Improving Failure Analysis Efficiency Of Handling Equipment By Using FMECA

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Abstract

This work is part of an applied research study on the most commonly used methods in the industry: Failure Mode, Effects and Criticality Analysis (FMECA). In this study, the method was applied more precisely in an industrial production environment in a company responsible for producing and marketing various materials for public works and construction. During the elaboration of a preventive maintenance program for one of its equipment, (handling equipment) newly installed “the Pellegrini 10T overhead crane”, the company noticed that it is very important to understand precisely its behavior in case of failure to prevent its dysfunction or that of one of its components. This study aims to reduce the potential failures of handling equipment in the industry by using FMECA, which will help avoid potential risks and reduce downtime.

1 Introduction

In today's industrial context, the problem-solving approach is a major financial issue for companies. Indeed, the appearance of problems in the operation of installations generates losses of productivity, time, and even significant customer dissatisfaction. An industrial machine is a complex piece of equipment, subject to multiple failure modes where the causes of breakdowns and/or incidents are multiple. On the one hand, these represent one of the main plagues of the industry and, on the other hand, a source of wealth for maintenance management. Therefore, it is important that companies are very responsive to these issues and can resolve them quickly and efficiently.

The root causes of problems are generally diverse and varied, and it is difficult to identify them quickly without rigorous methods. Numerous scientific works have dealt with this type of subject, and many problem-solving methods have been proposed. Among these methods, we find the FMEA. NASA first introduced FMEA in the 1960s as a tool for reliability and safety analysis in the aerospace industry [1]. These past years, it has been widely adopted for improving system safety and reliability [2] and for continuous improvement of a product or process design [3] in a variety of fields, e.g., wind energy [4], food [5], healthcare [6,7], fabrics [8], construction [9], and mining [10]. It is a systematic bottom-up failure analysis method at all levels, from component to system or process, to identify failure modes, analyze failure causes, and map failure effects [11].

By introducing a criticality analysis, the qualitative FMEA can be extended to a quantitative analysis of failure modes, their effects, and criticality (FMECA) [12]. The FMECA is thus an analysis methodology by which all potential failure modes are found, the causes and effects of the failure modes are analyzed, the critical failure modes are selected, and methods to mitigate or remove the effects of the critical failure modes are provided [13, 14, 15, 16]. Wang et al. [17] proposed an improved FMECA (IFMECA) to overcome the drawbacks of conventional FMECA, which does not consider the opinions of different team members or the relationship between failure modes and causes when assigning criticality.

The main concept and basic procedure are the same in all FMECA specifications, but a detailed procedure must be tailored to a specific application for each industry [18]. They need to provide a reliable and safe system for material handling equipment because workers use these systems to transport parts and machinery of all categories between different workshops. Thus, they also require process control methods of design, manufacturing, and maintenance to reduce costs while ensuring reliability, as these systems are expensive and have high maintenance costs. However, little research has been conducted on the FMECA process for material handling equipment, and no specialized FMECA specification has been proposed to date to our knowledge.

Therefore, in this study, a specialized FMECA procedure for material handling equipment was proposed by analyzing several FMECA specifications used in other industries and considering the characteristics and requirements of material handling equipment. The proposed procedure has been applied on a 10T rolling bridge, which is a essential equipment for the production, in the compactor assembly workshops of an Algerian company, to establish a means of diagnosis and to bring improvements to its operation and this can be done only by controlling the weak and critical points of the rolling bridge on which it is necessary to act to optimize its availability

First, we determined the criticality levels of the subassemblies of this rolling bridge after identifying the potential causes of failure in a second step. Then, we classified them according to their criticality to establish a plan of preventive and corrective actions that will define the maintenance policy to be undertaken to avoid the malfunction of the components of this system.

2 Literature Review

Many scientific works have dealt with this type of subject, and many problem-solving methods have been proposed. Among these methods is the FMEA, and its development and application is a subject of interest not only for academic researchers but also for industrial practitioners. Most design tools were created in industries to address specific industrial problems. Analysis of a hypothetical accident in a two-unit power plant allowed Plastiras [19] to develop and apply a new methodology for analyzing common causes of inter-systems (ICCA), which revealed problems not identified by traditional methods FMEA of inter-systems previously performed by design teams. Dale and Shaw [20] conducted a questionnaire survey on the use of FMEA in the UK automotive industry. They found that most suppliers only started using FMEA because it was a contractual requirement of their customers; however, a number are now looking to make greater use of the technique to facilitate their quality improvement process. They also noted that organizations are not satisfied with the current FMEA training courses.

