MSc Program
Engineering Management

Possibilities and challenges of maintenance digitalization in plant intensive companies with a focus on the Austrian pulp and paper industry

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
Em.O.Univ.Prof. Dr.h.c.mult. Dipl.-Ing. Dr. Techn. Peter Kopacek

Luisa Ludwig, BSc

12038049

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Affidavit

I, **LUISA LUDWIG, BSC**, hereby declare

1. that I am the sole author of the present Master's Thesis, "POSSIBILITIES AND CHALLENGES OF MAINTENANCE DIGITALIZATION IN PLANT INTENSIVE COMPANIES WITH A FOCUS ON THE AUSTRIAN PULP AND PAPER INDUSTRY", 63 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

Vienna, 06.04.2022

Signature

Acknowledgments

This thesis marks an end of an exciting and rather demanding time. My special thanks to Mr. Em.O.Univ.Prof. Dr.h.c.mult. Dipl.-Ing. Dr. Techn. Peter Kopacek for supervising this thesis and for the inspiring lecture.

I also like to thank Laakirchen Papier AG and all my colleagues that helped me out when I had to be at TU Vienna and missed meetings.

An additional thanks to the Austropapier for supporting me with my survey and all the participants.

Even this course was an unusual one, with sitting 10 hours straight in front of a laptop most of the time. I am happy to say that I met a group of inspiring people that made this time very special.

A big thank you to my family and friends that continuously support me.

Abstract

The paper manufacturing industry has evolved alongside every major industrial revolution since the 18th century. As the industry has developed, so has the manufacturing of paper. The digitalization of communication and media has critically reduced the global need for graphic paper. However, at the same time, there is an ever-increasing growth in packaging and hygiene paper products. New production concepts to produce more, faster, and cheaper at a customer satisfying quality have led to highly automated machines and high-tech products. The industry is decidedly automated maintenance in pulp and paper has yet to realize significant advantages from automation. According to the Central Pulp & Paper Research Institute, 10% of sales are maintenance costs, substantially higher than in other plant-intensive industries e.g.. the chemical industry. A significant factor of unexpectantly rising maintenance costs is unscheduled downtime. The machine must be in excellent condition to prevent that from happening, as most paper machines operate 24 hours, 365 days a year, excluding planned downtime. With such high availability rates, maintenance faces a significant challenge to act preventive and not reactive. Over decades also, maintenance procedures have changed alongside the production processes. Maintenance has to change from acting on failure to predictive maintenance, and with emerging technologies such as the internet of things, the next revolution is already in the pipes. Maintenance departments must step it up and adapt to their digitalizing surroundings to keep up with the pace. This thesis investigates the current situation of digitalization of maintenance departments within the industry and gives an outlook on what changes need to be done and what is to come.

Contents

1. Introduction

The global paper and pulp industry are in intense international competition. Austria as a production location has been under increasing pressure in recent years. The industry representatives complain about rising energy and transport costs, the ever-shrinking supply of wood, and sinking paper prices (Austropapier, 2020, 2021; Wolf, 2021). The ongoing digitalization of communication is the major push factor for the paper and pulp industry to re-invent itself. This change and trends like the paperless office, which encourages enterprises to digitize their processes (Orantes-Jiménez et al., 2015), have critically reduced the need for graphic paper. Table 1 shows the revenue of the Austrian Pulp and Paper Industry for the years 2000-2020, clearly picturing the decrease in revenue in 2020 when the pandemic hit. However, there is an ever-increasing growth in packaging and hygiene paper products (Austropapier, 2021; Wolf, 2021). With increasing online shopping and home delivery services rising the demand for packaging papers, the need for packaging papers rises. The year 2020, with the pandemic hitting in March, was challenging for almost every industry sector. As most of daily life was shut down, the need for graphic papers further declined. The demand for packaging paper started to explode. With everyone staying at home and most stores closed, people began to buy even more online. Online Shops like Amazon increased their revenue by 22 % in 2021 (Statista, 2022). Not just clothes or other items of daily life have been ordered online but also frozen and cooled groceries.

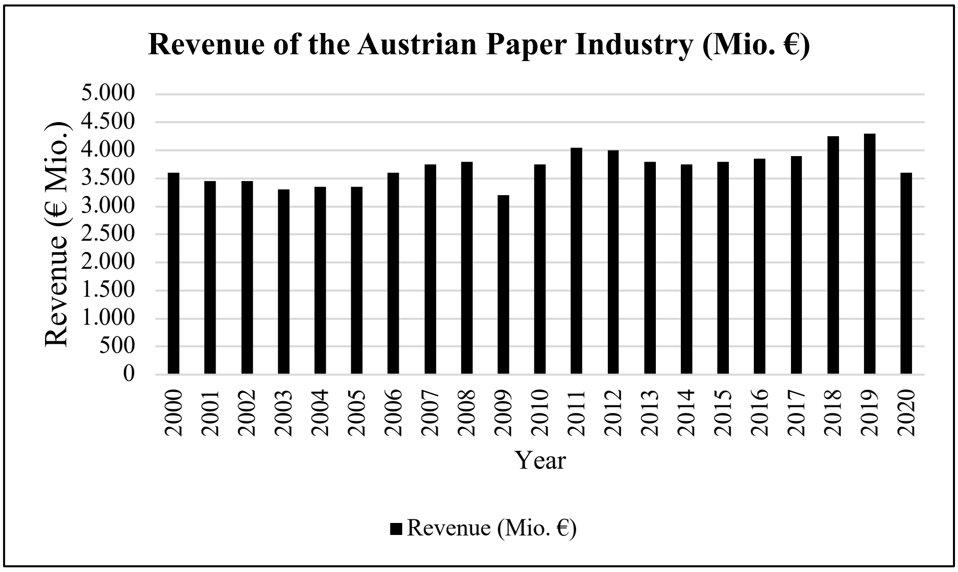

Figure 1: Revenue of the Austrian Paper Industry from year 2000-2020 (Austropapier, 2020)

Such goods require special packaging, and this trend and the factors mentioned above pushed the industry to new product concepts and new high-tech papers for special applications. The aim is to produce more, faster, and cheaper at a customer satisfying quality. This has led to highly automated machines and high-tech products. The industry is decidedly automated maintenance in pulp and paper has yet to realize significant advantages from automation (Editorial Team SKF Industrial AI and Analytics, 2020). Industries such as the automotive sectors are already highly automated and have already accomplished essential steps in transforming the processes into the digital age. As the industry faces many issues that must be solved, investments have been high in the past years, especially in creating a more environmentally friendly production (Austropapier, 2020, 2021). But with the rising raw material prices and decreasing prices for paper, the focus cannot be everywhere.

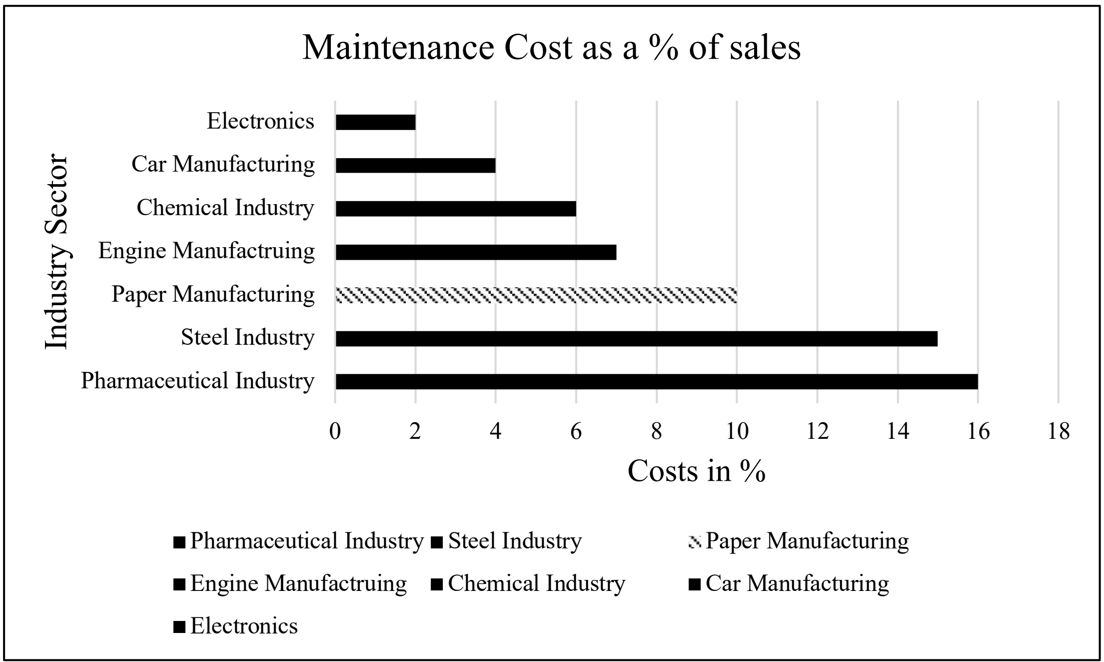

Figure 2: Maintenance Costs as a% of sales (Editorial Team SKF Industrial AI and Analytics, 2020)

Production-wise, digital transformation has already begun, and technologies such as the Industrial Internet of Things are used, e.g., for condition mentoring. As already mentioned, digitalization can be viewed from two points in the paper and pulp industry. On the one side, the reduction of paper usage reduces revenue. Still, on the other side, this is a chance to optimize further production processes producing more high-quality individual products for customers (Lassnig et al., 2017).In support of the high-tech production processes, the maintenance department also does have to digitalize itself and rethink strategies.

Additionally, reducing maintenance costs is another driver for digital transformation. Compared to other plant-intensive industries, the paper-producing industry has an average of 10 % maintenance cost per sale (Editorial Team SKF Industrial AI and Analytics, 2020). This is twice the cost of car manufacturers and 4% more than chemical manufacturers compared to the paper producing sector. This thesis aims to give insight into the current digitalization of maintenance departments of plant-intensive productions, focusing on the Austrian pulp and paper industry. Almost no literature focuses on the digitalization of maintenance departments in Austria’s pulp and paper industry. The author performed a survey with the Austropapier to evaluate the industry's situation and aim to reduce the lack of information and get an overview of the evolvement of digital maintenance management. Additionally, the author identified six steps that reoccur when implementing a digital structure and derivated actions from it. Next, the author will outline the structure of this thesis.

