R-MES SOFTWARE PLATFORM
General Characteristics

April 2012

1. INTRODUCTION

While, conceptually, the R-MES approach to Reliability Engineering (Throughputability-Availability-Reliability-Maintainability Engineering System) is clear and simple, its implementation can be complex due to the number, diversity and uncertainty of the various factors involved which must be processed in order to ensure results having a high degree of certainty. These factors include:

- quantity, variety and quality of historical data to be processed,
- evolution of the behavior of equipment during their life cycle,
- diversity of configurations and levels of the industrial installation,
- number and variety of equipment, components and failure modes
- multiplicity of KPI's used to describe the status of assets, their evolution, and future projection, as well as their impact on higher-level systems
- special characteristics of each production process
- variability of operational conditions and of the environment

To address this situation, Reliability Engineering requires analytical models and algorithms that, based on historical data, make it possible to produce statistical and probabilistic results of deterministic and stochastic characteristics. The latter are obtained by means of simulations that consider the distributions of the variables involved.

In order to implement Reliability Engineering, the above complex conditions require rigorous, flexible, and adaptable tools having the capacity to address the problem in a comprehensive manner, in order to assess the impact on the system (business), as well as in a disaggregated way, at the level of the system's basic components (inspectable, repairable and replaceable items), so as to determine the actions needed to improve the use and management of physical assets throughout their life cycle.

There are in the market different methodologies and tools associated with Reliability Engineering. These however, usually only provide partial solutions that do not allow the problem to be addressed in a comprehensive and methodical manner. They also require a great deal work to be performed and involve long processing times and approximations that fail to deliver the accurate and timely information that is needed for decision making.

The limitations of the available offer created the need for a computerized R-MES platform that would be precise, flexible, customizable and easy to use, so as to ease the implementation and development of Reliability Engineering in companies that are physical asset-intensive and that need to maximize their production capacity, and/or in engineering firms involved in the development of new investment projects that need to assess operational reliability factors before deciding on the best technical and economic options for the entire life cycle of equipment and facilities.

The R-MES platform has been used for the implementation and development of reliability engineering in many equipment-intensive companies, in various industrial sectors which seek to improve business results through proper use and management of assets. R-MES has also become a powerful tool for many engineering companies that have decided to monitor the operational reliability of their physical facilities in order to assure the required levels of performance, and to reduce the risk involved in investment projects throughout the evaluation horizon.

2. GENERAL CHARACTERISTICS OF THE R-MES PLATFORM

R-MES is a software platform that supports Reliability Engineering and is oriented to physical asset management and the design or modification of investment projects involving industrial plants and/or equipment fleets. R-MES makes it possible to analyze complex configurations, as well as their basic individual components, by means of Reliability Block Diagram (RBD) modeling and the use of various algorithms and simulations to obtain key indicators (KPI's) on the basis of the historical performance of the equipment and the corresponding probabilistic estimation (deterministic analysis) and simulations (stochastic analysis), in order to audit, plan and improve the overall capacity of assets throughout their life cycle. Data is loaded into the lowest level (components) of the RBD, and this data is then propagated to higher levels to create the systemic KPI's (at configuration level).

Functionally, the R-MES platform provides the user with an overview of asset performance, at the level of components, equipment and systems, in the dimensions of availability, utilization and productivity (production capacity). It also provides different indicators such as: Cost of Failure, Direct Costs, Failure Modes, Safety and Environmental Impact. The platform is complemented by various high-added-value modules that assess reliability, maintainability and usability at the level of replaceable component. The purpose of these modules is to develop and support master plans, and to simulate and suggest improvements in the system's general flowsheet, by evaluating the need for replacement of equipment, design modification, or incorporation of redundancies into the various processes.

R-Mes is a platform for the implementation and development of Reliability Engineering, which supports both asset management and evaluation of projects that involve the design of industrial plants and fleets, so it is useful not only in the operational phase of an industrial plant but also in the engineering phase, as well as for evaluating new investment projects, by incorporating the variable of operational reliability (operational risk) during the life cycle of the equipment and of the project.

Usually, the input data required by the R-MES software already exists in maintenance, management and production systems, so the R-MES platform can be easily integrated with the production and maintenance modules of most ERP, CMMS or EAM systems on the market (SAP-PM, Ellipse, Máximo, PI, Dispatch, Process More, etc.)

On the basis of the applied research work it has carried out, and the experience it has gained in the performance of consulting activities and Reliability Engineering studies, *Centro de Desarrollo de Gestión Empresarial* (CGS) - creator of both the R-MES approach and its software platform - has identified a number of key factors that must be taken into account to ensure proper asset management and project development in terms of operational reliability. These factors have been embodied as functions of R-MES. They include the following:

2.1. Justification of investments

- The R-MES system lets you identify the pieces and types of equipment that have a higher overall cost (direct cost, maintenance cost, and cost of failure), taking as a basis the universe of equipment and the components that make up an industrial plant or a fleet. This makes it possible to direct the efforts of the maintenance and production departments to those units whose marginal improvement in terms of availability and usability has a greater impact on the business.

