2 BASIC MODULE OF COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEMS

II.1 INTRODUCTION

CMMS stands for Computerized Maintenance Management Systems. This is specialized software for managing a technical service. CMMS can be defined as a software package which provides decision support in a company to control the costs of the installations to be maintained, Optimize the technical and human resources of maintenance as well as obtain precise measurements on the times of breakdowns, their root causes and the time required for their repair. Management of Assisted Maintenance by Computer consists of a database (history) which is populated by maintenance personnel via a form. The basis of the history is the equipment inventory. Having a Maintenance Management tool is essential today from a technical, budgetary and organizational point of view to optimize the productivity of company investments but also to guarantee availability at the lowest cost of the resource chain. production and logistics. The market for maintenance management software packages is a mature market which offers solutions capitalizing on strong know-how. [10]

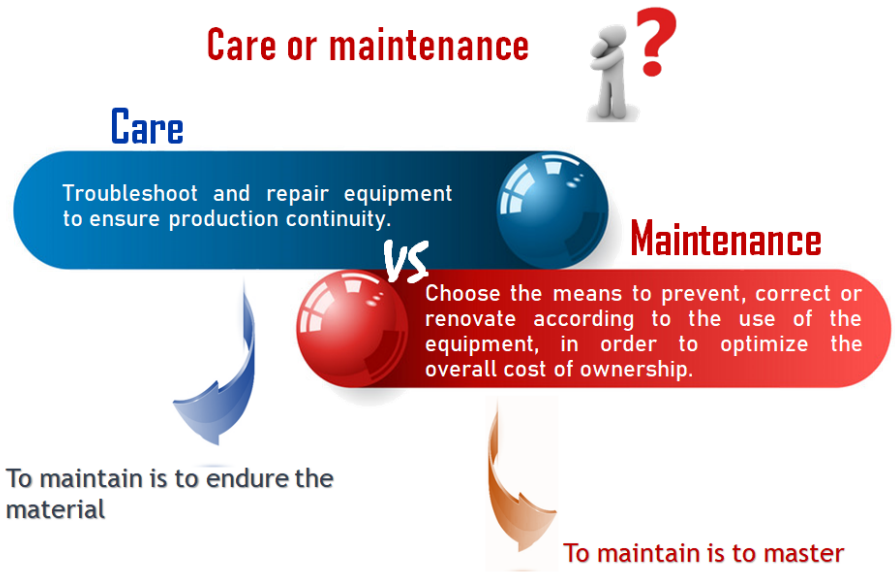


Figure II.1 Care versus maintenance

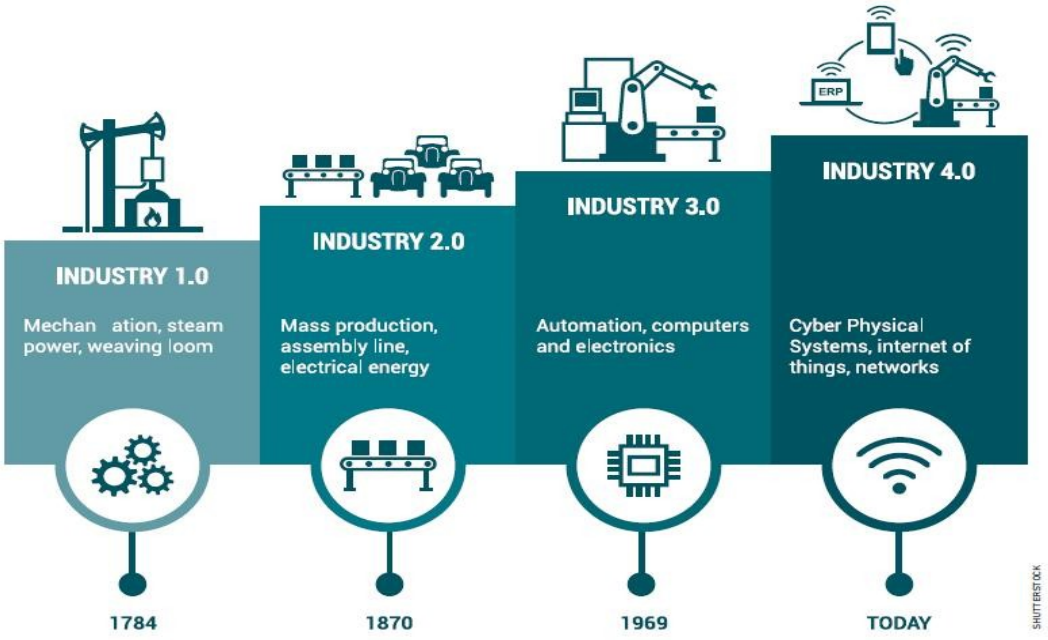
The CMMS is part of the information, management and control system of the maintenance function whose mission is to keep the installations in a state such that they can constantly meet the specifications for which they were designed and this in an efficient and economical way. The IT management tool is then an aid for tracing, archiving, analyzing and making decisions. [8]

II.2 EVOLUTION OF INDUSTRIAL COMPUTER

Industrial computing covers all design, analysis and programming techniques for systems based on interfacing of computing with electronics, electrotechnics, mechanics, robotics, etc., for industrial purposes. The term “industrial computing” designates the branch of computing bringing together all the techniques for design, analysis and programming of industrial computer systems. Constituting a very vast field, it finds multiple applications in industry. But what are the sectors and careers in industrial IT?

At a time when robots are increasingly working on assembly lines in factories, computer science that industrial has more than ever its place in the field, whether through:

- **CAMF**, Computer-assisted manufacturing, which allows you to program and control production tools
- **CAPM**, or computer-aided production management, which provides monitoring of the complete production cycle from the purchase of raw materials to the delivery of the finished product
- **CAM**, computer-assisted maintenance



It is therefore thanks to industrial computing that we program the automation stations assigned to production, but also that we detect their breakdowns and plan their maintenance. Very often, it is even the production line, or even the entire factory, which is controlled by the IT tool, whether it is a single central computer or a network of computers linked together.

