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A model based on TPM, SMED, and Industry 4.0 to increase machinery availability in a fish flour processing company

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Abstract*– Currently, availability is one of the most relevant indicators in the fishing sector. This is because it allows for increased productivity and efficiency, which are affected by unplanned downtime. Additionally, there is a significant amount of research proposing the use of TPM as a solution tool. Furthermore, successful cases recommend the use of SMED for high setup times issues. Technological advancements have also made their way into the food industries, as seen in the case of Industry 4.0. Based on this, the purpose of this article is to improve production and minimize operational costs due to urgent repairs and production losses. The case study is carried out in a fishing company where low machinery availability is one of the main problems. Therefore, the proposed solution model suggests implementing the following TPM pillars along with SMED: autonomous maintenance and planned maintenance. Additionally, the use of Industry 4.0 devices is proposed. Likewise, there is a goal to increase availability by 10% in critical machines in the drying and pressing processes. Furthermore, a 27% reduction in setup time is targeted. In this way, it is believed that the study will contribute to the literature on the implementation of TPM, SMED, and Industry 4.0 tools to increase machinery availability in a fish processing company in Peru.

Keywords-- **Fishmeal, availability, planned maintenance, SMED, Industry 4.0**

I. INTRODUCTION

The fishing sector is one of the most relevant globally, as over the years, the commercialization of its products has increased significantly. This is evidenced by its contribution during 2022, with an international trade value equivalent to USD 151,000 billion [1]. In recent years, Peru has become the leading exporter of fishmeal and fish oil. However, growth was affected by environmental phenomena, resulting in a 13.7% decline in manufacturing GDP [2]. By the end of 2022, the fishing sector experienced a higher export value, reflected in a 6.0% increase, ranking the sector as the third-largest contributor to foreign exchange in the country. Likewise, fishmeal ranks first among all products in the sector, contributing 44.5% to the total [1]. On the other hand, fishing industry facilities involve numerous processes ranging from harvesting to production, marketing, and export of fishmeal, canned goods, fish oil, among others. One of the main problems facing the sector is the need to process catches within a specified timeframe since raw materials cannot be stored in warehouses for more than 2 days [5,6]. Additionally, the fishmeal production process results in a large amount of waste, which is detrimental to plant facilities, the quality of the final product, and the environment. Therefore, a series of regulations must be implemented *[3,5]* within facilities to ensure product quality and compliance with the basic requirements for production sales. Subsequently, [3] indicates that the sector must have fixed plans to ensure cleanliness and order in the workplace.

The raw material yield is an indicator that consists of the variables of plant capacity in finished product and incoming raw material, resulting from the division of the former by the latter [6] [4]. This is an indicator approved by the FAO, establishing that the fishmeal sector maintains a value of 30% [5]. The company in the case study has a raw material yield indicator of 21%. Therefore, there is evidence of a 9% gap compared to the standard. The low level of raw material yield in the company is influenced by unplanned downtime *[7,12]* and high setup times, motivating the search for tools to overcome the situation. Yield is important in companies, as it allows the identification of problems related to process efficiency, availability, and quality [6]. Moreover, the high number of breakdowns resulting from unplanned downtime can compromise other key indicators in the company, such as product quality or delivery time. In previous studies, companies from different countries have sought to increase machine availability and reduce setup times, yielding different results. In a case study within a feed manufacturing company, the implementation of autonomous maintenance and planned maintenance helped achieve a 7% increase in critical machine availability and a 53% reduction in repair time [7]. In another study, the implementation of autonomous maintenance, planned maintenance, and 5S resulted in a 13% increase in availability in the line with the highest number of breakdowns [8]. Similarly, a case study succeeded in increasing availability by 0.16% and reducing annual maintenance costs by 20.32%, thanks to the implementation of preventive maintenance and Reliability-Centered Maintenance [9]. As for setup time reduction, studies by [20] and [36] resorted to using SMED to reduce changeover times by 30% and 35%, respectively.

The involvement of management in implementation is often highlighted in research as a success factor for TPM and SMED. Considering that all the research is deemed highly significant, as it seeks to create a model that can be applied to different companies in the same sector in Peru. This will involve the implementation of two pillars of Total Productive Maintenance: Autonomous Maintenance and Planned Maintenance, along with the SMED tool. To validate it, simulation methods in the Arena software will be employed. Similarly, it also aims to encourage new generations to research the issue and help restore fishing values to pre-2020 levels.

This article will address the State of the Art in Section II, where findings in the literature regarding the tools to be employed are discussed. The third section will develop the proposal's contribution based on the implementation of SMED, autonomous maintenance, and planned maintenance. Finally, the validation of the solution model and the bibliographic references will be concluded in Sections IV and V, respectively.

