State of play: initial phase and pillar of implementation of a maintenance management system promoting the integration of safety and environment aspects in maintenance : Case study.

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Abstract: - Industrial maintenance plays an increasingly important role in the productivity of the company. Today, manufacturers can no longer neglect the maintenance of their production tools. They become aware of the economic stakes by providing for maintenance in their choice of investment. Maintenance is considered as a source of optimization of the production tool or even a factor of profits. This function is no longer only to rehabilitate the work tool but more and more to anticipate its dysfunctions. The efficiency of the maintenance departments remains dependent on the management systems and policies put in place. Several maintenance policies have been successfully implemented in various industrial sectors. However, these maintenance policies focus mainly on the intrinsic factors of the equipment and do not emphasize the external factors that may affect its good performance, such as the modes of execution of the maintenance, their impact on the safety of the maintainers and on the environment. The components, safety and the environment, are largely omitted from the maintenance management systems implemented within the companies, which clearly appears through the performance indicators that show results below expectations. In this context, we have designed a maintenance management system that promotes the integration of safety and environmental concepts into facility maintenance, which is divided into four phases: state of play, feasibility study, conception phase, as well as implementation, evaluation and improvement phase. Through this work, we will present the different phases of our system and we will deploy the inventory phase.

Key Words: - Industrial Maintenance, Maintenance Management System, State of play, Safety, Environment, ISO 9001.

1 Introduction

Industrial maintenance, which aims to ensure the proper functioning of production tools, is a strategic function in companies. Maintenance, which was nothing more than an inevitable part of production, is now becoming a strategic commercial element [1]. In an industrial context of permanent research of operational efficiency for a control of the costs and a better reactivity of the companies, the maintenance must continue its mutation as much on the organizational aspects as methodological [2].

The maintenance function is a transversal function of the company, just like the quality, safety and human resources functions [3]. It groups together all the activities making it possible to ensure the durability of the production tools, according to the given conditions of safety of operation. It is therefore the set of skills necessary for a device to be available at different points in its life cycle, offering the required performances, namely: reliability, maintainability and safety (equipment safety, personal safety and environmental) [4].

Companies are increasingly looking for maintenance management systems that allow them to migrate from an availability-based maintenance policy to another one based on reliability. Today, the proportion of corrective maintenance and systematic preventive maintenance is gradually reduced by the implementation of conditional or even predictive maintenance strategies [5]. Predictive maintenance makes it possible to reduce product quality drift, insecurity and direct maintenance costs by better monitoring degradations and better maintainability compared to conditional maintenance [6].

Maintenance services must implement a maintenance policy in accordance with the regulations, based on the support of production, to ensure the safety of maintenance personnel and material assets and respecting the environmental standards in force. The maintenance strategy is the set of decisions that lead, on the one hand, to defining the maintenance production activity portfolio, that is to say, to decide on hardware maintenance policies: corrective methods, preventive, improvable to apply to each material, and secondly to structurally organize the system of conduct and productive resources to achieve it within the framework of the outsourced mission “unpublished” [7]. According to [8] the best maintenance does not mean "zero breakdown", the management of the maintenance corresponds to the defined policy. The latter is broken down into a strategy that must be applied as part of the company's accreditations (quality, safety, etc.).

Several maintenance policies have been successfully implemented in the industry, such as TPM (Total Productive Maintenance) and RBM (Reliability-Based Maintenance). However, these maintenance policies focus mainly on the intrinsic factors of the equipment (History, Basic conditions, Analysis of the causes of breakdowns, Age, Modes of failure, Criticality, Frequency, etc.) and do not focus external factors that could affect its proper functioning, such as the maintenance activity (Safe Operating Procedures, Conditions of Intervention, Risk Prevention, OHS, etc.). Safety and environment standards, which are widely covered in the literature, are rarely taken into account at the level of maintenance management systems. The combination of maintenance standards and those related to safety and the environment in a global management system is less studied.

The efficiency of the maintenance function within an organization is therefore no longer evaluated solely on the basis of the equipment availability indicators, but rather on a global management system also based on the management of safety and environment, the relevance of the procedures and the ability to prevent and control the risks associated with different interventions. Maintenance is an activity directly related to production on the one hand, and safety on the other [9].