Industry 1.0. The late 18th century introduced mechanical production facilities to the World. Water and steam powered machines were developed to help workers in the mass production of goods. The first weaving loom was introduced in 1784. With the increase in production efficiency and scale, small businesses grew from serving a limited number of customers to large organizations with owners, manager and employees serving a larger number. Industry 1.0 can also be deemed as the beginning of the industry culture which focused equally on quality, efficiency and scale.

Industry 2.0. The beginning of 20th century marked the start of the second industrial revolution – Industry 2.0. The main contributor to this revolution was the development of machines running on electrical energy. Electrical energy was already being used as a primary source of power. Electrical ma- chines were more efficient to operate and maintain, both in terms of cost and effort unlike the water and steam based machines which were comparatively inefficient and resource hungry. The first assembly line was also built during this era, further streamlining the process of mass production. Mass production of goods using assembly line became a standard practice.

Industry 3.0. The next industrial revolution resulting in Industry 3.0 was brought about and spurred by the advances in the electronics industry in the last few decades of the 20th century. The invention and manufacturing of a variety electronic devices including transistor and integrated circuits automated the machines substantially which resulted in reduced effort, increased speed, greater accuracy and even complete replacement of the human agent in some cases. The integration of electronics hardware into the manufacturing systems also created a requirement of software systems to enable these electronic devices, consequentially fueling the software development market as well. Apart from controlling the hardware, the software systems also enabled many management processes such as enterprise resource planning, inventory management, shipping logistics, product flow scheduling and tracking throughout the factory. The dispersion of geographical location of manufacturing led to the formation of the concept of Supply Chain Management.

Industry 4.0. It refers to the concept of factories in which machines are augmented with wireless connectivity and sensors, connected to a system that can visualize the entire production line and make decisions on its own. In essence, industry 4.0 describes the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the internet of things (IoT), industrial internet of things (IIOT), cloud computing cognitive computing and artificial intelligence.

It is also industrial computing that makes it possible to carry out computer-aided design (CAD) and computer-aided drawing (CAD). Geometric modeling software and techniques help develop products and the tools to make them, then test them virtually.

These technologies are used in many areas, notably in:

- **Mechanical**, including precision mechanics, to model numerous constraints linked, among other things, to the different materials used. Modern software makes it possible to design objects in three dimensions, virtually bend materials, drill parts or even make adjustments.
- **Electronic**, to design electronic circuits and microprocessors. The software suite allows for circuit schematic capture, simulation, component placement and routing. CAD is particularly useful in the case of printed circuits, especially when tracing tracks must be carried out on several layers.
- **Electrical engineering**, to develop electrical wiring plans for energy distribution, industry, automobiles and aeronautics. The IT tool makes it possible to manage the project as a whole, both the plans and the links between components, terminal blocks or wiring harnesses. Electronics software offers two types of design: symbolic mode, and more recently, object mode. This technique makes it possible to carry out modifications to devices and cables as well as updates to the project in real time, without worrying about having to regenerate, for example parts lists or terminal blocks.
- **Architecture**, particularly in the context of large projects. Presentations of files to decision-makers are often done using 3D drawings [11].
- **Town planning and urban planning**, in order to design buildings and entire neighborhoods using three-dimensional modeling. 3D software also makes it possible to integrate elements from heterogeneous sources such as highway companies, local authorities or public works companies.

• **Medicine**. In the medical sector, industrial computing finds applications both in the design of orthopedic equipment and in the molecular field, thanks to molecular CAD which makes it possible to digitize existing molecules but also to design new ones.

Industrial computing is nowadays commonly used in many fields. Closely linked to the future of the industry, this is a sector in constant expansion which recruits regularly: a promising branch where the positions to be filled and the remuneration offered are often among the most interesting on the job market in computer science

II.3 OBJECTIVES AND INTEREST OF CMMS

The objective of CMMS is to determine the initial causes of previously identified problems and, preventively, to find those that have not yet occurred, by evaluating their criticality. The essential objectives of CMMS are:

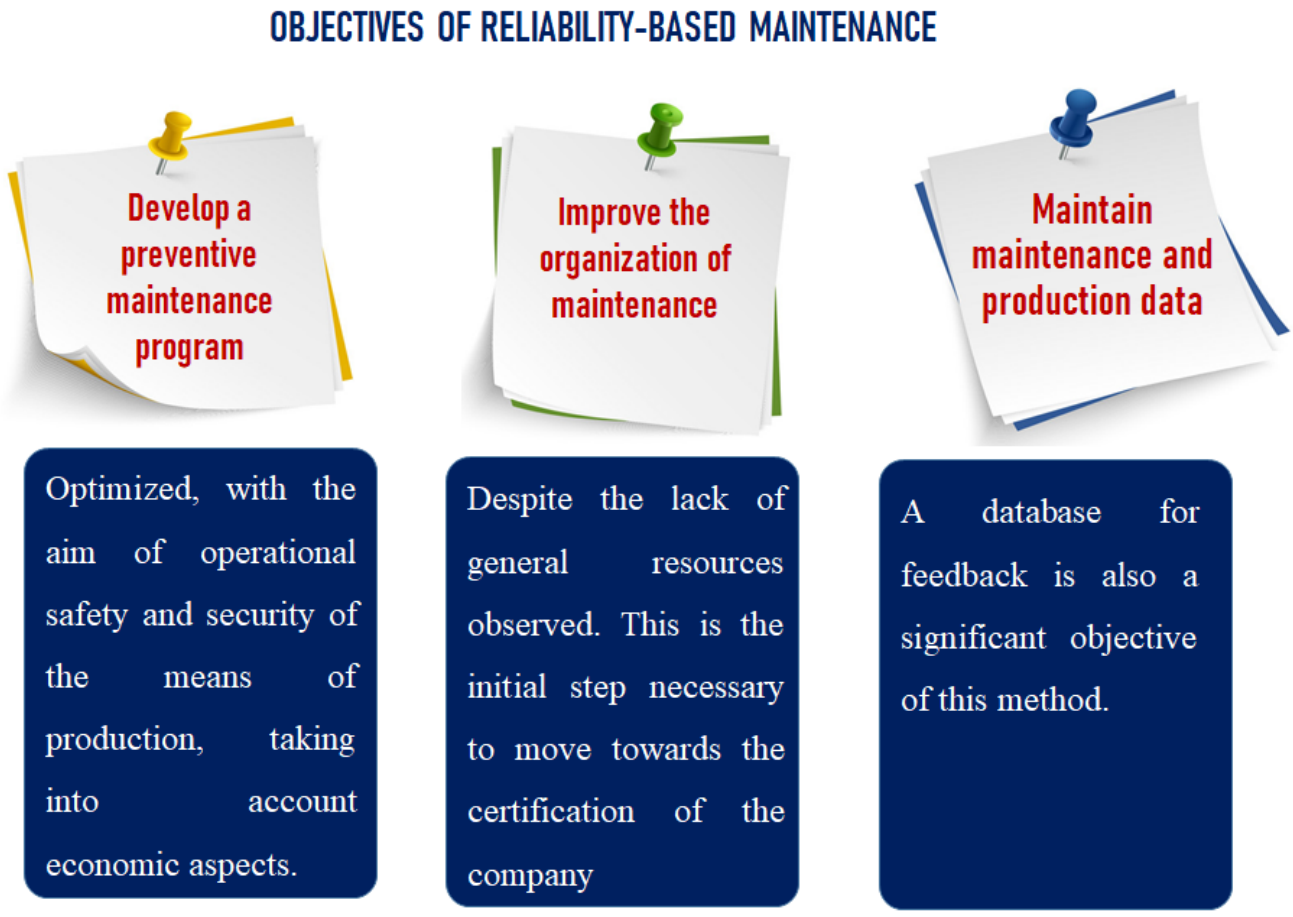


Figure II.2 CMMS objectives

II.4 BASIC CLASS AND STRUCTURE OF CMMS

The computerization of maintenance came late to the company. It is one of the last blocks to be computerized after accounting, production, purchasing, personnel management... Companies start with the development of maintenance functionalists who have a direct impact on the equipment such as the plan lubrication, purchasing and inventory management of spare parts [12]. At the same time as maintenance was recognized as a fundamental function in companies, they developed this procedure and computerized it, which led to the computerization of equipment files and to integrate all these automation islands, many software packages appeared on the market, offering to cover the functionalities that maintenance wanted to have. This is the birth of CMMS. We distinguish three classes of CMMS software packages:

• class I: products generally built around an ACCESS database. These are entry-level products aimed at SMEs that have a limited budget or need.

• class II: dedicated client/server products based on Oracle, MySQL database, etc. Offering greater stability and possibility, particularly in terms of indicators.

• class III: maintenance management module in a global industrial management software ERP (Enterprise Resource Planning) in French integrated management package.

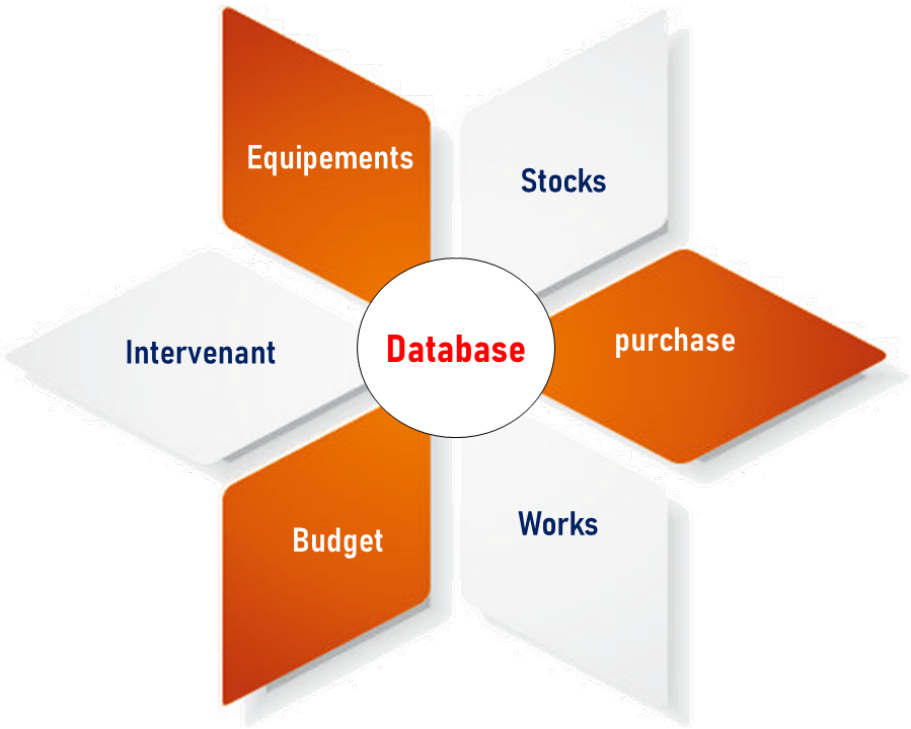


Figure II.3 Structures of a database management system

The typical architecture of a CMMS software package is based on a DBMS (Database Management System), which ensures the exchange and processing of data between the different modules of a CMMS. Currently, the relational type DBMS that we find on the CMMS market are mainly: ORACLE; MySQL; INGRES; INFORMIX; ORACLE.

II.5 GENERAL CHARACTERISTIC OF CMMS

Here is a table showing the benefits after implementing a CMMS according to a survey conducted by the French association of mechanical industries AFIM (the sum of the responses does not reach 100% because some companies did not respond to all the questions).

