وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research

BADJI MOKHTAR-ANNABA UNIVERSITY

جامعة باجي مختار عنابة

Faculty: Technology

Department: Mechanical Engineering

Field: Science and Technology

Speciality: Maintenance Engineering

THESIS

Presented with a view to obtaining the Master's degree
Mechanical engineering

Evaluation of the maintenance at

ALFAPIPE -ANNABA-

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In front of the jury

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Academic Year: 2024-2025

Acknowledgements

All praise is due to Allah, the Almighty and the Most Merciful, for granting us the strength, determination, and patience to successfully complete this modest work.

I would like to express my deepest gratitude to my esteemed supervisor, Mr. KHELIF Rabia, for the time he devoted to me, the valuable insights he kindly shared, and his numerous pieces of advice that helped me overcome the various challenges encountered throughout the preparation of this thesis.

My sincere thanks also go to Mr. Marniche Nabil and Mr. Oumdour Samir for their valuable support and guidance during my internship period.

Finally, I would like to extend my heartfelt appreciation to the jury members for kindly agreeing to review and evaluate this work.

Dedication

To You, my Lord,
For the strength, the patience, and the silent miracles You place along my path.

To the man of my life,
my eternal role model, my source of moral support, joy, and happiness
the one who has always sacrificed so much so I could succeed
to you, my father, Cherif Amrouni.

To my mother,
Your love was my first school, and your gaze my first source of motivation.

To my sisters,
Including Anaïs,
Thank you for your smiles, your words, and your presence even when discreet that bring warmth to days of doubt.

To all of you,
This work is a reflection of everything you have given me.

Table of Contents

TABLE FIGURE

LIST OF TABLES

Résumé :

Ce mémoire traite l'évaluation de la fonction maintenance au sein de l'unité ALFAPIPE du complexe sidérurgique d'El Hadjar, en appliquant plusieurs méthodes différentes comme la méthode d'audit LAVINA. L'étude commence par une présentation générale de la maintenance industrielle, puis une description détaillée de l'organisation, des équipements et des procédés d'ALFAPIPE. À travers un diagnostic structuré (analyse SWOT, audit fonctionnel, indicateurs de performance), l'état actuel de la maintenance est analysé. L'objectif est de relever les dysfonctionnements, proposer des actions correctives et renforcer la fiabilité et la performance des équipements. Des propositions ont été formulées pour une meilleure performance de l'organisme.

Mots clés : Diagnostic, Maintenance, Audit, Amélioration, Evaluation, SWOT, Indicateur de performance.

Abstract

This thesis focuses on evaluating the maintenance function within the ALFAPIPE unit at the El Hadjar steel complex, using the LAVINA audit method. The study begins with an overview of industrial maintenance, followed by a detailed description of ALFAPIPE's organization, equipment, and processes. A structured diagnosis is conducted (SWOT analysis, functional audit, performance indicators) to assess the current maintenance practices. The aim is to identify weaknesses, propose corrective actions, and improve the reliability and performance of the equipment.

Keywords: Reliability, Maintenance, Audit, improvement, Evaluation of maintenance, key Performance Indicator, intervention time.

الملخص

تتناول هذه الأطروحة تقييم وظيفة الصـــيانة داخل وحدة ALFAPIPE في مجمع الصـــلب الحجار، من خلال تطبيق طريقة التدقيق .LAVINA تبدأ الدراســـة بعرض عام للصـــيانة الصناعية، ثم وصف تفصيلي للتنظيم والمعدات والعمليات الخاصة بشركة .ALFAPIPE من خلال التشخيص المنظم) تحليلSWOT ، التدقيق الوظيفي، مؤشرات الأداء(، يتم تحليل الحالة الحالية للصـيانة. الهدف هو تحديد الأعطال واقتراح الإجراءات التصـحيحية وتحسـين موثوقية وأداء المعدات.

الموثوقية، الصيانة، التدقيق، التحسين، تقييم الصيانة، مؤشر الأداء الرئيسي، وقت التدخل

Introduction

General Introduction

In today's highly competitive industrial landscape where quality requirements are strict and cost pressures are constant, equipment maintenance has become a strategic and essential function. No longer limited to reactive repairs, modern maintenance is a proactive discipline aimed at ensuring reliability, availability, and long-term performance.

When properly managed, maintenance becomes a key driver of industrial performance, helping to reduce unexpected downtime, optimize operating costs, extend equipment lifespan, and ensure continuous production. However, for maintenance to be truly effective, it must be measured, analyzed, and critically evaluated to identify weaknesses, control risks, and define actionable paths for improvement.

This study, entitled "Evaluation of Maintenance in ALFAPIPE company" aims to conduct a structured and in-depth analysis of the company's maintenance function. By applying reliable and widely used evaluation tools, the goal is to assess current maintenance practices, measure their actual performance, and provide practical, sustainable recommendations for optimization.

We begin by presenting the theoretical foundations of maintenance evaluation, including the key concepts, methods, and performance indicators commonly used in the field. We will then provide a detailed overview of the maintenance structure and practices currently in place within ALFAPIPE Company.

The core of the study will focus on a comprehensive evaluation using the following tools:

- A SWOT analysis to highlight strengths, weaknesses, opportunities, and threats;
- A functional diagnosis to assess organizational structure, resources, and processes;
- A maintenance audit based on the Lavina method to determine the maturity level of the maintenance function;

• An evaluation based on performance indicators to quantify technical, economic, and operational effectiveness.

Finally, we will synthesize our findings and present targeted recommendations aimed at improving maintenance efficiency and supporting the company's broader industrial

performance goals.

In the absence of structured evaluation, ALFAPIPE’s maintenance system may not fully support its performance goals.

There is a need to assess its effectiveness, identify gaps, and define improvement actions.

How effective is ALFAPIPE’s current maintenance system, and how can it be evaluated and optimized to better support industrial performance?

CHAPTER I

Company overview

I.1 General Overview of the El-Hadjar Complex:

El-Hadjar Complex is a major steel production center located 15 km south of the city of Annaba. It covers an area of 800 hectares.

Its primary mission is to process iron ore from the OUENZA mines and produce steel products

Fig I.1 : General Overview of the El-Hadjar Complex:

The complex comprises four production zones:

- IRONMAKING ZONE
- LONG PRODUCTS ZONE
- FLAT PRODUCTS ZONE
- PIPE ZONE

El-Hadjar Complex is equipped with 3thermal power plants, 4 oxygen production units, and three water treatment facilities. It employs more than 9,000 personnel, including both managerial staff and operational workers, making it one of the largest industrial employers in the region

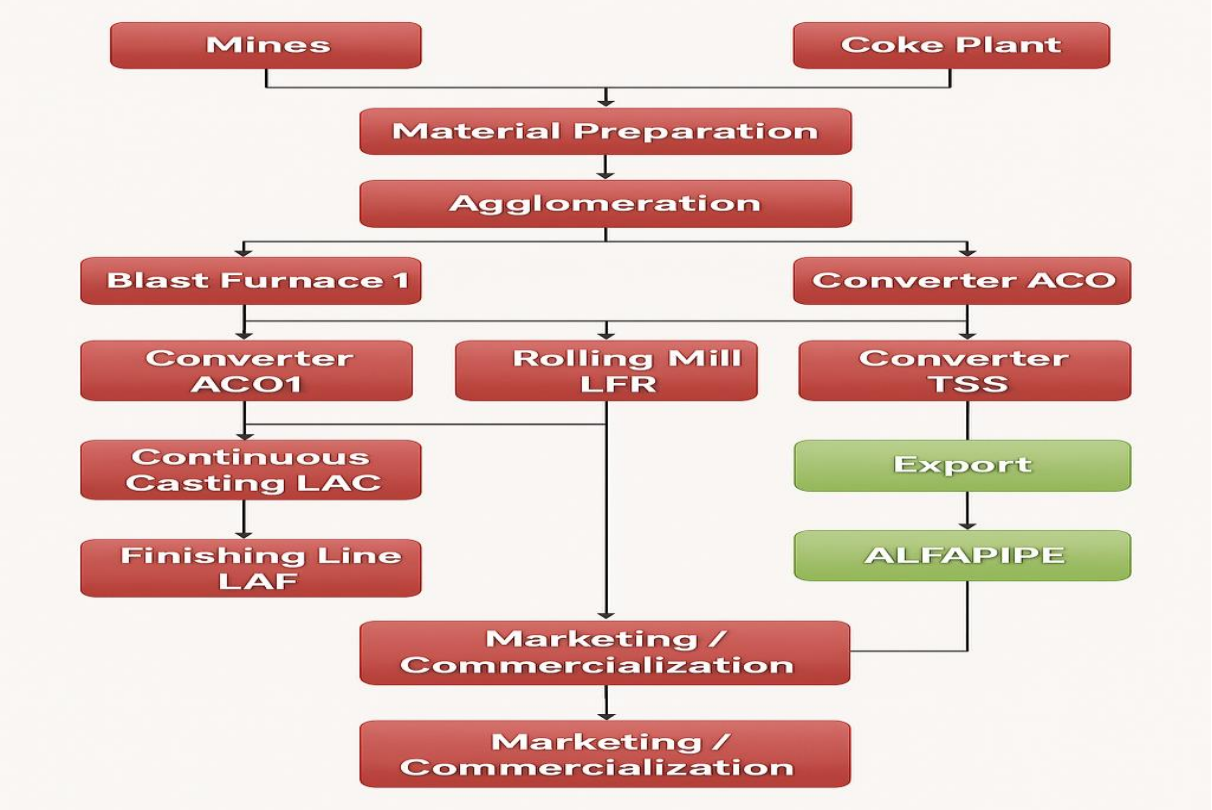
I.1.1. History of the El-Hadjar Complex:

The National Steel Company (SNS) was established on September 3, 1964, by ordinance No. 642-72. It was one of five national companies under the supervision of the Ministry of Heavy Industry. The company brought together several units across the country and aimed to support national development and improve Algerian living standards through industrial and economic progress.

The SNS benefited from multiple development plans and was later restructured into a national steel

In 1969, the SIDER Industrial Group developed the El-Hadjar steel complex to produce a wide range of steel products. Since its inception, the integrated complex has expanded its operations to meet the growing demand in sectors like housing and petroleum infrastructure. As part of the country's privatization policy aimed at stimulating growth, the El-Hadjar complex was acquired by the Mittal Group and became part of the international steel group ARCELOR-MITTAL.

I.1.2. General structure of the complex:



FigI.2 : General structure of the complex:

I.1.3. Products of the EL-HADJAR complex:

The main products are:

Table I.1: Products of the EL-HADJAR complex.

Facility	Products	Main Users
Coking Plant	Coke	✓ Metallurgy
Blast Furnaces 1 & 2 (HF1 & HF2)	Pig Iron	✓ Metallurgy
Oxygen Steelmaking (ACO1 & ACO2)	Slabs and Billets	✓ Manufacturing Industry
Hot Rolling Mill (LAC)	Heavy Plates	✓ Steel Construction✓ Shipyards✓ Gas Cylinders and Bottles✓ General Manufacturing
Cold Rolling Mill (LAF)	Thin Sheets	✓ Household Appliances✓ Metal Furniture✓ Manufacturing Industry
Spiral Pipe Mill (TUS)	Welded Pipes	✓ Hydrocarbon and Water Transport
Seamless Pipe Mill (TSS)	Seamless Pipes	✓ Hydrocarbon Extraction and Hydraulic Systems
Electric Arc Furnace (ACE)	Ingots	✓ Petroleum Research and Production✓ Hydrocarbon Transport
Wire Rod Mill (LFR)	Rebar (Reinforcing Bars)	✓ Construction and Hydraulic Public

I.2. Presentation of ALFA PIPE unit:

Our internship was carried out within the spiral welded pipe manufacturing unit, ALFAPIPE, which is part of El-Hadjar Steel Complex.

FigI.3 : Alfa pipe Unit

I.2.1. History of the ALFA-PIPE ANNABA unit:

SONATRACH has been a national hydrocarbon transportation and marketing company since 1966. Its considerable needs for transportation, oil, and gas pipelines are made of steel pipes.

The SNS national steel company was then tasked by the Ministry of Industry with taking all necessary steps to ensure the immediate fulfillment of this request. It is expected to meet a significant portion of SONATRACH's exceptional pipe requirements, in addition to those for hydraulics, agriculture, and industrial equipment in general.

This is why the project to establish spiral-welded tube manufacturing units within SNS (TSS) was under consideration.

Construction began in 1967 and was commissioned in May 1969.

Two major investments were made between 1975 and 1995 to meet the needs of the

hydrocarbon transport pipe market:

- In 1975, the establishment of an epoxy tube coating workshop, primarily used for gas pipes.
- In 1995, the establishment of a three-layer polyethylene exterior coating workshop.

Following SIDER's restructuring in 1999, the unit became ALFATUS (Algerian Spiral Welded Tube Manufacturing Company), a subsidiary of the SIDER group. In July 2006, ALFATUS SIDER signed its merger with PIPE-GAZ Annaba/Ghardaïa and became ALFAPIPE (the Algerian pipe manufacturing company) with a joint general management in Algiers. ALFA PIPE ANNABA occupies an area of 98,000 m2 15 km south of Annaba

I.2.2. Choice of location for the Spiral Tubery:

This choice met several criteria:

- Proximity to the port of Annaba (approximately 15 km), for the reception of raw materials, mainly from abroad (coils, welding wires, etc.).
- Proximity to the railway line for the evacuation of these finished products.
- Proximity to the hot rolling mill within the complex for the possible use of coils from the SNS hot rolling mill.

I.2.3. ALFAPIPE Unit Products:

ALFAPIPE produces and inspects spirally welded pipes from sheet metal coils. These pipes are designed for the transportation of gas, oil, and water. The range of pipes manufactured varies in diameter from 16 inches (406.4 mm) to 52 inches (1320.8 mm). Currently, most orders are for 48 inches (1219.2 mm) and lengths between 9 m and 12 m. The following table illustrates the specifications of the pipes manufactured.

