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Implementation of the Six Sigma Methodology to Improve the Process Performance in a MYPE

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Abstract

Those in charge of directing small and micro companies many see the application of improvement tools as something unnecessary; since, they think that they are complicated development methods that will represent unnecessary expense of time and money, and therefore they prefer to remain in the same situation and do not take advantage of the possibility of improving and growing as an organization. In the development of this research, the influence of the application of the Six Sigma methodology is studied and approached in a practical way; tool that allows to measure the performance of a process for the identification of defects and determine the ideal improvements to apply, in a MYPE. Different articles were analyzed, where the Six Sigma model had been applied; which presented improvements for the organizations to which they were directed. In addition, the Six Sigma methodology was implemented in a MYPE that provided the car wash service; whose process initially had a non-optimal performance, but by implementing the Six Sigma method, improvements were achieved such as: the increase in the availability of the pressure washer machine from 84.31% to 92.78%, the increase in the number of vehicles washed, reduction of 122 hours stopped for maintenance and reduction of rejected vehicles.

Keywords
Six Sigma, Improvement, Availability, DMAIC, MYPE.

1. Introduction

In Peru, small and micro companies have an important participation in favor of the national economy, which represent 95% of the business structure that contribute approximately 40% of the country's gross domestic product (GDP). MYPES (Small and Medium Enterprises) are valued in many countries as sources of job creation, social inclusion, competitiveness and the fight against poverty. However, many micro and small entrepreneurs tend to close their businesses because they cannot adapt to the changes that constantly occur in the markets or because of poor management that generates low productivity. Therefore, the implementation of the Six Sigma tool in an MYPE allows productivity to be optimized, eliminating and reducing process failures (Paprocka et al., 2020).

The Six Sigma methodology, which was developed in the 1980s by the Motorola company, is considered a multidimensional strategy that consists of a set of disciplined processes. These allow the development of products and services optimally for customers; its implementation and development are based on an exact compilation of process data that is analyzed and is intended to be improved, reducing waste, defects and process variability to a great extent (Alkoot, 2019). Six Sigma is made up of five phases of DMAIC (Define, Measure, Analyze, Improve and Control) that allows solving problems based on data that help make improvements (Siregar & Elvira, 2020). The goal of applying this methodology is to achieve continuous improvement that has the ability to evolve, which must assess the investment made, the success and goals achieved. (Boangmanalu et al., 2020)

Some MYPEs fail in the process of implementing the Six Sigma methodology without obtaining benefits for the improvement of process performance. The main reasons for this situation are the resistance to making changes for improvements, the absence of leadership on the part of the directors, the reduced budget, the lack of trained personnel for the development of the methodology and the absence of commitment on the part of all the members. that are part of a MYPE. It is for the reasons explained above that micro and small entrepreneurs see Six Sigma implementation as an additional complex problem that they have to face, instead of a solution and an opportunity for improvement.

The objective of this article is to demonstrate the effectiveness of the application of the Six Sigma methodology in increasing and improving the performance of the processes carried out in an MYPE that can lead to providing a better service or product that satisfies customers. An application of each of the phases of the Six Sigma methodology (DMAIC: define, measure, analyze, improve and control) will be carried out in a car wash center located in the city of Lima that provides car wash services, which presents a high number of failures in one of its machines which, according to the company, are high costs for corrective maintenance, unplanned work stoppages, low machine availability and decreased productivity.

2. Methods

The study is carried out in a small vehicle car wash center, considered an MYPE, in order to verify the benefits of the Six Sigma methodology to reduce the number of failures of a pressure washer machine, since this is an important element in this area. and it is essential to reduce unscheduled stops and failures during the execution of the services provided by the company. Therefore, the development of the research project is based on the implementation of the Six Sigma methodology, precisely with the DMAIC strategy, which is composed of the following phases: define, measure, analyze, improve and control. Next, the development of each of the DMAIC stages in the car wash center will be explained in detail.