The business of industrial maintenance is extremely diversified and security issues are complex and specific to each of these businesses. Indeed, the major difficulty in industrial maintenance work is the diversity of industries and the large number of contexts that workers face, generating a multitude of risks “unpublished” [10]. The Health and Safety Executive (HSE) estimates that more than three quarters of the accidents related to maintenance could have been avoided, if adapted preventive measures had been put in place [11]. The prevention of occupational risks can not be considered in a static and definitive way. On the contrary, it must be appreciated and constructed as part of an iterative process taking into account the evolution in the company of human, technical and organizational factors [12].

Maintenance policies must include safety and environmental management systems. In this context, we have designed a maintenance management system that promotes the integration of the concepts of safety and the environment into facility maintenance, which is divided into four phases: inventory, feasibility study, design phase and implementation as well as evaluation and improvement phase. This system is based on ISO 9001 version 2015 to be consistent and adapted to each type of company. It will deal with the different aspects: technical, operational, managerial and organizational to enable companies to be able to implement a reliable and safe maintenance system. For the development of a global approach taking into account the keys of the success and avoiding the factors of failure, we carried out two complementary studies :

- An analysis of the maintenance management system within a large Moroccan company in the field of chemical transformation, via a collective approach called DCA (in French applied short diagnosis), with stakeholders in order to identify the handicaps as well as the elements of the successful implementation of such a maintenance policy.

- A survey of an international organization expert in this field combined with the company studied to gather their opinion on the key factors of success as well as the guidelines to be followed to carry out the project design and implementation of a maintenance management system.

Through this work, we will present the different phases of our system and we will deploy the inventory phase.

2 Design Approach and Implementation of MMS / S & E

The design and implementation of the maintenance management system taking into account the safety and environmental requirements is structured around four phases.

