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Lean Operations Optimization Model Under the TQM and SLP in the Carwash Sector: Case of a SME in Peru

Alberto Muñoz, Andrea Briceño and Alberto Flores-Pérez
Facultad de Ingeniería
Universidad de Lima
Lima, Perú
20173639@aloe.ulima.edu.pe , 20152770@aloe.ulima.edu.pe , alflores@ulima.edu.pe

Abstract

This research article proposes the application of Lean Total Quality Management (TQM) and Systematic Layout Planning (SLP) tools to review, standardize and improve the car wash process of a SME in Peru. With SLP an improvement in the distribution of the washing station is proposed. Within TQM, the PDCA cycle tools were applied to identify problems and the 5S methodology to have improvements within each activity. Under the simulation of the proposed model validated with the Arena software, an 11% increase in the station's productivity was achieved based on a 13% decrease in washing time as well as a 36% reduction in the number of lost customers due to waiting time in queues or dissatisfaction with the service, improving service efficiency and reducing reprocessing.

Keywords
Carwash, lean manufacturing, TQM, SLP, SME.

1. Introduction
There are 1.446 billion vehicles in the world today (Hedges & Company 2020). In the case of Peru, the vehicle fleet has grown exponentially in the last ten years. A clear example of this is that by 2010, the number of vehicles in the country was 1.8 million, and to date the number is close to 3 million. (Gobierno del Peru 2020). One of the services associated with automotive manufacturing and maintenance is car washing. This is constantly growing and along with it also increases the waste of drinking water, energy consumption, time, (Meng et al. 2020) and labor informality. It is known that, for every vehicle washed, 150 to 600 liters of water are used (Veit et al. 2020) depending on the size and type of washing: manual or automatic. Due to this problem, new ways arise based on the prioritization of water resources for human consumption and the use of technologies such as steam washing, automatic washing, dry cleaning with biopolymers, and disinfection of vehicles with ozone or quaternary ammonium, among others. (STEAMERICAS 2022). These methods seek to generate efficiencies in washing process times and resource consumption in general. Currently, several problems affect the productivity of this business such as low standardization of its processes, lack of organization in the washing stations, and poor training of personnel, among others. (Medonos and Jurova 2020). All these challenges create the need to review and standardize processes to reduce the gap between manual and automated washing. In this case study, a Car Wash located in Santiago de Surco, Lima, Peru was analyzed, which has a low standardization in its processes, poor customer service and an average service level resulting in a decrease in its net profits and business margin. (Lamine 2018). To solve the mentioned problems, TQM and SLP tools will be applied, under the Lean methodology, counting on several success cases in similar sectors that allow it to show its success. (Anil 2019). In this way, the aim is to revalue and make the manual car wash service more effective to achieve significant improvements that translate into higher profits and efficiency in the use of resources. (Geca 2021). Finally, this article is divided into an introduction, literature review, methods, data collection, results and discussion, conclusions, and references.

1.1 Objectives
The main objective is to reduce the gap time of the car wash service by more than 50% through TQM and SLP tools. Additionally, as a specific objective, it is proposed to improve the washing process through the application of the Lean 5S and PDCA Cycle methodologies.

2. Literature Review
Productivity and actuality of the car wash sector
The number of private cars and buses and car wash services is steadily increasing. Manual washing mode generates water waste, time consumption and inefficiency. The automatic car wash industry is becoming increasingly popular. (Yanan Meng et al. 2021). Informal sector: overworked washers, lack of training and inadequate working conditions, as well as customers indifferent to the possibility of labor exploitation and informality. All this is overcome by a competitively priced and "better quality" service because manual cleaning can clean areas that an automated wash could not, such as the interior of the vehicle. In addition, these carwashes go to great lengths to mimic formalized suppliers by displaying professionally fabricated canopies, signage, and price lists. This makes them look like legitimate suppliers; even though the working conditions reveal the opposite. (Clark 2018)

Application of Total Quality Management TQM
Lean Manufacturing has a focus on continuous improvement and optimization, having a high and positive prevalence in the industry. (Jauregui et al. 2017), one of these tools is the Total Quality Management (TQM) allows all workers in a company to contribute to quality improvement. To start with this process an implementation in 5S (sort, set in order, shine, standardize, and sustain) is established. (Matias and Idoipe 2013). TQM success factors: top management, corporate strategy, managerial leadership, fact-based decision making, cross-functional teamwork, reward schemes, explicit and challenging objectives, and organizational characteristics factor. (Pearce et al. 2018) (Lamine 2018) (Anil 2019). PDCA (Plan, Do, Check and Act) cycle, which helps to identify and correct defects is compatible with TQM. (Matias and Idoipe 2013).