II. LITERATURE REVIEW

A. TPM Tool

To reduce unplanned downtimes, the implementation of TPM is suggested to improve equipment availability and prevent failures, emphasizing the importance of communication among personnel. A case study achieved an increase in OEE from 71.46% to the initial 68.98% [10]. Likewise, other studies show that the application of this tool led critical areas to reduce unplanned downtime by 34% [11]. On the other hand, innovative approaches combining Industry 4.0 with TPM are proposed, using sensors to collect real-time data and reduce breakdowns. This model allows us to achieve zero breakdowns in the most frequent cases, increasing machinery availability by 12.5% [12]. Furthermore, the combination of TPM and Industry 4.0, focusing on critical machines, is proposed. Although innovative, implementation across multiple machines remains a challenge [13]. Similarly, these studies emphasize the importance of performance indicators, adding methodologies such as DMAIC to improve data analysis and reduce production stoppages [14], [15]. The implementation of TPM methodologies and personnel training are key aspects in these studies [16].

In summary, these studies present a variety of approaches and models to address unplanned downtimes in fish flour processing companies, highlighting the importance of communication, real-time data analysis, and personnel training as fundamental elements to improve equipment performance. At first glance, the articles emphasize the importance of implementing the TPM philosophy to address equipment underperformance, specifically the Overall Equipment Efficiency (OEE) indicator [13]. It is recognized that improving this indicator is achieved through the improvement of its components: quality, availability, with performance being a key component of interest for the present topic. The approach of combining TPM with technological innovations together with STPM to adapt TPM to sustainability and Industry 4.0 [17]. On the other hand, the concepts of these tools allow eliminating problems of excessive times in the production process [18].

B. Asset Tracking

In the literature review, studies are considered where the production system consists of interconnected automated stations, similar to the current case study. [4] states that an appropriate maintenance management strategy is based on breakdown maintenance, preventive maintenance, and condition-based maintenance. Similarly, [39] assumes that inefficient maintenance management results in low availability in production lines with gaps of more than 20% above the target. Through indicators such as mean time between failures and mean time to repair, and Ishikawa diagram analysis, they concluded that one of the main causes was poor management and practice of equipment cleaning and lubrication. [32] applied a VSM where they identified excesses in setup times, reprocessing, and mechanical breakdowns. One of the causes of this problem is the peeling machine, which presents waste in the channels that transport the product. Furthermore, this is detrimental as residues get stuck between compartments, hindering cleaning. Therefore, the activity was assigned to a single operator per station with the assistance of using a rod that can enter compartments that cannot be reached. Similarly, [19] also turns to VSM but uses it to improve process efficiency by eliminating non-value-added activities. This reduces the time spent on these activities by 15.47%. On the one hand, [20] identified high times and costs for maintenance activities due to the large number of worn-out parts during the process. For this purpose, a diagram was used to track maintenance area activities to identify abnormalities. Furthermore, a log sheet describes the anomalies and performs autonomous maintenance based on TPM's Pillar II. On the other hand, [21] employed maintenance strategies based on TPM's pillars. These strategies are categorized into providing instructions, training operators, scheduling, acquiring new resources such as thermometers, and ensuring cleanliness of work areas.

C. Maintenance Management Strategies

The reviewed studies apply the SMED tool with the aim of standardizing work methods and optimizing the time for each activity. In the case of [22], the combined application of SMED and Centerlining is highlighted to maximize results. On the other hand, [23] identify critical activities to reduce their duration, proposing the integration of supervisors and the reorganization of the process. In a similar vein, [24] mentions the presence of other types of waste in the food industry, in addition to the setup times reduced by SMED. [25] use VSM to identify non-value-added activities, proposing the optimization of the number of operators in key stations. Conversely, [26] and [27] address the inefficient distribution of activities, proposing solutions such as plant redistribution and the implementation of VSM. In similar cases, the 5S tool is proposed to improve plant organization, as seen in the studies by [28], [29], where notable improvements in various aspects of the company are evidenced. Finally, tools for reducing breakdowns such as Reliability-Centered Maintenance (RCM), proposed by [9], [30], aim to optimize maintenance costs and improve system availability.

D. *Industry 4.0*

One of the new trends in industrial engineering is Industry 4.0. This has been considered in recent studies for its usefulness in facilitating decision-making and improving maintenance performance in companies. Additionally, it can be aligned with the principles of TPM (TORTORELLA). Industry 4.0 has helped improve availability, productivity, cost reduction, and flexibility in companies. In the study by [7], it was implemented using the internet and IoT services along with TPM pillars to reduce downtime on the most critical machine. Likewise, a maintenance model considered Industry 4.0 to monitor machines in a company and obtain essential operational data to calculate indicators and improve decision-making [13]. The decisions in the case involve better planning, scheduling, and execution of maintenance in a more precise manner. Similarly, a study by [12] also included the use of sensors to implement TPM. In this case, the goal was for sensors to help predict equipment failures and reduce them by 95%.

III. METHODOLOGY

The process begins with draining the anchovy, then cooking where a loss of solids occurs to finally dry it and thus produce fish flour.

A. *Foundation*

Maintaining a high flour performance indicator is highly favorable for the companies that achieve it [7]. Performance indicates the amount of finished flour product according to the anchovy raw material that enters processing [5]. The main obstacles that hinder this indicator are low machine availability and unproductive setup times. Therefore, for the company to optimize flour performance, it must aim to minimize such losses as much as possible. As a reward, it would improve its productivity, economic income, and mainly its competitiveness within the market [8].

