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The role of ERP system SAP on preventive maintenance

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Abstract
This study explores the role of SAP ERP in enhancing preventive maintenance within ENAFOR, a major Algerian drilling company. Using a qualitative methodology, the research investigates how the Plant Maintenance (PM) module supports planning, inventory coordination, and continuous improvement in maintenance processes. Data was collected through interviews with key personnel and document analysis. Findings show that SAP ERP enables real-time monitoring, improves cross-departmental collaboration, and ensures full traceability of maintenance and inventory activities. The system's integration and data-driven capabilities enhance equipment reliability, reduce downtime, and support strategic decision-making. The study highlights the potential of ERP systems to transform maintenance management in asset-intensive industries.

Key word: (SAP ERP, preventive maintenance, ENAFOR, Plant Maintenance module, maintenance planning, inventory coordination, continuous improvement, qualitative methodology .

Résumé
Cette étude examine le rôle du système SAP ERP dans l'amélioration de la maintenance préventive au sein d'ENAFOR, une entreprise algérienne spécialisée dans le forage pétrolier. À travers une approche qualitative basée sur des entretiens et l’analyse documentaire, la recherche met en évidence l’apport du module Plant Maintenance (PM) dans la planification des interventions, la gestion des pièces de rechange et l’optimisation continue des processus. Les résultats montrent que SAP ERP favorise la surveillance en temps réel, améliore la coordination interservices et garantit la traçabilité complète des opérations de maintenance. L’intégration du système permet une meilleure fiabilité des équipements, une réduction des temps d’arrêt et une prise de décision stratégique renforcée.

Les mots clés : (SAP ERP, maintenance préventive, ENAFOR, module de maintenance des équipements, planification de la maintenance, coordination des stocks, amélioration continue, méthodologie qualitative .

ملخص

تتناول هذه الدراسة الدور الذي يلعبه نظام تخطيط موارد المؤسسات SAP ERPفي دعم وتطوير استراتيجية الصيانة الوقائية داخل مؤسسة ENAFOR، إحدى الشركات الجزائرية الرائدة في مجال حفر آبار النفط. وقد اعتمدت الدراسة منهجًا نوعيًا استكشافيًا، استند إلى مقابلات شبه موجهة مع كوادر من أقسام الصيانة والمخزون، إلى جانب تحليل الوثائق ذات الصلة.

أظهرت النتائج أن نظامSAP ERP ، من خلال وحدة الصيانة الصناعية(PM) ، يسهم بشكل فعّال في تحسين عمليات تخطيط الصيانة، وجدولة التدخلات الفنية، وإدارة قطع الغيار، عبر تقديم منصة مركزية للتنسيق بين مختلف الأقسام. كما يوفّر النظام أدوات للتتبع الفوري، وتحليل الأداء، مما يتيح اتخاذ قرارات قائمة على بيانات دقيقة وموثوقة.

خلصت الدراسة إلى أن دمج نظام SAP ERP في منظومة الصيانة يشكل عنصرًا استراتيجيًا يعزز موثوقية المعدات، يقلل من فترات التوقف، ويدعم ثقافة التحسين المستمر داخل المؤسسات الصناعية ذات الأصول الثقيلة.

الكلمات المفتاحية:

(نظامSAP ERP ، الصيانة الوقائية، إينافور، وحدة صيانة المعدات، تخطيط الصيانة، تنسيق المخزون، التحسين المستمر، المنهجية النوعية .

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List of abbreviations:

Abbreviation	Full Form
AFNOR	Association Française de Normalisation (French Standardization Association)
AI	Artificial Intelligence
CEN	Comité Européen de Normalisation (European Commette for Standardization)
CMMS	Computerized Maintenance Management System
CO	Controlling (SAP Module)
CRM	Customer Relationship Management
DTCI	Direction des Technologies de la Communication et de l'Information (Directorate of Communication and Information Technologies)
ENAFOR	Entreprise Nationale de Forage (National Drilling Company)
ERP	Enterprise Resource Planning
FI	Financial Accounting (SAP Module)
GEMAO	Gestion de Maintenance Assistée par Ordinateur (Computer-Aided Maintenance Management)
HCM	Human Capital Management (SAP Module)
IIoT	Industrial Internet of Things
IFRS	International Financial Reporting Standards
IEC	International Electrotechnical Commission
KPI	Key Performance Indicator
MM	Materials Management (SAP Module)
MRP	Material Requirements Planning
NDT	Non-Destructive Testing
OEM	Original Equipment Manufacturer
PM	Plant Maintenance (SAP Module)
PP	Production Planning (SAP Module)
PS	Project System (SAP Module)

QM	Quality Management (SAP Module)
SAP	Systems, Applications, and Products in Data Processing
SD	Sales and Distribution (SAP Module)
SOX	Sarbanes-Oxley Act
TQM	Total Quality Management
WM	Warehouse Management (SAP Module)

GENERAL INTRODUCTION

General Introduction

Companies are under increasing pressure to maximize operational efficiency, cut costs, and guarantee the dependability of their assets in the highly competitive and technologically sophisticated industrial landscape of today. Adoption of integrated information systems that offer a centralized platform for managing business processes is one of the primary tactics used to achieve these goals. Enterprise Resource Planning (ERP) systems are among these that have developed into essential components of contemporary organizational infrastructures. ERP systems allow for streamlined operations, resource optimization, and well-informed decision-making by providing real-time access to consistent and accurate data across departments. Finance, procurement, inventory management, human resources, and most importantly maintenance operations are just a few of the functional areas in which they are relevant.

One of the most extensively used ERP systems in the world is SAP ERP, which was created by SAP SE. Organizations can choose and incorporate particular functions that complement their strategic objectives thanks to its modular architecture. Because it facilitates the planning, carrying out, and recording of maintenance tasks, the SAP ERP Plant Maintenance (PM) module is especially important for asset-intensive industries. The way businesses handle maintenance has changed as a result of the system's capacity to automate scheduling, monitor equipment performance, and produce real-time reports. SAP ERP assists businesses in moving from reactive maintenance procedures, which address problems after they arise, to more proactive and preventive tactics by providing an organized and data-driven framework.

The methodical process of performing routine inspections, minor repairs, and servicing in order to avert unplanned equipment failures is known as preventive maintenance. It is intended to guarantee that assets run effectively and securely for the duration of their intended life. Preventive maintenance aims to foresee issues and address them before they become serious problems, in contrast to corrective maintenance, which is carried out following a breakdown. It has been demonstrated that this strategy lowers overall maintenance costs, increases asset longevity, and decreases downtime. Improved visibility, more efficient use of resources, and better coordination between maintenance teams are all made possible by the integration of preventive maintenance into an ERP system such as SAP. These improvements ultimately lead to increased productivity and operational excellence.

With an emphasis on how its features are applied and used in an industrial setting, this dissertation aims to investigate how the SAP ERP system supports preventive maintenance. The study examines how SAP ERP helps with the planning, carrying out, and optimizing of preventive maintenance tasks using a qualitative case study of ENAFOR, a well-known drilling company in Algeria that works in the oil and gas industry. Because of its use of heavy machinery, strategic significance in the energy industry, and implementation of SAP ERP for maintenance management, ENAFOR offers a pertinent and useful context for this study.

The study also engages with existing literature on ERP implementation, maintenance strategies, and the benefits and challenges associated with preventive maintenance systems. It aims to bridge the gap between theory and practice by examining how the digitalization of maintenance processes through ERP systems can create added value for organizations operating in asset-intensive industries. Ultimately, this dissertation contributes to the broader understanding of how integrated information systems, and specifically SAP ERP, can play a transformative role in enhancing maintenance practices, increasing equipment reliability, and supporting sustainable operational performance.

Research Problems

Main question

What is the role of ERP system SAP on preventive maintenance

Secondary questions :

- How is the SAP ERP Plant Maintenance (PM) module implemented and utilized in the planning and execution of preventive maintenance activities at ENAFOR?
- In what ways does SAP ERP facilitate coordination between the maintenance department and other key functions such as production, procurement, and inventory management?
- What challenges do organizations face in integrating and using SAP ERP for preventive maintenance in the context of a heavy industrial sector?
- How can the use of SAP ERP be optimized to improve preventive maintenance strategies and support continuous improvement within asset-intensive environments?

Research Objectives

The main objective of this dissertation is to explore the role of the SAP ERP system in supporting and enhancing preventive maintenance practices within an industrial organization.

Specifically, the study aims to:

- Analyze how the SAP ERP Plant Maintenance (PM) module is implemented and used for preventive maintenance planning at ENAFOR.
- Examine the extent to which SAP ERP facilitates coordination between maintenance and other departments such as production, procurement, and inventory.
- Evaluate the impact of SAP ERP on the efficiency, reliability, and traceability of preventive maintenance activities.
- Identify challenges and opportunities associated with the use of SAP ERP in the maintenance function within the context of a heavy industrial sector.
- Propose practical recommendations for improving preventive maintenance strategies through the optimized use of ERP systems.

Chapter I:
revue of literature
and
conceptual framework

Chapter 1: review of literature and conceptual framework

Chapter One provides an overview of the key concepts and literature relevant to this study, focusing on Enterprise Resource Planning (ERP) systems, with particular emphasis on SAP , and their role in maintenance management. ERP systems have been widely studied for their ability to integrate organizational functions and improve data-driven decision-making. SAP , as one of the most widely implemented ERP solutions, offers specialized modules for asset and maintenance management, supporting both corrective and preventive approaches. Preventive maintenance, aimed at reducing equipment failure and optimizing operational performance, has gained prominence in recent literature as a strategic tool for improving efficiency and asset longevity. This chapter reviews existing research on ERP implementation, highlights the functionalities of SAP in maintenance processes, and sets the foundation for analyzing its impact on preventive maintenance practices.

Section 1: review of literature

Preventive maintenance management is essential to ensure the reliability and durability of industrial equipment. The integration of ERP systems, particularly SAP , plays a crucial role in optimizing these processes. This literature review explores the impact of SAP ERP on preventive maintenance operations in the manufacturing sector.

In their empirical study, (Al Nawaiseh & al, 2022) examine the link between Enterprise Resource Planning (ERP) systems and maintenance planning systems, focusing on the impact of the former on the effectiveness of the latter. Entitled *The Relationship Between the Enterprise Resource Planning System and Maintenance Planning System: An Empirical Study*, this research aims to evaluate how ERP integration helps improve coordination, planning, and monitoring of maintenance activities. The authors conducted a quantitative survey of several industrial companies, collecting data through structured questionnaires. Statistical analysis of the responses (notably through correlation and regression tests) revealed a significant and positive relationship between the use of an ERP system and the effectiveness of maintenance planning. The study concludes that ERPs, by centralizing data and automating processes, support more proactive and better-planned maintenance, thereby reducing downtime and operational costs.

In their article titled *Industrial Internet of Things on Integrated Preventive Maintenance and Enterprise-Resource-Planning Systems: A Case Study of Fastener Forming Manufacturing*, (Hsu, Lu, & Wang, 2023) analyze how the Industrial Internet of Things (IIoT) can enhance the integration between preventive maintenance systems and ERP systems. The study is based on a case study conducted in a company specializing in the cold-forming manufacturing of fasteners. Using a qualitative and applied methodology, the authors examine the real-world implementation of IIoT sensors connected to the maintenance module of an ERP system. This integration enables real-time monitoring of critical equipment performance indicators and automates preventive maintenance interventions. The study shows that this synergy between IIoT and ERP significantly reduces unplanned downtime and improves equipment availability. The authors also highlight the importance of data standardization and system interoperability to ensure successful integration.

(Damant & all, 2021) address the evolution from preventive maintenance to predictive maintenance by exploring the use of digital twins in this transition. Their study, titled *Exploring the Transition from Preventive Maintenance to Predictive Maintenance Utilising Digital Twins*, examines how digital twin technology can enhance the planning and management of maintenance in industrial environments.

Using a qualitative methodology, the authors present application cases and examples of how this technology is integrated into existing maintenance systems. They find that digital twins not only enable a shift from a preventive to a predictive approach but also help maximize equipment lifespan and reduce maintenance costs. The results show that integrating digital twins into maintenance management systems allows for more accurate failure predictions and optimized interventions. The study concludes that this transition enhances responsiveness to issues while improving overall efficiency in resource management.