2.1 Define Phase

A talk was held with the person in charge of the car wash who is involved in the process of executing the service and the administration of the business. Therefore, he knew the current situation in the car wash center and mentioned that the main problem and interest in finding a solution is the reduction of the failures that the hydro washer presents due to poor maintenance management that causes job instability, customer dissatisfaction for the delay and reduction in the profitability of the business. Therefore, the information that was collected from the company was the number of failures that the pressure washer had; as well as to observe its operation when carrying out the execution of the service by the operators in order to analyze the conditions.

Then, once the information is collected, a project statute (see Table 1) was drawn up to serve as a guide or founding act to keep the assignment of roles aligned, which allows others to be shown what problem is going to be solved and the reason for this, as well as the benefits that are expected after carrying out the project, the improvement objectives of the project, scope or limits, the duration when carrying out the DMIAC strategy and the project team.

Table 1. Project Status

Business case	Problem statement
By the 5th two-month period of the year 2022, have a good maintenance management that allows increasing the availability of machinery and avoiding unscheduled stops, ensuring the profitability of the company.	In the first two months of 2022, the pressure washer, an essential machine for car washing, had failures and an average availability of 84.31%; These were caused by improper handling by the operators and poor maintenance management, causing customer dissatisfaction due to the delay in the washing service.
Goal statement	Project scope
Have a correct maintenance management of the pressure washer from the 5th two months of the year 2022 through the Six Sigma methodology, reducing customer dissatisfaction due to the delay in washing service, job instability due to this problem and an average availability greater than 92%.	Within reach: pressure washer Out of range: Reception area Work environment

Project plan	Equipo de trabajo
Start: May 1 Define: May 31 Measure: June 20 Analyze: July 30 Improve: August 15 Control: September 20	Process owner: Car wash center owner Black Belt: Cristian Alexander Ortiz Velasquez Giancarlo Alexander Arrasco Juarez Green Belt: Operators

2.2 Measure Phase

In this stage, information is collected about the failures that the pressure washer has presented during a period of half a year from November 2021 to April 2022 in order to evaluate the current measurement system. The results are the following (see Table 2):

Table 2. Failures registered from November 2021 to April 2022

Company/Month	November	December	January	February	March	April
car wash center	18	15	21	25	17	20

With the number of failures obtained, the percentage of availability of the pressure washer machine will be calculated with the following equation:

$$Availability = \frac{(Total\ Hours\ -\ Hours\ stopped\ for\ maintenance)}{Total\ Hours}$$

The availability obtained in each month is presented in the table below (see Table 3):

Table 3. Total hours, faults presented, hours stopped and availability

Month	Total Hours	Faults presented	Hours stopped for maintenance	Availability
November	240	18	35	85.42%
December	240	15	29	87.92%
January	240	21	41	82.92%
February	240	25	49	79.58%
March	240	17	33	86.25%
April	240	20	39	83.75%

On the other hand, through the information collected from the company, it was possible to obtain the number of vehicles that were washed per month before the application of the respective improvements, as can be shown in the following table (see Table 4):

Table 4. Availability and washed vehicles from November 2021 to April 2022

Month	Availability	Washed vehicles
November	85.42%	756
December	87.92%	815
January	82.92%	750
February	79.58%	736
March	86.25%	811
April	83.75%	740

Likewise, the number of vehicles washed per month that the car wash center expects to wash is a maximum of 900 vehicles and a minimum of 800, with the help of the Minitab software (see Figure 1) it will be determined if the capacity of the process is adequate.

