4 Work management, planning & Optimization in maintenance

IV.1 INTRODUCTION

Maintenance not only allows the reactive identification of faulty elements, but also the prediction of breakdowns. Operators of production equipment entrust the maintenance and restoration of proper functioning to the maintenance department. Human resources are the main resources of the maintenance system. The organization of resource activities allows the maintenance department to be more efficient.

By restoring production equipment to good working order and preventing failures, the maintenance service has a visible impact on the competitiveness and responsiveness of companies. He implements intervention strategies in order to effectively deal with the different tasks he may encounter [26]. The maintenance service is organized around its human resources. They are the ones who carry out the tasks and act to make the production equipment available for its primary function: producing.

IV.2 MAINTENANCE CONTROL

A maintenance system can be viewed as a simple input/output system. The inputs to the system are manpower, failed equipment, material and spare parts, tools, information, polices and procedures, and spares. The output is equipment that is up, reliable and well configured to achieve the planned operation of the plant. The system has a set of activities that make it functional. The activities include planning, scheduling, execution and control. The control is achieved in reference to the objectives of the maintenance system. The objectives are usually aligned with the organization objectives and include equipment availability, costs and quality.

The feedback and control is an important function in this system that can be used to improve the system performance. A typical maintenance system with key processes and control function is shown in Figure IV.1. The figure exemplifies the role and the need for effective feedback and control.

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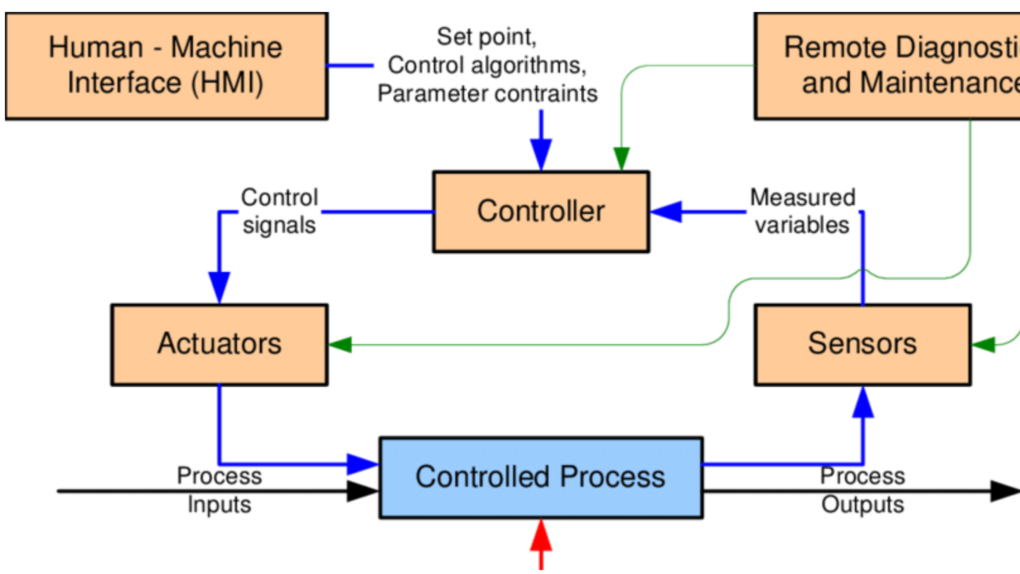


Fig. IV.1 Processes and control of maintenance management systems

IV.3 FROM MAINTENANCE TO E-MAINTENANCE

Skills, versatility and know-how are the aspects that characterize maintenance personnel. However, this staff is limited in number in companies. In order to give access to external expertise as quickly as possible, new forms of maintenance tend to allow staff to access information remotely. However, if this information is not enough to resolve the problems, it becomes possible to benefit directly from remote expert assistance [25].