First, fundamental information is given in Chapter 2 regarding digitalization topics, such as defining what digitalization is and what not (Chapter 2.1.), a definition of maintenance, and a short introduction to its history (Chapter 2.2.). Additionally, an overview of the Austrian pulp and paper industry from a historical point of view and the current situation is given (Chapter 2.3.). Chapter 3, the digitalization of the industry’s maintenance department within the industry. Insights into the current situation (Chapter 3.1.), as well as a six-step guide toward a digital maintenance structure, is explained (Chapter 3.2.1.) with a four-step recommendation on how to implement it in the existing structure (Chapter 3.2.2.). Furthermore, the study with the Austropapier provides information about the current state of digitalization in the Austrian maintenance departments. This is followed by a discussion of the insights given by this thesis, highlighting the pros and cons of digitalization in maintenance. Finally, an outlook on future developments and emerging trends are presented.

2. Fundamentals

2.1. Digitalization

2.1.1. Digitalization vs. digitization

Digitalization is the buzzword of the last decade and has not reached its peak yet. People are confronted with digitalization across industries and almost every aspect of daily life. With its wide application field and many different approaches to implementing digitalization, one single definition of the term in the literature cannot be found. Instead, depending on the point of view, there are many approaches to describe the term. Adding to the confusion, digitalization is often used interchangeably with digitization. The terms “digitization” and “digitalization” are two conceptual terms that are closely intertwined with each other. Still, there is an analytical value in explicitly distinguishing between those terms (Brennen et al., 2016). Digitization is the material process of converting analog information streams into digital bits (Brennen et al., 2016). There are many examples of digitization across industries, as there have been for many decades. Such as the transition from handwritten or typewritten text, also referred to as analog information, into digital form. A deep dive into Google Trends from 2010 till January 2022 reveals that both terms are nearing parity in internet searches for the last five years. This mirrors milestones in the digital era, as a continuous increase in digitization opens the way for digitalization (Figure 3).

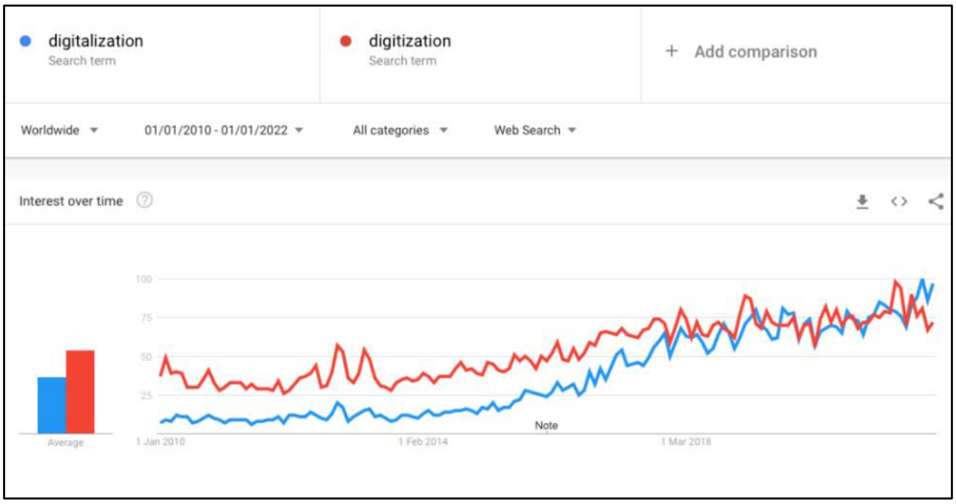

Figure 3: Google Trends of digitalization vs. Digitization from 2010-2022 (Google Trends, 2022).

In the following few paragraphs, the author discusses different definitions of digitalization to create common ground for the following chapters.

Brennen and Kreiss define digitalization as how many domains of social life are restructured around digital communication and media infrastructures (Brennen et al., 2016). For example, data throughout an organization and its assets are collected and processed through advanced digital technologies. Another definition by Gabler Wirtschaftslexikon describes digitalization as the change of communication or digital modification of instruments, gadgets, and vehicles (Gabler Wirtschaftslexikon, 2021). Gartner defines digitalization in its glossary as:

> *"[digitalization is] the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business* (Gartner Glossary, 2022)*."*

The first two definitions focus more on the change of communication and highlight the digital shift of social life and objects. The third focuses more on the business side and the value generated from digitalization. In conclusion, there is still not one definition, but the direction is clear; a shift into a digital and data-driven world is ahead.

There is no distinction between the terms in German, as digitalization does mean digitization and digitalization. When referring to digitalization below, only the English definition of the term is used.

2.1.2. Digital transformation

The acceleration of technological innovations transformed the use and behavior of individuals and organizations and the market structures (Henriette et al., 2016). Digital transformation (DT) has emerged as an essential phenomenon over the last decade. Especially the digital natives, which are the first generation growing up connected to the internet, have a different approach to how they select and consume offered products and services. Observing a high level, digital transformation is the profound change in society and industries through the increasing use of digital technologies. It can also be argued as an innovation driver at an organizational level, forcing companies and organizations to find strategies embracing digital transformation and driving optimal performance (Vial, 2021). Digital transformation is only one part of a complex puzzle that must be solved to remain competitive in an increasingly digital world. A strategy must focus not only on the production processes, change on an organizational level, including the structure (Selander et al., 2016), culture, and even ethics (Henriette et al., 2016) are required to secure a successful transformation. Digital transformation has many touching points; therefore, there is no one definition. Depending on the perspective and situation, the definitions differ. In literature, two main dimensions can be identified: Digital technologies and the user experience. Separating those dimensions is difficult as both are equally important for a digital transformation and are highly interconnected. Nevertheless, there is an urge for a general definition. Gregory Vial studied peer-reviewed reports from 28 sources of digital transformation, intending to construct a conceptional meaning and identify three similarities (Vial, 2021):

- first, digital transformation is primarily viewed from an organizational point of view,
- second, the types of technologies described in the definitions differ, as well as the transformation that is taking place,
- third, standard terms are used despite differences.

As a result, Vial constructed the following definition:

> *"a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies."* (Vial, 2021)

This definition is not organization-centric and refers to all targeted areas of digital transformation. Vial claims this definition is consistent with the related concept of digitalization. In comparison, Gong and Ribiere defined digital transformation as:

> *"A fundamental change process enabled by digital technologies aims to bring radical improvement and innovation to an entity [e.g., an organization, a business network, an industry, or society] to create value for its stakeholders by strategically leveraging its key resources and capabilities."* (Gong et al., 2021)

This definition focuses on the innovation aspect of the transformation and aims to improve the entity and individual like Vial. In conclusion, it is difficult to define one single definition of such another complex topic. For the following chapters, the author refers to digital transformation as the definition by Vial. Taking a closer look at a study asking top managers across industries which goals their companies follow with implementing a digital strategy and participating in the digital transformation clarifies why there is such a buzz about it. Over 89 % (Stoll et al., 2016) of the participants believe in preparing their business for the future with Digital Transformation. Maximizing customer satisfaction is the main goal for over 67% (Stoll et al., 2016). Maximizing the revenue is a goal for around 30% of the participants and cost reduction for 37% (Stoll et al., 2016).

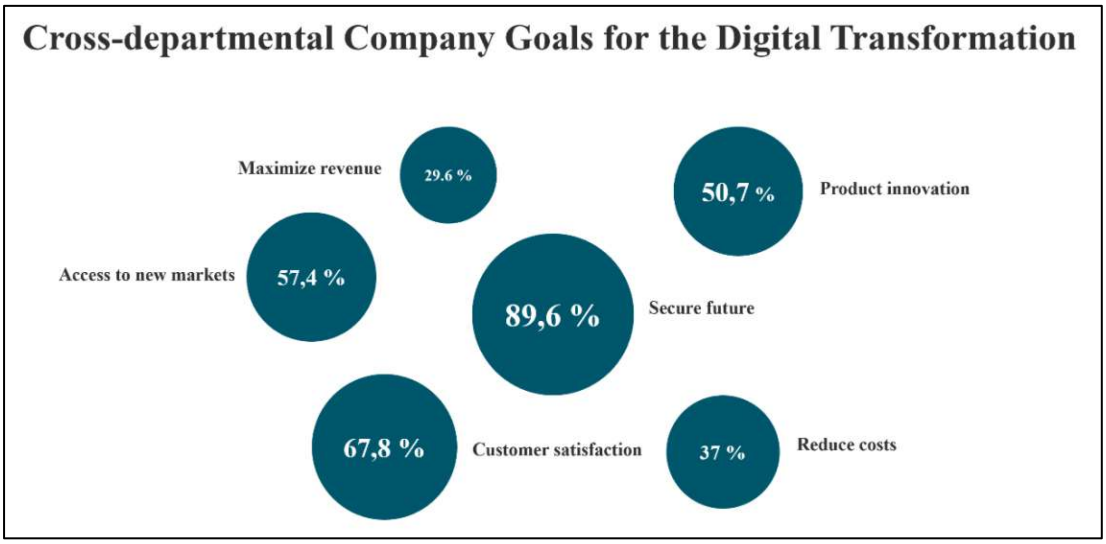

Figure 4: Cross-departmental Company Goals for the Digital Transformation (Stoll et al., 2016)

2.1.3. Internet of things vs. industrial internet of things

The IoT paradigm changes how people and organizations interact with things around them. It leads the way for creating pervasively connected infrastructures to support innovation and promises more flexibility and efficiency. It is highly interconnected with the rise of industry 4.0 and can be understood as an enabler. Such advantages are attractive for consumer applications and the industry (Sisinni et al., 2018). The IoT paradigm made its way into the industrial marketplace by designing new solutions and changing how processes and machines operate. To understand the concept of industry 4.0, it is necessary to differentiate between the Industry Internet of Things (IIoT) and the Internet of Things (IoT). In 1999 the term Internet of Things

