance \times Availability$
		First Pass Quality	
Human Resource Management (HRM)	Employee Involvement	Employee cooperation	$MfWR = \frac{\sum_{n=1}^{n}(N^{o}\ processes\ each\ worker\ mastered)}{Total\ N^{o}\ processes\ workshop \times n} \times 100$
		Team Working	
Supplier Communication Management (SCM)	Development of Excellent (lean) Suppliers	On time deliveries by suppliers	**Spare parts:** $\frac{\sum_{n=1}^{n}(N^{o}\ of\ purchase\ orders\ fullfiled\ on\ time\ and\ in\ full}{Total\ N^{o}\ of\ pruchase\ orders\ placed} \times 100$
			Third parties works: $\frac{\sum_{n=1}^{n}(N^{o}\ of\ purchase\ orders\ fullfiled\ on\ time\ and\ in\ full}{Total\ N^{o}\ of\ pruchase\ orders\ placed} \times 100$

The leanness service degree will be understood as the product of the 5 lean bundles. A lean degree was calculated for both the service process (preventive maintenance) and washing.

4.2.1. Percentage of customer satisfaction.

According to Yang (2010), customer value is reflected not only in monetary redrawing towards service, but by customer loyalty and satisfaction after service is complete. In this way, it is proposed to calculate the customer involvement through the percentage of satisfaction obtained from the quality surveys. Therefore, the percentage of customer involvement will be measured as the number of customers satisfied with the service over the total number of customers who required the service. For this study a 75% of customer satisfaction was measured.

4.2.2. Cost reduction and Waste evidence.

The elimination of waste is central to lean approach (Vijuca and Tonchia 2014). For the service context the main waste is time; firstly, because the customer pays according to the service time and second because each unit of time spent in the workshop affects not only the installed capacity of the latter but also in the customer's perception about the speed of attention of their vehicle, which lies in the satisfaction of the same (Guardia 2017).

Therefore, the value stream ratio formula will be used to measure this variable, which will measure the total process value added time on the total lead time of the service (from when the vehicle enters the workshop until it is trained to the customer). The data collection was achieved through an operations analysis diagram.

$$Value\ Stream\ Ratio = \frac{188\ min}{196\ min} \times 100 = 96\%$$

Equation 2: Process Cycle Efficiency for maintenance service.

4.2.3. Customer involvement and Flexible response to customer's demands.

Taking Wu's definition (2003) about frequent close contact with customers during a process, this variable is determined by taking the customer number they reported not having had some follow-up time on the total number of customers who entered the workshop. This result will give the total number of un tracked customers, so a unit will be subtracted from that percentage to get the reverse, that is, the total number of customers contacted during the service. The data was obtained from the satisfaction surveys. Applying the above:

$$Customer\ follow\ up_{SERVICE-WASHED} = 1 - \left(\frac{2}{373} \times 100\right) = 99.46\%$$

Equation 3: Percentage of customer follow up according to satisfaction surveys.

4.2.4. Standardization.

To measure this variable, it was decided to code in a dichotomous way, and if the process is standardized means 100%, while the opposite will be 1%. In order to specify, whether the process is standardized or not, a checklist was performed based on the terminus for a process is considered standardized. According to Fin et al. (2017) if the process has a takt time, work sequence and standardized inventory (minimum quantity of work in progress) then the process is considered standardized. It should be emphasized that the process must meet all the requirements to achieve the complete qualification, partial compliance with the requirements will involve 1% in standardization. The service maintenance process had 3 of the requirements obtaining a 100% rating. On the other hand, the washing process had none of the requirements, so a rating of 1% was reached.

4.2.5. Inventory Management.

Taking the definition of Work in Progress (WIP), the service inventory would be the number of vehicles in the workshop, either vehicles that are in process (service) or those that are waiting to be removed and/or stranded (Dahlgaard and Mi Dahlgaard-Park 2006). In order to determine inventory management, ideally in the workshop all vehicles entered on day (i) should be delivered at the end of the day, in order to reduce inventory therein, this will calculate this variable by dividing the number of vehicles delivered on average on the day over the total vehicles entered on average that day. It should be noted that the data correspond to the total cars delivered per day on average per month.

$$Inventory\ management_{SERVICE/WASHED} = \frac{106}{127} \times 100 = 83\%$$

Equation 5: Percentage of inventory management.