Upon reviewing case studies, it can be observed that numerous companies have presented irregularities related to the root causes of the problem. Regarding unplanned downtime due to breakdowns, TPM has often been considered as a solution [16]. The TPM methodology encompasses eight pillars; however, given the resources and time required, few companies can afford to implement all of them. Therefore, autonomous maintenance and planned maintenance tend to be among the pillars that are frequently implemented [7, 8]. In the face of poor cleaning and inadequate preventive maintenance, autonomous maintenance and planned maintenance pillars emerge as suitable pillars due to their characteristics. Likewise, SMED proves to be an effective tool for setup time reduction. Converting internal activities into external ones and optimization help to make the necessary improvements [23]. Therefore, the use of both tools is considered as the solution model for improving the performance of critical machines in the present case study company. In implementing the SMED technique, the study by [23] was considered. Similarly, for the development of autonomous maintenance and planned maintenance pillars, the

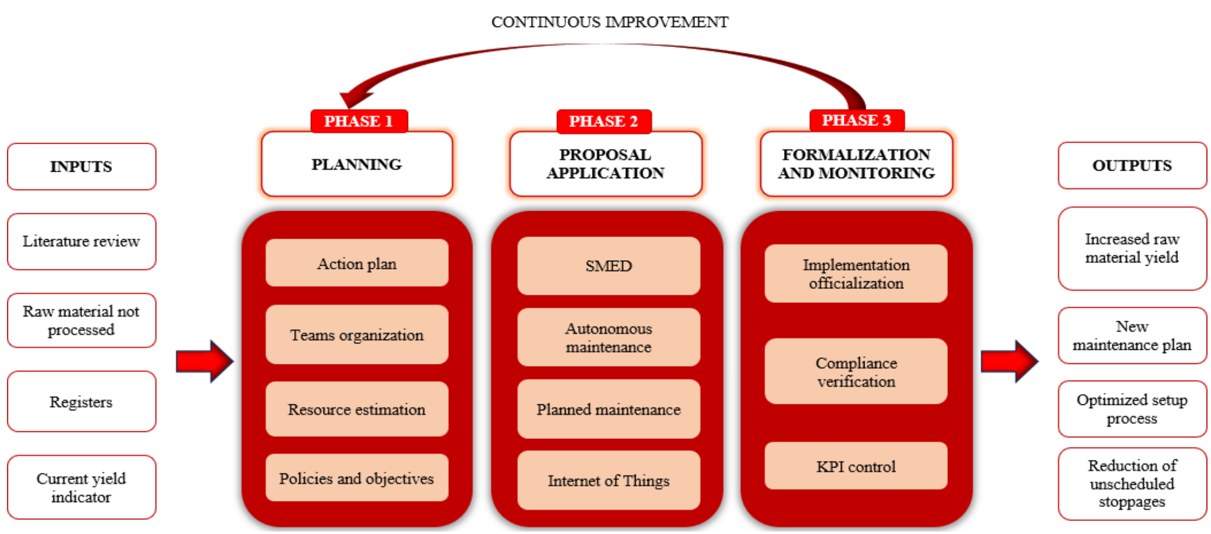


Fig. 1 Proposed Solution Model

works of [8] and [7] respectively were used as guides.

B. Proposed Model

The researchers proposed a model composed of three phases ranging from planning to formalizing the proposal. Thus, through the analysis of the collected data, inputs and outputs were established according to the main problem, which is the low raw material performance. In Figure 1, the graphical model based on the models of [7], [8], [35] can be observed.

The model is formulated in such a way that the completion of each of the three phases will result in an increase in flour performance as the main outcome.

The process begins with the planning phase. This phase has been considered important in other case studies, where it is noted that in such projects, objectives, resources, and action plans for the tools must be established [4]. In the second phase, solution techniques are implemented. It starts with SMED, a tool that [22] used to reduce changeover times in a food company. Subsequently, autonomous maintenance and preventive maintenance are implemented. This sequence is based on the sequence carried out by the authors [13], [36].

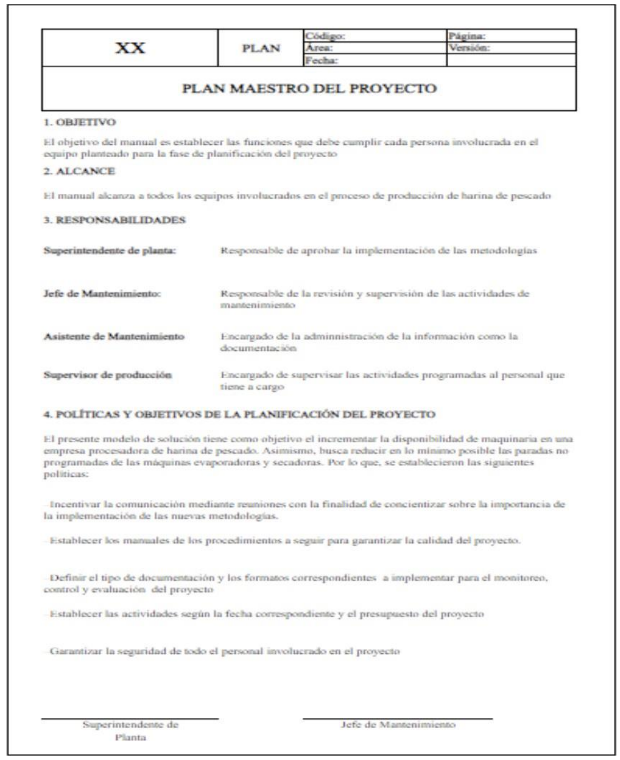
In this stage, it is important to train operators in critical areas to carry out basic maintenance activities on their own. Similarly, for planned maintenance, the development of a maintenance plan with preventive activities is proposed. Finally, the verification and monitoring phase correspond to the closure of the model. According to [3], it is essential to verify the results and compliance with the policies and objectives formulated at the beginning.