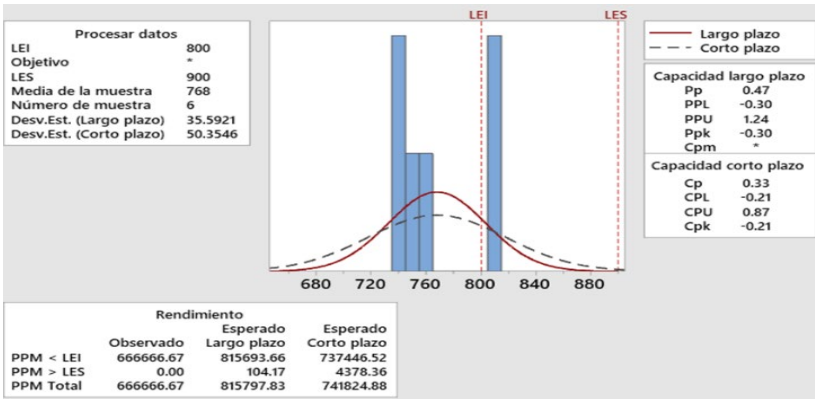

Figure 1. Process capacity graph for washed vehicles

In the graph obtained, the value of Cp is evaluated; which is an indicator of the potential capacity of the process based on the variation of the process in which if the resulting value is greater than 1, it is interpreted that the process is adequate. In this particular case of the research evaluation process, a value of 0.33 was obtained, which indicates that the performance of the process is not adequate.

2.3 Analyze Phase

At this stage, the Ishikawa diagram was used to determine the possible causes that cause the appearance of pressure washer failures based on the 6M method, which make up: labor, materials, environment, method, machines and measures. The diagram shows and involves elements such as the lack of training of the operators, the absence of a maintenance policy, there is no preventive maintenance, they do not have maintenance tools and other variables that cause poor maintenance management of the pressure washer that will be shown (see Figure 2).