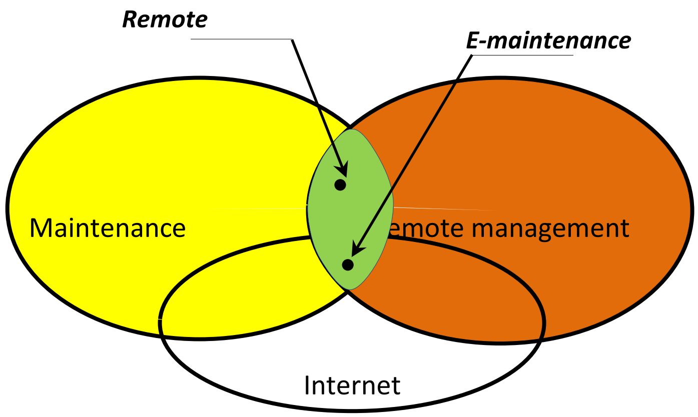


Fig. IV.2 New form of maintenance

In recent years, the use of information technologies has enabled the transformation of maintenance activity towards e-maintenance. Figure IV.2 presents the positioning of remote maintenance and e-maintenance. E-maintenance is then the intersection of different components with the aim of allowing staff to access intelligent tools remotely.

IV.4 REMOTE MAINTENANCE

IV.4.1 Remote maintenance

In order to optimize costs and allow better control of the operating status of equipment, companies are increasingly using remote control and maintenance means. This concept is called remote maintenance, the definition of which is specified in the AFNOR standard:

“Maintenance of an asset carried out without physical access of personnel to the asset”

A remote maintenance system is always composed of at least two distinct parts

- The expert maintenance center, also called the competence center;
- Sites to maintain.

These entities are not necessarily the only ones but it depends on the organization of the company. This will therefore involve monitoring the equipment of several sites and, in the event of a breakdown, assigning the best skills according to the maintenance to be carried out, in order to optimize intervention costs. Remote maintenance therefore aims to enable a large number of operations to be carried out quickly and remotely. This “reactive” management of maintenance tasks aims to maximize the availability of equipment as well as the cost of their maintenance.

The main component of a remote maintenance system is the network on which it relies for the circulation of information. The use of the Internet network is of real interest in facilitating remote access to equipment to be maintained. In order to allow personnel who do not have sufficient information to resolve their maintenance problems, the network can allow them to access intelligent tools. When intelligent tools are used via the remote maintenance system, we then speak of e-maintenance.

IV.4.2 E-maintenance

E-maintenance is therefore an intelligent form of remote maintenance. The researchers presented two e-maintenance solutions. The first is generally made up of a computer equipped with a web server or a programmable controller with a web coupler, called an Internet communicator. This is the only equipment that can communicate with the remote equipment. It concentrates all the information coming from the sensors controlling the process. Its main functions are:

- Access control and protection against intrusions.
- The “presentation” of the system equipment which must be visible from the web browser of the remote station. It must also manage the global "view" of the state of the system in the form of a database.
- Have complete knowledge of the configuration of system elements and

Possible locks, to allow downloading, remote configuration or modification of parameters [28].

The second solution consists of giving direct access to equipment, they then become buried web servers. An internet connection is then necessary on the equipment.

Throughout the maintenance process, it is possible to access information. The e-maintenance system can also include additional modules such as detection, diagnosis or even monitoring, the definitions of which we will give.

- Detection is the generation of distinctive characteristics of an abnormal operating state from observations
- The diagnosis is the determination of the components or organs characterized by abnormal functioning, specifying the causes of this anomaly. In the event of equipment failure, diagnosis therefore makes it possible to locate the component causing it. It then makes it possible to identify the cause. Diagnosis is therefore a key element in the proper functioning of a remote maintenance service.
- Monitoring is a module allowing the detection and diagnosis of an abnormal operating state. Monitoring can then be defined as a device capable of detecting system malfunctions.

It then allows them to be diagnosed by locating the components causing the failure and identifying its causes. E-maintenance is therefore not limited to the acquisition and processing of data remotely, but then becomes a more complete solution called an e-maintenance platform.

IV.4.3 The e-maintenance platform

This is made up of three main parts:

1. Remote monitoring of equipment during its life cycle.

2. Management of the maintenance and repair process (logistical part of access to technical document and knowledge bases, decision support tools as well as human resources).

3. The complete and synthetic presentation of the various data, including the monitoring and decision level, the dashboards, as well as the different maintenance contracts.

The implementation of such a platform can significantly increase the efficiency of e-maintenance centers. It provides maintenance solutions, particularly in distributed organizations.

IV.5 WORK MANAGEMENT

Planning and scheduling is at the center of good maintenance management. Here we arrive at what is “corrective maintenance” as part of our chain that must not be broken. It is important to understand the difference between planning and scheduling. These two elements of maintenance work management are essential and are too often mixed up. Most organizations, where scheduled shutdowns of the manufacturing process are common, we need to plan and schedule work for these shutdowns very well because there are immediate consequences if we do not.

