

Implementation of a Documentation Management System applied to Maintenance & Assets Management in a Wood-Based Panels Company

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“In order to be irreplaceable one must always be different”

- Coco Chanel

Abstract

Born from the manipulation of data in Internet of Things, IoT, systems there has been an increasing technological capacitation of processes and use of resources in industry. This new emerging concept, Industry 4.0, is responsible for transforming the way of working.

With the automation of production processes, the human being has had an increasing role in the control and maintenance of equipment as opposed to the reality experienced before. This transition is accompanied by a new way of transmitting knowledge: instead of being based on the experience of a group of individuals, it is documented and recorded in files with the most varied formats. Thus, Information Management has emerged as a response to this new need.

Having more and more importance, there is a growing focus on a multidisciplinary approach, making use of systems and technologies linked to other areas. If before, information was stored on paper, in physical archives, according to a traditional hierarchical organization by themes or areas, nowadays, there are different ways of storing information: from manuals and technical drawings to videos and images.

Thus, this project arises from the need to organize all the records associated with the Asset Management and Maintenance operations of Sonae Arauco Portugal, SA. This report will describe all the steps associated with the development of a Document Management System, with the purpose of developing a model that can be replicated by all plants associated with the group, promoting a standardization in the management of technical documentation.

Based on a prototype methodology and through the contact with different departments and external consultants, an integration between two software that the company already had was developed: Microsoft SharePoint and IBM MAXIMO; a strategy for the information upload and consultation processes was defined and a massive upload strategy was planned. During the development of the system, one of the main concerns was to keep the process simple and practical for the user that on a daily basis will need to consult information associated to a production line or a specific equipment to perform its functions and that does not involve extraordinary efforts from the IT departments of both entities.

Due to the short time available for the elaboration of this report, in comparison with the project's progress, it was not possible to test the system and implement it. Thus, as future work, it would be interesting to complete the development of SharePoint as a repository and the integration with MAXIMO as an access portal. Subsequently, it would be advantageous to outline and implement a solution for consulting information on mobile devices.

Keywords:

Information Management; Assets Management; Maintenance Management; Technical Documentation; Document Management System; Microsoft SharePoint; IBM MAXIMO

Resumo

Nascido da manipulação de dados em sistemas de IoT, Internet of Things, tem se verificado uma crescente capacitação tecnológica dos processos e uso de recursos na indústria. Este novo conceito emergente, Indústria 4.0, é responsável pela transformação na forma de trabalhar verificada nos dias de hoje.

Com a automatização dos processos produtivos, o ser humano tem tido cada vez mais um papel de controlo e manutenção dos equipamentos em oposição à realidade vivida anteriormente. Esta transição é acompanhada por uma nova forma de transmitir conhecimento: em vez de ser baseado na experiência de um conjunto de indivíduos encontra-se documentada e registadas em ficheiros com os mais variados formatos. Assim, a Gestão de Informação tem surgido como resposta a esta nova necessidade.

Tendo cada vez mais importância, há uma crescente aposta numa abordagem multidisciplinar, fazendo uso de sistemas e tecnologias ligados a outras áreas. Se antes a informação era armazenada em papel, disposta em arquivos físicos, segundo uma organização hierárquica tradicional por temas ou áreas, atualmente, são cada vez mais diversas as formas de armazenar informação: desde manuais e desenhos técnicos a vídeos e imagens.

Assim, este projeto nasce da necessidade de organizar todos os registos associados à Gestão de Ativos e operações de Manutenção da Sonae Arauco Portugal, SA. O presente relatório descreverá todas as etapas associadas ao desenvolvimento de um Sistema para a Gestão Documental, com a finalidade de desenvolver um modelo que possa ser replicado por todas as fábricas associadas ao grupo promovendo uma uniformização na gestão da documentação técnica.

Partindo de uma metodologia de protótipo e através do contacto com diferentes departamento e consultores externos, foi desenvolvida uma integração entre dois softwares que a empresa já possuía: Microsoft SharePoint e IBM MAXIMO; definida uma estratégia para os processos de carregamento e consulta da informação e ainda planeada uma estratégia de carregamento em massa. No decorrer do trabalho, uma das principais preocupações foi manter o processo simples e prático para o utilizador que no dia a dia necessitará de consultar informação associada a uma linha de produção ou a um equipamento específico para realizar as suas funções e que não envolvesse esforços extraordinários por parte dos departamentos de tecnologias de informação de ambas as entidades.

Devido ao pouco tempo disponível para a elaboração do presente relatório, face aos avanços do projeto, não foi possível realizar a testagem do sistema e respetiva implementação. Assim, como trabalhos futuros, seria interessante terminar o desenvolvimento do SharePoint enquanto repositório e a integração com o MAXIMO enquanto portal de acesso. Posteriormente, seria vantajoso delinear e implementar uma solução para a consulta de informação a partir de dispositivos móveis.

Palavras-Chave:

Gestão de Informação; Gestão de Ativos; Gestão de Manutenção; Documentação Técnica; Sistema de Gestão Documental; Microsoft SharePoint; IBM MAXIMO

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Abbreviations

AIIM	Association for Intelligent Information Management
AM	Asset Management
AM&R	Asset Management & Reliability
CBM	Condition Based Maintenance
CM	Corrective Maintenance
CMMS	Computerized Maintenance Management System
DMS	Documentation Management System
EAM	Enterprise Asset Management
EDM	Electronic Document Management
EDMS	Electronic Document Management System
ERP	Enterprise Resource Planning
IBM	International Business Machines Corporation
IIoT	Industrial Internet of Things
IM	Information Management
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technologies
MB	Megabyte
MDF	Medium Density Fiberboard
OSB	Oriented Strand Board
PB	Particleboard
RCM	Reliability Centred Maintenance
TB	Terabyte
TBM	Time Based Maintenance
URL	Uniform Resource Locator

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1 Introduction

The fourth industrial revolution and the underlying digital transformation, known as Industry 4.0, is progressing exponentially. The digital revolution is reshaping the way individuals live and work (Morteza, 2020). For the most part, computer systems have handled facts organised into data records. Far more valuable and important to organizations are the concepts and ideas contained in documents (Ralph and Sprague, 1995). Due to the growing volume of documentation associated with a company, more and more strategies and systems are being sought to organise and manage these files, in order to reduce a potential source of loss of value by reducing non-profitable time in information retrieval.

1.1 Context and Motivation

This project was developed at Sonae Arauco Portugal, SA¹, one of the leading producers of wood-based panels in the world. Due to the recent implementation of an Enterprise Asset Management (EAM) software, this project fits in the recently created Asset Management & Reliability (AM&R) department, giving the company the possibility to review and organize the technical documentation necessary and indispensable for the normal operation and maintenance of its assets.

The motivation for this work is to create a system where all documentation related to industrial equipment is properly organized and classified according to the defined rules, facilitating its access. As the final solution developed will be integrated with the EAM software adopted by the company, the ambition is to improve the efficiency of consultation, as well as the workflow of production and maintenance employees.

The creation of a Document Management System (DMS) model aims not only to organize and digitize all the technical documentation of a facility, but also to create a standard model so that it can be replicated for the entire group, facilitating the control and management of records while allowing the cross-referencing and comparison of the information collected.

1.2 Documentation Management in Sonae Arauco

Sonae Arauco¹, as a group, is the result of a joint between two leading world companies in the wood sector: Sonae Indústria² and Arauco³. This partnership was established in order to create solutions inspired by wood for a sustainable world and encompasses all the wood-based paneling, chemical and impregnated paper plants in Europe and South Africa.

The company produces raw products and decorative solutions, having as well a constructional brand named AGEPAN® SYSTEM.

¹<https://www.sonaearauco.com/>

²<https://www.sonaeindustria.com/>

³<https://www.arauco.cl/>

The wood based panels produced represent the most sustainable, flexible and functional alternative to solid wood. These raw products are divided in three types: Particleboard (PB); Medium Density Fiberboard (MDF) and Oriented Strand Board (OSB). Each wood-based paneling facility of the group produces only one type.

Taking into consideration the large amount and robustness of the equipment used by this sector, the group took the decision to create a specialized AM&R department in order to extend the life cycle of each asset, improving efficiency and reducing downtime.

Following the multidisciplinary initiative set by the complex concept of Industry 4.0, the group is recently implementing new improvements in many different areas, including the way how assets are used and managed. Starting with an update of the previously Computerized Maintenance Management System (CMMS), to a more complete and autonomous EAM. The end goal is to reunite all the information related to this area in a single place, which communicate with the Enterprise Resource Planning (ERP) software already implemented; this will not only enable a more precise data analysis but at the same time will create a solid base where the knowledge and best practices of the company are concentrated and organized in a clear way.

With this vision in mind, far often it is necessary to consult different types of technical documentation with dissimilar types of information applicable to non-identical types of equipment; since the majority of this records are hold in paper, filed in an archive with some of them in specific location where not all the employees have access, it has identified a loss of value in this process due to the fact that part of the time in a maintenance or operational order was used searching for the information, when the group has the resources available to build a digital solution.

1.3 Goals of the Project

Integrated in a Maintenance & Asset Management Improvement Operation, which aims to improve availability, reduce costs, move from an experience-based method to a knowledge-based one, increase the Preventive/Corrective Maintenance ratio and the Planning function; this project will contribute to the objectives previously proposed because, by implementing a functional Document Management System, it is expected to:

1. Concentrate the support to the maintenance processes in a single place;
2. Dispose the documentation collected in a clear, organized and accessible way;
3. Get a simple and objective referencing system;
4. Organize the access profiles according to the functions inherent to each one;
5. Define the responsible for maintaining and update the system;
6. Facilitate the functions of diagnosis and distance assistance;
7. Ensure that the speed of software is not compromised.

Regarding the architecture of the system, the final solution must have:

1. A structured and cohesive organization;
2. Reference system easy to understand and intuitive;
3. Storage integrated with the EAM adopted;
4. Capacity for multiple accesses and in different ways;
5. A clear and simple navigation and upload style.

1.4 Methodology and Planning

In software engineering the majority of the errors found are related to the requirements (Figure 1). It is important to evaluate and reevaluate the situation during all the steps of a system development. In the previous and most common way of design, where lifecycle phases are executed in a sequential manner, this constant communication with the other interested part does not exist, resulting in a final solution that does not fit completely the final needs.

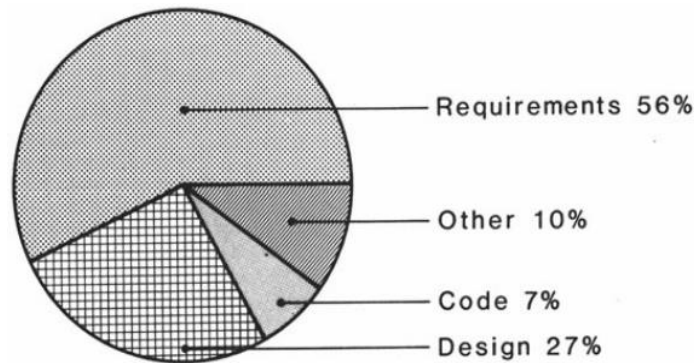


Figure 1: Origin of errors (DeMarco, 1978)

In a prototyping model the system moves in a circle, where communication represents a key to success, Figure 2. All parts are present and can contribute to refine the initial concept. Starting with the definition of the main goal, the second step is to analyze the initial features that already have been implemented and have to be respected. After that, start the creation of the design and the discussion with the appropriate partners or stakeholders, knowing that will be improvements that will need to be implemented afterwards; after this process and the suggestions previously made are installed, the interested parts consult and evaluate the outcome: if it fulfils their needs then the model will be implemented; if not, then the process will continue. With that being said, after the implementation of the system, it is important to remember that Documentation will evolve and be continuous, therefore it will always be room for improvement (Tavolato and Vincena, 1984).

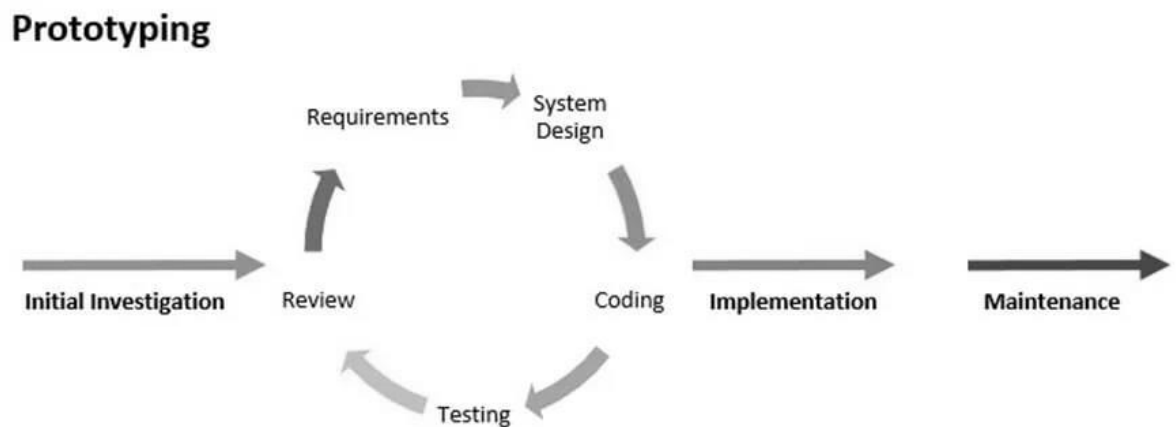


Figure 2: Phases of a Prototype Methodology (Martin, 2022)

Due to the short period of time available and the volume of documentation possessed by the company, the project will be focused on the development of a solution for the Web version, with the intention of being possible to carry out some tests in order to verify small flaws or to identify processes that can be improved, making the solution better for the company in question.

1.5 Dissertation Structure

The present dissertation is divided into five chapters, references and appendixes. Through a hierarchical structure of sub-chapters and sub-sub-chapters, the reader will be allowed to formulate a line of reasoning and follow the development of the project.

In the first chapter a framework was carried out as well as the motivation and the welcoming entity for this project. The methodology adopted and the structure of the report were also mentioned.

The second chapter presents the scientific literature review necessary to ensure the correct understanding of the concepts inherent to the project and to understand what consensus exists or does not exist on the subject under study.

Once the project and theme have been duly presented, the third chapter sets out the initial state of the problem, the initial considerations to be taken into account and the tools available for developing the solution.

The fourth chapter describes the solution developed and presents the decisions taken as well as the justifications that support them. The procedures associated to each process of the assembled system are also explained, ending with an evaluation of the expected results and an assessment of the identified advantages.

To conclude, the fifth chapter provides the conclusions of the report and the future work associated with the document management system defined above.

2 Literature Review

In this chapter an overview of the inherent concepts and scientific community consensus on best practices for a well-functioning document management system will be presented. Starting with a framework on the areas covered by this project to fully understand how important systems and data hold on records are, followed by the definition and importance of documentation, the systems to manage them and strategies used nowadays such as metadata.

Nowadays, information is everywhere, in multiple formats; because of that, Information Management (IM) is defined as a broad conceptual term that has various meanings and interpretations, but all of them seem to agree that *“concerns the control over how information is created, acquired, organized, stored, distributed, and used as a means of promoting, efficient and effective information access, processing, and use by people and organizations”* (Detlor, 2010).

Focusing on the organizational perspective of IM, normally companies focus their effort into managing data and information that is formalized and structured; in other words, data stored in a database. Although, unstructured information represents a larger amount of volume when compared to the first one, Detlor (2010) defines unstructured information as documents, email messages, presentations or reports - generated within the company or not.

