# Reliability Centered Maintenance Management in the laboratory area of a Higher Education Institution

# Gestión de Mantenimiento Centrado en Confiabilidad en el área de laboratorios de una Institución de Educación Superior

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**Abstract**

Maintaining that waits for failure to intervene to occur resulting in production losses, high costs and decreased life cycle of the asset. In the Head of Department of Laboratories and Audiovisual Resources institution of higher education, it requires teams with opportunity for improvement in terms of reliability, maintainability and availability are identified. The objective was: proposal for implementation of maintenance through the methodology of Reliability Centered Maintenance to manage equipment availability; which consists of seven steps: 1) define the system and determine the criticality of equipment, 2) identify and define their functions; 3) determine failures; 4) establish failure modes; 5) determine the effects of failures; 6) assess consequences; 7) and develop a plan for equipment maintenance. As a result seven critical to equipment failure analysis were obtained; technical specifications; recommendations for use; Application forms and work orders; schedule of activities, maintenance strategies and indicators for the area. It is concluded that the objective to make a proposal for implementation of maintenance measures that support generating increasing the availability previously compliance with reliability and maintainability fulfilled.

**Maintenance, Asset management, Reliability, Availability, Maintainability**

**Resumen**

El mantenimiento que espera a que se produzca la falla para intervenir se traduce en pérdidas de producción, costos elevados y disminución en ciclo de vida del activo. En la Jefatura del Departamento de Laboratorios y Recursos Audiovisuales de la institución de educación superior, se requiere que se identifiquen los equipos con oportunidad de mejora en aspectos de confiabilidad, mantenibilidad y disponibilidad. El objetivo fue: propuesta de implantación de mantenimiento a través de la metodología de Mantenimiento Centrado en Confiabilidad para gestionar la disponibilidad de los equipos; la cual consta de siete pasos: 1) definir el sistema y determinar la criticidad de equipos, 2) identificar y definir sus funciones; 3) determinar fallas; 4) establecer los modos de falla; 5) determinar los efectos de fallas; 6) valorar consecuencias; 7), y elaborar un plan de mantenimiento de equipos. Como resultados se obtuvieron siete equipos críticos al análisis de fallas; fichas técnicas; recomendaciones de uso; formatos de solicitud y Ordenes de Trabajo; cronograma de actividades, estrategias de mantenimiento e indicadores para el área. Se concluye que se cumplió el objetivo al realizar una propuesta de implantación de mantenimiento generando medidas que den soporte aumentando la disponibilidad cumpliendo previamente con la confiabilidad y mantenibilidad.

**Mantenimiento, Gestión de activos, Confiabilidad, Disponibilidad, Mantenibilidad**

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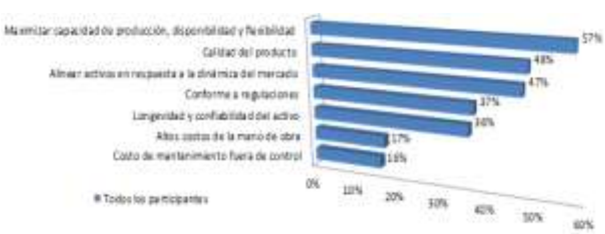
## Introduction

According to Sánchez (2010), technological and scientific development, including transportation and communications, have determined changes that emphasize competitiveness and sustainability, causing business activity and its form of administration to be constantly evolving. Therefore, according to Pérez (2011), organizations seek efforts, actions and decisions aimed at guaranteeing systems and assets operating efficiently and effectively; satisfied customers and users; reduced risks; minimal environmental incidents and optimal costs.

For Arata and Furlanetto (2005), this panorama has led to the management of physical assets and maintenance assuming an increasingly important role within industrial activities, since the diversity and complexity of production systems require ensuring the reliability of their facilities and equipment to meet production plans without neglecting quality and the environment. For this reason, physical assets such as real estate, basic technological systems and specialized production and service systems, play a fundamental role (Sánchez, 2010).

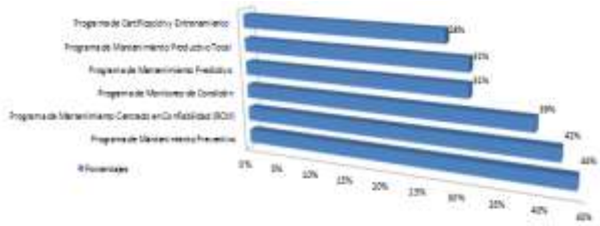
In accordance with previous ideas, Aberdeen Group (2006) refers to the fact that the volatility of the world economy and the austerity policies adopted by the various governments are the greatest threats to growth. In a study carried out by this service firm, 66% of Chief Executive Officers (CEOs) from various industries see that it is necessary to make changes through firm strategies.