As discussed earlier, the purpose of maintenance planning is to determine the correct maintenance jobs and get them ready for scheduling. To do this, a designated planner develops a work plan (sometimes called a job plan) for each work request. These work plans detail everything a technician must do and use to accomplish the task. There are six maintenance planning principles to guide planning in the appropriate direction.

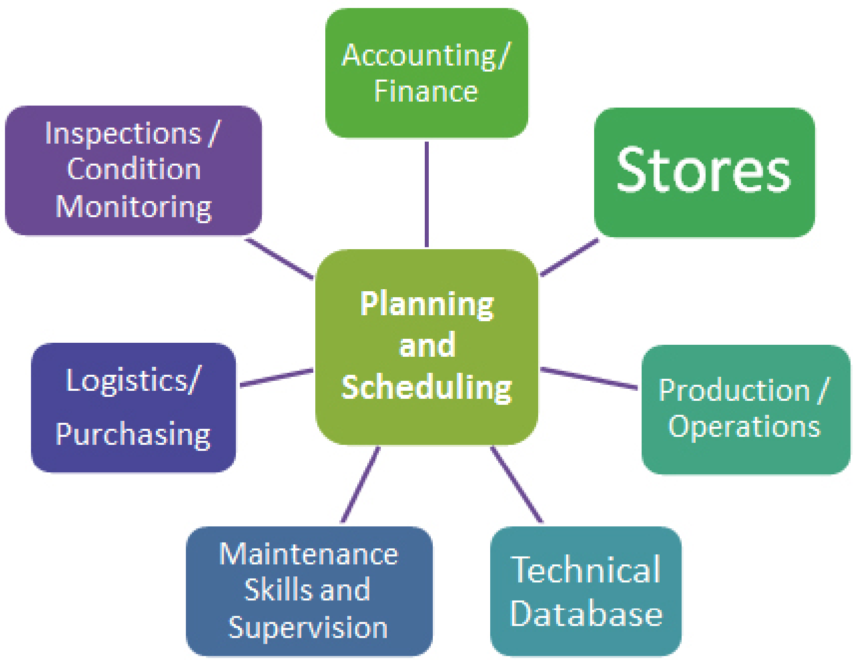
IV.5.1 Maintenance planning principles

IV.5.1.1 Protect the planner:

Planners are removed from the maintenance crews and put into separate groups to facilitate specialized planning techniques and focus on future work. By removing planners from the maintenance crew for which they plan and having them report to a different supervisor, the planning function is protected. As difficult as it may be at times, planners should never be used as field technicians to help complete work, so they can focus solely on planning for future work.

IV.5.1.2 Focus on future work:

This principle states that the planning group should only focus on future work – work that hasn't been started yet – so it can give the maintenance department at least one week of backlogged work that is already planned and ready to go. Having this backlog allows for the creation of a weekly schedule. With the exception of emergencies, job supervisors or the technicians themselves – not the planner – should resolve any problems that come up during the job.



Once a job is completed, the supervisor or lead technician should provide feedback to the planning group. Feedback should include things like problems encountered and changes in the work plan. In other words, if the crew encounters a problem, they should work it out themselves and finish the job. Once the job is completed, they can discuss issues with the planning group to offer helpful information about what went wrong to aid in planning for future work.

The reason for planners to be solely focused on future work is because it's easy to get caught up in helping with other tasks. For example, say a planner comes into work on a Monday morning needing to plan for the coming weekend's crew. She also needs to file work orders for a number of jobs completed last week. Two technicians come by her office to ask if she can help them run tickets to get parts out of inventory. Another technician calls her for help finding spare parts for a draft fan. Before long, she has spent most of her morning tracking down the manufacturer and getting sidetracked.