Aldridge et al. [21], during the application and design of FMEA at Garrett Automotive Ltd, Skelmersdale, and from an analysis of current methods of preparation and use of this technique, noted the reluctance of staff to product engineering and manufacturing engineering due to perceived lack of time or lack of understanding of process potential. Potente and Natrop [22] recommended the implementation of FMEA before the mass production of products to recognize errors that may occur during the manufacturing process, resulting in high scrap rates. The authors investigated that quality control was mainly performed by inspection of the final product. Chabane et al. [23] contributed to implementing an approach dedicated to the behavioral analysis of industrial systems from the design itself. This approach is a combination of three complementary tools. The SysML language is applied to express customer needs and requirements, such as functions and operating conditions of future systems. In addition, the FMECA method analyzes potential system malfunctions and recommends appropriate maintenance actions. Finally, the K-means method classifies the failure modes to obtain the detailed criticality of the modes instead of calculating them according to the old methods.

Similarly, combining the TOPSIS fuzzy belief method with FMEA to introduce an FMEA belief structure to describe expert knowledge by a several linguists as a grammatical phenomenon was proposed by Vahdani et al. [24]. Thivel et al. [25] analyzed the risk of a biomass combustion process using systematic methodological risk analysis and FMEA. FMEA has been used to study the reliability of many energy production systems. Arabian-Hoseynabadi et al. [26] applied it to a wind turbine system using a proprietary software reliability analysis tool. In a case study, Nazeri and Naderikia [27] proposed an approach for assessing and determining the risk of failure modes for a railway company. The authors aim to develop a risk-based method to select an appropriate maintenance strategy to have available and reliable tamping equipment in Iranian railroads. Raj Kumar and Jindal [28] applied the FMEA approach by evaluating the possible causes of failure and their effects on the sub-systems of CNC machines to improve their reliability in the industry and increase the performance of rate production through the prioritization of the failures occurring in them.

Since the risk priority number (RPN) calculation method is one of the critical subjects of failure mode and effects analysis (FMEA) research, Xiaojun and Jing [29] recently proposed a fuzzy beta-binomial RPN evaluation method by integrating fuzzy theory, Bayesian statistical inference, and the beta-binomial distribution. Early product defects have plagued many machine tool enterprises, especially small and medium-sized enterprises limited by capital. Against this background and to eliminate early defects and improve the reliability of computerized numerical control (CNC) machine tools, Zhang et al. [30] proposed a systematic early defect elimination method based on the after-sale data (customer field data) of CNC machine tools. The proposed method consists of four steps: defect data collection; a four-parameter non-homogeneous Poisson process model (NHPP); a mixed defect analysis method that is the combination of the fault tree analysis (FTA) method and the failure modes, effects, and criticality analysis (FMECA) method; and early defect elimination measures.

Other researchers have obtained useful results in improving performance in various industries and avoiding failure by combining FMEA with other improvement methods. For example, Almannai et al. [31] described an integrated approach to help management address technology, organization, and people at the earliest decision-making stages regarding manufacturing automation. The approach used the Quality Function Deployment (QFD) and the FMEA techniques. The key concepts from these two applications were merged into a decision tool; QFD identifies the most appropriate manufacturing automation alternative,

and FMEA identifies the risks associated with that option to be considered in the design and implementation phases of the manufacturing system.

On the other hand, Peeters et al. [11] proposed a method to perform failure analysis by combining the Fault Tree Analysis (FTA) method and the Failure Mode and Effects Analysis (FMEA) method. The authors reported that the main disadvantage of applying these two methods is time-consuming. As a result, the methods are often not applied thoroughly, leading to failure to identify important failure modes. Furthermore, Bertsche [32] stated that this could increase the number of failure modes found due to the different starting points of the two methods: bottom-up in FMEA versus top-down in FTA. Fault tree analysis (FTA) and fault mode and effects analysis (FMEA) approaches are widely used for fault analysis. However, they are time-consuming and expensive when fully implemented and can also lead to a loss of focus on the most critical parts of the system, which failure analysis is generally aimed at identifying.

Implementation of food safety management systems (ISO 22000:2018), as well as the incorporation of management tools such as HAZOP, FMEA, Ishikawa, and Pareto, were found to be proactive in maintaining a positive food safety culture and preventing cross-contamination and fraud in a case study by Lee et al. [33]. The FMEA model was too applied for the risk assessment of the pastries processing [34]. Trafialek and Kolanowski [35] used FMEA for auditing the HACCP system. The researchers showed that the designed method is ready to be used in all types of food enterprises. In addition, FMEA has been used to analyze and reduce risks (increase safety) in other areas such as industries. Papadopoulos et al. [36] automated failure modes and safety effects analysis of critical systems.