Application of Systematic Layout Planning SLP
Systematic Layout Planning (SLP) is the oldest method used in factory and workshop equipment layout design, through the design process, it solves the problem of equipment location design, relying on the intensity level as a factor for equipment location decision (Li, Zhang et al. 2019) workstation design, therefore, is a crucial process to ensure efficiency, customization, automation, and competitiveness in high-volume environments, using less time, space, cost, and inventory (Brito et al. 2020). Finally, an efficient design must consider the nature of the worker so that there is a synergy between the worker and his or her workstation. (Baccanti et al. 2021).

3. Methods
The proposed model is based on Lean techniques, where the development has been effective in several companies, highlighting for this work the TQM and SLP techniques, to increase productivity in the car wash service of a SME. It should be noted that everything must be quantified by KPIs to validate the proposed improvement, so we use a comparison matrix detailed in Table 1.

Table 1. Comparative Matrix.

Authors	Diagnosis	Planning	Execution	Validation
(Pandey, Agrawal, Saharan, Raut, and RD., 2022)	TQM	TQM	TQM	
(Li, Zhang, Wu, Shi, and LL., 2019)		SLP	SLP	SLP
(Rodriguez and Angelica, 2018)				KPIs
Proposal	**TQM**	**TQM & SLP**	**TQM & SLP**	**SLP & KPIs**

3.1 Proposed model

The proposed model is based on the lean tools of TQM and SLP, with the main objective of increasing productivity, reducing time, and optimizing distribution (Figure 1).

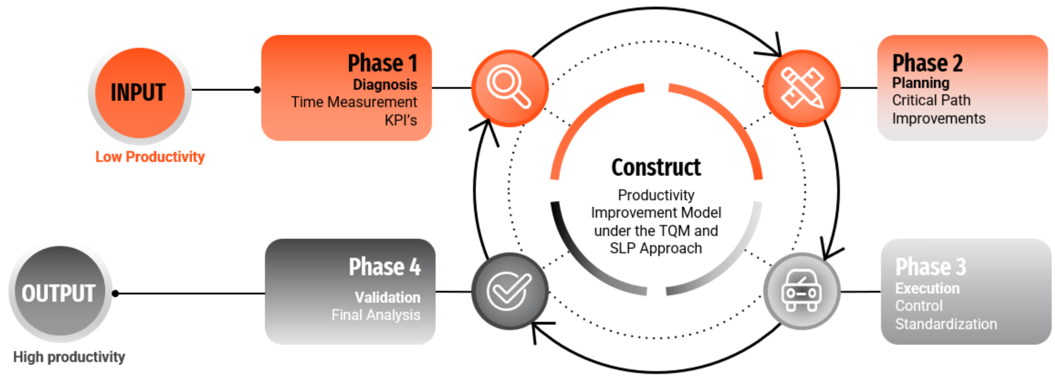

Figure 1. Model Construct

3.1.1 Phase 1 - Diagnosis

In this phase, the main problems of the delay in productivity will be identified through time measurements, interviews with employees and collection of photographic evidence. It was observed that the main problem was the loss of customers per queue, generated by the station's lack of capacity to serve new customers. In turn, this is due to the loss of time in the reprocessing of washing activities, the search for work tools and the lack of communication between operators and receptionists. A second problem was the loss of customers due to poor service, where it was diagnosed that, since there is no standardized method for service or proper training, each operator performs the tasks according to his expertise. This makes the washing service variable and subject to errors. These causes were found through an Ishikawa and a Pareto diagram was used to measure their importance.

3.1.2 Phase 2 - Planning

Once the problems were identified, the general and specific objectives were defined. Likewise, based on the problems found, the applicable methodologies were determined. Thus, it was considered that the implementation of the Lean Manufacturing strategy was important. The application of Total Quality Management (TQM) and Systematic Layout Planning (SLP) was also proposed to have an integrated solution that, in addition to focusing on the main problems, would also generate a positive impact on the work environment and take advantage of the knowledge of the team itself. The next step was the planning of the work strategy, the Gantt chart, and the additional requirements necessary for the correct execution of the research.