IV.5.1.3 Component-level files:

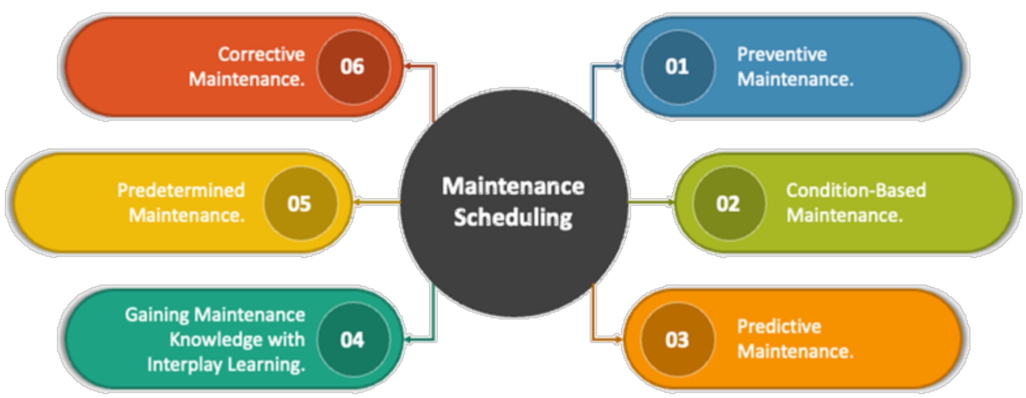
The planning group should maintain a simple, secure file system based on equipment tag numbers. In other words, planners should not file on a system level but rather on an individual component level. This helps planners use the equipment data obtained from previous jobs to prepare and improve future work plans. This especially holds true with repetitive tasks, since most maintenance tasks are repetitive over an extended period of time. When a component-level file or "mini-file" is made for each piece of equipment after the first time work is completed, data can be gathered and compared over time. Once a new piece of machinery is made available or is first worked on, planners make it a mini-file, labeling it with the same component tag number attached to the equipment in the field. Planners can use the information gathered over time to improve future processes.

IV.5.1.4 Use planner judgment for time estimates: Planners should use their experience and skills in addition to file information to determine time estimates for work orders. Time estimates should be reasonable with what a technician might require to complete a job without any issues. This means planners should have technical, communication and organizational data skills to make a reasonable estimate. This principle requires planners to be chosen from the organization's best technicians, possibly ones with the most seniority. For example, someone with 15 years of technician experience who accepted a planner position might notice in a previous work order file that a pump alignment took eight hours. He knows from experience that, when done by a competent mechanic, this task should only take around five hours, so he uses the five-hour estimate when creating the job plan for this task.

IV.5.1.5 Recognize the skill of the techs: Planners need to be aware of and recognize the skills of their craft technicians when determining job plans. Planners should determine the scope of the work request and plan the general strategy of the work, including a preliminary procedure if there isn't one, around skill level. The technicians then complete the task and work together with the planner on repetitive jobs to improve procedures and checklists. A common issue with this principle is making a choice between producing highly detailed job plans for technicians with minimal skills or creating minimally detailed job plans for technicians with highly skilled technicians.

How much detail should be included in a job plan? A good rule of thumb is to develop a general strategy for 100 percent of the work hours. This will be better than a detailed plan for only 20 percent of the work hours. If there is a procedure already in the file or notes from people who have previously worked on the equipment, include those in the job plans. Finding the best way to leverage the skills of the technicians and ensuring they are doing what they were trained to do allows planners to be confident that they will get a task done efficiently.

IV.5.1.6 Measure performance with work sampling: This principle states that wrench time is the primary measure of workforce efficiency and of planning and scheduling effectiveness. Wrench time is defined as the time in which technicians are available to work and are not being kept from working on a job site by delays such as waiting for an assignment or parts and tools, obtaining clearance, travel time, etc. Planned work decreases unnecessary delays during jobs, while scheduling work reduces delays in between jobs.



IV.5.2 Maintenance Scheduling Principles

You can have a great planning department working hard to outline planning procedures and work plans, but that doesn't mean more work will get done. That's because planning makes it easier to complete individual jobs. If one job that previously took four hours to complete, now only takes two, you've still only completed one job. This is where scheduling comes in. Scheduling helps increase productivity based around six principles:

IV.5.2.1 Job plans are needed for scheduling: Job plans should include the number of technicians required, the minimum skill level, work hours per skill level and information on job duration. Maintenance needs this information to schedule work, and job plans provide it in an efficient way. Does the job require welding? How many welders are needed? How many assistants does the engineer require? Asking questions like these during the creation of job plans helps determine scheduling requirements.