With that being said, there is a point where managing and knowing how to manage both types of information can result in a better output and improve the competitiveness of the organization.

2.1 Assets Management

In the organizational context, physical assets represent the base for a sustainable and successful future (Joe *et al*, 2010). According to the International Organization for Standardization (ISO), *“an asset is an item, thing or entity that has potential or actual value to an organization”*. The value added by an asset may change during his life, being this one reason why an asset's life is not always equivalent to the time it belongs to a company (ISO 55000, 2014).

Management revolves around decision making. Managing assets involves knowing how to acquire, use (operate and maintain) and retire equipment, machinery, etc.; taking into consideration different variables such as opportunities, costs, and risks against desired performance (Adolfo *et al*, 2021). As a result of this decisions, it is possible to examine the need for, and performance of, assets and asset systems at different levels. As mentioned before, an asset is not always valuable for an organization, so an efficient management enables the application of analytical approaches over different stages of its life cycle.

2.1.1 Fundamentals

As any other topic, there are a few fundamentals that support the concept of Asset Management (AM). ISO 55000 (2014) defines them as:

- 1) **Value:** The value (which can be intangible or tangible, non-financial or financial) provided by assets is the reason why they exist and are important to an organization and its stakeholders- therefore, the focus is not the asset itself;
- 2) **Alignment:** the decisions made in order to manage the assets (having a technical, financial or operational nature) of a company should collectively enable the achievement of the organizational goals. This implied:
 - Asset management plans are made based on the integration of risk-based, information-driven, planning and decision making activities;
 - Asset management processes are integrated with the other functional management process of a company (finance, human resources, etc.);
 - A specific, well designed and implemented Asset Management System.
- 3) **Leadership:** taking into consideration that regardless of the business nature of an organization, the realization of value is only achievable with a leadership, commitment and workplace culture well established.
- 4) **Assurance:** due to the necessity to effectively govern a company, it is necessary that the decisions made regarding of Assets Management give assurance, including the development of: connections between the required purposes with the performance of the assets; processes that guarantee the capacity during all life cycle stages and enough resources and capable employees to demonstrate assurance by assuming asset management activities.

2.1.2 Asset Management Systems

As stated before, Asset Management Systems represent the process of monitor and manage their assets. Through tools, techniques and software in some cases, it is achievable to obtain a desired pattern of control.

These systems allows business to maximize their return and reduce costs; it also allows stakeholders to keep track of overall performance and condition, allowing them to use the assets more efficiently according to their stage of life cycle (ISO 55001, 2014).

Some benefits associated with this digital solution are, according to ISO 55000 (2014):

- While achieving the organizational objectives, becomes possible to preserve the asset's value (through improving the process of decisions making by balancing in an efficient way different variables such as performance, opportunities and risks), improving incomes and returns and reducing costs;
- By making better decisions, consequently it will improve health and safety conditions, good will and reputation, leading to a reduce in financial losses. The environmental and social impact will also decrease, resulting in a reduce of costs associated with liabilities;

- Developing more the last sentence, through managing better their assets, a company will improve its ability to reduce emissions, preserve resources and adapt to climate change, improving its ethical business practices and bettering its social responsibility perception; this changes in the processes will improve its services and/or products as well, exceeding the standards established by stakeholders and customers.

Depending on the organization, assets can be managed in groups (by types, systems, etc) or individually. Regardless of the choice, managing them with efficiency demonstrate compliance since legal and regulatory requirements are respected with maximum transparency. This, not only improve processes, as stated before, but also helps reviewing them guaranteeing that the asset performance is maximized; as a result of all of these consequences the reputation of the company itself will enhance (ISO 55002, 2014).

2.2 Maintenance Management

Due to the technological revolution felt throughout the years, industrial equipment has become more and more mechanized and automated changing the way human resources are distributed: the number of people working in the production decreased and increased the capital employed in civil structures, production equipment and in the maintenance areas (Amik and Deshmukh, 2006).

As a result of these changes, guarantee that the assets of a company are operating with the best performance/costs ratio becomes a priority; because of that, Maintenance Management emerged as the process of controlling this equipment, resources and procedures by adjusting different variables such as time and cost, ensuring maximum efficiency. Thus, Maintenance Management fits into the concept of Assets Management, while the last one is aligned with the overall business activities and goals of the organization, the first one is a result of software, best practices and trained personnel, focused on defining and follow a maintenance plan. The decisions made based on the preservation of the assets in an industrial environment can impact significantly the long-term success of an organization (Trout, 2022).

From the most basic one, to complex and sophisticated equipment, depending on his usability, every single one will eventually breakdown or malfunction. In companies with production as its main activity it is fundamental to define procedures to maintain their assets. When done properly, Maintenance Management brings a lot of benefits to an organization, standing out the following ones:

- **Cost budgeting**, based on the data collected and evaluation of the asset, provided by maintenance tools, managers are able to control more the use of funds in order to invest them in the best deals;
- **Scheduling work** since Maintenance Management englobe much more than only equipment and facilities, it is also important to organize the human resources necessary to perform assigned tasks, by priority levels. A good plan allocating time and labour resources allows the company to perform them with minimum downtime and with less losses;
- By evaluating each asset of an organization, it becomes possible to **analyze each function**, if it is working on its optimal way or not; by doing that, **assets life is extended** and improvements can be made with low cost items;
- Through the information collected, programs like **training new employees for new tasks or positions, becomes easier** with more information and resources available;

- Considering the constant mind-set of improvement installed nowadays, the same data can also **help stablish trend lines and enroot problems** not detected until then (Trout, 2022), (O'Donoghue and Prendergast, 2004).

2.2.1 Maintenance Strategies

Depending on the equipment and their own specifications, there are different Maintenance Strategies that can be followed, since each will lead to various maintenance costs and asset availability.

Nowadays, there are four strategies identified. The most used way to classify them, according to Schneider *et al.*, (2006), is distinguishing between the condition of the component and the importance of itself as an important factor to take into consideration, Figure 3.

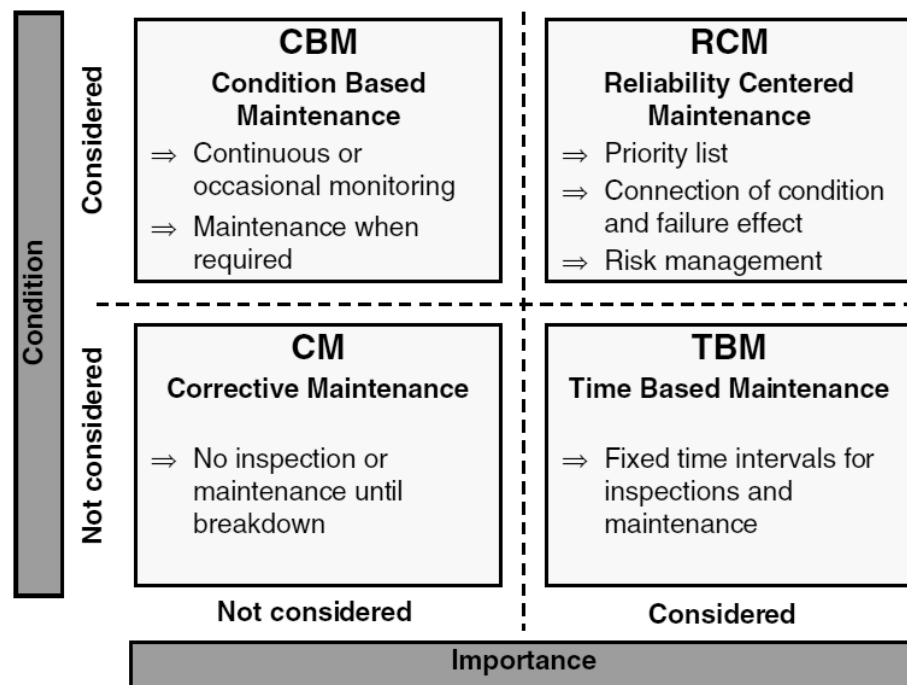


Figure 3: Maintenance Strategies (Blazer *et al.*, 1999)

Although some of these strategies are a result of digital transformation solutions- as it will be developed in the next subtopic- these new approaches carried a lot of new opportunities and set new quality standards, nevertheless old methods like Corrective Maintenance are still useful in some cases.

In Table 1 it is organized a list of advantages and disadvantages of these four strategies (Arbour, 2019), (Blazer *et al.*, 1999), (Schneider *et al.*, (2006):

Table 1: Comparison of different Maintenance Strategies

	ADVANTAGES	DISADVANTAGES
CM	- Minimal planning; - Simple process; - Ideal for low-priority and reduced cost equipment.	- Unpredictable failures; - Expensive and extended downtimes; - Safety risk can be high.
TBM	- Simple Tasks usually- do not need extensive training personnel; - Cheaper than breakdowns; - Work history can be easily recorded.	- Parts replaced before end of life; - Parts can still fail, especially when inspections are not done properly; - Involves planning time.
CBM	- Uptime optimized since maintenance only occurs when needed; - Reliability improved; - Decisions based in data analysis.	- Costs associated with implementation; - Advanced skills and knowledge required.
RCM	- Each component is analyzed and defects can be detected prior failure; - Reparations can occur without stopping operating; - In expensive and complex equipment long-term costs are lower than the cost of failure.	- Large investments of time and money are necessary; - Human and tech resources capable to handle and work with these systems are required.

2.2.2 Computerized Maintenance Management System

With the rise of Industrial Internet of Things (IIoT), is becoming possible to collect data and integrate it with connected devices in order to improve manufacturing operations, thanks to the use of intelligent maintenance software. Figure 4 shows the evolution.

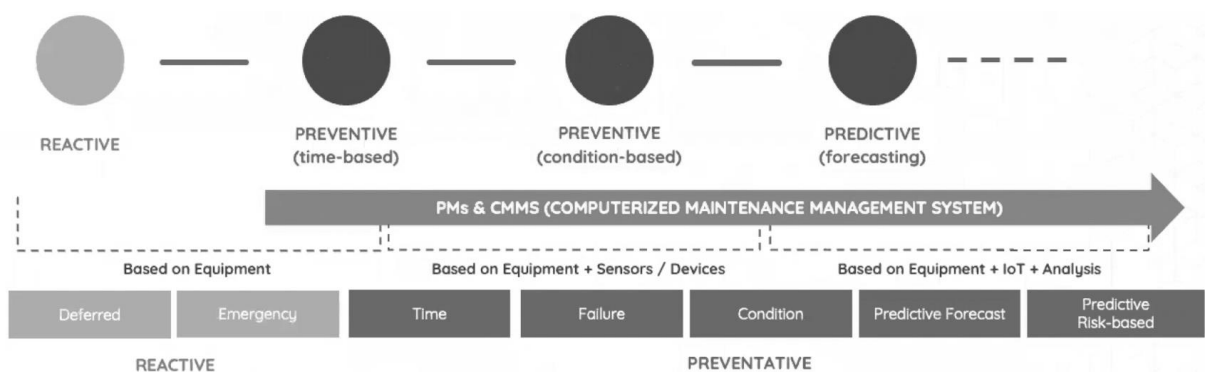


Figure 4: Evolution of Maintenance Strategies (Arbour, 2019)

To accomplish the benefits mentioned previously, it is necessary to achieve an effective combination of economic and technical expertise, since the majority of costs associated with maintenance are hidden and not always noticed in a short period of time, as listed in Figure 5.

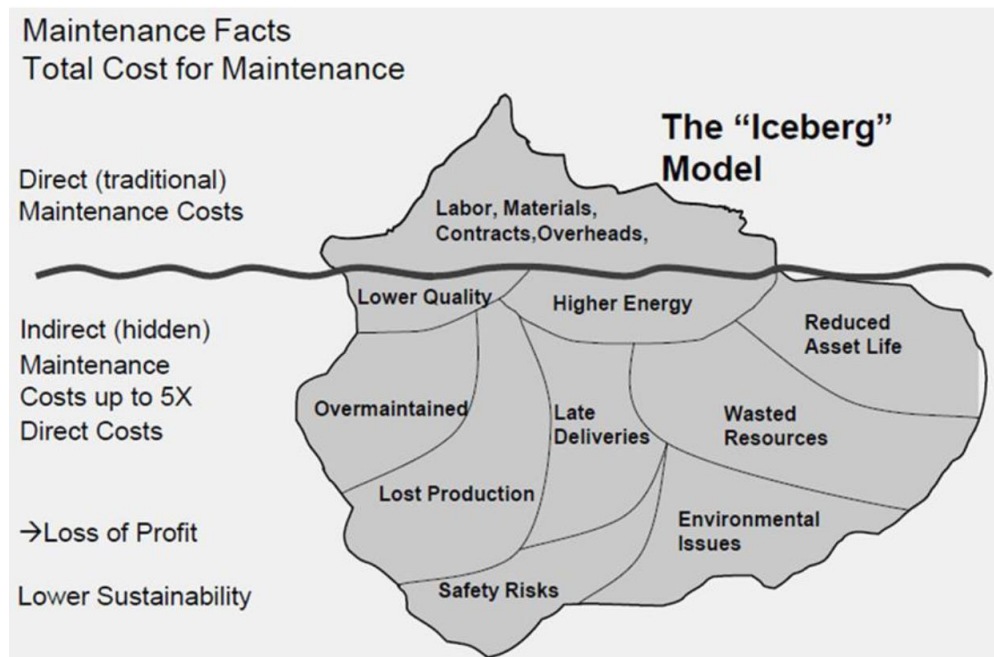


Figure 5: Total Costs of Maintenance - the "Iceberg" Model (Wienker *et al*, 2016).

After acknowledging how much impact this process of maintaining a company's assets has, one part just as important in order to guarantee maximum performance is to interpret and know how to handle the data collected. "Managing this process without a computer-based support is almost impossible", according to Wienker *et al*, (2016). As a result of this necessity, these same authors also claim that a CMMS offers the support needed for the already defined maintenance strategies. Often, the implementation of this systems fails because it can be perceived as a maintenance strategy itself.

Another reasons to justify poor implementations are:

- Jump to the decision of utilize a CMMS without being sure what stage of maintenance evolution are the companies in:

Since these systems are tools to analyze and monitorize different equipment it is important to already have a proactive strategy defined, taking into consideration what type of equipment and their function in the organization's context. With that being said, CMMS are more useful for Predictive Maintenance strategies rather than Corrective ones.

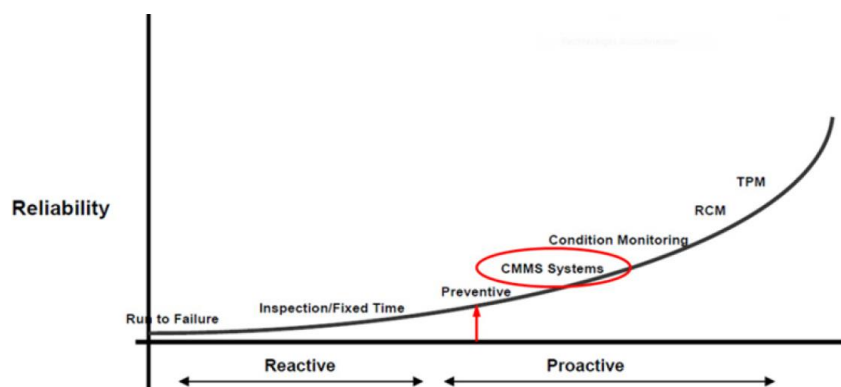


Figure 6: Stages of Implementation (Wienker *et al*, 2016).