3.1.3 Phase 3 - Execution

In this stage, the proposed strategy was implemented. For this purpose, frequent visits were made to the company where the measurement of service times, interviews with the work team, field observation and information gathering were conducted. In addition, a benchmarking of other companies in the same field were realized to have a general vision of the research. During this period, the first iteration of the simulation model was executed with Arena software and the proposed methodologies were applied.

3.1.4 Phase 4 - Validation

To analyze progress and verify whether the proposed improvements are producing results, five main indicators will be used.

Station Productivity (P): This refers to the number of cars washed (outputs) generated by the station. The number of cars that can be washed per station is calculated with the total number of hours the station works and the standard washing time (gap). The following formula is used for this purpose:

$$P = \frac{Number\ of\ Cars\ washed}{Number\ of\ Cars\ that\ can\ be\ washed\ per\ station} * 100$$

Percentage of lost customers (%CP): One of the main consequences of the low productivity of the car wash is the loss of customers due to poor service or waiting in queues. This indicator shows the percentage that these customers represent of the total number of customers served.

$$\%CP = \frac{\#total\ lost\ customers\ per\ day}{total\ clients\ per\ day} * 100\%$$

Service Gap (BS): It was determined that the standard washing service time is 25 minutes; therefore, if a service takes longer than this time, a gap is generated, which impacts costs, customer waiting time, and overall service experience. The following formula is used to calculate the gap:

$$BS = Average\ Total\ Service\ Times - 25$$

Service efficiency (E): the standard wash time is 25 minutes, if a wash service is performed at the same time, then the efficiency is 100% (25/25*100%). But what happens when the service takes more than 25 minutes? In that case, the efficiency would not be 100% and it is precisely that indicator that we seek to measure. The following formula is used for this purpose:

$$E = 100\% - \left[\frac{Total\ service\ time}{25} - 1\right]$$

If the total service time is greater than 25 minutes, the efficiency will be less than 100%, and when the total service time is less than 25 minutes, the efficiency will be greater than 100%.

Rework (R): The number of times an operator has to perform the same task because he/she has performed it incorrectly and/or forgot to perform it.

$$R = Number\ of\ reprocessing\ performed\ on\ a\ sample$$

4. Data Collection

The keywords considered for the search of the articles are car wash, lean Manufacturing, TQM and SLP. The databases used for the information search were Web of Science, Scopus, and Emerald. A total of 560 articles were found by searching for information in the three selected sources. Those articles that were not open access were discarded, which totaled 272 articles, leaving a final value of 288 articles. Likewise, duplicate articles were eliminated, discarding a total of 15 articles for this reason, leaving 273 articles. Subsequently, 189 articles were discarded after reading the title and summary, realizing that the content was not related to the objective of the research. After, 44 articles were rejected because they were not related to the variables and did not answer the research questions, resulting in a total of 40 selected articles. This information is detailed in Figure 2.

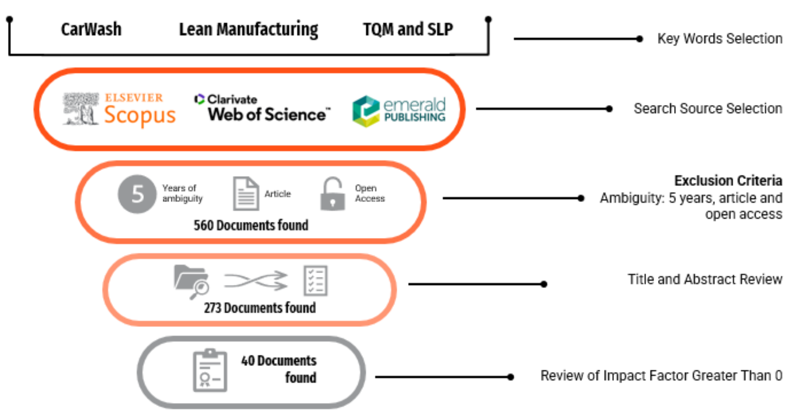

Figure 2. Database prism

5. Results and Discussion

5.1 Numerical results

To measure the improvement made, it is necessary to know the before and after, so a time calculation was made to find out how long it takes to wash a vehicle, with a sample of 20 services. It was determined that the interior and exterior service lasted 31.71 minutes. Thus, generating a gap of 6.71 minutes concerning the standard manual washing time, once the improvements were applied, a time of 27.59 minutes was obtained, which is detailed in Table 2.