IV.5.2.2 Schedules and job priorities are important: The weekly schedule and the priorities that help determine this schedule are essential to improving productivity. Weekly scheduling frees up crew supervisors to focus on the current week without worrying about the backlog. Maintenance and operations use the weekly schedule for coordinating their tasks in advance, so it's critical to properly determine the priority levels of new work orders to see if they should become part of the daily or weekly schedule. Prioritizing advanced scheduling helps make sure sufficient workloads are assigned, which increases productivity and ensures critical work orders are completed first.

IV.5.2.3 Schedule based on the projected highest skills available: This principle states that a scheduler should develop a one-week schedule for each crew based on the available technician hours, the highest skill levels available, job priorities and details from the job plans. Schedulers should select a week's worth of work from the plant backlog by using information on priority and job plan details. They should then use a forecast of the maximum capabilities of the technician crew for the coming week. After several weeks have passed, technicians should have a better idea about the amount of work they're responsible for in a given week and become more productive.

IV.5.2.4 Schedule for every available work hour: Bringing the previous principles together, this guideline details how much work to schedule. The scheduler should assign work plans for the technicians to complete a task during the following week for 100 percent of the forecasted hours. So, if a crew has 800 labor hours available, the scheduler would give them 800 hours' worth of work. Scheduling for 100 percent of the forecasted work hours prevents over- and under-scheduling.

IV.5.2.5 Daily work is handled by the crew leader: The crew leader or supervisor should develop a daily schedule based on the one-week schedule, current job progress and any new high-priority jobs that may arise. The supervisor should assign daily work to technicians based on skill level and work order requirements. In addition to the current days' workload, the supervisor should handle emergencies and reschedule assignments as needed. Daily scheduling is almost always fluid thanks to the progress of the work being performed. This makes it difficult to schedule precise job times very far in advance. Inaccuracy of individual time estimates and reactive maintenance are the two biggest factors contributing to this issue.

IV.6 MAINTENANCE SERVICE ORGANIZATION

If maintenance is not carried out by the company itself, it is then subcontracted. Monitoring as well as preventive and corrective maintenance can therefore be entrusted directly to the equipment manufacturer (expert on this type of equipment) or to a company specializing in industrial maintenance (expert in the field of monitoring and maintenance). remotely but general in terms of the equipment monitored). The equipment can also be rented, and if maintenance is not taken care of by the user company, this can also be subcontracted in the same way. We encounter different maintenance organizations: centralized, decentralized organization or even a mixture of the two. But it can also be subcontracted or even distributed. In the following paragraphs, we describe these different forms of organizations [23].

IV.6.1 Decentralized maintenance

The decentralized organization of maintenance services is characterized by the fact that part of the maintenance is carried out by the production department and the other part is carried out by the maintenance department. In such an organization, maintenance and production are located in the same place. It is therefore the personnel belonging to the production department who carry out diagnostics, place orders, supervise maintenance work and manage improvements.

This type of organization mainly makes it possible to control the degradation process as well as good prevention because the production personnel are in regular contact with the equipment. However, technical control being distributed between the production and maintenance services, coordination procedures must be repeated to avoid redundancy of interventions.

IV.6.2 Centralized maintenance

Centralized maintenance is the most common form of organization. The maintenance department is separate from production. He is the one who brings together the different technical departments of the company but he does not deal with problems related to production. The personnel of this department are essential for the smooth running of events, but the compartmentalization of each department in its function requires increased communication [27].

Indeed, production staff may be too busy to focus on low-level maintenance tasks and nothing signals this to the maintenance department. Maintenance staff may also have received specific and highly technical training on particular equipment, or work on installations presenting safety risks, which makes certain activities unfeasible for production staff. A centralized maintenance system can, thanks to the implementation of a mobile maintenance workshop, manage maintenance activities in a multi-site context. While the central maintenance workshop handles equipment repairs at the various sites as well as preventative maintenance, the mobile workshop carries out inspections and replacements.

IV.6.3 Mixed maintenance

The mixed organization requires all staff to have good technical knowledge of the equipment. Operators must be able to carry out technical operations or find and have access to the information necessary to carry out maintenance tasks. While production manages the logistics part, the maintenance department also ensures “routine” maintenance activities. A mixed organization also allows you to benefit from the advantages of both systems but requires a good technical level of maintenance operators who must be able to interpret and carry out diagnostics.

IV.7 FUNCTIONAL DECOMPOSITION OF MAINTENANCE SERVICES

After having introduced the basic notions of maintenance as well as the different forms of organization of maintenance services. Here we take a closer look at how it works. The design of most information systems is based on Herbert A. Simon's pyramid [26]. This follows the classic organizational plan at three strategic/tactical/operational levels.