With the implementation of the model, the aim is to address the three root causes, emphasizing 83% of the reasons for the problem.

C. Model Detail

1) Phase 1: Planning

- **Action Plan:** Detailed plan of all implementation activities is elaborated. This must be reviewed by management.
- **Team Organization:** The organizational chart of maintenance teams is developed for the implementation of the pillars. It may consist of workers of different ranks such as operators, supervisors, and area managers.
- **Resources:** The materials needed are listed. In the case study, manuals, PPE, office supplies, among others, are considered.
- **Goals and Objectives:** Policies and objectives are established to guide the implementation. It is important that management ensures their commitment in writing in this section, following the review of the master plan.



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		Area:	Versión:
		Fecha:	

PLAN MAESTRO DEL PROYECTO

1. OBJETIVO

El objetivo del manual es establecer las funciones que debe cumplir cada persona involucrada en el equipo planteado para la fase de planificación del proyecto

2. ALCANCE

El manual alcanza a todos los equipos involucrados en el proceso de producción de harina de pescado

3. RESPONSABILIDADES

Superintendente de planta:	Responsable de aprobar la implementación de las metodologías
Jefe de Mantenimiento:	Responsable de la revisión y supervisión de las actividades de mantenimiento
Asistente de Mantenimiento	Encargado de la adminnistración de la información como la documentación
Supervisor de producción	Encargado de supervisar las actividades programadas al personal que tiene a cargo

4. POLÍTICAS Y OBJETIVOS DE LA PLANIFICACIÓN DEL PROYECTO

El presente modelo de solución tiene como objetivo el incrementar la disponibilidad de maquinaria en una empresa procesadora de harina de pescado. Asimismo, busca reducir en lo mínimo posible las paradas no programadas de las máquinas evaporadoras y secadoras. Por lo que, se establecieron las siguientes políticas:

-Incentivar la comunicación mediante reuniones con la finalidad de concientizar sobre la importancia de la implementación de las nuevas metodologías.

-Establecer los manuales de los procedimientos a seguir para garantizar la calidad del proyecto.

-Definir el tipo de documentación y los formatos correspondientes a implementar para el monitoreo, control y evaluación del proyecto

-Establecer las actividades según la fecha correspondiente y el presupuesto del proyecto

-Garantizar la seguridad de todo el personal involucrado en el proyecto

Superintendente de Planta

Jefe de Mantenimiento

Fig. 2 Master Plan

2) Phase 2: Design of the proposal

a. Tool 1: SMED

- Equipment Identification: The most important components of the machines are identified.
- Preventive Maintenance Plan: The preventive maintenance plan is developed. This program includes maintenance activities, the person responsible for performing them, and the required frequency.
- Maintenance Scheduling: A schedule is created with important dates for maintenance activities.
- Information Management: Formats are included to track common failures.
- Review of New Anomalies: TPM cards are used to allow operators to report new anomalies on their machines.
- Sensor Installation: Proximity sensors are installed on critical area machines such as drying and pressing. These should not compromise functionality.
- Sensor Programming: The installed sensors are programmed to collect real-time data.
- Planned Maintenance Audit: Conducted to assess progress with the implementation of this pillar.

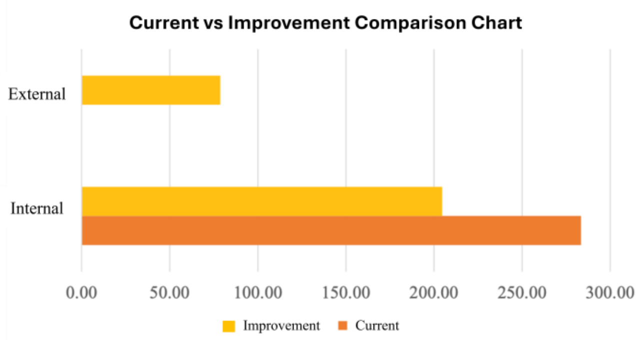

Fig. 3 Master Plan

b. Tool 2: Autonomous Maintenance

- Work Team Organization: Teams are formed to guide the implementation of the TPM methodology in the company.
- Workshop Policies Definition: Standards to be followed by participants in training workshops are established.
- Procedure Identification: Activities comprising the cleaning and lubrication process for the drying machine are identified.
- Maintenance Instruction Creation: Detailed maintenance activity instructions for the drying and separating machines are developed. These instructions guide operators on how to perform cleaning and lubrication.
- Topics Selection for Development: Topics and duration for autonomous maintenance training sessions are planned.
- Visual Resources: Posters are created to inform staff about TPM training sessions. Similarly, slides are prepared for presentations.
- Task Allocation: Maintenance area tasks are assigned to machine operators. Activities that do not require technical knowledge and are performed frequently should be considered.
- Autonomous Maintenance Audit: The implementation status of the pillar is assessed.