Table 2. Summary of washing times by activity

Process	Initial Time (min)	Final Time (min)
Prewash	1,95	1,79
Shampoo Application	1,82	1,7
Rinse	2,71	2,58
Transfer to drying area	1,4	0
Exterior Drying Cloth	4,31	4,2
Exterior Drying Torch	1,94	1,85
Exterior Silicone	1,29	1,14
Silicone coating of tires and plastic parts	2,64	2,25
Interior Vacuuming	9,74	8,92
Cleaning of carpets and windows	3,91	3,16
Total	**31,71**	**27,59**

5.2 Graphical Results

In order to have a better understanding, the Bizagi program was used to graph the current processes of the station, in which the work sequence, reprocessing and activities that do not add value can be visualized. The detail is shown in Figure 3.

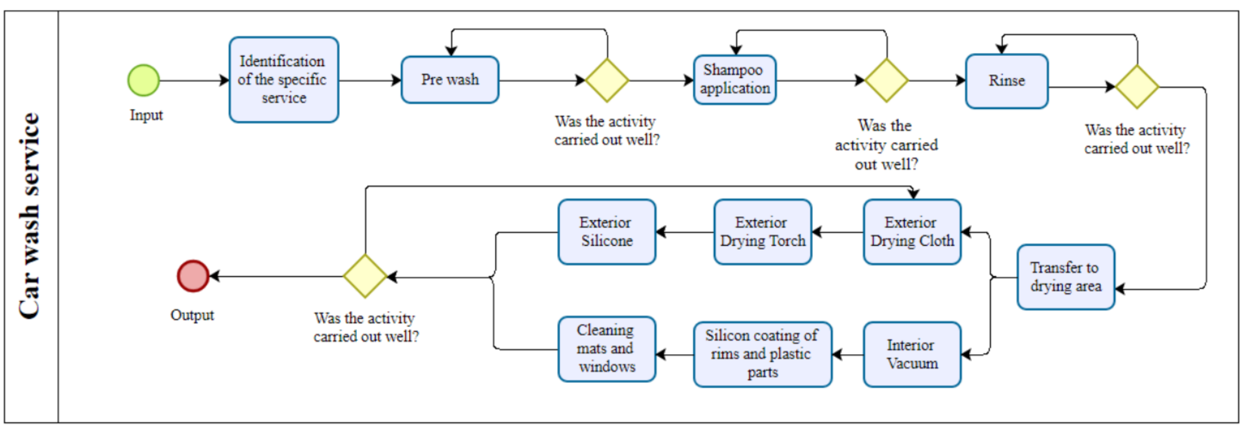

Figure 3. Lane Diagram of the car wash service.

Likewise, within the stations it was identified that the distribution of equipment and machines is not optimal, because some important elements are very far away as shown in Figure 4.

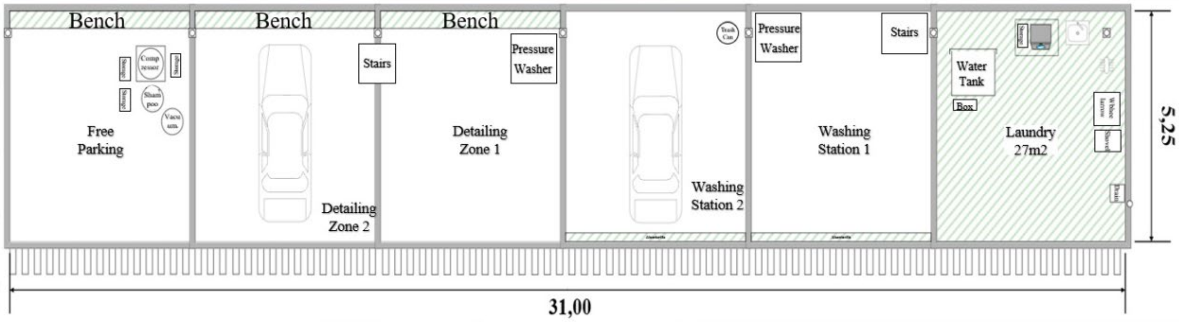

Figure 4. Layout plan of the washing stations

It was evident in the washing station that the organizing carts were being used incorrectly because they were not close to the operator and the work materials were not organized, as shown in Figures 5 and 6,7.

