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Improving Efficiency Using Standardized Work, Autonomous and Planned Maintenance in a Peruvian Baking SME

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The article addresses improving efficiency in a small baking company. The application of standardized work, autonomous maintenance and planned maintenance is proposed to adopt better work methods, strengthen the knowledge of the company's collaborators about the necessary care activities for the equipment and have a preventive action plan that eliminates delays. within the process. A poor distribution in the plant was identified through the route diagram and process activity diagram (DAP) which generated an economic impact of 20,000 PEN. With the Arena software, the proposed maintenance simulation was carried out, with process times and failures. It was possible to validate an increase in efficiency that went from 49.29% to 70.59% based on a 10% decrease in the time of activities carried out by the operator. Regarding economic validation, an NPV of 8,751 PEN and IRR of 57% were achieved. For environmental sustainability, the Leopold matrix was carried out , which obtained a result of 0.402, which is not very significant, that is, during the production process no raw material waste is generated.

Keywords
Standardized work, Autonomous maintenance, Planned maintenance, Baking industry and Efficiency.

1. Introduction
SMEs are relevant since they represent 30% of the national GDP (Quesada & Arrieta 2019) . In addition, the bakery industry has been chosen, because it is important in Peru, according to INEI (2022), the consumer goods industry has shown positive results, in this case, "in the production of bakery products with 17.21% due to increased production of cakes and cookies for internal and external consumption" (p.25). Also, 16.52% of the GDP is represented by the food industry, and it is known that one of the most consumed foods in Peru is bread (Zamalloa-Menacho et al. 2022).
The objective of the research was to improve the problem of low efficiency that generated a strong economic impact of 20,000 PEN, it was reduced through the application of principles and techniques of industrial engineering such as work standardization and two pillars of TPM, which are autonomous and planned maintenance. For this, the efficiency KPI was used, where the times of the total process had to be taken using a stopwatch, and 49.29% was obtained for the efficiency before the improvements, which indicates that it is slightly close to 50%. , so the company has a moderate workflow with opportunities for improvement, compared to other companies that present approximately 62%.

The tools used are work standardization and TPM which belong to the Lean philosophy. They are relevant, since, according to Hernández et al. (2020), a 25% decrease in production cycle time is achieved using these tools. The problem found in the baking industry is that poor performance has occurred, due to different reasons such as a lack of training in methods and tools that serve to improve processes. Also, it is known that approximately 65% of the bakeries in Lima are informal (Zamalloa-Menacho et al. 2022). In the same way, for the company's equipment that is worn out, there is total productive maintenance or TPM, related to equipment management, seeking to improve the installation to achieve better use of these, thus avoiding degradation (Ragab et al. 2018). Therefore, it was decided to make an improvement proposal based on Lean Manufacturing in a small baking company in Peru. Finally, concerning the structure of the article, it is divided into an introduction, methodologies, results, discussion, conclusions and references.

1.1 Objectives
The main objective is to increase the efficiency of an SME bakery to 90% by reducing unproductive times and having standardized work methods. To fulfill this purpose, lean manufacturing tools were used, which are made up of: Standardized work, Autonomous maintenance, and Planned maintenance. Specific objectives were also formulated for the design of an implementation plan and to carry out the validation of the proposed tools.

2. Literature review
Standardized work:
The application of this work method seeks to establish provisions for common and repeated use, achieving the optimal degree of order in a given environment, its application guarantees the reduction of variability and waste, and also encourages participation among interested parties (Pīlēna et al. 2021). In addition, failure reduction is achieved, because it is linked to continuous improvement (Ulloa et al. 2022). This tool is simple to implement, so the equipment can be easily adapted and used in different work areas (Miller et al. 2022).

Maintenance:
The combination of all technical and administrative actions, including monitoring, that ensure that a system is in the required operating state (Postiglione et al. 2024).

A. Autonomous Maintenance:
Basic maintenance by machine operators, and the process is commonly known as routine activity. Each worker inspects their equipment independently (Postiglione et al. 2024). The application of this tool provides greater productive and safe work for the operator. In research published recently, at the Fifth African Conference on Industrial Engineering and Operations Management, South Africa, Johannesburg, South Africa mentions that after the implementation of this practice, the operational efficiency of the equipment machines increased from 37.56% to 51.31% respectively. (Collao et al. 2024).