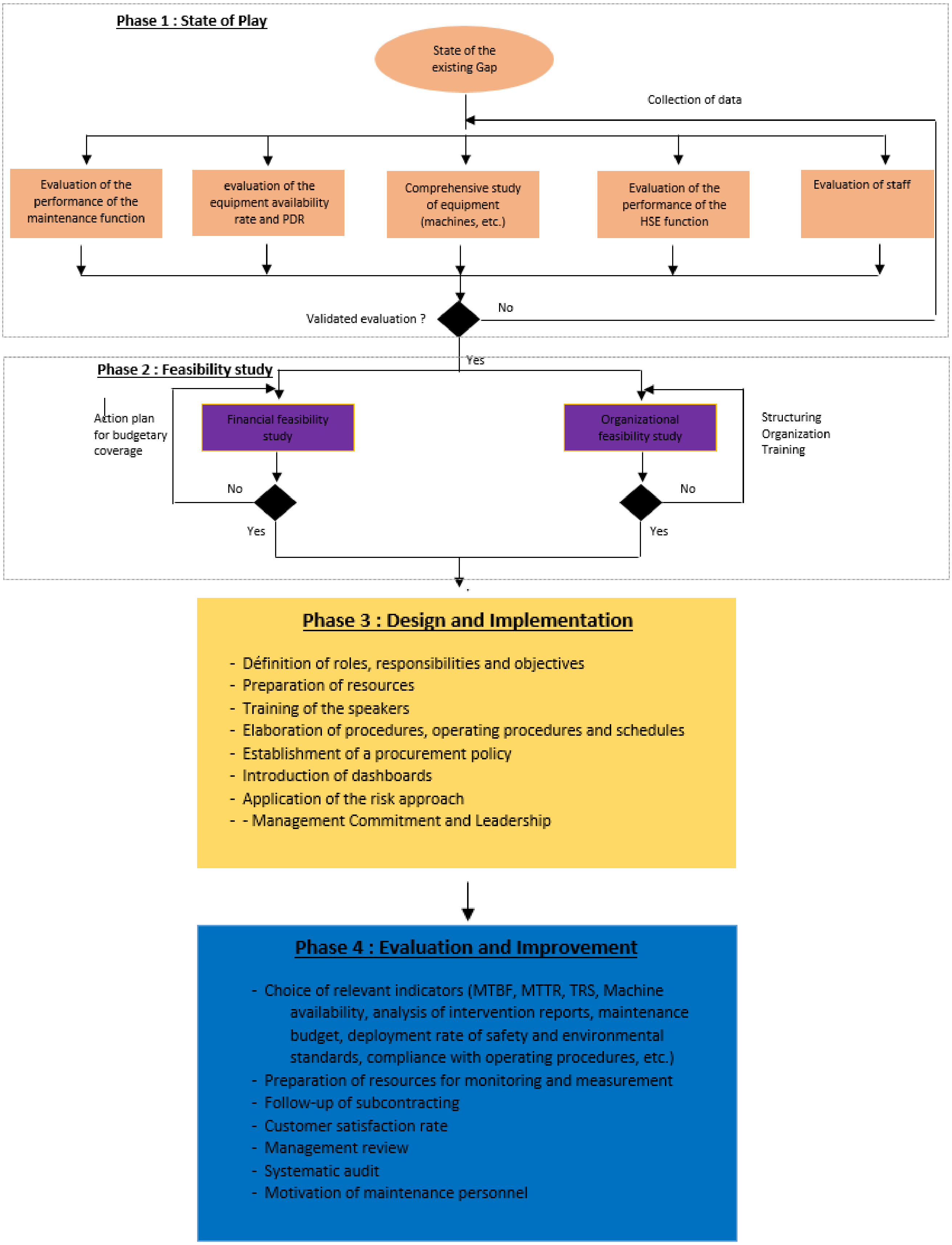

Fig. 1 The four phases of MMS/S&E design and implementation

2.1 Phase 1: State of play

The first step is to collect the different data relating to the maintenance management system and the OSH and environment components, aiming at establishing a state of the existing and measuring the current performances. It also enables the level of skills of personnel maintenance to be assessed.

This phase defines the state of the premises and serves as a tool for decision-making by the principals by analyzing the differences between the existing and the projected situation, to trace the corrective steps to follow and propose the evaluation axes and maintenance of performance.

2.2 Phase 2: Feasibility study

This phase focuses on the feasibility check of the design and implementation of MMS / S & E at the financial and organizational levels.

- Financial feasibility: In order to allow the project to be supported by the various stakeholders, it is necessary to demonstrate a significant return on investment. To do this, we must first estimate the financing needed for the development and sustainability of this project (Training Cost, Audit, Equipment, PPE, etc.) and compare it to the losses due to the current maintenance management system (Lack of production due to maintenance shutdowns, damage to equipment and property, work-related loss, demotivation of personnel, etc.).

- Organizational Feasibility: Project funding is a necessary but not sufficient condition. It is necessary to highlight the degree of maturity of the maintenance and HSE departments, and to propose an action plan allowing a restructuring, change of culture and habit and development of skills.

2. 3 Phase 3: Design and implementation

After drawing up an inventory and checking the feasibility of the project, the stakeholders will have to draw up the guidelines to be followed to carry out the implementation of the MMS / S & E.

• Freeze the objectives and expectations initially set;
• Preparation of the infrastructure, environment and human resources necessary for the effective implementation of the maintenance management system;
• Definition of functions, roles and responsibilities;
• Establishment of an implementation schedule;
• Definition of priorities according to the different assessments established in the first phase;
• Preparation of material resources;
• Exploitation of the skills matrix to map out the appropriate training plan;
• Preservation of appropriate documented information as evidence of skills acquired by the trainings;
• Identification of risk situations, environmental aspects and regulatory requirements;
• Internal and external communication;
• Development of safety and environment standards related to the maintenance activity (Risk analysis, Work at height, Work in confined spaces, Consignment & Deconsignation of energies, Management of external companies, Management of modifications, Analysis of process hazards , Management of Accidents and Work Incidents, Waste Management, Handling, Traffic, Material Safety Data Sheets, Work Authorization, Site Visits, Detection / Action, etc.);
• Development of maintenance procedures, all forms combined, preventive and corrective, taking into account safety and environmental standards;
• Development of master plans for deployment of standards and procedures;
• Preparing contingency plans and conducting simulations;
• Systematic update of the machine records;
• Creation of a system for recording and archiving data;
• Establishment of a spare parts procurement policy to meet maintenance needs, avoid repairs and risky solutions on the one hand, and optimize overstocks or dead stocks on the other hand;
• Mastery of outsourcing, skills required, interactions, effective communication;
• Introduction of dashboards (posting, one-off lessons, management and monitoring of outsourcing, Flash security, etc.) and systematic updating;
• Digitalization of data (CMMS, Databases, IT tools, etc.);
• Implementing actions to prevent human error;
• Establishment of a risk-based approach at each phase to identify factors that could cause a gap in the system in place compared to the expected objectives and put in place a preventive control in order to limit the negative and adverse effects and make the most of opportunities when they arise;
• Establishment of a system of communication with the customers allowing to have a return of

information, complaints, specific requirements allowing a total satisfaction of the customer;
• Establishment of a system allowing the participation and the cooperation of the maintainers;
• Commitment and leadership of management.