Figure 5. Organizer Cart A

Figure 6. Organizing Cart B

Figure 7. Current Layout of "Carwash El Derby"

5.3 Proposed Improvements

With the objective of proposing a new distribution, the SLP methodology was used, developing a table of proximity relationships which is shown in Figure 8. For this, reasons were identified in Table 3 and the values of proximity by code according to the values in Table 3 and Table 4.

Table 3. Reasons

N°	Concept
0	There's no need
1	Optimal Process
2	Better Supply
3	Better tool organization

Table 4. Proximity Value Definition

Code	**Proximity Value**
A	Absolutely Necessary
E	Especially Necessary
I	Important
O	Normal or Ordinary
U	No Significance

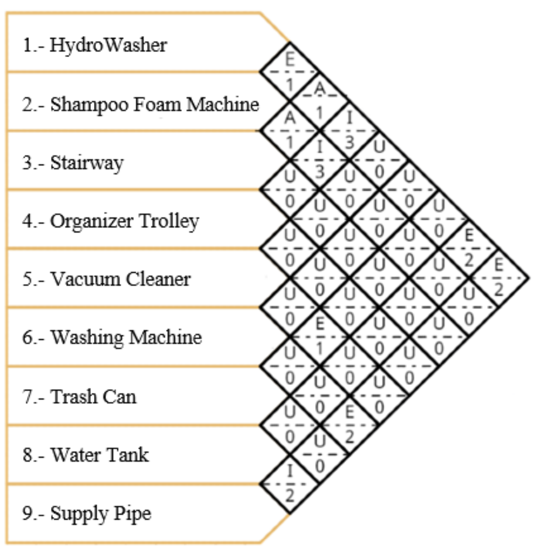

Figure 8. Proximity Relationship

Figure 9 proposes an improved distribution according to the proximity table worked. The layout of 4 wash stations, a backup area and a parking lot is shown. The washing stations were made independent of each other, placing the machines inside each station in such a way that the operator has the minimum movement within the station, reducing time.

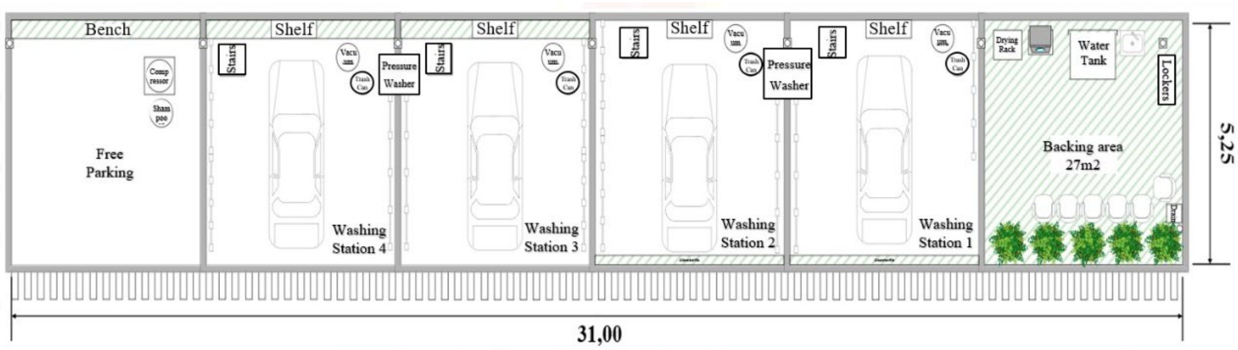

Figure 9. Distribution plan of the improved washing stations

Based on TQM, the improvement proposal was designed so that each workstation has a shelf with 9 divisions, where the implements to be used by the operator will be located; these divisions are organized according to the criteria of use.

5.4 Validation

Considering the improvement proposals, a simulation was modeled in the Arena program considering the scenario of all the washing services provided in the carwash. The case of the interior and exterior washing service of a car was specifically analyzed. A confidence level of 95% was used, a standard deviation of 4.18 and a margin of error of 0.05, which is detailed in Figure 10. The transfer of the vehicle to the dryer area was eliminated, considerably reducing the mobilization time of the operator. Likewise, travel times were reduced, obtaining an average time of 27.59 minutes after performing 150 replications in the simulation, reducing the gap to 2.59 minutes. Records were added for the analysis of KPIs, resulting in Table 5.