- It allows reliability personnel to take part in investment project decisions involving improvements and equipment replacement or increased redundancy in processes, by assessing the trade-offs between investment and cost of failure. The process consists of comparing the base (real) situation with simulations (technically feasible plant modifications) that the user is considering.

2.2. A preventive, rather than a reactive approach

- R-MES lets you estimate the reliability of maintainable units, and represents an effective mechanism for optimizing maintenance master plans, through the definition of appropriate frequencies of inspection and intervention, and the recommendation of optimal maintenance strategies (best maintenance policy mix).

- It helps optimize production maintenance plans by identifying the optimal mix between prevention aimed at reducing the costs of failure (unavailability of equipment) and corrective maintenance, thus lowering direct costs for non-critical systems. R-MES helps determine the optimal timing of preventive measures as well as the type of intervention needed in each case, depending on which stage of the life cycle the equipment is in, the corresponding durations of the repairs, and the relationship between the cost of corrective and preventive interventions.

- It lets you define optimal maintenance strategies (at a constant age), for equipment that is in the high-wear stage (increasing failure rate), thereby minimizing the cost of maintenance per hour of equipment availability.

- It lets you improve safety, given the greater risks, to people and assets, involved in equipment failure.

2.3. Standardizing metrics and criteria under a common system

- The R-MES system helps integrate the metrics of, and the calculation criteria for, key process indicators (KPI's), and eliminates the need for multiple calculation systems for the same indicators. This makes it possible to implement benchmarking systems between different business units.

- It is an auditable system, as it allows a historical record of the KPIs achieved to be kept, along with a record of the data that is fed into the system.

- R-MES is a flexible system, that is adaptable to user requirements, making it possible to customize the indicators according to corporate standards. It is also possible to undertake integration processes - through an interface - with production and maintenance management systems.

- It minimizes human error in data processing aimed at obtaining KPI's.

2.4. Improved management plans and indicators

- There is a growing trend, on the part of Maintenance Departments, to audit the behavior of assets, for the purpose of defining maintenance strategies. R-MES delivers the necessary tools to perform this task.

- R-MES analyzes processes in a transverse and comprehensive manner, going from the general to the particular and vice versa (system-maintainable component) and using a methodology of historical and probabilistic analysis (auditing and stochastics).

These tools together provide an overview of the state of industrial assets and the associated risks.

- The analysis of failure probability distributions lets you determine which stage of the cycle a piece of equipment is in (running-in, service life, or wearing out) and provides guidelines for the most adequate maintenance strategy. This is done on the basis of the historical record of equipment failure rate and the cost of each aspect of maintenance (inspections, preventive, corrective or symptomatic maintenance).

- Overall, probabilistic analysis tools make it possible to estimate the behavior of assets from the point of view of reliability of operation, and to evaluate the effectiveness of current maintenance plans.

2.5. Plant modeling methodology using Reliability Block Diagram (RBD)

- An important factor in asset management is the complexity of industrial processes, making them difficult to represent in a model capable of determining their operational reliability. This means that one must generally work on the basis of approximations or assumptions that distort the KPI's of the elements being studied.

- For the modeling of industrial plants and mobile equipment fleets, the R-MES system is based on the methodology of Reliability Block Diagrams (RBD), which consists of grouping maintainable components in logical / functional configurations from a bottom-up perspective, i.e. from the individual equipment to the corresponding group and the entire process being modeled, which represents the reliability of the whole. This methodology lets you obtain key process indicators (KPIs) at the level required by the user, from the basic units (fixed and mobile pieces of equipment) to the behavior of a complex configuration (plant / fleet), in terms of reliability, maintainability, availability, utilization and productivity.

- The platform includes the following preset configurations: Serial, Parallel, Stand By, Fractioning, and Partial Redundancy, thus providing a logical / functional representation of the different levels of redundancy and idle capacity in the different stages of a production process, taking into account the design capacity of the equipment, and the normal operating regime of the process. R-MES can also produce stochastic indicators that take into account the levels of stockpiles, since these stockpile factors are relevant for avoiding the effects caused by a shut-down on the sub-systems, directly affecting the reliability of the process. This modeling of R-MES delivers great versatility for representing any production system, whether it be an industrial plant or fleet.

▪ It is possible to obtain the level of KPIs required by the user, all the way from basic units (components) to complex configurations (lines, areas, plants and fleets). This makes it possible to identify critical equipment and the focus points of loss, develop performance comparisons of similar equipment and ultimately get a reliable diagnosis of overall asset performance.

▪ Importantly, R-MES has its proprietary RBD algorithms (Fractioning and Redundancy-Fractioning), developed in-house by its R & D department, giving the system great versatility to adapt to real processes of different nature. Additionally, R-MES has a simple, intuitive navigation scheme, which includes various features that contribute to smooth and efficient work, leading to increased user productivity.