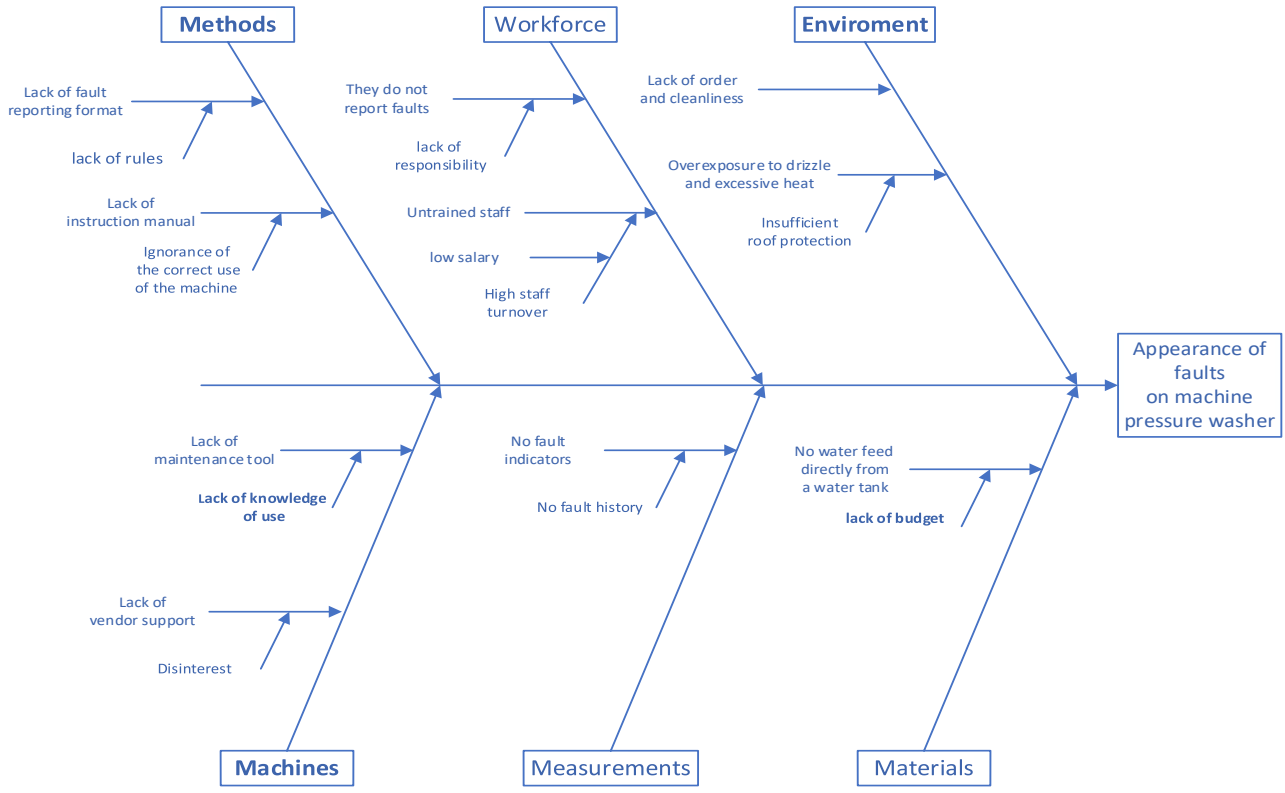

Figure 2. Ishikawa diagram

Then, to determine which of the 6M has a greater impact on maintenance management, a Pareto diagram was made to evaluate the level of priority and recognize which of the 6M should be focused on to find solutions, as well as in what order to carry them out (see Table 5).

Table 5. Factors, frequency, percentage and accumulated percentage

Factors	Frequency	Percentage	Accumulated percentage
Methods	14	38.90%	38.90%
Workforce	9	25.00%	63.90%
Machine	5	13.90%	77.80%
Materials	4	11.10%	88.90%
Measurements	2	5.60%	94.40%
Environment	2	5.60%	100.00%

2.4 Improve Phase

In this stage, an improvement plan is developed that seeks to achieve the goals and objectives that were set out in the project statute and in the define stage. For the problem of the non-existence of a format for reporting failures, the creation of one is proposed in order to identify failures with the participation of all direct and indirect operators (see Figure 3).

COMPANY LOGO	FAULT REPORT FORM	REPORT CODE	
		FRF22-01	
		FAILURE DATE	FAILURE TIME
		DD/MM/YYYY	00:00 am/pm
PROCESS AREA			
MACHINE DATA			
MACHINE NAME	BRAND	MODEL	MACHINE CODE
FAULT DESCRIPTION			
HOW DID IT HAPPEN?			
CONSEQUENCES OF FAILURE			
POSSIBLE CAUSES OF FAILURE			
PRODUCED BY:		REVIEWED BY:	
POSITION:		POSITION:	
SIGNATURE:		SIGNATURE:	

Figure 3. Fault Report Format

Likewise, another improvement is the creation of an instruction manual (see Figure 4) for the operators for the correct operation of the machine so that they know the procedure for the correct use of the machine and adapt to it to avoid failures during operations.

COMPANY LOGO	HYDROWASHER INSTRUCTIONS MANUAL	MANUAL CODE	
		M22-01	
		DATE OF ELABORATION	
		DD/MM/YYYY	
MACHINE DATA			
MACHINE NAME	Hydrowasher		High pressure machine for commercial use to clean dirt from surfaces with ease due to the high pressure that is driven by the motor.
BRAND	Karcher		
MODEL	HD 6/15 Cage		
MACHINE CODE	MHK-001		
INSTRUCTIONS AND RECOMMENDATIONS			
1. Connect the water filter to the equipment, verifying that it is clean.			
2. Connect the water supply hose to the filter placed on the equipment.			
3. Open the water supply. Purge without turning on the equipment until a continuous stream is achieved, then turn on the equipment to wash.			
4. Keep the gun trigger pressed throughout the cleaning process (avoid triggering). You should only release the trigger to rest or change any of the accessories.			
5. If during the operation you have periods longer than 5 minutes during which you do not use the equipment, you must depressurize it (release the pressure). The equipment should not remain more than 5 minutes with contained pressure.			
6. Depressurise: Remove pressure from the high pressure system to prevent water leaks and cracks in the system. (turn off the equipment and then press the trigger for a few seconds)			
7. After using the equipment none of the accessories should remain connected to it. So unplug, clean and save.			