4.2.6. Capacity Utilization.

For the Total Quality Management methodology as the quality of process control (Taylor and Brunt, 2001) it means the total use of the capacity of the workshop, as the main key to avoid bottlenecks (JIT) and maximize the number of jobs that can be completed profitably each day. Under this context and following Kirley et al. methodology of measurement (2002), in which the percentage of proficiency is heated by dividing the total flat rate hours produced over the total clock hours available. The calendar utilization by dividing the actual days worked monthly by days available (open) per month should also be calculated. With these calculations, and taking into account the number of technicians, hours per box work a week and weeks per year, you get the sop production capacity hours. This result was divided for the ideal production capacity (i.e.

assuming a calendar utilization of 100% a 100% Average proficiency to obtain the percentage of capacity over ideal). The same was done for the washing process.

Table 3: Capacity Utilization calculation for automotive workshop.

	Total Flat Rate Hours Produced	**/**	**Total Clock Hours Available**	**Total Shop Proficiency Percentage**
SERVICE	$\frac{5000\ hours\ billed\ per\ month}{\$34/man\ hour} = 147$	/	176	92%
WASHING	$\frac{699\ hours\ billed\ per\ month}{\$5.19/man\ hour} = 134$	/	176	84%
	Actual Days Worked Monthly	**/**	**Days Available (Open) per month**	**Total Calendar Utilization Percentage**
SERVICE	98 (5 technicians)	/	120	82%
WASWHING	26 (2 washers)	/	48	82%

$$\boldsymbol{Ideal\ Service\ production\ capacity\ in\ hours} = 5\ operators \times 44\ hours\ per\ bay\ per\ week \times 52\ weeks\ per\ year \times 100\%\ calendar\ utilization \times 100\%\ avg.proficiency = \mathbf{11.440\ hours}$$

$$\boldsymbol{Real\ Service\ production\ capacity\ in\ hours} = 5\ operators \times 44\ hours\ per\ bay\ per\ week \times 52\ weeks\ per\ year \times 80\%\ calendar\ utilization \times 84\%\ avg.proficiency = \boldsymbol{7.806\ hours}$$

Equation 6: Service Capacity Production in Hours per year.

$$\boldsymbol{Ideal\ Washing\ production\ capacity\ in\ hours} = 2\ operators \times 44\ hours\ per\ bay\ per\ week \times 52\ weeks\ per\ year \times 100\%\ calendar\ utilization \times 100\%\ avg.proficiency = \mathbf{4.576\ hours}$$

$$\boldsymbol{Ideal\ Washing\ production\ capacity\ in\ hours} = 2\ operators \times 44\ hours\ per\ bay\ per\ week \times 52\ weeks\ per\ year \times 50\%\ calendar\ utilization \times 84\%\ avg.proficiency = \boldsymbol{2.086\ hours}$$

Equation 7: Washing Capacity Production in Hours per year.

4.2.7. Total preventive maintenance.

Berhan (2016) in his style for measuring the effectiveness of Urban Public Transport used the Overall Service Effectiveness (OEE) metric applied to the service under the Overall Service Effectiveness (OSE) analogy. In this way, all the parameters of the OEE are extended to the OSE, and, adapted to the automotive workshop, the following equations are available:

$$Availability = \frac{Planned\ Preventive\ Service\ Time\ Available - Lost\ Service\ Time}{Total\ time\ Available}$$

$$Performance = \frac{N^{o}\ of\ cars\ attended}{Target\ N^{o}\ of\ cars\ to\ be\ attended}$$

$$Quality = \frac{N^{o}\ of\ cars\ attended - N^{o}\ of\ dissatisfied\ clients}{Total\ N^{o}\ of\ cars\ attended}$$

Equation 8: Equations applied to OSE.

4.2.8. Employee cooperation and team working.

In order to establish autonomous problem-solving teams and establish multifunctional training and development for Lean Human Resource Management (Deppe 1994); It was decided to use the Multifunctional Worker Rate indicator exposed by Monden in his book Toyota Production System (2012). In equation 9, n represents the total number of workers in the processes.

$$MfWR_{SERVICE} = \frac{6+6+6+6+6}{9 \times 5} = 67\%$$

$$MfWR_{WASHING} = \frac{1+1}{9 \times 2} = 11\%$$

Equation 9: Multifunctional Worker Rate for service and washing processes.

4.2.9. On time deliveries by suppliers.

Part of an effective lean grade is the supplier communication management, so that the entire supply chain has a zero-defect and waste approach (Overboom et al. 2010). Therefore, the main suppliers of the workshop are those of spare parts and labor by third parties. It is determined to calculate this variable by summing orders completed on time and in its entirety on the number of orders placed to the vendor.