(Irmansyah, 2024) explores the implementation of the Age Replacement method for preventive maintenance planning using the Odoo ERP system, through a case study of the company PT Fuli Elektrik Utama. His master's thesis, titled *Implementasi Penjadwalan Preventive Maintenance Metode Age Replacement Menggunakan ERP Odoo*, examines how this approach helps determine the optimal timing for equipment replacement based on age and condition, aiming to prevent unexpected failures. The methodology is quantitative, relying on the analysis of historical equipment data integrated into the ERP system to generate preventive maintenance schedules. The author concludes that applying this method within Odoo improves maintenance management, reduces costs, and enhances equipment reliability, while also optimizing both human and material resources.

(Alarcón, Martínez-García, & Gómez de León Hijes, 2021) examine the integration of energy and maintenance management systems within the framework of Industry 4.0 by presenting a real-world case study. In their article titled *Energy and Maintenance Management Systems in the Context of Industry 4.0. Implementation in a Real Case*, the authors highlight the application of advanced technologies in managing maintenance and energy in a connected industrial environment. The study employs a quantitative methodology, using real-time data collection tools to analyze energy performance and maintenance requirements. The results show that integrating intelligent systems, such as IoT sensors and energy management platforms, not only reduces operational costs but also optimizes preventive maintenance processes. The study also demonstrates that these systems can enhance the sustainability of industrial operations by enabling more proactive maintenance management and significantly reducing equipment downtime.

(Shaheen & Németh, 2022) .provide a comprehensive review on the integration of maintenance management functions with Industry 4.0 technologies and features. Their article, titled *Integration of Maintenance Management System Functions with Industry 4.0 Technologies and Features A Review*, analyzes recent trends that enhance the efficiency of maintenance management systems through advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and predictive analytics. The study adopts a qualitative methodology, based on an in-depth literature review of existing research and industrial case applications. The authors conclude that integrating these technologies into maintenance management systems brings significant benefits, including predictive maintenance, optimized resource management, and reduced maintenance costs. The study also highlights the importance of system standardization and interoperability to fully realize the advantages of such integration.

(Gupta,, Patel, & Sharma, 2020) explore the impact of ERP systems specifically SAP on improving preventive maintenance management in industrial environments. In their article titled *The Role of SAP ERP in Preventive Maintenance in Manufacturing Organizations*, the authors analyze how integrating SAP into maintenance processes enables effective coordination of scheduled maintenance interventions while ensuring resource optimization and cost reduction. The study uses a quantitative methodology, combining historical maintenance data analysis with simulations based on optimization models. The results indicate that implementing SAP ERP leads to improved maintenance activity planning by automating work order generation and ensuring accurate tracking of equipment performance indicators. The study concludes that SAP ERP not only helps maintain optimal equipment performance levels but also extends machine lifespan by anticipating failures through more proactive and better-coordinated maintenance.

This study aims to qualitatively explore the role of the SAP system in enhancing preventive maintenance within the company ENAFOR, with a particular focus on the contributions of the Plant Maintenance (PM) module in planning, monitoring, and optimizing technical interventions.

Ultimately, the objective is to propose recommendations for future ERP system implementations in industrial maintenance, drawing on the experiences and findings from the case study, while emphasizing the strategic impact of these technologies within the context of Industry 4.0.

Section 2: conceptual framework

Systems for managing and streamlining an organization's core business operations across departments are called enterprise resource planning (ERP) systems. These systems offer a centralized platform that makes it easier for information to move between departments like manufacturing, sales, maintenance, finance, human resources, procurement, and inventory.

2.1 ERP overview

Enterprise Resource Planning (ERP) systems are integrated software platforms used by organizations to manage and coordinate all the essential functions of their businesses. These functions typically include finance, human resources, supply chain, manufacturing, customer relationship management (CRM), and more. The core purpose of ERP is to facilitate the flow of information between all business functions inside the organization and manage connections to outside stakeholders (Monk & Wagner, 2009).

ERP systems emerged in the 1990s as an evolution of earlier manufacturing resource planning (MRP and MRP II) systems, expanding their functionality to support broader organizational needs. By integrating various business processes into a unified system, ERP enables real-time data sharing and improved decision-making across departments. This integration minimizes data redundancy, enhances productivity, and supports strategic planning (Bradford m. , 2015)

The implementation of ERP, however, is complex and resource-intensive. It involves substantial changes to existing business processes and may require significant organizational change management. Despite these challenges, ERP systems have become foundational in modern enterprises seeking to streamline operations, ensure compliance, and maintain competitiveness in global markets (Davenport, 1998).

2.1.1. ERP systems definition

An Enterprise Resource Planning (ERP) system is a computerized solution designed to manage all resources of an organization, emphasizing two primary objectives: seamless communication among various business functions and consistency of information. Serving as the central nervous system of an organization's information system, an ERP enables the integration and coordination of all key business processes (JEAN-LOUIS & Miranda, S., 2003) .

More specifically, an ERP is an integrated management software suite that supports core organizational functions such as human resources, accounting and finance, customer relationship management (CRM), procurement, and inventory management. It facilitates rapid and coherent responses to organizational needs by consolidating business operations within a unified system. ERP software is typically modular in structure, with each module corresponding to a specific business function. These modules are interconnected through a shared database, allowing for real-time data exchange and process synchronization across the organization (JEAN-LOUIS & Miranda, S., 2003).

Figure 1 - 1: ERP integration

Source: from (sim network, s.d.)

Enterprise Resource Planning (ERP) refers to integrated software systems that standardize, streamline, and integrate business processes across various departments within an organization. These systems typically operate in real-time and are built on a centralized database, ensuring that information flows seamlessly between functions such as finance, human resources, manufacturing, supply chain, and customer service. According to Monk and (Monk & Wagner, 2009), ERP systems are designed to "improve the efficiency of business processes by integrating information and automating tasks across departments," thereby enhancing organizational performance and decision-making.

ERP systems are not only technological tools but also strategic enablers that support organizational transformation, reduce operational costs, and enhance coordination across internal and external business environments (Bradford, 2015). The modular structure of ERP allows organizations to implement specific functions as needed, while ensuring that all modules share consistent data and process logic.

2.1.2 Basic principle of ERP

A fundamental principles of Enterprise Resource Planning (ERP) systems is the use of a *workflow engine*. This component automates the flow of information within an organization. Although not always visible to the user, the workflow engine ensures that once data is entered into the system, it is automatically propagated to all relevant modules based on pre-defined rules. This process ensures consistency and integration across all functional areas of the organization (Norigéon, 2010)

2.1.3 ERP characteristics

ERP systems offer a range of features that contribute to their efficiency and adaptability in complex organizational environments:

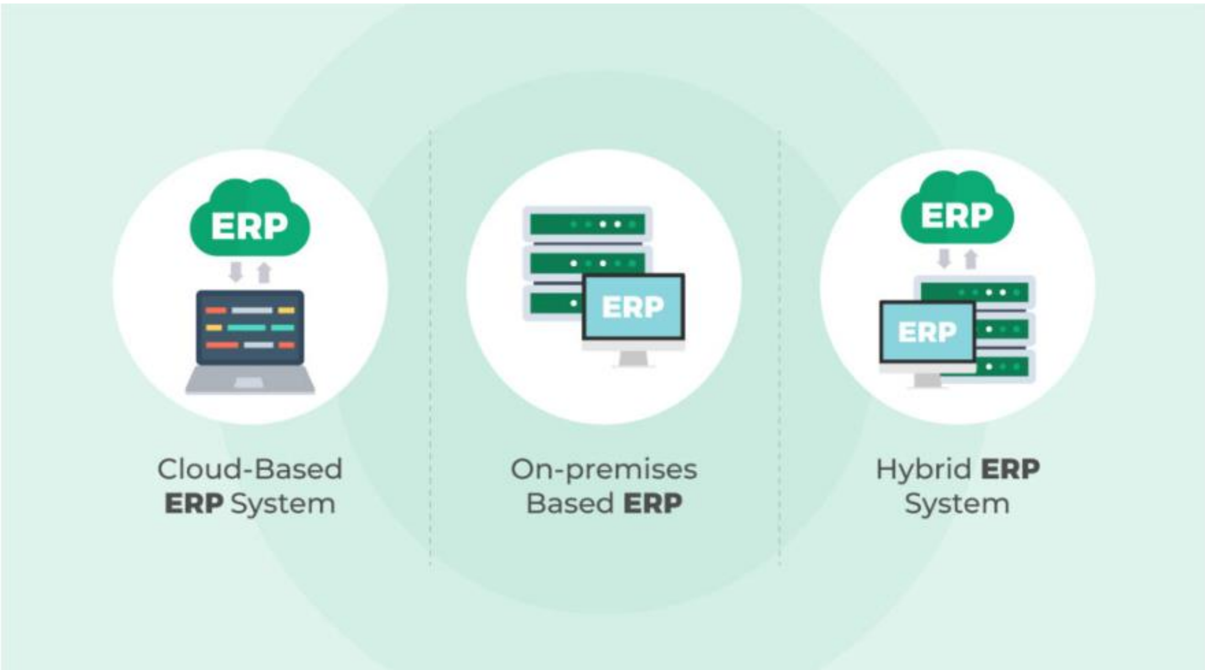
- Elimination of data redundancy: ERP systems reduce repetitive data entry across various information systems by maintaining a single, centralized database.
- Real-time updates: Any modification made in one module triggers immediate updates in all interconnected modules.
- Multilingual and multi-currency capabilities: ERP solutions are designed for global deployment, making them especially suitable for multinational organizations.
- Audit facilitation: In the event of a malfunction, ERP systems simplify the identification of the affected module(s), thus aiding internal audits.
- Comprehensive integration: ERP systems can fulfill all information system needs of an organization. Their modular structure allows for progressive implementation based on the organization's priorities.
- Information consistency and homogeneity: The shared database ensures uniformity across departments.

- Improved inventory control: Better stock management is achieved through integrated planning and monitoring.
- Enhanced coordination: ERP promotes better interdepartmental collaboration.
- System integrity and data uniqueness: ERP ensures that information is accurate, current, and non-duplicative.
- Improved internal and external communication: Sharing a common information system fosters more efficient communication throughout and beyond the organization (Norigéon, 2010) .

2.1.4 types of ERP systems

Enterprise Resource Planning (ERP) systems can be categorized according to their method of implementation within an organization's IT environment. The primary deployment types are on-premise, cloud-based, and hybrid ERP systems. Each approach has unique features, benefits, and limitations, making it suitable for different business requirements and strategic objectives.

Figure 1 - 2 : types on ERP deployment



Source : elaborated by student

- **On-Premise ERP**

An on-premise ERP system is installed locally on a company's own servers and managed by its internal IT staff. This model offers organizations full control over their data, infrastructure, and system customization (monk & wagner , 2013). It is particularly favored by large enterprises and firms operating in highly regulated industries, where strict data governance and compliance are necessary (Bradford M. , 2020) .

While on-premise ERP systems support deep customization and integration with legacy systems, they also involve significant upfront investment in hardware and licensing, as well as ongoing maintenance costs (Verdon, 2019). Moreover, the organization bears full responsibility for software updates, security, and system availability.

- **Cloud-Based ERP**

Cloud-based ERP, also referred to as Software as a Service (SaaS) ERP, is hosted on the vendor's servers and accessed by users through the internet. This model minimizes upfront costs, offers scalability, and facilitates rapid deployment (Gupta & Misra, 2016) Cloud ERP is typically offered via subscription-based pricing, allowing organizations to shift capital expenditures to operational expenditures.

One of the key benefits of cloud ERP is the reduced burden on internal IT teams, as the vendor manages upgrades, security, and system uptime. However, cloud solutions often limit the extent of system customization, and data security can be a concern, especially in sectors handling sensitive information (Bradford M. , 2020)

- **Hybrid ERP**

A hybrid ERP deployment integrates both on-premise and cloud-based systems, allowing organizations to retain critical applications on-site while leveraging the cloud for other functions such as analytics or customer relationship management. This model is well-suited to firms undergoing digital transformation or those with legacy systems that cannot be fully migrated to the cloud (gartner, 2020).