Figure 4. Hydrowasher Instruction Manual

Finally, a Checklist will be carried out to involve all company employees to maximize the efficiency and availability of the equipment, using a maintenance strategy that will be carried out daily by all members of the company. The implementation of the Checklist will allow controls to ensure the correct operation of the equipment during the

execution process, guaranteeing the care of the machine that will reduce unscheduled stops, failures and reduce corrective maintenance costs (see Table 6).

Table 6. Operator daily checklist

Operator's daily checklist
1. Avoid pressing with heavy objects and/or bending the hose at all times, in addition to always keeping it rolled up and stretched, without excessive buckling.
2. Firmly press the gun trigger to avoid self-starts or false starts.
3. Do not perform unnecessary, repetitive and/or excessive triggering as this causes wear and damage to the internal components of the pump as well as to the components of the electrical system of the equipment.
4. Daily check and clean the protection filter for the feeding water inlet.
5. Check the o-rings that they are in good condition.
6. Check that there is no water leak in the gun and/or hose.
7. Clean the pressure washer daily, previously disconnecting it.

2.5 Control Phase

In this last stage, the purpose of this is to guarantee compliance with the improvements proposed to maintain the sustainability of the project until it is ensured that a sufficiently strong culture has been built in which the operators make the necessary improvements. In the case of the investigation, three methods will be used: The improvement control plan, control chart and responsibility matrix.

For the preparation of the control plan, the parameters were defined, which will be constituted for strict compliance by all the people involved in the vehicle washing process. The elements of the control plan are described below:

- Process Name: Specific procedure to be performed
- Stage of the process: Specific moment of the procedure where the established measure will be carried out.
- Process Output: Results obtained after finishing the procedure.
- Frequency: The period of time in which the established improvement procedures will be carried out.
- Control Method: Procedure to record any data or observation.
- Reaction plan: Response to the observations obtained.

The control plan seeks to have listed and detailed the processes for the application of the improvement that is sought to be established in the car wash service center (see Table 7).

Table 7. Control plan for a correct

Control plan for proper maintenance management						
Car wash center				Team: General manager, vehicle wash operators		
Ítem	Name of process	Process stage	Process Output	Frequency	Control method	Reaction plan
1	Verification of failures of the pressure washer machine	Previous use of hydrowashing machine	Record of faults presented in pressure washer machine	Daily	Bug Report Format	In case of failures, an immediate repair or exchange for a new machine is suggested.
2	Daily maintenance of the pressure washer	Inspection of hydrowashing machine	Correct maintenance and care of pressure washer machines	Daily	Checklist of operating specifications of the pressure washer machine	Hold a meeting to involve all company employees to maximize team efficiency and availability
3	Review Instruction Manual for the use of the machine	Previous use of hydrowashing machine	Correct use and operation of pressure washer machines	Every time a new operator enters	Review of standards and rules of the Instruction Manual for the use of the machine	Retrain and assess in a practical way when the operator is washing a vehicle

On the other hand, the control chart allows the people in charge of the car wash service premises to visually review the behavior of the car wash service performance and ensure that the implementation of the improvements is having a positive impact on the fulfillment of the objectives. Next, the history of vehicles washed during the 6 months will

be displayed, indicating the lower control limits and the upper control limits. As can be seen in the graph below (see Figure 5), since the measures are not yet implemented, the performance of the car wash service is mostly below the expected minimum number of vehicles washed per month (800 vehicles/month).