- Lack of Communication

Implementing a CMMS involves changes in the way of work; thus, it is also necessary to reassure that the personnel affected are fully aware of the benefits created by these solutions, in order to commit and do not demotivate in the long term. These type of systems will only be at their full ability if users can communicate difficulties freely while feeling eared.

- Do not have the functional IT - Information Technologies - infrastructure necessary to implement and maintain the system run without problems

These type of decisions affect not only the maintenance personnel as stated before, but the IT department as well, since they will be the bridge between the users 'will and the system's capacity of delivery. For that, it is also important to guarantee a good network and quick respond capacity, besides resources and well trained employees to maintain it.

2.3 EAM vs CMMS

Enterprise Asset Management, EAM, according to IBM (n.d.), is a result of the combinations of services, software and systems conceived to address and handle the total asset lifecycle management (Figure 7). Although, it shares some objectives with a CMMS (both aim to increase productive uptime via asset maintenance- work order management, planning and scheduling functions) it also involves other areas, such as reporting and analysis; supply chain and inventory optimization, safety and health areas and financial management as well.

Taking this into consideration, EAM can be perceived as an asset lifecycle strategy itself, rather than just a tool, as CMMS (Emaint, n.d.); by being a part of a EAM system it helps centralizing assets information.

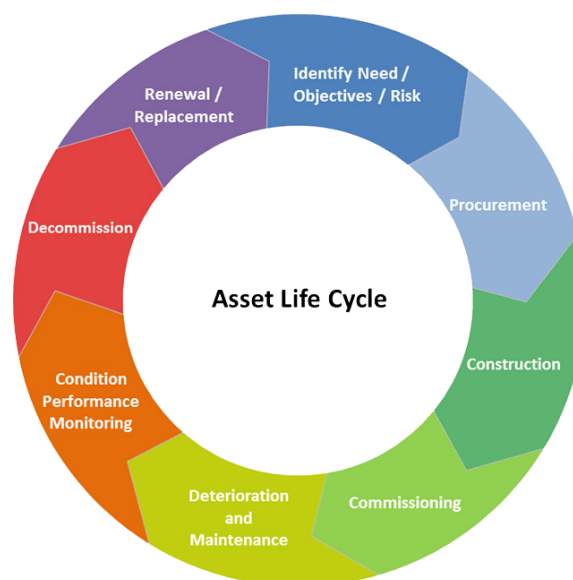


Figure 7: Asset Life Cycle (Leal, 2022)

Since EAM capabilities overlay CMMS functionalities, Figure 8, it is easy to think that the first one represents the best option regardless of the case; however, according to Agarwal (2018), the first one is more indicated to asset-intensive industries with several locations and extensive equipment. Organizations that require robust maintenance and asset management skills combined. For smaller companies, where the focus is on driving asset-uptime, a system like a CMMS, capable of handle maintenance management, workflows and inventory management is enough for their needs.

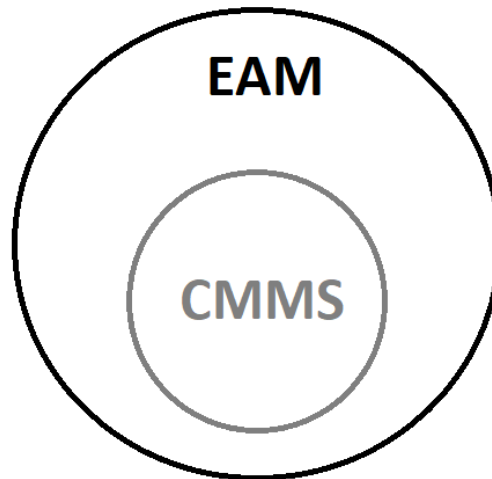


Figure 8: EAM and CMMS (adapted from Emaint, n.d.)

2.4 Documentation

According to ISO 12651-1 (2012), a document represents a “*recorded information or object which can be treated as a unit*”. This is why they play a key role within the company at various levels, and why it is important to manage these files efficiently, fitting them in with the company's structure.

Given the evolution in the past few years, more and more different types of files used by an organization are included in this concept. Sprague (1995) lists the following:

- Contracts and agreements;
- Reports;
- Manuals and handbooks;
- Business forms;
- Correspondence;
- Memos;
- New items and articles;
- Drawings, blueprints, photographs;
- E-mail and voicemail messages;
- Video clips;
- Script and visuals from presentations;
- Computer printouts;
- Transcripts from meetings.

2.4.1 Information Levels Management

Taking into account the diversity of records and consequently information circulating within a company, Pinto (2010) defines three hierarchical levels of management within an organization: Institutional, Intermediate and Operational (Figure 9).

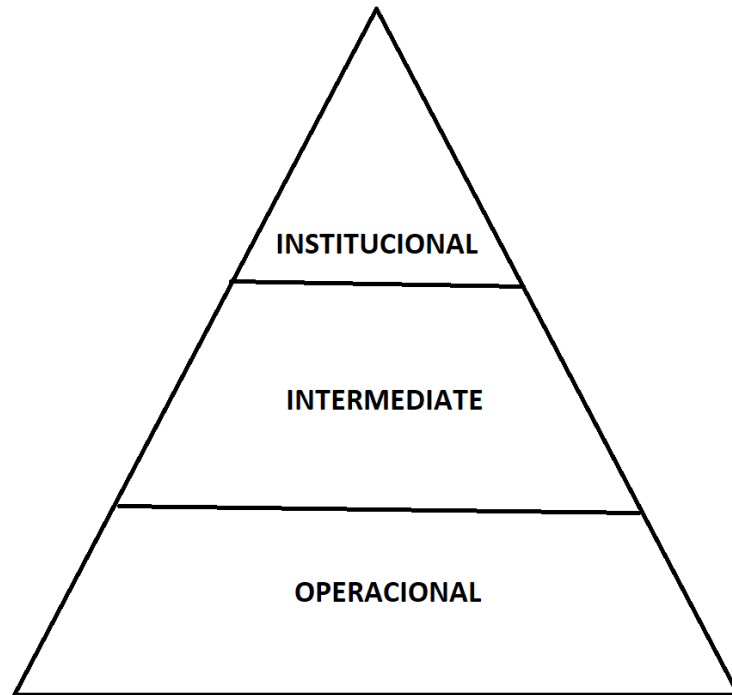


Figure 9: Management Levels (Pinto, 2010)

- The **Institutional level** corresponds to the top level involving administration, management and associated top positions. This level is characterized by the associated strategic component and the handling of available resources in favour of the development of general policies;
- At the **Intermediate level** a tactical aspect is presented, moving resources in the short term, drawing up plans and actions specific to a department or area of an organization. Given the general policies of a company, this level is usually associated with managers and directors of departments or functions;
- Finally, the last hierarchical level corresponds to the **Operational level**, characterized by the strong associated technical component, where the focus is on streamlining procedures and task performance. It is closer to the workers, working essentially from them to them. It is generally associated to an operations manager, or similar, depending on the nature of the company.

Integrating this last level of management and representing an integral part of the documents listed above, Technical Documentation emerges in order to provide information on a service or equipment to interested parties; maximizing its capability while safeguarding the entity in charge for the product and its functionality; Since its main goal is to describe the capacities, a procedure or the architecture associated with something, these documents should be clear and written focusing on the target audience (end-users or for internal audiences) (Indeed, 2021), (Zakoldaev, 2019).

In addition to the type of information and the target audience, a document, including Technical Documentation, is also defined by its format. Ismael *et al.* (2017) states that most developed countries have documentation in paper format, however, there is a growing increase in the volume of electronic documents, hence, to integrate and bring together this information, EDMS- Electronic Documentation Management Systems- are increasingly becoming tools required by organizations.

2.4.2 Document Management Life Cycle

The management of electronic files has been a major concern for computer scientists, since it is necessary to ensure, in an increasingly efficient way, a good archiving activity and information search in these files. Despite the increasing volume of electronic documents, it is useless if they are not inserted in a management system since the information is no longer within the reach of the interested parties.

Therefore, Document Management is currently presented as a computer system capable of transferring, storing and distributing any electronic document, allowing its interconnection with other systems and/or devices (Aurelia and Ana, 2008).

According to ISO 9000 (2000) and ISO 10013 (2001), a ISO9000 document control process is divided in three phases: (1) document creation/release, (2) change and (3) access. Looking at it from a cycle perspective, each category can be subdivided. So further developing this premise, Yao *et al.* (2003) formulate the following cycle, presented in Figure 10:

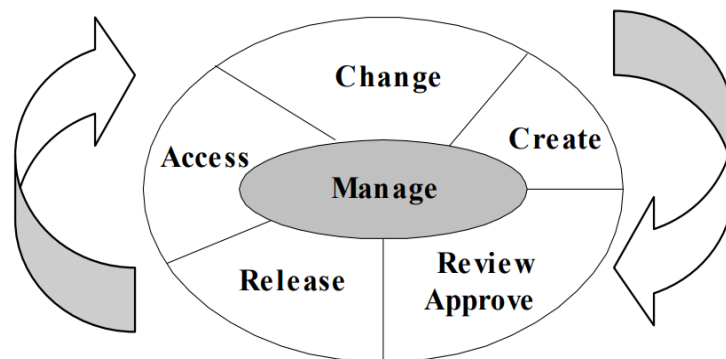


Figure 10: Document Management Life Cycle (Aurelia and Ana, 2008) (Yao *et al.*, 2003)

Documentation Management Systems

At the beginning of this chapter, the area where this project fits in, Asset Management, has been presented, as well as the computer systems associated with it, the importance of information and the documents that contain it for the various levels of a company.

In common, all the concepts and perspectives presented demonstrate an adaptation to the current digital transformation, with a new concept and a new need emerging: the creation of document management systems, especially electronic ones.

According to the Association for Intelligent Information Management, AIIM (n.d.), Documentation Management Systems represent the actions of store, manage and track through the use of computer systems and software of electronic documents and images of paper-based information captured through a scanner, in an organization.

As it has been one of the areas that has most evolved over the last decade, as stated previously, the same entity mentioned, AIIM, carried out a study in 2011, as Gomes Silva (2017) documents in his dissertation, "*Our tracking over the last few years shows that lack of confidence in the accuracy, accessibility and trustworthiness of electronic information has remained at 40%*"; in this research was analyzed the reason why an information management system was adopted. The results obtained are presented in Figure 11:



Figure 11: AIIM study results (Gomes Silva, 2017) (Doug Miles, 2011)

The main result identified by the research carried out meets what the scientific literature itself points out as a problem: the lack of organization of the contents generated and handled within a company.

Both Weintraub *et al.* (2001), and AIIM (n.d.), refer some key features associated with document management system that help solve this issue (Figure 12):

- **Document check-in/check-out:** keep control of the changes made, not allowing overwriting; if some change is not desired, it is possible to roll back to the previous versions;
- **Version control:** keep track of the previous versions of the document and how it evolves;
- **Document-level security:** Digital signature has been used for controlling user's access and document validation;
- **Attribute and full-text indexing, search and retrieval:** a document can be easily found since these systems allow the user to classify a document into many properties besides what is written.

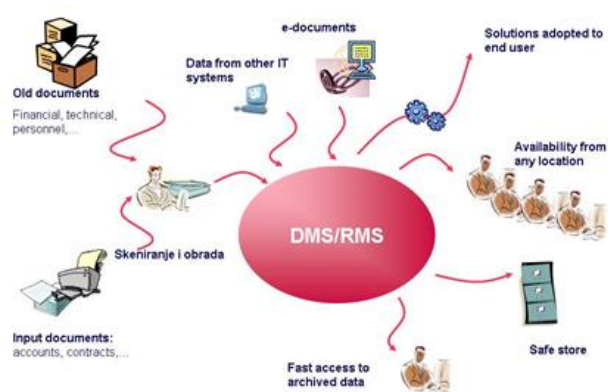


Figure 12: DMS workflow (Simić *et al.*, 2008)

Implementation Process of a DMS

Although it has essential features for an organization nowadays, it is important to consider the risks of implementing an unsuitable DMS, such as: high costs associated with finding entries and information, incorrect data in the system, not respect the requirements defined, reduce competitiveness and faulty decisions that compromise the productivity of a company (Simić *et al.*, 2008).

For this reason, the same authors that recognize the key features, Weintraub *et al.* (2001), define the five essential components to implement a Documentation Management System. Figure 13 illustrates the complementary nature of these components:

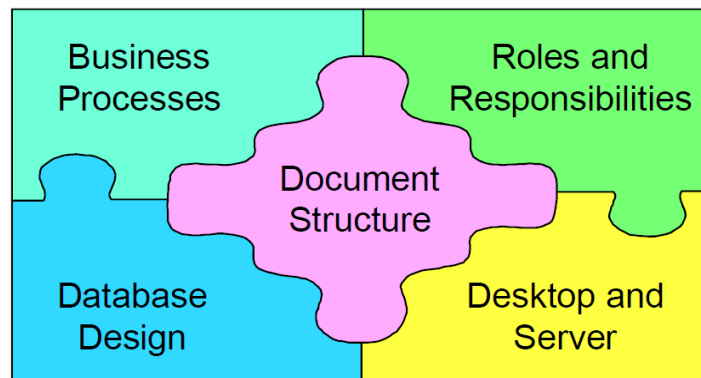


Figure 13: Five components of a DMS (Gartner Research. Weintraub *et al.*, 2001)

- **Creation of a document structure:** the first step should be defining all attributes, document types and relationships, if it exists, with other documents;
- **Analysis of the business processes:** companies should evaluate their processes based on the benefits they expect to obtain from the DMS;
- **Definition of responsibilities and roles:** since the implementation of such systems represents a multidisciplinary process, it is important to define who has sufficient knowledge, skills and responsibility to be in charge of each aspect - system administrators, authors, reviewers, users, etc.;
- **Design of the database:** design the structure, relationships, content and business data rules related with documentation;
- **Description of the desktop and server infrastructure:** infrastructure responsible for the necessary support to the implementation of the system; it must be organized in an efficient way to guarantee the response capacity to the needs that arise throughout the project.

Of the five steps defined, only the last two can be formally executed by standard procedures by IT teams, since the remaining steps always depend on the nature of the industry, the capabilities possessed, budget, and other limiting factors that justify the individual evaluation of each implementation by the team responsible for project management and the departments involved.

Functionalities of a DMS

Once the implementation process is complete, Carvalho (2008) defines Three Major Functionalities inherent to a Document Management System: usability, security and administration.

Associated with the usability function, as the name suggests, are the operations responsible for ensuring easy utilization and navigation through the information, guaranteeing clear communication; which include:

- Creation of templates;
- Formatting, cataloguing and indexing documents;
- Issue Classification- version, status, revision date;
- Document organization- hierarchical or not;
- Document Revision;
- Collaborative Work functionalities;
- Advanced Research skills;
- Document movement register;
- Support of different formats of records.

Regarding security functions, since a DMS manages confidential corporate documentation, it is important to guarantee the required access and control measures. Within the framework of this theme are the following operations:

- Encrypted data communication;
- Validation through digital signatures;
- User profiles and permission control.

Responsible for the overall operations of managing and ensuring the normal workflow of the system, the administrative functions englobe different operations, from different departments since it requires different skills and control of different variables.

Benefits of a DMS

By defining a good team for the implementation and maintenance of this system, its capacity to respond to the needs is maximized and the functioning of the operations described above is guaranteed. In these situations, these systems present innumerable benefits for the industry, highlighting the following, according to Sathiadas and Wikramanayake (2003):

- Lower cost of document creation and distribution: no paper involved;
- Faster creation and update processes;
- Improved and customized access: access to multiple files at once;
- Increase reuse and leverage of information: it is possible to link different documents or concepts in one file;
- Improvement of collaborative work;
- Reduced cycle times in document related processes;
- More complete regulatory;
- Refined control and reporting politics.