Arvanitoyannis and Savelides [37] implemented an interim FMEA approach in an industry producing filled chocolate to exclude the presence of genetically modified organisms (GMOs) in the final product. They used two structured methods (preliminary risk analysis and fault tree analysis) to analyze and predict the failure modes in the food chain system, based on the functions, characteristics, and/or interactions of the ingredients or processes on which the system depends. Aljazzar et al. [38] used FMEA and probabilistic counterexamples for the airbag system in the healthcare sector. In addition, FMEA can be used to increase patient safety in hospitals, Chiozza and Ponzetti [39] used it to reduce medical errors.

3 Methodology

FMEA was first developed to address reliability and safety issues in the aerospace industry in the late 1950s. Because FMEA focuses on proactive prevention of potential failures rather than solutions. It can help managers identify failures and causes/effects and eliminate failures by instituting corrective actions in the risk assessment process [40]. There are several types of FMEA/FMECA:

- **Design FMEA (DFMEA)**: It is used to ensure the reliability of a product by improving its design.
- **Process FMEA (PFMEA)**: It ensures the quality of a product by improving its production operations.
- **Concept FMEA (CFMEA)**: It ensures the availability and safety of production equipment by improving its maintenance.

Therefore, to perform an FMEA/FMECA, it is necessary to know the system's operation, process, or product being analyzed or, failing that, to have the means to obtain the information from those who have it. The FMEA/FMECA is a "step-by-step" procedure (a sequence of questions and answers) that involves, in the first instance, a tabulation of the system's functions or the system's equipment items, the failure mode of each item, and the effects of the failures on the system:

1. Establish the FMEA/FMECA team.
2. Describe the product/process/system you want to analyze.
3. Creating a Block Diagram of the product or process that shows the major components or process steps as blocks connected by lines that indicate how the components or steps are related.
4. List of Potential failure modes, causes of failure, and their effects on the system.
5. Assign Severity, Occurrence, and Detection rankings to each failure mode (Tables 1, 2, and 3).

6. Calculate the RPN (Risk Priority Number) using the mathematical formula ($RPN = \text{Severity} \times \text{Occurrence} \times \text{Detection}$) (Table 4). The results of an FMEA/FMECA are typically recorded in a table, such as the table shown in Figure 1.
7. Develop the action plan and Define who will do what and when.
8. Take the actions identified by your FMEA/FMECA team.
9. Calculate the resulting RPN after implementation of the actions.
10. Compare RPN before and after implementing the actions and Reassess each of the potential failures after improvements are made, and determine the impact of the improvements using the FMEA/FMECA.

Table 1
Severity of failure effects (S).

Level	Value	Definition
Minor	1	Failure stops the component but not the installation that operates in degraded mode.
Way	2	Failure stops the equipment but not the production that operates in degraded mode.
Major	3	Failure stops the production from 20 min to 1 h and requires maintenance.
Important	4	Failure stops the production for more than 2 h. Important intervention on the sub-systems.
Catastrophic	5	Failure stops the production, leading to serious problems for personnel safety or the installation/environment. Heavy intervention requiring knife equipment.

Table 2
Identification of the failure cause (Occurrence, O).

Level	Value	Definition
Exceptional	1	No participant memory
Rare	2	It has happened once or twice.
Frequent	3	It has already happened several times.
Certain	4	It will happen for sure.

Table 3
Failure detection capability (D).

Level	Value	Definition
Obvious	1	Certain detection
Possible	2	Detectable by the operator
Unlikely	3	Difficult to detect
Impossible	4	Undetectable

Table 4
Criticality levels.

Value	Definition
$1 < C < 8$	Negligible: we leave them aside.
$8 < C < 14$	Average: we wonder whether to leave them or keep them.
$14 < C < 27$	High: we need to find actions to implement and the importance of stocking components or organs.
$27 < C < 64$	Prohibited: the actions must be recorded, and the components or parts must be put in stock.

4. Case Study

4.1 Context

The case study was carried out in an Algerian company producing and marketing various materials for public works and construction. The methodology was applied to one of its handling equipment newly installed in the assembly workshops: Pellegrini 10T overhead crane (Figure 2). It was designed to lift and move heavy parts for the assembly of compactors. Table 5 lists the characteristics of this system.

