CONFERENCE ON PRODUCTION SYSTEMS AND LOGISTICS
CPSL 2023-2

5th Conference on Production Systems and Logistics

Improvement Proposal To Increase Productivity Of A SME In The Primary Manufacturing Sector Using Standardized Labor and TPM Tools

Diego Niño De Guzmán-Lunarejo [1], Dahana Anthuanet Obregon-Leon [1] and Alberto Flores-Perez [1*]

[1]Facultad de Ingeniería, Carrera de Ingeniería Industrial,Universidad de Lima, Perú
[*] Corresponding author: alflores@ulima.edu.pe

Abstract

The case study is situated in a SME in the primary manufacturing sector and focuses on increasing its productivity using lean manufacturing tools. First, productivity was identified at 15%, while the average for the sector was 25%, causing a negative economic impact of approximately U$301,309 per year. Through the diagnosis, it was found that the main reasons were machine downtime, caused by various factors such as unplanned downtime and maintenance; the second reason was inadequate sorting of raw material, due to the lack of standardized procedures, lack of protocols and disorder in the sorting area. To address these problems, an improvement model was developed based on 5S tools, standardized work and TPM (autonomous and preventive maintenance). To validate the model, a pilot project of 5S tools and standardized work was carried out through an internal audit conducted before implementing the tool and after its application, an increase in 5S compliance from 29% to 84% was evidenced. Likewise, the standardized work pilot reduced the cycle time of the raw material classification activity from 708 to 539 seconds thanks to the implementation of a procedures format that standardized the process and eliminated activities with no added value. Regarding TPM, it was validated using Arena software, achieving a 2% improvement in OEE and therefore a 19.4% increase in productivity.

Keywords

Productivity; TPM; Preventive Maintenance; Standardized Work; 5S.

1. Introduction

The manufacturing sector is made up of those economic activities that transform the chemical or physical composition of raw materials into new products. It is subdivided into two: manufacturing, which corresponds to the production activities of primary products that are generally used as raw materials, and non-primary manufacturing, which is made up of food and beverages; textiles, leather and footwear; chemicals, rubber and plastics; and non-metallic minerals, among others [1]. Peru is one of the world's largest producers of fishmeal, which is used to formulate balanced feed for activities such as aquaculture, poultry farming, livestock, etc [2].

Fishmeal production has been increasing by 19% on average since 2019, in addition, the contribution of the manufacturing GDP until 2021 had a growing trend reaching up to 13%, likewise it is considered of great importance in the generation of employment since until 2021 it has represented approximately 8.75% of the national Economically Active Population (EAP) [3][4][5]. The present case study has analyzed the non-primary manufacturing subsector because it studies the production of fishmeal from hydrobiological resources.

According to the literature reviewed, it was found that the main problem lies in low productivity due to various factors such as raw material selection, quality, equipment operation, reprocessing, among others. A case study identified as the main problem the amount of waste in the process, due to the lack of quality controls and inadequate transportation of raw material, which was countered with their proposal to apply lean tools such as VSM, Standardized Work and 5S, which reduced on average 33% the cycle time [6]. Similarly, in another case study, they found that their main problem was low productivity due to quality and waste or MUDAS throughout the process, once the waste and its causes were identified, it was proposed to organize the plant and reduce material search times, apply 5S. To achieve a continuous flow in the processes, minimize overproduction and reduce in-process inventories, the Heijunka tool was proposed [7]. Finally, the use of Jidoka was proposed to reduce quality problems and reduce costs due to defective products. In addition, a case study on an SME producer of giant squid concluded that its low productivity was directly related to plant downtime, so it sought to implement the TPM tool to reduce machine breakdowns and improve its production capacity, then apply the tool resulted in the reduction of such times by 39%, increased machine availability by 14% and improved the time between failures by 40% [8].

This case study presents a study carried out in a company that produces waste flour for export from hydrobiological residues. The company's main issue was low productivity, which is present in a similar way in other companies of the Peruvian manufacturing sector. According to a diagnosis carried out, the high number of machine failures, lack of standardized procedures and lack of organization at the workstation were identified as causal factors. These factors caused a slowdown in the production flow, resulting in less production than planned. Productivity was determined throughout the year by the ratio between the tons of finished product and the amount of raw material used, obtaining an average value of 0.15 (Tons of Finished Product / Tons of Raw Material). This value was contrasted with the ratio obtained by the leading company in the sector, which was 0.25 (Tons of Finished Product / Tons of Raw Material). In this way, a technical gap of 0.10 was obtained, thus demonstrating a significant difference in productivity. Additionally, it was identified that the economic impact amounted to U$301,309 per year, primarily due to the unproduced tons of finished product and excessive labor time paid.

This article is composed as follows: introduction, which presents the situation of the sector with emphasis on the main problems, literature review to verify success cases related to the proposal, the methodology of the contribution, validation and finally conclusions.