2.5 Metadata

Metadata is a concept that has evolved considerably in recent years, currently defined as the information stored within a file, despite not being evident to the user in many cases- it is an electronic “fingerprint” that automatically adds identifying characteristics. Bargmeyer and Gillman (2000) define Metadata as “*data about data*”, in a loosely way. It represents a strategy to make tracking and working with specific data- documents included- easier.

More than a strategy, metadata has become an indispensable component in research data management, as it supports the actions of data retrieval, interpretation and reuse. Castro (2020) summarizes that “*Metadata can be seen as a subset of data documentation, in the form of structured information to explain the purpose, origin, spatial and temporal coverage, authorship, access conditions and terms of data use*”.

Metadata Management encompasses different concepts, from the content, to the structure and design required. It is associated with vocabulary management and the management of metadata related to descriptive data, designs and processes. The development of models for defining content for metadata is also included. The construction and structuring of these relationships between terminologies and information allows a better definition and organization of terms. In addition to the resulting organization, there is also a better understanding and quality of the data held. The policies and criteria defined, in addition to better administration, end up creating and maintaining higher quality standards. (Bargmeyer and Gillman, 2000).

Types of Metadata

Given the versatility presented by metadata, depending on their purpose they can be divided into different types, namely:

The first, and most familiar one, is known as **Descriptive Metadata**, responsible for letting the user discover and locate data and their references, Gartner and Gartner (2016) refer that, because of its purpose, it is also designated as finding metadata. By using this type of metadata, the user should be able to find out something about the object, improving the accuracy of their search, even when they are not looking for anything specific; on the other hand, it allows them to exclude results from their search. The information provided allows the end-user to decide whether or not it is relevant to what they want.

Although descriptive metadata is the best known type, it is not, however, the most widely used today. Currently any information system needs another type to maintain its normal

operation, in this case the **Administrative Metadata** are responsible for ensuring that the data is stored, preserved and accessible when necessary. Given its vastness, this type of metadata has a subdivision.

Castro (2020) summarizes the three subcategories as follows: *Technical Metadata* as responsible for describing the tools needed to store and manage files, Gartner and Gartner (2016) add that they are usually automatically generated and invisible to the user; *Preservation Metadata* as information providers to support long-term management and maintenance strategies- responsible for ensuring that digital content will be well used and accessed in the future; and finally, *Right Metadata* related to the rights of intellectual properties used as resources.

Finally, and not so obvious, there is the **Structural Metadata**: responsible for creating the link between small data, necessary for the normal functioning of a larger and more complex system or digital object, which presents some value to the end user.

Analyzing the three categories presented, it can be seen that their importance and usefulness in the modern world is much more extensive and complex than one can imagine, and that they have become fundamental to the way of working and searching for knowledge today (Corti *et al.*, 2019).

Riley (2017) goes further and defines a final category as **Markup Languages**, being the result of a blending of metadata with content, something only used with some forms of metadata. It presents itself as an integration of metadata or other structural/ semantic markup integrated with data- such as the insertion of a paragraph or a formatting- use of italics in a text. Table 2 summarizes the purpose of each category of metadata presented above:

Table 2: Types of Metadata (Riley, 2017)

Descriptive metadata	For finding or understanding a resource
Administrative metadata - Technical metadata - Preservation metadata - Rights metadata	- For decoding and rendering files - Long-term management of files - Intellectual property rights attached to content
Structural metadata	Relationships of parts of resources to one another
Markup languages	Integrates metadata and flags for other structural or semantic features within content

3 Initial State Survey and Analysis

Given the necessary theoretical framework about the area, the systems involved and the consequent importance of technical documentation and its classification strategies, in this chapter a more in-depth analysis will be presented on the initial situation point of the problem, through the collection done in different factories of the group. This analysis will allow a better interpretation of the individual needs of each plant and the specifications needed for the final solution to cover the main requirements identified.

After the identification of the main problems, a survey was carried out on the initial considerations, taking into account the decisions made by the group corporation *a priori*. After this initial analysis, the main IT systems used by Sonae Arauco were analyzed, specifically by the departments of Asset Management, Maintenance and Production, in order to understand what their capabilities were and if there would be the possibility to build a Document Management System that understands both the needs and the identified considerations.

3.1 Problem Analysis - Documentation AS IS Situation

As explained in the first chapter, this project is part of an action to improve the asset and maintenance management strategy and systems. After the decision to invest in an EAM system, replacing the previous CMMS, capable of being integrated with the company's current ERP, one of the new problems identified was the disconnection between it and the information consultation process.

Through a visit to the Mangualde plant and by contacting other facilities of the group, it was possible to understand what progress had been made and/or what decisions had been taken regarding document management. The questions asked were pre-selected and the same to all of them for a better comparison and more precise analysis afterwards. The referred interrogations were the following ones:

1. *How do you have the documentation organized?*
 - a. *Folders?*
 - b. *Inside the ERP System? In the Server? In Paper?*
2. *Do you have any type of coding rule for the document?*
(any code connecting the functional location from ERP system with the documentation)
3. *Types of documents distinguished?*
4. *How do you upload documentation?*
5. *How do you access to the documentation?*
6. *Any vision about how the plant see this documentation process working?*

Gathering all the answers obtained, from all the facilities integrated in Sonae Arauco as a group, the answers of six of them were analyzed. The first conclusion was how manual this process still is, representing the time spent searching for the required information, a great loss of value- four out of the six still have the majority of their technical documentation in paper, hold into archives or offices- Figure 14 and Figure 15.



Figure 14: Valladoid's Archive



Figure 15: Mangualde's Archive

The records retained by each factory, are not identified or separated by type of documentation - based on the type of information it provides. Both the paper and the already digitized documentation have an organization strategy based on the location/zone of the plant. From this, it may or may not be distinguished by equipment. Another point identified in more than one facility is the lack of a review and update system: it was reported that there is still a lot of stored documentation of equipment that no longer exists or is outdated - constituting a source of wasted space and resources.

3.1.1 Mangualde

This Portuguese factory, predominantly has their files in paper in a room, as it is possible to see in Figure 16. A short time ago, one production line was deactivated and now only two are in operation. Regarding each one, it was possible to verify that:

- **Production Line 1** (deactivated): little documentation and disperse;
- **Production Line 2**: very well documented on paper;
- **Production Line 3**: corresponds to the most recent one and therefore, as it would be expected, already has some documentation in digital format, but without any defined organization.

Going through the shelves, it can be seen that the information is, as previously mentioned, organized by area, followed by equipment, according to the order of the workflow.

Most of the documents come from the manufacturer/supplier and therefore start with an index identifying the different parts considered within the folder.



Figure 16: Mangualde's Archive, another perspective

3.1.2 Valladolid

In this factory, located in Spain, the digitalization process already started. The documentation in digital format is uploaded to the server, as shown in Figure 17, however, it does not have a specific sorting criterion, it is only placed in the location and corresponding equipment, if applicable. In addition to the documentation of no longer existing equipment, there is the recognition of the lack of efficiency of the current search system. Similarly to Mangualde, the paper documentation is located in an archive (Figure 14) and in this one, the outdated documentation is moved and removed from the space.

Regarding access, the entire Maintenance team has permission to consult the files.

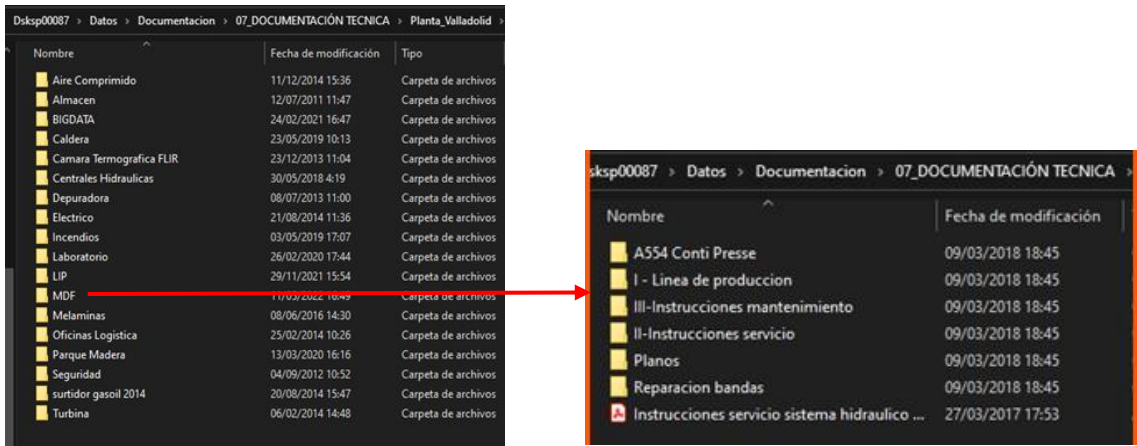


Figure 17: Valladolid's Server Organization

3.1.3 Meppen

Of all the plants analyzed, this one located in Northwest Germany, has the most advances. All its documentation is organized, by location, on the server, where everyone has access to consult and/or edit.

To improve their search system due to the increasing volume of documentation they are trying to define a convention for the titles of the documentation in order to facilitate the process, although there is nothing decided yet - Figure 18.

Name	Änderungsdatum	Typ	Größe
01-Stirnradgetriebe_-_Installation_und_W...	09.03.2022 07:20	Adobe Acrobat D...	1.652 KB
02-Lubrication_and_oil_supply_units_-_E...	09.03.2022 07:20	Adobe Acrobat D...	1.334 KB
03-Drive_-_LD-2450Z-20-L-E6_G6093813_...	09.03.2022 07:20	Adobe Acrobat D...	442 KB
04-Drive_-_LD-2450Z-20-L-E6_G6093813_...	09.03.2022 07:20	Adobe Acrobat D...	96 KB
05-EHD260230_PL060-1L-SD-GZWQ	09.03.2022 07:20	Adobe Acrobat D...	391 KB
Mail_Getriebe_Kühlstation	04.02.2022 07:11	Outlook-Element	5.886 KB
Mail_Adapterplatte Getriebe	04.02.2022 07:27	Outlook-Element	747 KB
Mail_Kupplungsdoku	04.02.2022 07:07	Outlook-Element	2.672 KB
Mail_Zulässiger Vibrationslevel am Stopfs...	30.03.2022 13:23	Outlook-Element	287 KB
TD_Bogenzahnkupplung_Jaure	04.02.2022 07:05	Adobe Acrobat D...	1.706 KB
TD_Klemmverbindung_Bogenzahnkuppl...	04.02.2022 07:06	Adobe Acrobat D...	775 KB

Figure 18: Meppen's Title Convention- Initial Steps

3.1.4 Nettgau

Following the same line of thought as Meppen, Nettgau also presents an advanced digitalization status, using the same strategy of uploading the files to the server. However, differing from the others, the information is managed by groups, according to the nature of the asset. Considering the area that this project fits into, the technical documentation is in the group of Electrical and Mechanical Equipment.

Taking into account the level of knowledge of the members, within the groups, the documentation is separated according to the type of information it provides, being further separated by production lines and their machines. Every member of each group is responsible for managing and editing the documents - Figure 19.

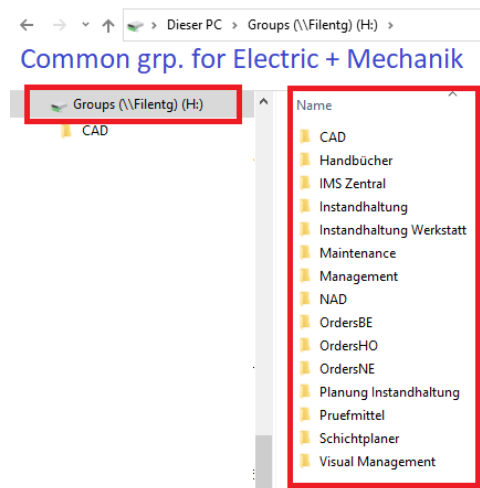


Figure 19: Nettgau's Server Organization

3.1.5 Beeskow

Beeskow has part of its documents on paper, without an associated codification and therefore a large part is dependent on manual search methods, going to the offices of those responsible or to the archive. The digitalized documentation is provided by the suppliers, organized by area/location, according to a codification created by them, and deposited on the server. The lack of involvement of the Maintenance team in this process sometimes creates difficulties in finding the desired file.

In the digitalization process, regarding the upload system, only the technicians of the electrical part make use of it, placing the documents in the most appropriate asset/area according to their usefulness.

3.1.6 Linares & White River

Linares, similarly to Beeskow, presents part of its documentation on paper and the rest on the server - without a defined codification. They have not yet started the digitalization process, so when they need it they either go to the offices where the information is located or they search on the server.

White River, the facility located in South Africa, is in a similar point: already started the digitalization process but it is still very dependent of the records stored in physical locations.

In order to synthesize all the information presented above and allow comparisons to be made, Table 3 lists the current situation points between the different plants of the group analyzed:

Table 3: Comparison of the Initial State of different Plants

CRITERIA	MNG (Mangualde)	MEP (Meppen)	VAL (Valladolid)	BSK (Beeskow)	NET (Nettgau)	LIN/ WRV (Linares / White River)
Digitalization	NOT YET	ADVANCED	IN PROCESS	LITTLE PROGRESS	ADVANCED	NON/LITTLE PROGRESS
Storage	PAPER	SERVER	SERVER/ PAPER	SERVER/ PAPER	SERVER	PAPER/ SERVER
Organization	LOCATION (OLD MAXIMO)	LOCATION	AREA OF THE PLANT	AREA BY EXTERNAL ENTITY	EQUIPMENT	LOCATION
Accessibility	WHO NEEDS	EVERYONE	MAINTENANCE TEAM	WHO NEEDS	ELECT+MECH TEAMS	WHO NEEDS
Naming convention	----	STARTING	----	---	---	---

3.2 Initial Considerations

Taking into account the methodology established in the sub-chapter 1.4 of this dissertation, after defining the project's objectives, it was necessary to define the initial features to be taken into account in order to reach a solution that respects them and, consequently, serves the real needs of the company in question.

Once the initial state of each plant was mapped out, it was necessary to assess which considerations needed to be taken into account before proceeding with research into best practices and which solution would best meet the needs of the company in question.

With that said, by meeting with the director and engineers of the Asset Management and Reliability department and the coordinators responsible in the IT team it has been concluded that:

Keep the Current Coding System

Consulting ISO 14224 (2016), to define a property it is necessary to understand the concept of taxonomy; which is a classification system that organizes elements into generic groups/ properties that they all have in common.

In this same standard, a schematization of how this classification should be carried out is presented: nine levels, the first being the highest and most generic, up to the ninth, representing a part or a piece of equipment - Figure 20.

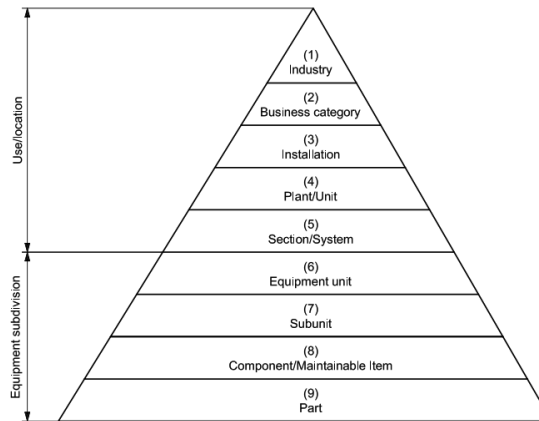


Figure 20: Taxonomy Classification (ISO 14224, 2016)

When analyzing the code previously established by the company, Figure 21, it can be seen that the same principle has been applied, having also defined a coding that respects the predefinitions of the EAM and ERP systems, so one of the first conclusions was to maintain the same coding rule for the associated locations/processes.