Table I.2: The range of tubes produced

Tube diameter in inches	16	24	30	36	42	48
Thickness in mm	5.0	7.5	9.0	11.0	11.0	12.0
Strip width in mm	800	1200	1500	1800	1800	1800
Production capacity (m of tube/hour)	57	47	42	34	24	14

The unit's machines can process hot-rolled steels with very high yield strengths in grades X60 to X70.

The coils used for the manufacture of spiral tubes are supplied untreated, and these supplies come primarily from Germany, Japan, Russia, and Lake Sider. The coils used can have thicknesses ranging from 5 to 15 mm, widths from 600 to 1,870 mm, and weights between 29 and 36 tons. Current production is around 130,000 tons/year.

I.2.4. The functional organization of the ALFAPIPE ANNABA unit:

ALFAPIPE ANNABA organization includes the following five (5) functions:

•Technical Function:

It is responsible for: scheduling the manufacturing of tubes and their completion, coating, quality control, maintenance management, troubleshooting, preventive maintenance, subcontracting, management of handling resources, and execution of storage operations.

•Sales Function:

It handles all sales and customer relations activities such as purchasing, sales, after-sales service, prospecting, scheduling, as well as handling customer complaints.

•Procurement Function:

It is responsible for managing spare parts inventories, manufacturing consumables, and customs clearance operations.

•Human Resources and General Resources Function:

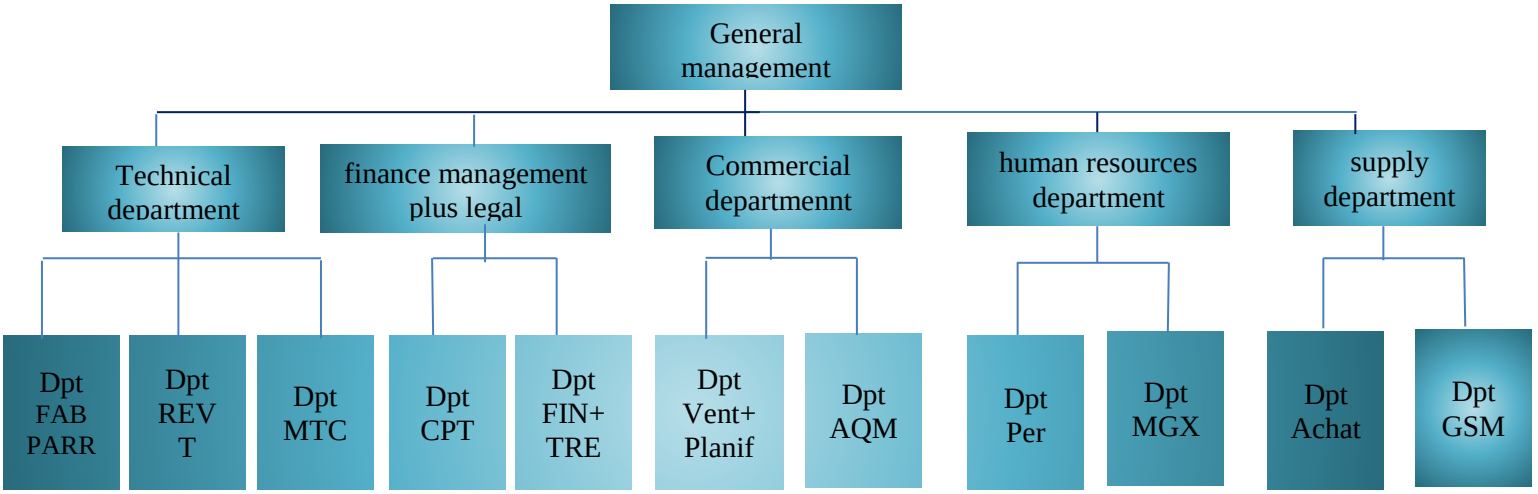
This covers the following activities:

- Human Resources: Personnel management.
- General Resources: External relations (mission, reception), industrial health and safety, vehicle fleet management, and commissary.

•Finance and Legal Function:

It handles the following activities: Budget, treasury, finance, asset management, insurance, tax and legal matters, general and cost accounting, and management control.

I.2.5. Organization chart of the ALFAPIPE ANNABA unit:



I.2.6. Unit Structure:

The facilities are divided into three industrial buildings:

- The polyethylene exterior coating building, built in 1993-1995, covers an area of 2,940 m².
- The epoxy interior coating building, built in 1973-1975, covers an area of 4,480 m².
- The spiral pipe mill consists of four halls covering an area of approximately 18,000 m², an administrative building, and a 15 kV/380 V electrical substation (three 1,600 kVA transformers and two lighting transformers).

The total installed electrical power is 3800 kVA. The coil storage hall is served by two railway tracks and an underground track directly connected to the LAC (Water Supply and Distribution Center), as well as a 44-tonne overhead crane. It can store 15,000 tonnes of coils, equivalent to the consumption of one and a half months of production. The welding machine hall is served by two railway tracks and a 44-tonne overhead crane. It houses four identical spiral welding machines, the coil preparation machine, and the flux regeneration machine.

The two tube finishing halls (pre-finishing) are arranged perpendicular to the two previous halls. They are each served by a 7.5-tonne overhead crane with a 34.8 m span, intended for machine maintenance and the rapid transfer of tubes, which are subject to spiral manufacturing procedures. Normal handling of tubes in the last two halls is done by a roller conveyor system and grids equipped with handling devices such as ejectors, loading magazines, stoppers, etc. Hydraulically controlled (by distributors), supplied by 7 independent hydraulic groups.

I.3 Spiral Pipe Mill Facilities:

This unit is designed for the cold transformation of sheet metal coils into spirally welded tubes and is equipped with:

Coil Tilter:

Sheet metal coils arriving vertically are placed horizontally on this facility for preparation.

Fig I.5 : Coil and its installation on the rocker

- **Coil preparation machine:**

This machine is fed with horizontally-axis coils by the overhead crane. The coil is then positioned and unwound to a certain length to undergo several operations:

The first part of the coil is cut squarely along the axis of the bung and is subjected to:

- A dimensional inspection (thickness, cracks, etc.)
- A visual inspection (dentations, cracks, etc.)
- An ultrasonic inspection to detect any internal defects (in the liners).

If the beginning of the strip is free of defects, the coil is considered suitable for consumption. If the beginning of the coil contains defects, the coil will be rejected.

Fig.I.6: Coil preparation machine

- **Welding Machine**

The spiral pipe mill has four (04) identical welding machines, which allow for several operations to be performed for tube manufacturing planning.

This operation consists of planing the end of the coil to connect it to the previous one using automatic submerged welding. The operation lasts approximately 30 minutes and requires production to be stopped.

- **Guiding**:

Four (04) hydraulically controlled guide rollers allow for rapid adjustment of the strip in the event of deviations due to variations in strip width.

- **Strip Straightening**:

A straightening roller train ensures perfect flatness and contributes to strip guidance.

- **Shearing**:

Edge shears allow the strip to be finalized to its width.

The scraps obtained by shearing are cut by simply rotating two (02) chopper rollers equipped with several steel knives.

Fig.I.7 : Machine (planing, guiding, strip dressing, shearing)

- **Strip forming:**

The strip is driven by two (02) cylindrical rollers, it undergoes preforming by cambering rollers, guide arms with TEFLON wear plates hold the strip. It is introduced into the forming cage consisting of several sets of rollers, adjusted according to the diameter to be produced.

The strip thus formed is welded internally, then half a turn after externally.

The process used is automatic submerged arc welding; a central unit allows the recovery of excess flux for recycling. The formed tube is cut to the desired length by an oxycutting trolley provided for this purpose.

- Two tube cleaning machines:

The tube thus cut to length is cleaned on a machine which removes all waste (flux, slag, etc.).

- **Visual Zone:**

At this level, the following operations are performed:

- Visual inspection of the sheet metal and bead.
- Dimensional inspection (length, diameter, thickness).
- Removal of certain types of defects by grinding.
- Transcription of this information onto the tube tracking card.

(Indicating the operations performed on the tube).

Fig I.8 : Tube inspection stand

- **Rework Welding Machine:**

This machine performs the external welding operation on planed parts.

The welding system is identical to that of spiral welding machines.

Fig I.9 : Weld bead

- **Repair area:**

Equipped with two (02) manual welding stations to carry out all repairs of harmful welding defects, indicated upstream by visual inspection.

Fig I.10 : Repair of defects

- **Tube cutting machine:**

This machine is used for oxy-cutting tubes according to the visual inspection instructions and those shown on the tube tracking card.

Fig.I.11 : Tube Cutting Machine

- **Hydrostatic test bench:**

This installation is used to test tubes at a pressure equivalent to 90% (test pressure) of the working pressure of the steel used. This operation aims to verify, on the one hand, the tube's

tightness, and on the other hand, the tube's behavior during pressure increase (resistance of the sheet metal and the weld bead).

Fig.I.12 : hydrostatic test bench machine

- **Two tube beveling machines:**

To enable manual welding, the tube is beveled on this machine according to work standards. The resulting angle is generally 30° to 35° with a 1.5mm bevel.

Fig I.13: Tube bevelers

Automatic ultrasonic testing machine:

Ultrasonic machine tested the weld bead by an electric using two (02) angled probes located on either side of the weld bead.

Flat probe tested the sheet metal by moving in translation between the two (02) turns

Fig I.14 : Automatic ultrasonic testing machine

- **Two radiographic and radioscopic inspection machines:**

Each welding defect detected by automatic ultrasound is subjected to an initial X-ray. A second radiographic device, identical to the previous one and specialized in taking X-rays of end welds. X-rays use a fluorescent screen to visualize the defects, but radiography uses X-ray films.

These installations are insulated by a lead screen, protecting personnel from X-rays.

Fig.I.15: X-ray control area

- **Final Inspection Area:**

The following operations are performed at this stand:

- Visual and dimensional inspection.
- Verification of the tube tracking card.

Two scenarios may occur:

• The tube is free of defects, and the operations listed on the tracking card have been completed.

In this case, the tube receives a shipping number and continues its journey to the storage facility.

• The tube has a defect, or the operation listed on the card has not been completed.

In this case, the tube is returned to the workshop to undergo the missing services.

CHAPTER II
General Concepts of Maintenance Evaluation

II.1. Introduction

Maintaining production equipment is a key issue for factory productivity as well as for product quality. It is an industrial challenge involving the questioning of current fixed structures and the promotion of methods adapted to the new nature of the materials [1].

II.2 Definition of maintenance

According to AFNOR (NF X 60-010):

Maintenance is the set of technical, administrative, and management actions during the life cycle of an asset, intended to maintain or restore it to a state in which it can perform its required function [1].

This definition includes the main concepts of maintenance, which are:

- Maintain: Contains the notion of "prevention" for a system in operation.
- Restore: Contains the notion of "correction" following a loss of function.
- Specified state or determined service: Implies the predetermination of the objective to be achieved, with quantification of characteristic levels.
- Optimal cost: This determines all operations with a view to efficiency [7].

II.3. Maintenance Policy:

- **Definitions**:

Maintenance strategy is a management method used to achieve maintenance objectives (NF EN 13306 standard).

The maintenance strategy, which results from the maintenance policy, imposes choices to achieve the set objectives.

These choices must be made to:

- Develop, adapt, or implement maintenance methods
- Develop and optimize maintenance procedures
- Establish work standards
- Define safety methods and resources
- Establish information flows (Flow Charts)
- Organize maintenance teams

- Manage and optimize inventory
- Manage maintenance human resources: selection, recruitment, training, communication, motivation, etc.

We can therefore consider the forms of maintenance (corrective, systematic, conditional predictive, routine and improvement) as maintenance strategies [2].

II.4. Maintenance Objectives:

The main objectives that the maintenance function must set are:

- Improving equipment reliability: Implementing preventive maintenance requires technical analyses of equipment behavior. This allows for both optimal preventive maintenance and the complete elimination of certain failures.
- Ensuring product quality: Machines are monitored daily to detect failure symptoms and ensure that adjustment and operating parameters are respected. Monitoring clearances (vibrations) and machine geometry helps prevent operational hazards. This ensures product quality and eliminates scrap.
- Improve work scheduling: the production department must validate thhe planning of preventive maintenance interventions, corresponding to the machine downtime schedule. This requires the collaboration of this department to facilitate the maintenance task. Maintenance technicians are often dissatisfied when the production manager does not allow the facility to be shut down, even though they have received a work order for the intervention. Good coordination provides for a shutdown according to a pre-defined schedule, taking into account impossibilities based on production requirements.
- Ensure human safety: Preparing preventive maintenance interventions not only involves adhering to the schedule, but must also take into account safety criteria to avoid dangerous unforeseen events.
- Improve inventory management: Preventive maintenance is plannable. It controls the replacement deadlines for components or parts, which facilitates inventory management. It also makes it possible to avoid stockpiling certain parts and only order them when the time comes [5].

II.5. Maintenance Management

II.5.1. Principles of Management

To manage is to administer, direct, govern, and exercise leadership and control functions, whether for oneself or for another.

The maintenance process in an industrial facility involves:

Defining quantified and measurable objectives.

Defining the means to be implemented to achieve these objectives.

The maintenance manager is responsible for implementing a management system adapted to their company. They must take into account:

- The company's specifications.
- Its size.
- The importance of maintenance.
- The level of information.

Measuring results, comparing objectives, analyzing gaps, and making decisions are all means of correcting deviations.

II.5.2. Maintenance Aspects

The maintenance of an asset begins with the consideration, from its design stage, of reliability and maintainability, which are increasingly included in the specifications.

Equipment begins to evolve shortly after its commissioning. These characteristics, its production capacity, and the quality of its workmanship, also represent operating costs that decrease shortly before they are eliminated.

It is therefore essential to take action to restore it to its original state.

II.5.3. Maintenance Approach

Equipment interventions are necessary to maintain their proper working order; it is therefore possible to keep track of:

- Failures not previously reported.
- Repair costs.
- Downtime.
- Costs of lost production during downtime.
- Changes to carrying techniques, etc.