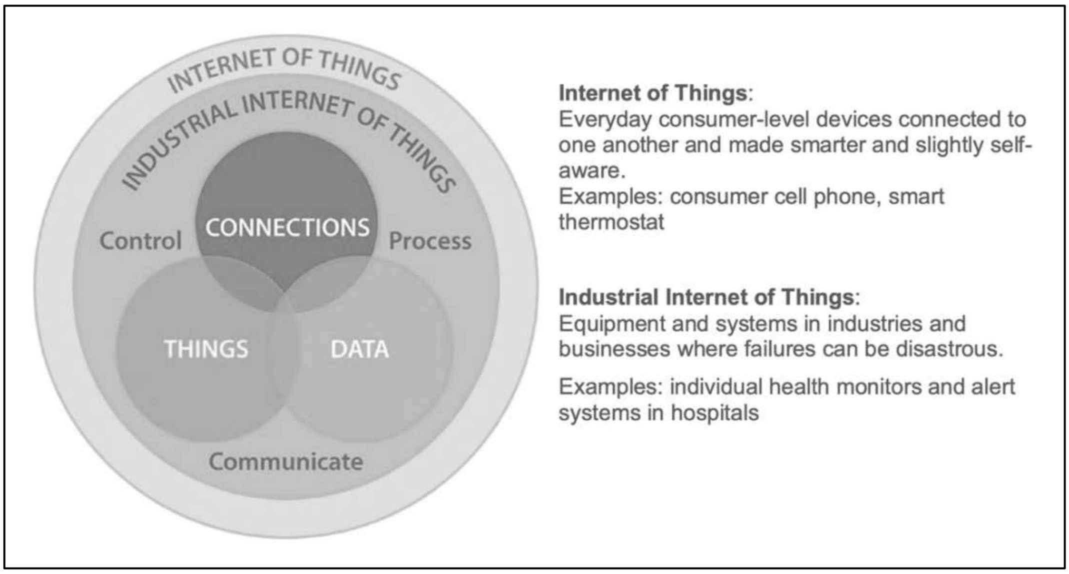

Figure 5: Connection of Iot and IIoT

It was understood as connecting devices in consumer, domestic, business, and industrial settings (Chakraborty et al., 2019). A significant amount of literature is available. However, almost none of those definitions show how this applies to an industrial setting. IoT definitions imply a similar approach to the high-level architecture of a system. Nevertheless, this is unhelpful as it hinders the analysis of alternative system architectures, not considering the type of data or the processing of information and associated performance and security issues (Boyes et al., 2018). Boyes et al. aimed to formulate a definition that respects all those aspects above and came up with this approach:

> *"Industrial Internet of Things: A system comprising networked smart objects, cyber-physical assets, associated generic information technologies, and optional cloud or edge computing platforms, which enable real-time, intelligent, and autonomous access, collection, analysis, communications, and exchange of process, product and/or service information, within the industrial environment, so as to optimise overall production value. This value may include; improving product or service delivery, boosting productivity, reducing labour costs, reducing energy consumption, and reducing the build to-order cycle."* (Boyes et al., 2018)

Industrial Internet of Things (IIoT) systems enables numerous devices' connectivity, which is heterogeneous in terms of their interfaces and supported protocols, into one system to derive more intelligent actions from data (Malakuti et al., 2018). New arising technology is digital twins; they are an exact digital replica, a twin, of an item and allow more accurate monitoring. Digital Twins are a crucial enabler for IIoT systems, which will enable the acquisition, access, and exchange of a far greater variety of data than today and previously unseen interoperability out of the box (Malakuti et al., 2018). IIoT is not just an enabler for new technologies and production processes, but it also is predicted to be one of the biggest drivers of economic growth. A Report from Microsoft estimated that IoT and IIoT will create 15$ trillion of global GDP by 2030 (2019 Manufacturing Trends Report, 2018). Based on such economic forecasts are numerous benefits for manufacturing and business activities recognizable (Figure 6).

Advantages of IoT and IIoT	
Manufacturing	**Business activities**
Optimizing of production processes	High return of investment (ROI)
Production of intelligent and high in quality products	Consistent achievement of business gials
Monitoring of production processes	Customer-centric approach
Shorter production times	Application of new business models and introduction of new services
Detecting malfunction of equipment beforehand	New source of income
Integration of existing systems	Low costs
Real-time evaluation of production data	Data-driven business decisions

Figure 6: Own Table, Advantages of IoT and IIOT

2.1.4. Big Data

Big data is practically ubiquitous these days, and the amount of data generated worldwide continues to grow. Although the name suggests that it is about working with large amounts of data, this description only partially gets to the core of the terminology. Because in addition to the amount of data, other characteristics, such as data diversity, also play an essential role. The data itself and the technologies used to process it are crucial (Volk et al., 2020). A few decades back, the overwhelming amount of data produced was useless. However, data has always been an essential part of every enterprise, big or small. When the term Big Data emerged, it was claimed as the hype.

Nevertheless, today we know data is more critical than ever, and the interest is reinforced by companies that use the relevant systems, achieving an average increase in productivity of around four percent (Müller et al., 2018). To clearly define the concept of Big Data, it is first necessary to determine the information itself and the difference between data and information. Data are structured facts suitable for processing for people, and Computers have no meaning. Data becomes information only when meaning is given to it (Latinovi et al., 2016). Figure 7 shows the value cycle of data, from raw data to decision making. First, a considerable amount of data is collected; in the second step, it is organized and becomes valuable information; in the third step, information is clustered and analyzed; the last step allows synthesizing to use of the data as decision-making data. The data now is categorized into internal data (enterprise application data) and external data (e.g., web data or data from the equipment producer)(Mohanty et al., 2013). Considering the literature and the information above allows us to conclude that the Big Data definitions include the following aspects to describe the characteristics of information:

- Volume
- Velocity
- Variety

Also known as the 3Vs. De Mauro et al. defined Big Data respecting the 3Vs as:

> *"Big Data is the Information asset characterized by such a High Volume, Velocity, and Variety to require specific Technology and Analytical Methods for its transformation into Value* (de Mauro et al., 2016)*."*

Irrespective of how data is managed within an enterprise, if it is adequately leveraged, it can deliver immense business value. In the early 2000s, concepts like Enterprise Data Warehouse (EDW), Business Intelligence (BI), and analytics helped companies transform raw data collections into wisdom. Analytics applications have become an essential part of the business applications architecture of any company (Mohanty et al., 2013). The internet has changed the way how companies and enterprises in general function. Almost any business is declared to be a "digital" business. The result was a data explosion. New application paradigms such as web 2.0, social media applications, cloud computing, software-as-a-service applications further contributed to the data explosion. This is the tipping point for big data being more than a trend and crucial to business survival. In production and maintenance, the big data platform has created the ability to handle vast amounts of data with the development of maintenance management Systems (CMMS) which assist decision-making in formulating maintenance strategies (Lee et al., 2017). Collecting data and the production by monitoring the process and the equipment involved allows maintenance departments to predict behavior. The predictive maintenance strategies would not be possible without big data. The operational data from vibration, heat, and pressure sensors, which provide sensory information stored in the Big Database, are embedded in the semiconductor machine to evaluate the machine's condition. The diagnostics and prognostics process may involve real-time and historical data for data mining procedures (Lee et al., 2017; Schreiner et al., 2020).

2.1.5. Artificial Intelligence

Before defining Artificial Intelligence (AI), we need to look closely at where it is coming from. Artificial Intelligence is not an invention of the 21st century. Humankind has been interested in AI for many decades. In 1950 Alan Turning asked, "can machines think?" with his research, he sidestepped the traditional debate about the definition of intelligence (IBM Cloud Education, 2020; Turing, 1950). Turning introduced a test that today is known as the Turning test, a practical test for computer intelligence, involving three participants: an interrogator, a human, and a computer following this procedure (Turing, 1950):

All communication during the test is done via a keyboard and a display screen. The interrogator may ask questions as wide-ranging as they like, and the computer is equally permitted to do everything possible to force a wrong identification. Several different people play the role of the interrogator. If a sufficient proportion of the interrogators cannot distinguish the computer from the human being, then the computer is considered an intelligent, thinking entity.

Since its publication, this test has undergone much scrutiny, but it remains an essential part of AI history. A few decades later, Stuart Russell and Peter Norvig then proceeded to publish a more modern approach to AI and updated it to the new state of the art, and differentiated between computer systems based on rationality and thinking vs. acting (IBM Cloud Education, 2020; Russell et al., 2003):

Human approach:

- Systems that think like humans
- Systems that act like humans

Ideal approach:

- Systems that think rationally
- Systems that act rationally

Artificial Intelligence combines computer science and datasets to enable problem-solving. Today much hype is still surrounding AI and AI development, which is reinforced by emerging technologies and innovations like product innovations like self-driving cars and personal assistants. Despite the hype and relevance of the topic still, no definition fully describes AI.

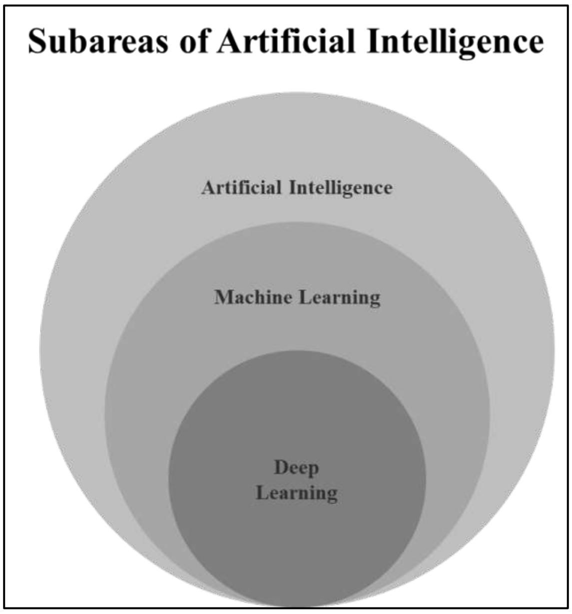

Figure 7: Subareas of Artificial Intelligence (IBM Cloud Education, 2020)

John McCarthy published one of the most common definitions in 2004 and described artificial intelligence as:

> *"It [AI] is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable."* (McCarthy, 2004)."

This definition clearly distinguishes human intelligence from non-human, artificial intelligence. It is necessary to understand that Artificial Intelligence itself will not enhance any production or maintenance process in the industry context. The two sub-fields of AI, Machine Learning (ML) and Deep Learning (DL), in combination with Big Data (Chapter 1.1.4.), are keys to success. Since Deep Learning and Machine Learning are frequently used interchangeably, it is worth mentioning that deep learning is a sub-field of machine learning and not vice versa. These disciplines are comprised of AI algorithms that seek to create expert systems that make predictions or classifications based on input data (IBM Cloud Education, 2020).