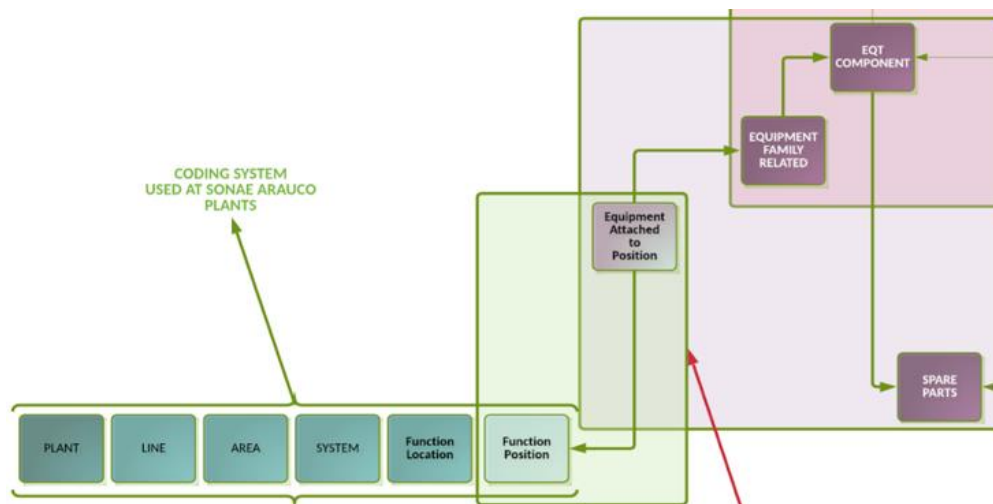


Figure 21: Sonae Arauco's Codification System

Design a Solution that uses the already adopted Services and Software

Given that the group had already started to design the architecture of the project responsible for the management of company documentation, explained in detail later, it was necessary to ensure that both projects did not conflict and complemented each other in their common objective: to ensure intuitive and organized access to information by all interested parts.

With this said, in a meeting with the person responsible in the IT department for the coordination of this project, it became clear that the group was not interested in considering the acquisition of new management information services or software. Thus, to achieve the intended goals, another point established was the use of Office 365 tools, namely Microsoft SharePoint, and IBM MAXIMO, as the software responsible for managing maintenance operations.

3.3 Available Tools

From the feedback collected in the first part of the project, it becomes clear the importance of evaluating and clearly defining the available tools: in order to understand which ones are best to obtain a customized solution as well as the most uniform as possible, since despite the different locations of the factories associated with the group, all have the same services and software; focusing on Document Management and the Assets Management area: Microsoft SharePoint and IBM MAXIMO.

3.3.1 IBM MAXIMO - Enterprise Asset Management Software

By being an EAM, as explained in the literature review of this dissertation, IBM, International Business Machines Corporation, define MAXIMO as *“a single, integrated cloud-based platform that uses artificial intelligence, IoT and analytics to optimize performance, extend asset lifecycles and reduce operational downtime and costs”*.

That is, analyzing data with artificial intelligence technology in order to allow the users to make better decisions, ensure efficient asset management- maximize investments in assets, schedule maintenance operations (perform preventive maintenance) and guarantee a continuous and fluid workflow.

Currently, IBM has a sales policy based on organic development and support for business growth: the services contracted are adapted to the needs of the clients - they only pay for what they contract - with the possibility of installing extra applications and/or functionalities as the business grows. As it is a cloud-based system, MAXIMO allows integration with other software/computing systems.

Key Features

According to *Gartner, Inc.* (Maximo Reviews, 2022), a technological research and consulting firm based in Connecticut that leads research on technology and shares these results both through private consulting as well as executive programs and conferences, MAXIMO is classified with an overall review of 4.3/5; being its main features and most well developed ones:

- Work Management;
- Asset Management;
- Inventory Management;
- Work Scheduling;
- Material Requisition/ Procurement;
- Analytics and Reporting;
- Mobility;
- Barcoding;
- Location Tracking.

Architecture and Components

Since it is a complete EAM, MAXIMO uses multicloud deployment for greater flexibility, requiring multiple software servers. In an attempt to explain the integration of these different components, IBM (System architecture and components, 2022) organizes the information in the scheme presented in Figure 22.

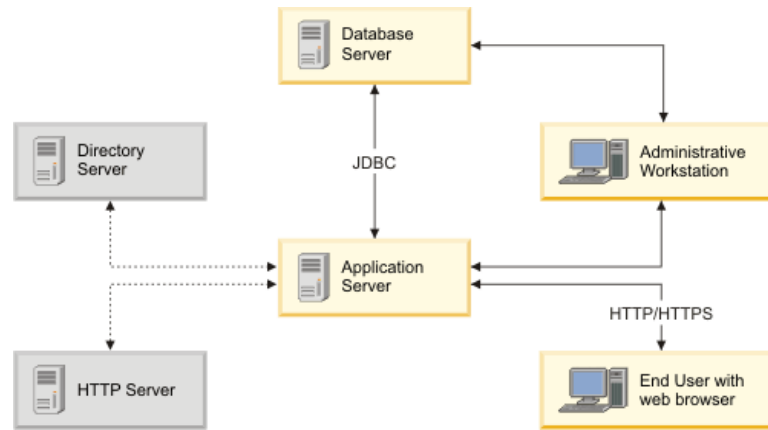


Figure 22: IBM MAXIMO Architecture and Components (IBM, April 19 2022)

- *Administrative Workstation*: initially used to install Maximo Asset Management; later to provide updates or the support for required configuration changes;
- *Database*: responsible for storing all asset-related information- condition, locations and relevant records;
- *Application server*: Manages Maximo Asset Management Java Server Pages, XML and business logic components;
- *Web Browser*: gateway to access Maximo, ensuring a connection to the internet or company network;
- *Directory Server*: server available for configuration to provide identity management and authentication for the Application server.

Web Version

Representing the main access, the web version starts by requiring authentication, only authorized personnel - in this case members of the group's maintenance department - have access to the software (Figure 23). After the appropriate authentication, the first work window shows the maintenance operations together with a set of predefined shortcuts in order to simplify the navigation process (Figure 24).

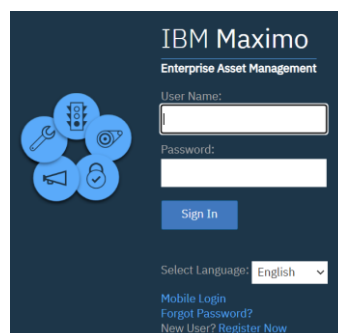


Figure 23: MAXIMO's authentication window

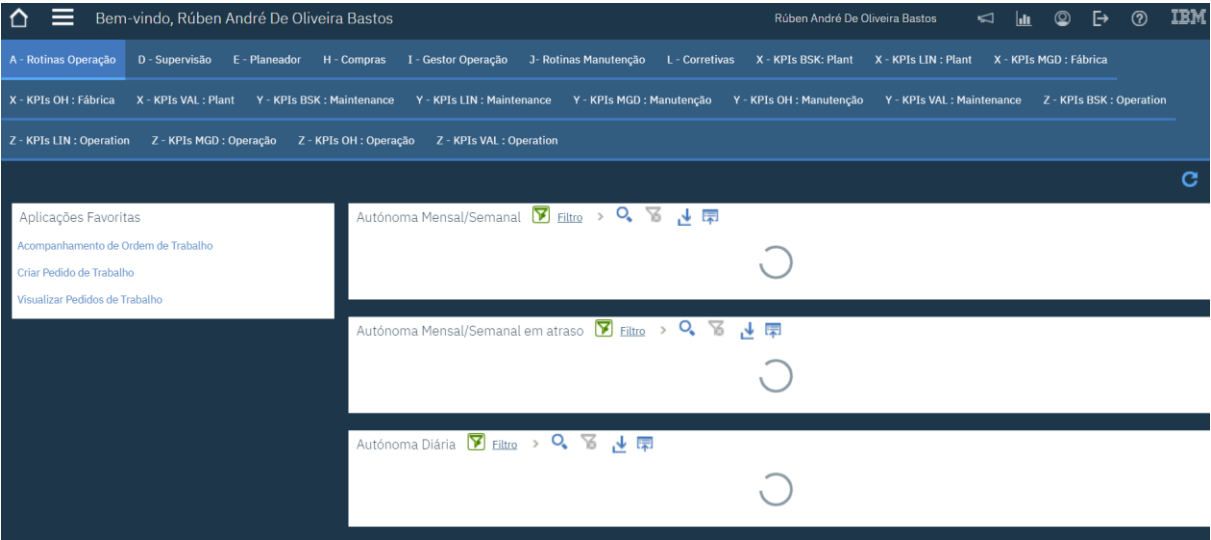


Figure 24: MAXIMO's first work window

Choosing to navigate according to location and/or asset, the information is organized hierarchically in the system by locations, starting with the location of the factory, tapering down to a specific position - following the coding system presented in the initial considerations, as shown in Figure 25.

Fábrica	
Linha	FAC
Área	FAC \ LINE
Sistema	FAC \ LINE \ AREA
Localização Funcional	FAC \ LINE \ AREA \ SYS
Unidade Funcional	FAC \ LINE \ AREA \ SYS \ LOC
Posição Funcional	FAC \ LINE \ AREA \ SYS \ LOC \ UND

Figure 25: Codification system integrated with MAXIMO

Associated with each location is information about each asset: specifications, condition records, work orders, etc.; there is also the possibility of attaching documents or files, such as images/photos of the equipment, using the attachment button shown in Figure 26.

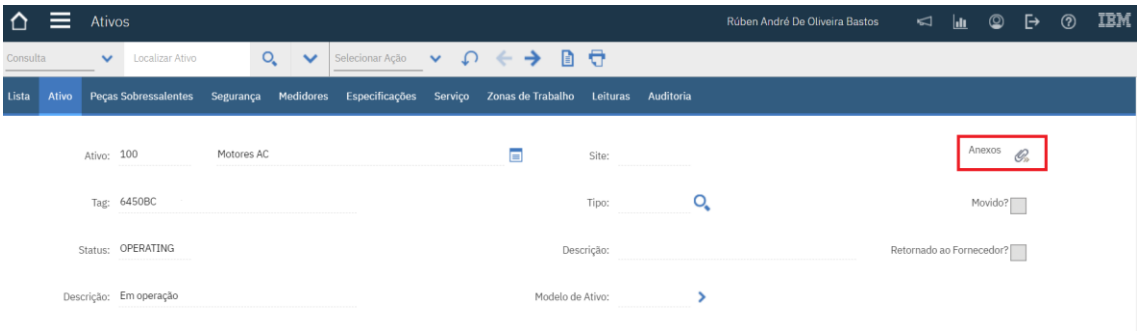


Figure 26: MAXIMO's Asset page with the attachments button

Mobility

With Maximo Mobile, built on the next generation of mobile technology, the application helps improve productivity by empowering technicians to easily navigate an intuitive platform - online or offline. Currently, in the company in question, the application used is for the execution of Working Orders - repairs, maintenance actions, condition assessment, etc.

Work Execution Functionalities (Figure 27):

- Start/Stop Work;
- Report time and materials;
- Filter work by scheduled start date;
- Search and sort work orders;
- Option to add comments on Working Orders;
- View and upload attachments, associated with Working Orders;
- Change status;
- Streamlined and Touch friendly.

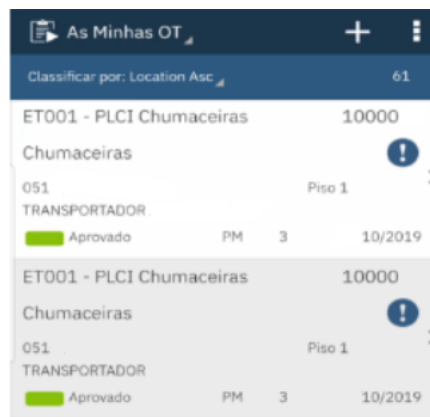


Figure 27: Mobile App for Working Orders Execution Screenshot

Service Request Functionalities (Figure 28):

- Allow end-users to quickly create Requests.;
- Data exchange with Maximo in real time;
- Integration with mobile device features like email, phone and camera.;
- In-app notification whenever a request has been resolved/ closed.

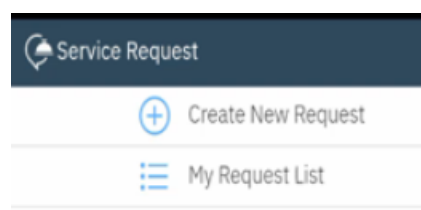


Figure 28: Mobile App Service Request Screenshot

3.3.2 Microsoft SharePoint

Microsoft SharePoint initially was launched as a document storage and management system, however, due to its high degree of customization (as shown in Figure 29, SharePoint covers different areas with different functionalities), Microsoft (April 19, 2022) define the platform as a “*cloud-based service that helps organizations share and manage content, knowledge and applications*”. The main goals of this platform are to empower teamwork, speed up the information research process and seamlessly collaborate across the organization.



Figure 29: SharePoint Key Feature areas (Gaspar,2010)

Key features

Further developing the multidisciplinary approach previously introduced, SharePoint as a platform is capable of, depending on each area:

- *Site*: Web analytics, audience targeting and governance tools;

The creation of sites in SharePoint is intuitive and allows the user to shape the platform according to his needs; the platform's great adaptability to other technologies/systems makes it even more attractive, as the client can create his own solution adapted to real needs. Being mainly a collaborative space it is also necessary to guarantee good privacy policies, so for teams, it allows the classification of data and projects into baseline, sensitive and highly sensitive; Considering that external entities such as consultants are often needed, some configurations are also defined, such as sharing files or specific folders and guest access on sites and teams.

- *Communities*: Personal profiles- management and search tools included;

SharePoint platform can be licensed individually or as part of the Microsoft 365 suite. It provides a collaborative environment, both inside and outside the company, as it allows several users to manipulate documents and the platform itself, through the accesses provided. It allows the hierarchical organization of a company's human resources in the system, through the creation of profiles from each individual's information, also enabling the integration of guests, as mentioned in the previous point, with tagging tools and notes to distinguish the different actions performed.

- *Content*: Document and record management- improved tools, metadata, content type management and automation services;

It has the capacity to manage and track all phases of a record: from its creation to its archiving, regardless of the associated format - from Office formats to PDFs and similar. It allows the classification of a document according to different properties (metadata) in order to guarantee an efficient organization and search for information; the management of versions and retention plans also contributes to a good workflow, all within the same platform.

- *Search*: Refined abilities, better search methods and integrations;

Invests in an interactive and visual search system - allowing to filter the results according to the metadata possessed, title, type, user, etc.

Since an organization has different employees with different needs, a multifaceted search using different systems is worth highlighting due to the ease of integration with other platforms - useful for different departments.

- *Insights*: decision-making and analysis tools;

From a complete reporting and analysis solution, it provides interactive dashboards and indicators to enable users to improve the decision-making process. It also allows the creation of a centralized control system, improving the efficiency of the IT department.