The higher level concerns the development of non-programmable decisions which are difficult decisions to make and for which the variables are qualitative and numerous.

This strategic level is that of the continuous definition of the goals and objectives of the company or services, as well as the control of the entire activity. At the middle level, programmable decisions are made. They are transmitted for execution to the lower level.

The tactical level will include maintenance process management and human resource management. The operational level corresponds to the execution of decisions made at higher levels and, in our case, to the assignment of tasks to resources. These three levels will therefore be presented in more detail in the following paragraphs.

IV.7.1 Strategic organization of maintenance activities

By breaking down the strategic level following the diagram mentioned previously as shown in Figure IV.3, we see that the decision-making system needs information to ensure management. Indeed, management is based in particular on comparisons between contracts which result from the maintenance policies put in place. But it also needs information flows, coming from the information system, which transmit data measuring the state of the indicators. These actual evaluations are carried out in the physical system. It is therefore the comparison between the contractual data and the information coming from the field that makes it possible to make decisions.

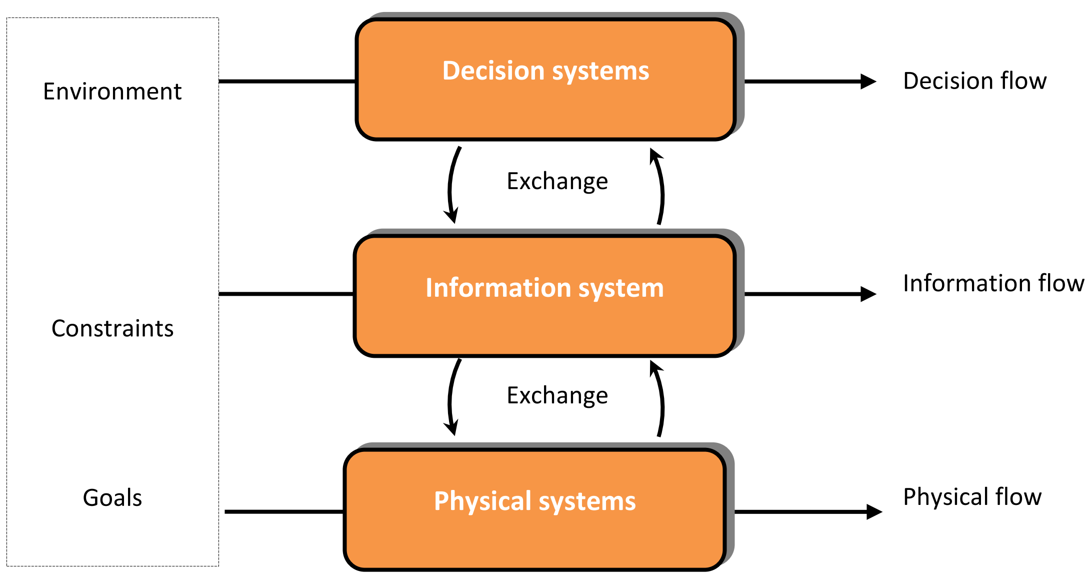


Fig. IV.5 Representation of the service organization

IV.7.2 Tactical programming of maintenance activities

The tactical level is also broken down according to the diagram in Figure IV.5. Just like production activities, maintenance activities are structured. The different stages are defined through the maintenance process. However, a link between maintenance and production may prove essential in certain structures. The CMMS then makes it possible to make the link between the different computerized management systems. Maintenance department decision-makers rely on human resources data to develop contractual relationships. It is mainly on their skills that they base their decisions.

IV.7.3 Maintenance from an operational point of view

The operational level is also decomposable. It is at this level that decisions regarding the priorities given to the different tasks to be processed are made. The importance of the speed of processing a task is not necessarily the same from the point of view of the production department or the maintenance department. The information flows representing the different data concerning resources and tasks are managed by the CMMS.

It allows the transmission of information concerning field personnel. In view of this data, the assignment and scheduling of tasks is then really done.

IV.8 INTERVENTION PLANNING TOOLS AND TECHNIQUES

When it comes to planning maintenance interventions, there are different tools and techniques that can be used to facilitate this process.