Benefits obtained with CMMS	Very Significant in %	Significant in %	None in %	no response in %
Labor reduction	9.2	37.5	31	11.5
Reduction in material costs	11.5	43.7	20.7	13.8
Increased availability	21.8	33.3	25.3	9.2
Increased reliability	21.8	35.6	24.1	8
Improved cost control	44.8	26.4	16.1	2.3
Improved feedback	46.6	18.4	23	2.3
Improved planning	32.2	36.8	18.4	2.3
Improvement of effective maintenance times	37.9	32.2	16.1	2.3
Improved spare parts management	24.1	37.9	23	4.6

CMMS software allows you to build a database in which you will find:

- Store items and suppliers,
- Managing the entry and exit of items and purchases,
- Asset management (equipment and subassemblies),
- Management of corrective and preventive interventions,
- Management of intervention requests,
- Financial analyzes and monitoring of maintenance indicators,
- Managing customer contacts and invoicing

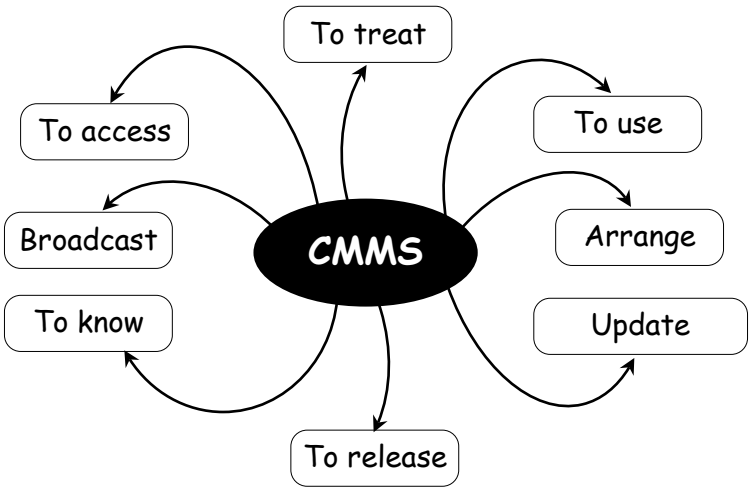
The growing concern to gain efficiency, speed and technicality means that computer-assisted maintenance is becoming increasingly widespread [13]. Many software programs have

been developed and are in production. To better choose, it is necessary to classify this software. The following sectors can be proposed as categories:

- **CMMS industry:** computer-assisted maintenance management on the industrial side; (Technical reports, warehousing, machine data sheet, project monitoring, PERT, planning);
- **CMMS tertiary part:** building management (planning, accounting aspect);
- **CMMS after-sales service**: customer monitoring, analysis of customer returns

The software must be simple, user-friendly, and must correspond to the operating logic of the maintenance department. The CMMS software must be able to operate over a network (Windows 7 or more, Mac, etc.) so that it can evolve with the needs of the service.

To achieve the success of the project, the implementation of a CMMS necessarily first requires a detailed and in-depth analysis of needs, a precise definition of objectives, careful preparation of the stakeholders and the support of all. Indeed, such an approach must be done under the leadership of management and the participation of the company's staff. These prerequisites will allow, on the one hand, to make a relevant choice among market proposals and, on the other hand, to think about the most intelligent and efficient organizations. The decision to invest in a CMMS tool calls into question the habits acquired by the company's various departments which, for historical reasons, use different coding systems for the same equipment depending on their own specific area (purchasing, methods, new works, maintenance, management). The evolution of the CMMS offers and the market is moving towards the use of nomadic technologies, which will lead to a new questioning of habits that have been adopted since the first installation. [11]



Process a large amount of data
Quickly use analysis results
Have reliable and precise information
Update plans and documents
Initiate and plan work
Know the distribution of costs
Disseminate and access information

The Internet is generally the solution for mobile technicians. It is also today the solution for setting up low investment solutions, it is thus possible to just pay for the hours of use. Training must be planned to quickly learn the software commands and the implementation methodology in the maintenance department. An annual maintenance contract which entitles you to telephone assistance and changes to the software must be subscribed to different maintenance management software packages coexist, notably DATASTREAM and MAXIMO from Microsoft.

II.6 COMPUTERIZATION OF MAINTENANCE

"CMMS software manages a database containing information relating to a company's maintenance operations. This information is intended to help maintenance personnel perform their jobs more efficiently." [12]. "Computer-assisted maintenance management (CMMS) is a tool to support short, medium and long-term decisions allowing optimal operational safety of equipment at the best overall cost." [13] "CMMS software manages a database containing information relating to a company's maintenance operations. This information is intended to help maintenance personnel perform their jobs more efficiently." [14] "Computer-assisted maintenance management (CMMS) is a tool to support short, medium and long-term decisions allowing optimal operational safety of equipment at the best overall cost". [15]

II.6.1 The contribution of CMMS: The CMMS will have to bring in money in productivity of the function, in staff efficiency, in availability of production tools, in extending the life of the machines. The goal is to involve the maintenance function in the company's performance objectives: cost reduction and improvement in the service rate directly contribute to improving productivity and increasing the competitiveness of the company.

II. 6.2 Information for decision-making: The CMMS system is intended to provide a service to the maintenance manager and maintenance technicians with the essential aim of improving decision-making. Users expect CMMS to help them in technical decision-making processes. Should we replace this machine or can we still expect many years of operation after repair? We aim to gather all the necessary information on the equipment in order to know it well, deduce adequate maintenance and no longer suffer from breakdowns. The professional can only decide if the machine history is up to date, if he has good MTTR and MTBF performance indicators, and if he knows the various costs generated by the various options he is considering. He will be even

more likely to use CMMS if the documentation and information delivered are of high quality and easy to access.

This does not only concern maintenance: the CMMS database will also provide a service to other functions of the company: directly to manufacturing, quality and safety, indirectly to management, control management, accounting…

II.6.3 Opening up of the maintenance function: The rapprochement with production and the establishment of simplified and more direct links with other services lead to the opening up of the maintenance function. We quickly observe an increase in the flow and exchange of information between all users of the maintenance department and other departments.

II.6.4 Control of the function: The CMMS should provide added value to the management of the maintenance department:

- Monitored budgets;
- Known detailed maintenance costs;
- Indicators and management tools;
- Immediate knowledge and more effective management of the activity;
- The elimination of administrative tasks;
- Better allocation of maintenance teams.

II. 6.5 Maintenance processes

By automating maintenance processes, CMMS reduces the administrative burden and improves the quality and speed of information processing. The system will act on the efficiency of maintenance: reduction in waiting times and wasted time, increase in the availability rate of production tools, reduction in spare parts in stock. The correct spare part is immediately identified by the nomenclature, the stock file consulted provides information on availability and allows reservations to be made. The same applies to special tools. Interventions are better prepared, more precise with the provision of the right information reported on the work order, safety instructions and rapid access to documents. Diagnostic tools and the capitalization of the experience inherent in CMMS lead to a reduction in downtime due to breakdowns, which corroborates the increase in equipment availability as a result of better prevention.