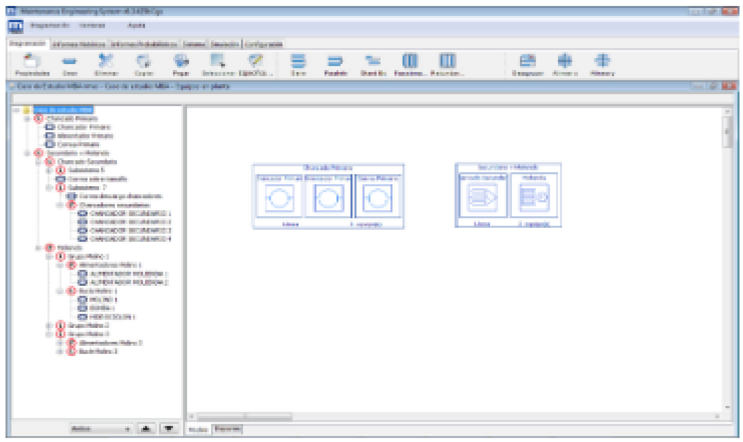

Figure 3.1. Workspace for RBD modeling and logical/functional tree

2.6. Efficiency in obtaining KPIs

▪ In practice, management control engineers or planners spend much of their time obtaining key process indicators, since they lack the necessary tools for systemic analysis. By implementing R-MES, they can significantly reduce the processing time of the data used to generate KPIs, allowing staff to spend more time developing higher value-added activities: planning, scheduling, logistics, engineering, analysis, optimization, etc.

2.7. Simulation of genetic modifications

▪ R-MES allows simulation of genetic modifications, a process that involves replacing equipment, incorporating redundancy into processes or implementing changes in the general flowsheet in order to improve plant reliability. This allows considerable progress to be made in the definition of investment projects, in terms of improvements that entail a reduction in the costs of process Failure Modes, without necessarily altering the reliability or maintainability of the equipment involved. Additionally, it makes it possible to determine whether reducing the loss (Cost of Failure) covers the necessary investment. This allows the return on assets over the life of the project (Capex v / s Opex) to be maximized.

- Alternatively, it is possible to simulate improvements in Reliability Indicators (increased MTBF) and Maintainability Indicators (reduced MTTR) of equipment, making it possible to quantify, at configuration-level and in terms of availability, the following: utilization, cost of failure, impact of proposed improvement actions, and the associated risk (through Monte Carlo simulation).

3. HISTORICAL ANALYSIS

R-MES enables key process indicators to be audited through historical analysis. The KPIs obtained represent the real performance of the plant/fleet with the following scope (these indicators are standard but other personalized ones can be incorporated according to own reality):

- Availability (A).
- Use (U).
- Effective Use (UE).
- Mean Time between Failures (MTBF).
- Mean Time to Repair (MTTR)
- Mean Time between Shutdowns (MTBS).
- Mean Time to Intervene, including preventive activities (MTTI)
- Failure Cost.
- Criticality (Unavailability-consequence)

The Failure Cost indicator represents the loss of valuated production due to shutdowns for maintenance. The comparative analysis of the failure cost between pieces of equipment enables the ranking of losses and their cause, making it a powerful tool for identifying points for improvement that have a high impact on the business.

One important aspect is the ease with which consultations can be made on the historical KPI's of a process since the user can easily define the period and intervals of analysis (for example: analysis of one year in monthly metric), thus enabling the development of a trend analysis of the indicators as a function of time.

The features of historical R-MES reports are described in more detail as follows:

3.1. Productivity, Production and OEE

This report makes it possible to effectively determine the causes for production down time for a plant or piece of equipment, defining the causes as operational or maintenance related and losses due to speed. It also shows the productivity of a plant measured in units per hour available, identifying periods of overuse or low rate for the process, compared to its nominal capacity. It also enables the relationship between actual and target production to be obtained.

3.2. Analysis of Availability, Total Use and Effective Use

Availability and Use indicators are calculated in the following way: for availability indicators, down time attributable to maintenance activities is not counted, and the total calendar time of the period studied is used as a base. For use indicators time associated with operational shutdowns are not counted, and as with the availability indicators calendar time of the period studied is used as a reference. Therefore, these indicators provide a complete view of the impact that maintenance and operational shutdowns have on the process. It is important to consider that R-MES has logical algorithms to identify timely maintenance opportunities, which are done habitually, taking advantage of the plant's operational or reserve shutdowns which do not affect the plant's unavailability but rather the utilization of the productive systems. In these cases, it is important to not lose the record of the activities that are considered for obtaining KPI's of the assets worked on. These indicators can also be calculated by considering the contribution of reliability to the configuration of one or more stockpiles by using the simulation module.

Finally, the Effective Use indicator considers the time of use of the process, using the time available to operate as a base, providing an indicator isolating the operational effectiveness of the process studied. The analysis of the three indicators combined identifies the sources of operation down time of the process and the main causes affecting the cost of the failure.

The ease of obtaining these indicators is an important factor of the R-MES system, since the user only has to define the time period to be analyzed and the interval calculated (metric period) for the system to deliver the KPI's for the whole logical-functional configuration tree automatically. It is also possible to graph the indicators together and establish a trend analysis of the indicator as a function of time.