c. Tool 3: Planned Maintenance

- Equipment Identification: The most important components of the machines are recognized.
- Preventive Maintenance Plan: The preventive maintenance plan is developed. This program schedules maintenance activities, assigns responsibility for performing them, and establishes their frequency.
- Maintenance Scheduling: A schedule with important maintenance dates is created.
- Information Management: Formats for tracking common failures are included.
- New Anomalies Review: TPM cards are used by operators to report the presence of new anomalies in their machines.
- Planned Maintenance Audit: Conducted to evaluate progress regarding the implementation of the pillar.

d. Tool 4: Industry 4.0

To develop IoT in the phase, it is important to select the appropriate sensors for critical equipment such as the press and dryer. These sensors must be able to adapt to the machine without compromising its operation. The selected sensor is the Column Load Cell, which allows for identifying the force applied at a specific point. These will be positioned in the couplings and bearings. Additionally, a microcontroller, specifically a Raspberry Pi, will be used to collect data from the cells and send it to the cloud via Wi-Fi and/or Bluetooth.

Once established, proximity sensors are installed on the machines in critical areas, such as drying and pressing. After that, the installed sensors are programmed to collect real-time data. Finally, an appropriate platform is selected for the situation to gather the information, and the system is configured to send alerts and notifications in case anomalies are detected. In this case, the selected platform is Google Cloud IoT.

XYZ	Plan de mantenimiento planificado para máquina prensadora				Versión: 01 Fecha: 4/3/24
Componente	**N°**	**Descripción de actividad**	**Frecuencia**	**Insumos necesarios**	**Responsable**
Cojinete	1	Comprobar el nivel de aceite.	Semanal	Lubricante Texaco Multifak EP	
	2	Abrir caja del cojinete y verificar la emisión de ruidos inusuales .	Semestral		
	3	Revisión completa del componente.	Cada 2 años		
Sello	4	Comprobar estado de los sellos.	Semanal	Lubricante Texaco Multifak EP	
	5	Revisión completa del componente.	Semestral		
	6	Lubricar engranajes.	Cada año y medio		
Correas en V	7	Comprobar tensión y ajustar en caso de ser necesario.	Semanal		
Motor	8	Comprobar y lubricar cojinetes.	Cada dos semanas	Manual del motor	
Reductor	9	Hacer primer cambio de aceite.	Después de 2 semanas	Aceite acorde a temperatura y medio ambiente Manual del reductor	
	10	Comprobar calidad y nivel de llenado del aceite. Limpiar filtro de aire en caso de presión baja de aceite.	Trimestral		
	11	Comprobar vibraciones o aumentos repentinos de temperatura.	Regularmente con la máquina prendida		
Placas perforadas	12	Comprobar desgaste. Sustituir en caso de daño.	Trimestral		
Horquillas basculantes	13	Apretar pernos según valores de par de apriete.	Cada 2 semanas (operación continua)		
	14	Apretar pernos según valores de par de apriete.	Mensual (operación continua)		
	15	Abrir jaula de prensa , verificar montaje y fijación correcta y comprobar desgaste.	Trimestral		
Husillos	16	Comprobar desgaste.	Trimestral		
Observaciones:			**Jefe de Mantenimiento**		

Fig. 4 Preventive maintenance plan

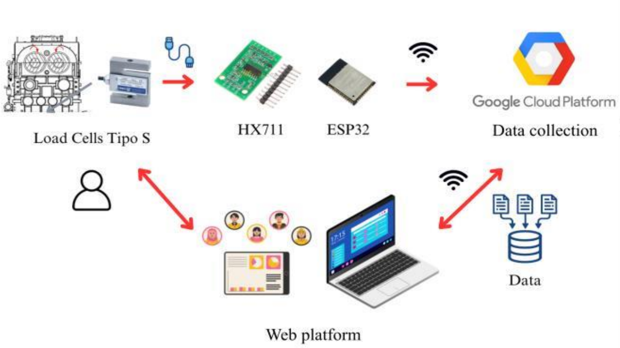

Fig. 5 Industry 4.0 Implementation Diagram

3) *Phase 3: Verification and Monitoring*

- Project Initiation Letter: The implementation of the project is officially announced through a letter.
- Control Records: Formats are designated for monitoring compliance with the activities established in the instructions.
- Indicator Records: Indicator sheets are prepared to track changes post-implementation.