IV.8.1 Calendar and agenda: A calendar or diary is an essential tool for visualizing and organizing different maintenance tasks. It allows interventions to be planned based on available resources, deadlines and priorities. It allows for a balanced distribution of work over a given period.

IV.8.2 Priority management: It is important to establish priorities when planning maintenance interventions. This may be based on the impact on production, safety or compliance. A careful assessment of risks and business needs will help define the order in which maintenance work will be carried out.

IV.8.3 Computer-assisted maintenance management software(CMMS): CMMS software are tools specifically designed for the management of maintenance interventions. This software facilitates the overall management of maintenance activities.

IV.8.4 Predictive analysis: Predictive analytics involves using historical data and statistical models to anticipate equipment outages or failures. By using techniques such as machine learning and data analysis, it is possible to identify warning signs of problems. This means that maintenance interventions can be planned proactively.

IV.8.5 Communication and collaboration: Fluid communication and effective collaboration between maintenance teams, managers and other stakeholders are essential to ensure smooth planning of interventions. The use of communication tools such as messaging software, online collaboration applications or regular meetings make it possible to share relevant information and make decisions collectively.

IV.9 OPTIMIZATION OF MAINTENANCE

IV.9.1 Introduction:

The maintenance function strongly influences the level of performance of an installation. Its optimization is complex because it must take into account different sometimes antagonistic criteria such as availability and costs [26], [27].

Furthermore, there are a multitude of ways to maintain an installation. We can play on the type of maintenance, on the types of tasks, on their frequency, on the level of intervention, etc. To make these strategic choices, methods to optimize the performance of the systems are applied, including 'Optimization of Maintenance based on Reliability [28].

Maintenance managers therefore come to consider real strategies and are no longer satisfied with monitoring and repairing. They seek to predict events and evaluate the different alternatives available to them to make the best use of the installations according to the technical and budgetary constraints imposed. Decisions are mainly made on the basis of qualitative information provided by experts and sometimes supported by feedback data, or REX. However, it would be useful to be able to make choices based on quantitative criteria describing the performance of maintenance programs [29].

IV.9.2 Maintenance based on MBF reliability:

Maintenance Optimization based on Reliability was developed by EDF from 1990, [21]. It is based on MSG-3 [25] and the RCM, Reliability Centered Maintenance, method of the Electric Power Research Institute, its American counterpart in R&D. After pilot studies, a first implementation was made in 1993 on the systems considered to be the most important with regard to the safety and availability criteria of operating costs of nuclear power plants.

The Maintenance Optimization method based on Reliability constitutes a global decision support approach to determine preventive maintenance actions to control costs and the required level of availability of an installation or system, and more broadly, to guarantee a level of operational safety [28]. It is a rational approach which aims to limit as best as possible the consequences of failures of material origin on the operation of the installation.

The study of systems and equipment makes it possible to determine:

- Or preventive actions are necessary (on what equipment),

- What actions should be taken?
- When (with what frequency) should they be carried out.

IV.10 SPARE PARTS AND MATERIALS

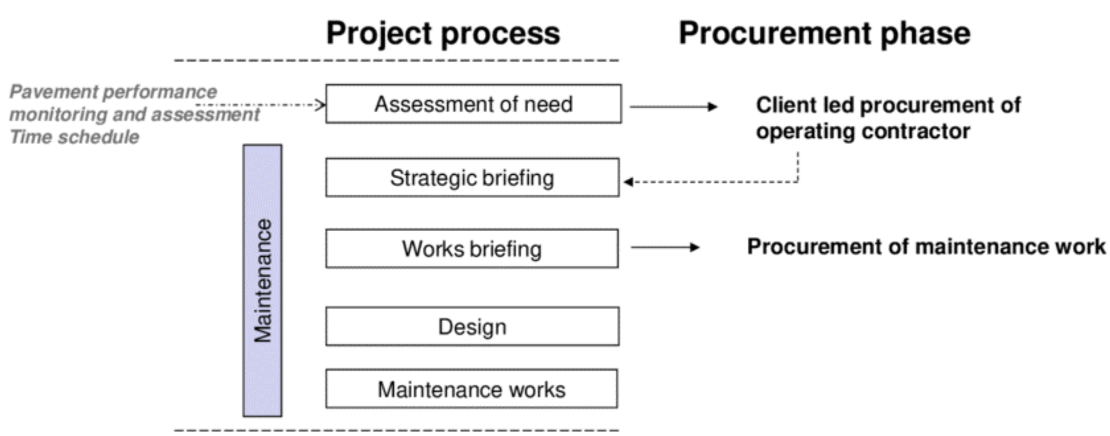
Materials management ensures that necessary parts and materials, meeting established quality or design requirements, are available and appropriate when needed. Suitable organizational units are established to procure, receive, store and issue materials, spare parts and components for use in the plant. Spare parts and materials important to safety are accompanied by documentation certifying that all requirements specified in the purchase order have been met.