This requirement leads to the creation of a file for each piece of equipment, which is divided into two parts:

- Technical File
- Machine File
- Technical File

This file includes everything specific to a machine model: manufacturer's data, drawings, electrical diagrams, parts list, etc. Therefore, one technical file is sufficient for each machine type.

- Machine File

Related to each individual machine, the machine file includes the specific information concerning that machine (year of commissioning, investment amount, operating configuration, GRAFCET, GEMMA) [1].

II.6. Maintenance Department Functions:

Generally, to carry out its various activities, the maintenance department must include several functions or sub-departments. The internal organization of the maintenance department obviously varies depending on the type of company, its size, and the nature of its product. For information purposes, five functions are essential [13]:

II.6.1. Study Function:

Its main mission is to analyze the work to be performed based on the chosen maintenance policy. This involves the implementation of a maintenance plan with quantified objectives and measurable indicators.

II.6.2. Preparation Function:

The preparation of maintenance interventions must be considered an integral part of the maintenance process. All the conditions necessary for the success of a maintenance intervention must be planned, defined, and characterized. This preparation must, of course,respect the general objectives defined by the maintenance policy, such as cost, time, quality, and safety.

II.6.3. Scheduling Function:

Scheduling represents the role of "conductor" in a maintenance department characterized by an extreme variety of tasks in terms of type, duration, urgency, and criticality

II.6.4 Implementation Function:

Implementation consists of deploying the resources defined in the preparation file, in accordance with best practices, in order to achieve the expected results within the planned timeframe.

II.6.5 Management Function:

The maintenance department's management function must be capable of managing equipment, operations, inventory, human resources, and the budget.

II.7. Types of Maintenance:

II.7.1. Corrective Maintenance:

Corrective maintenance involves responding to an event: a partial or complete breakdown.

Definition:

The AFNOR X 60-010 standard defines corrective maintenance as: "Effect of maintenance after a breakdown."

This approach is comparable to traditional maintenance commonly practiced before the advent of maintenance in industry. It is not a proactive step, but simply a monitoring of the essential operations, limited to lubrication and oil changes.

Corrective maintenance includes operations to restore a faulty system to service. A breakdown never occurs without the system being used, but these operations allow for a rapid resumption of production.

It differs from these aspects:

- Palliative operations, called troubleshooting, whose objective is to eliminate the effects of the failure in order to resume production. They do not cover specific characteristics.
- Curative operations called repairs, whose objective is to bring the system back to a given level of performance. They form the second phase of troubleshooting [4].

II.7.1.1. Corrective maintenance time:

Because corrective maintenance actions are so diverse, it is always difficult to predict the intervention time:

- It can be short (from a few seconds to reset a circuit breaker or change a fuse to a few minutes to replace a leaking seal).
- It can be very long (from 0.5 hours to several hours) in the case of replacing several components simultaneously (engine flooded).
- It can be significant in the case of personal injury (several days in the case of a police investigation) [5].

II.7.1.2. Corrective maintenance operations:

- **Trouble shooting**: action on a faulty asset with the aim of restoring it to working order. Depending on the objective, a troubleshooting action may be limited to temporary results and performance conditions outside of procedural, cost, and quality rules, and in this case, it will be

followed by repair.

- **Repair**: definitive and limited corrective maintenance intervention following a breakdown or failure. The repair may be decided upon either immediately following an incident or failure, or after troubleshooting, or after a conditional or systematic preventive maintenance visit [6].

Note: Repair is a definitive action. The repaired equipment must provide the performance for which it was designed. All equipment is affected

II.7.2. Preventive maintenance:

While it is necessary to correct the effects of failures to ensure continued production, it is preferable to prevent them in the first place.

Definition:

The AFNOR X 60-010 standard defines preventive maintenance as:

"Maintenance performed with the intention of reducing the probability of failure of an asset or the degradation of a service provided."

A preventive maintenance operation is therefore a planned intervention prepared and scheduled based on various parameters with the aim of avoiding the probable occurrence of an identified failure [4].

II.7.2.1. Objectives of Preventive Maintenance:

- Increase equipment lifespan.
- Reduce the probability of in-service failures.
- Reduce downtime in the event of overhauls or breakdowns.
- Prevent and also plan for costly corrective maintenance interventions.
- Enable corrective maintenance decisions to be made under optimal conditions.
- Avoid abnormal consumption of energy, lubricants, etc.
- Improve working conditions for production personnel.
- Reduce maintenance budgets.
- Eliminate the causes of serious accidents.

II.7.2.2. Systematic preventive maintenance:

This is preventive maintenance performed according to a schedule established by time or the number of units of use. Although time is the most common unit, other units can be used.

Such as: the quantity, length, and mass of manufactured products, distance traveled, number of cycles performed, etc. This intervention frequency is determined from the time of commissioning or after a complete or partial overhaul.

- This method requires knowledge of:
- Equipment behavior.
- Degradation modes.
- The average time between two failures.

Application scenarios:

- Equipment subject to current legislation (regulated safety): lifting equipment, fire extinguishers, pressure tanks, conveyors, elevators, hoists, etc.
- Equipment whose failure could cause serious accidents: any equipment providing public transportation for people, airplanes, trains, etc.
- Equipment with a high failure cost: components of an automated production line, continuously operating processes (chemical or metallurgical industries).
- Equipment whose operating costs become abnormally high over its service life: excessive energy consumption, lighting from worn lamps, ignition and carburetion
- Malfunctions (combustion engines), etc.

II.7.2.3. Condition-based preventive maintenance:

This is also called predictive maintenance (a non-standard term). It is preventive maintenance subject to a predetermined type of event (self-diagnosis, sensor information, wear measurement, etc.). Condition-based maintenance is therefore experience-based maintenance that uses information collected in real time. It is characterized by the identification of weak points. Depending on the case, it is desirable to monitor them and, from there, decide on intervention when a certain threshold is reached. However, inspections remain systematic and are part of non-destructive testing methods. All equipment is affected; this condition-based preventive maintenance is performed through relevant measurements on the equipment in operation.

The parameters measured may include:

- Oil level and quality.
- Temperatures and pressures.
- Voltage and current of electrical equipment.
- Vibrations and mechanical play.

- The equipment required to ensure condition-based preventive maintenance must be reliable to ensure its continued usefulness. It is often expensive, but in well-chosen cases, it quickly pays for itself [5].

II.7.2.4. Preventive maintenance operations:

These operations are defined in standards NF X 60-010 and NF EN 13306.

Inspections

Monitoring activities consisting of periodically identifying anomalies and performing simple adjustments that do not require specific tools or downtime of the production facility or equipment.

Visits

Monitoring operations that, as part of systematic preventive maintenance, are carried out at a set frequency. These interventions correspond to a list of pre-defined operations that may involve disassembling components and downtime of equipment. A visit may result in corrective maintenance action.

Controls

Conformity checks against pre-established data followed by a judgment. Monitoring can

- Include an information activity
- Include a decision of acceptance, rejection, or postponement
- Result, like visits, in corrective maintenance operations
- Monitoring operations (checks, visits, inspections) are necessary to monitor changes in the actual condition of the asset. They are carried out continuously or at predetermined or non-predetermined intervals, calculated over time or the number of usage units [6].

II.7.3. Improvative Maintenance:

Improving capital equipment is a "set of technical, administrative, and management measures designed to improve the operational safety of an asset without changing its required function" (NF EN 13306 standard). Modifications are therefore made to the original design with the aim of increasing the lifespan of components, standardizing them, reducing energy consumption, improving maintainability, etc.

This is an important aid if one subsequently decides to build equipment performing the same job but using modern technology: the same problems will no longer arise.

II.7.3.1. Objectives of Improvative Maintenance

Improvative maintenance is a state of mind requiring critical observation and a creative attitude. An improvement project necessarily involves a serious economic study: the improvement must be profitable. All equipment is affected, except, of course, equipment close to retirement. The objectives are:

- Increased production performance.
- Increased reliability.
- Improved maintainability.
- Standardized certain components or subassemblies.
- Increased user safety.

II.7.3.2. Improvement Maintenance Operations:

❖ **Renovation**

This involves the complete inspection of all components, complete dimensional adjustment or replacement of deformed parts, verification of specifications, and, where appropriate, the repair of defective parts and subassemblies [8].

It is therefore a possible follow-up to a general overhaul. A renovation may result in a standard exchange.

❖ **Reconstruction**

"Action following the dismantling of the main asset and replacement of assets that are nearing the end of their service life and/or should be systematically replaced."

Reconstruction differs from overhaul in that it may include modifications and/or improvements. The objective of reconstruction is normally to give an asset a useful life that may be longer than that of the original asset. Reconstruction requires the replacement of vital parts with original or equivalent new parts [5].

La reconstruction peut être assortie d'une modernisation ou de modifications.

Les modifications peuvent apporter un plus en terme de disponibilité (redondance), d'efficacité, de sécurité, etc. Attention toutefois à une forme particulière de reconstruction c'est la « cannibalisation » qui consiste à récupérer, sur le matériel mis au rebut (casse), des éléments en bon état, de durée de vie espérée inconnue, et de les utiliser en rechanges ou en pièces de rénovation.

❖ **Modernization**

The replacement of equipment, accessories, and software with subassemblies that, thanks to technical improvements not present on the original asset, improve the asset's usability. Modernization can occur during renovation or reconstruction operations [5].

II.8. Maintenance Levels:

According to the AFNOR standard (NF X60-O11), the maintenance and operation of an asset are carried out through numerous operations, sometimes repetitive, sometimes occasional, commonly defined until now into five maintenance levels.

The classification of these operations allows them to be prioritized in multiple ways. This may be based on the following criteria:

Define who does what for each maintenance level:

• Production personnel.

• Maintenance personnel, taking into account the qualifications of the person performing the maintenance.

• Company personnel or a subcontractor.

A combination of the three.

➢ **Level 1:**

Simple adjustments provided by the manufacturer using components accessible without any equipment disassembly, or the safe exchange of accessible components.

➢ **Level** 2:

Troubleshooting through standard replacement of components provided for this purpose, or minor preventive maintenance operations.

➢ **Level 3:**

Identification and diagnosis of faults, repairs through the exchange of functional components, and minor mechanical repairs.

➢ **Level 4:**

Major corrective or preventive maintenance work.

➢ **Level 5:**

Renovation, reconstruction, or major repair work entrusted to a central workshop [14].

Table II.1 : Maintenance Levels

Level	Task Complexity	Required Skill	Tools Used	Location	Example
1	Simple adjustments	Technician or Operator	Basic tools (brush, gauge)	On-site	Lubrication
2	Low-complexity actions	Qualified Technician	Standard portable tools (wrenches, pliers)	On-site	Belt replacement
3	Complex actions	Specialized Technician	Specific tools (multimeter)	On-site or Workshop	Distributor repair
4	High-importance actions	Specialized Technician or Team with Supervision	Collective and specific tools	Specialized Workshop	Transformer repair
5	Highly complex operations	Construction Team	Manufacturer-specific tools	External Workshop	Machine overhaul

II.9.Evaluation of the Maintenance:

It is a fundamental process aimed at analyzing, measuring, and improving the performance of maintenance activities within an organization. This approach involves evaluating the effectiveness of maintenance practices, resources, and processes to ensure the proper functioning of equipment, minimize unplanned breakdowns, and optimize costs. It is crucial to ensure production continuity, reduce the risk of industrial accidents, and extend equipment lifespan.

The Importance of the evaluation:

Regular evaluation of the maintenance system is essential for several reasons:

- ❖ Ensuring equipment reliability and availability:

Ensuring equipment reliability and availability means that machines and facilities are always ready to operate when needed, without unplanned interruptions. This is crucial for maintaining high levels of production and productivity.

- Optimizing maintenance costs:

Optimizing maintenance costs involves efficiently managing resources to reduce expenses without compromising equipment quality or performance. This includes planning, preventive maintenance management, spare parts management, and process improvement.

- Improve facility security:

Improving facility safety involves minimizing the risk of accidents and catastrophic breakdowns that could endanger worker lives and cause significant property damage. Safety is a critical aspect of industrial maintenance.

- Extending asset life:

Extending asset life means maximizing equipment utilization before it requires replacement. This is achieved through preventive and predictive maintenance programs that identify and address problems before they become serious.

- Ensuring regulatory compliance:

Ensuring regulatory compliance involves complying with applicable laws and standards that govern maintenance operations and equipment safety. Non-compliance can result in legal penalties, fines, and temporary or permanent facility closures.

II.10. Maintenance Assessment Tools:

II.10.1. Audit-Based Method:

According to the international standard ISO 19011:2018, an audit is a "methodical, independent, and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which audit criteria are met."

The audit approach allows for the identification of discrepancies between what was planned and what was actually done, the identification of discrepancies between reality and the objectives to be achieved, and the characterization of the adequacy of the framework for the objectives to be achieved.

II.10.1.1 Audit Types [1]:

ISO 19011 distinguishes audits as follows:

a) **Internal Audit:** Internal audits, sometimes referred to as "first-party audits," are conducted by, or on behalf of, the organization itself for internal purposes and may form the basis of a self-declaration of conformity.

b) **External Audit:** External audits include what are generally referred to as "second-party or third-party audits." Second-party audits are conducted by parties, such as clients, with an interest in the organization, or by others on their behalf.

Independent external bodies conducted Third-party audits. Such organizations, generally accredited (standard NF ISO/CE 17021), provide registration or certification of conformity to requirements such as those of ISO 9001 or 14001 or NF ISO/CEI 27001 relating to information security management systems.

II.10.1.2 Audit Characteristics [2]:

- Auditee: The organization being audited.
- Auditor: A person with demonstrated personal capacity and the necessary competence to conduct an audit.
- Audit team: One or more auditors conducting an audit, assisted, if necessary, by technical experts. An auditor on the audit team is appointed as the audit team leader. The audit team may include auditors in training.
- Technical expert: A person providing specific knowledge or expertise to the audit team. This specific knowledge or expertise relates to the organization, process, or activity to be audited, or consists of linguistic or cultural assistance. Within the audit team, a technical expert does not act as an auditor.
- Audit client: The organization or person requesting an audit. The sponsor may be the auditee or any other organization with the regulatory or contractual right to request an audit.
- Competence: Personal qualities and demonstrated ability to apply knowledge and skills.