With these conditions on the near horizon, asset management and maintenance are presented as important allies, since there are factors that must be addressed in the short term and in the years to come to ensure optimal performance in the manufacturing sector (see Figure 1).




**Graphic 1** Factors targeting asset management

In addition to the study, it was requested to mention or identify the action strategies that lead to achieving its goals in terms of the efficient management of its assets. In Graph 2, you can see the responses with their respective percentage to which they were referred by the CEOs.



**Graphic 2** Best asset management strategies

It is said that the RCM has been conceived as a process that provides benefits for the determination of maintenance requirements of all machines in their operating context, which allows determining each of the activities in order to ensure that the equipment fulfills its function.

For this reason, it is planned as a tool that allows determining the performance of the system in terms of the impact of a failure and the mitigation of the results through design, detection or effective maintenance (Barros, Valencia and Vargas, 2014). In recent years, maintenance has received brilliant contributions from the field of statistics and reliability theory.

According to Hung (2009), RCM is seen as a process used to determine the maintenance requirements of physical assets in their operational context, characterized by: a) considering the inherent or proper reliability of the equipment / installation; b) ensure the continuity of the performance of its function and c) maintain quality and productive capacity. This approach represents a radical change in the historical development of maintenance; because before this, the preventive and planned focused on the assets and the RCM focused on the locations and production processes (Gardella, 2010).

According to Quintero (2011), increasing asset productivity by 10 to 15 percent can often translate into profits and shareholder value of 30 to 40 percent.

In the same vein, Amendola (2012) mentions that the application of Asset Management supposes at least a 10% savings in production and maintenance costs, up to a 50% improvement in deviations from the maintenance plans of active or 15% reduction of errors in the finished product (Trujillo, 2013).

In such a scenario, Higher Education Institutions (HEIs) are called upon to fulfill an extremely important role to favor the development of the country and contribute to the well-being of people, through public and private HEIs (CACEI, 2014). Among the institutions accredited by organizations such as the Engineering Teaching Accreditation Council (CACEI) and reported in the National Association of Universities and Institutions of Higher Education (ANUIES), is the Technological Institute of Sonora (ITSON).

As part of the support process, and related to the Management of Infrastructure and Support Services (GISA), there is the Head of the Department of Laboratories and Audiovisual Resources (JDLRA). Among its functions is the support for teaching with laboratories equipped with instruments, materials, reagents and with classrooms equipped with audiovisual equipment, as well as support for research with the installation and maintenance of specialized equipment. The infrastructure that the department has is the following: Veterinary Laboratory; of chemistry; Biological and Food Sciences; of Civil Engineering; Chemical Engineering; of Electrical and Electronic Engineering; of Industrial Engineering; of food and beverages; and Graphic Design.

The JDLRA is made up of supervisors for specific areas such as Chemical and Biological Sciences, Maintenance, Engineering and Safety and Hygiene, who have people in their charge. Speaking specifically of the maintenance area, equipment with pneumatic, hydraulic, mechanical, electronic and optical characteristics is contemplated; supported by the knowledge and experience of the seven members that make it up. According to ITSON (2014) as part of its daily activities, the JDLRA attended 7,215 practices programmed by the various academies; of these 2,748 (38.08%) were for engineering and 4,467 (61.91%) for the areas of chemical, biological and veterinary sciences.

To ensure the operation of the laboratory equipment in the different areas, a total of 1,113 work requests were attended by the maintenance area personnel, of which 532 were corrective and 581 preventive. By 2015, in the area of Natural Resources there were 6,075 practices distributed in 405 groups. It is important to highlight that the TOs that were fulfilled to support both the teaching area and the research in the year by the maintenance area were 540 corrective and 355 preventive. Of this total of OT's, there were 244 corrective (45.18%) and 340 preventive (95.7%) for the Natural Resources area.

Through unstructured interviews with the responsible personnel and the Head of the Laboratory Department, gaps or opportunities are presented: a) comments by users on the insufficiency, condition and modernity of equipment; b) absence of performance indicators of the equipment in the maintenance area and corresponding laboratory areas; c) non-existence of classifications based on criticality, urgency and optimization of resources and equipment; and d) lack of documentation and follow-up on the causes that originate the malfunction of the reported equipment.

According to the JDLRA (2016) and as part of the analysis of information contained in the JD Edwards system on the failures of the equipment under study, it was determined as relevant data that during the period 2015 and until March 2016; 385 OT's were executed for the engineering areas, while in natural resources there were a total of 1,297 OT's.