B. Planned Maintenance:
The set of activities that aim to reduce the probability of specific failure modes occurring or detect hidden failures (Postiglione et al. 2024). On the other hand, another use of planned maintenance is to increase production without failures or defects to produce the required quantity and level of quality, in the same way, it must ensure the availability of the equipment (Alakazaai et al. 2017).

3. Methods
To make a proposal for improvement, comparisons were made with the previously selected articles that contained the tools for process standardization, and autonomous and planned maintenance, for this a comparative matrix was developed, Table 1, which contributes to having a vision of the broader panorama for determining the techniques that were used.

Table 1. Comparative matrix

Causes or Objectives / Scientific Articles	**Improved efficiency**	**Improve storage space distribution**	**Process improvement**	**Improve productivity**
Castro, M. del RQ, & Posada, JGA. (2019).	Lean Manufacturing (Poka Yoke, kaizen and TPM)			
Ferreira, William & Maniçoba da Silva, Adriano & Zampini, Eugenio & Pires, C.. (2017).		Lean Manufacturing		
Ulloa-Durand, J., Vargas-Altamirano, A., Flores Pérez, A., Quiroz Flores, J., and Collao Diaz, M., (2022).			Lean Manufacturing (Standardized Work)	
Garcia-Garcia, G., Yadvinder S. & Sandeep J. (2022).			Lean Manufacturing (SMED)	
Zamalloa-Menacho, A., Manani-Rojas, R., Flores-Perez, A. & Collao-Diaz, M. (2022).				Lean Manufacturing
Pinto, G., Silva, F., Fernandes, NO, Casais, RCB, Baptista, A., & Vale, N. (2020).			TPM	
Ragab, RE, Abdelwahab, SA, Shehata, G., Samed, NAE, Kaytbay, S., & Elnahas, W.M. (2018).			TPM	
Miller-Verano, C., Robello-Ponce, R., Flores Pérez, A., Quiroz Flores, J., & Collao Diaz, M. (2022)	Lean Manufacturing (Standardized Work)			
Proposal	**Standardized work**	**Lean Manufacturing**	**TPM / Standardized Work**	**Lean Manufacturing**

3.1 Proposed model

The proposed model begins with the identification of the origin of the main problem using path diagram, DAP and time recording with the objective of increasing efficiency and reducing process times.

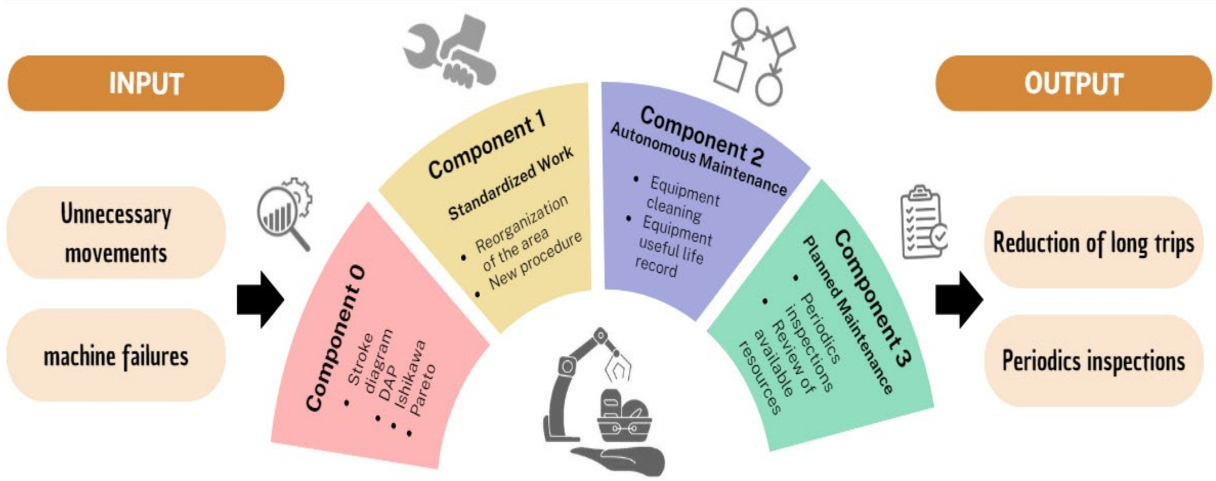

Figure 1. Proposed model

3.2 Components

3.2.1 Component 0 - Diagnosis

In this part the main efficiency problems will be identified. It begins with taking the times of each activity of the production processes, where there is a total time of 383.5 minutes, in the mixing and baking activity 15 and 18 minutes respectively. This is due to the failures that occur occasionally and the time it takes to repair each machine until it is operational again and the process continues. The route diagram was used to verify the distances and routes that the baker makes within the plant to carry out his daily activities, where it was observed that there are repetitive movements in the activity of weighing raw materials. The Process Activity Diagram (DAP) served to visualize in a broader and more specific way where the delays exist, and also helped to identify the paths. The causes of these problems were determined using an Ishikawa and Pareto diagram to order them according to importance within the project.