Hybrid ERP offers flexibility, scalability, and the ability to gradually modernize IT infrastructure. However, it also introduces complexity in system integration, data consistency, and governance, as organizations must manage multiple platforms simultaneously (Gupta & Misra, 2016)

2.1.5 The advantages ERP

Enterprise Resource Planning (ERP) systems offer numerous benefits that contribute to the optimization and integration of business processes across organizations. Among the most significant advantages is the optimization of management processes, which allows for increased efficiency and streamlined workflows. ERP systems also ensure coherence and consistency of information by centralizing data, thereby reducing discrepancies and redundancies (Ghssiss, 2010)

Another critical advantage is the integrity and uniqueness of the information system, which enhances decision-making through reliable and consolidated data. Moreover, ERP platforms are often multilingual and support multiple currencies, making them particularly suitable for multinational corporations that operate across different countries and regions (OpenConcerto, s.d.)

ERP systems facilitate both internal and external communication by enabling various departments and stakeholders to access and share the same standardized information. This integrated structure leads to better coordination among services, allowing for more effective process monitoring, such as improved order tracking and stock control (Ghssiss, 2010)

Additionally, ERP implementation contributes to the standardization of human resource management, particularly beneficial for organizations with geographically dispersed entities. From a cost perspective, ERP systems support the minimization of training and maintenance costs, and offer better control over implementation and deployment timelines (Ghssiss, 2010; OpenConcerto, s.d.)

2.1.6 disadvantages of ERP

Despite their many advantages, ERP systems also come with a number of limitations. Their implementation is often complex and time-consuming, as it requires the active involvement of various stakeholders across the organization. Furthermore, ERP systems are frequently described as rigid and difficult to modify once deployed, making them less adaptable to evolving organizational needs (Ghssiss, 2010).

One major drawback is their high cost. Although open-source ERP solutions exist, which reduce licensing expenses, organizations must still invest in user training and may need to rely on support services provided by the software vendor. Additionally, ERP systems are sometimes underutilized, with companies failing to leverage all available functionalities due to insufficient training or mismatches with operational needs.

The implementation process itself can be heavy and inflexible, potentially slowing down organizational responsiveness. Employee resistance to change and difficulties in adapting to the new system can hinder the system's acceptance and effectiveness. Lastly, the successful deployment of an ERP system requires a thorough understanding of the organization's business processes, which is essential to ensure proper integration and alignment with operational goals (Ghssiss, 2010) .

2.2 SAP ERP overview

One of the top enterprise resource planning systems in the world is SAP (Systems, Applications, and Products in Data Processing). Created by the German firm SAP SE, it offers a complete, integrated platform that lets businesses handle essential business operations in a single system, such as finance, logistics, HR, procurement, and maintenance.

SAP's modular architecture enables businesses to deploy just the parts they require, like the Plant Maintenance (PM) module for overseeing maintenance and technical equipment. Better decision-making, operational efficiency, and resource optimization are made possible by its cross-departmental integration, workflow automation, and real-time data access.

2.2.1 SAP ERP definition

SAP (Systems, Applications, and Products in Data Processing) is a global leader in enterprise resource planning (ERP) software solutions, widely recognized for its role in transforming organizational processes through integrated information systems. Founded in 1972 in Walldorf, Germany, SAP has evolved into one of the largest software companies in the world, serving businesses across diverse sectors including manufacturing, finance, logistics, healthcare, and public services (Hossain, Patrick, & Rashid, 2002)

One of SAP's most significant contributions to enterprise computing is its modular architecture, which allows companies to adopt and configure specific components based on their operational needs. This flexibility has positioned SAP as a dominant force in the ERP market, with solutions like SAP S/4HANA offering advanced capabilities such as in-memory computing, real-time analytics, and cloud integration (SAP, 2025).

2.2.2 Core SAP Modules

SAP ERP is structured into a suite of integrated modules, each designed to manage specific business functions. These modules are central to the system's ability to provide a unified platform for enterprise-wide operations. The modular architecture allows organizations to adopt SAP incrementally, enabling scalability and customization according to specific operational needs (Klaus, Rosemann, & Gable, 2000)

The **Financial Accounting (FI)** module is fundamental to SAP's suite, supporting core accounting processes such as general ledger, accounts payable, accounts receivable, and asset accounting. It ensures compliance with external reporting requirements and integrates seamlessly with other modules for accurate financial data (Magal & Word, 2011).

The **Controlling (CO**) module complements FI by focusing on internal cost tracking and managerial accounting. It facilitates budget management, cost center accounting, profitability analysis, and internal order tracking, thereby supporting decision-making at various managerial levels (Davenport T. , 1998)

The **Materials Management (MM)** module is responsible for procurement, inventory management, and logistics operations. It supports the entire procure-to-pay cycle and plays a critical role in supply chain efficiency by ensuring material availability and optimizing inventory levels (Monk & Wagner, 2009)

The **Sales and Distribution (SD)** module manages customer orders, pricing, billing, shipping, and credit management. It provides end-to-end support for sales processes, from order creation to product delivery and invoicing, ensuring customer satisfaction and revenue tracking (Chung,, Snyder, & Kern, 2009) .

Production Planning (PP) is another core module that handles production workflows, material requirements planning (MRP), and shop floor control. It allows for the integration of manufacturing processes with other business functions, contributing to efficient production scheduling and resource utilization (Snabe, Rosenberg, Møller, & Scavillo, 2008)

The **Human Capital Management (HCM)** module encompasses functions related to personnel administration, payroll, time management, and organizational management. It supports the strategic alignment of human resources with business goals through talent and workforce planning tools (Kosasi, 2019) .

Other significant modules include **Warehouse Management (WM)** for optimizing storage and retrieval processes, **Quality Management (QM)** for monitoring product quality across the supply chain, and **Plant Maintenance (PM)** for managing equipment upkeep and lifecycle (Word & megal, 2011). **Project System (PS)** supports the planning and execution of complex projects, ensuring resource allocation, scheduling, and cost tracking.

The foundation of SAP ERP is made up of these modules, which work together to provide a complete and integrated system that improves data transparency, process standardization, and operational efficiency throughout the company.

Figure 1 - 3 : SAP modules

source : (SAP Main Modules, s.d.)

2.2.3 SAP Architecture

The architecture of SAP ERP is designed as a multi-tiered client-server model, structured to separate concerns across distinct functional layers. This architecture not only enhances scalability and performance but also ensures maintainability and system reliability. The three primary layers Presentation Layer, Application Layer, and Database Layer each serve a specialized role in facilitating enterprise computing and seamless user experience (Magal & Word, 2011).

- **Presentation Layer**

The **Presentation Layer** is the user interface through which end-users interact with the SAP system. Traditionally accessed via the **SAP GUI (Graphical User Interface)**, it enables users to perform transactions, view reports, and manage processes. More recently, SAP has introduced **SAP Fiori**, a modern web-based interface built using HTML5 and SAPUI5 technology, offering a responsive, role-based experience across devices. Fiori enhances usability by simplifying workflows and providing intuitive, task-oriented applications (Snabe, Rosenberg, Møller, & Scavillo, Business Process Management: The SAP Roadmap, 2008).

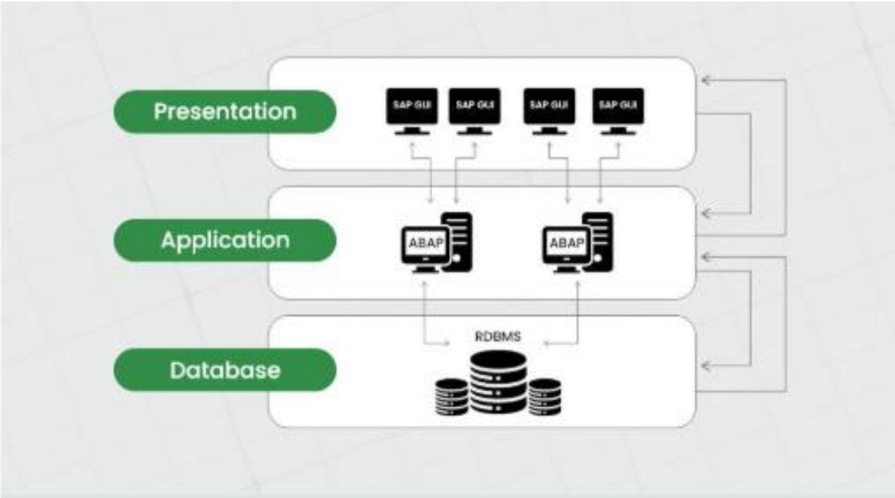
- **Application Layer**

The **Application Layer** is the core of the SAP system, where the business logic and rules are executed. It processes user inputs from the presentation layer and manages communication with the database layer. This layer houses the ABAP (Advanced Business Application Programming) runtime environment and application servers, which coordinate processes such as order processing, inventory control, and financial transactions. The application layer is also responsible for task distribution and load balancing across system components (Monk & Wagner, 2009) .

- **Database Layer**

The **Database Layer** handles data storage, retrieval, and management. It maintains all enterprise data, including transactional records, configuration data, and metadata. The database layer supports relational database systems like SAP HANA, Oracle, or Microsoft SQL Server. With the introduction of **SAP HANA** (High-Performance Analytic Appliance),

Figure 1 - 4 : SAP architecture



Source: (geeksforgeeks, s.d.)

in-memory computing has significantly accelerated data access, enabling real-time analytics and reporting (Plattner & Zeier, 2012).

In order to process complex enterprise operations efficiently, each layer communicates dynamically while operating independently. This three-tier architecture facilitates modular maintenance and upgrades, improves system security, and supports distributed computing.

2.2.4 Integration Capabilities

A defining strength of SAP ERP lies in its **integration capabilities**, which enable seamless coordination across various business functions within an organization. This integration is foundational to the value proposition of ERP systems, facilitating end-to-end visibility, consistency in operations, and improved decision-making based on real-time information (Davenport, 1998).

Integration Across All Business Functions

SAP ERP integrates diverse business processes including finance, procurement, production, sales, human resources, and logistics into a single, cohesive system. Each functional module shares a common data repository and communicates with others through tightly coupled business logic. This unification minimizes data silos, reduces redundancy, and ensures that all departments operate from a consistent and up-to-date data set (Monk & Wagner, 2012). As a result, organizations can achieve higher levels of process efficiency, accuracy, and operational coherence (Klaus, Rosemann, & Gable, 2000) .

Real-Time Data Sharing Between Departments

One of the key features of SAP is its ability to enable **real-time data sharing** across departments. When data is entered in one module (e.g., a sales order in SD), it is immediately available to other relevant modules (e.g., inventory in MM or revenue forecasting in CO). This real-time integration reduces latency, prevents manual data reconciliation, and supports agile decision-making. The capability is further enhanced by the use of **SAP HANA**, SAP's in-memory database, which allows for high-speed transaction processing and analytics (Plattner & Zeier, 2012).

Workflow Automation and Process Standardization

SAP incorporates **workflow automation tools** that standardize and automate routine business processes. Automated workflows reduce the likelihood of human error, ensure compliance with internal policies, and accelerate process execution. For example, purchase requisitions can automatically trigger approval workflows, budget checks, and supplier notifications without manual intervention. These standardized processes enhance organizational control, promote transparency, and support continuous improvement initiatives (Magal & Word, 2011)

SAP ERP facilitates digital transformation by allowing businesses to synchronize their operations, react quickly to market demands, and stay competitive in challenging environments thanks to its integrated architecture.

2.2.5 Benefits of SAP ERP

SAP ERP offers a wide range of strategic and operational benefits, making it a critical tool for organizations seeking to enhance performance, agility, and compliance in increasingly complex and data-driven environments. Through its integrated design and advanced technological foundation, SAP enables enterprises to optimize workflows, improve data quality, and support evidence-based decision-making.

Improved Data Accuracy and Reporting

One of the primary benefits of SAP ERP is the enhancement of **data accuracy and reporting** capabilities. By centralizing information across functional modules such as finance, logistics, and human resources SAP eliminates data silos and duplication, thus ensuring consistency and accuracy. Accurate data, in turn, supports more reliable financial reporting, operational analysis, and audit readiness (Monk & Wagner, 2009). SAP's embedded reporting tools and integration with business intelligence platforms allow for real-time insights into key performance indicators (KPIs) and organizational metrics (Magal & Word, 2011).