The report makes it possible to obtain the direct cost indicators of maintenance, the cost of the failure and the global cost for each piece of equipment and the systems contained in the logical-functional diagram tree. The analysis is complemented with Pareto Diagrams that rank the cost variable of the failure associated with the equipment or configuration selected by the user, enabling the critical elements to be determined in each case.

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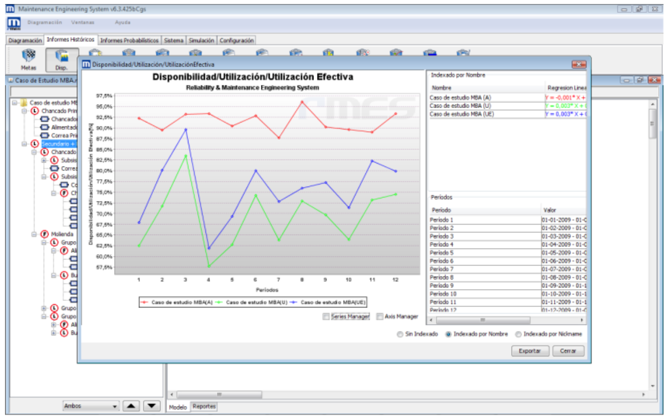

Figure 3.2. Historical report graph of availability, use and effective use.

3.3. Jack Knife

Complementary to this, R-MES has the Logarithmic Dispersion Graph report on equipment reliability and maintainability. The dispersion graph defines the positions of the analyzed elements into four quadrants: Acute: elements with low failure frequency but a high MTTR; Chronic: elements with high failure frequency but a low MTTR; Acute and Chronic: high failure frequency and a high relative MTTR; and Under Control: elements with low failure frequency and a low MTTR.

The analysis serves to guide policies on equipment maintenance through the improvement of reliability (design, spare part quality, etc.), maintainability (staffing, logistics, etc.) or both.

At the same time, the dispersion graph of the failure modes of the diagram nodes that the user deems appropriate to analyze can also be obtained. In this case, it is also possible to establish the relative positions of each failure mode. (Failure Catalogue reports).

Figure 3.3. Jack Knife report

3.4. Analysis of Unavailability / Consequence

The purpose of analyzing critical elements based on unavailability/consequence is to quantify the impact a piece of equipment has on the system (cost of the failure), taking away two components from it: the time that the piece of equipment was out of service or configuration (its unavailability) and its effect on the system's shutdowns (consequence). This enables the effects on the system particular to the piece of equipment and its logical-functional configuration in a system to be separated.

This report also includes the analysis for Environmental Safety Cost which incorporates two factors for the criticality analysis: first is the impact of the failure of a piece of equipment on the environment or safety of the plant, and second is the cost to repair the failure. With this, RMES provides risk analysis reports related to environmental safety.

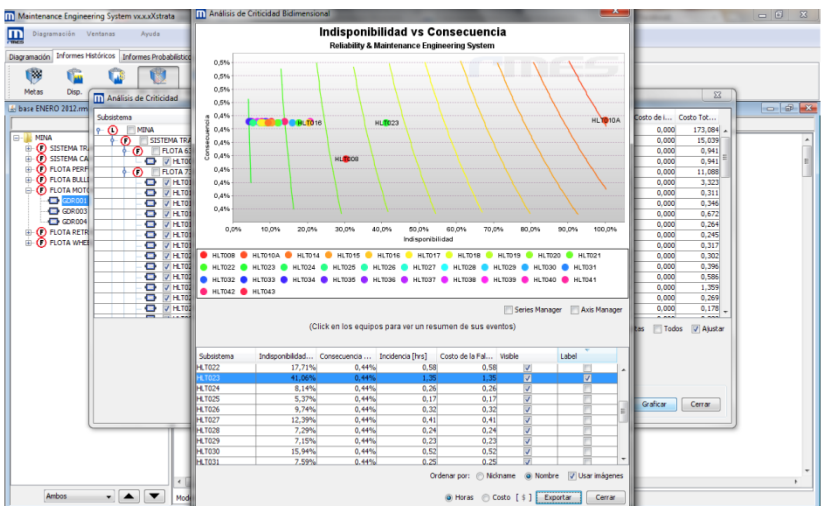

Figure 3.4. Unavailability-Consequence Report

3.5. Statistical Indicators

Besides the historical indicators previously presented, the indicators of reliability, maintainability and operational continuity of the assets are emphasized, since the maintenance policies for improvement and implementation are very different depending on the deviations detected in each aspect.

As a historical indicator of reliability, Mean Time between Failures (MTBF) is calculated, which indicates the time of use of equipment or a system between two consecutive failures. Similarly, Mean Time between Shutdowns (MTBS) indicates the time of use of equipment or a system between two shutdowns, regardless of whether such shutdowns are operational or for maintenance.