The CMMS has every interest in campaigning for a reduction in complex document circuits. Spare parts inventory management reports substantial savings:

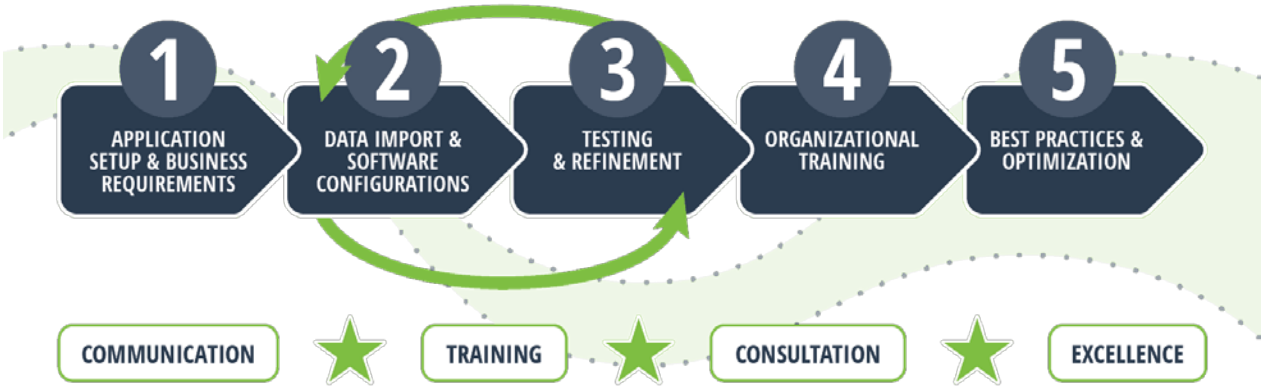


Figure II.4 CMMS process

When it is effective (reduction and better control of maintenance costs, and ultimately reduction in staffing requirements), CMMS contributes to a reduction in the cost price of products.

II. 6.6 Staff motivation

The CMMS should also, and this is not the least expected objective, improve “the morale of the troops”. The penetration of new technologies and the use of a powerful IT tool are mobilizing elements, factors for revitalizing the service. Less time wasted, less hesitation, less back and forth, less paperwork, faster and more efficient responses to work requests, give staff a better image of their own efficiency [16].

In general, the maintenance agent must constantly adapt to changes in equipment and technologies among the machines he handles. CMMS is the complementary vector of raising the cultural level and qualifications. New behaviors oriented towards rigor and precision will gradually emerge among users whose CMMS will increase their autonomy and self-responsibility. Making the company's objectives visible in the maintenance department, raising awareness for example of the costs of breakdowns, this is what to expect from CMMS.

CMMS also allows you to stand out from the competition and improve the company's brand image.

II. 6.7 Replace existing maintenance management tools

Before even talking about computerization, maintenance has adopted procedures and tools to carry out its work. There is most often, prior to computerization, a manual procedure which allows a maintenance intervention to be carried out.

This procedure is more or less extended to all work, including major shutdowns. There is at least one equipment lubrication plan. For certain equipment, an inspection plan is in force. Routine interventions are well known by maintenance personnel. Information describing the equipment is recorded on sorted sheets and stored in appropriate bins. A register groups together the available spare parts. In the best cases, these files and procedures are computerized. Between several factories of the same company, variations exist in the mode of operation of the different maintenance departments and their procedures. Identical spare parts may be stored in two factories of the same group under different names [16].

Subcontracting is regularly used to cover a temporary shortage of staff. The maintenance computerization project is often presented as a means of harmonizing and giving coherence to the different approaches to maintenance management. It then becomes a general framework for the design, definition, support, monitoring and optimization of maintenance strategies and policies.

We will use CMMS to define an operating mode and procedures, computerize them and implement them at the level of each person, cell, group then department, finally factory. We will then seek to make this tool communicate with the company's other computerized tools, so that there is communication and sharing of information and that maintenance is freed up. In particular, some companies expect a rapprochement between maintenance and production in terms of maintenance, inspection and operational monitoring procedures:

- Cover the management of equipment in maintenance and inspection: routine, monitoring, major shutdown, modification management;
- Guarantee technical traceability and regulatory aspects (inspection) by managing maintenance and inspection functions with the same product;
- Cover the different types of equipment: fixed, rotating, electricity and instrumentation
- Guarantee the traceability of risk analysis and intervention safety measures.

This is the opportunity for a group with several factories to support CMMS with a single product for the group and interfaced with the other site and group IT systems. Underlying this project is the desire to control maintenance costs. But we also expect the mastery and conservation of maintenance know-how (including the subcontracted part).

II. 6.8 CMMS best practices: Are considered “good maintenance practices”

- ✓ Work management using work orders to ensure perfect traceability of events that occur;

- ✓ Preparation as well as planning in advance of the intervention with a view to optimizing the use of all resources;
- ✓ Management of the criticality of equipment, with variation of preventive measures and adjustment of spare parts inventory management parameters for critical equipment;
- ✓ Implementation of procedures to predict the life of the equipment by observing its behavior (predictive or forecast);
- ✓ Optimization of spare parts in conjunction with equipment nomenclatures;
- ✓ Use of equipment history and breakdown analysis;
- ✓ Permanent adjustment of the preventive maintenance program based on observations drawn from history;
- ✓ Performance analysis and maintenance management using a dashboard.

The CMMS will have to provide solutions to maintenance needs that support these best practices. It will be an automated framework which will accommodate certain existing functionalities that are essential or specific to a particular profession, particularly in terms of security, standards or traceability. By using an integrated product, we will replace, strengthen and improve existing functionalities and gradually promote best practices.

II.7 FUNCTIONALITY OF THE CMMS

All CMMS software packages have in common the same modular structure offering the same functions. But, depending on the software, the functions performed are variously named, variously distributed and variously organized. In this section we present the functional modules common to all CMMS software packages.

II.7.1 Intervention management

II.7.1.1 Management of intervention requests: For the numerous BPT (Small Work Orders), no DT request (Intervention Request) or number allocation, but a rapid recording posteriori of their duration, their location and their nature [17].