Better Decision-Making Through Analytics

SAP supports **data-driven decision-making** by providing integrated access to real-time analytics and dashboards. Advanced solutions like **SAP S/4HANA** leverage in-memory computing to process large volumes of data quickly, enabling timely insights and predictive analytics. This empowers managers to make informed decisions in areas such as resource allocation, customer behavior, and market trends (Plattner & Zeier, 2012). The system's analytical capabilities enhance strategic planning and operational control across the enterprise (Bradford m. , 2015) .

Enhanced Productivity and Efficiency

The automation of routine tasks and the integration of business processes significantly enhance **employee productivity and organizational efficiency**. SAP streamlines operations by minimizing manual interventions, reducing transaction times, and facilitating cross-departmental coordination. Workflow automation tools embedded in the system ensure timely execution of business processes, while integrated communication channels support collaboration across functional units (Davenport T. H., 1998). These efficiencies translate into cost savings and faster time-to-market for products and services.

Compliance with Legal and Regulatory Standards

SAP ERP systems are designed to help organizations maintain **compliance with legal, regulatory, and industry-specific standards**. The system includes features for audit trails, access control, document management, and electronic reporting, which support compliance with financial reporting regulations such as SOX (Sarbanes-Oxley Act) and IFRS (International Financial Reporting Standards). SAP also regularly updates its compliance frameworks to meet evolving global regulations, ensuring that enterprises can operate legally and ethically across jurisdictions (Magal & Word, 2011).

In conclusion, by offering quantifiable enhancements in data quality, process performance, decision support, and regulatory compliance, SAP offers a strong basis for digital transformation.

2.3 Maintenance Management Concepts

In industrial systems, infrastructure management, and information systems, maintenance plays a critical role in ensuring the long-term performance, safety, and availability of assets. As systems become more complex and technologically integrated, the need for a structured approach to maintaining operational continuity has grown substantially. Maintenance is not limited to the physical repair of equipment but also encompasses a range of administrative, technical, and strategic actions designed to preserve or restore system functionality. It contributes to minimizing downtime, optimizing asset life cycles, and reducing overall operational costs.

2.3.1 Definition of Maintenance

According to the AFNOR standard X 60-010, maintenance is defined as:
“All technical, administrative and managerial actions during the life cycle of an asset, intended to maintain it in, or restore it to, a state in which it can perform the required function” (AFNOR, 1995).

Similarly, the International Electrotechnical Commission (IEC 60050-191) defines maintenance as: “The combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function” (International Electrotechnical Commission, 1990)

These definitions emphasize the multi-dimensional nature of maintenance, which includes not only corrective actions (repair after failure) but also preventive, predictive, and even proactive measures aimed at sustaining performance over time.

2.3.2 types of maintenance

- **Corrective Maintenance**

Corrective maintenance is a fundamental component of an organization's asset management and reliability strategy. According to the AFNOR standard (AFNOR, 1995), corrective maintenance is defined as *“the set of activities carried out after the failure of an asset or the degradation of its function, intended to restore it to a state in which it can perform the required function, at least temporarily. These activities include, among others, locating the failure, diagnosing it, repairing with or without modification, and verifying that it functions properly”* (Souris, 2010).

This type of maintenance is deployed *post-failure* and is essential in ensuring the continued functionality of systems across diverse sectors, including industrial, service, and transport environments. While the terminology and quality processes of maintenance remain consistent, the time sensitivity of maintenance execution may vary depending on whether the context involves discrete manufacturing or continuous processes (Souris, 2010).

At the European level, this terminology and classification have been standardized by the CEN (Comité Européen de Normalisation, s.d.), building upon national definitions first introduced by the AFNOR in France. Within the functional domain of maintenance, the "maintain – corrective maintenance" process is a key operational activity. It encompasses a structured sequence of tasks aimed at restoring functionality after failure. These tasks typically include:

- Detection and localization of the failure symptoms
- Initial diagnosis and identification of the failure mode
- Determination of the root cause of the breakdown
- Restoration or repair of the system, with or without modifications
- Verification of proper functionality after repair
- Documentation of the intervention and analysis of the failure process

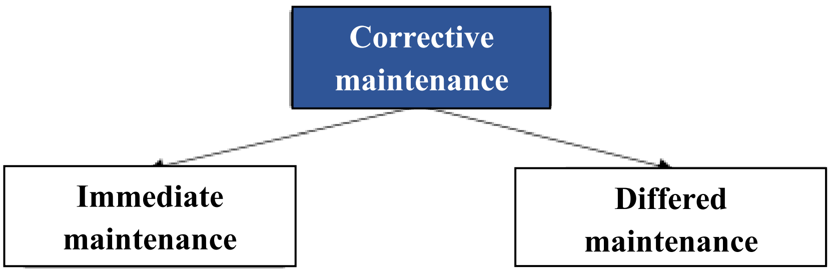
Forms of corrective maintenance:

Forms of Corrective Maintenance: **Immediate and Deferred**

Corrective maintenance, as standardized by (Comité Européen de Normalisation, s.d.) (CEN), is further classified into two distinct categories: immediate corrective maintenance and deferred corrective maintenance. These categories are differentiated based on the timing and intended permanence of the interventions carried out following the failure of an asset.

Immediate corrective maintenance refers to actions undertaken directly after the detection of a failure, with the goal of restoring an asset to its specified functional state or enabling it to fulfill the required function on a permanent basis. These interventions typically involve permanent repairs, modifications, or adjustments designed to eliminate the root causes of the failure. The essential characteristic of immediate maintenance is that it restores the full, long-term operability of the equipment or system (Comité Européen de Normalisation, s.d.) **deferred corrective maintenance** In contrast, commonly referred to as *troubleshooting* or *palliative maintenance* involves temporary measures aimed at allowing an asset to continue performing all or part of its intended function until a more permanent solution can be applied. This form of maintenance is often used in urgent or resource-constrained situations where immediate full repair is not feasible. However, it is imperative that these temporary actions are followed by curative maintenance to fully resolve the underlying issues (Comité Européen de Normalisation, s.d.).

Figure 1 - 5 : types of corrective maintenance



source : elaborated by student

This classification enables maintenance teams to prioritize interventions based on criticality, resource availability, and operational context, thus supporting a more flexible and responsive asset management strategy.

- **preventive maintenance:**

  Preventive maintenance is a proactive strategy aimed at minimizing the likelihood of equipment failure and mitigating performance degradation. It is defined by the European Committee for Standardization (CEN) in the standard EN 13306 as *"maintenance performed at predetermined intervals or according to prescribed criteria, intended to reduce the probability of failure or the degradation of the functioning of an item"* (Comité Européen de Normalisation, s.d.).

Preventive maintenance is generally categorized into three primary types:

- **Systematic Maintenance**

  This form of maintenance is conducted at fixed time intervals or after a defined number of usage units, regardless of the actual condition of the asset. It does not require prior inspection or monitoring. Systematic maintenance is commonly employed in industries where safety or regulatory compliance is critical and downtime must be strictly scheduled (Comité Européen de Normalisation, s.d.) (Wireman, 2008)

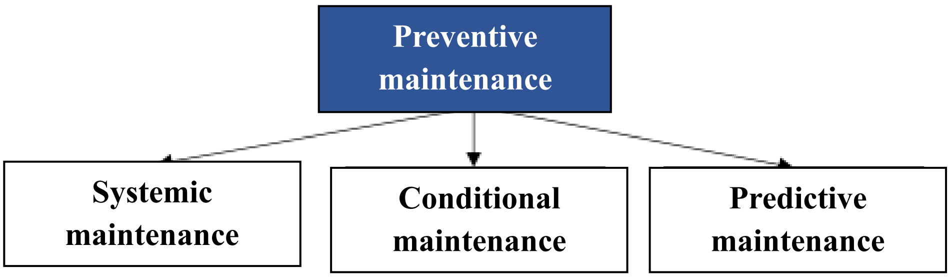
- **Conditional Maintenance**

  Conditional maintenance involves monitoring the operational parameters of a system or component to identify early signs of deterioration. Maintenance actions are then taken based on observed deviations or conditions that indicate potential failure. This approach is more efficient than systematic maintenance as it is tailored to the actual state of the asset, often relying on sensors or performance indicators (Mobley, 2002)

- **Predictive Maintenance**

  A subcategory of conditional maintenance, predictive maintenance utilizes extrapolated data and predictive analytics to anticipate failure. It is typically informed by non-destructive testing (NDT) techniques such as infrared thermography, oil analysis, vibration analysis, and ultrasonic thickness measurement. These methods provide valuable insight into wear trends and help schedule interventions before failure occurs (Mobley, 2002); (Jardine, Lin, & Banjevic, 2006).

Figure 1 - 6 : types of preventive maintenance



Source : elaborated by student

2.3.3 maintenance levels

The concept of maintenance levels aims to preserve the value of an industrial machinery fleet by ensuring optimal equipment performance, safety, and longevity. Effectively applying these various maintenance levels leads to more efficient and effective upkeep.

To this end, the French Standardization Association established a classification (AFNOR, 1995) . of five maintenance levels, each level reflects a specific degree of complexity in maintenance tasks.
This classification helps determine the necessary level of expertise and the appropriate methods for each maintenance operation. It also supports decision-making regarding whether tasks can be handled in-house or require specialized external service providers.

Level 1: Basic Maintenance (User-level Maintenance)

Level 1 maintenance includes basic tasks that can be performed by equipment operators or users without the need for specialized training or tools. These activities typically involve visual inspections, cleaning, lubrication, and other simple operations that help maintain equipment in good working order. The goal is to empower operators to take part in the upkeep of their tools or machines through routine care (Mobility Work, 2020).

Level 2: Intermediate Maintenance by Skilled Operators

This level encompasses more advanced tasks that still fall within the capabilities of trained operators but require a higher degree of skill. Level 2 maintenance may include minor part replacements, instrument calibrations, or simple dismantling operations that are guided by documented procedures. It serves as a bridge between basic autonomous maintenance and specialized technical intervention (Mobility Work, 2020).

Level 3: Specialized Maintenance by Technicians

This maintenance is performed by maintenance technicians with formal technical training. The activities involve complex operations such as diagnosing breakdowns, replacing major components, conducting precision measurements, and using specialized tools. This level signifies a transition from operational support to technical expertise and deeper diagnostic capabilities (Mobility Work, 2020).

Level 4: Expert Maintenance by Highly Skilled Technicians or Engineers

Tasks at Level 4 require extensive expertise and are usually executed by senior maintenance personnel, such as engineers or specialized technicians. These interventions often include equipment reconditioning, software reprogramming, and complex fault analysis. It also involves coordinating with OEMs (Original Equipment Manufacturers) or external service providers when necessary (Mobility Work, 2020) .

Level 5: Overhaul and Redesign by External Specialists

Level 5 maintenance is the most advanced and involves significant interventions such as complete equipment overhauls, major upgrades, retrofitting, or redesigns. These operations are typically outsourced to external experts or the equipment's original manufacturer. They are infrequent but critical for extending the lifecycle of complex systems (Mobility Work, 2020) .

Table 1 - 1 : levels on maintenance

Level	Activity
Level 1	Routine checks, basic maintenance, greasing
Level 2	Standard replacements, operational checks
Level 3	Diagnostics, minor repairs, minor preventive operations
Level 4	Preventive and corrective maintenance, adjustment of measuring instruments
Level 5	Renovation, reconstruction, and major repairs

2.3.5 Maintenance objectives

The longevity, safety, and operational effectiveness of physical assets are all dependent on maintenance. Its goals are in line with those of the company, which include lowering operating expenses, guaranteeing product quality, and minimizing downtime. The following are the main goals of maintenance, as backed by research and business publications.

- **Ensuring Equipment Availability and Reliability**

One of the primary objectives of maintenance is to maximize equipment availability and ensure operational reliability. High availability means that machines and systems are ready for production when needed, which is essential for minimizing production interruptions and meeting customer demand. Reliability refers to the ability of equipment to perform its intended function without failure over a specified period (Kelly, , 2006) .

- **Extending Equipment Lifespan**

Maintenance aims to preserve the condition of equipment, thereby extending its useful life. Regular maintenance interventions, including lubrication, cleaning, inspection, and parts replacement, can significantly delay wear and deterioration. This contributes to better asset utilization and deferred capital expenditure (Wireman, , 2010).