2. Literature Review

2.1 Improved productivity in the manufacturing sector

Within the manufacturing industry, several improvement models have been developed, applying different methodologies and tools, with the objective of increasing productivity and reducing waste in the different stages of the process. In this sector, low productivity caused by a high level of waste and machine stoppages is recurrent. Therefore, among the solution alternatives, tools such as TPM can be implemented to reduce the frequency of machine stops and tools such as standardized work and SLP to reduce production cycle times, thus increasing productivity and reducing economic losses [9]. On the other hand, a study conducted in the food industry shows as a result a reduction of waste to optimal levels for the industry, thanks to the application of a model based on lean manufacturing tools such as 5S, Standardization and Kanban [10]. In another case study, a low production capacity and the disorder in different areas of the company were evidenced. After implementing the SMED, TPM and 5S tools, the model allowed a reduction of 25% in maintenance times and, at the same time, the training of more qualified personnel to deal with the problem, thus achieving a higher production capacity [11].

2.2 5S

The implementation of the 5S tool promotes cleanliness and order, which has a positive impact on work quality and efficiency. In addition, it helps reduce waste generated during manufacturing processes. By implementing 5S effectively and efficiently, organizations experience significant improvements in productivity. Also, this implementation results in higher profits and increased competitiveness globally in both manufacturing and non-manufacturing sectors [12]. A case study developed in an assembly line, presents the implementation of the tool, where it was possible to reduce the search time from 8.6 h to 3.1 h, thus improving the total process cycle efficiency [13]. Similarly, the 5S were applied with the objective of improving the organization of consumables, which caused a great impact on the efficient operation of workshops and maintenance activities. Thanks to it, a 70% reduction in the time required to locate materials was achieved, which went from 45 seconds to 15 seconds [14].

2.3 Standard Work

Standardized work is a tool used to improve the overall productivity of a company, since it helps to identify areas for improvement by highlighting waste in a process and specifies exactly how work can be performed to gain a competitive advantage [15]. A study conducted in the automotive sector focused on standardizing operations, reducing or eliminating the number of activities that do not generate added value and increasing productivity. Thanks to the implementation of this tool, it was possible to balance the activities, achieving similar execution times. In addition, the new operating methods made it possible to reduce the number of workers required and shorten the distance between operations on the line [16]. Similarly, in another investigation, the tool was applied for reducing activities that do not add value to the product, managing to increase the workstation's capacity, saving 31.6 seconds per cycle, and increasing process productivity by up to 6.5 [15]. In another study, this tool was applied in an assembly line of agricultural machinery, resulting in an improvement in the continuous flow of materials and a significant increase in speed and quality in meeting the assembly line's needs [17].

2.4 Total Productive Maintenance

The TPM tool is defined by some authors as a system designed to eliminate waste such as downtime, unscheduled stops, production slowdowns and defective products [18]. A study conducted in an auto parts machining line implemented TPM in the bottleneck, where a reduction of lost hours due to unplanned maintenance, a 33.21% reduction in lost production and a 10.7% increase in production capacity were achieved [19]. Similarly, the productivity level of an organization was improved by applying a methodology based on the Autonomous Maintenance pillar, with which it managed to reduce the MTTR from 17 to 9 hours and maximize the OEE by 30% [20]. On the other hand, it was designed and applied a sequential scheme to implement TPM in a bottling line, which allowed increasing OEE by 62.6% during after 9 months [21]. Another relevant study, a training plan was carried out to improve workers' skills, resulting in the increase of the MTBF value from 124 to 155, the reduction of MTTR from 5.26 to 4.56 and a remarkable increase in OEE from 95.9% to 97.1% [22]. This tool also allowed the absolute increase in yield by 6.83% and OEE by 6.45% [23]. Finally, a 23% decrease in breakdowns was obtained in the CNC lathes sector and there was an increase in machine availability and OEE of approximately 5% [24].

3. Contribution

To develop an improvement model, a literature review was conducted to find case studies covering problems related to machine downtime, lack of standardized procedures and lack of organization. Unlike other research, the present model applies the TPM, Standardized Work and 5S tools. These tools were selected with the objective of covering some of the main problems of the sector. Likewise, it was identified that there are no studies applied to fishmeal processing SMEs. Table 1 shows the articles selected and the tools used to solve the problems identified.

Table 1: State of the art vs. main problems comparison matrix

Authors	Unplanned shutdowns	Maintenance shutdowns	Lack of standardized procedures
Coppo et al. (2022)	Preventive and Autonomous Maintenance		
Mor et al. (2018)			Standardized Work
Bataineh et al. (2019)	Autonomous Maintenance		
Pinto et al. (2020)	Autonomous Maintenance	Preventive Maintenance	
Santos et al. (2021)			Standardized Work
Rojas et al (2021)			Standardized Work
Proposal	**Autonomous Maintenance**	**Preventive Maintenance**	**Standardized Work**

3.1 Proposed Model

Based on the literature review, an improvement model was proposed to increase productivity in a company of the primary manufacturing sector through the use of three lean manufacturing tools: 5S, Standardized Work and TPM. These tools will be implemented together, with the objective of obtaining a greater impact on productivity improvement, reducing the time lost due to machine stoppages and inadequate raw material classification. As can be seen in Figure 1.1, the proposed model consists of 3 components: Execute protocols and order in the organization, implement standardized procedures and Reduce machine stoppages.