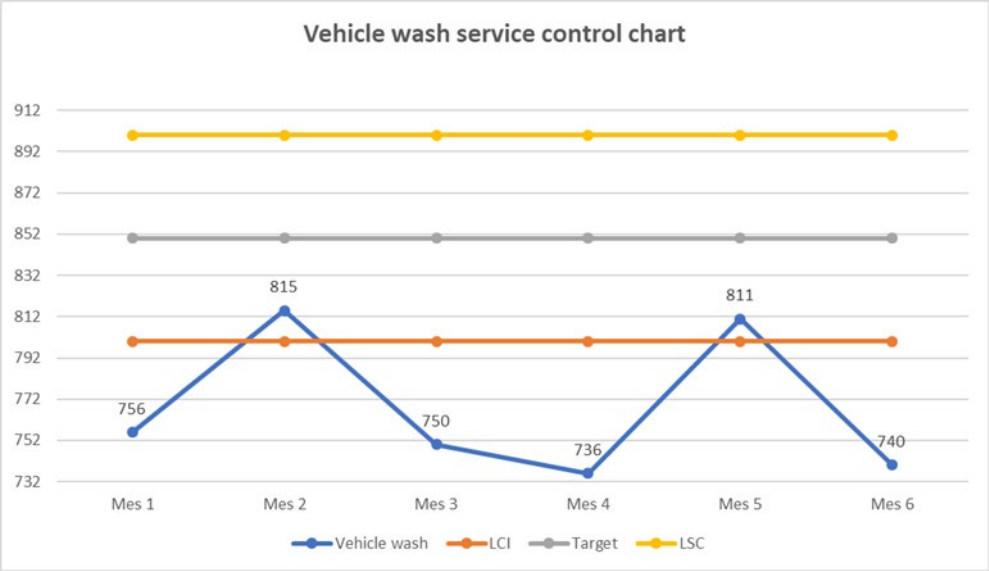

Figure 5. Control chart

The responsibilities of all those involved in the established activities of the proposed improvements will be established in the responsibility matrix. The responsibilities assigned to each member (see Table 8, Table 9, Table 10) will be placed in each of the tasks: Responsible (R), Approver (A), Consulted (C) and Informed (I).

Table 8. Matrix of responsibilities for the application of the fault format

Fault Record Format	Operator 1	Operator 2	Operator 3	Operator 4
Preparation of fault record formats	R	C,I	A	
Format review	C,I	R		A
Printing and delivery of the fault record format	R		C,I	
Fault Format Data Collection			A	R
Report making			I	R

Table 9. Responsibility matrix: operator's daily checklist

Operator's daily checklist	Operator 1	Operator 2	Operator 3	Operator 4
Collection of information for the checklist		R		I
Design verification format	R			C
Format Approval				A
Checklist publication	R		A	

Table 10. Matrix of responsibilities: instruction manual training

Instruction Manual Training	Operario 1	Operario 2	Operario 3	Operario 4
Induction Registration			R	A
Choose the person in charge		I		A
Prepare audiovisual material	R	C		

Summon staff for the induction process		C	R	A
Start the induction process			R	
Staff evaluation			R	

3. Results and Discussion

3.1 Results

Through the application of the proposed improvements and the controls to ensure the development and compliance with the measures, it was possible to obtain the new records of failures presented in the following six months (see Table 11), achieving a reduction in failures presented with an average availability of 92.75%.

Table 11. Total hours, failures, idle hours and availability after improvements

Month	Total Hours	Faults presented	Hours stopped for maintenance	Availability
1	240	9	17	92.92%
2	240	9	17	92.92%
3	240	10	19	92.08%
4	240	10	19	92.08%
5	240	9	17	92.92%
6	240	8	15	93.75%
Average Availability				92.75%

The performance of the vehicle washing process was evaluated after applying improvements in the Minitab software (see Figure 6); the value of the process capability indicator (Cp) resulted in a value greater than 1; therefore, it was determined that the behavior of the process is optimal and better than in its initial state, when the proposed improvements had not yet been applied.