Regarding maintainability indicators, R-MES provides the Mean Time to Repair (MTTR), which reflects the average time of corrective intervention of equipment or a system. Another indicator is Mean Time to Intervene (MTTI), which represents the average time of intervention of equipment considering both preventive and corrective maintenance activities.

The importance of these indicators is that they report the reliability and maintainability status of an industrial asset. This is important for defining the intervention frequencies contained in the maintenance plans, as well as for proper estimation of the time required for shutdowns of production lines to carry out interventions.

Regarding the ease of obtaining these historical indicators, the calculation logic is equivalent to the indicators presented previously (Availability, Total Use, and Effective Use), including the graph applications described previously.

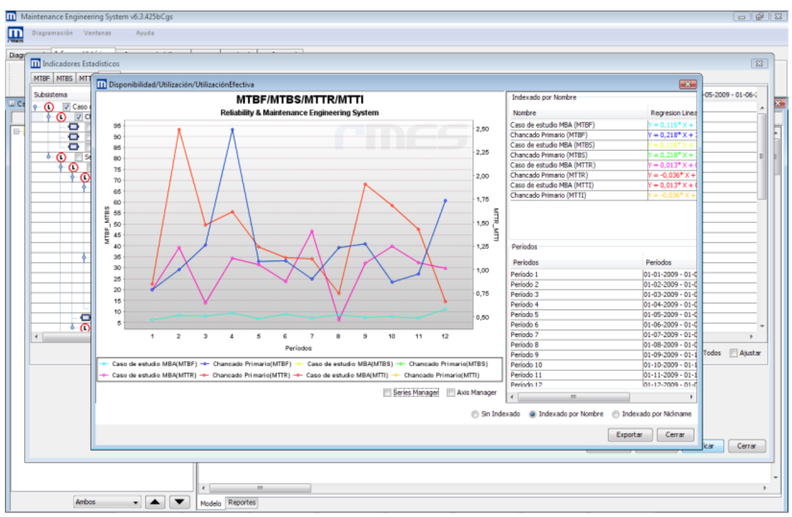

Figure 3.5. Historical graph report of mean times.

3.6. Mix maintenance

This report shows the structure of the work orders implemented on a piece of equipment, defining the percentage of corrective v/s planned activities. The report considers two values separately: implementation time and number of activities.

Nelson-Aalen

The Nelson-Aalen diagram enables the follow-up of maintenance and operational activities carried out on a piece of equipment or configuration during a determined period of time. This is useful for analyzing the sequence of activities carried out as per specialization (mechanics, electricity, instrumental, etc.), providing information on the reliability of the equipment and the quality of the repairs performed based on their analysis (for example: high frequency of corrective shutdowns for preventive maintenance). Additional information can also be obtained with respect to the time of each maintenance activity and its impact on the system of the equipment.

The functionality of Nelson-Aalen graphs satisfies the need to represent all historical events occurring in a piece of Equipment/Configuration during a period of time in a graph. This graph details information such as the type of event, if it did or did not cause the System to shutdown, the impact of the event on the System and the duration of the event.

In each graph the size of the bubble indicates the event's impact on the System, the marker indicates the specialization of the activity carried out (differentiated by the form) and the color of the marker indicates if the System shut down or not (red or green). Additionally, a tag for each point is included indicating the duration of the event and the numerical value of the impact.

3.7. Pareto for Shutdowns

Using the Pareto Diagram, equipment that is more important in regard to time and frequency of maintenance can be detected through the application of the Pareto principle (vital few and trivial many), which states that in general 80% of the total results originate in 20% of the elements studied.

In this case the R-MES system presents the time and frequency of intervention/shutdowns of equipment and configurations in a hierarchy. Besides showing actual results, it also shows the cumulative percent curve in a secondary scale. The graph is very useful for visually identifying in one single review the minority of vital characteristics that it is important to pay attention to, thus enabling all of the necessary resources to be utilized to carry out a corrective action with a proper allotment of efforts and resources.

It is important to consider that the user can create filters of the types of interventions/shut downs to be analyzed in the Pareto diagrams; this possibility brings greater flexibility to the application.

3.8. Failure Catalogue Reports

For corrective maintenance activities, the capacity to capture the failure catalogue of each piece of equipment or component is included in the database. The information is classified according to a list of failures specific to the client, which is configured in the R-MES system to define the corresponding types.

The failure catalogues administrated by R-MES has three categories, namely Symptoms, Failure Modes and Cause, which conceptually correspond to the stipulations of ISO Standard 14224. The Symptoms and Cause categories only have a Frequency Pareto report which orders them according to the number of events, while the Failure Mode category has a Pareto report that includes the frequency and duration aspects, a frequency v/s duration dispersion report and a global maintenance cost (direct and indirect) dispersion report v/s the impact on safety and environment that finally measures criticality based on risk.

The purpose of these reports is to feed the analysis of equipment failures (Root Cause Analysis – RCA), mainly based on the Paretos for Symptoms, Failure Mode and Causes, as well as to support the risk analysis of failure modes when using MAFEC methodology, mainly based on the CSA dispersion diagram.

