Criticality analysis of production equipment in a coffee processing company

Análisis de criticidad de los equipos de producción en una empresa procesadora de café

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Abstract

This project seeks, through the implementation of a criticality analysis, to control and improve the availability of the equipment, allowing a correct planning and programming to carry out the maintenance activities and also not to affect the internal processes when intervening with repair activities. The research is developed through a quantitative approach since observation is applied in order to collect numerical information. This work was developed in the field, it is a descriptive type of research, its purpose is to observe, describe and determine the level of criticality in the maintenance equipment. In addition to the design, a criticality analysis was carried out on 357 pieces of maintenance equipment using the risk matrix tool, of which 120 were critical according to the evaluation carried out. These critical equipment were prioritized to receive more frequent and rigorous preventive maintenance, with the objective of minimizing possible failures and guaranteeing the company's operational continuity. In addition, an action plan was established to address the deficiencies identified in the non-critical equipment to improve its performance and extend its useful life.

Criticality Analysis, Reliability, Maintenance

Resumen

En el presente proyecto se busca, a partir de la implementación de un análisis de criticidad controlar y mejorar la disponibilidad de los equipos, permitiendo una correcta planificación y programación para llevar a cabo las actividades de mantenimiento y así mismo no afectar a los procesos internos al intervenir con actividades de reparación. La investigación se desarrolla mediante un enfoque cuantitativa puesto que se aplica la observación para poder recolectar información numérica. El presente trabajo se desarrolló en campo, es una investigación de tipo descriptivo, tiene como propósito observar, describir y determinar el nivel de criticidad en los equipos de mantenimiento. Se logró además de diseñar, llevar a cabo el análisis de criticidad sobre 357 equipos de mantenimiento mediante la herramienta matriz de riesgos, de los cuales 120 resultaron críticos de acuerdo a la evaluación realizada. Estos equipos críticos fueron priorizados para recibir un mantenimiento preventivo más frecuente y riguroso, con el objetivo de minimizar posibles fallas y garantizar la continuidad operativa de la empresa. Además, se estableció un plan de acción para abordar las deficiencias identificadas en los equipos no críticos y así mejorar su rendimiento y prolongar su vida útil.

Análisis de criticidad, Confiabilidad, Mantenimiento

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Introduction

The use of risk analysis techniques involves searching for and evaluating scenarios that may have a negative impact on a facility or production line, identifying the most risky scenarios and issuing recommendations for actions to minimise the risk (Aguilar-Otero et al., 2010). Criticality analysis is based on the evaluation of the risks associated with each process, system or equipment, considering factors such as the probability of failure and the impact it may have on the operation. In addition, this methodology allows identifying opportunities for improvement and establishing preventive maintenance strategies to minimise unplanned downtime (Díaz-Concepción et al., 2019).

The criticality analysis method allows knowing the level of importance and priorities of facilities, systems and activities it allows establishing ranges to make a representation of the probability and frequency of occurrence of events or errors, as well as possible occasional events (Omar Campos-López et al., 2018). Criticality analysis is a widely used tool in risk management, as it allows identifying and prioritising those events that could have a greater impact on the operation of the Facility, System, Equipment or Device. In addition, this technique facilitates decision-making by providing a clear and concise visual representation of the associated risks (Daquinta-Gradaille et al., 2018).

This analysis allows identifying the critical elements that could have a significant impact on the operation of the plant and establishing the necessary preventive and corrective measures to minimise the associated risks (Álvarez, David; Rosero, Laura.; García, 2019). In addition, it helps to optimise resources by focusing efforts on those elements that are most important for the safe and efficient operation of the plant (Castillo-serpa, 2009).

Risk assessment within the industry considers the probability or frequency of a failure occurring and considers the impact of that event on production, labour and repair costs (Parra et al., 2021).

These assessments allow identifying and prioritising the most significant risks for the company, with the aim of implementing appropriate preventive and mitigating measures (Suresh and Jayadeva, (2023). Furthermore, they provide a solid basis for strategic decision-making in terms of investment in safety and improvements in industrial processes (Bernardino-Flores et al., 2018).