An interesting fact is that there is an increase or difference of 337% of the OT's of the latter with respect to the engineering areas, so it can be said that during that period of time approximately 65% of the total of maintenance work to attend to situations related to natural resources, 20% to engineering and the remaining 15% to other needs or audiovisual equipment.

The JDLRA would hope to improve the use of resources assigned to the maintenance area, analyze the root cause of failures, generate measures to facilitate the care of assets, preserve the reliability of the equipment for as long as possible, take advantage of the information contained in the JD Edwards system database and increase area performance and asset life cycle time.

Therefore, the need arises for the critical points of the Maintenance Area to be identified and improvements in aspects of reliability, maintainability and availability at least of the equipment considered as critical due to its risk of failure. Based on the above, the following research question is generated: What type of methodological tool is relevant to the maintenance area to improve the reliability, availability and maintainability of the equipment in the Laboratories under study?

Therefore, the objective was defined, which consists of making a maintenance implementation proposal through the RCM methodology to manage the availability of laboratory equipment.

## Methodology to be developed

The object under study was the equipment available in the Veterinary, Biotechnology and Chemical Engineering Laboratories of the Itson Campus Náinari. It was decided to work with the procedure proposed by Moubray (2004) that breaks down the development of an RCM into seven phases. The seven steps considered are defined below: 1) Define the system and criticality of the equipment; 2) Define the functions of the teams; 3) Determine the failure modes of the equipment; 4) Determine the effects of equipment failure; 5) Determine the causes of equipment failure; 6) Assess consequences of failures detected in the equipment; and 7) Prepare a maintenance plan for the equipment.

## Results

In this section, the results obtained from each of the steps considered as part of the methodology were analyzed.

## Definition of the system and criticality of the equipment

A complete list of equipment was generated (magnetic stirrer, autoclaves, incubator, muffle, thermobath, centrifuge, stoves, grills, water bath, compressor, muffles, cold rooms, mass, volume, density, specific gravity, etc. temperature, speed and flow rate Among the most important equipment are: autoclave, vacuum pump, boiler, still, spectrophotometer and pH meter.

In order to have a more representative sample, it was necessary to reduce the number of computers, and it was determined that those that should be kept available for as long as possible for user service were included. To this second list, another filter was applied taking as a reference an analysis by risk weighting, which considered different values for aspects of: a) failure frequency; b) operational impact; c) operational flexibility; d) maintenance cost; e) impact on safety, hygiene and environment. Remaining a definitive list which were: 1) autoclaves; 2) microscopes, 3) refrigerators; 4) scales; 5) incubators and 6) Ph meters (potentiometers) and 7) boiler; corresponding to the values that were found close to or greater than 100 in the risk weighting analysis.

Afterwards, a query was made in the JD Edwards system to know the amount of OT's generated for the equipment under study between January 2014 - March 2016 (see Table 1).

| Equipment under study | Number of OT's executed per period | | |
|---|---|---|---|
| | 2014 | 2015 | 2016 |
| Microscopes | 238 preventive OT's<br>42 corrective OT's | 222 preventive OT's<br>33 corrective OT's | No preventive<br>30 corrective OT's |
| Incubators | 1 preventive OT<br>3 corrective OT's | 1 preventive OT<br>2 corrective OT's | No preventive<br>2 corrective OT's |
| Autoclaves | 30 preventive OT's<br>29 corrective OT's | 30 preventive OT's<br>28 corrective OT's | No preventive<br>16 corrective OT's |
| Balances | 1 preventive OT<br>20 corrective OT's | 1 preventive OT<br>27 corrective OT's | No preventive<br>9 corrective OT's |
| Refrigerators | 20 preventive OT's<br>17 corrective OT's | 20 preventive OT's<br>11 corrective OT's | No preventive<br>2 corrective OT's |
| Potentiometer | No preventive<br>3 corrective OT's | No preventive<br>5 corrective OT's | No preventive<br>No corrective |
| Boiler | No preventive<br>5 corrective OT's | No preventive<br>5 corrective OT's | No preventive<br>2 corrective OT's |

**Table 1** Amount of OT's teams under study
*Source: JDLRA (2016)*

Similarly, as part of a more detailed analysis and based on the OT's record of the JD Edwards system, the failures associated with the equipment under question were established (see Table 2), which are entered as a requirement at the time of that the order is requested by the laboratory worker (only one part)

| Equipment | Failures associated with the equipment according to corrective OT's |
|---|---|
| Microscope | Missing pieces; damaged switch; does not turn on; out of focus; short in cable; it does not rise or fall correctly; does not focus; macro metric corrupted; loose knob; lamp blinks; The light goes out; it looks fuzzy. |
| Incubator | Engine does not start; overheats; it is not calibrated; trouble regulating temperature. |

**Table 2** Associated failures
*Source: JDLRA (2016)*

### Defining the functions of the teams

Once the teams were established, each one was described considering its function within the process, description of its characteristics, among other relevant aspects.