- Audit program: A set of one or more audits planned for a specific duration and conducted for a specific purpose. An audit program includes all the activities necessary for planning, organizing, and conducting audits.*Plan d'audit :* description des activités et des dispositions nécessaires pour réaliser un audit.
- Audit Scope: The extent and boundaries of an audit. The scope typically describes the locations, organizational units, activities, and processes, as well as the time period covered.
- Audit Criteria: A set of policies, procedures, or requirements. Audit criteria are the benchmark against which audit evidence is compared. In English, audit criteria are commonly referred to as an audit framework.
- Audit Evidence: Records, statements of fact, or other information that are relevant to the audit criteria and verifiable. Audit evidence can be qualitative or quantitative.
- Audit Findings: The results of evaluating audit evidence against the audit criteria. Audit findings may indicate compliance or noncompliance with the audit criteria or opportunities for improvement.
- Audit conclusions: the result of an audit reached by the audit team after considering the audit objectives and all audit findings.

II.10.1.3. Different maintenance audit methods [5]:

Several maintenance audit studies have been developed. Many companies have developed their own internal audit methods for their production systems. However, published studies is:

□ LAVINA method:

We cannot establish an effective maintenance management program without knowing the state of the production facilities and the maintenance function. It will be necessary to know the current state of the production system, the available resources, how spare parts are managed, the maintenance processes already implemented, and the priorities assigned to production machines and their criticality. To achieve this, a two-step assessment method is applied. The first involves collecting information on the production and maintenance system. The second involves analyzing, through a questionnaire, the operation of the current maintenance system [8].

II.10.2 SWOT Analysis:

SWOT analysis is an assessment method used to identify the strengths, weaknesses, opportunities, and threats surrounding your business, but it can also be applied to a single

project. Furthermore, although it is primarily used by organizations (small businesses, non-profit organizations, and large corporations), SWOT analysis can be used both personally and professionally. Simply put, SWOT stands for strengths, weaknesses, opportunities, and threats. It is important to examine each of thes factors to properly plan your business's growth. This is where the analysis comes in. Analyzing these four factors will provide a broader view of the situation and how to move forward.

Strenghts:

Strengths refer to internal initiatives that are achieving good results. Analyzing this factor may involve, among other things, a comparison to other initiatives or an external competitive advantage.

- To analyze a company's strengths, we begin by asking the following questions:
- What are our strengths?
- What makes our company unique?
- What aspects of our company do our target audience value?

Weaknesses:

Company weaknesses refer to underperforming internal initiatives. Identifying internal weaknesses is a starting point for improving company performance.

Similar to examining strengths, different questions can be asked to begin identifying weaknesses:

• Which initiatives are underperforming and why?

• Where can we improve?

• What resources are available for better results?

Opportunities:

Opportunities are the possibilities the company may have from the external environment. Since there are many ways to find opportunities, it may be helpful to ask the following questions before beginning:

• What resources can we use to address our weaknesses?

• Are there market aspects not covered by our services?

• What are our goals this year?

Threats:

Threats refer to areas that could cause problems. They differ from weaknesses in that they are external and generally beyond our control.

Here are some questions you can ask to identify external threats:

• What industry developments are causing concern?

• What market trends are emerging in the future?

• Where are our competitors performing better than us?

II.10.2.1 Methodology to follow to carry out the SWOT analysis [15]:

Table II.2 : Relations between the factors of SWOT analysis

Step 1: Mecting preparation	
This analysis is often conducted as meetings gathering taklerolcs or stakeholders or experts concerned by the strateholders or expérts. Preparing the sele selection of the group size, potential division into sub-groups (thematic, regional, actors' categories, etc.) is essential. Largely rely on documentary analysé klend or resources clès providus key resources clés **Table 1. Important points to consider for the selection of participant selection**	
WHO?	**HOW MANY?**
• Equitable distribution by interest group • Avold bias related to certain actors' influence • Respect everyone's speaking timé	• How many participants to consider for the of activit should be to be analyzed? • How many analysts to do obtain a satisfactory result?
Step 2. Identify and examine the 4 paraetes It faut differentiate between INTERNAL and EXTERNAL tf the desired activity and assess ae their potential or freindering the development of the territory. **Table 2. SWOT (strengths, weaknesses, on. al (yses) analysis matrix of the territory**	
Internal analysis	**STRENGTHS** / **WEAKESSES**
	These are resources already available (wood production, mushroom production, etc.) / These are territorial gaps, needs (training, mining permits, extraction sites, etc.)

EXTERNAL analysis	OPPORTUNITIES	THREATS
	These do not depend on the territory but may aid the desired activity (growing demand for non-timber forest products, existing market for timber with growth potential, laws favoring these activities etc.)	These do not depend on the business but may ay hinder the desired activity (high risk of wildfires, low timber prices, policies not conducive to management, heavy visitor traffic deg-rading fragile ecosystems, etc.)

Tab (II.3): Relationships between factors of SWOT analysis

	List of Strengths	List of Weaknesses	Examine how strengths can help control weaknesses
List of Opportunities	How to maximize the opportunities?	How to use strengths to seize opportunities?	How to correct weaknesses by taking advantage of opportunities?
List of Threats	How to minimize threats?	How to use strengths to reduce threats?	How to minimize weaknesses and threats?
Examine how opportunities help minimize threats			

II.10.2.2 Advantages of SWOT analysis:

The SWOT method is simple, flexible, and can be applied to different types of organizations. It also offers great potential for methodological adaptations.

The SWOT method, like any participatory method, encourages participants to take ownership of the findings and conclusions of the process.

Through generally intense discussions among them, it promotes the exchange of information, communication, and collective opinion formation. It provides an opportunity to better understand each person's perceptions.

The SWOT matrix requires all staff to reflect on their company's current situation and its future, focusing on weaknesses and threats in the environment while also allowing them to see their organization's strengths and the opportunities the environment offers them.

The strategy will be built on a foundation shared by all. This diagnosis will allow each member of the working group to reflect on one or more actions to deal with the situation, and to become aware of the impact of their action and its repercussions at the level of the entire organization.

II.10.3. The method based on functional maintenance diagnosis:

The method based on functional maintenance diagnosis is a systematic assessment tool for identifying an organization's strengths and weaknesses in industrial maintenance. It is based on an in-depth analysis of various key functions such as mission definition, work methods, operation preparation and execution, spare parts management, cost control, and information technology integration. By assigning scores to a set of specific criteria divided into several areas (e.g., organization, documentation, performance, safety, etc.), this method allows for an objective and quantified assessment of the maintenance function. It thus provides a solid basis for guiding continuous improvement plans, aligning maintenance strategy with production objectives, and ensuring improved equipment availability [10].

II.10.3.1 Intervention strategy:

Optimizing maintenance costs and performance primarily involves analyzing the existing system to compare it to others. If, for example, an ISO standard exists for quality, an audit can be carried out against an existing standard where auditors compare reality to the requirements of the standard. In maintenance, the absence of a standardized standard leads the consultant to conduct a diagnosis using a methodological approach such as questionnaires.

The approach consists of objectively indicating the consultant's opinion on the degree of performance of the analyzed functions of the overall maintenance organization in the company using questionnaires based on 10 themes, from 8 to 10 questions for each theme with an appropriate rating. In order to validate the opinion given by the consultant, with the chosen rating, the company must provide supporting elements such as: documents, reports, definition of functions, indicators, dashboards, meeting programs, interviews and all information explaining and demonstrating the opinion given.

The diagnosis will be conducted using a questionnaire covering the following 10 themes:

1. Definition of missions and responsibilities
2. Working methods
3. Preparation for implementation
4. Performance of maintenance operations
5. Management and maintenance of spare parts
6. Overall cost control

7. Maintenance interface
8. Human resources and facilitation
9. Service provider utilization strategy
10. Information system and IT use

Each question is designed to assess a specific criterion, such as the existence of procedures, the quality of documentation, or the effectiveness of planning.

- **Scoring system**

For each question, the user selects a score from the following values:

• 0 (total absence),
• 25, 50, 75 (increasing degree of implementation),
• 100 (practice fully mastered and integrated).

This scale allows for a gradual and comparative assessment and can be used to calculate an average per area, as well as an overall performance score for the maintenance function.
The rating used is defined by the following grid:
Following the responses, the questionnaire will be analyzed to create a "radar chart" or "KIVIAT diagram" that will visualize the entire maintenance function, identifying strengths and weaknesses (areas for improvement).
Consolidating the results positions the maintenance department in a global context, allowing the user to situate themselves at a given moment and identify the actions that need to be taken to improve the overall effectiveness of maintenance and move toward progress or improvement.

First, the response is accompanied by a proposal for areas for improvement that will enable the company to achieve progress in terms of activity and results. Second, an optimal planning process based on seven steps is proposed to the company.

II.10.3.2. Purpose of the tables:

These tables are used to:

• Identify the strengths and weaknesses of the maintenance department.
• Structure a comprehensive assessment of the existing organization.
• Prioritize improvement actions in the least efficient areas.
• Support a certification or compliance process (e.g., ISO 9000).
• Monitor progress over time through regular assessments.

A practical study will be presented in the last chapter.

CHAPTER III:

Maintenance performance indicators

III.1. Introduction:

The objective of this chapter is to delineate the concept of performance:it’s definition, internal dimension, and how to measure or evaluate it. In the first section, we will discuss the notion of performance to define its content and its internal dimensions.

III.2. Definition of a performance indicator:

A performance indicator can be defined as "quantified data that measures the effectiveness of all or part of a process or system, in relation to a standard, plan, or objective that has been determined and accepted, within the framework of an overall strategy [12]."

A performance indicator is quantified data. This means that it refers to the necessary quantification of a phenomenon. When it comes to physical phenomena, quantification generally poses little or no problem.

On the other hand, when referring to psychological phenomena such as employee motivation, for example, quantification poses a problem. An indicator measures effectiveness, and therefore the ability of a process to generate performance.

It therefore appears inseparable from a continuous improvement approach.

Measurement should be used to make actionable decisions for improvement. An indicator is expressed within the framework of an overall strategy. It is necessary to check the consistency of all indicators used at all levels in the company.

III.3. Importance of Performance Evaluation

The concept of business evaluation is based on the idea that it is possible to optimize a company's performance. This performance translates into improved competitiveness, but also gives rise to a distribution of this performance, which is important because optimizing a company also improves social cohesion (including corporate governance), which ultimately constitutes intangible capital (increasingly important for service marketing due to the proximity between the customer and the service provider).

Thus, performance evaluation consists of a periodic and systemic review of performance in order to identify strengths and weaknesses, as well as their causes, and ultimately arrive at a clear vision of the company's state of health with a view to taking urgent and more or less long-term corrective measures necessary to achieve overall efficiency.

However, performance appraisals offer numerous benefits for both employees and managers, including performance recognition and career advancement for the former, and assistance with

management, strategy, and company competitiveness for the latter.

*Performance appraisals can help managers assess actual results by comparing them with previously set objectives and decide whether adjustments are needed;

*Finally, performance appraisals are a necessary means of improving profitability because they highlight strengths that need to be strengthened and weaknesses that need to be addressed. Such an appraisal serves to improve agency performance only to the extent that it also serves to identify the causes of both good and poor results.

III.4. Classification of Indicators:

III.4.1.Technical indicator:

- **Mean Time Between Failures (MTBF):**

Definition: Average operating time of equipment between two successive failures:

$$\textbf{MTBF} = \frac{\text{Total operating Time}}{\text{Number of failures}}$$

Importance: Used to assess equipment reliability. A high MTBF indicates equipment that is more reliable.

- **Mean Time To Repair (MTTR):**

Definition: Average time required to repair equipment after a breakdown:

$$\textbf{MTTR} = \frac{\text{Total repairsTemps}}{\text{Number of interventions}}$$

Importance: Allows you to measure the effectiveness of maintenance processes and the responsiveness of maintenance teams.

- **Equipment availability rate :**

Definition: Percentage of time that equipment is operational and available for production compared to the total planned time:

$$\textbf{Disponibilité} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Importance: Indicates the reliability of equipment and its ability to operate without interruption.

III.4.2.Economic Indicators:

- **Maintenance cost per unit of production:**

Definition: Total maintenance cost divided by the number of units produced.

$$\textbf{M cost} = \frac{\text{Total maintenance cost}}{number\ of\ units\ produced}$$

Importance: Used to analyze the economic efficiency of maintenance operations. Lower costs may indicate better maintenance management.

- **Overall Equipment Effectiveness (OEE):**

Definition: OEE is an overall indicator that reflects the level of efficient use of equipment, including losses due to downtime, slowdowns, and quality defects.

OEE = Availability x Performance x Quality.

Importance: Evaluates equipment efficiency by taking into account downtime, slowdowns, and production defects.

III.4.3.Organizational Indicators:

- Preventive maintenance schedule compliance rate:

Definition: Percentage of preventive maintenance tasks completed on time compared to the total number of planned tasks:

$$\%\textbf{Respect}\ \text{plannig} = \frac{\text{Number of interventions}}{\text{Total number of planned interventions}} X100$$

Importance: Indicates the level of compliance with the industrial preventive maintenance plan, which can affect equipment performance and durability.

III.5.The Maintenance Dashboard

III.5.1 Benefits of Dashboards:

A dashboard is a set of indicators organized into a system monitored by the same team or manager to help decide, coordinate, and control the actions of a department.

The dashboard is a communication and decision-making tool that allows the management controller to draw the manager's attention to key management points in order to improve them.

III.5.2. Information Collection and the Maintenance Dashboard:

Once the indicators have been selected, we will build them with the information at our disposal. Indeed, any indicator must be populated with a set of relevant information to qualify as a "credible indicator." The planned amounts are determined by the period's forecasts, while the actual amounts are provided by the maintenance manager through daily and monthly reports.