3.2.2 Component 1 - Standardized work

For the first component, the standardized work tool was used to reduce process times by 10% and have a more orderly and structured work. In research published by the IEOM at the fourth Asia Pacific international conference on Industrial Engineering and Operation Management, it is mentioned that after having implemented standardized work, transfer times were reduced by 6.5 hours, which represents a reduction of 68.07% over the time initial (Flores et al, 2023). This component begins by verifying the most important activities, according to the impact they have on the company and continues by establishing a series of procedures to direct activities in a more orderly and efficient manner. This allowed better performance in the work area and greater ease for people to do their jobs.

3.2.3 Component 2 - Autonomous maintenance

For the second component, it was proposed to use the second pillar of TPM, autonomous maintenance, as a technique to reduce failures in the mixer and the oven. An investigation published by the IEOM mentions that with the identification and analysis of problems related to the training of the workforce according to Costa et al. (2022). Likewise, it was decided to increase the useful life of the equipment and improve operational efficiency. For this, training was carried out for the company's staff where they were provided with the necessary resources so that they themselves could independently carry out basic inspections and maintenance of the equipment such as: Exterior and interior cleaning of the machine, lubrication of parts. and oil change. This allows downtime to be reduced and employees to develop greater skills.

3.2.4 Component 3 - Planned maintenance

In the third component there is the third pillar of the TPM tool, planned maintenance, this method was used to carry out scheduled maintenance tasks to prevent failures and guarantee the optimal functioning of the equipment. An investigation published by the IEOM mentions that with the identification and analysis of problems related to the training of the workforce according to Costa et al. (2022) In addition, it allows new information to be collected from each inspection carried out, improving operational efficiency and prolonging the use of the equipment for longer.

3.3 Indicators

To carry out the analysis of the project, efficiency indicators were used for production times, whose formula is related to the hours used in production among the available hours available for the work day. Furthermore, to determine the average activity time of the equipment, the MTBF indicator was used where the available time (Td) was divided from which the operating time (To) was subtracted by the number of failures (#Failures). Similarly, to verify the average repair time, the MTTR was used where the repair time (Tr) is divided by the number of failures or a number of repairs.

Table 2. Indicators

Indicator	Definition	Aim	Formula	Result
Efficiency	Operating time compared to available time	Increase the efficiency of the production process to 70%	$E=\frac{horas\ utilizadas}{horas\ disponibles}$	**E = 49.29%**
Mean Time to Failure (MTBF)	Average uptime versus number of failures	Reduce the number of failures by 10%	$MTBF=\frac{Td-To}{\#Fallas}$	Mixer **MTBF = 75.27 min** Kiln **MTBF = 64.2 min**
Mean Time to Repair (MTTR)	Average repair time compared to the number of failures	Reduce repair time by 50%	$MTTR=\frac{Tr}{\#\ Fallas}$	Mixer **MTTR = 3.27 min** **MTTR** oven **= 15 min**

4. Data collection

To determine the search for articles, certain criteria had to be applied to filter them and leave only what provided the information sought for the project. The databases that were most used were Scopus , Sciencedirect , Proquest . The criteria used in this research were: The first criterion that was applied was the year, a range of up to 5 years old was mainly considered, since the more recent the information, the more beneficial it will be; However, some items more than 5 years old but not exceeding 10 years were also considered. As a second criterion, we consider that there is free access to information, be it scientific articles, magazines, among others, to be able to review the complete information. For the third point we decided to mainly use scientific articles with indexed information, however, theses and research projects were also considered. The fourth criterion was that the articles or research projects contain lean manufacturing or TPM tools in the title or in the information. The fifth point was that the articles be in Spanish and English, since they are the languages in which the latter is the universal language and the former is our native language, in addition this way we avoid translating it and distorting the information. Finally, for the last criterion, the key words that are related to the research topic were established, the words we used were: Lean manufacturing , baking industry, food industry, bakery, Food industry , Bakery , 5S, TPM. To summarize the selection process during the search for the articles that were used in this research, it is shown in the following prism diagram, which details everything described above.