4.2.10. Leanness Degree results.

The results of the lean grade for the automotive workshop in terms of preventive maintenance service processes and washing process are shown in the following table:

Table 4: Results for Leanness Service Degree for automotive workshop.

	Percentage
Customer Interaction	75%
Total Preventive Maintenance and Just in Time	22%
Total Quality Management	39%
Human Resource Management	39%
Supplier Communication Management	90%
TOTAL	**2%**

The leanness degree for the automotive workshop's after-sales service and washing processes is 2%.

According to a comparative study of world-class Japanese firms, Koenigsaecker (2012) suggests an added value of lean manufacturing operations of 90%. However, an average of 40% lean implementation was achieved in the qualitative study by Overboom et al. (2010) based on the questionnaire desalted by Shad and Ward (2007), evaluated to two logistics services companies. Therefore, the current lean degree is poor, so it is expected that with the implementations, an increase of 10% of the current lean service grade will be reached.

4.3 Analyze

Considering that most of the dissatisfied expectations demonstrated in the initial pareto corresponded to 43% delays, it was decided to analyze the capacity of both processes in Minitab software. For the washing process, the upper specification limit was set to the standard 107 minutes for preventive maintenance and as a result a negative process capacity index (Cpk) of -0.04 was obtained (Burdick et al 2018). This designates that the process mean is outside the specification limits by labeling the process as incapable as seen on **Figure 3**. Similarly, the washing process resulted with a negative Cpk of -0.01 indicating that the process mean is outside the specification limits and is therefore not capable. Similarly, the magnitude of the Cp was obtained to be greater than Cpk, indicating that the process is decentralized.

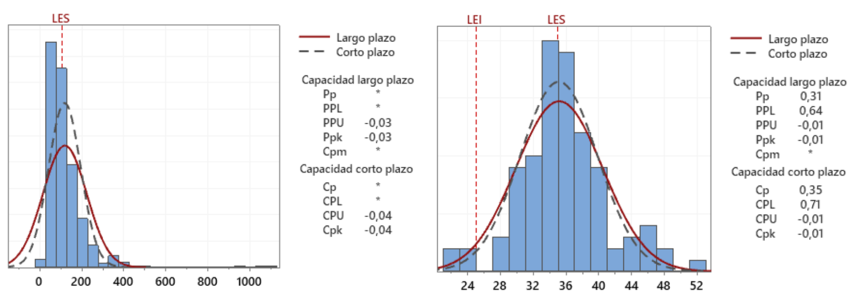

Figure 3: Capability Analysis for preventive maintenance service (left) and washing processes (right).

Since the capacity of both processes are inefficient, a 6M cause-and-effect diagram was made to understand the root causes of such service and washing delays. **Figure 4** shows the mentioned diagram.

Figure 4: Cause and Effect Diagram for delays in washing process.

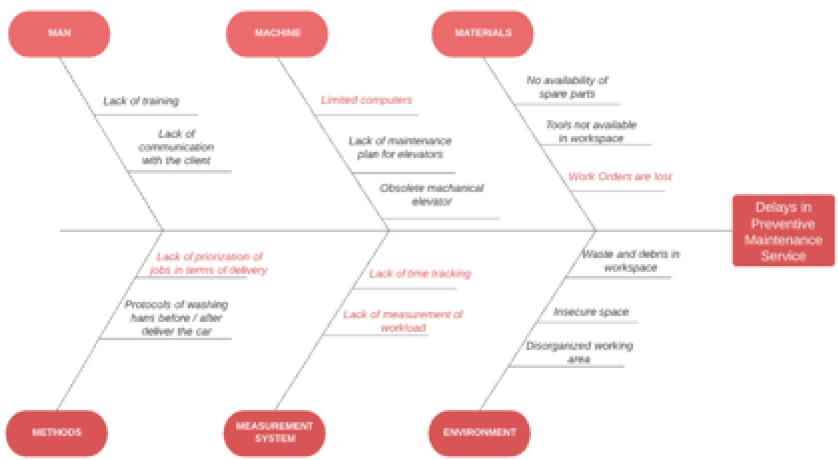

Figure 5: Cause and Effect Diagram for delays in preventive maintenance service.

Likewise, it was necessary to analyze the quality driver in mechanical service since it is part of the vital causes for customer dissatisfaction. On the other hand, the quality driver in customer service was not carried out since the main causes could be identified in the Define phase, thanks to feedback from the customers themselves.

Figure 6: Cause and Effect Diagram for driver quality in customer service.