Typical documents showing spare parts management are:

- Procurement, receipt, storage and issue procedures;
- Samples of purchase orders and specifications;
- QA documentation.

IV.10.1 Procurement

The responsibility for procurement, receipt, storage and issue of spare parts and materials is clearly defined. Procurement specifications are clear and unambiguous, include current technical and QA requirements and include the requirement that no substitutions of materials or components should be made without advising the purchaser. Storage and shelf life requirements are specified by the supplier.



Spares are purchased to the same technical standards and QA requirements as the equivalent installed plant items. Items are obtained only from suppliers who are qualified and approved in accordance with safety requirements. Selected spare parts, which are important to safety, have all the necessary certificates.

Receipt inspections of spare parts provide sufficient assurance of compliance with design, procurement specifications and QA requirements. The process for certifying commercial-grade material and parts for use in systems important to safety is appropriate. Management is responsible for providing the resources necessary to assure personnel have the knowledge and capability to prevent CFSI from entering the facility, and to identify and dispose CFSI that already exist in the facility. Therefore, management is responsible for developing a quality assurance programme (QAP) that:

- Ensures that items intended for application in safety systems comply with the design, applicable specifications/standards and procurement documents.
- Identifies and disposes CFSI that create potential hazards in systems and applications.
- Reports discoveries of and shares information about CFSI within the facility and with external organizations.
- Maintains current, accurate information on CFSI and associated suppliers using all available sources within the industry.
- Analyses CFSI information for trends.
- Obtains remedies from suppliers of CFSI.

Personnel are trained, within their respective areas of responsibility, to identify, prevent and eliminate the introduction of CFSI into the facility. Specific training is undertaken for:

- The detection of installed CFSI.
- Identifying CFSI during receipt and inspection.
- Using CFSI information within the procurement process.
- Including the potential for CFSI as a factor in component failures.

It is generally recognized that those facilities most effective in detecting CFSI have common characteristics:

- An engineering department that serves in a leadership role responsible for the tracking and evaluation of CFSI.
- Engineering staff involvement in procurement and product acceptance.
- Effective source inspection, receipt inspection, and testing programmes.
- Thorough, engineering-based programmes for review, testing and dedication of commercial- grade products for suitability in safety systems.

IV.10.2 Storage and control

The material management facilities provide adequate support to the plant. Warehouse administration and the interface with maintenance planners are appropriate. Parts and materials are available when needed in the plant.

Materials are stored and identified in a manner that permits timely retrieval. Adequate stock records are maintained, purchase orders are tracked, and safety-related parts are readily traceable from purchase order to installation. Proper engineering approval is obtained for any deviations from design specifications for parts or material [27].

Storage facilities are operated in a manner that takes into account special environmental requirements for storing certain components. Spare parts with limited life are stored separately and clearly marked to indicate acceptable periods of use. Materials with special hazardous are properly segregated and adequate procedures are in place to regulate their receipt and use.

Preventive maintenance activities are performed on certain spare equipment (e.g. large rotating electrical motors). Appropriate minimum, maximum and reorder levels are defined for warehouse stock. Non-conforming and damaged spare parts are stored separately and regulated to prevent inadvertent use

IV.11 CONCLUSION

Maintenance is one of the components that influences business performance. Nowadays, it not only allows the reactive identification of faulty elements, but also the prediction of breakdowns. Maintenance services mainly carry out two types of tasks: corrective maintenance and preventive maintenance tasks. The main difference between these tasks is that the preventive tasks are known for a specific horizon while the arrival of the corrective tasks is not planned. However, they have in common that they require the intervention of competent human resources. These resources are organized in the maintenance department. This ensures the maintenance and repair of equipment in good working order. It makes commitments to the operators of this equipment. These human resources are, as a general rule, versatile but depending on their background and professional experience, their effectiveness may vary.