2.4 Phase 4: Evaluation and Improvement

Several maintenance policies, developed and implemented at the level of industrial enterprises, have not yielded the desired results because the systems and processes put in place do not give much importance to evaluation and continuous improvement aspects. At each phase of the project, it is necessary to evaluate, improve and put in place a device not to regress (The PDCA wheel block).

• Choice of relevant indicators that reflect a realistic picture of the maintenance management system;

• Resource preparation for monitoring and measurement and traceability of results;
• Indicators for monitoring subcontracting;
• Customer satisfaction rate and interested parties;
• Evaluation of the effectiveness of planning and actions implemented in the face of risks and opportunities;
•Internal Audit;
• Data analysis, interpretation and implementation of improvement plans;
• Management review to assess progress;
• Systematic analysis of the differences between state E and state E-1;
• Motivation of maintenance staff to maintain progress;
• Increased performance requirements by applying the risk approach.
• Adoption of various forms of improvement in addition to correction and continuous improvement, such as breakthrough change, innovation and reorganization.

3 Deployment of The Status Phase

Our study focused on a large Moroccan chemical processing company that has many facilities at risk and has been practicing maintenance for more than 30 years. Despite its long experience in maintenance, the commitment and expertise of its staff, the results obtained by the various maintenance departments and HSE are far from the expected objectives, a number of accidents and incidents at work important therefore affecting the maintenance efficiency. As a first step, we conducted a global audit of the systems in place. We have been able to detect a big difference, in particular as regards the respect of the norms of safety and environment and standards of maintenance. A quantitative evaluation of the relevance of the maintenance programs, during the years between 2010 and 2017, allowed to record an accident and incident rate higher than 95% that could be avoided if appropriate preventive measures had been implemented.

This first phase will be divided into several stages, each of which will highlight, by means of relevant indicators, the failures on the maintenance management system in terms of HSE, evaluate the current performance and get hold of the key factors and important levers that will allow us to propose effective remediation and improvement actions.

3.1 Impact of outsourcing and outsourcing on HSE maintenance activity

Outsourcing is no longer just a growing part of the business, it is becoming almost indispensable. Subcontracting certain activities is an organizational practice that is increasingly used by businesses [13]. Statistics show more work-related accidents on the part of outsourced employees compared to employees of contractors, but it should be borne in mind that some companies subcontract their activities. The most risky, especially in the industrial sector [14]. In order to better understand the impact of outsourcing, we will present some indicators dealing with several aspects. The following figures show the percentage occupied by subcontracting within the company, a comparison between the two internal and external service providers on the HSE training plan and a breakdown of accidents and incidents at work for both cases.

Fig. 2 Overall impact of subcontracting

3.2 Breakdown of accidents and incidents

This indicator consists of collecting data on reported accidents and work incidents and analyzing them, according to different criteria, in order to highlight and detect the main differences, anomalies and failures. The following figures show the distribution of accidents by type of activity and type of anomaly.