XYZ	FICHA DE INDICADOR			Versión 1: Pág 1 de 1
Nombre de la organización	Empresa procesadora de harina de pescado XYZ			
Nombre del indicador	Disponibilidad de maquinaria			
Nombre del proceso	Prensado			
Objetivo del indicador	Determinar la disponibilidad de la máquina que trabaja en el proceso de prensado de la harina de pescado			
Meta del resultado	Superior al 90%		Escala de medición	Porcentaje
Plazo de cumplimiento	Última semana del mes		Tipo de indicador	Indicador de resultado
Expresión matemática	$\frac{TT - TPNP}{TT} * 100\%$			
Leyenda	TT: Tiempo total			
	TPNP: Tiempo de paradas no programadas			
Nivel de referencia de cumplimiento	Crítico	Menor al 70%	Tendencia esperada (Aumentar o disminuir)	Aumentar
	Riesgo	Entre 70% a menos de 90%		
	Adecuado	Mayor o igual a 90%		
Fuente de información	Registro de paradas no programadas			
Frecuencia de medición	Diaria		Frecuencia de reporte	Mensual
Responsable de medición	Coordinador de área		Destinatario del reporte	Jefe de prensado
Seguimiento y gráfica				
Observaciones	Las fuentes de información se cargan en la base de datos de Excel			

Fig. 6 Availability indicator control traffic light tab

D. *Proposed Model*

The proposed model follows a sequence of steps to implement its three phases. In Figure 8, the corresponding steps for carrying out the planning of the tools in the company are shown.

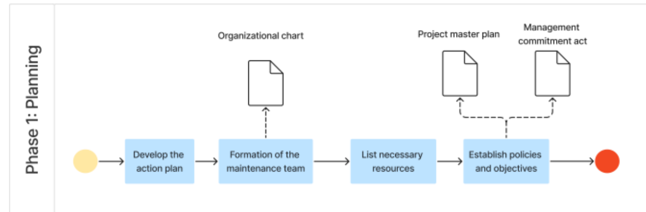

Fig. 7 Flowchart of the planning phase

In Figure 9, the sequence for implementing SMED, autonomous maintenance, and planned maintenance is established.

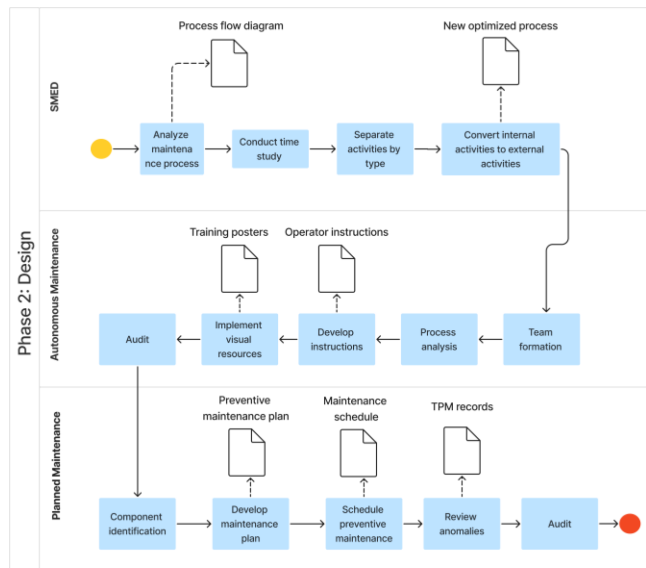

Fig. 8 Flowchart of the design phase

Finally, Figure 10 represents the process of the last phase corresponding to verification and monitoring.

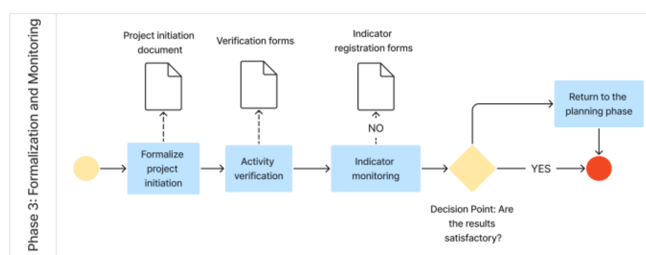

Fig. 9 Flowchart of the verification and monitoring phase.

E. *Model Indicators*

The proposed solution model aims to increase flour processing, machinery availability, reduce unplanned downtime, and decrease setup time. Therefore, based on the reviewed articles, indicators have been proposed considering other case studies with similar goals to the current case. Table 1 shows the proposed indicators.

TABLE I
PROPOSED INDICATORS

Indicators	AS-IS	TO-BE	Papers
Fishmeal Yield	21%	30%	[5]
Availability	81.5%	91.9%	[7], [8], [37]
Unplanned Downtime	1993.14 hrs	1390.8 hrs	[11], [38]
Setup Time	283.4 min	205.2 min	[19], [23], [39]

a) Indicator 1: Fishmeal Yield

This is the primary indicator of the case study. It is expected that its value will increase to approach the stipulated target.

$$Yield = \frac{Plant\ capacity\ in\ finished}{Required\ raw\ material} \qquad (1)$$

b) Indicator 2: Availability

Represents the relationship between the time the equipment operates and the total time they should operate.

$$Availability = \frac{\text{Total time} - \text{time of unscheduled stoppages}}{\text{Total time}} \qquad (2)$$

c) Indicator 3: Unplanned Downtime

Unplanned downtime refers to the hours during which the machines stopped when they were not scheduled.

$$\text{Unplanned Downtime} = \text{Total Time} - \text{Scheduled stoppages} \qquad (3)$$

d) Indicator 4: Setup Time

Represents the preparation time for working with the machines. This becomes evident during shift changes in the company.

$$\text{Setup Time} = \text{Current setup time} - \text{New setup time} \qquad (4)$$

IV. VALIDATION

For the selection of the validation method, the literature review of this article was considered. In which, 2 validation methods were identified: implementation and simulation [40].