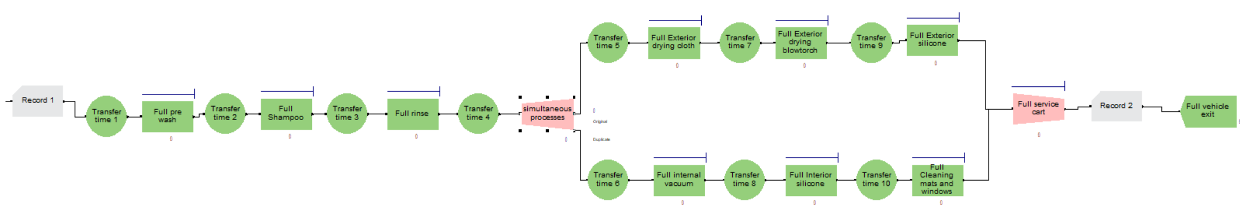

Figure 10. Sand Simulation with Washing Service Upgrades

Table 5 KPI's Analyzed

Indicator (*)	Initial result	Final result
Station productivity (P)	78.95%	89.47%
Percentage of clients lost (%CP)	11%	7%
Service Gap (BS)	6.71	2.59
Service efficiency (%E)	73.16%	89.64%
Rework (R)	35	17

Note: The results of the software arena n:150 are considered.

6. Conclusion

The simulation of the proposed model resulted in an 11% improvement in station productivity associated with increases in station capacity, reduction of transfer times, downtime, and elimination of non-value-added activities. This is accompanied by a 36% decrease in the number of customers lost due to long waiting times in queues or dissatisfied customers. As for the service gap, according to the model, a reduction of 61% was obtained, meaning this is ideally close to the gap time proposed at the beginning of the research. As for service efficiency, the new simulated efficiency indicator resulted in 89.64%, which represents an increase of 16% concerning the current indicator. Finally, we concluded that the main significant changes in the improvement of the gap were to eliminate vehicle transfers between stations and to decrease transfer times within the station due to a better distribution of space thanks to the SLP and TQM developed.

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Biographies

Alberto Muñoz, Bachelor's degree in Industrial Engineering from the University of Lima, technical degree in marketing from the San Ignacio de Loyola Institute. Has over 5 years of work experience in administrative and general services. I have held coordination positions, implementing operational improvements in logistics companies and educational institutions. Currently, works as an external consultant in process improvement, personnel management, among other areas.

Andrea Briceño, Graduated from the Industrial Engineering program at the University of Lima, specializing in Project Management. Currently working as a Supervisor of Strategic Projects in the Peru Division of Parque Arauco, a leading

Latin American real estate rental company in the region. Established as a publicly traded company in Chile, with an annual turnover exceeding 350 million USD and more than 120 employees in Peru. With over 5 years of work experience in the Retail, Real Estate, and Services sectors, she has held positions as an Operational Business Analyst and Service Analyst, managing the company's non-commercial revenue accounts within her professional profile.

Alberto Flores-Perez holds a doctorate degree in Education from Universidad de San Martin de Porres. Master's degree in supply chain management from Universidad ESAN and Universitat Ramon Llull La Salle in Barcelona. Engineer in Food Industries from Universidad Nacional Agraria La Molina. Currently working as an undergraduate professor at Universidad de Lima and a postgraduate professor at Universidad Nacional Agraria. Professional, consultant, businessperson, and professor with more than 27 years of experience in project implementation, quality management, safety, and agro-industrial plant management. Expert in Supply Chain (supplier management, storage systems, transport modeling, and distribution systems), Supply Chain and Operations. Specialization in integrated management system audit and Shortsea Logistics at the Escola Europea Short Sea Shipping. Leader of transformational projects, productivity, and change generator. Specialist in the implementation of Continuing Improvement Projects, PDCA, HACCP, and BPM in the agro-industrial sector, trainer of national government institutions and the United Nations (UNDP). Development of a high-performance team. Member of IEEE, SCEA Ohio, IOEM, and CIP (College of Engineers of Peru).