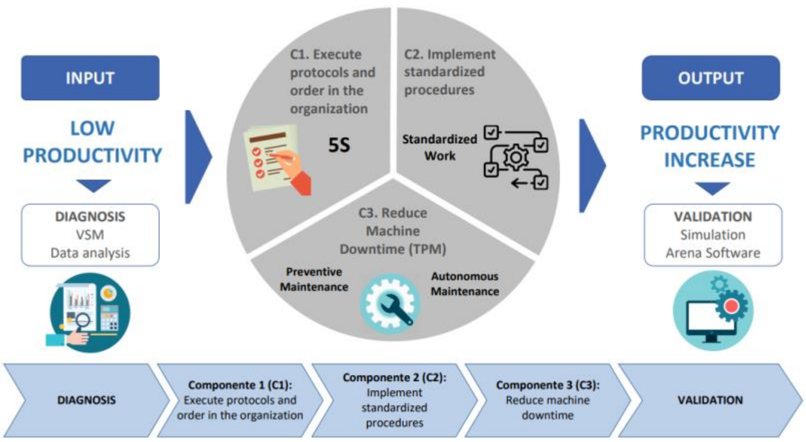

Figure 2: Proposed model

3.2 Model components

The proposed model consists of three components, which are clearly related to the tools to be used for the improvement proposal as shown in Figure 1, each of these will be detailed in greater depth for its subsequent application.

3.2.1 Component 1: 5s

The first phase consists of implementing the 5S tool in the raw material selection area, since it became evident that the operators do not have an adequate and clean space in which they can carry out their activities.

Also, this tool will be used as a basis for implementing the following tools in a more orderly and efficient manner, since, according to the literature reviewed, 5S is responsible for laying the groundwork for applying other tools that can have a greater impact on improving processes.

3.2.2 Component 2: Standardized Work

In this second component, it is proposed to implement Standardized Work, which is one of the tools that allows increasing productivity in companies and is defined as the specific instructions that help to make a product in the most efficient way [15]. This tool consists of elaborating determined procedures, to standardize the execution of operations and previous activities, with the objective of improving the productivity of the operators. At the beginning of this phase, the operations to be improved must be identified and a work sequence must be established so that the operators have a single way of working, as well as determining the standard time and carrying out a continuous control to validate compliance.

3.2.3 Component 3: TPM (preventive and autonomous)

The TPM tool will be implemented with the objective of having an established procedure for the prevention of equipment failures to foresee losses that will affect productivity in the future. From this tool, only 2 of the TPM pillars will be implemented, which are preventive maintenance and autonomous maintenance. For the first pillar, it is necessary to evaluate the equipment in question and diagnose the current situation of them, what they need and identify the causes of this problem. Then the operators will be helped to restore the deterioration of the equipment, correct design weaknesses and extend the life of the equipment through good planning and scheduling of maintenance, schedules for spare parts, lubrication, and the necessary technical information such as data sheets, operating manuals, types of materials and lubricants used by each equipment, etc. Finally, the aim is to standardize maintenance techniques to reduce the frequency of failures of equipment and its parts in order to extend its useful life and make the best possible use of it without losing the quality of the final product.

3.3 Model indicators

To measure the results of the implementation with respect to the initial state of the company, the following indicators will be used.

Productivity: Used to evaluate the number of tons of finished product obtained for each ton of raw material used.

Objective: To increase the productivity level by at least 10%.

$$Productivity = \frac{Metric\ Tons\ of\ Residual\ Flour}{Metric\ Tons\ of\ Hydrobiological\ Residues} \quad (1)$$

OEE: Used to evaluate the overall efficiency of the machines involved in the production process.

Objective: To achieve an OEE of at least 85%.

$$OEE = Availability\ x\ \%\ Yield\ x\ \%\ Quality \quad (2)$$

Cycle time: Used to measure the time it takes to classify a batch of residual flour.

Objective: Reduce cycle time by at least 30%.

$$CT = \sum(\ Total\ Classification\ Time) \quad (3)$$

4. Validation

This chapter will show the results obtained throughout the realization of the case study. First, after a diagnosis of the current situation of the company, the productivity was 15%, which was below the productivity of the sector obtained from the ratios of a leading company in the sector that has a productivity of 25%, which shows the existence of improvements. After implementing the proposed tools, a productivity ratio of 19.3% was obtained, which translates into a productivity increase of 4%. On the other hand, the factors that were related to low productivity were machine stoppages and deficient classification of raw material.

4.1 Initial Diagnosis

Regarding the diagnosis made, Figure 1 shows the trend of the productivity indicator of the case study throughout the year 2022, which was between 10% and 15%, a result below the sector value of 25%, which shows the existence of a technical gap to be improved. The following are the first results to be improved for the identified causes: Deficient classification of raw material and machine stoppages.

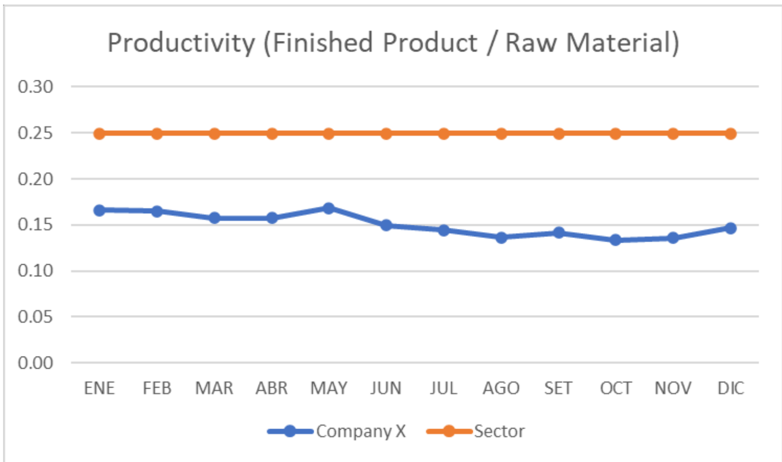

Figure 2. Technical gap in productivity

Table 2 details the activities sequentially for the selection and classification of raw material, which has a cycle time of 708 seconds.