2.1.6. Enterprise Resource Planning

Over the decades, Enterprise Resource Planning (ERP) tools have been developed by vendors for Sales and financial departments to be an essential and powerful tool housing all relevant data to run a company successfully. An ERP system can be described as an enterprise resource planning system that is an integrated software solution, typically offered by a vendor as a package that supports the seamless integration of all the information flowing through a company, such as financial, accounting, human resources, supply chain and customer information (Davenport, 1998). Since its introduction to the market, many more application fields have been introduced. An ERP consists of fully integrated modules that run out of a single database (Samara, 2015). All those modules support a specific business process and provide the employees in that department with the needed transactions and insights to fulfill their tasks (SAP Insights, 2022). It covers all company functions and allows users to have real-time access to data.

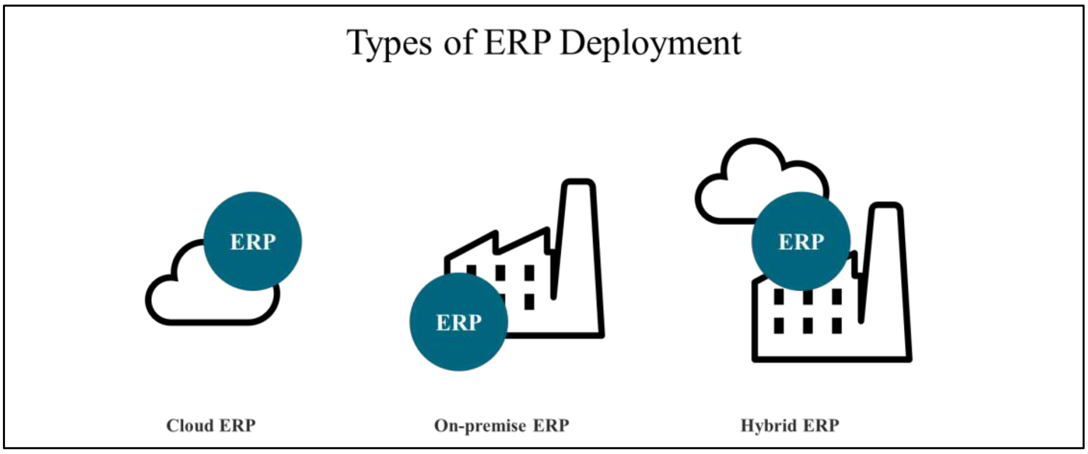

Figure 8: Types of ERP Deployment (SAP Insights, 2022)

Today many providers of ERP systems offer cloud solutions or hybrid solutions to provide even faster access to real-time data and analysis of the data (Figure 8). ERP systems contribute to the integration in two ways (Samara, 2015):

- process-wise
- data-wise

The uniqueness of databases and the adoption of the company's workflow management systems support the integration of the information flows that connect the different parts of the firm and enhance performance (Berett, 2002). These systems are comprehensive software solutions that aim to integrate all business processes and functions (Samara, 2015). In times of the digital transformation (Chapter 2.1.2.) and big data (Chapter 2.1.4.), modern ERP systems are increasingly taking advantage of new technologies such as AI (Chapter 2.1.5.), the industrial internet of things, and the internet of things (Chapter 2.1.3.), machine learning and in-memory databases. They provide businesses with insights from both transactional and unstructured data to ultimately remain competitive in a time of unprecedented change (SAP Insights, 2022).

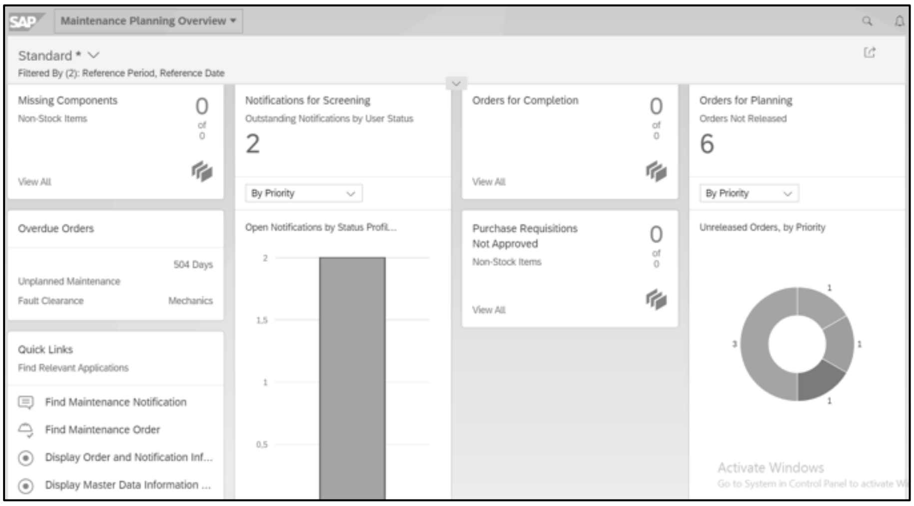

Figure 9: Own Figure showing SAP S/4 Hana Fiori App "Maintenance Planning Overview"

2.2. Maintenance

2.2.1. Definition

The term maintenance is defined by the DIN 31051 norm as:

"Combination of all technical and administrative measures and measures of management during the life cycle of an item maintaining the functional condition or returning it to this condition. Therefore it can fulfill the required function." (DIN-Normenausschuss Dienstleistung, 2019).

Accordingly, maintenance can be divided into preventive maintenance and fault-related maintenance. Preventative maintenance is more complex and can be divided into four different subcategories:

- Maintenance (e.g., cleaning, lubricating)
- Inspection (determination and assessment of the condition)
- Planned repair (e.g., system revisions)
- Improvement (measures to increase functional reliability)

The above mentioned and in figure 11 shown categories are the core competencies of maintenance departments. Those competencies are changing the context of the digital transformation that will be discussed in the following chapters.

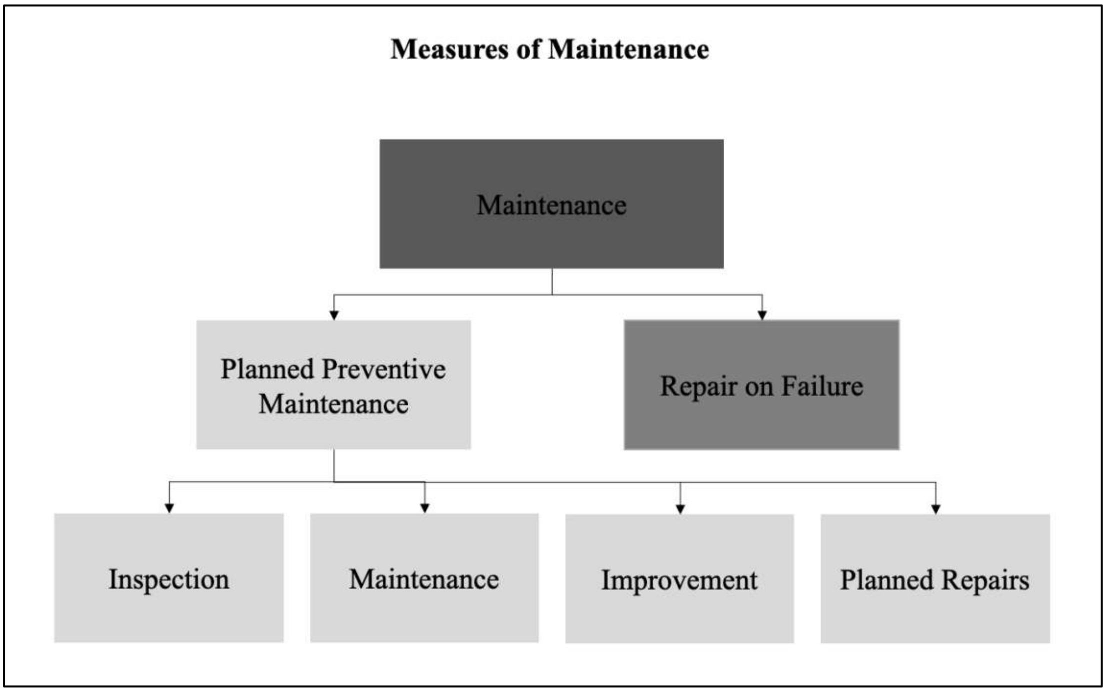

Figure 10: Measures of Maintenance (Sihn et al., 2016)

2.2.2. Evolution of maintenance

The evolution of maintenance machines and production lines did evolve alongside the industrial revolution. As the machines and the whole production process became more complex, maintaining those became more complex. Since 1930 this development can be tracked over four generations (Figure 5). Those four maintenance generations can be classified based on expectations, views on failure, and maintenance techniques (Labib, 2006).

The first generation lasted till World War II and was concerned about fixing the machines and equipment when failing. Failure was considered inevitable, and all equipment was expected to wear out (Labib, 2006). This resulted in long downtimes, but at this stage, mechanization was not yet that far developed, and downtimes did not have the same effect as today (Sihn et al., 2016). The only measures taken towards maintaining and enhancing production were routine checks and lubrication of the machines, which are still important today. Additionally, the complexity of repairing the appliances was fundamental and did not require extensive special qualifications.

From circa 1950 till the late 1970s, the second maintenance generation occurred. During those over two decades, machine availability became more critical, as the workforce was limited after World War II, and the demand for goods rose. As a result, production became more mechanized and machines more complex (Sihn et al., 2016). The maintenance tasks changed from repairing at the failure to ensuring higher equipment availability, a longer lifetime, and low maintenance costs. Life Cycle Costing (LCC) was commonly used (Labib, 2006). This was the first time the concept of preventive maintenance arose by using scheduled overhauls, project management skills, and very slow and big computers.

In that period, maintenance was perceived as a cost factor and not as valuable (Eisenmann et al., 2020). The third generation lasted from early 1980 till the early 2000s and was highly influenced by globalization and rising price competitiveness in the international markets. At the same time, external effects, environmental regulations, and workplace safety did influence (Labib, 2006). Additionally, the machines became more complex, less mechanical parts and more electric equipment that is highly interconnected. The high interconnectivity also leads to more downtime if one component fails; others tend to fail as well, resulting in high downtime costs. This is a significant push factor towards viewing as asset maintenance. The main concern of higher equipment availability and achieving excellence in quality lead to new maintenance methods, such as total quality management (TQM) and six sigma. Failure is described in different patterns, and breakdown is one of six significant losses to the Overall Equipment Effectiveness. Maintenance techniques are condition-based monitoring (CBM), design for maintainability and reliability, failure mode and effect analysis (FMEA), fault tree analysis (FTA), and team-based approaches (Labib, 2006). Additionally, ERP Systems were introduced to control data on one platform, run statistics and analyze.