- *Composites*: Pre-built workflow templates, Business Connectivity Services;

SharePoint provides the components and tools necessary to create business solutions, even without coding. A very useful feature for the industry is that it can also handle data from other systems, allowing you to work online or offline (Microsoft, April 19 2022) (Gaspar, 2010).

Using the same consulting firm as a reference, according to *Gartner Inc.* (SharePoint Reviews, 2022), SharePoint has an overall rating of 4.4/5, highlighting as characteristics:

- Product capabilities;
- Service and Support;
- Integration and Development;
- Evaluation and Contracting.

3.4 Corporate Documentation Management System

Having already well cemented the premise of how fundamental it is for an organization to keep its documentation in order, Sonae Arauco has recently started to develop a system for the group's document management, focusing on corporate documentation; subject to the same initial consideration, it was decided that this solution would also be assembled from the services and software acquired by the group.

The project is being developed by the IT team and has not yet been launched, taking advantage of the previously described customization features of the SharePoint platform. This system will be integrated with the company's main access portal, where the repository will be located. For this system it is planned to upload all finished versions of documentation for each department, including the following types of documents:

- Policies;
- Processes;
- Procedures;
- Work Instructions;
- Manuals;
- Equipment Technical Documents;
- Product Technical Documents;
- Technical Specifications;
- Marketing Documentation;
- Certificates;
- Binding Requirements;
- Templates;
- Licenses.

According to the strategy outlined, at the time of upload a document is classified according to different properties, metadata, providing the information needed about its type and responsible department – *Title, Type, Process, Area, Country, Site, Language* and *Keywords* - keeping in mind that the list of properties is still subject to change. The prototype describing the strategy developed by the IT team is presented in Figure 30.

The screenshot shows a web application interface for document management. On the left, there is a sidebar titled 'Documents' with a sub-header 'Upload a Document'. Below this, there are several filter sections, each with a dropdown menu labeled 'Select value':

- Process**
- Type**
- Area**
- Country**
- Site**
- Language**
- Doc Process**

The main content area has a search bar at the top with the placeholder text 'Enter your search terms...'. Below the search bar, there is a section titled 'Results' showing '2 results'. Each result is represented by a document icon, a title, a date, and a list of metadata fields:

- Result 1:**
 - Title: **Payment approval**
 - Date: June 1, 2022
 - Metadata:
 - Process: Invoice & Payment
 - Type: Processes
 - Area: IT
 - Country: Portugal
 - Site:
- Result 2:**
 - Title: **HR**
 - Date: June 1, 2022
 - Metadata:
 - Process: Invoice & Payment
 - Type: Processes
 - Area: IT
 - Country: Germany
 - Site:

Each result also features a green arrow icon pointing to the right.

Figure 30: Corporate Documentation Management System Prototype

4 Development of the Solution

The scope of this dissertation falls within the corporate document management project, since the technical documentation associated with Asset Management and Maintenance is included in its objectives. However, the solution outlined by the corporation does not meet the real needs of technicians.

- *SharePoint is seen as a unique platform to access information*, contrasting with the reality of Maintenance, which uses MAXIMO as a work tool and represents a recent investment of the group as EAM, making it more important to use as the main access platform;
- *The defined classification categories do not respond to Maintenance search needs*: since it represents a solution for the whole group, there is the need to be as succinct as possible, otherwise it ends up losing its usability due to the amount of possibilities; however, analyzing the volume of documentation associated to assets and maintenance procedures, separating by area and plant location is not enough, being necessary more categorizations within the type of information provided and location (one plant has different areas and equipment in each one of them)

After surveying the initial status and analyzing the limitations - identified in each factory when the project initiated - the development of the solution for the technical documentation of the Asset Management and Maintenance department was carried out with the support of the company's IT department and IBM's external consultants, in order to ensure that the solution designed was feasible for the platforms considered.

4.1 Information Consultation Strategy

Mihm *et al.* (2010) affirm “*Search is pervasive in organizations.*” In an increasingly competitive and efficient reality, the time spent searching for information must be minimal. Being more and more present in the day-to-day corporate life of industries, it makes sense to opt for an automated consultation method, minimizing the human effort needed to achieve the desired goal: in this case, finding the required file.

In this situation, a hierarchical folder structure represents a potential source of confusion and loss of traceability of records along the way, due to the high number of folders and subdivisions required to respond to the high volume of existing locations, assets and document types. Through a hierarchical organization, the search process cannot be executed all at once, because there is no information processing capacity to answer the problem - some navigation by the user is always required in this type of problem (Mihm *et al.*, 2010).

4.1.1 Definition of the Criteria

Considering the situations in which records will be needed, when searching for them it is important to know the area/location, the type of information you are looking for, in order to understand what type of document can provide it and the equipment/asset, if applicable - bearing in mind that much documentation may refer to an entire production line/process; The scheme explaining this strategy is defined in Figure 31.

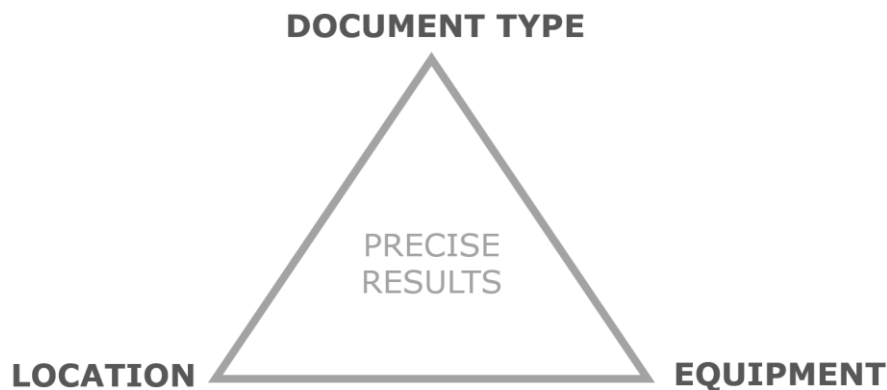


Figure 31: Research Strategy- Properties

Document Type

Analyzing the types of documentation that Kelly (2006) defines and in discussion with the maintenance department it was concluded that seven different types of records would be necessary, each one providing a certain type of information. Thus, the categories defined are:

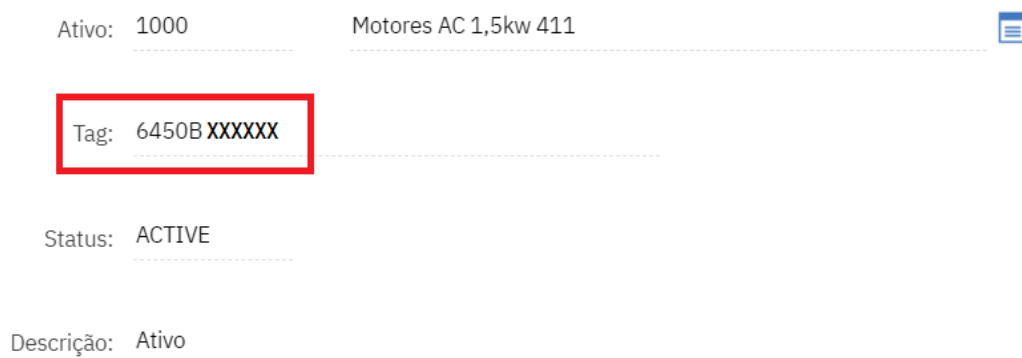
- *Essential Technical Data*: information from the manufacturer providing details, guarantee periods and technical specifications associated with one or a set of equipment;
- *Drawing Records*: graphic representation necessary to interpret the assembly process and/or the constitution of a production line/equipment/component set - all types of equipment are included in this category, apart from mechanical equipment, electrical diagrams are also defined here;
- *Maintenance Instructions Manual*: information, from the manufacturer or prepared by the responsible technicians in the company, where the maintenance instructions and plans can be found;
- *Catalog of Standard Procedures*: catalogues with information on standard procedures, complementary information on corrective and preventive work;
- *Operational & Safety Instructions*: information with operating instructions and safety practices, taking into account the importance of ensuring a safe workplace and responsible operator performance when handling large equipment performing dangerous operations. Also useful for training new employees;
- *Reports*: quality reports and inspections of areas and equipment (ultrasound, thermography, performance evaluations, etc.), which are also important for defining new strategies and action plans;
- *Spares Parts*: lists associated with the control of spare parts and associated information.

Location

As mentioned in 3.2, one of the conditions to be respected in the development of this project was to maintain the current coding system. Thus, the location is provided by the coding system defined by the company (also taking into account that the solution developed will be aligned with MAXIMO) previously presented in Figure 25.

Asset

As not all documentation will relate to a specific piece of equipment, it will not always apply. However, when this happens, the asset will be defined through a specific code created in MAXIMO - recognized as TAG, Figure 32; This code is assigned to all registered assets, being unrepeatable, eliminating any possibility of confusion.



The screenshot displays a form for an asset record. At the top, it shows 'Ativo: 1000' and 'Motores AC 1,5kw 411' with a small blue icon to the right. Below this, a red rectangular box highlights the 'Tag: 6450B XXXXXX' field. Further down, the 'Status: ACTIVE' is shown, and at the bottom, 'Descrição: Ativo' is visible.

Figure 32: Example of an assigned TAG

4.2 Software Definition for the Document Management System

In a first phase, when analyzing the problem and the needs, one of the first hypotheses was to place all the documentation in MAXIMO, taking advantage of the file attachment functionality that the EAM offers. However, this solution raises some problems, namely:

- Process not efficient

Being a system acquired by the company, only properly licensed profiles can access it - in this case, the maintenance teams - restricting the upload task to team employees. Besides this, it would force a navigation through the list of assets and locations, going to each one individually to upload the desired file, this process would be inefficient, requiring a pre-organization of the documents to at least upload all the associated records at the same time.

- Not compatible with the corporate solution developed

Although the main objective is to meet the objectives set by the group's maintenance teams, the solution projected must be aligned with the general goals of the group itself. In this case, respecting decisions previously taken by higher management teams to organize all documentation in the same place, promoting the standardization of data organization.

- Loss of fluidity:

Despite having functions for attaching documents, MAXIMO is not designed to be a DMS, presenting limitations in this sense, such as only allowing the loading of files smaller than 10MB (megabytes).

Considering only files with a size below the limit, it is estimated that in the worst case scenario, 30MB per asset is required; analyzing the number of assets registered in the platform for the plants located in Portugal - Table 4 - it is concluded that it would be too heavy to continue to ensure the current fluidity and processing speed (as it would take almost half a terabyte (TB) just for the estimate of the Portuguese factories); since the company has already acquired the software with greater storage capacity, also necessary to register the different data of each plant and maintenance operations, without considering that the estimate presented doesn't take into account the documentation associated with locations and not assets.

Table 4: Estimation of the storage required for Portuguese Plants

Portuguese Plant	Nº of Assets	Required Storage [MB]	Required Storage [TB]
1st location	7751	232 530	0.23253
2nd location	6852	205 560	0.20556
Portuguese Plants Total:			0.43809
ESTIMATE TOTAL:			4.0

It should also be noted that the group in question is spread over 9 countries with more than 10 industrial units, making the value presented only a small part of the total storage required for all documentation. The only advantage of using MAXIMO would be the possibility of consulting the documentation on mobile devices without internet access; however, as the application provided to the company only allows the consultation of documentation linked to work orders, it is necessary to solve this limiting factor before making the viewing of offline contents a priority. Table 5 shows the advantages and disadvantages of each software.

Table 5: Advantages and Disadvantages of both software

	PROS	CONS
	• Work offline;	• No Folder Management; • Do not have a research system; • Workflow's speed can be compromised;
	• Structured document organization; • Faster Research System; • More knowledge available; • Quick folder management.	• Internet Connection required;

Thus, and taking into account that the main access to the documentation must be through MAXIMO, the best solution is to use Microsoft SharePoint as a repository, creating an integration with MAXIMO guaranteeing the connection of the documentation to the correct position within the EAM.

4.2.1 Planning an Integration Strategy

Starting from the classification criteria necessary to follow a technical document and the projected vision for the system, the next step was to analyze the best solution to perform a good and fluent navigation between both platforms, keeping in mind that the process should be as intuitive and fast as possible - so that the user does not have to perform extra steps that would not be necessary if the system was all in the same software. Therefore, it was defined as the ideal situation:

- The User authenticates himself and navigates through MAXIMO normally, directing himself to a specific location or asset;
- The User clicks on the Attachment/ or similar button on the toolbar which launches a SharePoint page in the user's browser where they have an option to attach any type of record or consult the list of all the attachments associated;
- The User can view attachments through SharePoint without accessing MAXIMO.

Outlined the navigation overview, during several meetings with IBM's external consultants and with the person responsible in the IT team for the system assembled on SharePoint, there were factors that deserved special attention:

Firstly, the necessary Programming skills to perform the integration: taking into account that the solution involves efforts from both individuals, it must be validated and evaluated by them given the need to establish realistic deadlines from achievable tasks that are in accordance with the planned by the AM&R department.

Secondly, the job at the user's expense should be simple and doable by anyone at any time. This project, although important, is being executed at the same time as other operations to improve efficiency associated with production and maintenance, so to ensure the good adhesion of employees it is necessary to ensure that the effort required of them is minimal and can be performed by anyone at any time, since not all plants are at the same starting point, therefore it must be ensured that it operates smoothly in phases.

With this said and examining the classification properties defined for corporate documentation, the field with the greatest freedom and which allows the organization of the defined classification criteria is the *Title*. Besides being a field that can be searched intuitively, it gives room for the creation of an internal organization adapted to each department. From a technical point of view, by using only one field of properties to meet the needs raised, the programming required will be focused only on a portion of the solution already set up in SharePoint, allowing for greater focus and speed of execution.

4.3 Definition of a File Naming Convention

Antin (2016) affirms *"file naming convention will always be your most powerful and easy method for organizing and retrieving your documents"*, since it refers to a systematic method for naming files. As its main function is to increase the reading and interpretation capacity associated with the name of a document, some advantages described by the same author are:

- Better recognition of the type of information provided by a document without opening it;
- Increased accuracy in filtering results;

- Greater document management and organization in the directory;
- Improved version control, when appropriate.

Some important factors to consider when defining a naming convention for records is to start with the most important parameter, specifying more and more after that until the least significant component: this ensures that the user, when filtering his search, does not end up losing the information he is looking for. Another important factor taken into consideration is not to use special characters and spaces in the middle of the name, since in computer systems the space has an associated coding and in some of them it may make it impossible to recognize the rest of the title.

So, given the purpose of the target documentation to be organized, the following convention was defined:

[LocationCode]_[AssetTAG]_[DocumentType]_[Description]_[SequentialNumber]

As each plant will be responsible for uploading its files, the first and most important information to give is about the location associated to the documentation, following the code explained in Figure 25; from this, if the record is associated to an asset it is important to be properly identified through its TAG, which is unique and not transferable (Figure 32). Answering the question about what it refers to, it is important to understand from this what kind of information is supplied - so, in this sense, for the categories defined on 4.1.1, acronyms were created for each one - presented in Table 6. In order not to obtain a list of documentation identified solely by codes, a descriptive field has been added, where the name of the asset or location is presented, to facilitate the reader's interpretation. Finally, a sequential number is added to guarantee that information does not overlap and to keep it organized in the system.