5. Results and discussion

5.1 Numerical results

To verify if the process is working correctly, the total process times were taken, as detailed in Table 1, for each activity, as presented below. This shows a lag of 57 minutes compared to other companies.

Table 3. Times of each process

Activities	Time (minutes)
1. Flour transportation	0.5
2. Flour weighing	10
3. Yeast transport	0.5
4. Heavy yeast	10
5. Salt transportation	1
6. Heavy salt	10
7. Transport of butter	1.5
8. Heavy water	12
9. Sugar transportation	0.5
10. Heavy sugar	5
11. Transport to mixer	0.5
12. Pour dry supplies	6
13. Filling with water	1.5
14. Mixed	fifteen
15. Remove dough	5
16. Transport to work table	1
17. Form dough	1
18. Transport to trays	2
19. Transport to the fermentation room	1.5
20. Fermented 1	120
21. Transport to the forming table	1.5
22. Formed	10
23. Transport to the fermentation room	1.5
24. Fermented 2	120
25. Transport to the oven	5
26. Baking	18
27. Transportation to the finished product table	6
Continuation Table 3.	8

28. Place bread on the finished product table	
29. Count and inspect	8
30. Finished product ready for distribution	1
Total	**383.5**

5.2 Graphic results

The company's machines have failures that cause an increase in production time.

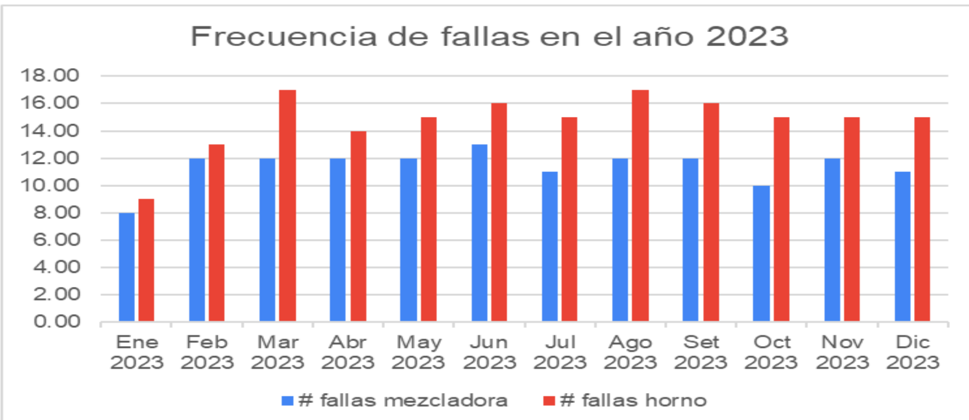

Figure 2. Frequency of machine failures

Furthermore, the company's plant layout is not optimal, because they use the work space and inputs far from each other as seen in Figure 3.