- **Reducing Maintenance and Operating Costs**

An important goal of maintenance is cost optimization. While maintenance activities do incur costs, they are strategically designed to prevent more significant expenses associated with breakdowns, production losses, or emergency repairs. A balanced maintenance strategy helps organizations achieve cost-effectiveness through preventive and predictive approaches. (Moubray, , 1997) .

- **Enhancing Safety and Environmental Compliance**

Maintenance is vital for ensuring the safety of personnel and compliance with environmental regulations. Malfunctioning equipment can lead to hazardous situations such as fires, leaks, or exposure to dangerous materials. A well-structured maintenance program includes inspections and risk assessments aimed at mitigating these risks. (Smith & Hawkins, 2004) .

- **Supporting Product Quality and Process Stability**

Poorly maintained machinery can cause defects in the production process, leading to compromised product quality. Maintenance ensures that machines operate within specified tolerances and production parameters. This objective supports total quality management (TQM) principles and continuous improvement efforts. (Nakajima, 1988)

- **Improving Asset Performance and Efficiency**

Maintenance contributes to optimizing the performance of physical assets by ensuring they operate at peak efficiency. This includes reducing energy consumption, minimizing downtime, and improving throughput. Efficient operations also enhance competitiveness and customer satisfaction. (Alsyouf, 2007)

Chapter 2:
Methodology
And
company presentation

Chapter 2 : Methodological choices

Chapter Two outlines the methodological approach adopted for this research and presents the case study organization, ENAFOR, a leading Algerian drilling company specializing in oil and gas exploration. This study employs a qualitative research methodology to gain an in-depth understanding of how the SAP ERP system supports preventive maintenance practices within an operational context. The qualitative approach allows for a detailed exploration of processes, user experiences, and organizational dynamics through interviews, document analysis, and observation. ENAFOR was selected as the case study due to its strategic importance in the energy sector and its ongoing efforts to integrate advanced ERP solutions, including SAP, to enhance its maintenance operations. This chapter justifies the choice of methodology, introduces the organizational context, and sets the stage for data collection and analysis in the subsequent sections.

Section 1: Methodological choices of the research

In order to thoroughly investigate the role of Enterprise Resource Planning (ERP) systems in preventive maintenance within ENAFOR, this study adopts a **qualitative research methodology**.

Qualitative research is particularly suited for exploring complex organizational processes, understanding user experiences, and capturing the contextual factors that influence system effectiveness. Given the nature of the research objective which aims to understand how ERP systems support and enhance preventive maintenance practices this approach allows for an in-depth exploration of perceptions, practices, and organizational dynamics.

research approach :

This study is exploratory in nature, aiming to uncover the underlying mechanisms through which ERP systems contribute to preventive maintenance at ENAFOR. The qualitative approach facilitates the collection of rich, detailed information that cannot be captured through quantitative metrics alone. It emphasizes understanding *how* and *why* certain outcomes occur, rather than merely *what* occurs.

1.1 Qualitative approach:

According to (Denzin & Lincoln, 2011) "Qualitative research is a situated activity that places the observer in the world. It consists of a set of interpretive and material practices that make the world visible. These practices transform the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos. At this level, qualitative research involves an interpretive and naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people assign to them".

Also defined by (Creswell & Poth, 2016) "Qualitative research begins with assumptions and the use of interpretive/theoretical frameworks that inform the study of research problems addressing the meaning individuals or groups assign to a social or human issue. To study this problem, qualitative researchers use an emerging qualitative approach to inquiry, data collection in a natural setting sensitive to the people and places being studied, and data analysis that is both inductive and deductive, establishing patterns or themes"

Basically The study of research problems addressing the meaning that individuals or groups assign to a social or human issue is informed by interpretive/theoretical frameworks and assumptions, which are the foundation of qualitative research. To investigate this issue, qualitative researchers employ a newly developed qualitative method of inquiry, gather data in an environment that is sensitive to the subjects and locations, and analyze the data both inductively and deductively to identify trends or themes.

1.2 Justification for Methodological Choices

The choice of a qualitative approach is justified by the study's objective: to gain an in-depth understanding of the ERP system's role in supporting preventive maintenance, beyond what quantitative metrics can capture. By engaging with the lived experiences and expert opinions of ENAFOR staff, the research provides nuanced insights that can inform both academic discussions and managerial decisions regarding ERP implementation and optimization.

1.3 Data Collection Methods

To gather relevant data, **semi-structured interviews** were conducted with key personnel involved in maintenance operations, ERP system management, and IT support. This method enables flexibility while ensuring that essential themes related to ERP functionality, integration, and decision-making support in preventive maintenance are thoroughly covered.

Table 2 - 1 : List of interviewees

Role	Experience	Duration /method
Stock Manager – Maintenance	8 years	30 minutes / Face to face
Head of GEMAO Department	8 years	25 minutes / video call
GEMAO Maintenance Engineer	6 years	45 minutes /face to face

Source: elaborated student

Additionally, **document analysis** was used to complement the interviews. Internal reports, ERP system documentation, and maintenance logs provided valuable insights into system capabilities and operational practices.

Document analysis is a systematic qualitative method used to examine and interpret various sources whether physical or digital with the aim of generating meaning, understanding concepts, and producing empirical knowledge. This approach enables researchers to contextualize data, identify recurring themes, and triangulate findings with other qualitative sources, thereby enhancing the validity and reliability of the analysis (Morgan, 2022)

1.4 Sampling Strategy

A **purposive sampling** strategy was employed to select participants who have direct experience with the ERP system and its application in maintenance planning. This included engineers, system administrators, and department heads from both the maintenance and IT divisions. Their insights were deemed essential to fully understand the ERP system's role in preventive maintenance.

1.5 Data Analysis Technique

The collected data were analyzed using **thematic analysis**, which involved coding the interview transcripts and documents to identify recurring patterns, themes, and categories. This method supports the systematic examination of how ERP systems are perceived and utilized in the preventive maintenance process, and how these systems impact operational efficiency and reliability.

Section 2: company presentation

The Enterprise Nationale de Forage (ENAFOR) is a joint-stock company (Société par Actions - SPA) with fully commercial capital, wholly owned (100%) by the national oil company SONATRACH. The company operates under the governance of Article 610 of the Algerian Commercial Code and is subject to the laws and regulations applicable to state-owned enterprises.

ENAFOR is managed by a Board of Directors, in accordance with its current foundational statutes and Ordinance No. 95-25, dated September 25, 1995, related to the management of state-owned commercial capital. The company holds a significant market share of approximately 40% at the national level, with its operations primarily focused on **drilling and**

well maintenance. It also manages a set of operational and logistical bases, the majority of which are strategically located in Hassi Messaoud, Algeria's central oil hub.

In addition to its core activities, ENAFOR is engaged in several support services, including:

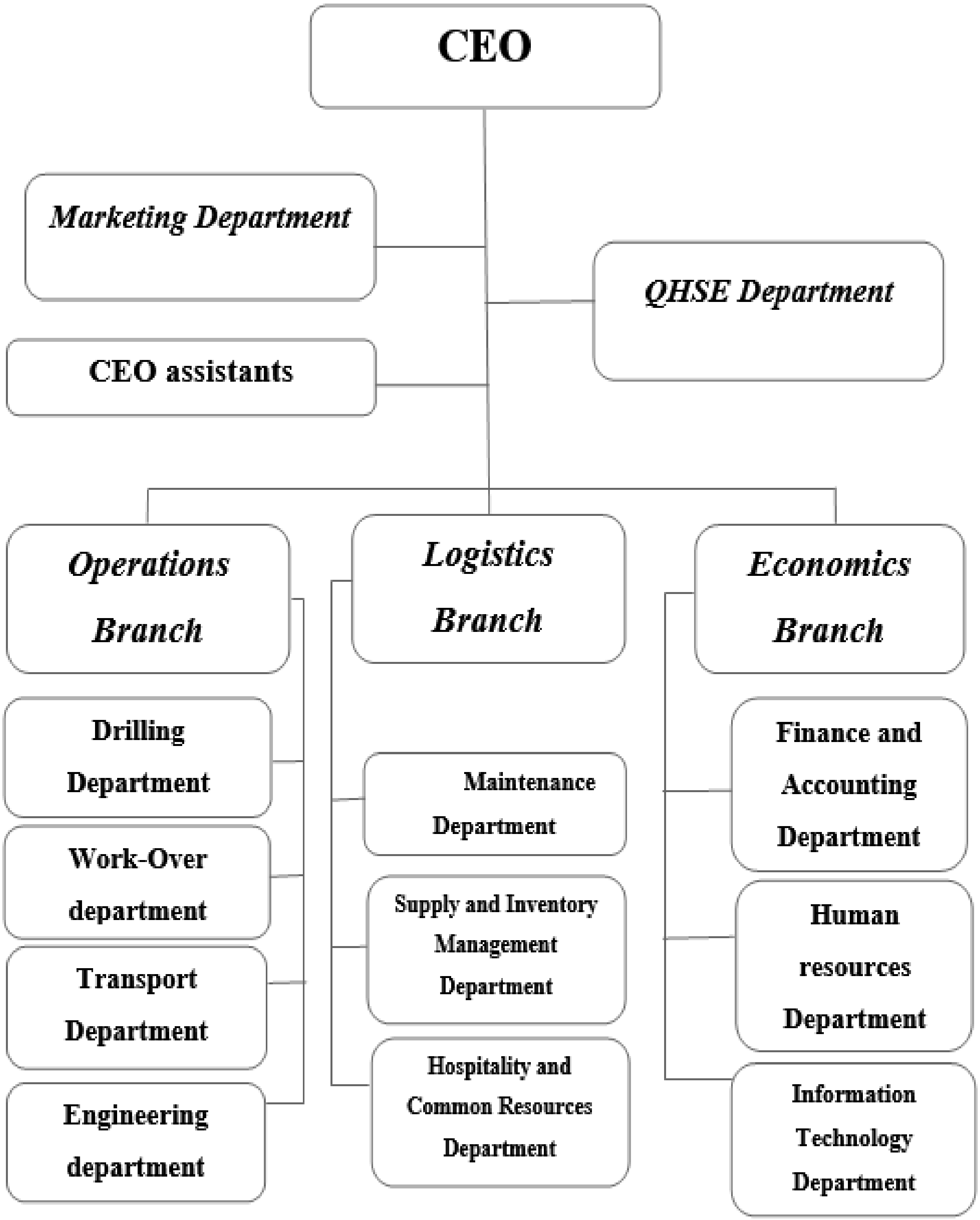
- Catering and accommodation services for employees stationed at remote drilling bases and workshops,
- Dismantling, transport, and reassembly of equipment (D.T.M),
- Oilfield maintenance services.

2.1 Historical Background and Development of ENAFOR

- 1966: The company was originally established under the name ALFOR (Algérienne de Forage), in line with SONATRACH's development strategy. ALFOR was a joint venture between SONATRACH (Algeria) and SEDCO (USA), with the shareholding structure divided as follows:
    - 51% for SONATRACH
    - 49% for SEDCO
- 1981–1982: Following the dissolution of ALFOR, ENAFOR was officially established by Decree No. 81-170 on August 1st, 1981. The decree was implemented starting January 1st, 1982, marking the formal transfer of all drilling projects to the newly formed national enterprise.
- 1989: By decree dated November 26, 1989, ENAFOR was restructured into an independent joint-stock company (SPA) with a capital of 20,000,000 Algerian Dinars. The shareholding was divided as follows:
    - 51% held by SONATRACH
    - 49% held by INDJAB (Société de Gestion des Participations)
- 2005: ENAFOR became a fully owned subsidiary of SONATRACH, holding 100% of the company's capital.

2.2 organizational chart of the company:

Figure : 2 - 1 : organizational chart of the company



Source : provided by company

The organizational structure of ENAFOR reflects a functional and hierarchical model, designed to support its operations in the oil and gas drilling sector. This structure ensures clarity in roles, efficient decision-making, and coordination across various operational and support units.

2.2.1 Top Management and Strategic Oversight

At the apex of the structure is the President Director General (PDG), who assumes overall responsibility for the strategic direction and management of the company. The PDG is supported by several key directorates and departments, including:

- **DRHU (Human Resources Directorate) –** responsible for managing personnel affairs, recruitment, training, and employee welfare.
- **DPCG (Planning and Management Control Directorate)** – oversees strategic planning, budgeting, and performance evaluation.
- **DFIN (Finance Directorate)** – manages financial operations, including budgeting, accounting, and auditing.