The fourth generation, which lasts till today, is more demanding than any other generation before. Maintenance oversees the availability rate and improves the machine performance by changing the construction or even designing machines/ components. This is a new aspect of maintenance. With Digital Transformation, a shift from the number one cost factor to a value-creating and competitive asset can be observed (Eisenmann et al., 2020). Like in the third generation, additional environmental and work safety regulations on national and EU- Levels significantly influence today's maintenance departments. The machines and plants consist of more components and are more prone to failure, so they need to be monitored and repaired frequently (Sihn et al., 2016). The availability constantly increases, and the necessary downtime for maintenance measures decreases (Sihn et al., 2016). At the same time, machines are built more and more complex, and identifying the origin of failure is not that simple anymore and takes up more time and workforce. Failure is described in different patterns, and breakdown is one of six significant losses (the Overall Equipment Effectiveness. Maintenance techniques are condition-based monitoring (CBM), design for maintainability and reliability, failure mode and effect analysis (FMEA), fault tree analysis (FTA), and team-based approaches (Labib, 2006). Additionally, ERP Systems were introduced to control data on one platform, run statistics and analyze. Additionally, ERP Systems were introduced to manage data on one platform, run statistics, and analyze.

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2.3. Pulp and Paper Industry

2.3.1. History

Austria has given its geographic location and landscape an ideal location for the pulp and paper industry. Easy access to the eastern and mid-European market and plenty of forests and water access. The first production of paper made of organic fiber in Austria is dated back to the beginning of the 14th century. Until the late 19th century, old textile tissue was used as raw material (Weber, 1874). In those early days, the Austrian paper industry was strongly dependent on imports, as the textile tissues needed were scarce in Austria. The paper was hand scooped before the invention of the paper machine in 1798 by Nicolas- Louis Robert (The Editors of Encyclopaedia, 2021). With the continuous production process and the invention of wood pulp and cellulose in the mid 19th century (Widl, 1994), paper was produced in more considerable quantities and more affordable. This was the crucial invention that allowed Austria to grow into one of the most important paper producers worldwide. Additionally, the production did not depend on imports anymore, as wood was available in vast quantities.

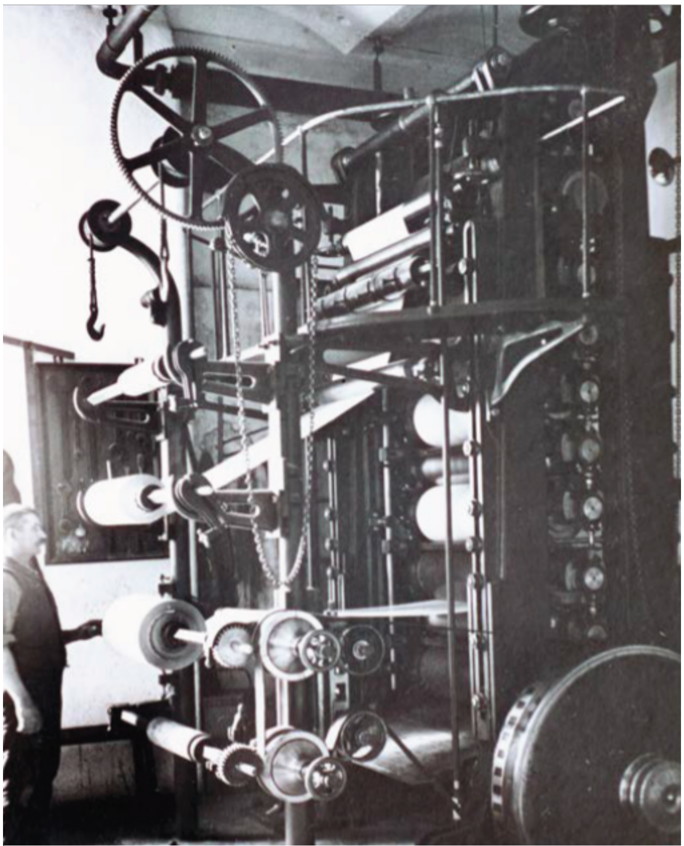

Figure 11: Employee next to a calender ca. 1906 (Müller, 2018)

This also explains the location of most production sites; they were chosen as resource-oriented, close to water access, and forests (Salzer, 1937). Figure 12 shows a production site in upper Austria in ca. 1950 and 2002 at the exact location, next to the river Traun. After World War I, the “Donauraum” was split, and Austria became a small “Bundesstaat” with this, almost half of the previous market was lost. Additionally, high taxes made it difficult to export paper. This ruined the industry and led to challenging competition within Austria. Multiple companies ran out of business. To solve the situation the Österreichische Papierverkaufsgesellschaft m. b. H. was founded in 1935 to regulate the sector. World War II and the after-war period did not significantly affect the paper sector. From 1938 the Austrian industry was included in war production and stopped producing paper in large quantities. With Europe’s rebuilding from 1950 till 1960, the long necessary modernization of the paper and pulp industry had been done. After this period, the Austrian sector was ready to compete in the European market and was leading in producing environmentally friendly paper and pulp (Austropapier 1992).

In the early 1990s, paper consumption within Europe declined, and international competition grew; there was a need to act towards securing the European pulp and paper industry. New markets were entered, products became more specialized, and fast adaption to change became a constant companion. With this second wave of modernization, the industry’s structure changed again towards less but high-volume producers.

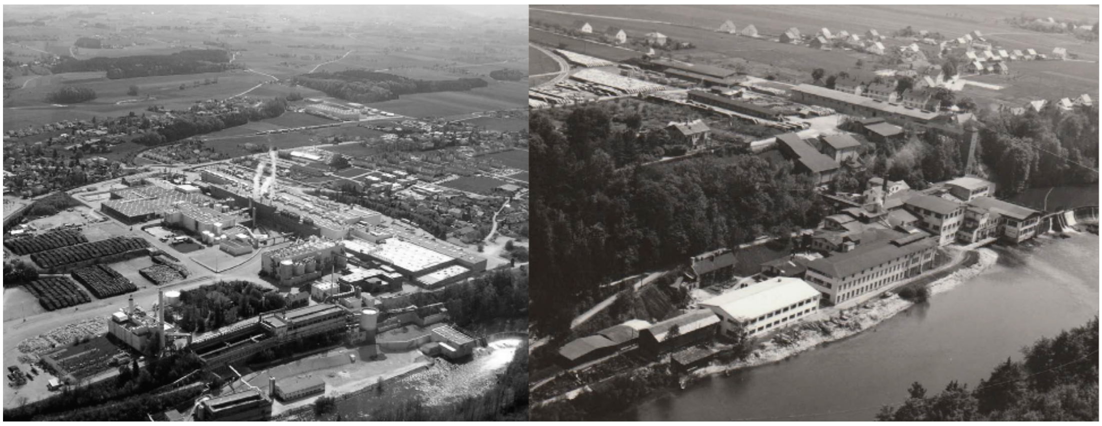

Figure 12: Pictures of Laakirchen Papier AG in 2002 (top) and in the late 1950 (bottom)(Müller, 2018)

2.3.2. The current situation in Austria

The Austrian pulp and paper industry in Europe is one of the most specialized sectors, measured on the industry value creation of 4%. Only two northern countries, Finland (11%) and Sweden (8%), and one southern competitor, Portugal (5%), have a higher value creation (Wolf, 2021). Today, the industry comprises 23 production sites producing 4,7 million tons of paper and 2,0 million tons of pulp with a turnover of 3,581 million € in 2020 (Austropapier, 2021). The Austrian paper industry is essential for the European market, with an export quota of 86,6% (Austropapier, 2021). However, at the same time, depending highly on exporting, as the industry produces more than the home market is consuming. Germany and Italy are the most significant import countries of Austrian-produced pulp and paper (Austropapier, 2021). From 2000 to 2010, many companies left the pulp and paper sector due to high investments that had to be made to stay competitive. Currently, the industry comprises 23 production sites owned by 21 companies. In 2019 the paper industry invested more than 319 million euros (Austropapier, 2021). As the market is about to change, companies do have to adapt even further to survive and provide products at a lower price than the competition, but at the same time make money. In 2020 the investments were reduced by 40,7% (Austropapier, 2021) but were expected to rise again as machines need to be faster and more efficient. 2020 has been a challenging year in

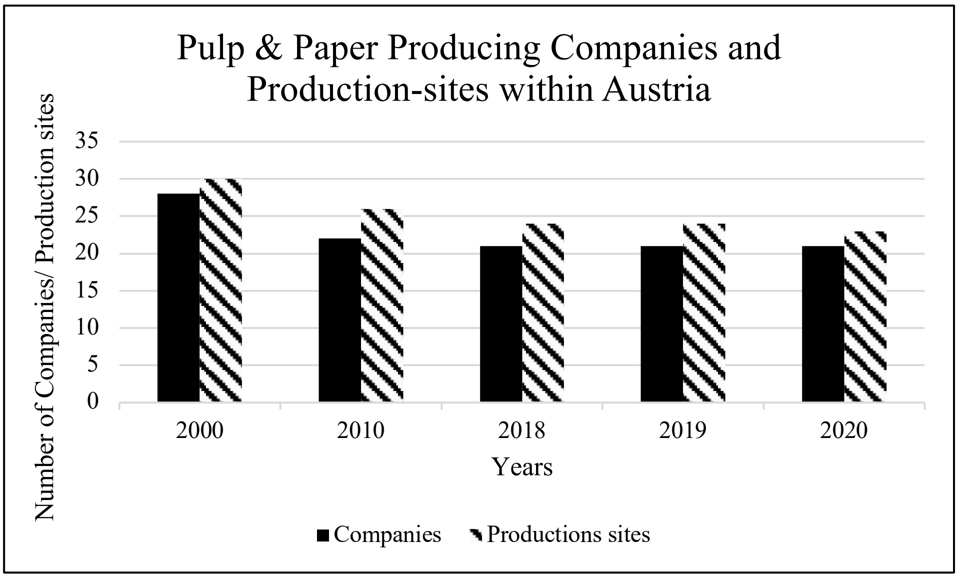

Figure 13: Pulp & Paper Producing Companies and Production-sites within Austria (Austropapier, 2020)

March, a global pandemic hit, and most public life was shut down. The awareness of the consumer that packaging waste is harmful to the environment started a trend that began before the pandemic and is still ongoing to produce paper and cardboard from wastepaper. To produce paper, over 2,6 million t of wastepaper are used. Most of the paper is recycled within Austria; this is possible due to the high paper recycling quota of 76% (Knill et al., 2020). Due to the pandemic, the wastepaper return rate dropped to 70%; in mid-2020, the prices rose and reached an all-time high in March 2021(Wolf, 2021). At the same time, the paper demand and prices dropped worldwide, which caused a stressful situation within the industry. Some companies stopped producing 24/7, shutting down machines entirely or partially. In the third quarter of 2021, the market started to normalize.