Table III.1: Summary Table of Data Sources

Indicators	Data Source
Costs	Production Department / Maintenance Control / Methods Office
Equipment	Methods Office / Workshops
HSE (Health, Safety, Environment)	HSE Department
Employees	Human Resources Department

A dashboard isn't isolated; it's linked to a database that feeds back information so it can be used to calculate indicators.

The major constraint for the maintenance management controller in creating a maintenance activity dashboard lies in the reliability of the information received. Indeed, delays in data entry by workshops or the failure to enter certain information impacts the calculated indicators.

Based on the previously developed characteristics of dashboards and their composition, they can be considered a multidimensional tool that can perform several functions:

- Performance measurement tool: The dashboard highlights physical or financial results compared to pre-established objectives.

The difference constitutes a variance, expressed as a value or percentage, which reflects the performance achieved.

- Alert and diagnostic tool: By calculating deviations from indicators, the dashboard draws managers' attention to those that are significant or exceptional. - Decision-making and development tool: By constantly making managers aware of the key points of their management, and by highlighting deviations from the objectives, the dashboard encourages them to make decisions.

CHAPTER IV

EVALUATION OF THE EXISTING MAINTENANCE POLICY IN THE COMPANY

Improving and optimizing a maintenance policy is as delicate as implementing a new one. The key here is to evaluate the current policy, identify weak points, and make the necessary changes.

IV.1. TOOL 1 : Maintenance Audit (LAVINA) :

We propose the following questionnaire inspired by the work of Lavina [20]. This questionnaire is established in 12 sections, for each section a series of questions is asked. For each question, five answer choices are offered. For each answer, a score is awarded. At the end of each section, the total points are added. This questionnaire was established thanks to the assistance of several managers of the company involved in the different sections below. The numbers in bold underlined are the score awarded by each manager.

IV.1.1 . Questionnaire results

A - Organisation générale	**No**	**Rather No**	**Neither yes nor no**	**Rather yes**	**Yes**
1. Have you defined in writing and obtained approval for the organization of the maintenance function?	0	10	15	20	30
2.Are the responsibilities and tasks defined in the organization periodically reviewed?	0	2.5	5	7.5	10
3.Are the responsibilities and tasks of the various stakeholders clearly defined?	0	5	10	15	20
4. Is there sufficient management and supervisory staff?	0	10	15	20	30
5. Is each stakeholder's activity constrained by an operating budget?	0	2.5	5	7.5	10
6. Is there a person responsible for coordinating work, supplies, installation studies and training?	0	5	10	15	20
7. Are there job descriptions for each of the executive positions?	0	5	10	15	20
8. Do the personnel operating the equipment have written instructions for maintenance tasks?	0	10	15	20	30
9. Do you meet periodically with the workers to review the work to be performed?	0	5	10	15	20
10. Are the objectives written down and are they monitored regularly?	0	10	15	20	30
11. Are you consulted by the workers, or by the Engineering Services during the study or installation of new equipment?	0	10	15	20	30

A – 237,5 Points obtained /250 possible points

B - Work Method	No	Rather No	Neither yes nor no	Rather yes	Yes
1. For large-volume and/or repetitive work, is work preparation prioritized?	0	10	15	20	30
2. Do you use printed materials to prepare work or prepare estimates?	0	5	10	15	20
3. Do you have written operating procedures for complex or sensitive work?	0	5	10	15	20
4. Do you have a written procedure defining work authorizations for high-risk work?	0	10	15	20	30
5. Do you keep and file preparation files in a specific manner?	0	2.5	5	7.5	10
6. Are there any actions aimed at standardizing components and parts?	0	10	15	20	30
7. Do you have time estimation methods other than the overall estimate?	0	2.5	5	7.5	10
8. Do you use the PERT method for preparing long-term work?	0	5	10	15	20
9. Do you use formalized troubleshooting methodologies?	0	10	15	20	30
10.Do you reserve parts in-store, or do you have kits prepared for your work?	0	10	15	20	30
11. Is the documentation strictly classified and easily accessible?	0	5	10	15	20

B – 222 ,5 Points obtained /250 possible points

C - Technical Monitoring of Equipment	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do you have summary lists by location of the equipment in your unit?	0	10	15	20	30
2. Does each piece of equipment have a unique identification number other than the chronological asset number?	0	5	10	15	20
3. Does all equipment on site have a visible identification number?	0	5	7.5	10	15
4. Are modifications, new installations, or removals of equipment recorded systematically?	0	5	7.5	10	15
5. Is a technical file opened for each piece of equipment or installation?	0	10	15	20	30
6. Do you have a work history for each piece of equipment?	0	10	15	20	30
7. Do you have information regarding hours spent, parts consumed, and costs for each piece of equipment?	0	10	20	30	40
8. Is there a person responsible for maintaining the work history?	0	5	10	15	20
9. Do you formally track information related to visit reports or preventive inspections?	0	10	15	20	30
10. Are the histories analyzed once a year?	0	5	10	15	20

C – 250 Points obtained /250 possible points

D - Work Portfolio Management	**No**	**Rather No**	**Neither yes nor no**	**Rather yes**	**Yes**
1. Do you have an established preventive maintenance program?	0	10	20	30	40
2. Do you have preventive maintenance records?	0	5	10	15	20
3. Is there a person responsible for preventive maintenance actions?	0	2.5	5	7.5	10
4. Are equipment users responsible for adjustment and routine maintenance?	0	5	10	15	20
5. Do you have a system for recording work requests?	0	10	20	30	40
6. Is there a specific person responsible for work scheduling?	0	5	10	15	20
7. Have you defined rules for assigning work according to priorities?	0	10	15	20	30
8. Do you have a constant knowledge of the workload?	0	10	15	20	30
9. Is there a "Work Order" document to track all interventions and that is systematically used for all work?	0	10	15	20	30
10. Do managers meet regularly to address various issues?	0	10	15	20	30
11. Do you have a weekly work start schedule?	0	10	15	20	30

D - 290 Points obtained /300 possible points

E - Spare Parts Inventory Management	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do you have a warehouse for storing spare parts?	0	5	10	15	20
2. Do you offer self-service for everyday consumables?	0	2.5	5	7.5	10
3. Do you keep inventory records up to date?	0	10	15	20	30
4. Do you automatically eliminate obsolete parts?	0	2.5	5	7.5	10
5. Do you track item consumption by equipment?	0	2.5	5	7.5	10
6. Is the value and number of items in stock readily available?	0	5	10	15	20
7. Are the parts properly stored and identified?	0	5	10	15	20
8. Have the trigger threshold and replenishment quantities been clearly defined for each item in stock?	0	5	10	15	20
9. Are interchangeable parts identified?	0	10	15	20	30
10. Are procurement procedures flexible enough to store as much as possible at the supplier's premises?	0	10	15	20	30

E – 182.5 Points obtained /200 points possibles

F - Purchasing and Supply of Parts and Materials	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do we have a formalized and appropriate procedure for issuing purchase requests and placing orders?	0	5	10	15	20
2. Is there a resource in the department specifically responsible for monitoring purchase requests?	0	5	10	15	20
3. Does any request for high-cost parts require the approval of the department manager?	0	10	15	20	30
4. Are the lead times for issuing a request short enough, in your opinion?	0	10	15	20	30
5. Are there negotiated contracts for standard items?	0	10	15	20	30
6. For items consumed regularly, do you use suppliers other than the equipment manufacturer?	0	10	15	20	30
7. Do you have a supplier approval process?	0	5	10	15	20
8. During the various negotiations with suppliers, is there a high degree of cohesion between the purchasing department and the maintenance department?	0	5	10	15	20

F – 160 Points obtained /200 points possibles

G - Physical Organization of the Maintenance Workshop	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Is the maintenance workshop space sufficient?	0	10	15	20	30
2. Could your workshop be better located in relation to	40	30	20	10	0
3. Are the supervisors' offices on the same level as the workshop?	0	5	10	15	20
4. Does your workshop have heating and air conditioning?	0	2.5	5	7.5	10
5. Is the tool and spare parts store near your workshop?	0	5	20	15	20
6. Is there a store manager?	0	2.5	5	7.5	10
7. Is the tool store exclusively used for maintenance and new work?	0	5	10	15	20
8. Does each worker have a clearly identified workstation?	0	5	10	15	20
9. Are the workshop's handling equipment suitable?	0	10	15	20	30

G –200 Points obtained /200 possible points

H – Tools	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do you have an inventory of tools and test equipment?	0	5	10	15	20
2. Is this inventory updated regularly?	0	5	7.5	10	15
3. Do you have all the special tools and test equipment you need?	0	10	15	20	30
4. Do you perform preventive maintenance on the test equipment you have?	0	10	15	20	25
5. Are the tools and test equipment readily available and in sufficient quantity?	0	10	15	20	25
6. Is the calibration of measuring devices clearly defined and performed?	0	5	7.5	10	15
7. Have you defined in writing the process for the provision and use of tools?	0	2.5	5	7.5	10
8. Does each worker have a personal toolbox?	0	10	15	20	30
9. Do you have sufficient handling equipment on site?	0	10	15	20	30

H – 190 Points obtained /200 possible points

I - Technical Documentation	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do you have sufficient general technical documentation?	0	5	10	15	20
2. Do you have the necessary general plans and diagrams for all equipment?	0	15	20	30	40
3. Are the technical operating and maintenance manuals and spare parts lists available for the equipment?	0	10	15	20	30
4. Are the installation plans easily accessible and usable?	0	10	15	20	30
5. Are the plans and diagrams updated?	0	10	15	20	30
6. Are equipment modification work recorded and the corresponding preparation files filed?	0	5	10	15	20
7. Are maintenance contracts easily accessible?	0	5	10	15	20
8. Are the reprographic and filing facilities sufficient?	0	2.5	5	7.5	10

I - 185 Points obtained /200 possible points

J - Personnel and Training	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Is the work environment generally positive?	0	10	20	30	40
2. Do managers supervise the work carried out by the workers under their responsibility?	0	10	15	20	30
3. Are problems often discussed in a group that includes workers?	0	10	15	20	30
4. Are there annual performance reviews for supervisory and operational staff?	0	5	10	15	20
5. Are human resources sufficiently available?	0	10	15	20	30
6. Do you consider the technical skills of your staff to be satisfactory overall?	0	15	25	35	50
7. In their daily work, do you believe that staff demonstrate the necessary initiative?	0	10	15	20	30
8. Do managers ensure the professional development of their staff?	0	10	15	20	30
9. Do managers receive training in new technologies?	0	10	15	20	30
10. Does your staff receive regular safety training?	0	10	15	20	30
11. Is staff training scheduled and managed by the maintenance department?	0	5	10	15	20
12 Are staff qualifications and accreditations rigorously monitored?	0	5	10	15	20
13. Are you experiencing significant production time losses?	30	20	15	10	0
14. Is the relationship between your staff and customer service good?	0	2.5	5	7.5	10

J -380 Points obtained /400 possible points

K – Subcontracting	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do you have a formal process for evaluating subcontractors?	0	2.5	5	7.5	10
2. Are the work descriptions and specifications carefully prepared?	0	15	20	30	40
3. Are subcontractors selected based on technical expertise and skills?	0	5	10	15	20
4. Are you able to use multiple subcontracting companies locally?	0	5	10	15	20
5. Do you subcontract tasks for which you lack sufficient technical expertise?	0	10	15	20	30
6. Do your contracts with subcontractors include performance clauses?	0	5	10	15	20
7. Do you develop quality assurance and partnerships with your subcontractors?	0	10	15	20	30
8. Do you create and update a file per project according to a predetermined procedure?	0	5	10	15	20
9. Is the subcontractor's work monitored by a single person?	0	10	15	20	30
10. Do you have documentation to facilitate maintenance by external companies?	0	10	15	20	30

K - 250 Points obtained / 250 possible points

L - Activity Control	No	Rather No	Neither yes nor no	Rather yes	Yes
1. Do you have a dashboard to help you decide on corrective actions?	0	10	20	30	40
2. Are there regular reports tracking labor hours, parts consumed, and labor costs?	0	10	20	30	40
3. Is department performance monitored?	0	10	20	30	40
4. Is the efficiency of maintenance staff monitored?	0	10	15	20	30
5. Do you control your workload?	0	10	15	20	30
6. Do you have maintenance costs tracked, item by item?	0	10	15	20	30
7. Does the maintenance department have a computerized activity management tool?	0	10	15	20	30
8. Do you have summary information available within a sufficiently short timeframe?	0	10	15	20	30
9. Do you issue regular activity reports?	0	10	15	20	30

L –270 Points obtained /300 possible points

IV.1.2. Discussions and Interpretation of Results

For each domain, the score obtained is tallied and the percentage relative to the maximum possible is calculated. The columns of the table show the areas of analysis, the score obtained for each section, the maximum possible score, and finally the ratio of the score obtained to the maximum possible score.

Table IV.1: Results of the questionnaire carried out at the company ALPHA PIPE

Areas of Analysis	Scores obtained	Max. Possible	Percentage
A. General Organization	237 ,5	250	95%
B. Work Methods	222,5	250	89%
C. Technical Monitoring of Equipment	250	250	100%
D. Work Portfolio Management	290	300	96.66%
E. Spare Parts Inventory	182.5	200	91.25%
F. Purchasing and Supply of Parts	160	200	80%
G. Workshop Physical Organization	200	200	100%
H. Tools	190	200	95%
I. Technical Documentation	185	200	92.5%
J. Personnel and Training	380	400	95%
K. Subcontracting	250	250	100 %
L. Activity Control	270	300	90%
TOTAL SCORE	2817,5	3000	93.91%

Table IV.1 identified the areas requiring priority action; these are those where the percentage obtained is lower than the overall total score (93.91%).

The areas identified as requiring priority action are those where the percentage obtained is lower than the overall total score (93.91%).

The areas requiring improvement are:

• B. Work Methods (89%)

• F. Purchasing and Parts Supply (80%)

• L. Activity Control (90%)

This indicates that the maintenance function of the assessed company is performing well, but targeted efforts in a few areas could still improve it.