It is necessary to create a library of the different useful codes relating to clients, stakeholders, and the different statuses of the intervention. Furthermore, each piece of equipment must correspond to a library of standard codes, relating to the breakdown of the equipment, the triggering effect (often mistakenly called “cause” of shutdown) and the identified cause. An Interface specially adapted and dedicated to intervention requests, it allows any person, with the rights, to report a problem to the technical service. The entry support tools allow you to enter the location, equipment and report to create a request. The request is instantly transmitted to the technical service. A tracking interface

allows the requester to follow their requests and view their progress. The ManageMaint software, or G2IT, allows additional information to be recorded on:

- Desired completion time
- Degree of importance
- Automatic location of selected equipment
- Identification of the applicant

The author of the request is automatically identified. The request is instantly transmitted to the technical service. Monitoring requests for technical interventions.

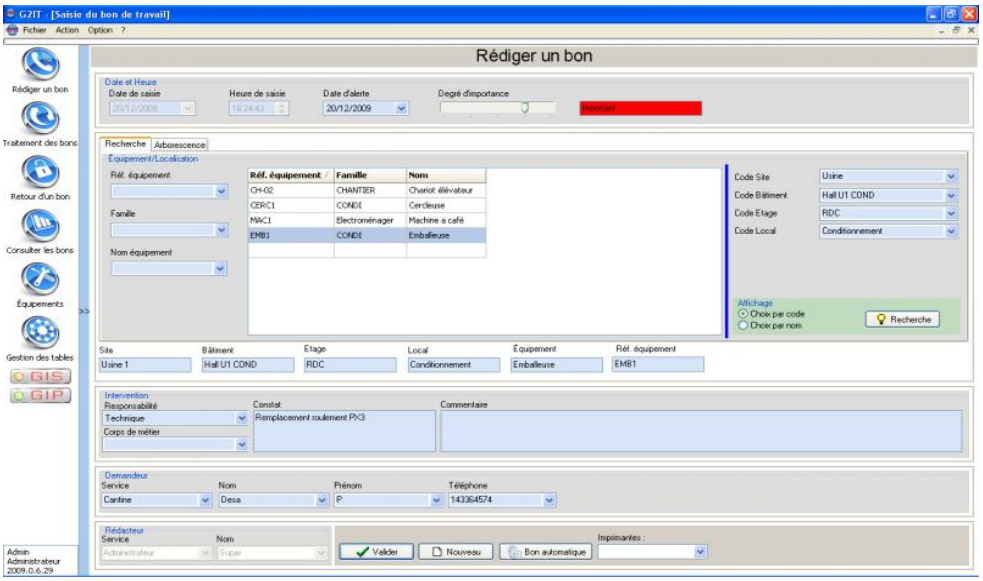


Figure II.5 Management of technical intervention requests

A tracking interface allows the requester and the writer to follow their requests and view their progress. A confirmation by email can be automatically sent to the requester and the writer each time the status of the request changes [18].

II.7.1.2 Management of technical intervention: CMMS software packages have a specific interface which allows the technical department to easily view the intervention requests which have just been issued, the preventive vouchers which are generated automatically, but also the vouchers linked to company maintenance contracts exterior. Thanks to this interface, maintenance agents can connect and consult precisely the vouchers assigned to them or all of the vouchers. Alerts are automatically triggered when a voucher has not been processed within the expected time frame.

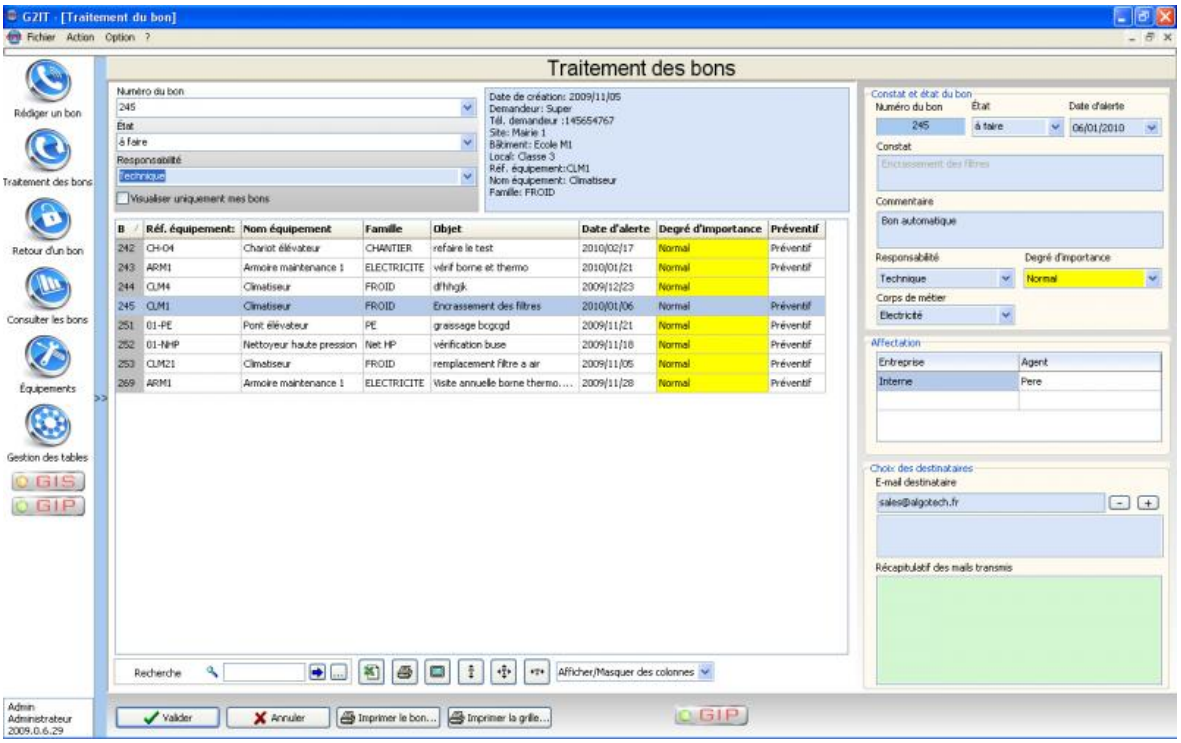


Figure II.6 Management of technical interventions

II.7.2 Equipment management: CMMS allows you to inventory all of your structure's equipment and locate it geographically. You will be able to manage sets and sub-sets of equipment without limiting the number of levels. G2IT allows you to associate one or more item lists with one or more pieces of equipment simultaneously. Equipment prevention is done in the "Preventive" function. Equipment is associated with one or more meters. These counters trigger alerts which can directly generate an intervention. Each piece of equipment can be associated with as many documents as you wish. G2IT allows you to manage any type of document format: Word, Excel, Powerpoint, photo, video DXF, DWG, etc.