Since several causes were related to each other, it was decided to use the Vester Matrix to prioritize problems based on the effects they can have (Cruz et al. 2015). The Vester Matrix objectively evaluates each cause based on the influence and dependency parameters with qualification criteria:

- 0: Nor cause it
- 1: indirectly causes it or has a very weak causal link
- 2: It causes it semi-directly or has an average causal link
- 3: Causes it directly or has a strong causal link

Critical causes based on the Vester Matrix were highlighted in red on **Figure 4** and **Figure 5.** Additionally, through an analysis of the 5 Why's, it was possible to show that most of the causes for inefficiency in the quality of mechanical service visualized in **Figure 6** were the same that led to delays in the process. By ender, improving the delays of the mechanical service will mean improving the quality of the service itself. Most root causes focused on the lack of process standardization, limited layout, lack of training and lack of importance from management.

4.4 Improve

4.4.1. Total productive maintenance.

One of the causes that contributed to the inefficiency of the process is the limitation of computers of mechanical technicians, therefore, of the 5 computers in the workshop only 1 was operating during the development of this project. Therefore, once these computers were repaired, it was proposed to install software that would serve as preventive maintenance for computers (Strasser 2004). *Crystal Disk Info* is a free software designed to monitor the health of the PC's hard drive, additionally, it uses support of S.M.A.R.T technology, which helps to detector and prevent future disk errors (Rosso 2018). In this way, technicians were trained on the handling of the Andon software and format. Thus, weekly each technician must run the program in order to monitor the health and temperature status of the computer, and such information should be recorded, in a weekly basis, in the Andon format shown in **Figure 7**. According to Kaur et al. improvements like this focuses upon the significant contributions of TQM organizational initiatives like quality related queries; top level support and level of total employee involvement; culture of continuous improvement (2013).

COMPUTER W1001						
Brand:		SAMSUNG				
Model:		DP300A2A				
Serial Nº		SS0R227340Z1				
Location:		Parent Workshop				
Last repair:		__/__/__				
MONTH:						
		W1	**W2**	**W3**	**W4**	**W5**
C:	**Wealth:**					
	Temp:					
D:	**Wealth:**					
	Temp:					

Figure 7: Andon TPM for Service Maintenance Computers.

Following the TPM improvement, nonconformity and deficiencies have been expressed in the washing process due to the absence of the water washer. In this way, a Preventive Maintenance

Program for the Hydrowasher has been developed, which consists of an autonome maintenance of daily parts, and preventive maintenance with monthly, semester or quarterly frequency depending on the item. Washers will be trained to perform such maintenance and will be responsible for filling out the Andon format in **Figure 8**, in terms of preventive maintenance.

PRESSURE WASHER HD760	
Brand:	BTA
Model:	HD760
Serial N°	841044.2
Location:	Parent Workshop
Date arrival:	1/4/2021

LAST MAINT:

JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC

NEXT MAINT: ___ /___ /___

Figure 8: Andon TPM for Pressure Washer.

These improvements will allow the efficient use of equipment and the elimination of waste from: waiting for an available computer to perform the mechanical service (5 minutes), and preparing a pressure washer (5 minutes) for vehicle cleaning.

4.4.2. Kanban board.

Because there is no traceability of work orders, issues such as lack of time tracking lack of measurement of workload and lack of priorization of jobs in terms of delivery occur. Currently in the automotive workshop there is a control table of operating times, with a box per technician to place work orders. Similarly, it has two educational boxes to place stopped jobs and ready-to-deliver jobs. It could be seen that the board had a Kanban purpose to speed up the service and physically observe the operation (Serna 2015). In the face of the underutilization of the board, it has been established to improve it through a Kanban System extended to the entire after-sales service including spare parts. Taking as an illustration the use of Kanban boards for the classification / organization of medical appointments and surgeries of the study in Lean hospitals of Graban (2016), the Kanban board visualized on **Figure 9** was presented. It demonstrates the traceability of appointments by preventive maintenance service; hence the work can be assigned efficiently to the technicians on the schedule board. Above all, work orders will be placed in lockers and relocated by each technician once each process is finished until the vehicle is checked in and delivered. Red delays are coded, either because the car needs corrective maintenance, or is waiting for spare parts or jobs by third parties.