Graphical presentation of the results obtained:

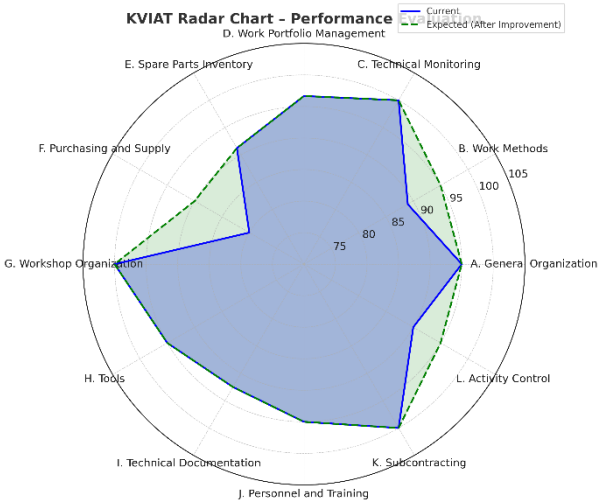


Figure IV.1: Kiviat diagram

Comment:

Using the KIVIAT diagram helped identify the main weaknesses in the current maintenance policy, namely:

- Insufficient management and supervisory staff.
- An operating budget that is inadequate to meet the actual needs of those involved.
- The lack of accurate estimation methods for work completion times.
- The lack of scheduling methods for preparing long-term projects.
- The lack of clear rules for assigning work according to priorities.
- The workload is not known at all times.
- Obsolete parts are not automatically eliminated.
- Slowness in issuing work requests.
- Poorly negotiated contracts for standard items.
- Inflexible procurement procedures that do not allow for maximizing supplier inventories.

IV.1.3. Criticisms and suggestions for improvement

TableIV.1: suggestions for improvement

Questionnaire sections	Suggestions for improvement	Expected percentage
B. Work Methods	- Train teams in the use of advanced planning methods (PERT) -Furthe rstandardize troubleshooting procedures and methods - Improve document management	95%
F. Purchasing and Supply	- Accelerate the request and ordering processes - Establish framework contracts for standard items - Formalize supplier approval	90%
L. Activity Control	- Use dynamic dashboards to track indicators - Implement a CMMS to automate data collection - Increase the consistency of activity reports	95%

IV.2.TOOL 2: Maintenance Function Diagnosis:

Maintenance diagnosis is a methodical examination of a situation related to an organization or maintenance services, with the aim of verifying compliance with established maintenance rules. Indeed, the diagnosis is carried out in collaboration with the stakeholders whenever a decision is made to change the organization or to make improvements to maintenance practices.

IV.2.1.Questionnaire Results:

1- DEFINITION OF DUTIES AND RESPONSIBILITIES

Questions	**0**	**25**	**50**	**75**	**100**
1- Is there an organizational chart describing all functions?					X
2- Is there an organizational chart for the maintenance function, defining all structures?					X
3- Is it known to management and supervisory staff?					X
4- Is the organizational chart known to operational staff?					X
5- Are there job descriptions?					X
6- Is there a written maintenance policy defining objectives and results measurement?					X
7- Are maintenance operations tracked by type of operation (corrective, preventive, improvement, management, etc.)?					X
8- Are maintenance operations tracked by trade?					X
9- Is there a performance dashboard that allows for objective-based management?	X				
10- Does maintenance operate under ISO 9000 assurance?					X

2-Working Methods :

Questions	0	25	50	75	100
1- Is there a preventive maintenance policy?					X
2- Is there a maintenance methods structure responsible for developing the preventive maintenance plan?					X
3- Was the preventive maintenance plan developed using methods such as MBF, FMEA, history, manufacturer data, etc.?					X
4- Is there a specific record of major actions (renovations) allowing for feedback?		x			
5- Are the majority of interventions described by operating procedures and intervention ranges?				X	
6- Is there an incident report including an analysis based on the causal chain (cause, mode, effect)?		x			
7- Are there formal cyclical meetings dedicated to analyzing the main malfunctions observed?	X				
8- Is there a procedure for managing technical documentation?					X
9- Is the existing documentation sufficient for the activity?				X	

3. Intervention preparation:

Questions	0	25	50	75	100
1- Are there written procedures defining the creation, validation, and processing of documents ?					X
2- Are all work requests analyzed and validated before execution?					X
3- Are maintenance methods personnel trained in failure analysis and diagnostic methods?			x		
4- Are work orders and operating procedures systematically reviewed based on the work performed?				X	
5- Are deviations between planned and actual times analyzed?		x			
6- Does production support the first level of maintenance?		x			
7- Are the documents (instructions, recommendations, inspections, regulations) up to date?					X
8- Are mandatory inspections (equipment subject to regulations) actually performed?					X
9- Are there skills for preparing, planning, and monitoring major shutdowns? 10- Does maintenance support ISO quality requirements (calibration, inspection and testing procedures)?					X
1- Are there written procedures defining the creation, validation, and processing of documents ?					X

4- Performance of maintenance operations:

Questions	0	25	50	75	100
1- Are teams operational within 10 minutes of starting their shift?				X	
2- Does each professional know precisely what work they will have to undertake after the current work is completed?				X	
3- Can the progress of all work be determined in less than 10 minutes?					X
4- Is the preventive maintenance program being followed?				X	
5- Does the accumulation of postponements disrupt the workload?					X
6- Is the tooling causing disruptions in the execution of interventions?				X	
7- Is the return of work orders monitored to ensure they are fully completed before being recorded? (What and why?)					X
8- Is there a procedure for receiving completed work?					X
9- Is there an internal or external procedure for continuous improvement?				X	

5- Management and maintenance of spare parts:

Questions	0	25	50	75	100
1- Is there an inventory management policy?					X
2- Are storage rules followed?					X
3- Are spare parts grouped in a catalog that specifies all inventory management and maintenance parameters?					X
4- Is there an expense analysis by equipment?			x		
5- Is there a morphological coding system to avoid duplication and enable standardization?					X
6- Is there an effective procedure for reserving parts for planned work?		x			
7- Are strategic parts specifically identified and tracked?					X
8- Is there a systematic analysis of high-value parts to limit their cost?					X
9- Are inventory discrepancies less than 10%?					X
10- Is there a procedure for qualitatively receiving spare parts?					X

6- Overall cost control :

Questions	0	25	50	75	100
1- Is there a system for calculating direct maintenance costs?	X				
2- Are maintenance budgets coordinated between production, quality, and maintenance departments?	X				
3- Are the budgets the result of an action plan based on a technical and economic analysis?	X				
4- Does the maintenance department receive information that allows for comparison against objectives?	X				
5- Is a periodic assessment of production losses attributable to unavailability and resource incapacity?	X				
6- Are expenses tracked by destination (equipment, maintenance lines, responsibility centers, etc.)?	X				
7- Is there a monthly dashboard combining accounting results, availability indicators, and various status indicators (preparation, emergencies, safety, etc.)?	X				
8- Is there a monthly dashboard with maintenance performance indicators? 9- Are there indicators of maintenance effectiveness based on production results (availability and quality)?					X
10- Is maintenance consulted on the renewal or purchase of new equipment?	X				
1- Is there a system for calculating direct maintenance costs?					X

7- Maintenance interface:

Questions	0	25	50	75	100
1- Is there a daily meeting (production/maintenance/quality) to address immediate issues?	X				
2- Is there a monthly production/quality/maintenance meeting to monitor common issues and plan interventions?					X
3- Is there a quarterly production/quality/maintenance meeting to assess service quality?					X

4- Is there an annual production/quality/maintenance meeting to define the budget?	X				
5- Are maintenance expenses communicated to maintenance "customers"?	X				
6- Are failures resulting in a drop in quality analyzed with the quality department?	X				
7- Is the maintenance department consulted by purchasing regarding the final selection of spare parts suppliers?					
8- Are skills management initiatives coordinated with HR?					X
9- Is there feedback on maintenance services performed by production? 10- Is maintenance involved in matters concerning hygiene, safety and the environment?	X				
1- Is there a daily meeting (production/maintenance/quality) to address immediate issues?					X

8- Human resources and facilitation:

Questions	0	25	50	75	100
1- Is the social climate in maintenance favorable?					X
2- Is there a skills management procedure?	X				
3- Is the age pyramid a factor in personnel management?				X	
4- Are intervention and method personnel trained in maintenance and problem-solving concepts?					X
5- Is there a function and development approach for maintenance personnel?				X	
6- Is the nature and scope of skills available to maintain each facility known?		x			
7- Is personnel management carried out with performance and behavioral objectives?			x		
8- Is there a suggestion system that calls for staff input?		x			
9- Does maintenance have a staff mobility approach?					X
10- Is there a paper or electronic information medium to inform staff about the life of their department or the company?					X

9- Supplier utilization strategy:

Questions	0	25	50	75	100
1- Is the outsourcing rate part of an ongoing strategic approach?		x			
2- Is the outsourcing rate considered satisfactory to manage the workload?					X
3- Is there a qualification procedure for evaluating service provider companies?					X
4- Are the purchasing and maintenance departments fully proficient in all contractual forms?				x	
5- Is the maintenance department organized to manage service provider contracts?					X
6- Is there a procedure for retaining the knowledge acquired by subcontractors within the company?			x		
7- Is there a process for accepting work performed by service providers?					X
8- Is there a process for auditing work performed by service providers?					X
9- Is outsourcing used to reduce maintenance operating costs (e.g., outsourcing parts production workshops)?					X

10- Information system and IT use

Questions	0	25	50	75	100
1- Is the maintenance efficiency improvement program supported by an effective information system?				x	
2- Does maintenance use CMMS?	X				
3- Is inventory management computerized?					X
4- Is documentation management computerized?					X
5- Does maintenance use a CAD system for creating workflows and diagrams?	X				
6- Is incident analysis computerized?					X
7- Are the dashboards computerized and presented in the form of graphs?					X
8- Does maintenance use specific computer applications (simulation software, FMEA, expert systems)?				x	

IV.2 .2. Discussions and Interpretation of Results

N°	Criteria	% Obtained	% Max
1	Definition of missions and responsibilities	90%	100%
2	Working methods	66%	100%
3	Intervention preparation	77 ,5%	100%
4	Performance of maintenance operations	86,1%	100%
5	Management and maintenance of spare parts	85,6	100%
6	Overall cost control	20%	100%
7	Maintenance interface	40%	100%
8	Human resources and facilitation	65%	100%
9	Supplier utilization strategy	83,33%	100%
10	Information system and IT use	56,25	100%
	Total / Average	66,97%	100%

Table IV.2: Comparative table of results by criterion (Benchmarking)

N°	Criteria	% Obtained (ALFAPIPE)	% Target (High-Performing Company))
1	Definition of missions and responsibilities	90 %	95 %
2	Working methods	66 %	90 %
3	Intervention preparation	77,5 %	90 %
4	Performance of maintenance operations	86,1 %	95 %
5	Management and maintenance of spare parts	85,6 %	95 %
6	Overall cost control	20 %	80 %
7	Maintenance interface	40 %	85 %
8	Human resources and facilitation	65 %	90 %
9	Supplier utilization strategy	83,33 %	90 %
10	Information system and IT use	56,25 %	85 %
	General Average	66,97 %	89,5 %

Graphical presentation of the results obtained:

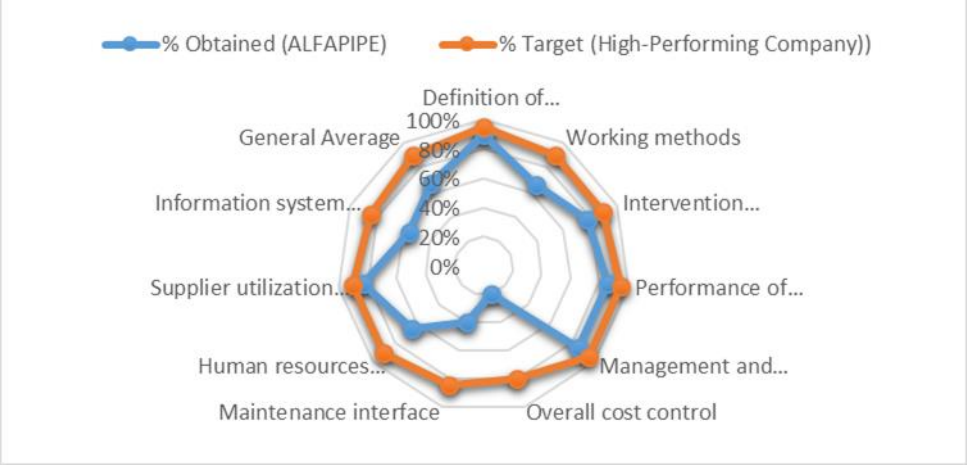


Figure IV.2 : Diagramme de Kiviat

Comments:

Figure (IV.2) shows the Kiviat diagram where we can see the current situation of the maintenance function and the one envisaged after improvement.

- The assessment shows that the maintenance function at ALFAPIPE is generally weak in almost all of the areas assessed:
- Definition of missions and responsibilities: Incomplete. Organizational charts and job descriptions exist but are not known by everyone, especially by those working on the project.
- Working methods: Lack of a solid preventive plan, lack of incident analysis and feedback tools.
- Intervention preparation: Very weak. Documents are not formalized, gap analysis is absent, and production is poorly involved.
- Operations execution: Teams are responsive, but monitoring, analysis, and acceptance of work are deficient.
- Spare parts management: Very weak structure. No codification or rigorous inventory management.
- Overall cost control: A few tracking tools exist, but no reliable performance dashboard.
- Maintenance/production/quality interface: limited communication. Few joint analysis or planning meetings.
- Human resources: acceptable social climate, but significant weaknesses in training, skills management, and internal mobility.
- Use of service providers: poorly formalized management. Contracts and outsourced knowledge are poorly monitored.
- Information system: presence of CMMS and CAD, but partial use. Incident analysis, document management, and dashboards are not properly computerized.