### Determination of equipment failure modes

Once the above was done, for the Failure Mode and Effect Analysis (FMEA) a generic format was defined where information regarding the number, name and components of each team began to be included in the corresponding columns. Afterwards, the potential or functional failure modes registered at the time of satisfying the purpose were defined for the established components according to their design / process, performance requirements and user expectations during their commissioning. As a result, a list of mode variables was obtained, a starting point to understand the behavior of the team and integrate the FMEA (see Annex 1).

### Determination of the effects of equipment failures

By considering the failure modes attributable to each equipment, the effects were determined for each one.These were seen as the symptoms detected by the user when exposed to the failure mode and that affect the service provided by the JDLRA. This stage was tried to be carried out with the greatest possible care, since the information provided was used and subsequently evaluated, an aspect that represented a direct impact on the expected results (see Annex 1).

### Determination of causes of equipment failure

When establishing the failure modes and their effects / consequences, it was necessary to include the causes that led to such situations. In a special column previously established in the FMEA format, the potential reasons, measures or actions that were ignored and that caused it to manifest itself as weakness at a certain time, translated as a potential failure - functional towards the user, were included. In general, the causes were attributed to design and process factors, the first inherent in the specifications of each piece of equipment and the second corresponding to the type of use given to it by the user. As a complement, in another column the current controls or actions carried out by the maintenance area were added in the event of such failures, in response to a later solution (see Annex 1).

### Assessment of the consequences of failures detected in the equipment

Considering that not all the failures presented by the equipment have the same impact, we proceeded to include in table three of annex 1, columns considering Severity, Occurrence and Detectability.

Severity took the effect as a reference, while the Occurrence with which they could manifest themselves was taken for causes. Finally, the weighting of Detectability was based on the current capacity or controls available to address the failures that were presented and considered in the FMEA. The values of these three parameters, when multiplied by each other, generated a Risk Weighting Number (NPR). If its value was $\geq$100, it was indicated that this failure mode-maintained priority over the others, it was indicated with a red color, indicating the need to focus efforts to eradicate it or mitigate its impact on user service. If its value ranged from 80 to 99, it was set to yellow as it is considered intermediate priority. Finally, in values $\leq$ 79, the color green was assigned, representing that your attention can be delayed a little in order to work on those activities that require immediate actions. To obtain the necessary information when assembling the FMEA, the manufacturer's data, generic lists of failure modes, information found in the OT's of the JD Edwards system, people who operate and maintain the equipment were used.

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### Preparation of equipment maintenance plan

It was necessary for the information obtained from the equipment through the implementation of an FMEA to be used and translated into relevant actions or measures to mitigate the occurrence and effects of failures, in such a way that it would allow adequate planning, programming and execution of activities by the maintenance area.

In the document called maintenance plan, in its first version, technical formats (technical sheets, recommendations for use), as well as management formats (service request, work order, resume), protocols of maintenance (autonomous maintenance file, preventive activity schedule) and aspects to take into account for predictive maintenance. A schedule was used within the maintenance plan (See Figure 1), where the maintenance activities to be carried out on the equipment under study were grouped. In addition, a group of tasks, their procedures, indicators and other considerations applicable to the maintenance area were integrated.

**Figure 1** Schedule for preventive maintenance

### Annexes

You can see in Annex 1 the FMEA of the equipment called balance, which includes what is mentioned in the previous steps of the methodology developed.

**Figure 2** FMEA of a balance

### Conclusions

From the functional analysis and FMEA that was carried out on the equipment, it was determined that it is necessary to take advantage of the maintenance history contained in the JD Edwards system, as well as the experience of those responsible for maintenance and laboratory in order to offer a service quality to the user. It was concluded that documentation must be available containing adequate information to understand the events presented during the use of the equipment and the source of the cause of the failures must be identified to maintain the reliability projected by the equipment supplier.

It was possible to determine by means of a risk weighting analysis, that seven teams of all those considered are critical for the laboratories under study. Due to the approach used by RCM and FMEA, it was possible to include new types of failure and equipment for analysis in the maintenance plan.

The objective proposed as part of the maintenance management was fulfilled, strategies and measures could be established to increase the reliability, maintainability and availability of the equipment referred to as critical.

Among the recommendations, measures such as: a) consider the economic part because it has a direct impact on the Department's budget; b) involve staff in the maintenance process through training, relevant talks, knowledge transfer, and more efficient communication.

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