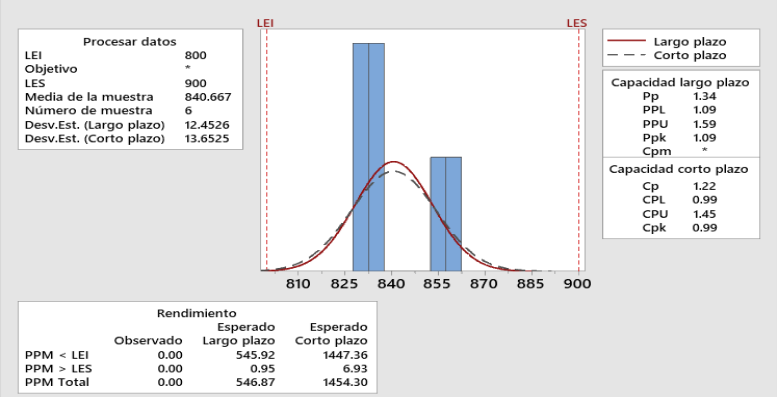

Figure 6. Process capacity graph of washed vehicles after the implementation of improvements

The control graph after the improvements (see Figure 7) shows that the number of vehicles is within the limit established in the vehicle wash center, unlike the Control stage where a behavior well below the lower limit is observed.

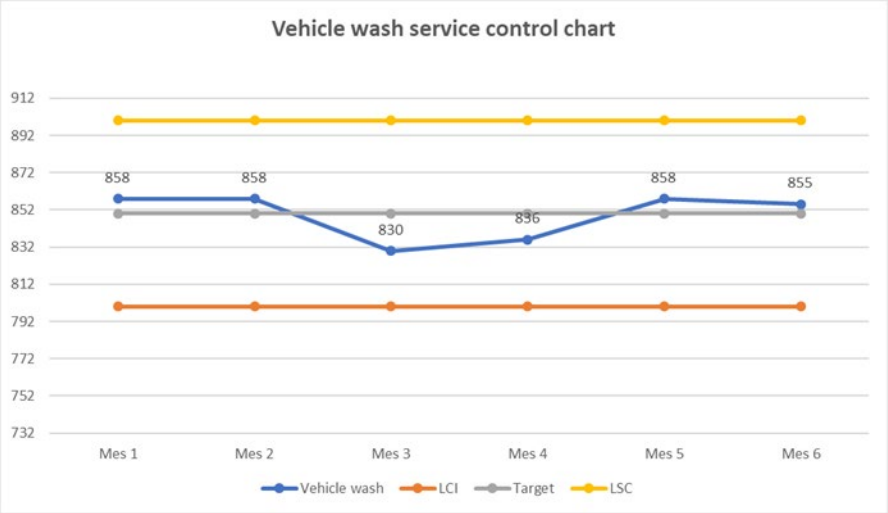

Figure 7. Vehicle wash service control chart

As can be seen in the table below (see Table 12); thanks to the simulation of the car wash process in the Arena program; the results were 748 vehicles washed (below the limits of 800 and 900 expected units), 152 vehicles not washed and a total of 226 hours stopped for maintenance before the application of the Six Sigma methodology; All the results were obtained by entering an average availability of 84.31%, which was obtained from the information provided by the place that provided the car wash service. With the implementation of the detailed improvements: failure report format, instruction manual for the use of the pressure washer machine and the operator's daily checklist; an average availability of 92.78% is estimated in the next six months after the respective implementation. When entering the new availability, the number of vehicles washed was 845 (within the limits of 800 and 900 units expected) and also a significant reduction in the hours stopped for maintenance to 104, which proves an evident impact on performance. of the car wash process.

Table 12. Comparison: before and after the implementation of improvements

Indicators	Before the upgrades	Difference	Variation	After improvements
Washed vehicles	748	97	12.97% (increase)	845
Unwashed vehicles	152	97	63.82 (reduction)	55
Average availability	84.31%	8.47%	10.04% (increase)	92.78%
Hours stopped for maintenance	226	122	53.98% (reduction)	104
Washed vehicles	748	97	12.97% (increase)	845
Unwashed vehicles	152	97	63.82 (reduction)	55
Cp	0.33	0.89	2.69%(increase)	1.22

3.2 Discussion

The findings obtained in the investigation show us that the implementation of the Six Sigma methodology is feasible and effective in order to reduce the variations that prevent the desired operation of the process belonging to an MYPE, in the particular case of the investigation carried out it is about the service vehicle wash. The investigations and assertions that were made by various authors for the elaboration of this stage of the discussion will be analyzed. Likewise, articles indexed in the Scopus database between the years 2016 and 2022 were searched.