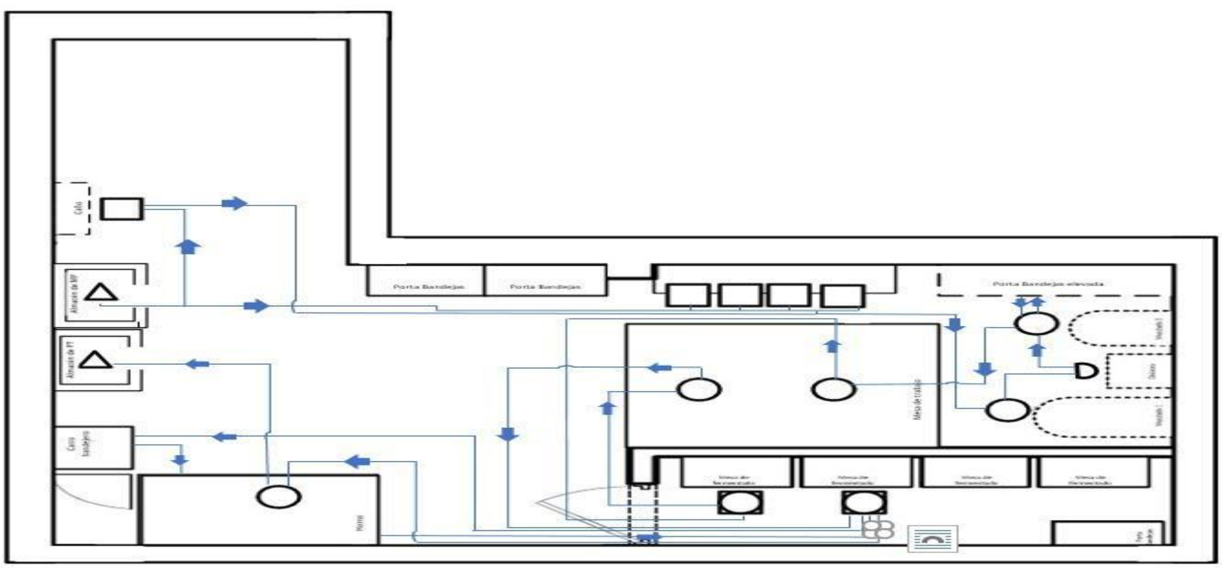

Figure 3. Bakery route diagram

5.3 Proposed improvements

It is desired to implement work standardization in order to reduce times by 10%. The following diagram was made to detail in depth the activities to be carried out, as well as the place, time and person responsible for doing them.

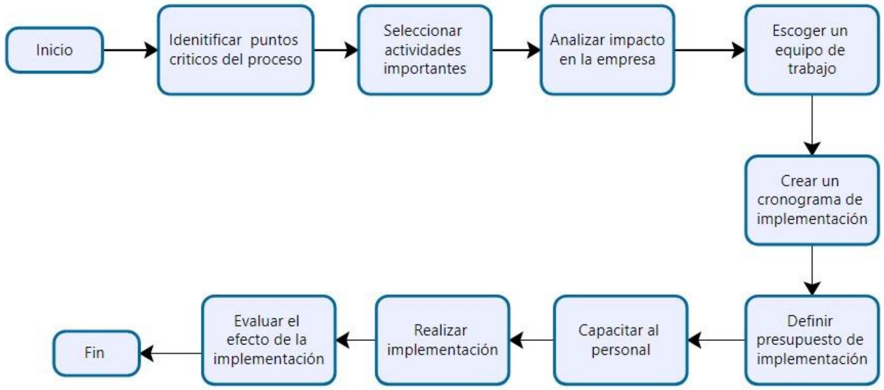

Figure 4. Work Standardization Component

The implementation of the TPM technique is of utmost importance for the company, since they have different machines for the production process, from a mixer to an industrial oven, which work at their maximum productive capacity, and they also lack a maintenance plan. and control, generating that on occasions it stops due to wear of parts, which generates a delay in the production of the day, it is for this reason that it is proposed to apply this tool and thus the plant operators themselves have basic knowledge of how to repair it and carry out maintenance monitoring so that the machines are in optimal condition.

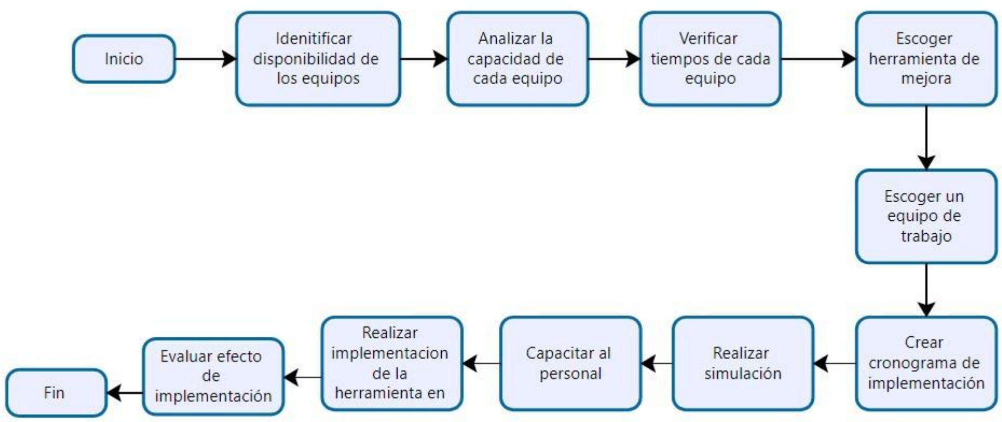

Figure 5. TPM component

5.4 Validation

Taking into account the improvement proposal, a simulation was carried out in the Arena program, which shows the 10% decrease in the activities carried out by the operator, likewise, a decrease in failures by approximately 40% is obtained, since which is reduced from an average of seven mixer failures to four. For this, 160 replicas were made.