Table 5
Pellegrini 10T rolling bridge characteristics.

Type	Use	Structure	Possible movement	Capacity/Useful strength	Motor	Order
Double girder posed	Compactors assembly area	Box spring frame Mechanically welded beam	- Longitudinal translation	10T/	- 4 <i>asynchronous motors</i> :	Wireless control radio type AIR A8
			- Transverse translation	100kN	- 2 gearmotors for longitudinal translation	
			- Lifting		1,1Kw	
			- Longitudinal and Transverse translation at the same time		- 1 gearmotor for transverse translation 1,1Kw. - 1 cage motor for lifting 8Kw	

4.2 Results and Discussion

After identifying all failure effects and the root-cause analysis of the failure modes in the teamwork, all corresponding RPN values were calculated (Table 6).

^a**Table 6** Analysis of failure modes, their effects, and criticality (FMECA).

Sub-system	Component	Failure	Failure effects	Causes of failure	Detection	S	O	D	RPN
Mechanical system	Beam	- Cracks	- Incorrect control - Load instability - Deformation or deterioration of the structure	- Overload - Fatigue - Bad facilities	Visual report/Verification device	5	1	3	15
Mechanical system	Bearing surfaces	- Elevation of the roughness	- Elevation of vibrations and noise	- Fatigue - Tearing of the top layer	Visual Report / Auditory	3	2	2	12
Mechanical system	Rollers (bridges and carriages)	- Wear	- Risk of falling - Noise	- Misalignment of the rails (loosening of the screws over time) - Bad assembly	Alignment device - Measuring device	3	2	3	18
Mechanical system	Support rollers	- Loosening (unscrewing)	- Increased noise - Elevation of vibrations	- Repetitive movement - Overload - Vibration	Visual Report / Auditory	4	1	2	8
Mechanical system	Carriage chassis	- Deterioration of rollers, - Deformation of the structure	- Difficult control of the bridge - Motors overloaded	- Repetitive movement - Overload - Deterioration of the bearing surface	Visual report	3	1	2	6
Mechanical system	Bearings	- Blocking - Wear - Jamming of the ring	- Noise - Vibrations	- Bad alignment - Bad lubrication - Heating of the bearings - Incorrect choice of lubricant	Visual Report / Auditory	3	3	2	18
Mechanical system	Reducers gears	Tooth wear - Scaling - Jamming of teeth	- Reducer malfunction - Heating of teeth (wear) - Increased vibrations and noise	- Insufficient greasing - Mechanical overload - Inadequate teeth heat treatment	Visual report / Measuring device	4	3	2	24

Sub-system	Component	Failure	Failure effects	Causes of failure	Detection	S	O	D	RPN
Mechanical system	Drum	- Deformation, - Seizure, - Deterioration of the drum/reducer coupling	- Blocking of the load + vibration - Consumption of cable and bearings - Noise	- Overweight - Bad lubrication - Bad alignment	Visual report / Measuring device	3	1	2	6
Mechanical system	Pulley Block	- Seizure	- Cable breakage, blockage Cable / load	- Insufficient greasing - Overload	Visual report	3	1	2	6
Mechanical system	Limit switch	- Seizure - Deformation - Rupture	- Risk of shock between the load and the trolley	- Fatigue - (Atmospheric agents)	Visual report	3	2	2	12
Mechanical system	Mechanical braking system	- Faulty	- Loss of control over the load and how far it should go	- Wear of the disc lining - Joint wear - Deformation	Visual report / Verification device	4	1	4	16
Mechanical system	Handling cable	- Cable wear - Decrease in the section of the cable	- Cable breakage - Risk of a falling load	- Fatigue - Overweight of the load to be lifted - Improper handling	Visual report	5	2	2	20
Electrical system	Electrical cabinet	- Power cut - Heating of electrical components - Electric overload - Voltage drops - High mechanical effort	- Failure of an electrical component (cable, fuse, transformer, push button, contactor, thermal relay, etc.)	- Malfunction - Stop of the bridge	- Visual report	4	3	2	24