According to Alkoot (2019), Six Sigma is a disciplined technique that helps products and services, which are aimed at consumers, to be in the best conditions. The elimination of waste and inefficiency increases the level of satisfaction that customers perceive when they are served. In his research, the Six Sigma methodology was applied to improve the

results of higher education in institutes, the results obtained led to a better performance of the graduated students, thanks to the diagnosis of the existing problems and then to identify the root causes on which suggested possible solutions. Fontalvo et al. agree with these results. (2020), who in their study about the service quality evaluation method of a user service unit in a water service company; managed to determine the performance of customer service through the variables: number of services attended, opportunity for error, rejected services and process performance; at the end of their investigation they determined that the performance of the water service company is generally good; however, if he presented a couple of months where his performance was not as expected. Da silva et al. (2019), stated that by eliminating variability, it reduces waste and increases productivity. In addition, by offering higher quality achieved by applying the Six sigma methodology, organizations seek to achieve greater competitiveness. Likewise, according to Navarro et al. (2017), Six Sigma's main objective is to measure to improve quality, based on the collection of data and the examination of processes in detail to achieve the closest perfection, having as pillars the time and commitment of all the parties involved. For a correct operation of the Six Sigma implementation, according to Suresh (2016), products and services must be improved from their design stage, since it is more feasible to try to apply improvements in later phases when irreversible failures may occur, the goal it should focus on building better process quality through a preventative approach. The context of the Covid-19 pandemic that affected the world since 2020 cannot be ignored, as mentioned by Ramírez (2021), in his research entitled Lean Six Sigma and Industry 4.0, a review from the administration; Given the appearance of the pandemic and the feeling of uncertainty generated, the implementation of tools and methodologies are a great alternative so that their performance is not affected and take advantage of their opportunities for improvement.

On the other hand, the application of the Six Sigma methodology is not easy to apply, as stated by Galli (2018), because it intensively addresses the risks of applying Six Sigma in different organizations, the main ones being: the risk of lack of leadership, risk of poor resource management, risk of poor data collection, risk of poor selection of the project to study, risk of lack of financial support from the administration and risk of lack of predisposition To the change. Organizations and companies need to understand that for the implementation of Six Sigma in their processes they must identify the risks in a timely manner in order to manage them properly and thus ensure that the Six Sigma tool meets its main objective of reducing failures, reducing costs and increase the quality of the service or product being offered. The success of the change cannot depend only on a limited group of people in charge, the commitment must be absolute from all the parties involved, from the operators responsible for the operation of the service provided or product development to those in charge of the organization, only in this way can implement the required changes and that they remain both in the short and long term.

4. Conclusion

This article has presented the application case of the Six Sigma methodology in an MYPE from Lima-Peru dedicated to providing the vehicle washing service that seeks to improve the performance of its process. In the development of the investigation, the entire human group that makes up the vehicle washing center was involved, since it is a small group of people between operators and those responsible for the administration of the place where the service is provided, all were duly instructed. about the steps to be involved and the benefits that will be brought to the company. Likewise, the data collection was carried out carefully and with the greatest possible precision to avoid errors in the measurement phase, when the improvements were implemented, they were complemented with control measures that allowed each person to remember and recognize their role in each stage of the process. process and that the results are within the expected limits.

At the end of the Six Sigma implementation process, it was possible to improve the performance of the process by increasing the capacity of vehicles washed on average per month from 748 to 845 vehicles, reducing the number of hours stopped from 226 to 104; All of this could be demonstrated numerically by means of the process capability indicator (Cp) obtained by means of the Minitab tool, reaching a value of 1.33, which demonstrated that the performance of the process is optimal. If the commitment of all the parties that belong to an MYPE is achieved, the impact of the Six Sigma methodology will translate into improvements that will allow a better development and development of the same with the aim of being more competitive and productive.

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