- ❖ Breakdown by nature of activity

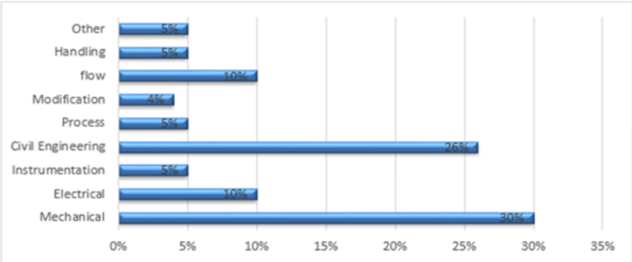

Fig. 3 Division of accident by activity type

- ❖ Distribution by type of anomaly

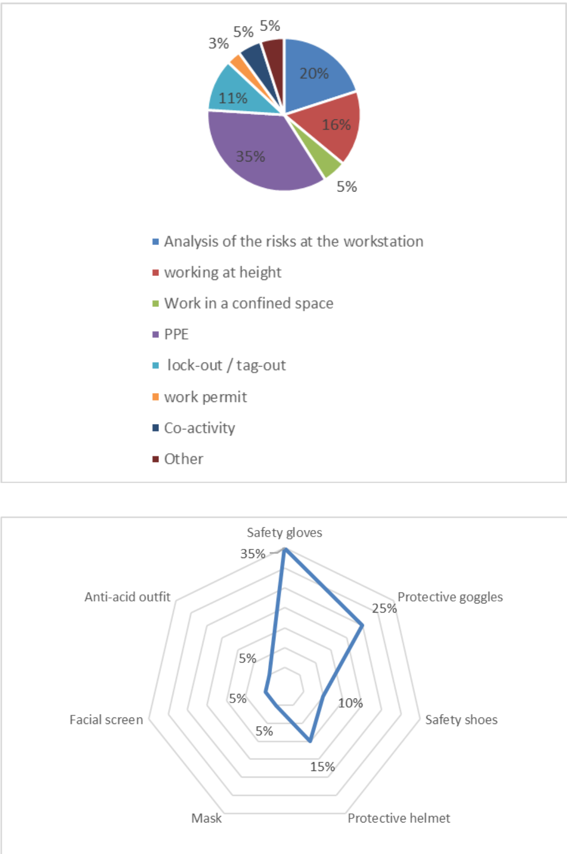

Fig. 4 Division by type of anomaly

The accident investigation / analysis is a process that identifies the causes of accidental events and recommends corrective actions “unpublished” [15].

3.3 Number of modifications on the installations

Our state of play study also included changes made by staff to existing facilities. Although the distribution of accidents and incidents revealed that, the modification was only incriminated because in 4% of the total number of accidents and incidents, we considered it advisable to focus on this anomaly because the consequences related to it have the severest severity. To this end, we have recorded the number of changes made, we found that 75% of the changes have not been declared and validated by the management and have consequently caused significant material and bodily harm.

3.4 Waste management

As part of our goal to improve environmental performance, we conducted a study on the current state through several indicators, we cite some examples:

- Regenerated or reused hazardous waste rate (regenerated or reused hazardous waste / hazardous waste generated);
- Recycled hazardous waste rate (recycled hazardous waste / hazardous waste generated);
- Rate of hazardous waste recovered from energy (hazardous waste energy recovered / hazardous waste generated);
- Incinerated hazardous waste rate (incinerated hazardous waste / hazardous waste generated);
- Rate of hazardous waste landfilled (hazardous waste landfilled / hazardous waste generated);
- Filling rate of TS (temporary stockyard);
- State of development of the sorting areas (planned number / number achieved).
- Status of the development of the TS (planned number / number achieved).
- State of development of controlled landfills (planned number / number achieved).

3.5 Assessment of staff skills

We have focused on evaluating the maturity of the company in terms of staff qualification, particularly in terms of safety standards and environment in force during the execution of maintenance operations. In order to highlight weaknesses, we measured the skills of staff at all levels. The following figure shows the indicators for this evaluation step.

❖ Operational Mastery

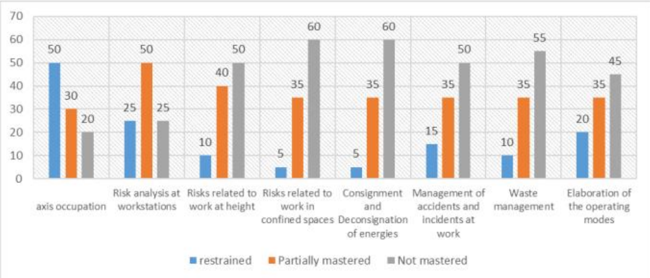

Fig. 5 Division by type of anomaly

The evaluation reveals that the operational control remains very weak to be able to face the different risks related to the operations of maintenance. This result justifies the discrepancies in relation to the number of accidents and work incidents recorded.

❖ Perception of risks

In the last thirty years or so, studies on the perceptions, expectations and demands of the general population or the salaried population for risk have been added to the characterization and control of risks [16]. The development of safety culture is often presented as an important factor in improving the control of risks to health and safety at work [17]. In order to be able to find the factors that can improve the current situation, we will carry out a complementary analysis of the maturity of the staff, based on intrinsic factors, namely: the degree of motivation and profit-sharing as well as the perception of risks at the level of each operator.

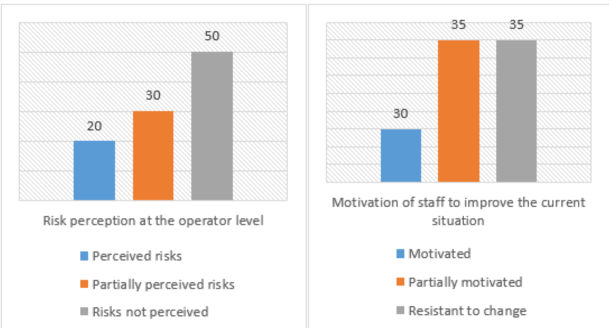

Fig. 6 Division by type of anomaly

This approach demonstrates that the risk factor is not highly perceived by the personnel carrying out the maintenance operations. The risks associated with the various interventions are largely underestimated because of the safety culture of each operator and his skill level. Resistance to change to migrate to the projected situation also remains a challenge. In organizational context, resistance is also synonymous with blockage, brake, obstruction, obstruction and opposition, hence its traditional meaning. Organizational resistance would be used to signify what prevents the construction of a new organized system from being put in place [18].