Reliability Centered Maintenance (RCM) is a methodology that serves as a basis for the elaboration of maintenance plans contemplating preventive or predictive strategies (SAE - Society of Automotive Engineers, 1999). RCM is based on the detailed analysis of equipment and systems, identifying critical functions and potential failure modes (García Reyes, 2013). From this information, the most appropriate maintenance strategies are selected to maximise operational reliability and minimise associated costs. This methodology has proven to be effective in various industrial sectors, allowing management to be optimised (Díaz-concepción et al., 2012).

Methodology

Quantitative research is applied to understand frequencies, patterns, averages and correlations in order to understand cause and effect relationships, test hypotheses or theories based on statistical analysis (Hernández Sampieri et al., 2014). The effects of such research can be represented by numbers or graphs. For the collection of information, observation will be used to determine the coding of events and to be able to express them in numbers. Therefore, the present work is considered as quantitative research since observation is used to collect numerical information. This work was carried out in the field, it is a descriptive type of research, its purpose is to observe, describe and determine the level of criticality in the maintenance equipment. It will also allow us to analyse and evaluate the factors and failures that affect the maintenance process. The methodology consists of two stages, which are described in figure 1.

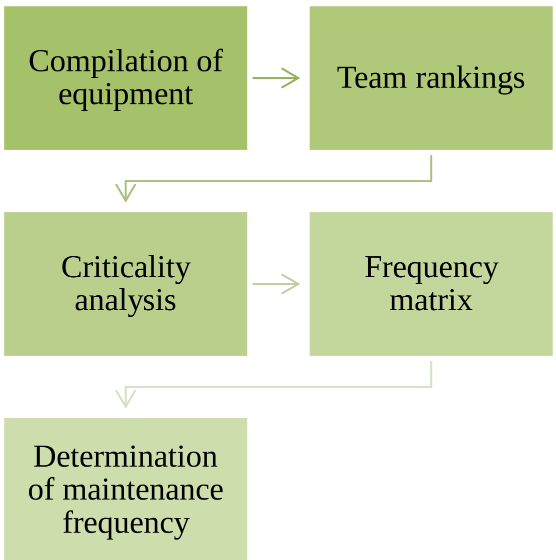

Figure 1 Methodology applied

The first step of the methodology consists of compiling the technical information of the equipment in plant 1, then we proceed to the classification of the equipment, where we will start by compiling all the equipment in the industrial area, then the classification will be made taking into account mainly how many of the equipment failures cause plant stoppage, on this it will be decided whether a piece of equipment is critical, main or auxiliary.

The third step, the criticality analysis is developed from the result obtained in the classification, on the number of critical equipment results a criticality analysis will be applied in which to determine the criticality of a unit or equipment a frequency matrix must be used by consequence of the failure. The frequency of failures and the impacts or consequences that the equipment will suffer if a failure occurs must be represented. Finally, the frequency of maintenance should be determined by considering the weights of the impact on safety, spare parts, labour and the probability of failure, thus obtaining the risk value.

Results

A format was designed to have a control of the equipment, considering elements such as; work area, name of the equipment, quantity of equipment in stock and a bar code was generated to facilitate the control of the maintenance activities, an example is shown in figure 2.

In order to carry out the criticality analysis, it was first necessary to define the criticality of the equipment based on its impact on the coffee production process and the existence of a spare part in case of failure or breakdown. In this way, it was possible to carry out a pre-study that helps to focus on the equipment that is only 1 in stock in the plant and, in addition, the equipment that most frequently presents eventualities.

POSICION	AREA DE TRABAJO	EQUIPO	CANTIDAD	CODIFICACION
1	2	TRANSFORMADOR	1	
2	2	SISTEMA DE DESMINERALIZACIÓN DEL AGUA	15	
3	2	SUAVIZADOR DE AGUA	1	
4	2	MOTOR TRIFASICO BONORA	1	
5	2	BOMBA CENTRIFUGA MULTIETAPAS	1	
6	2	MOTOR TRIFASICO WEG	1	
7	2	MEDIDOR DE GAS	1	
8	2	QUEMADOR DE ALTA PRESION	1	
9	2	CALDERA INDUSTRIAL SERIE 500	1	
10	2	CALDERA INDUSTRIAL SERIE 400	1	

Figure 2 Coding of equipment

As a result of having a total of 120 pieces of equipment considered critical for causing plant stoppages due to their failures, the criticality analysis must be applied to these pieces of equipment. In order to carry out the analysis, we proceeded to establish the variables that were considered in the analysis, through brainstorming and according to the department's indicators, 4 variables were identified as criteria or headings to determine the severity (impact) of said equipment when affected by eventualities. Table 1 shows the variables and the weighting given to support the severity.