Thus a technician can easily access a maintenance range or a user manual or even the electrical diagram of an installation, etc. It is :

- Describe and code the tree structure of the entire park to be maintained.
- Identify and characterize by DTE (Technical Equipment File) and history.
- Functional division.

This will allow:

1. Locate and identify a subset in the tree structure.

2. Know the functional criticality index of the equipment.
3. Quickly access the equipment maintenance plan.
4. Direct access to technical, historical and commercial characteristics from DTEs.

The technician can easily access a maintenance range or a user manual or even the electrical diagram of an installation, etc. Figure II.7 is a screenshot of the G2IT software in the equipment module

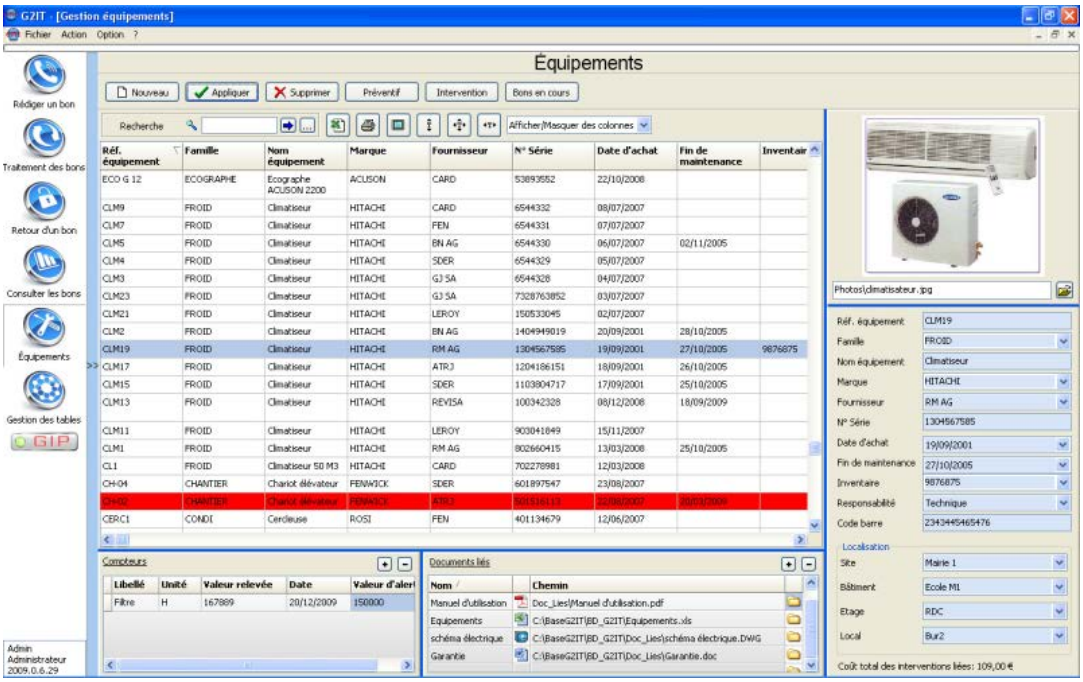


Figure II.7 Equipment management using G2IT software

II.7.3 Preventive management

The management of preventive technical interventions allows agents to have a predefined intervention schedule [19]. It is an essential function of the CMMS which must be easy to use and accessible to all, it allows you to:

- The creation of preventive programs.
- The association of several pieces of equipment to a program.
- The program triggers a certain number of days before the due date.
- The overall or partial modification of a preventive program.
- To display a summary schedule of preventive programs, trigger dates and intervention dates.

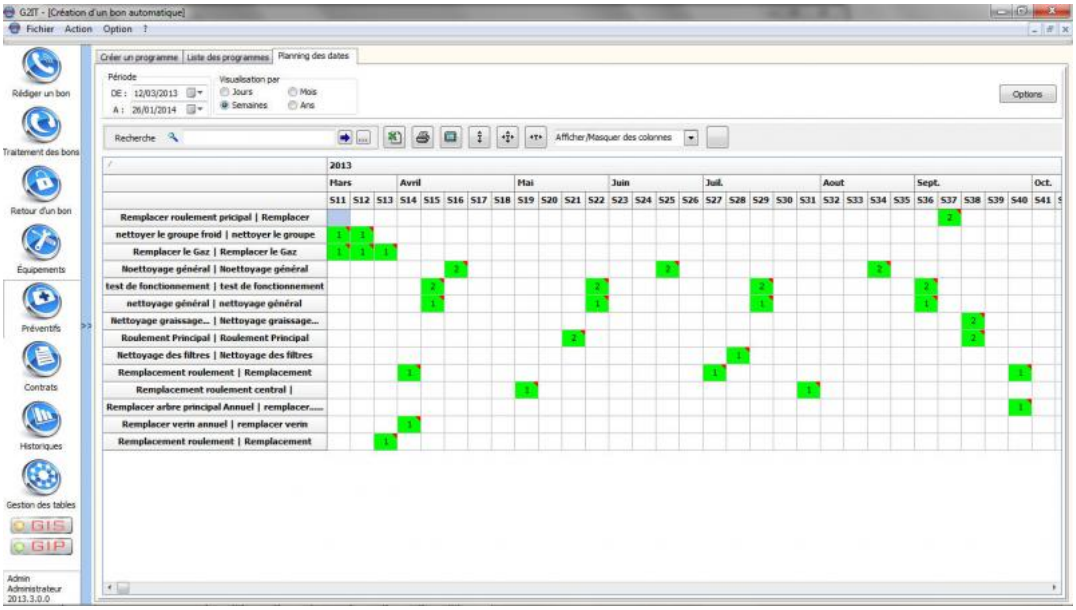


Figure II.8 Preventive management using G2IT

II.7.4 Human Resource Management: Personnel management refers to the definition of their skills, their available resources, their attendance times and these related activities. Directly from their personal file, the user can know their workload and know the progress of their requests, their orders or even their planned work.