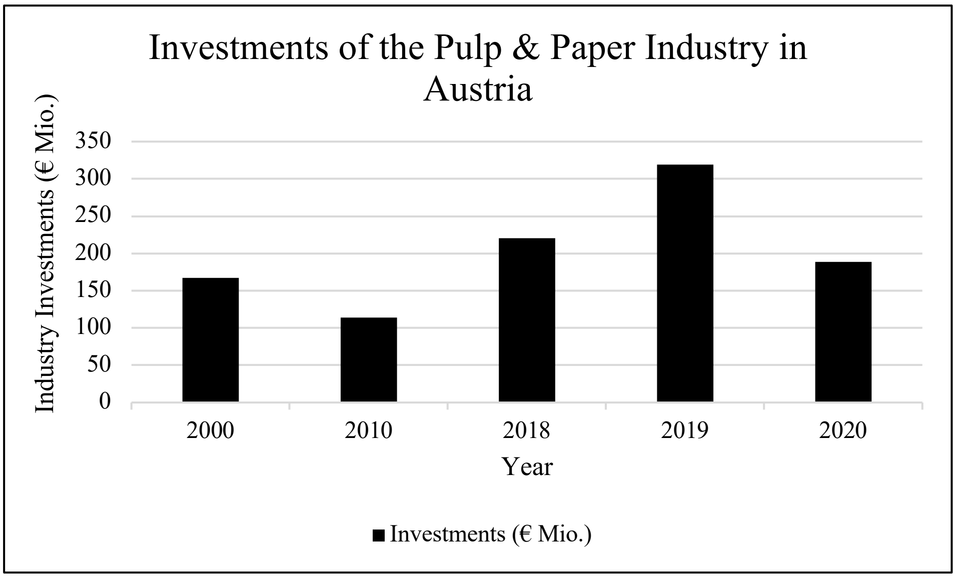

Figure 14: Investments of the Pulp & Paper Industry in Austria (Austropapier, 2020)

Nevertheless, the pandemic did not just cause shortages but also created a higher demand for packaging papers and cardboard. As stores had to stay closed for most of 2020, consumers ordered more online. Therefore, more parcels were sent than ever. The shift from graphic papers towards extraordinary-packaging papers and cardboard has been observed for the last decade. Digitalization is one of the push factors for companies to change products; thus, graphic paper is still used, and we have not entered a paperless society yet. Product innovation is a crucial topic to increase competitiveness and enter new markets. Some companies in the paper sector are developing paper grades with unique properties for special applications, especially in the technical and packaging sector (Austropapier, 2021).

Pulp and paper companies thrive for more efficiency during production and are pioneers in the bioeconomy. Pulp mills are highly efficient biorefineries that each optimally uses wood components, cellulose, and lignin, to produce by-products. Those are used in different industries, such as the paint industry or the pharmaceutical industry. For the food industry, products such as acetic acid, vanillin, or the sugar substitute xylitol are won. Residual materials that are not recycled serve as a renewable energy source by incineration (Austropapier, 2021; Knill et al., 2020).

This leads to an almost no waste circular economy as with every step along the value creation chain, value is created. Some pulp companies also entered the textile market, providing dissolved pulp for yarn production. This market is essential as the pulp is made of natural and regrowing resources, and there is a shift in the textile industry for more sustainable materials (Lenzing AG, 2022). However, this sector also suffered during the pandemic as less clothing was bought.

3. Maintenance digitalization in the pulp and paper industry

3.1. Current situation

The author worked in the maintenance department of a pulp and paper producing company with multiple production sites and therefore did get insights into the industry. The company changed from a traditional ERP System to an in-cloud service during that time. As this was done across the production sites with the aim of one single point of truth, the maintenance departments had to harmonize their processes, which was seen as a chance to optimize remodel processes. This system change was the initiative to digitalize the maintenance department further. The author would like to demonstrate the current situation regarding digitalization in the pulp and paper industry and present her finding.

Maintenance departments are in a constant tension triangle of organization, technology, and people. As described above (Chapter 2.2.2.), maintenance has undergone and is still in the process of a transformation from a cost center to a value creator. With digitalization slowly finding its way into maintenance routines, another change needs to be adapted to the current organization of maintenance departments. The challenge is even greater this time around as the people factor is more critical than ever before. The situation in the labor market has been tense for years, and qualified employees are hard to find.

Additionally, the demographics of maintenance employees are more homogenous, and in the next 1-2 years, many retirements are happening. This highlights the importance of digitalizing processes more and more fast. Another issue is knowledge management. Digitalization is not the solution management expects without the knowledge and the data. In the following paragraphs, the author likes to give insights into the current situation of the maintenance department and focus on the following aspects:

- Use of technologies
- Maintenance routines
- Knowledge management

There are many more aspects to be examined, but this thesis focuses on those mentioned above. The pulp and paper producing sector in Austria does have a long history and tradition (Chapter 2.3.1.). Many production sites are older than 100 years and have grown over time. This is important to mention as this influences the organization and management of maintenance departments. It is always easier to maintain newly built machines and facilities than ones that have undergone many modifications or even been rebuilt and added over time. Naturally, the machines and production are always a step ahead of the maintenance departments. With new equipment come new maintenance requirements and the maintenance department evolves alongside this process.

Paper machines and pulp-producing processes are complex. For example, the paper is carried by mesh wire and felt over a dozen rolls. Not to forget the upstream processes that depend on the raw material, recycled paper or pulp, and are also made up of much equipment. The upstream and production processes need to work perfectly together to produce paper. This is a challenge for maintenance departments in case of a breakdown and during planned shutdowns. The distance between the paper machine and the upstream machinery can sometimes be more than 50 meters. Paper and pulp production sides extend over long distances. This is a challenge for the maintenance employees as the workshop might not be located nearby. Digitalization already highlights its benefits; maintenance employees are equipped with smart devices like smartphones or tablets to look up information about the maintenance order that has been assigned. Such information can:

- the location of the equipment
- parts list
- technical drawings
- service level agreements
- …

If the work requires more information, it will be provided in the app, connected to the ERP system on the smartphone or tablet. Some companies have already changed their traditional ERP Systems to cloud-based ERP systems, making it possible to access real-time data anywhere. With one click on the Equipment number, all additional information such as the History of the equipment and the location where it might have been used before (e.g., motors can be built in after service at a different location) is given. This information allows for making better and faster decisions when maintaining or repairing. Predictive systems are attached and, in some cases, can detect global issues. Today, many sensible areas and sensible machine parts are monitored in the production process.

Using such predictive maintenance tools allows operators and maintenance employees to act before a failure occurs. Some of these approaches are:

- sensors on machines that trigger alarms when vibration or temperature thresholds are exceeded.
- Sensors that predict failures by analyzing sensor data to identify the "signatures" of known failure modes.

Successful predictive maintenance programs reduce the requirement for planned and unplanned maintenance interventions, reduce maintenance costs, and increase production and throughput. In addition, these programs can increase the useful life of high-cost components and minimize safety risks related to machine failure events. Currently, no technologies such as data glasses are used to support monitoring systems and detect irregularities while the machine is running. Using such systems to their full potential requires skilled employees. Even there are already parameters set from the machinery producer on which they operate best. When a failure might occur, every paper machine is different and does have its peculiarities. The senior staff knows such peculiarities from working several years in the same company. Over the last couple of years, the awareness of lost knowledge with the retirement of highly skilled employees has arisen. Until today, not many companies do have a knowledge management system where vital information or knowledge gained over the years is actively collected, digitally processed, and offered to everyone at the company. In worst-case scenarios, the knowledge is lost. This costs maintenance departments much money as the know-how must be bought externally. This creates a dependency on other firms and their quality and availability of highly skilled employees. This causes a stressful situation if in an area is more than one paper or pulp production site and both plan major maintenance shutdowns simultaneously. Who then does get the extra workforce? This drives prices up and has further consequences if not the most critical maintenance works can be performed. In general, planning shutdowns involves much logistics, takes up much time, and needs routines. A few software's help plan shutdowns, for example, setting up timetables with the work to be done step after step. However, there was no digital solution used during the shutdown itself where it sometimes can get chaotic, and more than 100 people are involved.

If looking at data collection and data usage in maintenance departments, there is still a lot to do. Big data is on the rise, and much data is collected, but not all of it is valuable data, and not everywhere a single point of truth is given. Shared folders in the company's intranet are mostly provided but not always used, and some files are still only stored on the employee's desktop or not shared files. On the other hand, transparent processes should be followed for specific maintenance tasks and provide the information to attach pictures or additional data to the work order or the equipment number in the ERP System. ERP Systems are also used to track recurring maintenance tasks. Depending on the parameter set, a maintenance plan is triggered every week, monthly, yearly, or other customized intervals. The responsible person for this maintenance plan does get a mail with the information that a plan is due. Maintenance plans are usually collective plans, and several, e.g., motors, need to be checked. As mentioned above, most maintenance departments are equipped with smart devices; using one for a maintenance plan allows the responsible person to check off one item after the other and give real-time feedback on the status.

Another important aspect is the management of spare parts. The correct spare part must be available in the right quantity at the proper time. Making sure that this is always the case involves a lot of human resources. Maintenance departments and purchasing departments work closely together to avoid dead stock and make sure everything that is needed is available. Most companies have already installed digital systems to make spare part tracking easier. Such systems allow both departments to have live data of the stock of every spare part, given that the established process is followed (spare parts are only allowed to be picked when a work order with a barcode is scanned and the selected item is booked on that order, in some cases only the staff of the warehouse is allowed to pick the items). If the stock is below a specific point, a notification is sent to the person responsible for the equipment where the spare part belongs; and an order is generated through the ERP System. Picking spare parts and ordering new parts are already digitalized to a certain degree, with room for optimization and upgrades.

Furthermore, tools management must be considered when working in a plant-intensive environment. Essential tools like hammers, screwdrivers, wrenches, etc., are available to every maintenance staff, and no formal process is implemented. More expensive tools like drillers and special tools are manually handed out at a tool issue by a co-worker. There are excel tables where the tools/devices are listed in some cases. There is no real control over who is using what, when, and did they return it in a proper state. To a certain degree, this is still built on trust and the co-workers knowing each other. For example, is not everybody allowed to use cars, and the key is not allowed to be issued to people who do not have this permission. There is not yet everywhere a digital process implemented.