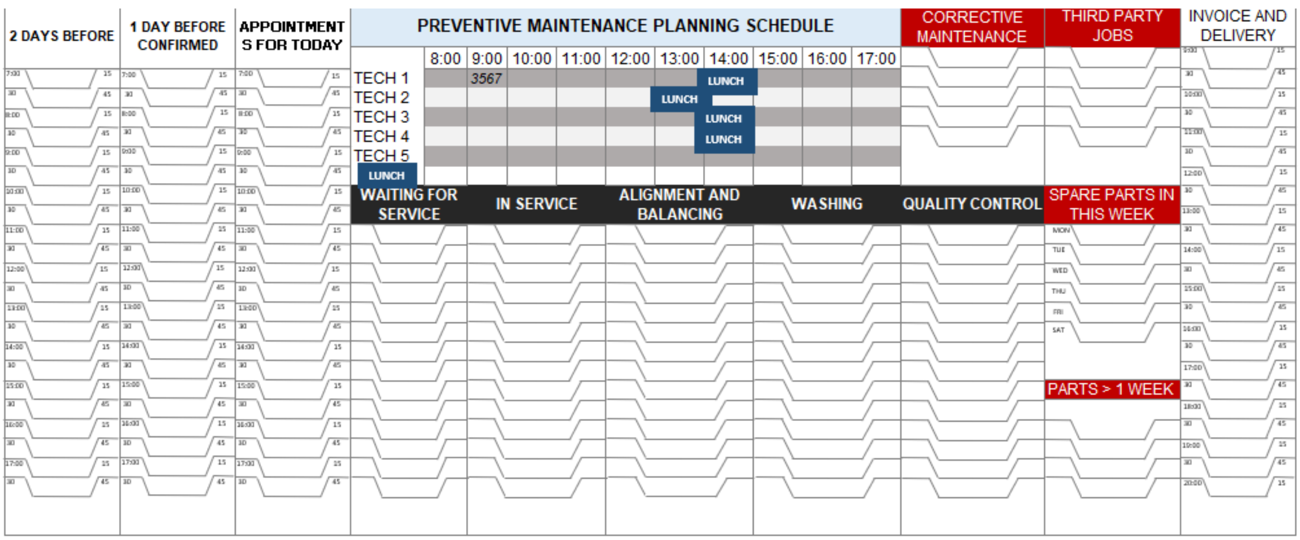

Figure 9: Aftersales Kanban board upgrade proposal.

4.4.4. 6'S.

In order to apply quality in the process and eliminate waste of movements and delays of workers, it was decided to apply the 5'S methodology following Monden's 5'S steps in his book Toyota Production System (2012). Juxtaposed to the above, it was decided to conduct a 19-question audit as a modification of the 50-question questionnaire developed by Hoo (1999) for the context of the workshop. In the course of the development of the questionnaire, the need to evaluate standards according to the security (Shunkan) was seen and a sixth "S" was included in the evaluation.

It should be emphasized that all 6'S was implemented for both the service area and the washing area. During the sort phase, necessary things were separated from the unnecessary ones. The most common tools were placed prioritized to stay in the jobs of technicians or washers as seen on **Figure 10, Figure 11, Figure 12,** and **Figure 13**. As part of the Set in Order process, carts that were underutilized in the workshop were used, so that the implements could be placed in an orderly and easy-to-reach manner. For Safety phase, signs were placed indicating the toxicity of the materials, as well as snapshots diagrams of how the operator should work when operating with oils or derivatives (i.e**. Figure 14**). In order to improve Shine, Standarization and Sustain activities was instructed to the technical cleaning policies so at the end of the working day, it is obligatory for the technician to apply the 5'S and leave his workplace in order.

Once the 6'S was implemented, the audit was performed again and a 159% improvement was obtained for the service area and a 176% improvement for the washing area.

Figure 10: 6'S Implementation Results in Service.

Figure 11: 6'S Implementation Results in Service.

Figure 12: 6'S Implementation Results in Washing Process.

Figure 13: 6'S Implementation Results in Washing Process.

Figure 14: 6’S Security Implementation Results in Service4.4.5. Linear programming for assembly line.

As discussed in the measurement phase, it was determined that the washing process received a score of 1% in terms of the standardization variables, affecting the lean rating of its category. In this way, it has been established to standardize the process by assigning process activities to the 2 operators. Thus, in order to have a lean, efficient and balanced process, it has been decided to use the balancing of production lines applied to the context of the service. Tompkins et al. (2011) highlights the measurement of activities between departments as one of the most important factors for the efficiency and disposition of the departments of a plant. Therefore, using the example of Ford's cell assembly lines, a mathematical model applied to the washing context has been made, which will assign the process activities to operator k in order to minimize the associated costs (which in this case will be the times). In other words, the mathematical model presents a linear programming model that seeks to minimize, at the same time, the number of operators (stations), the cycle time and the penalties associated with assigning more operators than planned (Orejuela and Flórez 2019). For the development and analysis of the case, the following main assumptions were taken into account:

- 27 washing operations were identified
- The maximum number of stations allowed will be 2 (number of operators).
- The cycle time will be considered as the 30 minutes set as a goal.
- The precedence of the activities should be taken into account to model a real and possible sequence.