Table 6: Document Types Abbreviations

Document Type Classification	CODE
Essencial Technical Data	TD
Drawing Records	DRW
Maintenance Instructions Manual	MM
Catalog Of Standard Procedures	SP
Operacional & Safety Instructions	OSI
Reports	RE
Spare Parts	SPP

4.3.1 Record's Format

Regarding the file formats, it was defined that no files in heavy formats, resulting from engineering software, such as CADs for example, would be saved. The higher resolution in some documents, such as technical drawings, does not justify compromising the server's processing speed or the device itself used to perform the query.

With that said, files in any format supported by office (Word, Excel, PowerPoint, etc.) and PDFs and similar, such as video and image formats, can be uploaded to the repository.

4.4 IBM MAXIMO and Microsoft SharePoint Integration

In a meeting with the two responsible entities, it was agreed that the best way to connect the two platforms would be by a partition system, i.e. from the title, when a file is uploaded to SharePoint, MAXIMO will divide it into parts, properly configured according to the defined convention, and search in its database for a match for each one: the location and the asset's TAG. If it finds a match it associates the file to it; otherwise, it does not. The schematization of this process is described in Figure 33.

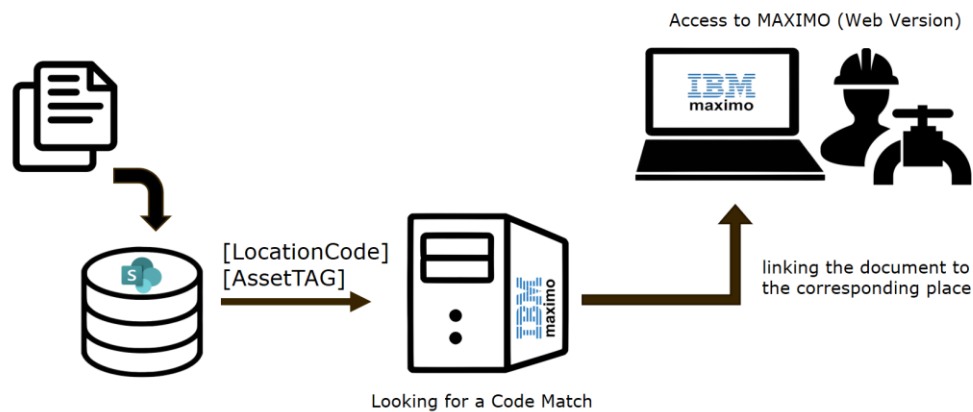


Figure 33: Schematization of the MAXIMO and SharePoint's Integration

4.4.1 Upload Process

Upload represents the most important step of the whole process, since it is the one that requires more rigor from the user. If the definition of the properties, particularly the title, is not according to what was established, MAXIMO will not be able to find correspondences and, therefore, the documentation will not be where it should be. Thus, it was a source of interest to ensure that the file naming process would be as automated as possible, in order to avoid errors and meet the points raised throughout the project, since manually, it would require the person responsible for uploading files to SharePoint to be comfortable with the coding assigned and even then it would assume a very high error rate due to the number of characters needed.

Analyzing the performance of other tasks, it was found that there was a habit of using excel files to organize the coding of MAXIMO; therefore, a method was outlined that followed the same shape. The steps listed below are only required for the first use, thereafter it is to use the same excel files to keep track of the documentation.

1st Extract a list of required data from MAXIMO to an Excel file

Each factory will then have two excel files with information related to MAXIMO data:

- For documentation associated with locations only a list with the corresponding code and description will be extracted - Figure 34;
- For records related to an asset, the data referring to its location, TAG and description will be retrieved - Figure 35.

Local	Descrição	Access	Criticidade
P0XX	FABRICA MANGUALDE		
P0XX - XXX	ÁGUA		
P0XX - XXX - XXX	REDE ÁGUA INDUSTRIAL		
P0XX - XXX - XXX - XXX	SISTEMA ÁGUA INDUSTRIAL	BOMBAGEM ÁGUAS	
P0XX - XXX - XXX - XXX - XXX	BOMBAGEM ÁGUA INDUSTRIAL	BOMBAGEM INDUSTRIAL	

Figure 34: Example of MAXIMO's list of Locations

Ativo	Descrição	Tag	Estado	Local
100 XXX	Motores AC	6450BXXXXX	OPERATING	P0XX - XXX - XXX
100 XXX	Motores AC	6450BXXXXX	OPERATING	P0XX - XXX - XXX
100 XXX	Motores AC	6450BXXXXX	OPERATING	P0XX - XXX - XXX
100 XXX	Motores AC	6450BXXXXX	OPERATING	P0XX - XXX - XXX - XXX
100 XXX	Motores AC 1,5kw 4110043	6450BXXXXX	ACTIVE	5861

Figure 35: Example of MAXIMO's list of Assets

2nd Add the columns and the formulas needed

Once Maximo's data lists have been extracted, three columns with the necessary additional information will be added: Type of Document, Sequential Number and Title (where the final result will appear). The Document Type will be introduced according to the document that is wished to be uploaded to the repository, according to the abbreviations previously described, Table 6; on the other hand, the Sequential Number and the Title will result from the application of the formulas described below:

For the creation of the Sequential Number, once all the records are stored in excel, through Equation 1, being x the row that was analyzed, it will be counted if there is or there is not a document of the same type associated with the same location/asset, Figure 36;

Equation 1: Sequential Number Formula

$$=COUNTIFS(AssetTAG: Cx; Cx; LocationCode:Dx; Dx; DocType:Fx;Fx)$$

	B	C	D	F	G
1	Description	TAG	Local	DocType	SeqNum
2	Fundos Móveis	43 xxxxxxxx 1	P05 x - xxx - xxx - xxx -0010-005	DRW	001
3	Fundos Móveis	43 xxxxxxxx 2	P05 x - xxx - xxx - xxx -0010-010	SP	=COUNTIFS(
4	Fundos Móveis	43 xxxxxxxx 3	P05 x - xxx - xxx - xxx -0010-020	SPP	001
5	Fundos Móveis	43 xxxxxxxx 4	P05 x - xxx - xxx - xxx -0010-030	TD	001
6	Fundos Móveis	43 xxxxxxxx 4	P05 x - xxx - xxx - xxx -0010-030	TD	002

Figure 36: Screenshot Demonstration of the Numerical Sequence formula

Once all the parcels needed for the creation of the title have been defined, it is mandatory to join them and organize them according to the defined convention, thus, through Equation 2 the information is automatically organized, without the need for any extra effort on the part of the employee, Figure 37. Note that when entering the Sequential Number, it is necessary to take the precaution of transforming the number into a string, giving it the desired format, which allows the numbering of files from 001 to 100.

Equation 2: Title formula

$$=LocationCode\&"_ "&AssetTAG\&"_ "&DocType\&"_ "&Description\&"_ "&TEXT(SeqNum;"000")$$

	B	C	D	F	G	H
1	Description	TAG	Local	DocType	SeqNum	Title
2	Fundos Móveis	43 xxxxxxxx 1	P05 x - xxx - xxx - xxx -0010-005	DRW	001	=LocationCode&"_ "&AssetTAG&"_ "&DocType&"_ "&Description&"_ "&TEXT(SeqNum;"000")
3	Fundos Móveis	43 xxxxxxxx 2	P05 x - xxx - xxx - xxx -0010-010	SP	001	001 SeqNum;"000")
4	Fundos Móveis	43 xxxxxxxx 3	P05 x - xxx - xxx - xxx -0010-020	SPP	001	001 P05 x - xxx - xxx - xxx -0010-020_43 xxxxxxxx 3_SPP_Fundos Móveis_001
5	Fundos Móveis	43 xxxxxxxx 4	P05 x - xxx - xxx - xxx -0010-030	TD	001	001 P05 x - xxx - xxx - xxx -0010-030_43 xxxxxxxx 4_TD_Fundos Móveis_001
6	Fundos Móveis	43 xxxxxxxx 4	P05 x - xxx - xxx - xxx -0010-030	TD	002	002 P05 x - xxx - xxx - xxx -0010-030_43 xxxxxxxx 4_TD_Fundos Móveis_002

Figure 37: Screenshot Demonstration of the Title formula

3rd Uploading to SharePoint

Once the Document title has been generated the next step is to open the company portal where there will be a tab directing the user to the repository giving him the chance to view and filter the stored documentation or make an upload. Once the option to upload a document is chosen, an application integrated in the site is opened, developed by the IT team, where after the document is selected, the properties required for its upload will be filled in as shown in Figure 38:

- The Title will be according to the established convention;
- The language, country and place according to each plant;
- The remaining properties according to the guide shown in Table 7.

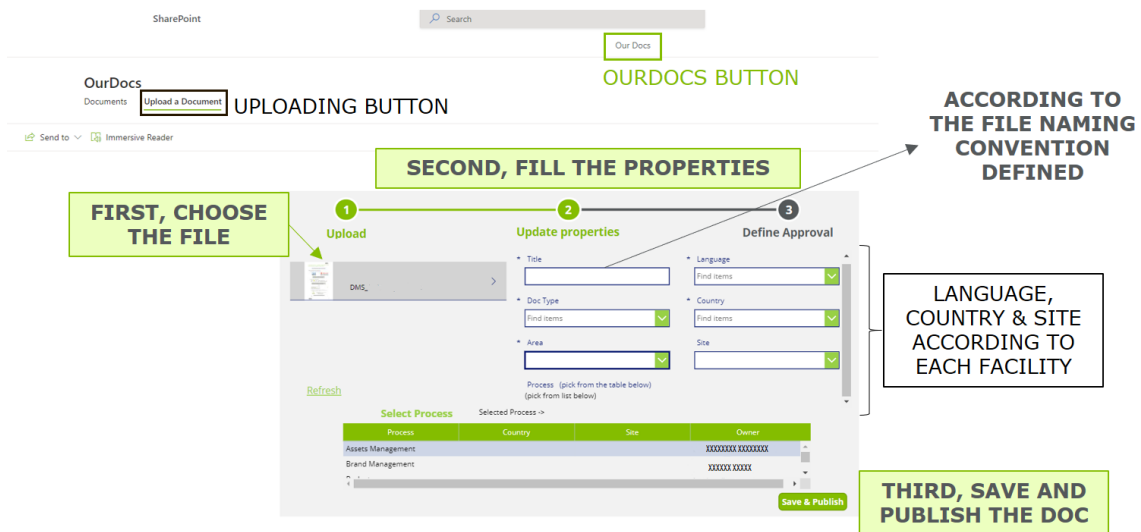


Figure 38: Upload Scheme

Table 7: Properties Guide for Technical Documentation

Document Type Classification	CODE	DOC TYPE	AREA	PROCESS	APPROVAL ?
Essencial Technical Data	TD	Equipment Techncl Document	AM&R	AM	---
Drawing Records	DRW			AM	---
Maintenance Instructions Manual	MM	Manual		MM	---
Catalog Of Standard Procedures	SP			MM	---
Operacional & Safety Instructions	OSI	Equipment Techncl Document		MM	---
Reports	RE			AM	---
Spare Parts	SPP			MM	---

Regarding the process, some records will be more framed in the Asset Management (AM) area and other specifically focused on Maintenance Management (MM). Since the documentation associated to MAXIMO has only the purpose of consultation and improvement of operations and maintenance, there is no need of the identified document types to go through an approval process by the department director.

4rd Linking SharePoint documentation to MAXIMO

As previously described, and schematized in Figure 33, through the integration developed by IBM and the company's IT team, MAXIMO will separate the title in parts and associate the respective documentation whenever it finds a correspondence in the defined codes, both for locations and assets.

4.4.2 Consultation Process

To consult the documentation, following the same principle of the integration developed for the upload, the company's IT team developed a variable URL, Uniform Resource Locator. That is, as the relevant information for Maintenance is in the title, from this URL whenever it is requested to connect to SharePoint - the user presses the attachments visualization button, Figure 26 - it will open the repository page in SharePoint applying a query in the Title field filtering according to the location/asset associated to the access point in MAXIMO. The scheme of this process is presented in Figure 39.

In a meeting with IBM consultants, this solution was validated, guaranteeing that MAXIMO has the capacity to handle and work with a dynamic URL, so it becomes relevant to create the connection of the developed generic URL with the attachments button of the software, in order to guarantee the correct and fluid connection between platforms.

If the user wishes to access through SharePoint, he/she may filter by the traditional title and characters present in the documents or by specifying the metadata associated with the document he/she is looking for.

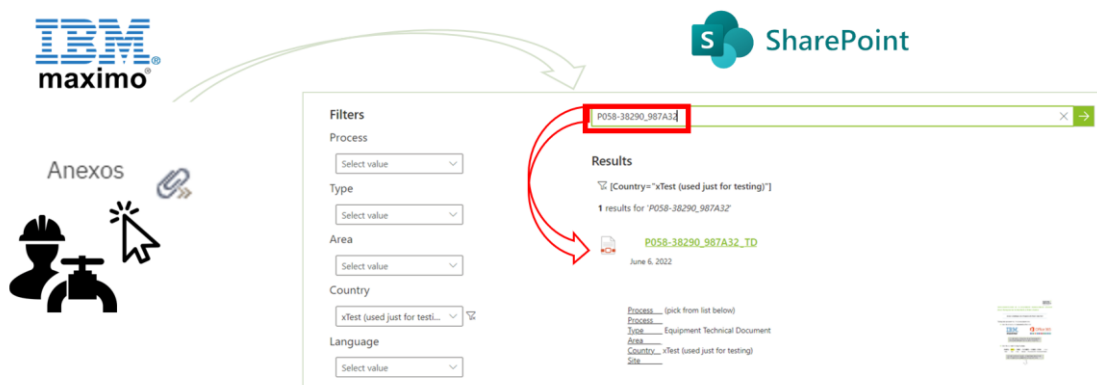


Figure 39: Consultation Scheme

If the list of results is too long to find the desired information, the user should add the type of document; SharePoint also has a functionality to quickly consult the document without having to open it, where it is possible to view the content of each document, as shown in Figure 40.

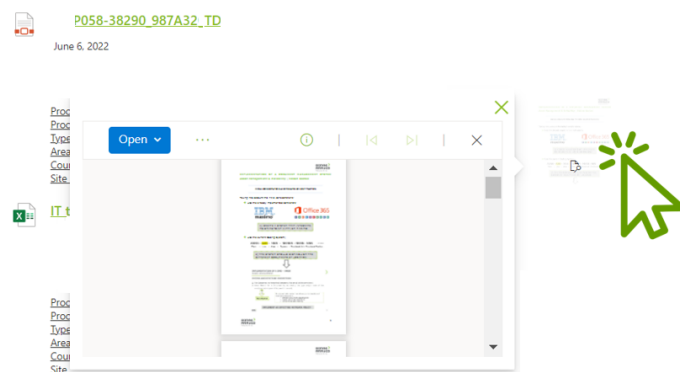


Figure 40: Preview Functionality

4.5 Expected Results and Advantages of the Developed Solution

Once the solution is presented, the process of transition from a physical archive to an organized, digital system is expected to be gradual and at the pace of each factory. Remembering that this project will be developed at the same time as other operations, it is important to ensure that it does not require any external skills or additional training.

Taking into account the goals set when the integration strategy was planned, the proposal made uses an organization method very present in the group. Excel among other collaborative tools provided by Office 365, and the subsequent maintenance of files by each plant, also meeting the principles increasingly present in the industry to automate more and more processes and reduce the rate of effort required by the worker - in the same line of reasoning, the developed system does not require the same individual to perform the tasks.

The model designed for the Document Management System is compatible with the development of a strategy for massive uploads since it is possible to add files to each line of the lists created in Excel:

- For facilities with a large number of paper records, it would simplify the digitization process as they could outsource the service to external entities with a concrete plan of their needs;
- From a technical point of view, the strategy also seems to facilitate the development of an application for simultaneous upload of different files, since the information is organized by columns, making it possible to create associations between its position in the table and the property fields to be filled in.