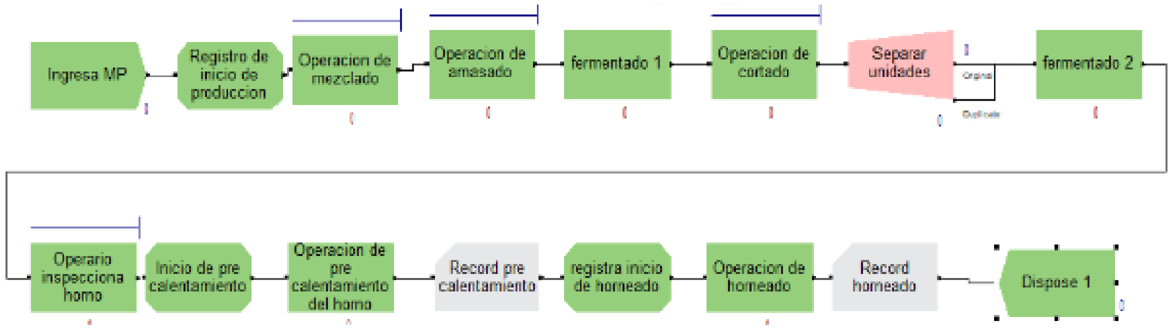

Figure 6. Simulation with improvements

For the economic evaluation, the investment cost variable was taken into consideration, having a positive and negative scenario if this cost decreases or increases. The results are favorable with an NPV of 8,751 PEN and IRR of 57%, because the NPV is greater than zero and the IRR greater than the COK.

With respect to environmental validation, an average of 0.402 was obtained through the Leopold matrix, it is between the ranges 0.4 < 0.49, which indicates a level of significance of little significance; That is to say, during the production process no raw material waste is generated, since with the products that are not sold, new products are made for other uses that also generate income for the company, on the other hand, after implementing the proposed improvements It is expected that energy consumption will be reduced due to the use of the equipment, likewise, it is expected to be able to eliminate the generation of solid waste, responsible consumption of water and thus be able to contribute to the mitigation of pollutants to the environment.

Table 4. Results of the proposed model

Indicator	Initial result	Final score	State
Efficiency	49.29%	70.59%	Accomplished
Mean Time to Failure (MTBF)	Mixer **MTBF = 75.27 min** Kiln **MTBF = 64.2 min**	Mixer **MTBF = 72.89 min** Oven **MTBF = 61.45 min**	Accomplished
Mean Time to Repair (MTTR)	Mixer **MTTR = 3.27 min** **MTTR** oven **= 15 min**	Mixer **MTTR = 2.89 min** **MTTR** oven **= 13.5 min**	Accomplished

6. Conclusions

It was possible to improve the efficiency of more than 20% of the baking SME with a result of 70.59%, through a reduction in the times of each activity carried out by the operator, which was also simulated in the Arena Software. Likewise, the chosen tools resolved the problems found through the Ishikawa and Pareto Diagram, which showed that the main problems were work methods with 42.49% and machines with 25.51%. Regarding validation, on the financial side, a positive NPV was achieved with PEN 8,751 and an IRR of 57%, which was greater than the company's COK; On the environmental side, the result was 0.402, which means that the process does not generate significant waste.

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Biographies

Antonella Díaz – Cornejo tenth cycle student of the Industrial Engineering Degree at the University of Lima. With interest in the area of marketing and project management. He is currently developing a research project on improving the efficiency of a baking SME in Peru with the application of standardized work, autonomous and planned maintenance. This project seeks to optimize production process times and generate greater profitability for the company.

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Alberto Flores-Pérez has a doctorate in Education from the University of San Martín de Porres. Master in supply chain management from the ESAN University and the Universitat Ramon Llull La Salle of Barcelona. Engineer in Food Industries from the National Agrarian University La Molina. He currently works as an undergraduate professor at the University of Lima. Professional with more than 27 years of experience in project implementation, quality management, safety and management of agro-industrial plants. Supply Expert Chain (supplier management, storage systems, transportation modeling and distribution systems), Supply Chain and Operations. Specialization in auditing integrated management systems and Shortsea Logistics at the European Short Sea Shipping School . Specialist in the implementation of Continuous Improvement Projects, PDCA, HACCP and GMP in the agroindustrial sector, trainer for national government institutions and the United Nations (UNDP). Member of IEEE, SCEA Ohio, IOEM and CIP (College of Engineers of Peru).