Sub-system	Component	Failure	Failure effects	Causes of failure	Detection	S	O	D	RPN
Electrical system	Electric motors	<ul style="list-style-type: none"> - Copper melting of the motor winding - Deteriorated bearings - Not coaxial with the reducer shaft - Unbalance - Breaking of the fixation motor + deterioration of the gear unit 	<ul style="list-style-type: none"> Increased vibration - Noisy engine - Engine heating - Engine malfunction - Engine stopping 	<ul style="list-style-type: none"> - Gradual increase in energy consumption - Electrical overload - Mechanical overload - Cooling system failure - Locking of the braking system - Loosening 	Visual Report Measuring / Verification device	4	3	4	48
Electronic system	Load limiter	<ul style="list-style-type: none"> - Deprogramming - Operation stop 	<ul style="list-style-type: none"> - Formatting - Bad programming - Short circuit - Atmospheric agents 	<ul style="list-style-type: none"> - Malfunction - Breakage cable - Overload on the lifting motor - Falling load - Danger of death for workers 	Visual report / Verification device	5	1	4	20

^aBased on the results obtained in the FMECA table, we were able to identify the critical organs, monitor them and propose preventive operations to avoid the failure occurrence.

The criticality hierarchy can be formalized as a histogram (Figure 3). The criticality threshold is set at 10 by the working group's proposals. This threshold is the limit beyond which preventive actions must be taken. It is also possible to draw up a list of critical points or a table of Corrective/Preventive actions that must be taken on the elements of the Pellegrini10T overhead crane (Table 7), having risks of critical failures. A reduction in criticality can be achieved by acting on one or more factors of the product, as follows:

$$RPN = S \times O \times D.$$

To propose preventive actions to the anomalies detected by the FMECA study, we based ourselves on the history of failures of overhead cranes similar to our system and existing in the company and on the manufacturer's manual.

^b**Table 7** Corrective/Preventive actions on the Pellegrini 10T overhead crane sub-systems.

Criticality level	Sub-systems	Criticality	Preventive / corrective actions
Criticality between $1 \leq C < 12$ Negligible criticality	Carriage chassis	6	- No modification design
	Drum	6	- Corrective maintenance
	Pulley Block	6	
	Support rollers	8	
Criticality between $12 \leq C < 16$ Medium criticality	Limit switch	12	- Improved element performance
	Bearing surfaces	12	- Systematic preventive maintenance
Criticality between $16 \leq C < 20$ High criticality	Beam	15	- Review of subassembly design and selection of elements for specific monitoring
	Mechanical braking system	16	
	Rollers (bridges and carriage)	18	
	Bearings	18	
Criticality between $20 \leq C < 80$ Criticality prohibited	Handling cable	20	- Complete rethinking of the design
	Load limiter	20	
	Reducers gears	24	
	Electrical cabinet	24	
	Electric motors	48	

^bComponents with a criticality of less than 12 are considered negligible and do not require design changes but only corrective maintenance. Components with criticality greater than or equal to 12 and less than 16 are considered medium criticality and require an improvement in the performance of the element. In the case of high criticality, which ranges from 15 to 20, the components require a design review and special monitoring. From 20 to 48 the very high criticality considered as forbidden which requires the complete redesign of the component.

4.3 Recommended maintenance plan for the Pellegrini 10T overhead crane

☞ **Table 8** Maintenance plan for the Pellegrini 10T overhead crane sub-systems.

Sub-systems	Criticality	Comments and Actions	Periodicity
Limit switch	12	<p>Interpretations: This safety element automatically stops the crane if it exceeds the desired distance, thus avoiding the risk of impact between the load and the trolley.</p> <p>Actions:</p> <ul style="list-style-type: none"> - It is strongly recommended to inspect it regularly (required by the manufacturer). 	Daily
Bearing surfaces	12	<p>Interpretations: Worn, abraded, or oxidized surfaces can represent a progressive degradation accelerator of the various components of the equipment (system).</p> <p>Actions:</p> <ul style="list-style-type: none"> - Knowledge of the type of materials used for this component is strongly recommended. -Control by vibrometer or accelerometer is recommended. 	Annual
Beam	15	<p>Interpretations: The potential risks of improper beam assembly and the risks associated with machines such as cracks propagating through vibration and overload are considerable.</p> <p>Actions:</p> <ul style="list-style-type: none"> - It is strongly recommended to inspect them regularly even if the frequency of occurrence of its problems is rare because the consequences are serious on equipment and the personnel. - Visual inspection with appropriate light is sufficient. 	Annual
Mechanical braking system	16	<p>Interpretations: This hydrodynamic system, even if it is not frequent to break down, but its effects are catastrophic, which justifies its criticality value, so a daily vacuum control is mandatory knowing that it only takes two minutes.</p> <p>Actions:</p> <ul style="list-style-type: none"> - No-load functional check - Control of brake pad wear 	Each 6 months
Rollers (bridges and carriage)	18	<p>Interpretations: These components represent the mobility organ of the bridge, so to avoid its immobility, it is necessary to check them often. Actions:</p> <ul style="list-style-type: none"> - Checking the alignment of the rails -Compliance with the rules for mounting the rollers + checking it - Vibration control - Adequate lubrication 	Daily
Bearings	18	<p>Interpretations: Many system vibration comes from misplaced or worn bearings. This is due to friction between the moving and stationary surfaces and the increased temperature between them.</p> <p>Actions:</p> <ul style="list-style-type: none"> - Conditional control by accelerometer - Respect the frequency of bearing replacement - Lubrication recommended 	Each 6 months