The flowchart of the described solution can be found in appendix A, including also the suggested strategy for massive uploads

5 Conclusions and Future work

At the beginning of this dissertation, the impact that Industry 4.0 has had on the great transformation that is currently taking place in the way information is managed and consulted was mentioned. More and more new paperless solutions and technologies are being launched, driving market and user interests towards increasingly ambitious goals with more stringent quality standards than ever before.

Recognising the importance of remaining competitor, always betting on improvement measures, there is a general gathering of efforts for the reduction of possible sources of loss of value, in this case, the time spent searching for information.

The development of this solution started with a framework of the area in question, since this project focused on a specific type of documentation, understanding which are the Asset Management scope domains and how it differs from Maintenance in some aspects. From there, it was possible to clearly define the objectives for the project and which issues need to be solved. This initial analysis allowed a more objective and coherent collection of the initial situation of different plants of the group, so that comparisons between them could also be established. This phase was interesting and important to the process because it raised important points to be considered such as the digitisation process, as most locations still rely heavily on paper documentation, developing a solution that took this initial step and following transition phase into consideration.

As any area of interest, systems and software have been developed and adapted to the new needs of companies, maximizing the available functionalities. Thus, it was also an important factor to evaluate the tools available. In this case, due to previously made decisions, the solution would be restricted to the company's current services; however, this evaluation phase was the one that presented the most difficulties during the entire project, besides the difficulties in reconciling the different existing interests, the multidisciplinary nature that the development of this system required was somewhat challenging, and ended up becoming a limiting factor due to the short period available in comparison.

Nevertheless, the solution designed meets most of the needs raised: it ensures the organization and storage of information on a platform where there is no compromise to the processing speed of the EAM; it is easy to understand and can be replicated throughout the group, with no special requirements, and is in line with the standardization principles that are increasingly important. Unfortunately it was not possible to start the testing phase before the four-month period was over, also due to the work required from the IT team and IBM, which ultimately conditioned the definition of the strategy for massive uploads.

5.1 Future Work

Today there is no software or development method that is collectively recognized as the perfect solution. Being a project framed in the area of information management there will always be many limiting factors and specific needs of each case, making the best solution to be always customized according to the real needs and possibilities of the company.

Thus, and recognizing that document management will always be an area in constant evolution, the next step is to release the developed system on SharePoint for corporate documentation. This system is still under development, having used its test version to perform the necessary experiments in the course of the project, so it is mandatory to ensure its correct functioning in order to move forward with the planned integration. However, the fact that it is still under development creates windows of opportunity such as the creation of metadata that responds more easily to the needs of Maintenance - one possibility being the creation of a property that indicates when a document is to be accessed through MAXIMO, avoiding the filling of more general fields, not necessary for the objective of this type of documentation.

After the launch and adjacent testing phases, it is important to start evaluating a massive upload strategy, in this case validating the feasibility of the outlined one or defining a better one at the time since the volume of paper records is considerable and the adhesion of employees depends on how quickly they can see the change.

One problem that could not be addressed in the development of the integrated system presented was the consultation of records on mobile devices. Currently only documentation associated with work orders can be consulted on the device, so there is another problem to be answered before thinking about the integration of the web solution; thus, it will probably be necessary to program a custom application together with IBM in order to enable the consultation and navigation of different locations and assets making it possible to consult the documentation associated with each one.

References

- Adolfo Crespo Márquez, Dragan Komljenovic, Joe Amadi-Echendu, (2021), “14th World Congress on Engineering Asset Management (WCEAM) Proceedings”, International Society of Engineering Asset Management (ISEAM) 2021, last access: May 2022, DOI: <https://doi.org/10.1007/978-3-030-64228-0>
- Agarwal K., (2018), “EAM vs. CMMS: Comparison of the Difference Between Them”, last access: May 20 2022, URL: <https://www.selecthub.com/cmms/difference-eam-cmms/>
- AIIM, (n.d.), “What is Document Management (DMS)?”, last access: June 3 2022, URL: <https://www.aiim.org/What-Is-Document-Imaging>
- Amik Garg, S.G. Deshmukh, (2006), "Maintenance management: literature review and directions", Journal of Quality in Maintenance Engineering, Vol. 12 Iss: 3 pp. 205 – 238, last access: May 2022, DOI: <http://dx.doi.org/10.1108/13552510610685075>
- Antin, K. R. I. S. T. I. N., (2016), “File naming conventions: why you want them and how to create them”, last access: June 2022
- Arbour G., (2019 February 1), “What Are The 4 Types of Maintenance Strategies?”, last access: May 2022, URL: <https://www.fiixsoftware.com/blog/evaluating-maintenance-strategies-select-model-asset-management/>
- Aurelia, P., & Ana, T, (2008), “A document management system modelling”, ANALELE UNIVERSITĂȚII DIN ORADEA, 1479, last access: June 2022
- Balzer G., Brandl M., Schmitt O., Strnad A., ETG-Tage (1999), “Rechnergestu” tzte Instandhaltungsplanung von Betriebsmitteln der Elektrischen Energieversorgung”. p. 411–20, last access: May 2022
- Bargmeyer, B. E., & Gillman, D. W., (2000), “Metadata standards and metadata registries: An overview”, In International Conference on Establishment Surveys II, Buffalo, New York, last access: June 2022
- Carvalho, R. M. D. S., (2008), “Integração do iPortalDoc com sistemas ERP”, Faculty of Engineering of the University of Porto, last access: June 2022, URL: <https://repositorio-aberto.up.pt/bitstream/10216/58310/1/Resumo.pdf>
- de Castro, J. D. A., (2020), “Engaging researchers in research data management: Creating metadata models for multi-domain dataset description”, Faculty of Engineering of the University of Porto, last access: June 2022, URL: <https://hdl.handle.net/10216/129396>

Corti, L., Van den Eynden, V., Bishop, L., & Woollard, M., (2019), “Managing and sharing research data: A guide to good practice”, Sage, last access: June 2022

DeMarco, Tom, (1978), “Structured Analysis and System Specification”, Yourdon, 2nd Edition, last access: April 2022, ISBN: 0917072073, 9780917072079

Detlor, Brian, (2010), “Information Management.” International Journal of Information Management, 30 (2) (April): 103–108, last access: April 2022, DOI: 10.1016/j.ijinfomgt.2009.12.001.

Doug Miles, (2011), “State of the ECM Industry 2011”, page 29, URL: http://www.aiim.org/pdfdocuments/IW_ECM_State-of-Industry_2011.pdf.

Emaint, (n.d.), “What is Enterprise Asset Management?”, last access May 9 2022, URL: <https://www.emaint.com/what-is-enterprise-asset-management-eam/>

Gartner, Inc., (2022), “Office 365 (including SharePoint online) Reviews”, last access: June 21 2022, URL: [Top Office 365 \(including SharePoint Online\) Competitors and Alternatives - Gartner 2022](#)

Gartner, Inc., (2022), “Maximo Reviews”, last access: June 11, 2022, URL: [IBM Maximo Reviews, Ratings, and Features - Gartner 2022](#)

Gartner, R., & Gartner, R, (2016), “Metadata”, Springer, last access: June 2022

Gaspar, T. J. C., (2010), “Gestão documental/enterprise content management na Santa Casa da Misericórdia do Porto”, last access: June 2022, URL: <http://hdl.handle.net/10216/58685>

Gomes Silva M., (2017), “Gestão Documental”, last access: June 2022, URL: <https://repositorio-aberto.up.pt/handle/10216/106966>

IBM, (n.d.), “What is Enterprise Asset Management?”, last access May 5 2022, URL: <https://www.ibm.com/topics/enterprise-asset-management>

IBM, (April 19,2020), “System architecture and components”, last access: June 20 2022, URL: <https://www.ibm.com/docs/en/mam/7.6.1?topic=overview-system-architecture-components>

Indeed Editorial Team, (2021), “What Is Technical Documentation? Definition, Types and Tips”, Indeed.com, last access: June 15, 2022, URL: [What Is Technical Documentation? Definition, Types and Tips | Indeed.com](#)

Ismael, A., & Okumus, I., (2017), “Design and Implementation of an Electronic Document Management System”, Mehmet Akif Ersoy Üniversitesi Uygulamalı Bilimler Dergisi , 1 (1) , 9-17, last access: June 2022, DOI: 10.31200/makuubd.321093

ISO 9000:2000(E), (2000), “Quality Management Systems: Fundamentals and vocabulary”, International Organization for Standardization, Geneva, Switzerland, last access: June 2022, www.iso.org

ISO 10013:2001(E), (2001), “Guidelines for quality management system documentation”, International Organization for Standardization, Geneva, Switzerland, last access: June 2022, www.iso.org

ISO 12651-1:2012(E), (2012), “Electronic document management — Vocabulary — Part 1: Electronic document imaging”, International Organization for Standardization, Geneva, Switzerland, last access: June 2022, www.iso.org

ISO 14224:2016(E), (2016), “Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment”, International Organization for Standardization, Geneva, Switzerland, last access: June 2022, www.iso.org

ISO 55000:2014(E), (2014), “Asset management — Overview, principles and terminology”, International Organization for Standardization, Geneva, Switzerland, last access: May 2022, www.iso.org

ISO 55001:2014(E), (2014), “Asset management — Management systems — Requirements”, International Organization for Standardization, Geneva, Switzerland, last access: May 2022, www.iso.org

ISO 55002:2014(E), (2014), “Asset management — Management systems — Guidelines for the application of ISO 55001”, International Organization for Standardization, Geneva, Switzerland, last access: May 2022, www.iso.org

Joe E., Amadi-Echendu, Kerry Brown, Roger Willett, Joseph Mathew, (2010), “Definitions, Concepts and Scope of Engineering Asset Management”, Springer-Verlag London Limited, last access: May 2022, DOI: 10.1007/978-1-84996-178-3

Kelly A., (2006), “Maintenance Systems and Documentation”, Elsevier Ltd., ISBN-13: 9780750669948, ISBN-10: 0750669942

Leal A., (2022), “Understand the life cycle of IT assets”, last access: May 10 2022, URL: https://www.greenteksolutionsllc.com/blog/Understand_the_life_cycle_of_IT_assets

Martin M., (2022, April 16), "MIS Development Process with System Development Life Cycle", last access: May 7 2022, URL: [MIS Development Process with System Development Life Cycle \(guru99.com\)](https://www.guru99.com/mis-development-process-with-system-development-life-cycle/)

Microsoft, (April 19, 2022), “Introduction to SharePoint in Microsoft 365”, last access: June 23 2022, URL: <https://docs.microsoft.com/en-us/sharepoint/introduction>

Mihm, J.; Loch, C. H.; Wilkinson, D.; Huberman, B. A., (2010), “Hierarchical Structure and Search in Complex Organizations.”, 56(5), 831–848, last access: June 2022, DOI: 10.1287/mnsc.1100.1148

Mithas, S., Ramasubbu, N., & Sambamurthy, V., (2011), “How Information Management Capability Influences Firm Performance”, MIS Quarterly, 35(1), 237–256, last access: April 2022, DOI: <https://doi.org/10.2307/23043496>

Morteza Ghobakhloo, (2020), “Industry 4.0, digitization, and opportunities for sustainability”, *Journal of Cleaner Production*, Volume 252, last access: April 2022, DOI: <https://doi.org/10.1016/j.jclepro.2019.119869>, URL: <https://www.sciencedirect.com/science/article/pii/S0959652619347390#>

O'Donoghue, C.D., Prendergast, J.G., (2004), “Implementation and benefits of introducing a computerised maintenance management system into a textile manufacturing company”, *Journal of Materials Processing Technology*, Volumes 153–154, Pages 226-232, last access: May 2022, DOI: <https://doi.org/10.1016/j.jmatprotec.2004.04.022>

PINTO, Maria M., (2010), “Gestão de Serviços de Informação”, Faculty of Letters of the University of Porto, last access: June 2022

Riley, J., (2017), “Understanding metadata”, Washington DC, United States: National Information Standards Organization (<http://www.niso.org/publications/press/UnderstandingMetadata.pdf>), 23, last access: June 2022

Sathiadas, J. P., & Wikramanayake, G. N., (2003), “Document management techniques & technologies”, last access: June 2022, URL: <http://archive.cmb.ac.lk:8080/research/handle/70130/66>

Schneider, J., Gaul, A.J., Neumann, C., Hogräfer, J., Wellßow, W., Schwan, M., Schnettler, A., (2006), “Asset management techniques”, *International Journal of Electrical Power & Energy Systems*, Volume 28, Issue 9, Pages 643-654, last access: May 2022, DOI: <https://doi.org/10.1016/j.ijepes.2006.03.007>, URL: <https://www.sciencedirect.com/science/article/pii/S0142061506000834>

Simić, R., Bolfek, B., & Stoić, A., (2008), “Document management system as source of competitive advantage”, In 9th International Scientific Conference New ways in Manufacturing Technologies

Sprague, Jr., Ralph, H., (1995), “Electronic Document Management: Challenges and Opportunities for Information Systems Managers”, *MIS Quarterly*, Vol. 19, No. 1 (Mar., 1995), pp. 29-49, last access: April 2022, DOI:10.2307/249710 URL: <http://www.jstor.org/stable/249710>

Tavolato, P., Vincena, K., (1984), “A Prototyping Methodology and Its Tool”. In: Budde, R., Kuhlenskamp, K., Mathiassen, L., Züllighoven, H. (eds) *Approaches to Prototyping*. Springer, Berlin, Heidelberg., last access: April 2022, DOI: https://doi.org/10.1007/978-3-642-69796-8_38

Trout, J., (2022), “Maintenance Management: An Overview”, Noria Corporation, last access: May 2, 2022, URL: [Maintenance Management: An Overview | Reliable Plant](#)

Weintraub, A., Logan, D., Landers, G., & Calvert, M., (2001), “Implementing an Integrated Document Management Strategy”, Strategic Analysis Report Gartner Group RAS Services.

Wienker M., Henderson K., Volkerts J., (2016), “The Computerized Maintenance Management System an Essential Tool for World Class Maintenance”, *Procedia Engineering*, Volume 138, Pages 413-420, last access: May 2022, DOI: <https://doi.org/10.1016/j.proeng.2016.02.100>, URL: <https://www.sciencedirect.com/science/article/pii/S1877705816004641>

Wilkins J., (2019), “Document Management vs. Records Management: What’s the Difference?”, AIIM, last access: June 3 2022, URL: <https://info.aiim.org/aiim-blog/document-management-vs.-records-management>

Yao, Y. H., Trappey, A. J., & Ho, P. S., (2003), “XML-based ISO9000 electronic document management system”, *Robotics and Computer-Integrated Manufacturing*, 19(4), 355-370, last access: June 2022

Zakoldaev D. A., Gurjanov A. V., Shukalov A. V., Zharinov I. O., (2019), “The life cycle of technical documentation in the smart factory of Industry 4.0”, *IOP Conference Series: Materials Science and Engineering*, Volume 665, The International Scientific and Practical Conference "Materials Science, Mechanical Engineering and Energy: Problems and Prospects for Development" 27–28 June 2019, Polzunov Altai State Technical University, Russian Federation, DOI: <https://doi.org/10.1088/1757-899x/665/1/012016>

APPENDIX A: Flowchart of the Solution

This appendix shows the flowchart of the solution presented above. In it is already contemplated the strategy of massive uploads outlined.