IV.2.3. Criticisms and suggestions for improvement

Table IV.3:Plan d'action priorisé pour l'Amélioration de la Fonction Maintenance chez ALFAPIPE

Functional Area	Main Finding	Proposed Action	Responsible	Deadline	Priority
1. Definition of missions and responsibilities	Lack of clear organizational chart and incomplete job descriptions	Develop and share a detailed maintenance org chart and job descriptions	Maintenance Manager	1 month	High
2. Working methods	Preventive maintenance plan is incomplete and unstructured	-Develop a maintenance plan based on FMEA, historical data, and OEM guidelines -Proposal of a maintenance procedure	Methods Engineering Team	2 months	Very High
3. Intervention preparation	Weak traceability and no structured feedback (REX) system	Implement a formal feedback and experience return system	Maintenance Engineer	3 months	High
4-Performance of maintenance operations	No formal procedures for control and validation of work	Draft and apply standardized procedures for work inspection and acceptance	Maintenance Team Leader	1 month	Medium
5-Management and maintenance of spare parts	Critical parts are not clearly identified or tracked	Identify, classify, and track critical parts using the CMMS	Storekeeper + CMMS Manager	2 months	High

6--Overall cost control	Budget tracking is insufficient and underutilized	Implement a monthly dashboard for maintenance costs and KPIs	Finance + Maintenance Manager	3 months	High
7-Maintenance interface	Few formal meetings between production, quality, and maintenance departments	Establish monthly coordination meetings between departments	Production Supervisor	Immediate	Medium
8-Human resources and facilitation	Lack of training in failure analysis and diagnostic tools	Launch a targeted training program (FMEA, 5 Whys, cause-effect analysis)	HR + Maintenance Management	2 months	Very High
9-Supplier utilization strategy	No documentation or knowledge retention from subcontractor work	Create a centralized archive of external maintenance services	Subcontracting Supervisor	3 months	Medium
10-Information system and IT use	Underutilized CMMS and scattered technical documentation	Optimize CMMS usage and centralize technical documents	IT + Maintenance Manager	2 months	High

Priority Legend:

- Very High: Direct impact on equipment reliability and safety
- High: Improves planning and organizational performance
- Medium: Useful for optimization but not urgent

➢ Proposal of a maintenance procedure :

OBJECT :

The purpose of this procedure is to describe the methods of maintenance management in order to guarantee the availability and conformity of the resources

Field of application:

This procedure applies to all resources necessary to produce the product.

Example of resources: means of production, communication, transportation, information (IT), any means which, if not functioning, would prevent the company from satisfying the customer.

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REFERENCE USED:

ISO 9000 Quality Management System – Fundamentals and Vocabulary
ISO 9001 Système de management de la qualité – Exigences

ISO 9004 Quality Management Systems – Guidelines for Performance Improvement

NF X 60-010

Technical Notices Related to Resources

3|TERMINOLOGY:

Maintenance: set of actions enabling an asset to be maintained or restored within a specified timeframe or capable of providing a specific service.Maintenance curative :Action permettant de remédier à une panne machine qui se produit pendant le cycle de production.

Preventive maintenance: Action carried out on each machine, according to a pre-established schedule, allowing the machine fleet to be kept in working order as a preventive measure.

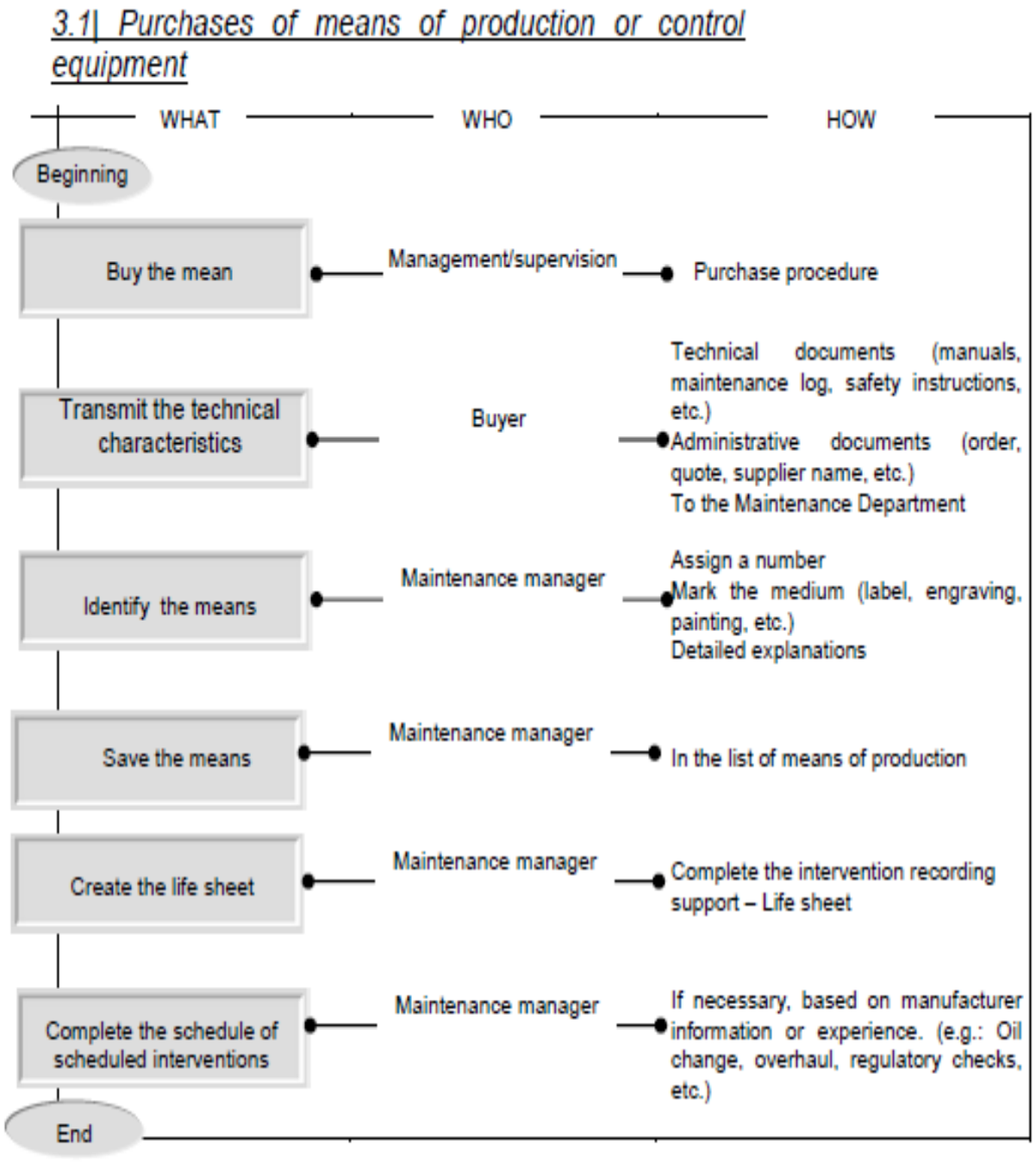
Systematic maintenance: Action to preventative maintenance carried out at regular intervals in order to avoid the occurrence of malfunctions (anticipation of wear)

Maintenance conditionnelle : Utilisation d'indicateur (capteur) qui indique l'évolution de certains paramètres afin de déclencher une intervention de maintenance quand les limites spécifiées sont atteintes.

DOCUMENTS USED:

Periodic intervention schedule
Life sheet – equipment log
Production resources and control equipment list support
Equipment maintenance log
Specific intervention instructions

4|PROCEDURE:

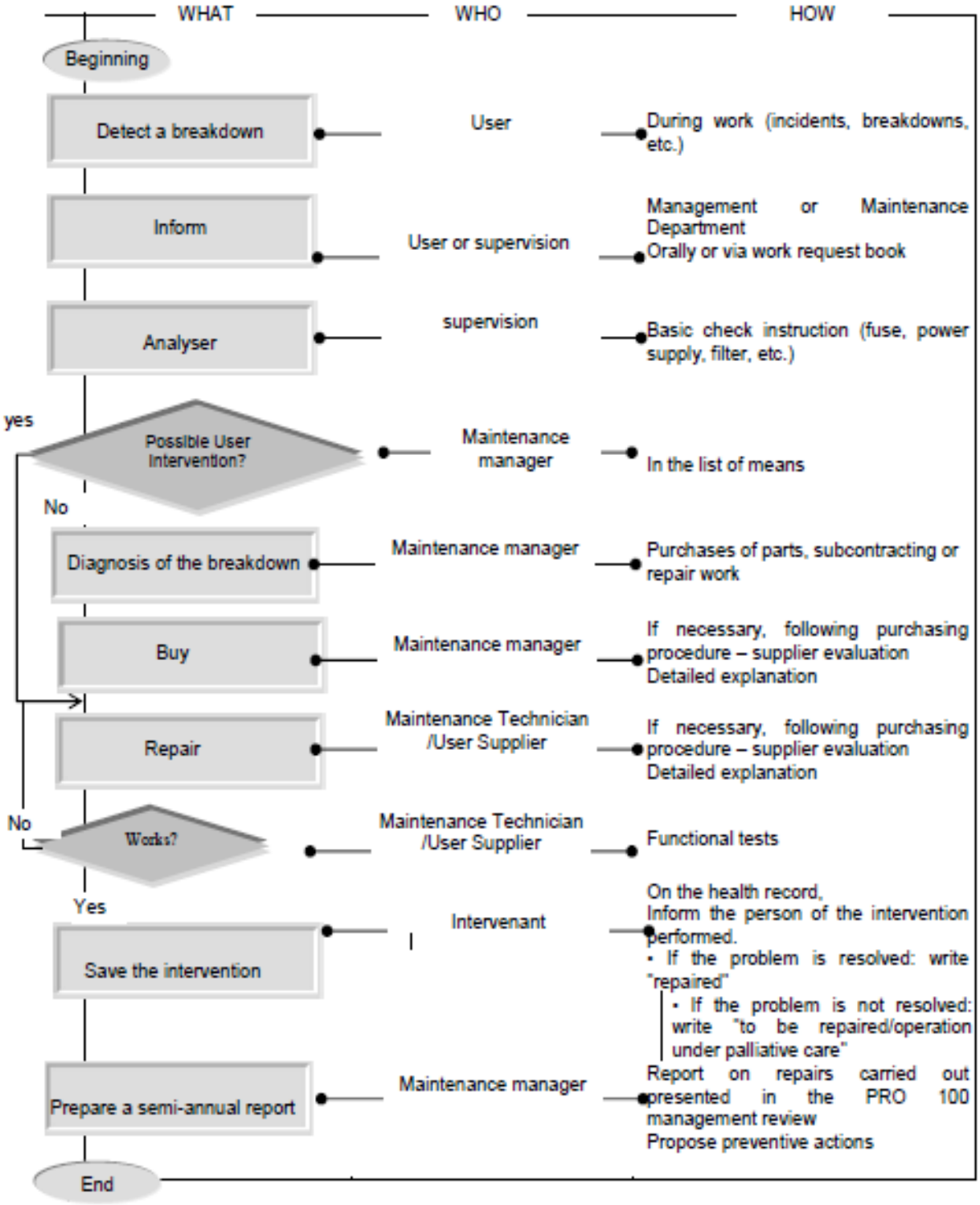


3.1.1 Detailed explanations:

- Assigning a number:

The number assigned to a production facility or control equipment is composed of:
The first three letters designating the type of facility + a chronological number
Example:
CHA 030: Forklift number 30

3.1| Intervention



3.1.1 Purchasing maintenance services:

The company may decide to outsource for various reasons, such as:
- To allow the intervention of highly qualified and regularly trained personnel on the most complex equipment
- To avoid the creation of an underemployed maintenance team
- To be able to allow maintenance interventions to be carried out at any time and thus avoid potential labor disputes- ...

If, based on the above information, the company deems it necessary to use subcontracting, the terms and conditions should be precisely defined in this paragraph.
First, specify the areas of intervention that are subject to subcontracting and those that are the responsibility of the company.
It is indeed desirable to carry out preventive and systematic maintenance operations in-house and to subcontract only the most technically advanced operations.
In the event that subcontracting operations are carried out, the company must require guarantees of results regarding machine availability.
Therefore, it is advisable to establish contracts that define in detail the company's requirements and expectations for each type of work, including work schedules, the qualifications of the personnel involved, etc.
A subcontractor assessment must be carried out in accordance with the "supplier assessment" procedure.
To do this, it is important to ensure the competence and accreditation of the subcontracting companies consulted.