3.2. Implementing a digital maintenance structure

With the information of the chapters above in mind, there are six reoccurring steps toward successful digitalization in maintenance departments. In the following paragraphs, the author describes the steps identified, the recommendations for action derived from them, and how to implement them into maintenance management.

3.2.1. 6 steps towards a digital structure

1. Digitalization of machine data

As described in chapter 1.1.4. Big Data, data is necessary and crucial for successfully implementing digital processes. Studies show that over 40% (Stoll et al., 2016) of Companies do not know how to use their data to generate more efficient processes. When digitalizing data into an enterprise-resource-planning (ERP) platform, it is important to decide how far back historical data should be considered. Nevertheless, all data such as warranties, original blueprints, service level agreements, and information regarding service intervals, parts lists, and handbooks should be digitalized. This gathered information should be linked to the equipment numbers or machine part sections in the ERP platform.

Additionally, it is crucial to ensure there is one single point of truth and not multiple versions, e.g., handbooks are saved in individual folders on computers spread through the department. Cleaning the data is also an important step; cleaning is referred to as looking at the collected data, e.g., condition monitoring data of bearings and deciding the are, in this case, amplitude rage that is of interest and only focusing on this rage than instead collecting all data and not knowing the value of it. This helps make reliable decisions and prepares for future AI applications such as virtual reality.

2. Digital resource planning

Taking the resource planning into a digital tool is a game-changer for all maintenance managers and forepersons. Especially in the case of working in shift models and juggling 4-5 different working schedules. Using ERP platforms or additional software with an interface to the ERP platform allows planning workforce and other resources more efficiently. Such tools allow maintenance managers to control the workload of the department and the individual employee. This is also beneficial from a legal point of view. For specific tasks, special training is needed. Ideally, this information is provided in the employee's profile; this allows to assign special work orders to employees with the qualification. In a dashboard, the work orders can be assigned to employees, and the duration of the work can be planned. This created transparency as every employee knows which tasks must be done and gets all the required information. In case of early or late finish or missing spare parts, the employees can give feedback via an app on their smartphone, and another task can be started. In case of sick leave, digital resource planning also does make it easier to find a replacement, as all information such as resting time, skills, and training is provided on the platform.

Another benefit of digital resource planning is that special equipment like forklifts or cars can be planned with such tools. It also allows for restricting such resources for people who do not have training or a license for using it. Again, this is important from a legal perspective. It is safer than looking up the information on lists or basing it on trust.

3. Mobile access to machine and equipment data

Mobile access to machine data and other relevant data enables to reduce of maintenance time in two aspects. First, if data can be monitored online, regardless of the location, unplanned downtime can be reduced as critical situations can be identified beforehand. Secondly, it reduces the time needed to repair equipment. The employee does not get necessary information about repairing the item on his phone or smartphone; unnecessary idle time is reduced (e.g., walking to the next computer station).

In general equipping maintenance employees with mobile devices reduces the steps needed in a regular maintenance workflow. On the app connected to the ERP platform, all data is accessible, including the essential repair history of an item and the parts list. Combining with an IoT platform housing digital twins of the machine equipment enables smart solutions for predictive maintenance.

4. Protocol Data

Protocoling data before, during, and after a repair is essential. Any changes to the machine equipment must be traceable and therefore documented. This documentation is helpful for future repairs or optimizations. As production processes are highly intertwined, equipment A changes may also affect equipment B, and this knowledge is essential to keep the operation running. Also, using a checklist attached to the equipment on the ERP platform is beneficial for documenting recurring work orders. Another great benefit of accessing data online and recording where the work is carried out is that pictures can be taken, which helps to understand the situation better.

5. Digital material logistics

Material logistics is usually not a key competency in maintenance management, but maintenance departments must know what is in stock and whatnot. In case of an emergency repair, the spare part stock must be reliable as otherwise, the unplanned downtime will be even longer, which is cost-intensive. Transferring every warehouse stock to the ERP platform and maintain and keep the stock up to date on the platform. Implementing a digital workflow allows live tracking of the stock. Planning with an extended delivery time using big data and data mining will reduce errors.

Another aspect of material logistics is managing the tool availability. Digitalizing the tool issue does not only reduce loss but also does make sure the correct number of tools of high quality is available. There are several tool issue systems on the market; most of them work similarly and use RFID technology or pin codes to identify the user and track which tool was taken and if it was returned. Such systems allow the user to give additional information when returning a device, e.g., if it is broken, the next person will not be offered the broken tool but an alternative. Tracking who used an item creates awareness to take better care of the tools and reduces costs.

Additionally, it does allow to deposit information on who is allowed to take what kind of tools. More expensive tools then must be requested, which gives more control over usage. Another advantage is that zero-turn tools can be identified and removed from the tool issue with the data collected.

6. Transparency

Transparency is essential; it must be clear why, when, where, what, and who is carrying out a task. Making data accessible to the relevant stakeholder groups enables them to carry out their work better and faster. Dashboards are great to have a visual overview for maintenance managers and help communicate the data to c-level staff and support requests for, e.g., more staff.

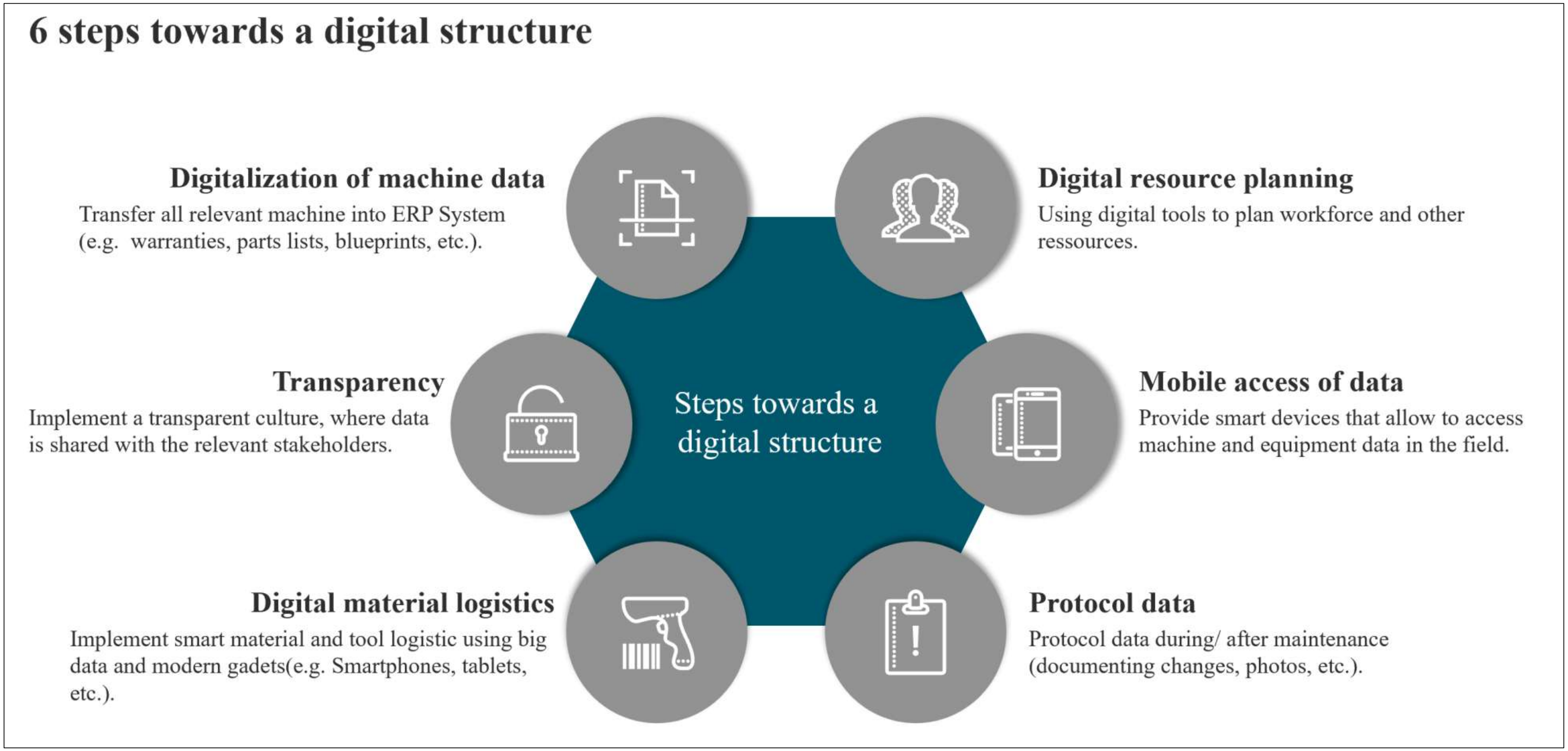

Figure 15: 6 steps towards a digital structure. Source: Own illustration

3.2.2. How to implement a digital Structure

When implementing a digital structure, certain obstacles need to be overcome. With the transformation to digitalized workflows, previous structures are changed and need to be adopted by the maintenance employees. To make this shift easier to handle, as well as to create more transparency following the four steps should be considered:

1. Define Processes

When implementing a digital structure, it is essential to define processes across the whole department, the production site, and, if necessary, across the whole company, including all production sites. Every single process should be reviewed and, if needed, adapted, harmonized, or created from scratch.

2. Integration of all interfaces

All IT-Systems need to integrate into the digital structure. Before implementing the new structure, it is essential to inspect whether the IT Systems are all up to date and are the right fit for the new digital concept. Also, even after implanting a digital structure, companies should keep their eyes open for new, more fitting, and efficient digital solutions and integrate them into the processes.

3. Inform

Informing the employees is essential, not just during change. As new processes and tools can motivate some employees, others might be afraid and boycott the change. Information on the upcoming changes should be communicated in advance to prevent defensive behavior. It also helps to implement change agents that act as a link between management and employees. Those change agents are there to listen to the prejudices against the change and proactively inform. In general, it is helpful to set up change management.

4. Education

Education is the most critical aspect when implementing a digital structure; the employees need training on how to use new tools and be informed of any changes in the workflow. Such training should be professional and repeated at specific intervals to ensure a smooth transition.