2.2.2 Support and Governance Functions

Several directorates provide cross-functional support and uphold governance standards:

- **SEC (General Secretariat) –** manages administrative coordination and company documentation.
- **DAUD (Internal Audit Directorate) –** ensures compliance, conducts audits, and supports risk management.
- **DJUR (Legal Affairs Directorate) –** handles legal matters and regulatory compliance.
- **SIE (Internal Security Service)** – oversees security operations and internal risk controls.
- **Assistants** – offer administrative and strategic support to top management**.**

2.2.3 Technical and Operational Departments

- **DERO (Engineering and Development Directorate)** – plays a central role in the technical planning and development of drilling projects.
- **DTCI (Communication and Information Technologies Directorate)** – manages the company's IT systems, digital infrastructure, and communication technologies.
- **DQSE (Quality, Safety, and Environmental Directorate) –** ensures compliance with environmental and safety standards.
- **DAGE (General Administration Directorate)** – handles internal logistics and administrative services.
- **DEDS (Drilling School Directorate)** – responsible for training personnel in drilling operations through ENAFOR's dedicated training center.

2.2.4 Operational Branches

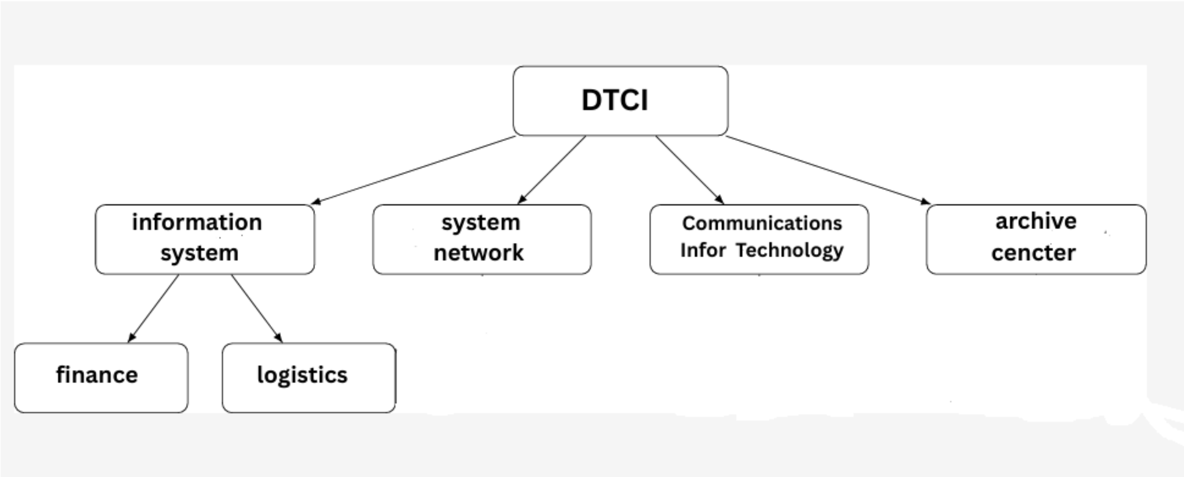
At the bottom tier, the structure branches into two main operational entities:

- **Operations Branch** – includes:
  - **DFOR** (Drilling Directorate),
  - **DWOK** (workover Directorate),
  - **DTRS** (Transportation and Logistics Directorate).

- **Specialized Equipment Branch** – includes:
  - **DAGS (**Heavy Equipment Directorate),
  - **DMEP (**Special Equipment Maintenance Directorate**),**
  - **DHEI (**Wellhead Equipment Directorate).

2.3 Organizational chart of the the Directorate of Communication and Information Technologies (DTCI):

Figure : 2 - 2 : DTCI department organizational chart



Source: provided by the company

The structure of the DTCI department (Direction des Technologies de la Communication et de l'Information). The chart shows that the department is divided into four main branches, each overseeing different technical and administrative domains:

- **Information System:**

  This division is further split into two sub-units:

  a. Finance: Likely manages financial information systems and related software tools.
  b. Logistics: Handles systems related to procurement, supply chain, and inventory.

- **System Network:**

  This unit manages the network infrastructure, including servers, connectivity, and cybersecurity.

- **Communications & Information Technology:**
  This division likely deals with digital communications tools, IT support, and software services.
- **Archive Center:**
  Responsible for managing and preserving digital and physical records or documents.

Chapter 3:
Results
and discussion

Chapter 3: results and discussion

This chapter presents and analyzes the main findings of the study, based on interviews with key personnel involved in maintenance and inventory management. It explores how the ERP system SAP supports preventive maintenance through three thematic axes: planning and scheduling, spare parts and inventory management, and continuous improvement. The Results section outlines the practical uses and perceived benefits of SAP as expressed by participants, while the Discussion section critically reflects on these findings in light of existing literature. Together, these sections highlight SAP's role as a strategic tool for improving maintenance efficiency, coordination, and decision-making.

Section 1: results

This section summarizes the main findings from interviews with department heads and engineers at ENAFOR , based on the structure of our interview guide.

1.1 Summary and Interpretation of Results:

The purpose of these interviews was to explore how the SAP ERP system influences preventive maintenance at ENAFOR. To fully capitalize on the qualitative data gathered, we applied a multidimensional analysis based on four main approaches:

- A **word frequency analysis** to highlight commonly used terms and key discussion topics;
- A concept map (Cognitive mapping) to visually show how different ideas and concepts are linked in participants' responses;

1.2 Lexical Approach

The lexical analysis focused on identifying the most frequently used words and expressions in the interviews with ENAFOR employees. This approach allowed us to highlight the key concepts and recurring themes related to the use of the SAP ERP system in preventive maintenance using Nvivo. By examining the vocabulary used by participants, we were able to uncover the central concerns, priorities, and experiences expressed in relation to system functionality, maintenance planning, and operational efficiency. The frequency and context of these terms provided valuable insight into how the ERP system is perceived and its practical impact on day-to-day maintenance activities.

Table : 3 - 1 : most frequent used vocabulary

Word	Length	Count	Weighted Percentage (%)
Maintenance	11	16	2,47
Experience	10	6	0,93
Continuous / Ongoing	8	5	0,77
Department	11	5	0,77
Availability	13	4	0,62
Production	10	4	0,62
Maintenance / Servicing	9	3	0,46
Logistics	10	3	0,46
Optimization	12	3	0,46
Scheduling	14	3	0,46
Planning	13	3	0,46
Process	9	3	0,46
Spare (parts)	8	3	0,46
Anomalies / Irregularities	9	2	0,31
Facilitates / Eases	8	2	0,31
Manager	12	2	0,31
Engineer	9	2	0,31

Source : elaborated by student using Nvivo

Figure : 3 - 1 : word cloud

source: elaborated by student using Nvivo

1.3 Cognitive mapping

The concept map constructed from participants' responses presents a comprehensive view of how various aspects of maintenance management are interconnected through the use of SAP ERP. At the center of the map is the core theme of maintenance, around which several key domains are organized. These domains reflect operational activities, strategic decision-making, cross-departmental coordination, and professional experience, providing insight into how maintenance functions are supported and optimized by ERP systems.

One of the most prominent themes is maintenance planning and execution. Participants highlight the use of SAP ERP to create and manage maintenance plans, generate work orders, and track their completion. Concepts such as "work order number," "order follow-up," and "action effectiveness" demonstrate how the system facilitates structured and traceable maintenance workflows. This also includes the use of operational checklists and activity logs, ensuring that interventions are executed systematically and documented thoroughly.

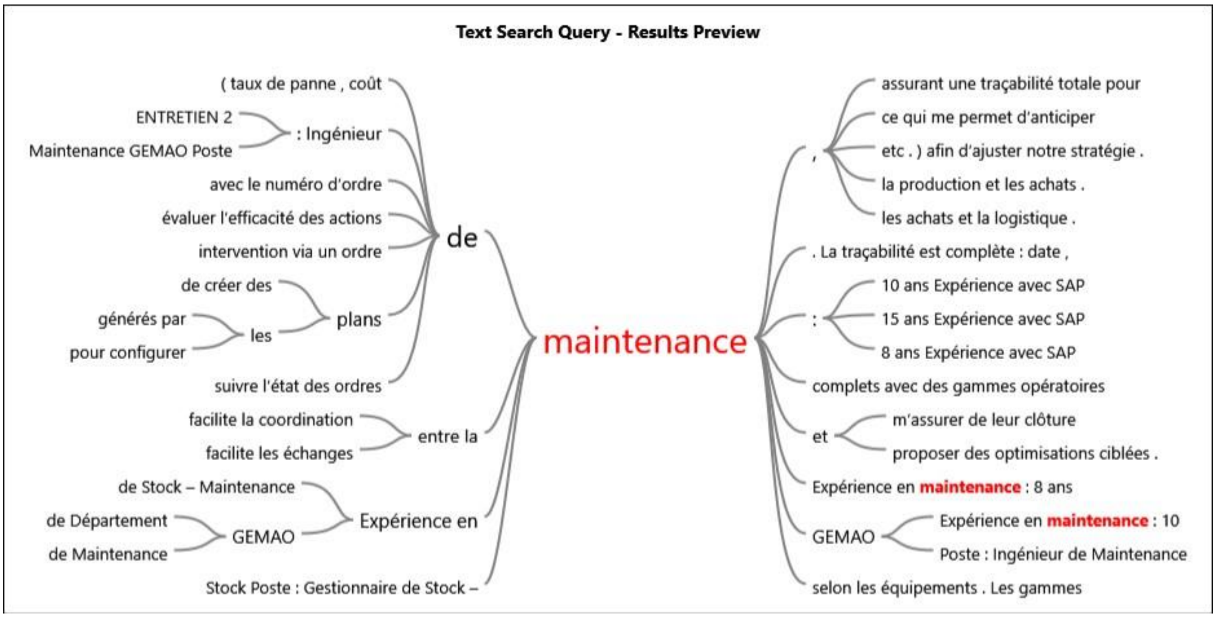
Another major area is data utilization and performance measurement. Respondents frequently mention the use of key performance indicators such as equipment failure rates and maintenance costs to evaluate the impact of maintenance actions and inform future planning. This reflects a shift toward data-driven maintenance strategies, where historical and real-time data from SAP are used to continuously adjust and improve maintenance operations. The ability to trace actions and outcomes within the system enables better diagnostics and decision-making.

Cross-functional collaboration emerges as another critical dimension. The concept map shows how SAP ERP supports coordination between the maintenance, production, procurement, and stock management departments. Shared access to data across these functions promotes operational alignment and transparency, which in turn enhances the organization’s ability to anticipate needs and respond efficiently to equipment issues or inventory constraints.

Experience and expertise are also central to the participants' narratives. Many respondents emphasize their years of experience with SAP ERP and in maintenance roles, indicating that sustained exposure to the system strengthens their capacity to leverage its features effectively. This also suggests that user proficiency plays a key role in maximizing the value of ERP in maintenance contexts.

Finally, the concept map reflects the strategic role of SAP ERP. Beyond operational utility, the system is seen as a platform for continuous improvement and strategic alignment. It enables users to identify patterns, propose targeted optimizations, and align maintenance activities with broader production and supply chain strategies.

Figure : 3 - 2 : text search query



source : Nvivo

1.3 thematic approach:

1.3.1: planning and scheduling

the pivotal role of the ERP system specifically SAP in structuring and enhancing planning and scheduling processes within the framework of preventive maintenance. The insights provided by different stakeholders reveal how the ERP facilitates the alignment of maintenance activities with production requirements, resource availability, and spare part logistics.

- **Centralization and Standardization of Maintenance Planning**

The CMMS department head emphasizes the ability of SAP to formalize maintenance strategies through comprehensive planning features. SAP allows the creation of detailed maintenance plans that include operational sequences, periodicities, and deadlines. This capability fosters a standardized and systematic approach to preventive maintenance, ensuring that recurring tasks are neither missed nor executed arbitrarily.

Similarly, the maintenance engineer confirms that these plans are not generic but rather customized for each equipment type. The automated cycles ensure that the preventive maintenance workload is predictable and repeatable, reducing manual interventions and the risk of oversight.

These responses suggest that SAP acts as a central repository for maintenance scheduling, reducing variability and enhancing control over long-term maintenance planning.