Table 2. Activities of the raw material classification process

N°	Activity	VA/ NVA	Cycle time per operator (seconds)				
			1	2	3	4	Average
1	Receive raw material	VA	304	365	258	350	48.75
2	Load the raw material into the hopper	VA	22	26	19	25	23.034
3	Visually inspect and remove contaminants and unsuitable material.	VA	260	242	299	312	278.2
5	Dispose of contaminants and unsuitable material in the deposition area	NVA	40	38	51.2	36	41.3

6	Collect waste from deposition area and place in container	NVA	160	184	144	200	172.0
7	Take waste to disposal area	VA	167.5	116.58	134	160.8	144.72
Total:							708.00

On the other hand, in the case of machine stoppages, a record of the frequency of failures was obtained for each piece of equipment over the course of a year, as shown in Table 3, which provided a clearer view of the availability and operability of the equipment.

Table 3. Machine stoppages in a year

Equipment	**Frequency**
Mixed stove	40
Rotary pre-strainer	40
Double screw press	40
Wet grinding mill	44
Rotary tube dryer	100
Purifier	32
Dry grinding mill	44
Antioxidant hopper	44
Bagging machine	37

Finally, Table 4 shows the OEE calculation made to verify the current situation of the equipment in use, with a result of 64% below the recommended OEE.

Table 4. OEE case study

Productive hours 2374	Available hours 2880	Availability index 82%
Designed production 2883.65	Produced capacity 3351.62	Yield index 86%
Good production 2595.29	Designed production 2883.65	Quality index 90%
	OEE	**64%**

4.2 Implementation for the pilot plan

According to what was previously described, with respect to the proposed model, it is known that 3 lean tools have been implemented, which are 5S, standardized work and TPM. For the 5S tool, an internal audit was conducted on the current situation of the raw material reception and selection area, which allowed measuring the degree of opportunity for improvement in the mentioned area. It is evident that there is an improvement in the order of the area together with improvements to identify the tools that should be used in the process, since the tool has not been implemented, it can be observed that the organization has a 5S score of 29%, which is very low compared to other companies. Likewise, a minimum score of 85% was defined to be reached after its implementation, however, it reached a value of 84% after applying each one of the 5S in the organization, a training program was carried out for all the collaborators, a team was formed in charge of the implementation and the pilot test was started with the elimination of everything that was not used in that area and occupied space that it should not, A general cleaning of the area was carried out in order to have a cleaner and more hygienic environment, and the health of the workers was also prioritized by placing trash cans that are constantly changed so that waste does not accumulate. The company also seeks to implement measures to ensure that organization and order are complied with following the 5S methodology, which is why a checklist will be used to validate implementation. Finally, activities were established to verify that the 3S already implemented persist over time and reinforce good habits when necessary, through the last 2S.

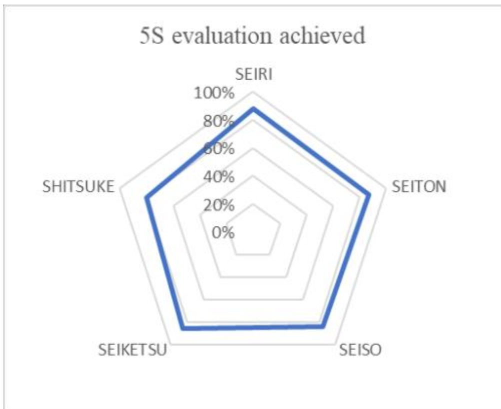

Figure 3. Qualification achieved after implementation

For the standardization of the work, the steps for the selection of raw material were identified, as well as the activities without added value that proceed to be eliminated to speed up the process, without altering the quality of the raw material that will enter the production. In addition, a document was designed to provide a visual presentation of the procedure, facilitating understanding by the operators, and always guaranteeing the application of the new procedure. Figure 4 shows the mentioned document.

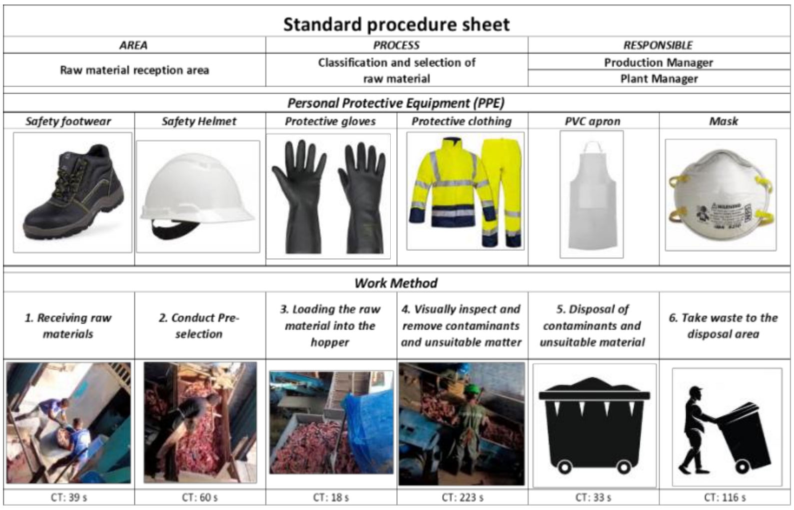

Figure 4. Procedure for raw material classification

Based on the document, the activities were carried out as a pilot test, omitting those that have no added value, thus reducing the initial cycle time. Table 5 shows the most efficient activities and their respective time.