Sub-systems	Criticality	Comments and Actions	Periodicity
Handling cable	20	<p>Interpretations: Handling cable degradation is evident but needs to be slowed.</p> <p>Actions:</p> <ul style="list-style-type: none"> - Proper and regular lubrication - Periodic control with a magnifying glass after cleaning - Periodic cable replacement (from the cable and block manual) - Check the general condition daily (recommended by the manufacturer) 	Recommended by the manufacturer
Load limiter	20	<p>Interpretations: The load limiter is a very sensitive element, so it is highly recommended that working on this type of device requires special knowledge in programming and electronics.</p> <p>Actions: The maintenance person must be qualified and well trained, perform the overload test according to the manual on-site, and not remove it and operate the bridge without it.</p>	Each 6 months
Reducers gears	24	<p>Interpretations: The perfect transmission of the movement requires a more sophisticated control because the problem of the reducers is frequent. Therefore, we must have the necessary tools to control in the best conditions while saving the time factor.</p> <p>Actions:</p> <ul style="list-style-type: none"> - Conditional control by accelerometer, - Regular lubricant change respecting each mechanism's life and types of lubricant. 	Each 6 months
Electrical cabinet	24	<p>Interpretations: This organ is a parallelepiped container fixed to a beam. It gathers and protects the electrical components of the system. The failure of one of its components affects the operation of the machine.</p> <p>Actions:</p> <ul style="list-style-type: none"> - Verification of the tightness of the connections of the electrical devices and their operation (change of the defective elements) - Cleaning of ventilation filters - Ensure a perfect seal - Control electrical components (contactor contacts, schematic sequences, adjustment of time relays, protection relays, etc.) 	Each 6 months
Electric motors	48	<p>Interpretations: The main problem with motors is usually electrical overload which causes temperature rise and mechanical overloads, so it is recommended to place overload protection devices.</p> <p>Actions:</p> <ul style="list-style-type: none"> - Conditional control by an accelerometer - Monitoring by an infrared device - Periodic verification by torque wrench - Creating easy access for quick intervention. 	Each 6 months

°The implementation of such a preventive maintenance plan makes it possible to prevent and reduce the interruption of production operations, to maintain the equipment in such a condition that it can operate efficiently and to ensure the quality of the service to be provided or that of the finished product.

5 Conclusions

The objective of this study was to determine how to achieve maximum equipment efficiency and high industrial performance. A cost-effective maintenance strategy applicable to strategic equipment was applied to the machinery park of an Algerian company on the Pellegrini 10T rolling crane, operating in the compactor assembly workshops. This maintenance strategy optimized the maintenance team's costs, time, and effort.

Studies have shown the feasibility of implementing a maintenance optimization method as the influence of maintenance activities becomes more and more important in the management of companies. The method used in this study is the FMECA. It is one of the tools for continuous improvement. In addition, it allows quality to be achieved through preventive rather than curative action.

The FMECA was carried out in four stages:

- Preparation
- Functional decomposition
- Analysis phase
- Establishment and monitoring of action plans

The results obtained allow us to prioritize the potential causes of the failures identified, target the most critical, and propose a maintenance plan-based on preventive/corrective operations to improve and optimize the machine's performance and ensure its availability.

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Figures

Date of analysis	Failure mode effects and criticality analysis					Machine operating phase	Page:			
	System		Subsystem				Name:			
Component	Function	Failure	Causes of failure	Failure effect	Detection	Criticality				Preventive / Corrective Actions
						S	O	D	RNP	

Figure 1

FMEA/FMECA spreadsheet.

Figure 2

Pellegrini 10T rolling bridge.

Figure 3

Hierarchical histogram of the Pellegrini 10T overhead crane sub-systems criticality.