3.6 Study of the equipment park

The equipment fleet is very diversified, the production lines use rotating equipment, such as pumps, reducers, agitators, compressors, turbines, turbo-alternators, grinders, electric and hydraulic motors, etc., as well as static equipment such as storage bins products, heat exchangers, etc.

❖ Equipment classification

The identification of the equipment constituting the production lines represents the basic element for setting up a reliable maintenance system. This first step makes it possible to establish a classification of the different equipments. The latter will be based on the TDPC method, focused on four criteria: repair time, degree of influence, probability of failure and criticality of the equipment. These criteria are detailed in the table below.

Criteria	Abbreviation	Description
Repair time	T	Mean time of repair (MTTR) calculated from the history of interventions
Influence factor	D	Use of equipment, Impact on safety and the environment
Probability of failure	P	Frequency of breakdowns (MTBF)
Criticality of the equipment	C	Criticality of the equipment according to the stops of production
Classification score = T + D + P + C		

Tab. 1 Division by type of anomaly

After calculating the score of each piece of equipment, a classification in descending order and grouping by equipment class as described in the table below is required.

Evaluation score	Class type		Description of the class
95% – 100%	Class AA	5%	Very high criticality
80% – 95%	Class A	15%	High criticality
20% – 80%	Class B	60%	Medium criticality
0% - 20%	Class C	20%	Low criticality

Tab. 2 Division by type of anomaly

The summary of the result obtained is presented in the following figure :

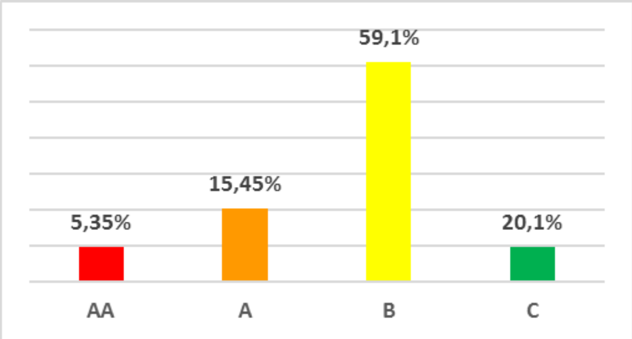

Fig. 7 Division by type of anomaly

This classification technique enables maintenance departments to identify critical equipment, and focus on areas that could lead to production shutdowns and negatively impact the safety of personnel and the environment elsewhere.

❖ Maintenance plans and machine records

Among the causes implicated in the inefficiency of the maintenance systems put in place, the unavailability of technical data relating to the equipment. Maintenance workers must acquire a great knowledge of the different equipment, especially on the technical and operational aspects. We considered it necessary to analyze the rate of coverage of the fleet by machine records and maintenance plans. The results of this analysis are reported in the following figure :

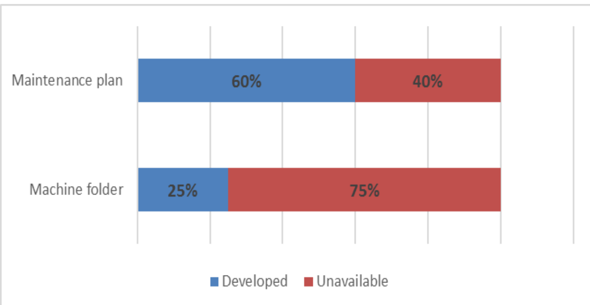

Fig. 8 Division by type of anomaly

❖ Equipment performance monitoring

Predictive maintenance or conditional preventive maintenance allows the readjustment of maintenance operations forecasts to be made as a function of time or units of use, based on a permanent or periodic analysis of the condition of each equipment [19]. These maintenance policies remain a major asset to monitor the evolution of equipment performance and to intervene within the given deadlines. These tools, which are not very exploited by the industrialists, make it possible to anticipate the breakdowns and to reduce the palliative interventions generating risks on the maintainers. The following figure shows the equipment monitoring rate :