- **Integration of Resource Allocation with Production Priorities**

Both the CMMS head and the maintenance engineer underline that SAP supports resource planning based on human skills and material needs. Tasks are not scheduled in isolation but are instead integrated into the overall production schedule. This coordination ensures optimal timing of interventions to minimize disruption and align with production cycles.

Specifically, the CMMS head points out the prioritization of resource allocation based on urgency and production context, facilitated directly through SAP. **This allows for proactive decision-making and better synchronization across departments**.

This demonstrates that SAP contributes significantly to adaptive scheduling, wherein preventive maintenance is not only timely but also context-aware.

- **Real-Time Monitoring and Feedback Loops**

An important element brought up by the CMMS head and the maintenance engineer is the availability of real-time dashboards and reporting tools within SAP. These dashboards track the status of maintenance work orders, alerting stakeholders to delays, anomalies, or incomplete tasks.

The maintenance engineer uses these insights to ensure timely closure of maintenance orders, which is critical for both performance monitoring and compliance with maintenance schedules. This feedback loop enables continuous improvement and reactive adjustments, increasing the reliability of the preventive maintenance process.

- **Forecasting and Synchronization with Inventory Management**

From the perspective of the stock manager, SAP plays an equally critical role in planning by anticipating spare parts requirements. Maintenance plans automatically trigger notifications of parts needs, allowing the stock manager to prepare kits in advance. This proactive approach reduces delays caused by part unavailability and supports just-in-time inventory practices.

The integration between the maintenance and inventory modules of SAP offers a clear view of upcoming demands, enhancing coordination between technical and logistical teams. The stock manager's ability to verify work order progress and part availability in real-time ensures smoother execution and better alignment of maintenance and inventory workflows.

1.3.2 Spare Parts and Inventory Management

The responses from the CMMS department head, the CMMS maintenance engineer, and the stock manager offer a comprehensive view of how SAP ERP is used to enhance the efficiency, traceability, and reliability of spare parts and stock management in a preventive maintenance context.

- **Automated and Predictive Replenishment**

The CMMS department head underscores SAP's capacity to automatically trigger replenishment processes when predefined stock thresholds are reached. This functionality ensures that critical components are restocked proactively, reducing the likelihood of emergency procurement and the risks associated with stockouts. The stock manager reinforces this point by explaining that reorder alerts are configured in SAP, and that replenishment suggestions are based on both consumption rates and supplier lead times.

Furthermore, the department head highlights the role of the MRP (Material Requirements Planning) module, which incorporates consumption history and component criticality. This enables predictive inventory control, ensuring that stocks are neither underutilized nor excessive. Such an approach directly contributes to inventory cost optimization, avoiding overstocking while maintaining high operational readiness.

- **Integration with Maintenance Orders and Technical Operations**

Another key element emerging from the interviews is the tight integration between inventory and maintenance planning. The CMMS head emphasizes that each spare part is linked to specific maintenance orders in SAP. This connection ensures that parts consumption is directly traceable to specific interventions, equipment, and users. The engineer echoes this by noting that all parts used during interventions are logged and tracked, supporting post-maintenance analysis and technical diagnostics.

Similarly, the stock manager confirms that each withdrawal from stock is recorded with its corresponding maintenance order number, enabling full traceability of parts usage. This integration strengthens not only operational coordination between maintenance and logistics but also supports regulatory compliance, internal audits, and reliability engineering.

- **foreseeing and Demand Anticipation**

From a planning standpoint, the maintenance engineer uses SAP to anticipate future parts requirements based on upcoming maintenance plans. This forward-looking use of the ERP helps to minimize urgent and last-minute orders, which are often costly and operationally disruptive. The engineer adds that SAP's forecasting capabilities, supported by dynamic thresholds and historical usage data, help in striking a balance between availability and cost.

This shows that SAP contributes to strategic spare parts planning, enabling better budgeting, improved coordination with suppliers, and enhanced service levels across the maintenance function.

- **Complete Traceability and Auditability**

All three respondents stress SAP's ability to provide end-to-end traceability of spare parts. Whether it's the date of issue, the equipment on which the part was used, the user who handled it, or the corresponding maintenance operation, every stock movement is recorded and auditable. This level of traceability is critical not only for quality control and safety but also for failure analysis and root cause identification in the context of recurring issues.

The stock manager specifically mentions that SAP allows for technical and audit analysis, ensuring that the organization can justify inventory decisions and link them to operational needs.

1.3.3 Continuous Improvement and Process Optimization

The interviews conducted with the CMMS department head, the maintenance engineer, and the stock manager reveal how SAP ERP serves as a critical enabler of continuous improvement and process optimization. Through data centralization, cross-functional integration, and performance analytics, SAP supports the iterative enhancement of maintenance strategies, inventory practices, and interdepartmental coordination.

- **Data-Driven Diagnosis and Root Cause Analysis**

The CMMS department head highlights SAP's role in identifying the most failure-prone equipment, leveraging historical maintenance data stored within the system. This functionality allows the organization to track patterns of breakdowns, isolate recurring issues, and implement corrective actions directly within the ERP platform.

The maintenance engineer corroborates this, noting that SAP facilitates root cause analysis and provides visibility into the effectiveness of previously implemented corrective measures. By using structured reports and analytics, SAP empowers maintenance teams to propose targeted optimizations rather than relying on reactive or ad-hoc interventions.

These insights demonstrate that SAP enables evidence-based decision-making, ensuring that improvements are not only implemented, but also evaluated and refined continuously.

- **Performance Monitoring and Strategic Adjustment**

SAP plays a central role in the monitoring of key performance indicators (KPIs) related to maintenance. According to the CMMS department head, metrics such as failure rates, maintenance costs, and equipment availability are extracted from SAP to assess the impact of preventive maintenance programs and adjust strategies accordingly.

This KPI-centric approach fosters a culture of performance and accountability; whereby operational decisions are anchored in quantifiable outcomes. It also enhances the organization's ability to set realistic improvement targets and allocate resources effectively.

The maintenance engineer reinforces this point by noting that SAP-generated reports are used to track progress and evaluate interventions, making it possible to fine-tune maintenance plans with precision.

- **Cross-Functional Integration for Holistic Optimization**

All three respondents emphasize the role of SAP in facilitating interdepartmental coordination, which is essential for process optimization. The CMMS head and maintenance engineer note that SAP ensures seamless collaboration between maintenance, production, and logistics teams, thanks to the integration of its various functional modules.

This integration means that data related to machine failures, spare part consumption, procurement delays, and production requirements are visible to all relevant actors, enabling collective problem-solving and aligned decision-making.

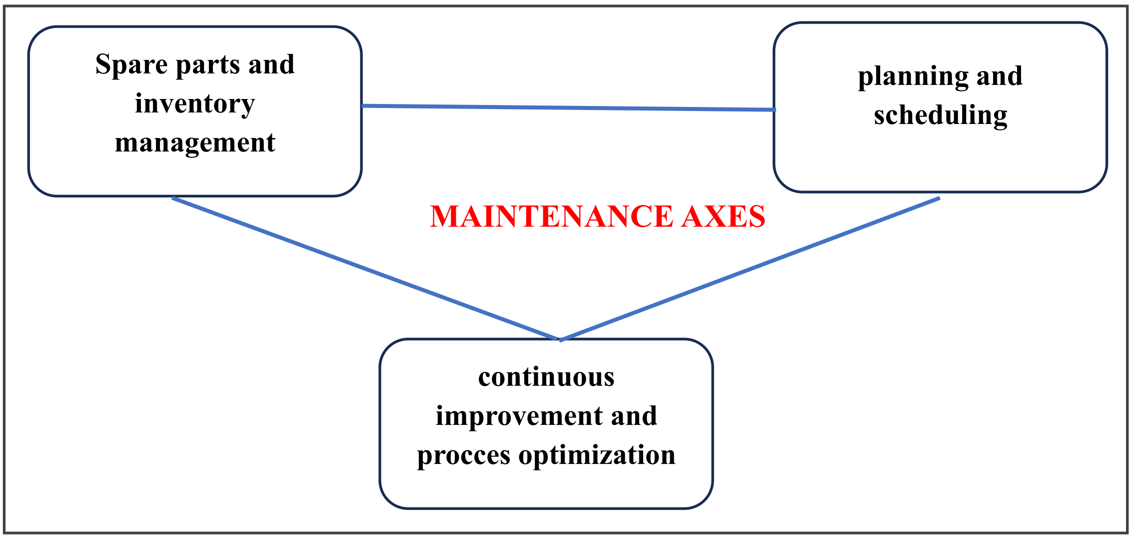
Although not directly responsible for continuous improvement, the stock manager provides a valuable perspective by showing how SAP allows for the analysis of inventory movement data. By identifying consumption anomalies and recurring stock imbalances, the stock manager contributes to inventory process refinement, ensuring that stock levels better match operational needs.

- **Centralization and Transparency of Information**

The centralization of data in SAP ensures that all improvement initiatives are built upon a single source of truth. The stock manager, in particular, notes that this centralization enhances transparency and communication between departments. Whether for audit purposes or collaborative planning, this unified database eliminates data silos and strengthens the consistency of organizational responses.

This reinforces the notion that ERP systems do not merely support operations, but actively contribute to organizational learning, where insights are systematically collected, shared, and acted upon.

Figure : 3 - 1 : preventive maintenance axes



Source: elaborated by student

1.4 SWOT analysis

Table : 3 - 2 : SWOT Matrix

Strengths	Weaknesses	Opportunities	Threats
Centralized and standardized planning ensures consistency and reduces oversight.	Dependence on user proficiency requires ongoing training.	Integration with IIoT or predictive analytics for predictive maintenance.	Employee resistance to change if system is perceived as complex.
Real-time monitoring via dashboards enables timely detection of issues.	Potential system complexity may lead to underutilization.	Enhanced user training to maximize feature utilization.	System rigidity limits adaptability to unique needs.
Cross-functional integration aligns maintenance, production, and inventory.	Limited flexibility in standardized workflows.	Strengthened collaboration via shared KPIs and dashboards.	Ongoing maintenance costs for updates and support.

Automated inventory management optimizes stock levels and reduces delays.		**Expanded application to other maintenance types (e.g., corrective).**	**Data security risks in centralized data systems.**
Data-driven decision-making supports root cause analysis and improvements.		**Continuous improvement culture via analytics-driven refinements.**	
Traceability and auditability ensure compliance and failure analysis.			

Source : elaborated by student

1.4.1 Detailed Analysis

➢ **Strengths**

- **Centralized and Standardized Planning**: SAP's Plant Maintenance (PM) module facilitates detailed, equipment-specific maintenance plans with automated cycles, ensuring standardized scheduling, reducing variability, and minimizing missed tasks, as noted by the CMMS department head and maintenance engineer.
- **Real-Time Monitoring and Feedback**: Dashboards and reporting tools provide real-time visibility into work order status, enabling early detection of delays or anomalies, ensuring timely task completion, and supporting schedule compliance, as emphasized by the CMMS head and engineer.
- **Cross-Functional Integration**: SAP integrates maintenance with production and inventory management, aligning resource allocation with production priorities, minimizing disruptions, and enhancing coordination, as reported by all interviewees.
- **Automated Inventory Management**: The Material Requirements Planning (MRP) module automates spare parts replenishment based on consumption history and criticality, reducing stockouts, supporting just-in-time practices, and optimizing inventory costs, per the stock manager and CMMS head.
- **Data-Driven Decision-Making**: Historical data and KPIs (e.g., failure rates, maintenance costs) enable root cause analysis and performance evaluation, allowing targeted improvements to maintenance strategies, as noted by the CMMS head and engineer.

- **Traceability and Auditability**: SAP logs every spare part's usage, linking it to specific maintenance orders, equipment, and users, ensuring full traceability for regulatory compliance, quality control, and failure analysis, as confirmed by all respondents.

➢ **Weaknesses**

- **Dependence on User Proficiency**: The emphasis on respondents' experience suggests SAP's effectiveness relies on user expertise, with less experienced staff potentially struggling without adequate training, limiting impact.
- **Potential System Complexity**: Sophisticated features (e.g., automated workflows, dashboards) indicate complexity that could lead to underutilization if users find the system challenging to navigate or exploit fully.
- **Limited Flexibility in Workflows**: The focus on standardized processes suggests SAP's rigid workflows may not fully accommodate unique or rapidly changing operational needs, potentially constraining adaptability.