In the case of implementation, a defined structure must be followed to ensure that the project is efficient through testing, documentation, and monitoring. Likewise, this seeks to develop a detailed plan that must include a master plan, policies, criteria, resources, schedule, and indicators. On the other hand, simulation consists of creating project scenarios using models or simulators to evaluate the proposal in a real case study. Therefore, it is considered that through this, possible problems can be identified, thus being able to correct the model in such a way that it meets the established objectives in the project. Similarly, it allows evaluating performance and efficiency, generating greater flexibility and control of the proposal. Unlike the first method, this can be adjusted quickly and represents different problems that can be addressed during implementation. Even these two methods can complement each other for validation development because simulation would reduce risks and address potential problems that may occur during the proposal. That is, simulation allows the identification of possible bottlenecks and prevents damage to equipment, generating greater security over them. Finally, this validation method will be implemented within the case study since it allows versatile representation, reducing the costs generated by tests in real scenarios.

As a first step in the validation method selection, the literature review of validation models of case studies implementing TPM and SMED as proposed solutions will be considered. In the case of [41], Arena software is used to simulate preventive maintenance processes, considering that with the proposal, these will be carried out, and the rest of the maintenance activities will be performed by other operators.

Unlike [22], which uses implementation where it defines operations, objectives, technical support, methods, data collection, and resources to be implemented. In this case, an additional study is being carried out to measure the possible risks that may affect SMED and the factors within the company that should be considered. To use a simulator for the data collected during implementation. On the other hand, for the TPM implementation, the same validation methods were determined, but mostly these are implementation. In the research of [42], a plan for implementation based on experimental type is carried out. In which, samples are taken to demonstrate that proper equipment lubrication and cleaning significantly minimize the proliferation of microorganisms. In addition, using experiments with other types of materials as a risk control method is performed. To avoid any problem that may arise during project execution. Compared to [8], where the authors create a flowchart of the project's master plan where they define all processes from planning to continuous improvement. In this case, the way in which the plan's risks are managed is through the PDCA cycle, where the effects are analyzed, and the system's improvement is evaluated. To generate that the proposal is in constant continuous improvement in front of all scenarios that appear during the plan's development. From all the, it is proposed to use simulation as the validation method for the solution model.

In this article, 2 methodologies are proposed to be implemented, which are SMED and TPM. First, SMED is used with the purpose of reducing setup times for shift changes generated in the separator machines. On the other hand, in the case of TPM, autonomous and planned maintenance pillars will be used to ensure the correct execution of maintenance activities. Therefore, the times taken to perform the separator machine preparation activities will be needed as inputs. Likewise, the times for breakdowns due to inadequate cleaning and/or lubrication will be needed. Finally, the time for stops due to motor vibrations generated by material overload will be needed. Below, Figure 11 shows the flowchart of the validation model based on the research of [41] and [43].

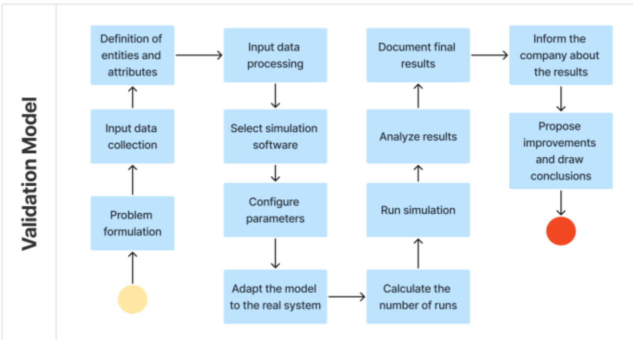

Fig. 10 Flowchart of the validation model

A. Initial Diagnosis

The case study company is engaged in the processing and preservation of products derived from fish. The main product by sales share and production volume is fishmeal made from anchovies.

During the year 2023, there were numerous unplanned machine downtimes in the fishmeal production line. Using a Pareto diagram, machines with the highest downtime throughout the year were classified. Figure 12 shows the machines with the highest downtime in hours.

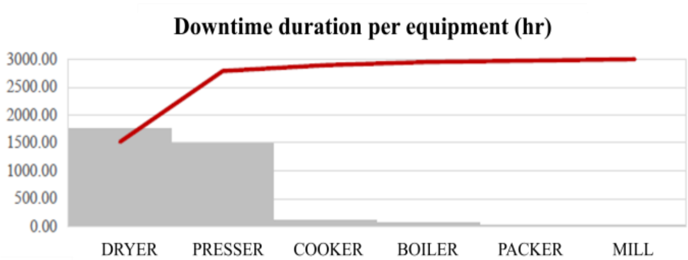

Fig. 11 Equipment Downtime in Hours 2023

Unscheduled downtimes in the drying and pressing machines posed problems for the company as they resulted in lower availability compared to standard values and consequently, limited tonnage production. Figure 7 displays the machinery availability percentages in the company during the months of the year 2023.