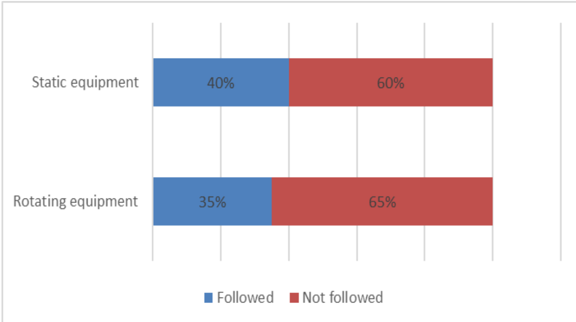

Fig. 9 Division by type of anomaly

It appears that a large part of the equipment is not followed, the evolution of their performance remains unknown and disrupts the activity of the maintainers. The increase in the number of breakdowns generates an overload on the personnel and generates more risks because of the non-planning, an insufficient preparation and the random nature which knows this type of intervention. It is therefore necessary to clearly define the criterion of choice which makes it possible to determine the times of intervention on the system and the type of intervention to be performed [20]. The preparation of maintenance interventions must be considered as a full function of the maintenance process [21].

The techniques of this type of maintenance, such as vibratory analysis, thermography, thickness measurements, etc., are the subject of several research studies. They are considered as a success factor favoring the implementation of a reliable and effective maintenance management system in terms of professionalization of maintenance and compliance with safety and environmental standards. As surveillance equipment becomes less expensive, conditional maintenance strategies are more easily considered [22].

3.7 Evaluation of the performance of the maintenance function

❖ Elaboration, communication and application of the operating modes

The development of equipment maintenance plans allows maintainers to develop strong technical links with the equipment, and dissect interventions at workstations. Each operation generates a multitude of risks, the analysis and the prevention of these risks is an essential requirement to maintain equipment without having to suffer accidents or incidents during work. Each workstation must be prepared and be subject to a detailed operating procedure based on a detailed risk analysis. These procedures will have to be, not only elaborated, but rather communicated to all the personnel and applied correctly. We conducted an analysis of the existing operating modes, the results of which are shown in the figure below :

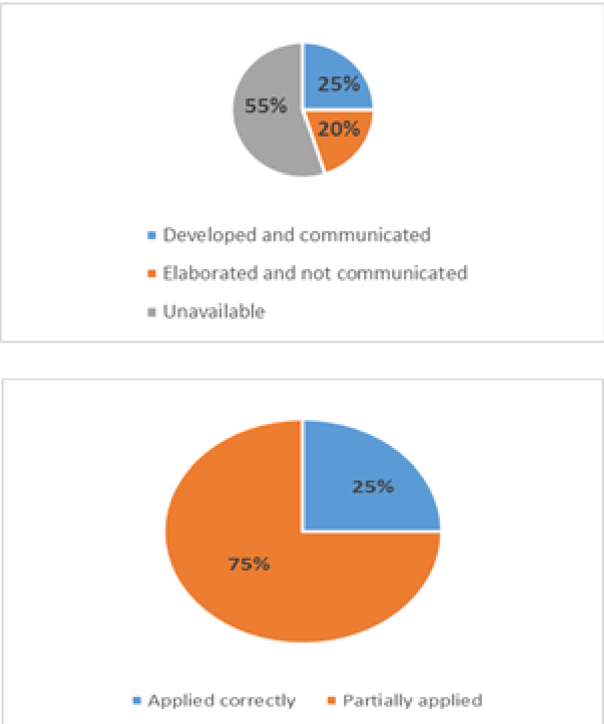

Fig. 10 Division by type of anomaly

It turns out that more than 50% of maintenance interventions are performed without following operating procedures taking into account the risks associated with it, an additional factor likely to increase risk situations. The available procedures are, in the majority of cases, applied partially or not communicated.

❖ Records and reports of interventions

The effectiveness of the maintenance function is also influenced by the introduction of a system for archiving intervention data through the preparation of reports for each operation. The latter make it possible to analyze each intervention, the difficulties that have arisen, the risks that have occurred, the accidents or incidents that occurred during the intervention, the technical means used, etc. The analysis of the history of maintenance interventions reveals that only 20% of the interventions were the subject of a report at the end of the work, 75% of which were not developed in an exhaustive manner.