Table 5. Implementation of the standardized procedure

No.	**Activity**	**VA/NVA**	**Average observed time (seconds)**
1	Reception of raw material	VA	44.35
2	Preselection	VA	69.43
3	Load Raw Material into hopper	VA	26.47
4	Visually inspect and remove contaminants and unsuitable material	VA	235.24
5	Deposit contaminants and unfit material in container	VA	36.1
6	Take waste to disposal area	VA	127.37
		Total	538.96

Regarding the improvement proposal for recurring machine stoppages, the TPM tool is implemented in the autonomous and preventive pillars, firstly, the autonomous pillar aims to train operators so that they can perform inspections and adjustments of the equipment when required and have a faster response capacity to any eventuality, A training session was held to introduce the employees to the principles of autonomous maintenance and explain its importance for maintaining high levels of productivity, after which theoretical and practical training is provided in a more specialized way and focused on each of the equipment used in the production process.

Table 6. Autonomous Maintenance Training Program

AUTONOMOUS MAINTENANCE TRAINING	
User profile	**Methods**
Aimed at all production and maintenance related workers: production manager, plant supervisor, maintenance manager, technicians, and operators.	Lectures, slide presentations, videos, group dynamics, presentation of success stories, question and answer session.
Objectives	
1. To introduce the concepts and principles of autonomous maintenance. 2. To raise awareness of the benefits and advantages of autonomous maintenance in the improvement of production efficiency. 3. To learn the steps and activities to be performed for the implementation of the autonomous maintenance program. 4. To learn how to inspect and detect machine failures. 5. Acquire knowledge about corrective actions for the solution of failures. 6. Understand the critical success factors in the implementation of Autonomous Maintenance.	
Description of contents	
1. **Introduction and awareness:** • Concept of autonomous maintenance • Characteristics of an AM program • Benefits of its application • Objectives of the program • Show success stories 2. **Program implementation** • Description of the detailed steps for implementation • Define the tasks of the operators 3. **Technical training** • Fault detection • Root cause analysis • Corrective Actions • Training in equipment cleaning, lubrication, adjustments, and calibration activities.	4. **Audit of the AM program** • Evaluation of standards and procedures • Program performance indicators and metrics. • Checklist to measure compliance with activities. 5. **Actions to sustain the AM** • Evaluation and follow-up of activities • Development of corrective actions • Ongoing establishment of clear goals and objectives. 6. **Success factors of the AM** • Explain the importance of leadership and commitment. • Promote active participation of operators • Establishment of clear standards and procedures
Program duration	
From 06/01/2023 to 06/30/2023	

The procedure detailed in Table 6 will allow the operators to be able to solve any unforeseen failure, to the extent that they can solve it by verifying everything that is stated in the form. Otherwise, the maintenance team should be called to solve major failures.

On the other hand, the preventive pillar of TPM was implemented, with the objective of reducing the frequency of failures so that they operate in the best conditions and do not cause production stoppages, in the same way as for the autonomous pillar, all operators must be trained, and a team must be formed to follow the schedule that will be established. In addition, operating manuals and instructions are required so that operators can detect small failures in time and even act in advance. After implementing these pillars, a 38% reduction in machine stoppages was estimated, an average calculated from a review of case studies where the tool was applied [6][25], so Table 7 shows the new data to be used in the simulation on the reduction of machine stoppages.

Table 7. Machine stops after pilot test

Equipment	Frequency
Mixed stove	24
Rotary pre-strainer	25
Double screw press	24
Wet grinding mill	27
Rotary tube dryer	62
Purifier	19
Dry grinding mill	27
Antioxidant hopper	27
Bagging machine	22

4.3 Simulation improvement proposal

To validate the model proposed in the previous chapters, the simulation software Arena was used to run the results obtained in the pilot test and see the impact it would have on the main indicators which are productivity and OEE. The simulation shown in Figure 5 was designed for the entire production process, from raw material to the production of 50 kg bags of fishmeal. In the first instance, the Input Analyzer software was used to determine the number of samples necessary for the replications in the simulation, of which 30 were used since it is the minimum recommended value for case studies, using a confidence level of 95% and a percentage of error of 10%, and allows obtaining the adjusted distribution for the duration time of each of the operations. On the other hand, two scenarios were considered for the development of the simulation, firstly, with the current machine stops and secondly, the number of stops and repair time reduced after the pilot plan, the purpose of being able to simulate both scenarios is to see the impact on productivity and availability in the mype, as well as to obtain an improvement in the OEE result.