➢ **Opportunities**

- **Integration with Advanced Technologies**: Data-driven strategies and forecasting capabilities suggest potential for integrating SAP with IIoT or predictive analytics, enabling a shift to predictive maintenance with real-time sensor data.
- **Enhanced User Training**: Improved training programs could address user expertise gaps, ensuring all staff fully utilize SAP's features for consistent and effective maintenance outcomes.
- **Strengthened Cross-Functional Collaboration**: Integration benefits could be expanded by institutionalizing shared KPIs and dashboards, further aligning maintenance, production, and inventory teams for holistic optimization.
- **Expanded Application Scope**: SAP's modular architecture could be extended to other maintenance types (e.g., corrective), creating a comprehensive asset management strategy.
- **Continuous Improvement Culture**: KPIs and analytics for performance monitoring offer opportunities to foster a data-driven culture, driving iterative refinements and long-term efficiency gains.

➢ Threats

- **Employee Resistance to Change**: The complexity of SAP's features could lead to resistance from staff perceiving the system as disruptive or difficult, hindering full adoption.
- **System Rigidity**: Standardized workflows may limit SAP's adaptability to evolving or unique operational requirements, reducing effectiveness in dynamic contexts.
- **Ongoing Maintenance Costs**: The sophisticated nature of SAP implies ongoing costs for system updates, training, and support, which could strain ENAFOR's resources.
- **Data Security Risks**: The centralized data repository enabling integration and traceability poses cybersecurity risks if not properly secured, potentially compromising sensitive operational data.

Section2: discussion

The findings of this study, based on a detailed case analysis at ENAFOR, reaffirm and extend the existing literature on the role of ERP systems particularly SAP in optimizing preventive maintenance operations. The literature consistently highlights the central role of SAP ERP in formalizing, structuring, and automating maintenance planning processes. Studies such as those by (Gupta,, Patel, & Sharma, 2020)) and (Al Nawaiseh & al, 2022) demonstrate that SAP's centralized data architecture enables the creation of maintenance schedules that align with operational demands, thus reducing downtime and maintenance costs. These conclusions are strongly reflected in the current case, where stakeholders from the CMMS department confirm that SAP's Plant Maintenance (PM) module facilitates the definition of detailed, equipment-specific maintenance plans with customized cycles and deadlines. This not only enhances planning precision but also contributes to the standardization and predictability of maintenance tasks, reducing manual oversight.

Furthermore, the study aligns with prior research by illustrating SAP's ability to integrate resource allocation with production priorities. Maintenance activities at ENAFOR are coordinated in real time with production schedules and resource availability, ensuring that interventions are context-aware and minimally disruptive. The insights from the CMMS head and maintenance engineer demonstrate SAP's adaptive scheduling capabilities, where urgency, production cycles, and human and material resources are dynamically aligned through the ERP system. This supports the claims made in earlier studies about SAP's integrative capacity to synchronize diverse operational functions.

A critical aspect of the findings is the role of SAP in real-time monitoring and feedback loops. The dashboards and reporting tools used at ENAFOR allow for continuous tracking of maintenance work orders, enabling early detection of delays and anomalies. This facilitates a closed-loop system of performance monitoring, where maintenance effectiveness is constantly evaluated and plans are adjusted accordingly. Such findings echo the observations of (Shaheen & Németh, 2022), who emphasize the importance of system transparency and data accessibility in enabling continuous improvement.

In addition to planning and monitoring, the study reveals that SAP plays a fundamental role in managing spare parts and inventory. The integration between SAP's maintenance and inventory modules enables automated replenishment based on consumption history and criticality, as highlighted by both the CMMS department head and the stock manager. This functionality corresponds with (Irmansyah, 2024) emphasis on ERP-enabled optimization of stock levels and just-in-time inventory management. Moreover, each spare part used in maintenance operations is fully traceable through SAP, ensuring that withdrawals, usage contexts, and responsible personnel are logged and auditable. This level of traceability is vital for regulatory compliance, failure analysis, and quality assurance.

The system's ability to generate replenishment alerts and demand forecasts based on historical usage enhances coordination between technical and logistics teams, reinforcing the findings of (Alarcón, Martínez-García, & Gómez de León Hijes, 2021)regarding ERP's role in aligning energy, maintenance, and supply chain functions. These capabilities not only reduce the risks of stockouts or overstocking but also improve the financial sustainability of maintenance activities through optimized inventory control.

Finally, the study underscores the strategic function of SAP ERP as a platform for cross-functional integration and continuous improvement. The case shows that SAP facilitates collaboration among maintenance, production, and procurement departments through shared access to real-time data, which enhances transparency, accountability, and collective decision-making. Maintenance teams use performance indicators derived from SAP such as equipment failure rates and maintenance costs to identify optimization opportunities and assess the impact of previous interventions. This data-driven approach supports a culture of strategic adjustment, where maintenance strategies are continuously refined based on measurable outcomes.

While previous studies have explored the potential of advanced technologies such as IIoT, AI, and digital twins for predictive maintenance, the current study demonstrates that substantial gains in efficiency, reliability, and coordination can already be realized through the full utilization of SAP's native features within the PM module. In doing so, it highlights the ERP system not only as an operational enabler but as a core component of strategic maintenance management, especially in contexts where Industry 4.0 technologies are still being phased in. By focusing on the practical use of SAP ERP at ENAFOR, this study offers a grounded contribution to the literature, illustrating how a well-implemented ERP system can act as a lever for operational excellence, organizational learning, and sustainable asset management.

Conclusion

Conclusion

This study set out to explore the role of the SAP ERP system in supporting preventive maintenance within ENAFOR, a prominent Algerian drilling company operating in the oil and gas sector. Through a qualitative approach based on semi-structured interviews and document analysis, the research provided a detailed examination of how SAP's functionalities particularly within the Plant Maintenance (PM) module facilitate planning, execution, and optimization of preventive maintenance activities.

The findings demonstrate that SAP ERP serves as a pivotal tool in structuring maintenance processes through centralized planning, automated scheduling, and real-time monitoring. The system enhances coordination between maintenance, production, and inventory management, enabling proactive resource allocation and minimizing operational disruptions. The integration of modules and data transparency provided by SAP also supports traceability, performance evaluation, and strategic decision-making, which are critical for continuous improvement and long-term asset reliability.

Moreover, the study confirms the alignment of practical insights from ENAFOR with existing literature, which highlights ERP systems particularly SAP as enablers of operational efficiency, cost control, and sustainable maintenance strategies. The capacity of SAP ERP to generate accurate forecasts, standardize workflows, and support data-driven diagnostics underscores its strategic value in industrial environments characterized by complex operations and high equipment dependency.

While advanced technologies such as the Industrial Internet of Things (IoT) and digital twins offer promising avenues for predictive maintenance, the case of ENAFOR illustrates that significant improvements in maintenance performance can be achieved through the effective deployment of standard ERP capabilities. As such, the research reinforces the importance of fully leveraging existing digital infrastructure as a foundation for future technological advancements.

In conclusion, SAP ERP is not merely a software solution but a comprehensive platform for organizational transformation in maintenance management. Its implementation at ENAFOR demonstrates how digital systems, when effectively integrated into operational practices, can drive reliability, efficiency, and strategic alignment. These insights offer valuable implications for other asset-intensive organizations seeking to enhance their maintenance capabilities through ERP adoption, and provide a strong basis for further research into the evolution of maintenance practices in the context of Industry 4.0.

Despite its contributions, this study is subject to several limitations. First, the qualitative design, while appropriate for exploring user perceptions and contextual factors, limits the generalizability of the findings beyond ENAFOR. The insights are specific to one organization and may not reflect the experiences of companies operating in different industrial sectors or regions. Second, the data collection was based on a limited number of interviews due to access constraints, which may restrict the diversity of viewpoints captured. Additionally, the study focused solely on the preventive maintenance dimension of SAP ERP, without addressing the full spectrum of maintenance practices, such as predictive or corrective approaches. Finally, the research did not quantitatively measure performance improvements, relying instead on reported experiences and qualitative analysis.

Based on the findings, several recommendations can be proposed for both practice and future research. For ENAFOR and similar organizations, it is essential to invest in continuous training and capacity-building initiatives to ensure that maintenance personnel can fully exploit the features of the SAP PM module. Enhanced user proficiency can improve system utilization and lead to more consistent maintenance performance. Furthermore, organizations should consider integrating advanced analytics and real-time sensor data (e.g., from IoT systems) into SAP to gradually evolve from preventive to predictive maintenance frameworks.

From a managerial perspective, cross-functional collaboration should be further institutionalized by promoting shared KPIs and dashboards across maintenance, inventory, and production departments. This can enhance alignment and foster a culture of continuous improvement. Finally, future academic research should expand on this study by employing mixed-methods or longitudinal designs, allowing for the measurement of performance impacts over time and across varied industrial contexts. Exploring the interplay between ERP systems and emerging Industry 4.0 technologies will also provide valuable insights into the next evolution of digital maintenance management.

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Appendices

Annexes :
Interview guide :
Guide d'Entretien : Rôle de l'ERP SAP dans la Maintenance Préventive

Bonjour [Nom de l'interviewé(e)],

Je vous remercie de prendre le temps de discuter avec moi aujourd'hui. L'objectif de cet entretien est d'explorer en profondeur le rôle et l'impact de l'ERP SAP sur les processus de maintenance préventive au sein de votre organisation. Nous aborderons cet aspect selon quatre axes principaux.

PARTIE 01: Informations sur l'Interviewé(e)

- Poste Occupé :
- Nombre d'Années d'Expérience dans le Domaine de la Maintenance (en général) :
- Nombre d'Années d'Expérience avec l'ERP SAP (en lien avec la maintenance) :
- Département/Service **:**

PARTIE 02: **Rôle de l'ERP SAP dans la Maintenance Préventive**

Axe 1 : Planification et Ordonnancement de la Maintenance Préventive

- **Question 1.1 :** Comment l'ERP SAP est-il utilisé pour planifier les activités de maintenance préventive (création des plans de maintenance, définition des gammes opératoires, établissement des cycles et des échéances) ?
- **Question 1.2 :** Quelles sont les fonctionnalités de l'ERP SAP qui facilitent l'ordonnancement des interventions de maintenance (gestion des ressources humaines et matérielles, planification des dates et des heures, gestion des priorités) ?
- **Question 1.3 :** Comment l'ERP SAP permet-il de visualiser et de suivre l'état d'avancement des plans de maintenance préventive ? Disposez-vous de tableaux de bord ou de rapports spécifiques ?

Axe 2 : Gestion des Pièces de Rechange et des Stocks

- **Question 3.1 :** Comment l'ERP SAP est-il utilisé pour gérer les stocks de pièces de rechange nécessaires à la maintenance préventive (définition des seuils de réapprovisionnement, suivi des mouvements de stock, gestion des fournisseurs) ?
- **Question 3.2 :** Quelles sont les fonctionnalités de l'ERP SAP qui permettent d'optimiser la disponibilité des pièces de rechange critiques pour la maintenance préventive tout en maîtrisant les coûts de stockage ?
- **Question 3.3 :** Comment l'ERP SAP assure-t-il la traçabilité des pièces de rechange utilisées lors des interventions de maintenance préventive ?

Axe 3 : Amélioration Continue et Optimisation des Processus

- **Question 4.1 :** Comment l'ERP SAP soutient-il les initiatives d'amélioration continue des processus de maintenance préventive (identification des axes d'amélioration, suivi des actions correctives et préventives) ?
- **Question 4.2 :** Quelles sont les fonctionnalités de l'ERP SAP qui permettent d'évaluer l'efficacité des stratégies de maintenance préventive mises en œuvre et d'identifier les opportunités d'optimisation (par exemple, analyse de la fiabilité des équipements, évaluation des coûts de maintenance) ?
- **Question 4.3 :** Comment l'ERP SAP facilite-t-il la communication et la collaboration entre les différents acteurs impliqués dans la maintenance préventive (équipes de maintenance, production, achats) ?

Conclusion (Remerciements et prochaines étapes)

Je vous remercie sincèrement pour vos réponses détaillées et vos précieux éclaircissements. Ces informations seront très utiles pour notre analyse. Auriez-vous d'autres commentaires ou des aspects que nous n'avons pas abordés et que vous souhaiteriez mentionner ?