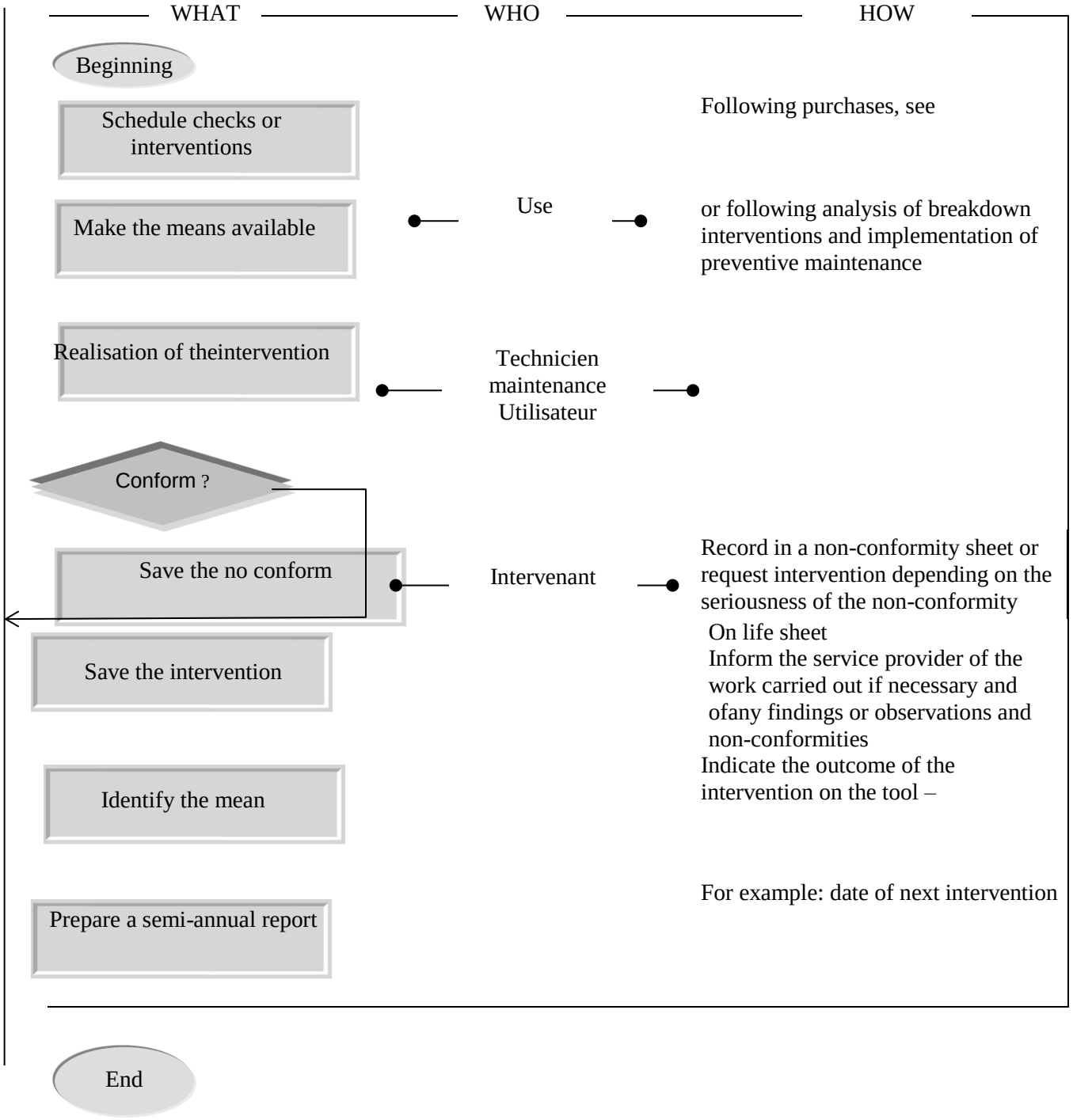
3.1.2Établir rapport semestriel :

Maintenance interventions must be financially monitored by the maintenance department.
The company must therefore implement indicators allowing it to assess maintenance-related costs and create dashboards visualizing them. All provisions relating to this area and adopted by the company must be detailed in this paragraph.
A detailed presentation of the ratios, dashboards, and the evaluation method applied must also be included here.
When assessing maintenance costs, the following two categories should be distinguished:

- Maintenance costs include personnel costs, subcontracting costs, spare parts costs, and consumables.

- Maintenance ineffectiveness costs include machine downtime, poor product quality directly attributable to maintenance issues, additional equipment costs, etc.

3.2 Periodic interventions:



Track Changes:

Revision	Revision	Revision Date Changes - Observations

Mailing list:

Diffusé le: par:

RECIPIENT	N° Copy	Fonction	Reception visa

IV.3.Tool 3: SWOT Analysis:

SWOT analysis evaluates the strategic position of organizations and is often used in the preliminary stages of decision-making processesto identify internal and external factors that are favorable and unfavorable to achieving goals. Users of a SWOT analysis ask questions to generate answers for each category and identify competitive advantages [16].

IV.3.1. Analysis results:

Strengths

- + Strong customer relationships: Strong loyalty with TRC/SONATRACH (90% of revenue).
- + Quality certifications: ISO 9001, API Q1/Q4, which is crucial for the sector.
- + Strategic location: Industrial zone, close to the port and steel complex.
- + Established expertise: In production since 1981.
- + Strong management: Committed management, social stability.
- University partnerships: Favorable to

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Weaknesses

- – Customer dependence: 90% of revenue comes from a single customer (TRC/SONATRACH), major risk.
- – Limited range: 16-18" diameter, 3.5-14.3 mm thickness (little market flexibility).
- – Aging facilities: 65% obsolete, negative impact on competitiveness.
- – High costs: 80% of the cost comes from the steel coil.
- – Inadequate HSE culture: a potential area for improvement.

W Experienced but aging human resources.

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- + Market demand: TRC/SONATRACH is planning major rehabilitation projects.
- + Favorable government policy: national preference, import tax.
- + Training & development: skills upgrade programs.
- + Possible product diversification: thickness 3.5–25.4 mm, diameter 16"–42".
- + ISO 9001:2015 transition: modernization opportunity.
- + Strategic geographic area: access to North African markets.

Opportunities

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+Falling oil prices: impacts demand in the sector.

+Administrative/tax complexity: slows down projects.

+International competition: loss of preferential benefits (WTO, AfCFTA).

+Regional instability: Mali, Libya, Nigeria, etc.

+Rigidity of the recruitment system: lack of specialized profiles.

Threats

IV.3.2. Discussions and Interpretation of Results:

- The company has a solid foundation for operating efficiently, with recognized quality and an advantageous geographic position. This provides a stable platform for seizing opportunities.
- These weaknesses compromise the company's resilience and diversification, particularly in the event of the loss of its main client. Investments in technology and human resources are urgent.
- There is real potential for expansion and improvement if the company can modernize its tools and expand its offering to capture other segments or clients.
- The macroeconomic and geopolitical context remains uncertain, with threats to margins and the sustainability of current contracts.

Strategic Recommendations:

1. Customer diversification: Target other companies in the energy or construction sectors.
2. Industrial modernization: Prioritize investment plan for facility renewal.
3. Development of higher value-added products: Larger-thickness/diameter tubes.
4. Strengthening HSE skills: Alignment with international standards.

Regional positioning: Exploit the strategic region to export to Africa.

IV.4.Tool 4: Performance Indicator:

Period	Total Number of Failures	Total Operating Time (h)	Total Downtime for Repair (h)
January	35	6,200	220
February	30	5,600	180
March	38	6,300	250
April	32	6,000	210
May	40	6,300	270
June	36	6,000	230
July	42	6,400	300
August	28	5,000	190
September	37	6,200	240
October	35	6,300	260
November	33	6,000	200
December	31	6,200	210
TOTAL	417	73,100	2,760

Data collection table

No.	Data to Collect	Unit	Annual Value 2024	Comments / Source
1	Maintenance costs	DZD / Year	20 million	To be completed by the company (accounting)
2	Number of tubes produced	Units	500,000	Continuous production
3	Production workforce	People	100	HR department
4	Gross updated asset value	DZD		To be completed by the finance department
5	Preventive maintenance hours	Hours	2,000 – 3,000	20 to 25% of total maintenance
6	Total maintenance hours	Hours	10,000 – 12,000	High reliance on corrective maintenance

7	Value added produced	DZD		To be completed from financial statements
8	Downtime (failures)	Hours	1,500 – 2,500	Old machinery
9	Total operating time	Hours	70,000 – 80,000	24/7 operation – 3 shifts
10	Failure costs	DZD		Related to unplanned downtime
11	Breakdown repair hours (corrective)	Hours	7,000 – 9,000	Mostly corrective interventions
12	Total maintenance activities	Activities	4,000 – 6,000	Preventive + corrective
13	Production working hours	Hours	130,000 – 150,000	150 employees × 2,000 h/year
14	Total presence hours	Hours	140,000 – 160,000	Includes overtime

IV.4.1. Maintenance Indicator Calculations – 2024

- **MTBF (Mean Time Between Failures)**

Formula:

Data Used:

Total Operating Time = 73,100 hours

Total Number of Failures = 417

Calculation:

MTBF = 73 100 / 417 ≈ 175,2 hours

Result : MTBF ≈ 175,2 hours

- **MTTR (Mean Time To Repair)**

Formula :

MTTR = Total downtime / Total number of breakdowns

Data Used:

Total downtime = 2,760 hours

Total number of breakdowns = 417

Calculation:

MTTR = 2 760 / 417 ≈ 6,62 hours

Result : MTTR ≈ 6,62 hours/int

- **Equipment Availability**

Formula:

Availability = MTBF / (MTBF + MTTR)

Data Used:

MTBF = 175.2 hours

MTTR = 6.62 hours

Calculation:

Availability = 175.2 / (175.2 + 6.62) ≈ 0.9635

Result: Availability ≈ 96.35%

- **Maintenance Cost per Unit Produced**

Formula:

Cost per unit = Total maintenance cost / Number of units produced

Data used:

Total cost = 20 million DZD

Production = 500,000

Calculation:

Cost per unit = 20,000,000 / 500,000 = 40 DZD/unit

Result ≈ 40 DZD/unit DZD/unit

- **OEE (Overall Equipment Effectiveness)**

Formula*:*

OEE = Availability × Performance × Quality

Data used:

Availability ≈ 0.9635

Performance ≈ 0.85

Quality ≈ 0.95

Calculation:

OEE = 0.9635 × 0.85 × 0.95 ≈ 0.776

Result*:* OEE ≈ 77.6%

- **Preventive maintenance schedule compliance rate*:***

Formula:

Rate = (Number of preventive interventions performed / Number of planned preventive interventions) × 100

Data used:

• Number of planned preventive interventions = 4,000 hours

• Number of preventive interventions performed = 2,500 hours

Calculation*:*

Rate = (2,500 / 4,000) × 100 = 62.5%

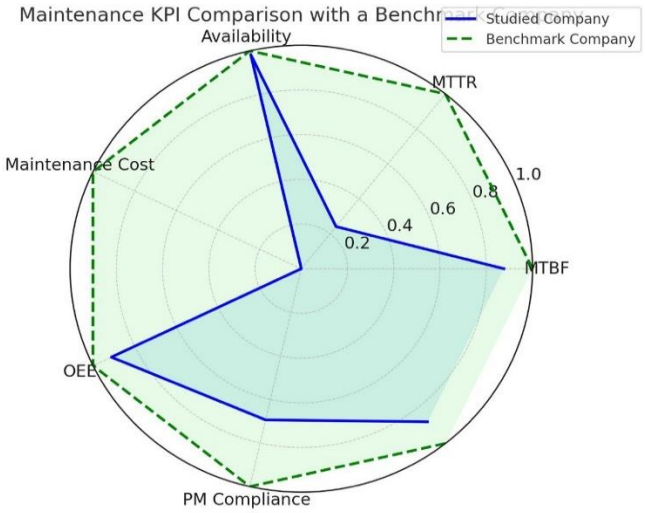
Result*:*

Preventive maintenance schedule compliance rate = 62.5%

Result*:* Compliance rate ≈ 50%

IV.4.2 Discussions and Interpretation of Results

. Figure IV.3 Graphical Analysis of Maintenance Indicators 2024:



Gap analysis:

The radar chart above compares the current values of the maintenance indicators against the Objectives set:

- MTBF is below target (machines break down too frequently).
- MTTR is above target (repair time too long).
- Availability remains close to target, but below target.
- OEE is insufficient (cumulative performance losses).
- The preventive schedule compliance rate is very low (50% instead of 90%).

IV.4.3 Dashboard – Maintenance Indicators 2024:

Indicator	Description	Target	Current Value	Gap	Action	Comments
MTBF	Mean Time Between Failures	≥ 200 h	175.2 h	–24.8 h	Strengthen preventive maintenance	Improve equipment reliability
MTTR	Mean Time To Repair	≤ 5 h	6.62 h	+1.62 h	Optimize repair processes	Train staff and improve responsiveness
Availability	Proportion of time equipment is available	≥ 98%	96.35%	–1.65 %	Reduce unplanned downtime	Implement continuous improvement plan
Maintenance cost per unit	Average maintenance cost per unit produced	≤ 20 DZD/unit	40 DZD/unit	+20 DZD	Analyze overspending causes	Optimize maintenance expenses
OEE (Overall Equipment Effectiveness)	Overall equipment efficiency	≥ 85%	77.6%	–7.4%	Analyze performance losses	Improve work methods
Preventive maintenance compliance rate	Compliance with planned interventions	≥ 90%	62.5%	–27.5 %	Implement strict scheduling follow-up	Address absence of CMMS (GMAO)

Conclusion:

This final year project was carried out in an industrial context marked by increasing demands in terms of quality, availability, and cost reduction. In this environment, equipment maintenance can no longer be limited to simple repair operations after a failure; it must be regarded as a strategic pillar of industrial performance.

Our study focused on evaluating the maintenance function within ALFAPIPE unit, which specializes in the production of spiral welded pipes used for the transportation of hydrocarbons and water. This unit, integrated into El-Hadjar steel complex, benefits from a technically and logistically complex organization, as well as recognized expertise in tubular steel manufacturing.

After thoroughly studying the unit's operations, equipment, manufacturing and coating processes (both internal and external), we analyzed the existing maintenance system using a multi-faceted approach that combined:

- A SWOT analysis (Strengths, Weaknesses, Opportunities, Threats)
- A functional diagnosis (organization, resources, procedures)
- The application of the LAVINA method to audit the maturity level of the maintenance function
- A performance indicator-based assessment (technical, economic, organizational)

This approach allowed us to identify several key strengths: strong internal expertise, discipline in executing critical operations (coating, welding, quality control), and the presence of a structured production process. However, the study also revealed significant shortcomings: lack of formalized maintenance procedures, poor tracking of failure histories, insufficient integration of digital tools (such as CMMS), and a still-improvable maintenance planning system.

Based on these findings, several recommendations were proposed, including:

The implementation of a Computerized Maintenance Management System (CMMS)

Strengthening preventive and condition-based maintenance

Providing ongoing training for maintenance staff in modern methodologies

Improving the monitoring of performance indicators and failure histories

Optimizing the management of spare parts and inventory

In conclusion, this study has demonstrated that maintenance should serve as a powerful lever for competitiveness, provided it is well-structured, effectively planned, and supported by a culture of continuous improvement. The evaluation carried out has offered a clear view of the

current situation and potential areas of development for ALFAPIPE unit. Its gradual implementation could significantly improve equipment availability, reduce downtime costs, and help the company meet the high standards required by the strategic markets it serves.

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