B. Design of validation

As mentioned earlier, Arena software was chosen to conduct simulation validation. The fish flour production line serves as the basis for representing a system in the program. To meet its characteristics, the number of subprocesses, Once the validation of the proposed solution had been carried out, 3 scenarios were proposed with respect to the original state to obtain results.

operators, and collected data will be utilized. Therefore, batches are considered as transit entities and operators as permanent entities in each work process. Accordingly, a graphical representation of the system was created, as shown in Figure 8, to enhance understanding.

Within the scope of the improvement proposal analysis, the goal is to assess downtimes across the entire production line, given the absence of auxiliary processes. It is important to emphasize the evaluation of production and downtimes during the process.

C. Results Analysis

In Table 2, the results of the simulation performed in the Arena software can be observed. In this case, improvements were made by modifying the parameters within the same program, as the construction of this program included stops, times, and related processes. Similarly, three improvement scenarios were proposed based on the mentioned indicators.

The indicators are defined as: AS-IS Current operational baseline (81.5% availability,283.4 min. setup time), Pessimistic: Minimal improvement (5.1% availability gain) Moderate: Realistic targets, and Optimistic: ideal outcomes.

TABLE II
INDICATORS

Indicators	AS IS	Pessimistic	Moderate	Optimistic
Additional Batches		23	44	57
Availability	81.5 %	5.1%	11.1%	15.9%
MTBF Improvement	18.89	11%	20%	25%
MTTR Improvement	4.29	18%	25%	30%
Setup Downtime Reduction		15%	29%	40%

The results obtained from the simulator in the three proposed scenarios in the research achieve one of the main objectives, which is to decrease the MTBF indicator by 20%, the MTTR by 25%, and the setup time by 29%. The main goal of increasing availability by 11% in the moderate scenario is also met.

V. DISCUSSION

A. Main Results

Once the validation of the proposed solution had been carried out, 3 scenarios were proposed with respect to the original state to obtain results.

In the pessimistic scenario, the improvement is not very significant; however, this represents the situation in which there are more obstacles than necessary for the implementation of the project. In this case, the improvement in availability would be 5.1%, reaching 85.6%. The moderate scenario is the most realistic. It considers the situation of the industry and its capacity to face challenges of this magnitude. In a moderate scenario, an improvement of 11.1% is expected to surpass the target barrier and reach 90.5%. Unlike the previous cases, the optimistic scenario contemplates that the implementation will be successful and that the company will adapt it by requiring everything necessary.

Thus, an improvement of 15.9% could be obtained, resulting in final availability of 94.4%. In summary, the results may vary depending on the scenario. It is important to mention that in all cases an improvement is experienced, therefore, the solution would be to fulfil its purpose.

B. *Scenarios vs Results*

Since there are different scenarios, the results obtained vary as well as their impact. In the case of the economic impact, a cash flow is obtained for each scenario obtained, where the following parameters shown in Table 3 are considered.

TABLE III
CASH FLOW CONSIDERATIONS

Investment	s/ 66,110.00
Value per sale	s/ 6,080.00
Variable costs	s/ 4,400.00
Employee participation	10%
COK discount rate =	20%

Pessimistic scenario: The first scenario increases availability by 5.1%. Consequently, this leads to an increase in flour production. An NPV (Net Present Value) value of S/. 9,660 and an IRR (Internal Rate of Return) of 26% is obtained. Moderate Scenario: In the second case, availability is increased by 11.1%. By experiencing this improvement, an NPV value of S/ 78,842 and IRR of 66.9% is obtained. Optimistic scenario: In the third scenario, higher profits are expected due to higher production. Availability increases by 15.9% compared to the original scenario. An NPV value of S/ 121,669 and IRR of 89.79% is obtained.

In all 3 cases, seeing that the Net Present Value is always greater than 0 and the Internal Rate of Return is higher than the discount rate of 20%, it is concluded that the proposed solution is economically viable.

VI. CONCLUSIONS

This research presents a solution model applied in a fish flour processing company where the following pillars of TPM, along with SMED and Industry 4.0, were utilized: autonomous maintenance and planned maintenance. The emergence of new technologies has allowed for the automation and improvement of efficiency in numerous processes within the food sector. Therefore, its application in fish flour processing companies is highly beneficial, given that processes tend to be complex, and their monitoring is contingent on the problems encountered during production.

Within the case study, a low processing of fish flour was identified, an indicator commonly used in the sector to gauge process performance. Through database analysis, it was evident that the problem was in the pressing and drying machines. Additionally, this low availability was primarily due to frequent downtimes in these machines. These were caused by inadequate cleaning and lubrication of equipment, material overload, and excessive machine setup times.

Therefore, through literature review, the necessary tools to address these issues were identified, namely TPM, SMED, and Industry 4.0. This enabled the simulation of proposed improvements, resulting in significant percentage improvements in key indicators, specifically reducing MTBF by 20%, MTTR by 25%, and Setup by 29%.

The seafood industry has not been studied much in terms of equipment availability. The sector faces several variables that affect its production; however, studies tend to focus more on the chemical and physical factors of the products. The use of tools such as the TPM and SMED pillars has been successful in numerous industries, however, their application in fishmeal companies is still uncommon. Thus, it is expected that the present work will contribute to the problems of machine availability in the sector. Likewise, the use of technological devices for the Internet of Things can improve such problems, showing progress and flexibility in maintenance management within similar companies.

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