3.9. Maintenance Plans

Algorithms that address topics such as calculations based on hourmeters, RCA and MAFEC analysis that ease the preparation of Productive Maintenance Plans.

4. Probabilistic Analysis

As a complementary analysis, R-MES has tools to estimate key process indicators (KPI's) based on the behavior of the failure of the equipment by adjusting the probability distribution (Exponential or Weibull). This tool allows the user to determine the current life cycle phase of the equipment (Early Life, Useful Life, or Wearout Life) in order to define the optimum maintenance policies for each particular case. In parallel, this analysis shows the reliability curves for equipment and configurations under study, representing the probability of the proper functioning of the element over time. The process is highly effective for adjusting intervention frequencies contained in the master maintenance plans.

The historical and probabilistic analyses as described are tools that enable the critical points of a process to be identified. The analyses have a different, albeit complementary, outlook that is essential in identifying projects for improvement either at the management or investment level.

4.1. Deterministic

4.1.1. Definition of Optimum Maintenance Policies

Given that the direct cost of performing a maintenance activity is different in the case of preventive maintenance than for corrective maintenance, R-MES has an application for maintenance policies for constant age, which applies to equipment at the Wearout phase and enables the intervention frequency optimizing the global maintenance cost to be determined. It also defines, for the optimum frequency found in this module, the forecast of the annual maintenance structure, in terms of expected number of corrective and preventive maintenance activities and the cost associated to each type of activity. This tool, therefore, is useful in estimating budgets representing intervention requirements of the maintainable units.

One important aspect of R-MES is that it provides the possibility of evaluating the optimum policy on the replaceable component (this factor is present in the failure mode category) which is finally where the logical-functional disaggregation of the equipment is connected with the maintenance plan.

4.1.2. Reliability Curves and Failure Rate

The report enables to know the good functioning probability of a piece of equipment, configuration or plant over time based on the adjustment of the distribution curve of failure probability (pdf). It can also determine the conditional probability of failure or failure rate of an element, a report that is able to determine the life cycle phase of equipment (Early Life, Useful Life, or Wearout Life). It is important to consider that R-MES enables the development of comparative graphs of equipment for the aforementioned variables.

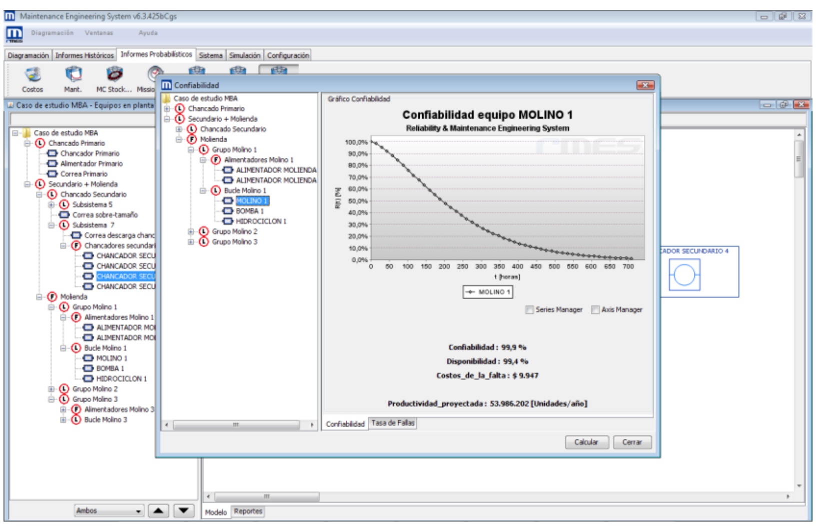

Figure 3.6. Reliability probabilistic report

4.1.3. Maintenance Policies

Considering the maintenance costs (corrective, preventive and inspections), as well as the life cycle phase of the equipment analyzed, as input information, R-MES defines guidelines of the policies applicable to each piece of equipment, and includes Corrective (RTF-Run to Failure), Cyclical Preventive or Predictive (Symptomatic) maintenance as options.

This module additionally provides an optimization algorithm for cyclical maintenance, applicable for equipment in the wearout phase, which enables the optimum frequency for maintenance of the equipment analyzed to be determined. This permits the optimization of maintenance plans, defining the expected combination of corrective/preventive maintenance and associated costs (annual forecast).

4.1.4. Mission Time

This is an application for determining the probability that a piece of equipment will reach a programmed shutdown without failing. This report is a powerful tool for adjusting programmed shutdowns of process lines (short-term analysis) as well as comparatively determining which pieces of equipment have a greater probability of failing, alerting the maintenance units about equipment that is critical in terms of reliability. This tool can also be used in the opposite manner, to postpone programmed maintenance activities if the equipment's reliability for the programmed maintenance time is assessed as high.