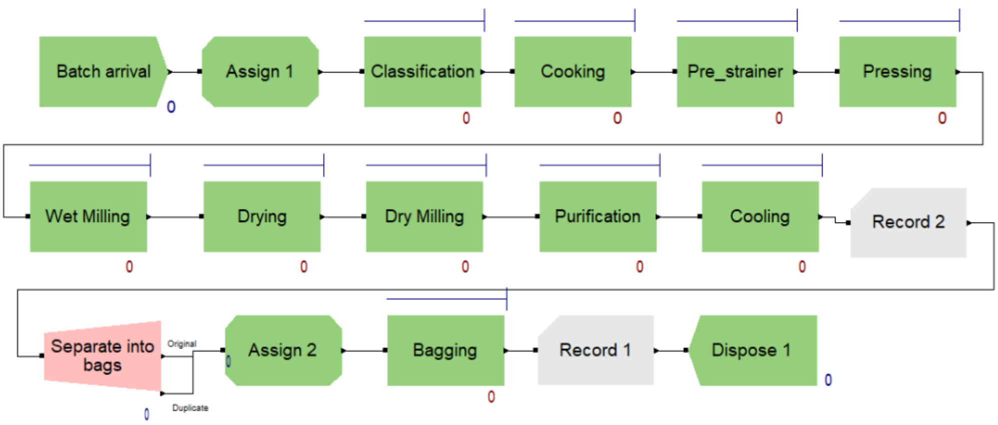

Figure 5. Simulation model of the process in Arena

Next, Table 8 will present the indicators proposed to measure the impact of the implementation of the tools used, with the objective of making a more precise comparison between the initial situation and the scenario obtained after having implemented the proposed tools, through pilot tests for the case of the 5S tools and standardized work and simulation for the TPM tool.

Table 8. Results metrics

Measurement of the improvement project							
Problem	Current	Objective	Enhanced	Indicators	Current	Objective	Enhanced
Low Productivity	15%	25%	19.3%	OEE	64%	85%	66%
				Cycle Time	708 sec.	489 sec.	538.96 sec.
				5S compliance level	29%	85%	84%

5. Discussion

From the literature reviewed it has been possible to verify the existence of various problems in the sector, however a problem constantly mentioned is the amount of wastage [6], in the present case study it is not supposed to be a problem since the case study company manufactures the product from hydrobiological resources therefore, the wastes can be reprocessed in the next batch as raw material.

To develop the proposal, case studies were investigated where the problems present in the sector have been solved and have had quantitative and significant improvements in the companies. Such is the case of a Peruvian company that used the TPM tool to reduce machine stops, managing to reduce the frequency of these stops by 40%, managing to increase OEE by 4%, and improve productivity by 4.3% [23]. Furthermore, in a plastic company, the 5S tool was applied on the assembly line, which allowed them to improve the efficiency of the activities involved and increase the 5S score, from 20% to 80% [13]. Finally, with the objective of eliminating activities that do not generate value in the system, the Standard Work tool was used, where study cases were identified that validate an improvement in their activities after applying it, the case of a line of pre- assembly in a gearbox manufacturing company managed to reduce its total cycle time from 67.53 to 64.69 hours for demand per day [26]. Based on the studies reviewed, it was possible to identify that the results obtained both in the literature and in the present research are consistent, obtaining favorable results in improving productivity. These findings demonstrate the importance of implementing lean tools in the peruvian manufacturing sector to overcome the recurring problems of the sector. In this way, the proposed model can serve as a framework for the application of these tools in other MSEs in the sector.

The research project has proposed the use of TPM tools (preventive and autonomous pillars) and standardization of work to increase productivity, although it is true that a slight improvement was obtained, it is recommended to maintain and further investigate the other problems that occur in the case study company and make use of other Lean tools such as Kaizen to work together with those already proposed. In a case study it could be evidenced that the use of TPM plus Kaizen contributed to reduce the number of losses due to machine stoppage, with this, the OEE increased by more than 10%, this tool would allow to maintain a culture of continuous improvement in the company and thus greater commitment to comply with the standardized work procedures and TPM that were applied in the improvement project [27].

Likewise, one of the main limitations in developing the proposal was the implementation of a lean culture within the case study company because it involved a new way of working and changing the traditional methods to which the workers were accustomed. Often, they tend to resist changes due to uncertainty and lack of confidence in the new methodologies, especially when the workers are not familiar with the benefits that the application of new tools would bring. To counteract this obstacle, training was developed regarding the lean tools to be implemented so that they feel involved and part of the project.

Another significant limitation of this study is that the validation of the TPM was based on a simulation to evaluate and compares the initial and final scenario. However, this could have limited the ability to obtain results that accurately reflect the actual conditions and challenges that could arise during TPM implementation in an everyday work context. Therefore, it is recommended that future research delve into the empirical evaluation of the application of TPM, through its step-by-step implementation and the recording of the corresponding indicators for impact assessment.

6. Conclusion

This study proposes the use of lean tools such as Standardized Work and TPM (autonomous and preventive) to mitigate the identified problem of low productivity. The main causes were identified through engineering tools such as Ishikawa diagram, Pareto diagram and TIS analysis to know them in detail and directly attack each of them. Therefore, a literature review related to the proposed topic was carried out to validate the use of the proposed tools. Based on the improvement model, the tools specified therein were applied.