Variable	Ponderation
Industrial safety	.25
Spare parts	.20
Labour	.30
Consequences	.10

Table 1 Variables and weighting of weights to assess impact

Subsequently, Como proceeded to give a value to the variables determined to obtain the severity for the industrial safety variable in figure 3, the reference values are observed, it is considered as 0 when there is no effect on people or equipment and it is qualified with 4 when the failure or condition generates permanent disability or death, to one or more people.

For the spare parts variable, 0 was established as 0 when only cleaning and adjustment of the current installed spare parts is required, while a weight of 4 was established when specific parts need to be purchased or made abroad.

Refacciones	
Requiere limpieza y ajuste de sus actuales refacciones	0
Requiere de herramienta de almacén para reemplazo	1
Requiere la compra de refacciones	2
Requiere mandar a hacer piezas específicas	3
Requiere compra o mandar a hacer piezas específicas en el extranjero	4

Seguridad Industrial	
No afecta personas ni equipos	0
Afecta a una persona y es posible que genere incapacidad de tipo temporal	1
Afecta de dos a cinco personas y puede generar incapacidad de tipo temporal	2
Afecta a más de cinco personas y puede generar incapacidad de tipo temporal o permanente	3
Genera incapacidad permanente o la muerte, a una o más personas	4

Mano de obra	
Se necesita 1 operario	0
Se necesita de 2 a 3 operarios	1
Requiere operarios bajo supervición de personal directivo	2
Se necesita contratar personal externo	3
Se necesita contratar más de un servicio de personal externo calificado	4

Consecuencias	
No existe fallas ocultas que puedan ocasionar fallas múltiples, paros y/o pérdidas de producción	0
Existe una posibilidad baja de que la falla no sea detectada y ocasione fallas múltiples	1
En condiciones normales la falla será oculta y ocasionará fallas múltiples	2
Existe una posibilidad baja de que la falla sea detectada y ocasione fallas múltiples y cuente con una alta posibilidad de paro en planta	3
La falla siempre será oculta y ocasionará fallas múltiples a gran escala, paro en planta y pérdidas de producción	4

Figure 3 Standardised weights for variables

In order to obtain the gravity value the formula 1 was used.

$$G = SG * K_{SG} + R * K_R + MO * K_{MO} + C * K_C \quad (1)$$

In order to assign a value to the Probability of failure, it was decided to take the useful life of the critical equipment as a reference. And as we have been working on the development of the analysis, we again use a scale with values from 1 to 5 to define the probability that some of the equipment in question will present eventualities, each value representing the years of life of the critical equipment.

Each of the values represents the years of life of the critical equipment. Figure 4 shows the scale defined and used.

PROBABILIDAD DE FALLO (ENFOCADO EN VIDA ÚTIL)	
El equipo tiene 1 año o menos de uso.	1
El equipo tiene de 1 a 3 años de uso.	2
El equipo tiene de 3 a 5 años de uso.	3
El equipo tiene de 5 a 10 años de uso.	4
El equipo tiene más de 10 años de uso.	5

Figure 4 Probability of failure

To obtain the risk value of the critical equipment, the product of the value assigned to the probability of failure and the value obtained with the above formula for severity (impact) was determined. The formula 2 is applied to obtain the product of the risk value:

$$Riesgo = G * PFallo \quad (2)$$

To obtain the risk level of the equipment, four risk levels were used in relation to the severity and estimated probability of failure. 4 values to show the criticality that was collected as a final result. Given that the equipment to which the analysis was applied was already considered critical equipment in terms of the plant stoppage it can cause when it fails, these values were used to give a risk level result for the equipment. The criteria are shown in table 2 and are used to estimate the level of risk according to the product obtained in formula 2.