4.1.5. Probabilistic KPI's Reports

Considering the historical information of maintenance activities of equipment, R-MES performs distribution adjustments on the failure probability (Exponential or Weibull), which enables reliability curves of equipment and their probable Mean Time between Failures (MTBF) to be determined. The life cycle phase (Early Life, Useful Life and Wearout Life) of the piece of equipment is determined based on this information. It also performs Maintainability analyses, measured by the Mean Time to Repair (MTTR), presuming Normal distribution. The probabilistic analysis includes Inherent Availability and Failure Costs expected for the equipment, systems and Global Plant.

The probabilistic analysis enables to project the behavior of equipment with better planning in the medium and long-term, focusing on elements that will generate a higher failure cost of the productive system.

4.1.6. Probabilistic Costs

Based on the probabilistic MTBF indicator, and considering the average intervention cost of a piece of equipment, the R-MES system provides an estimate of the annual maintenance cost, which eases the generation of annual maintenance budgets. It can also obtain consolidated budgets for subsystems and the global plant, which is nothing more than the sum of the local indicators obtained for their constituent equipment. The value of this is that the budget estimate is based on the current condition of equipment through the application of probabilistic reliability applications of the R-MES platform.

4.1.7. Other Probabilistic Indicators

Regarding complementary probabilistic indicators, the R-MES system calculates the Reliability, Availability and Failure Cost for equipment and subsystems. With respect to Reliability, which is a function variable of time to operate the equipment or system, its probabilistic application is useful to audit the effectiveness of the maintenance plans, providing the maintenance structure expected in the medium-term (corrective and preventive). It also enables to know the critical elements for a specific time of operation, through a comparative analysis of the reliability curves of different pieces of equipment.

With respect to Availability, the reach of the indicator is similar to the historical definition, except that it is calculated based on the probabilistically defined MTBF and MTTR through the corresponding probability functions. In this case, it is estimated that a maintenance cycle is constituted of the available time of MTBF over a base time of MTBF and MTTR for the equipment or subsystem analyzed. Finally, the Failure Cost is nothing more than the valuation of the unavailability of the system to produce, a value that is proportional to the elements of the logical-functional configuration tree, in accordance with the impact made by each element.

As can be seen, the reach of the indicators is similar to that set forth in the historical analysis, with the main difference being, in the case of the probabilistic analysis, the current life cycle phase of the piece of equipment is considered (Early Life, Useful Life, Wearout Life), a factor that impacts the KPI’s expected in the performance of each piece of equipment or system.

4.2. Stochastic Indicators

4.2.1. Montecarlo Simulation

Notable among the probabilistic indicators is the stochastic availability and use simulation through the use of the Monte Carlo algorithm. This application uses historic information or the user’s own parameters to conduct multiple simulations of the behavior of the same production system, considering in each iteration the potential input values of each variable, including the MTBF and MTTR of each piece of equipment. Ultimately it provides a probability distribution of expected availability or usage that allows the determination of risk and the likelihood that each scenario will occur.

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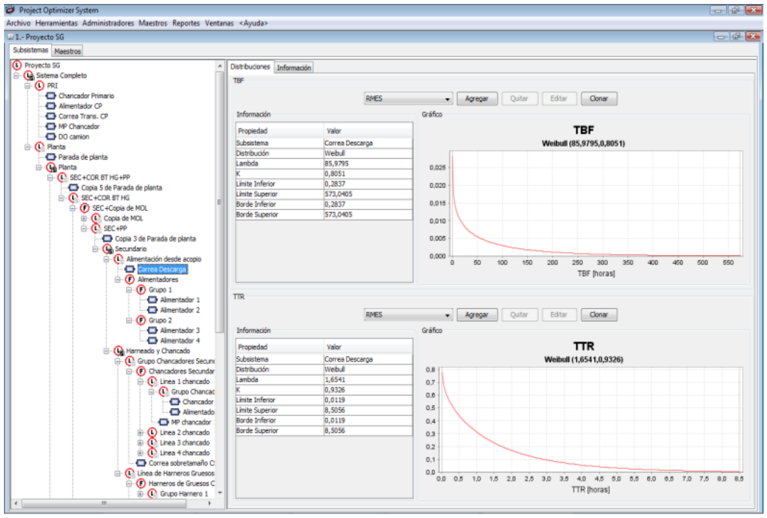

Figure 3.7. Distributions for generating random data

4.2.2. Modeling and Simulation of Stock Pile Systems

As an extension of the previous report, R-MES allows, in its stochastic KPIs for availability and use, the presence of stock systems such as stockpiles, tanks, and inventories, among others. The objective is to obtain a real picture of the process through a simulation that quantifies the impact of a stockpile system on the reliability and variability of the process. This report is essential for optimum scaling of stockpiles in new investment projects as it allows different scenarios to be iterated.

4.2.3. Assessment of Investment Projects

R-MES, through the T-RAM (Throughputability- Reliability, Availability and Maintainability) scenario simulation, supports the assessment of new investment projects. In this context, reliability engineering provides new variables for decision making that allow the expected production level to be estimated for different investment options and therefore the economic benefits to be obtained for each in terms of LCC (Life Cycle Cost).