In this way, the generalization of the problem is summarized in the following equations:

$$x_{ik} = \begin{cases} 1 \; if \; task \; j \in T \; is \; asign \; to \; the \; operator \; k \in E \\ 0 \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad other \; way \end{cases}$$

$$Min \; \# \; workers = \sum_{j \in T} \sum_{k \in E} c_{jk} x_{jk}$$

Equation 10: Objective function.

In manufacturing, the objective function is to minimize the number of stations, however in this case it will be to minimize the number of workers, where c_{jk} is the cost associated with assigning tasks *j* to more operators *k*.

The restrictions are as follows:

$$\sum_{k \in E} x_{jk} = 1 \qquad \forall j \in T$$

Equation 11: Every task must be assigned.

$$\sum_{j \in T} x_{jk} \leq C \qquad \forall k \in E$$

Equation 12: Cycle time C must not be exceeded.

As explained above, it is necessary to be able to respect the precedence of the activities since the workflow is under a synchronized line concept (Tompkins et al. 2011). Therefore, a precedence diagram with color code per washer was carried out as seen on **Figure 15** In this way, a source restriction is used to respect the flow of activities.

$$x_{jk} \leq \sum_{n \epsilon E | n \leq k} x_{in} \quad \forall k \epsilon E, j \; in \; T, i \epsilon P_j$$

Equation 13: Respect precedence of tasks.

$$x_{jk} \quad \forall j \epsilon T, k \epsilon E$$

Equation 14: Binary variables.

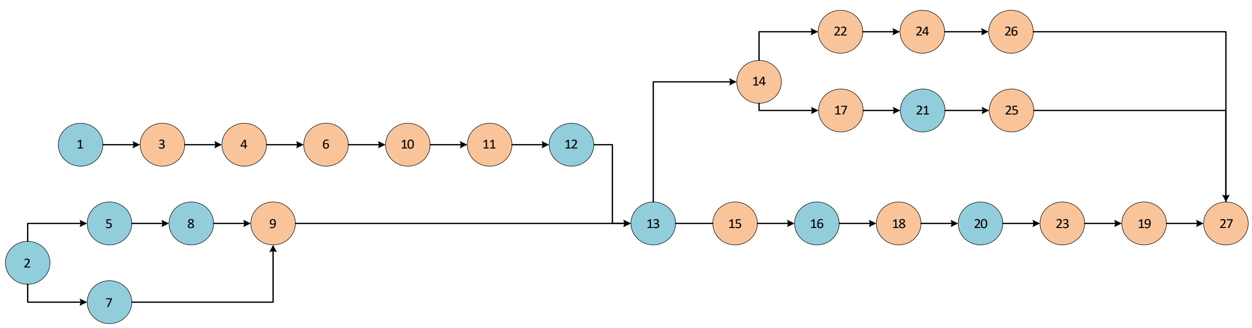

Figure 15: Precedence diagram washing process (Blue-operator 1, Orange- Operator 2).

With the help of the AMPL software, the generalized mathematical notation of the problem was compiled, together with the time data collected for each activity. As a result, the 27 operations were assigned to each operator, results can be seen in **Table 5.** The numberings of the operations in blue correspond to activities in the drying area, and those in orange color correspond to the drying area.

Table 5: Results of assigning tasks to each scrubber.

	ACTIVITY	MINUTES	OPERATOR
1	Open the hood	0,1	1
2	Wet the car	2,1	1
3	Wet surface of engine	0,1	2

4	Apply soap to the surface of the engine and the inside of the bonnet	0,5	2
5	Apply soap on car	2,1	1
6	Rinse off motor soap	0,5	2
7	Apply soap to tires	0,6	1
8	Rinse soap from car	2,1	1
9	Rinse soap from tires	0,2	2
10	Blow compressed air to the surface of the engine	0,4	2
11	Remove excess water from the entire surface of the engine and internal part of the hood with a rag	0,3	2
12	Spray degreaser on the entire surface of the engine and internal part of the hood	0,1	1
13	Move the car to drying area	0,1	1
14	Remove excess water from the car with brush	0,6	2
15	Remove seat carpets	0,3	2
16	Blow compressed air to the car interior	2,3	1
17	Dry car with drying frannel	6,0	2
18	Vacuum seat carpets	0,7	2
19	Lay seat carpets in place	0,7	2
20	Vacuum interior of car	5,3	1
21	Polish windows	2,2	1
22	Dry tire rims with drying frannel	1,1	2
23	Interior cleaning (panels-cup holders-steering wheel-doors) with frannel	2,0	2
24	Apply tire shine	0,7	2
25	Polish car with drying frannel	1,1	2
26	Place car shine on lower plastic edges of the car	0,8	2
27	Drive car outside the drying area	1,0	2