Risk	Value	Action
Very Serious	> 13	Requires urgent attention
Significant	9 a 12	Mandatory preventive measures
Appreciable	3 a 8	Planned preventive measures
Secondary	< 3	Subject to continuous observation

Table 2 Risk estimation

Finally, a column was added to the matrix to establish the frequency with which preventive maintenance is to be carried out for the equipment in question. This function is determined with the frequency from formula 3 in Excel.

$$si.conjunto(M30 \geq 15, \text{MENSUAL}, M30 \geq 9, \text{CUATRIMESTRAL}, M30 \geq 3, "SEMESTRAL") \quad (3)$$

Table 3 shows the maintenance frequency considering the values obtained in (2), obtaining the periodicity of maintenance according to its severity.

Frequency of maintenance	Estimated value of the risk
Equipment is highly critical and requires full attention	15
Equipment is medium critical, requires attention.	9
Equipment is low critical, requires attention.	3

Table 3 Maintenance frequency

Figure 5 shows 6 pieces of equipment in the boiler and services area, of which the steam generator, gas burner and the 800 CC boiler motor have a very high risk level. On the other hand, with a high risk level, the tower fan, cooling unit and tank feed pump have a great impact when they fail, as they generate multiple consequences, such as not allowing other operators to continue with their coffee processing activities.

MATRIZ									FRECUENCIA
DESCRIPCION	S I (0.25)	R (0.20)	M O (0.30)	C (0.10)	Pfallo	G	Riesgo	Nivel de riesgo	MANTENIMIENTO PREVENTIVO
GENERADOR DE VAPOR HURST800 CC	4	2	4	4	5	3.6	18	MUY ALTA	MENSUAL
QUEMADOR DE GAS POWER FLAME	3	2	4	3	5	3.05	15.25	MUY ALTA	MENSUAL
VTF MOTOR 30HP DE CALDERA 800 CC	2	2	4	4	5	3.1	15.5	MUY ALTA	MENSUAL
VENTILADOR TORRE DE ENFRIAMIENTO 1	3	2	2	4	5	2.85	14.25	ALTA	CUATRIMESTRAL
UNIDAD ENFRIAMIENT AGUA HELADA CHILLER	2	2	3	4	5	2.85	14.25	ALTA	CUATRIMESTRAL
BOMBA ALIMENTACION AGUA CISTERNA	2	2	2	3	5	2.3	11.5	ALTA	CUATRIMESTRAL

Figure 5 Probability of failure

The result of the first classification of all the equipment in plant 1 of the coffee processing company is shown in table 4, with four variants of the classification. Of the 120 critical equipments analysed, a total of 13 equipments present a very high risk level, 93 equipments with a high risk level and 14 equipments with a medium risk level.

Of which respectively they should be subject to monthly preventive maintenance for equipments with a very high level, every four months for equipments with a high level and every six months for equipments with a medium level.

Clasification	Total number of teams
Critical equipment	120
Main equipment	200
Auxiliary equipment	35
Non-operational equipment	2
Total	357

Table 4 Classification of equipment

Conclusions

In addition to the design, a criticality analysis was carried out on 357 pieces of maintenance equipment using the risk matrix tool, of which 120 were critical according to the evaluation carried out. After completing the analysis of the critical equipment and presenting recommendations as well as following up on the project for future work, the following conclusions can be drawn: It is important to identify the different equipment with which the plant works on a daily basis, to have a history of equipment failure or otherwise an analysis already applied in which the variables that determine its criticality can be appreciated (Hidalgo et al., 2023).

It is important to have spare and replacement parts in stock, so as to avoid wasting time in the time it takes to obtain the necessary spare parts. It is important to train and keep informed the operators who handle the equipment, so that in case of any failure they immediately know what to do and/or who to notify about the current failure. It is necessary to adapt the next maintenance plans according to the results obtained in the criticality analysis.
In order to provide adequate continuity to the present project, it is necessary to adapt the next maintenance programme according to the results obtained in the criticality analysis, so that in this way the seriousness of a critical piece of equipment can be considered if it is not attended to at the right time in order to avoid causing multiple losses in the plant.

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