❖ Supply Management and Stocks

Spare parts supply and maintenance are two related operations that must be considered both to achieve cost efficiency and logistical support [23]. Today, the management of supplies and stocks is considered a success factor allowing maintenance workers to carry out their interventions in accordance with the rules of art, avoid repairs by lack of spare parts and comply with the stipulations and instructions of the manufacturers. We have calculated some indicators to identify the performance of the procurement policy put in place, including the monitoring of past consumption, the nature of consumption and the stock-out rate. We present the results in the following figures :

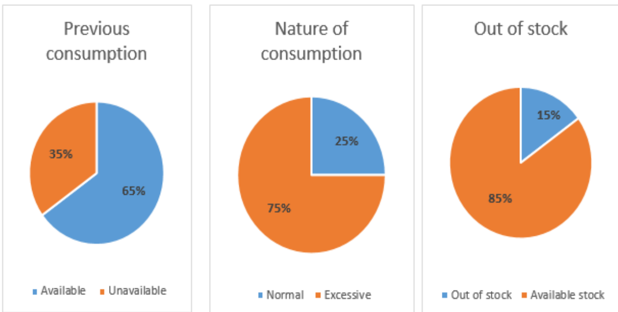

Fig. 11 Division by type of anomaly

It shows that the maintenance department does not have the full history of consumptions of spare parts, 75% of parts consumed excessively and 15% out of stock. It turns out that the procurement and inventory management policy needs to be improved and should highlight the weaknesses of the maintenance function within the company.

❖ Equipment and tools

The maintenance of the installations requires the contribution of the material and tools required for the proper execution of the preventive and corrective maintenance operations. Non-compliant material is a source of risk that can cause injury to maintainers. In this regard, we conducted an audit on the tools used to raise the deviations from the compliance requirements. We report the results obtained in the figure below :

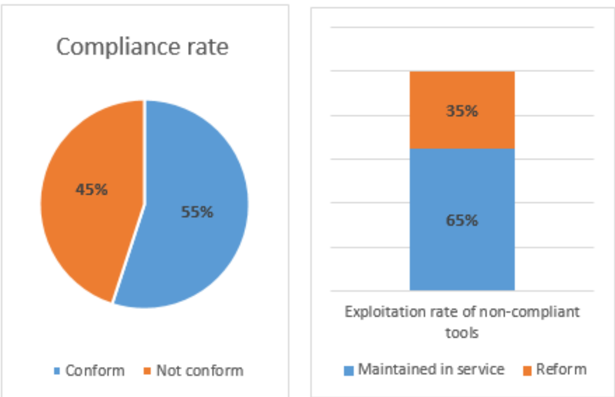

Fig. 12 Division by type of anomaly

3.8 Summary of the state of play

The study of the state of play focused on several different evaluation axes:
• Assessment of staff skills;
• Performance evaluation on the HSE plan;
• Evaluation of the performance of the maintenance function;
• Global study of the equipment park.

The main conclusions drawn are the following :

- Operational control remains very weak in order to be able to cope with the various risks related to maintenance operations; the various risks at the workstations are largely underestimated or not perceived;
- Maintenance activities generate a large number of accidents and incidents, explained by the non-deployment of the requirements and standards of safety and environment in force on the one hand, and the impact of the human factor on the other hand;
- Procedures should be developed following detailed risk analyzes, communicated to all staff and deployed effectively;
- Procurement and inventory management policies do not reveal relevant indicators to set up the desired maintenance management system;
- A system for archiving the data of the interventions must be put in place, making it possible to capitalize on the feedback of experiences through detailed intervention fact sheets and reports;
- The monitoring of the equipment park is rarely considered, giving rise to a maintenance policy based on repairs and repairs that favor risk situations.

4 Conclusion

The maintenance management policies and systems put in place within companies represent the mode of success or failure for their evolution, in terms of productivity, quality, operational control and safety and environmental management. Maintenance management systems and those related to safety and the environment are treated separately, the result of their deployment can be perceived only if we combine the two in a global management system. In this context, we have designed a maintenance management system that promotes the integration of safety and environmental concepts into facility maintenance, which is divided into four phases. Through this work, we have deployed the initial phase of the project to set up our system, including the inventory phase. This phase, which represents the pillar and the basis of successful implementation of such a system, has also made it possible to present, through several indicators, the actual state of the maintenance and HSE functions within the organization studied as well as its degree of maturity to migrate to this new vision. This study allowed us to detect the elements of success and the factors of failure towards a professional maintenance policy at all levels. The state of play that has been conducted has made it possible to map out the roadmap to be followed, the necessary resources and the master plans of progress and progress of the project in order to reach the expected objectives. Future work will be devoted to deploying the other phases of our system and translating them into a well-detailed execution process, by developing the implementation procedures and the evaluation indicators that will guarantee the success of the project.

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