This makes it possible, through quantitative analysis, to establish criticalities, identify opportunities to improve the design, fine tune the optimum capacity of accumulation systems and adjust redundancy levels based on the capacity of the equipment. Thus, this kind of analysis allows the quantification of the real economic benefit of an increase in Capex (Capital Expenditure) or the determination of the best investment option based on budgetary constraints and on a productive goal, in order to avoid paying for more reliability than is needed.

In addition, the stochastic reports enable the risk associated with each one of the options to be quantified. In other words, they not only produce deterministic values but also a distribution of potential values to establish the likelihood that a given investment option will reach the expected production level.

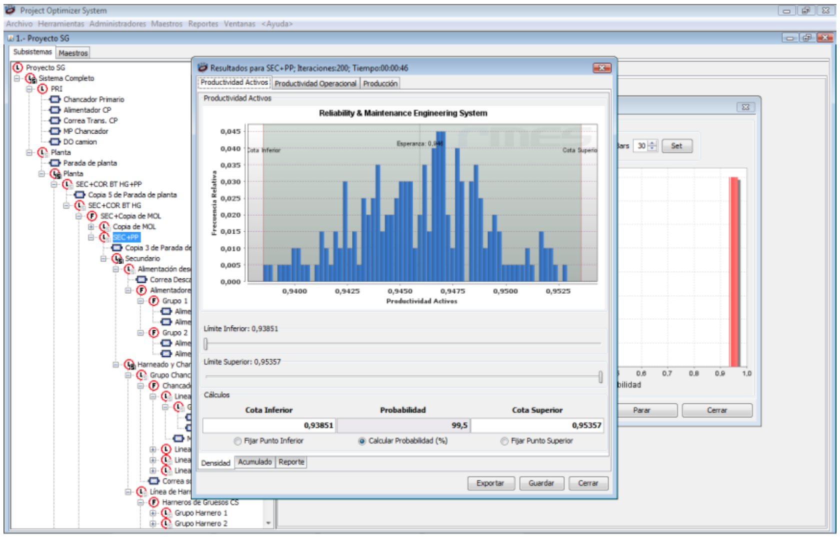

Figure 3.8. Histogram of asset productivity

5. Other capacities

The R-MES system possesses a series of complementary utilities that are specially designed to make the system easy to use and data easy to handle.

5.1. Identification of Maintenance types

This enables the differentiation of 8 types of interventions/stoppages to obtain KPIs for each specialty (Preventive and Corrective Mechanical, Electrical and Instrumental Maintenance; Scheduled and Unscheduled Operational Stoppages; Scheduled and Unscheduled Operational Delays).

5.2. Configurable maintenance types

The identifiers that are associated with each type of maintenance can be configured by the user in accordance with conditions within the company.

5.3. Compatibility of formats

The system enables the exportation of different reports in formats compatible with MS-Excel and Internet Explorer. Through its interface with the ERP it also can provide data and export them to that application.

5.4. Search function and counter

For complex systems, applications for conducting searches and counting of equipment in a logical-functional diagram become especially important. This makes it very easy to navigate among the models developed.

5.5. Data Verification and Control

R-MES maintains a registry of the data imported into the system, which enables follow up of the maintenance activities conducted through specific work orders (WO); this in turn enables the study and validation of maintenance data.

5.6. Configurable equipment lists

R-MES has the capacity to generate lists and/or subsystems that can be used to speed up the process of selecting equipment and/or subsystems in the reports that can be selected. This functionality allows equipment to be grouped into families.

5.7. Importation of Equipment and Properties from Excel

R-MES allows equipment and their respective properties to be directly imported from Excel. This function is useful to begin diagramming, especially in the case of fleets. It also takes advantage of the features offered by Excel to assess and sensitize the effect of changes on the equipment parameters.

5.8. Personalized Metrics

The metric of the indicators can be personalized to align with each company's defined KPIs.

5.9. Data Repository and Mass Data Upload

To upload the data from local databases (MS-Excel) or maintenance management systems, the R-MES system enables the mass uploading of the equipment or subsystems contained in a logical-functional diagram, which minimizes the time required to obtain results.

5.10. Mass configuration of equipment parameters

R-MES has a mass-configuration capacity that can be used for the maintenance data of multiple pieces of equipment and/or subsystems.

5.11. Validation of data upload

For data uploading, algorithms have been installed that verify the validity of the data imported according to criteria defined by expert consultants.

5.12. ERP Interface

R-MES has an interface to capture data from notifications and work orders for Scheduled and Corrective Maintenance registered in ERP platforms, which enables the automation of data uploading in order to prevent duplication of data fed into the system. At the same time, interfaces can be created for other CMMS or EAM management systems.

5.13. SAP Interface

R-MES has a direct interface with SAP through sapjco2, which enables data needed to feed the system to be obtained directly from SAP.

The R-MES Software is designed to relate to the R-MES Portal, which is a solution that enables the software's own capacities to be used in conjunction with the potential of a WEB platform. This solution facilitates access and enables the sharing of information among different users, which allows integrated information from different situations to be made available.