II.7.5 Inventory management:

This module makes it possible to optimize the relationship with suppliers and subcontractors while reducing purchasing costs and delays associated with the maintenance process with the aim of guaranteeing the availability of parts.

Figure II.9 Inventory management in a CMMS

II.7.6 Schedule management: Our CMMS integrates a planning module or software (GIP) which allows the user to easily view the technical interventions assigned to agents and equipment in an OUTLOOK type interface. You will be able to select several agents to compare their workload. The interventions assigned to the agents can be moved graphically. You can also select a piece of equipment or a family of equipment to consult the associated preventive or curative maintenance. It also allows you to edit maintenance indices such as MTBF, MTTR, TRS, gross operating rate, etc.

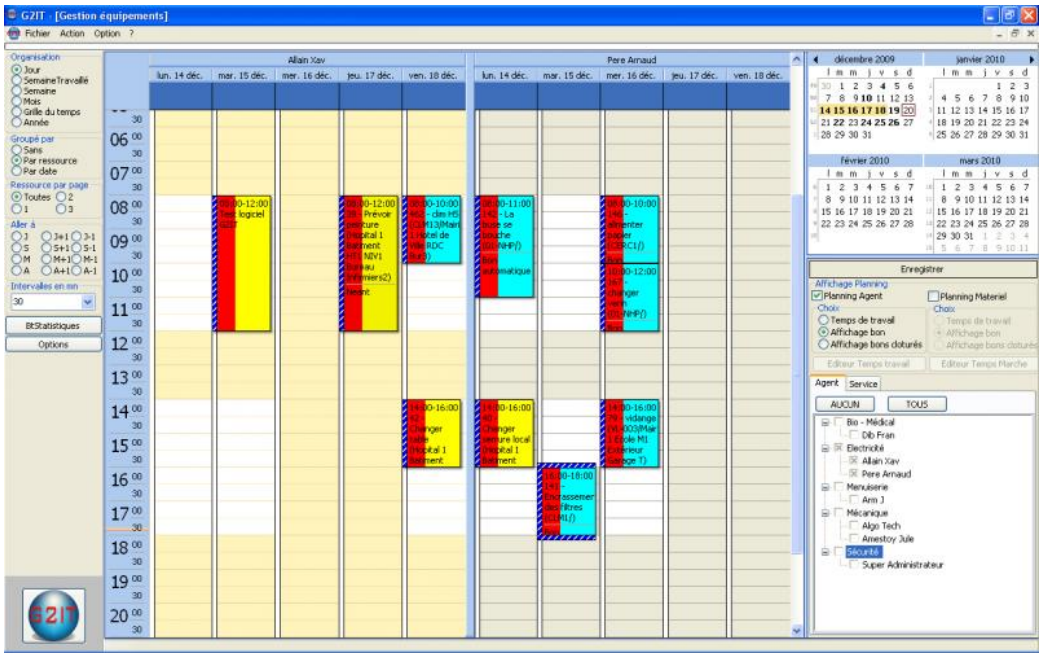


Figure II.10Management of schedules using G2IT

II.8 CMMS USERS:

The CMMS is used by technicians, production and maintenance operators and the purchasing department (excluding raw materials).

II.8.1 Maintenance technicians: as

- Preparation of work, reports
- Finding technical information
- Running diagnostics, viewing history

II.8.2 Responsible for maintenance: as

- Cost control and monitoring.
- Checking invoices and sending them to accounting

II.8.3 Warehouse workers: as

- Receipt of materials and their management
- Identification of requests in advance and their preparation
- Stock management
- Inventories Checking invoices and sending them to accounting

II.8.4 Managers: as

- Tracking costs per machine, production line, installations
- Performance monitoring, load optimization
- Participation in the activity dashboard Control of invoices and their sending to accounting

II.9 EVALUATION OF CMMS SOFTWARE

The objective here is to have a match between CMMS software and the needs of a company. For this we evoke the following grid

Software Name					
	Performance level				
Functions	**1 Low**	**2 Medium**	**3 Good**	**4 Very Good**	**5 Excellent**
Manage preventive and conditional work	Census of preventive works	Establishment of preventive maintenance sheets	Development of an adjustable preventive plan	Incident tracking	Implementation of condition-based maintenance
Ensure technical monitoring of equipment	Calendar history of work	Calendar history by type of maintenance	Malfunction analysis	History of units of work	Monitoring and analysis of equipment availability
Manage personal resources, tools, etc.	Resource List	Managing resource usage	Resource availability management	Resource allocation management	Quantification management
Monitor the activity of the maintenance department	In-store budget monitoring	Monitoring of internal invoicing	Analytical monitoring of expenses by other equipment	Maintenance service operating account	Activity tables, function, expenditure
Manage spares stocks and purchases	Maintaining stock in store	Permanent stock inventory and parts list	Reservation and restocking	Inventory management	Inventory management and purchasing tracking
Satisfaction rate: 60%					

II.10 CONCLUSION

Computer-aided maintenance management (CMMS) is a crucial element that governs the economic value of the organization itself. Maintenance management describes the practice of leading and transforming the organization through the deployment and management of available resources such as financial, human, material, skill and technological resources. Therefore, maintenance management should be emphasized by all means of planning, direction, implementation and control as well as several improvement methods to achieve the economic aspects of the organization [20]

The cost of maintenance is increasing due to rapidly changing maintenance strategies and resources, forcing the organization to consider proactive maintenance management to deal with maintenance issues, not just to save money. Maintenance management is a crucial element that governs the economic value of the organization itself. Maintenance management describes the practice of leading and transforming the organization through the deployment and management of available resources such as financial, human, material, skill and technological resources. All management activities determine the objectives and priorities set by the organization, including strategies, responsibilities and implementation. Therefore, maintenance management should be emphasized by all means of planning, direction, implementation and control as well as several improvement methods to achieve the economic aspects of the organization.