First, it was possible to demonstrate that the application of 5S allowed to improve order and cleanliness in the area, obtaining a substantial improvement in the level of compliance with 5S, which went from 29% to 84%, since at first the lack of order in the space could be observed with the naked eye. However, thanks to an initial audit it was possible to specifically detect which areas were causing the greatest problem, to be solved and finally evaluated in a final audit. In addition, this tool made it possible to lay the foundations for the implementation of the Standardized Work and TPM tool. Subsequently, a standardized procedure was implemented that detailed the steps to be followed to perform the activity correctly and in the shortest possible time, thus eliminating downtime, thus reducing the cycle time by 23. 88%. Finally, the TPM tool was implemented in the autonomous and preventive maintenance pillars, resulting in a 38% reduction in the number of machines stops.

Regarding the validation of the results, the Arena software and the pilot test allowed the comparison of the results before and after its application. It was also possible to verify that the reduction of machine failures generated an impact on the increase of OEE indicators of 2% and an increase of 4. 3% in productivity.

References

[1] La crisis de la covid-19 y su impacto en la manufactura. (2020, 9 de noviembre). La Cámara. Available: https://lacamara.pe/la-crisis-de-la-covid-19-y-su-impacto-en-la%20manufactura, Accessed on Mar 11, 2023.

[2] Sociedad Nacional de Pesquería. (s.f.). Harina de Pescado: Perú lidera su producción mundial. https://www.snp.org.pe/industria-pesquera/harina-de-pescado/#:~:text=El%20Per%C3%BA%20es%20el%20principal,al%20grado%20de%20una%20harina.

[3] Instituto Nacional de Estadística e Informática. (2023). Población económicamente activa ocupada, según principales características. https://www.inei.gob.pe/estadisticas/indice-tematico/ocupacion-y-vivienda/

[4] Instituto Nacional de Estadística e Informática. (2023). Producto Bruto Interno según Actividad Económica (Nivel 9) 1950 - 2021 (Valores a precios constantes de 2007). https://www.inei.gob.pe/estadisticas/indice-tematico/economia/

[5] Instituto Nacional de Estadística e Informática. (2023). Transformación de productos pesqueros, según giro industrial. https://www.inei.gob.pe/estadisticas/indice-tematico/economia/

[6] Siriban-Manalang, A. B., Brillante, J. B., Cabahug, F. I. V., & Flores, R. P. (2019). Clean & Lean Production in Fish Canning Industry—A Case Study. In Lean Engineering for Global Development (pp. 191–223). Springer International Publishing. https://doi.org/10.1007/978-3-030-13515-7_7

[7] Jimenez, G., Santos, G., Sá, J. C., Ricardo, S., Pulido, J., Pizarro, A., & Hernández, H. (2019). Improvement of Productivity and Quality in the Value Chain through Lean Manufacturing – a case study. Procedia Manufacturing, 41, 882–889. https://doi.org/10.1016/j.promfg.2019.10.011

[8] Gallesi-Torres, A., Velarde-Cabrera, A., León-Chavarri, C., Raymundo-Ibañez, C., & Dominguez, F. (2020). Maintenance Management Model under the TPM approach to Reduce Machine Breakdowns in Peruvian Giant Squid Processing SMEs. IOP Conference Series: Materials Science and Engineering, 796(1), 012006. https://doi.org/10.1088/1757-899X/796/1/012006

[9] Pacheco-Colcas, F. A., Medina-Torres, M. P., & Quiroz-Flores, J. C. (2022). Production Model based on Systematic Layout Planning and Total Productive Maintenance to increase Productivity in food manufacturing companies. Proceedings of the 8th International Conference on Industrial and Business Engineering, 299–306. https://doi.org/10.1145/3568834.3568854

[10] Rojas-Benites, S., Castro-Arroyo, A., Viacava, G., Aparicio, V., & del Carpio, C. (2021). Reduction of Waste in an SME in the Meat Sector in Peru through a Lean Manufacturing Approach Using a Model Based on 5S, Standardization, Demand Forecasting and Kanban. The 2021 7th International Conference on Industrial and Business Engineering, 279–285. https://doi.org/10.1145/3494583.3494592

[11] Valverde-Curi, H., De-La-Cruz-Angles, A., Cano-Lazarte, M., Alvarez, J. M., & Raymundo-Ibañez, C. (2019). Lean Management Model for Waste Reduction in the Production Area of A Food Processing and Preservation SME. Proceedings of the 2019. 5th International Conference on Industrial and Business Engineering, 256–260. https://doi.org/10.1145/3364335.3364378

[12] Chandrayan, B., Solanki, A. K., & Sharma, R. (2019). Study of 5S lean technique: a review paper. International Journal of Productivity and Quality Management, 26(4), 469. https://doi.org/10.1504/IJPQM.2019.099625

[13] Makwana, A. D., & Patange, G. S. (2022). Strategic implementation of 5S and its effect on productivity of plastic machinery manufacturing company. Australian Journal of Mechanical Engineering, 20(1), 111–120. https://doi.org/10.1080/14484846.2019.1676112