4.4.6. Discrete Event Simulation.

Due to resource limitations, it has been decided to perform a discrete event simulation to evaluate the optimal assignment of tasks obtained from the linear programming above. Discrete event simulation is an analysis tool that supports decision-making related to production and operations planning (Nevins et al. 1998).

In **Figure 16**, a screenshot of the implementation in the FlexSim software can be visualized. As a result, a decrease in the washing time from 33 minutes to 24 minutes and a maximum use of the operator was obtained, demonstrating that both operators are balanced in terms of the allocation of times and activities as seen on **Figure 17**. As well as delays were reduced, car-trolley resources were placed in the simulation, in order to reduce movements in such a way that the operators have the washing supplies at hand.

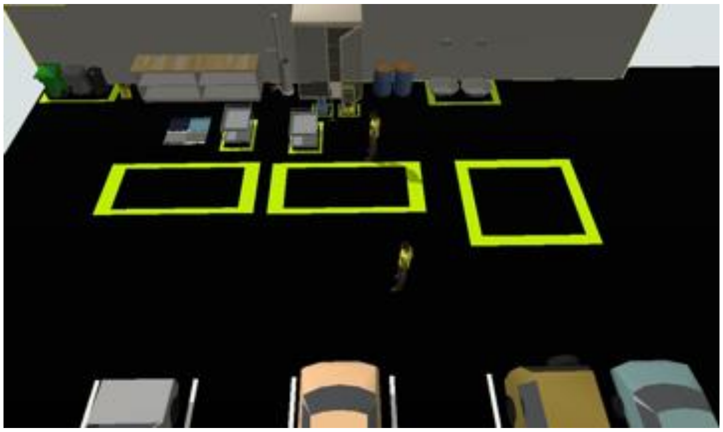

Figure 16: FlexSim Simulation of washing process.

Figure 17: Statistics Collector of washing process dashboards.

4.4.6. Cost of Improvements.

Aguilera (2017) indicates that to establish correct decision-making when improving a process, it is necessary to present the associated costs and, where possible, emphasize a cost-benefit corresponding to each course of action. In **Table 6** the quotes for each improvement proposal are indicated.

Table 6: Detail of the cost of the improvements.

Detail	Quantity	Unit Value	Total Value
Andon TPM Tag	6	$3	$18
After-Sales Kanban Board	1	$200	$200
Kobetsu Kaizen Board	1	$80	$80
Wall Digital Led Clock for washing area	1	$30	$30
Car-trolley for washing processes	2	$40	$80
			$403

4.4 Control

Due to the scope of the project, the control phase will not be carried out in depth. However, future work plans have been established that will include measuring improvements after 2 months. It has been decided to document the process through process manuals that allow the dissemination of information. In addition, ongoing training is planned for all after-sales personnel on the Lean Six Sigma philosophy.

Since Lean Six Sigma focuses on continuous improvement, Kaizen events will be held every time a problem arises, or periodically, depending on the objectives and / or needs of the after-sales area (Glover et al. 2011). To this end, a Kobetsu Kaizen Board has been held as seen in **Figure 18**. Kobetsu Kaizen was chosen since it is defined as a TPM methodology that allows guiding the proposed improvements towards a vision of reducing or eliminating losses (Varhan 2014); which perfectly suits with the present lean approach project. This methodology implemented on a blackboard will allow a better visibility of the improvements, as well as a high involvement of the members of the organization in the improvement projects.

Figure 18: Kobetsu Kaizen Board proposal.

5. DISCUSSION

The results of this invention allowed to demonstrate the Lean Six Sigma implementation in an after-sales service of an automotive workshop. It is important to emphasize that since the publication of the lean production thesis (Womack et al. 1990), interest in the concept of thinness has grown and the notions of agility and responsiveness have evolved even more.

Leanness Degree provides an effective lean definition and a commitment from top management to achieve effective process improvement (Swarnakar and Vinodh 2016). However, there is quite a stark gap between investigations for a lean degree for manufacturing and a lean degree for services.

As Overboom et al. (2010), many of the methods or variables to measure a lean degree were specifically adapted to the manufacturing environment. In this way, and with the motivation to reduce this gap in literature, a mathematically measurable and objective lean degree was developed, since most of the measures to measure the lean grade are based on qualitative surveys, stories such as the well-known original tool to measure the lean grade. in manufacture by Shah and Ward (2007). By using “Lean Bundles” (Overboom et al. 2010) and the main lean variables based on a systematic literature review (Vijuca and Tonchia 2014), a lean grade was tropicalized for the context of a service. Even though the results were disappointing for a current 2% read grade; It should be taken into account that the product of the same generates said result. Now if a lean grade that multiplies all the bundles were not used, but rather an average was made, a more visually favorable result would be due. However, it was decided to use the product due to the suggestion of the lean grade of Amrani et al. (2016).

With the improvements implemented, it was possible to reach a Lean degree of 13%, which represents an increase of more than 100% for the base leanness service degree. Given that there is no literary evidence that indicates a limit or standard to be met on the lean result obtained, the same study by Overboom et al. (2010), was taken as a reference, who obtained a leanness degree of 40% on average for the study of two logistics service companies. On the other hand, in manufacturing, a lean degree of 90% is desired based on the added value of the process operations according to Koenigsaecker (2012).

Finally, the leanness service degree developed in this paper can be used as a key performance indicator to measure how lean a company is set in the context of service.

6. CONCLUSIONS

The context of this paper was set in a highly competitive economic sector in Ecuador, automotive industry, where after-sales services such as maintenance and repair are becoming increasingly crucial for local service firms. Despite the crucial importance of quality in after-sales service, productivity and lean measures severely lag behind those achieved in manufacturing investigations (Resta et al. 2015).

The gap in literature between the leanness degree implementations in manufacturing firms against service firms is surprising, giving the growing practical relevance of lean methodology. In this paper, it was aimed to achieve an objective and mathematical measure of the lean degree of a service. Thus, the calculation of a leanness service degree of 2% was successfully obtained, until an improvement of 13% was reached.

The DMAIC methodology made it possible for the project to have a structure towards continuous improvement. Likewise, the Lean Six Sigma methodology encouraged the use of several tools that substantially helped the development of the project. In this way, the problem was addressed through a quantitative analysis of the voice of the customer (VOC) by satisfaction surveys carried out by the workshop's Contact Center staff. The result was the identification of 3 main drivers for customer satisfaction. Thanks to the CTQ Tree it was possible to outline metrics, baselines and objectives. The leanness service degree, as an adaptation of Amrani et al. (2016), and, Villacís and Burneo (2020) made it possible to objectively evaluate the continuous improvement of the preventive maintenance and washing service processes, identified as two key processes for customer satisfaction.

It was necessary to establish a capacity analysis in order to reinforce the need for improvement in the washing and preventive maintenance processes. Subsequently, a cause-and-effect analysis was prepared from the pareto diagram of customer satisfaction. The vital causes were prioritized using the Vester Matrix according to the degree of dependence and effect. For further analysis of the critical causes, an analysis of the 5 Why's was carried out, by means of which a correlation could be determined between the causes of delays in the mechanical service and the quality of the service, allowing to generate comprehensive improvements.

Under this context, improvements could be made with the use of lean tools: 6'S (adaptation of the 5'S), Kanban, Andon, TPM and the standardization of the washing process through line balancing for cell assembly lines based on the case of FORD studio. This last implementation is important to emphasize since it made use of the linear programming implemented in the AMPL software. Due to the limitations of the current COVID-19 pandemic, data collection was impossible with improvements implemented in the workshop, so the simulation of discrete events offered by the FlexSim program was used. Through simulation it was obtained that the washing process went from 33 minutes to 24 minutes. Likewise, the improvements showed that the preventive maintenance process was reduced from 117 minutes to 92 minutes. This of course met the expectations of the project, in addition to inducing an increase in the capacity of the automotive workshop from serving 9 cars a day to serving 13 to 15 cars per day, meaning a greater increase in earnings per hours billed. The latter will even represent a benefit in relation to the implementation costs of $ 403. The Kobetsu Kaizen methodology was disseminated in the workshop in order to maintain the feat of continuous improvement in the control stage.

Finally, the lean grade evidently increased from 2% to 13%, which is considered a still poor grade based on the Overboom et al. (2010) leanness degree results of 40% (on average). However, future research should be carried out in order to identify if said lean grade represents a lack or rather indicates a competitive advantage to any other workshop.

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