[14] Pombal, T., Ferreira, L. P., Sá, J. C., Pereira, M. T., & Silva, F. J. G. (2019). Implementation of Lean Methodologies in the Management of Consumable Materials in the Maintenance Workshops of an Industrial Company. Procedia Manufacturing, 38, 975–982. https://doi.org/10.1016/j.promfg.2020.01.181

[15] Mor, R. S., Bhardwaj, A., Singh, S., & Sachdeva, A. (2019). Productivity gains through standardization-of-work in a manufacturing company. Journal of Manufacturing Technology Management, 30(6), 899–919. https://doi.org/10.1108/JMTM-07-2017-0151

[16] Antoniolli, I., Guariente, P., Pereira, T., Ferreira, L. P., & Silva, F. J. G. (2017). Standardization and optimization of an automotive components production line. Procedia Manufacturing, 13, 1120–1127. https://doi.org/10.1016/j.promfg.2017.09.173

[17] Santos, D. M. C., Santos, B. K., & Santos, C. G. (2021). Implementation of a standard work routine using Lean Manufacturing tools: A case Study. Gestão & Produção, 28(1). https://doi.org/10.1590/0104-530x4823-20

[18] Reyes, J., Alvarez, K., Martínez, A., & Guamán, J. (2018). Total productive maintenance for the sewing process in footwear. Journal of Industrial Engineering and Management, 11(4), 814. https://doi.org/10.3926/jiem.2644

[19] Morales Méndez, J. D., & Rodriguez, R. S. (2017). Total productive maintenance (TPM) as a tool for improving productivity: a case study of application in the bottleneck of an auto-parts machining line. The International Journal of Advanced Manufacturing Technology, 92(1–4), 1013–1026. https://doi.org/10.1007/s00170-017-0052-4

[20] Amorim, G., Hatakeyama, K., & Rojas-Lema, X. (2019). Implantation of Total Productive Maintenance: A Case Study in the Manufacturing Industry (pp. 259–267). https://doi.org/10.1007/978-3-319-93488-4_29

[21] Bataineh, O., Al-Hawari, T., Alshraideh, H., & Dalalah, D. (2019). A sequential TPM-based scheme for improving production effectiveness presented with a case study. Journal of Quality in Maintenance Engineering, 25(1), 144–161. https://doi.org/10.1108/JQME-07-2017-0045

[22] Ribeiro, I. M., Godina, R., Pimentel, C., Silva, F. J. G., & Matias, J. C. O. (2019). Implementing TPM supported by 5S to improve the availability of an automotive production line. Procedia Manufacturing, 38, 1574–1581. https://doi.org/10.1016/j.promfg.2020.01.128

[23] Coppo-Romero, P., Soto-Loncharich, D., Quiroz-Flores, J. C., Flores-Pérez, A., & Collao-Díaz, M. (2022). Application of a Maintenance Management Model based on LEAN TPM to Increase OEE in Canning SMEs. Proceedings of WCSE 2022 Spring Event: 2022 9th International Conference on Industrial Engineering and Applications. https://doi.org/10.18178/wcse.2022.04.037

[24] Pinto, G., Silva, F. J. G., Baptista, A., Fernandes, N. O., Casais, R., & Carvalho, C. (2020). TPM implementation and maintenance strategic plan – a case study. Procedia Manufacturing, 51, 1423–1430. https://doi.org/10.1016/j.promfg.2020.10.198

[25] Quiroz-Flores, J. C., & Vega-Alvites, M. L. (2022). REVIEW LEAN MANUFACTURING MODEL OF PRODUCTION MANAGEMENT UNDER THE PREVENTIVE MAINTENANCE APPROACH TO IMPROVE EFFICIENCY IN PLASTICS INDUSTRY SMES: A CASE STUDY. South African Journal of Industrial Engineering, 33(2), 143–156. https://doi.org/10.7166/33-2-2711

[26] Saravanan, V., Nallusamy, S., & George, A. (2018). Efficiency Enhancement in a Medium Scale Gearbox Manufacturing Company through Different Lean Tools - A Case Study. International Journal of Engineering Research in Africa, 34, 128–138. https://doi.org/10.4028/www.scientific.net/JERA.34.128

[27] Ahmad, N., Hossen, J., & Ali, S. M. (2018). Improvement of overall equipment efficiency of ring frame through total productive maintenance: a textile case. The International Journal of Advanced Manufacturing Technology, 94(1–4), 239–256. https://doi.org/10.1007/s00170-017-0783-2

Biography

Diego Niño De Guzmán (*2001) is a student of the last cycle of industrial engineering at the University of Lima, with experience as an intern in the financial sector, where he gained knowledge about process automation, database management, data analysis and continuous improvement.

Dahana Obregon (*2000) Industrial Engineering graduate from the University of Lima, with experience in laboratories carrying out experimental research projects, as well as applying lean tools for the operation of equipment and the distribution of space in various laboratory projects.

Alberto Flores-Perez has a PhD in Education from Universidad de San Martin de Porres and a master's degree in supply chain management from Universidad ESAN. He holds a degree in Food Industry Engineering from Universidad Nacional Agraria La Molina. Specialist in the implementation of Continuous Improvement Projects, PDCA, HACCP, GMP in the agro-industrial sector, trainer of national governmental institutions and the United Nations (UNDP). He is a member of IEEE, SCEA Ohio, IOEM and CIP (College of Engineers of Peru).