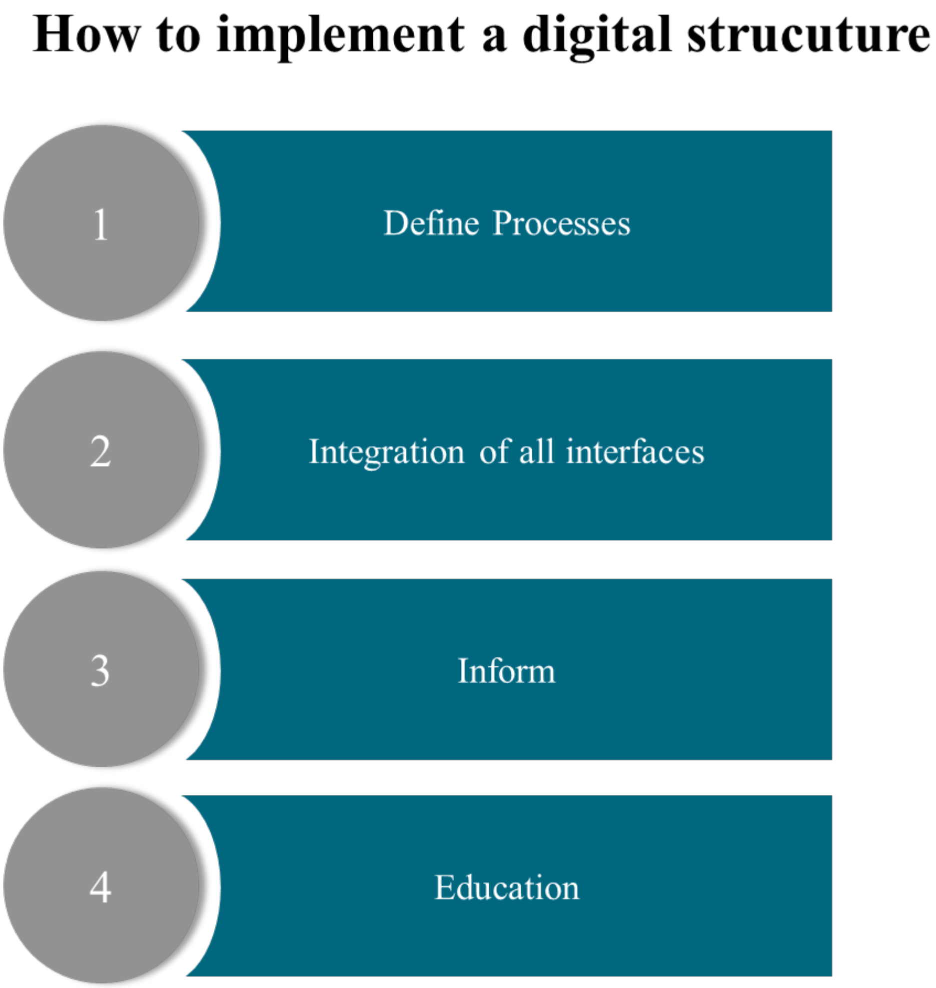

Figure 16: Own Figure showing the steps of implementing a digital structure

4. Survey with the Austropapier

The survey with the Austropapier and its members is evaluated in the following two chapters, and the method is explained.

4.1. Method

The data was collected through an online questionnaire. SoSci, a Germany-developed online survey tool, was used to conduct this survey. The choice was made as the survey participants should be assured that their information is handled according to European data laws. No server outside the European Union is hosting the survey, and the data is not used for other purposes. SoSci also deletes all data after 90 days, and no information is stored on their server after this period. This highlights the benefit of using this tool if handling sensible data.

The online questionnaire comprises 31 qualitative questions in German, as the survey participants are located in Austria and divided into five sections. A closed question format is preferred over an open question format due to objectivity, clear evaluation possibility, and higher comparability. The questions included general questions about the company and maintenance department size and the maintenance budget in Section two. The third section focuses on the changes in the job profile of the maintenance technician. In the fourth section, the focus is on the digitalization of the tasks performed in maintenance departments. The fifth and last section asks questions about data collection and usage.

The survey participants were the Austrian pulp and paper industry employees working in the maintenance department, especially in management positions (Head of the maintenance department) targeted. To reach this specific and small group, the author received the support of the Austropapier, the Association of the Austrian Paper Industry.

4.2. Analysis of the Survey

The survey aimed to investigate the digitalization of the maintenance departments in the Austrian pulp and paper industry, as there is not much data available on this specific industry. The questionnaire has been translated for the analysis into English as the questions have been asked in German to ensure they are understood correctly by the participants. In this survey, 25 pulp and paper industry employees answered the questions. In the following paragraphs, the 31 questions are analyzed section-wise. An overview of all questions and answers is pictured on pages 44-45.

The first section concentrated on questions about the participant's employer's company and maintenance department size. The finding of questions 1-5 is that 20 participants are working in the paper producing sector, with half producing graphic paper and the other half producing recycling paper. Over 68% of the survey participants are employed in a higher managerial position, such as head of the maintenance department; this was also the survey's target group. Additionally, the answers show that the majority of the Austria producing companies employ between 301 and 400 employees (Figure 17). With 32% of the companies employing more than 46 people in their maintenance departments and 16% employing more than 15 people in their departments.

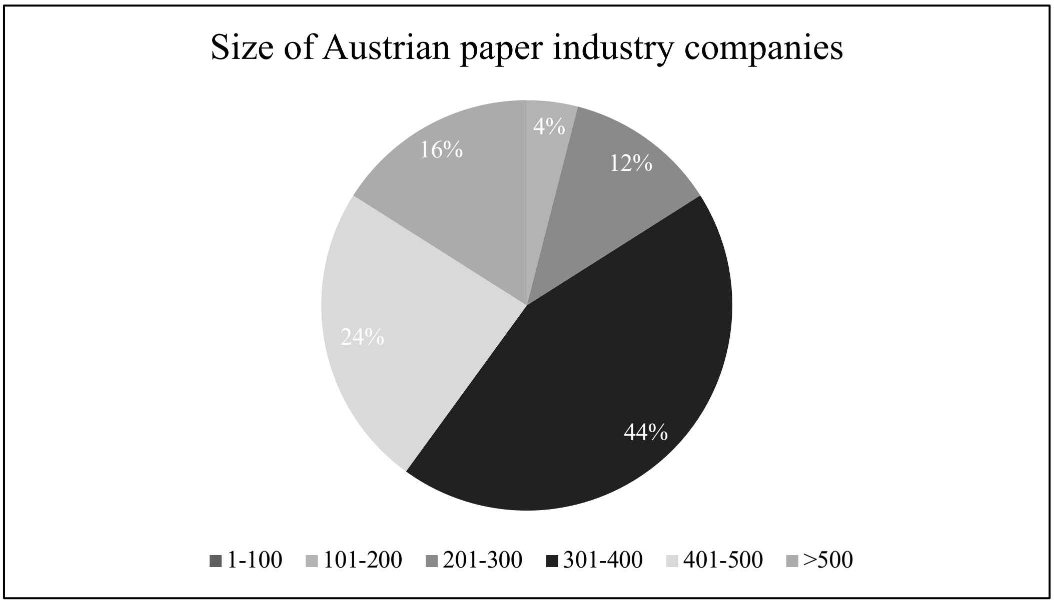

Figure 17: Own Figure showing the results of Q2: How many employees work in your company?

An interesting finding of the second section asking questions about maintenance budgets is that over 60% of the participants did not answer those questions. This was expected as the industry is relatively small, and no one wants too much information public. Susceptible data such as budgets. The answers that have been given allow assuming that an average maintenance budget is approximately 10 € Mio. for one fiscal year. Furthermore, only 20% of the participants stated that their company does have a separate budget for digitalization investments (Figure 18).

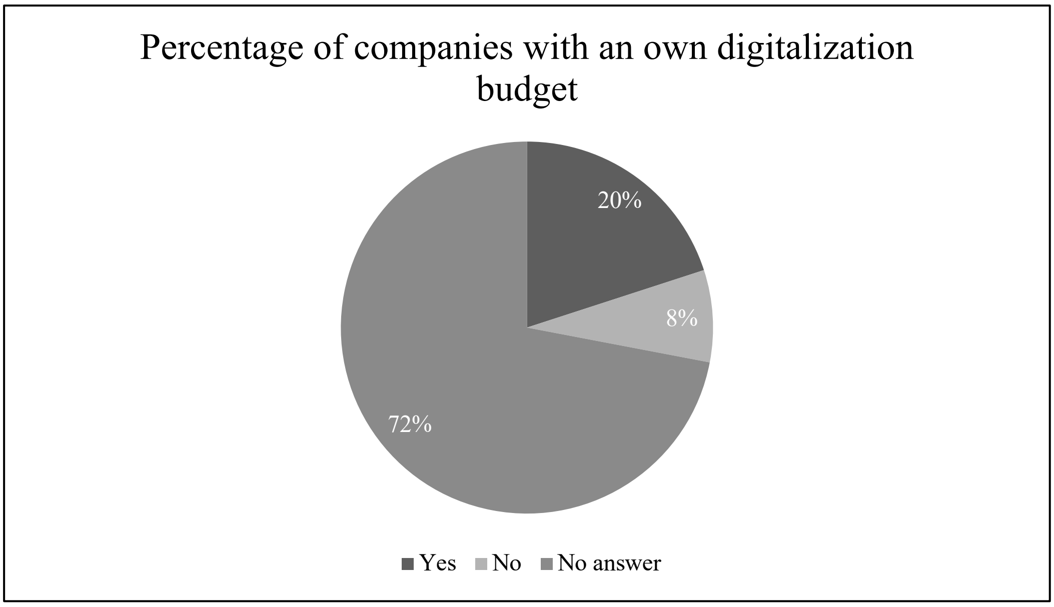

Figure 18: Own figure showing the results of Q8: If not included in your budget, are there extra budgets for digitalization?

The third section focused on questions about the current digitalization status of the maintenance departments. To evaluate the current situation, questions 9-14 have been asked. The key takeaway is that despite the debates that have been going on over the past years, 40% of the participants do not think that digitalization is cutting jobs, but over 40% do see a change in the job profiles of maintenance professions (Figure 19). Surprisingly only 16% said that they are using a digital system to allow employees to clock in and out of work orders by themselves. This is quite interesting as 28% of the participants already use smart devices such as tablets and smartphones to support employees during maintenance work. Over 40% believe that more smart devices should be used and that there is room for improvement. If, as stated above in the question about the budget, there is no actual budget for digitalization, it is no surprise that there are not yet enough smart devices used.

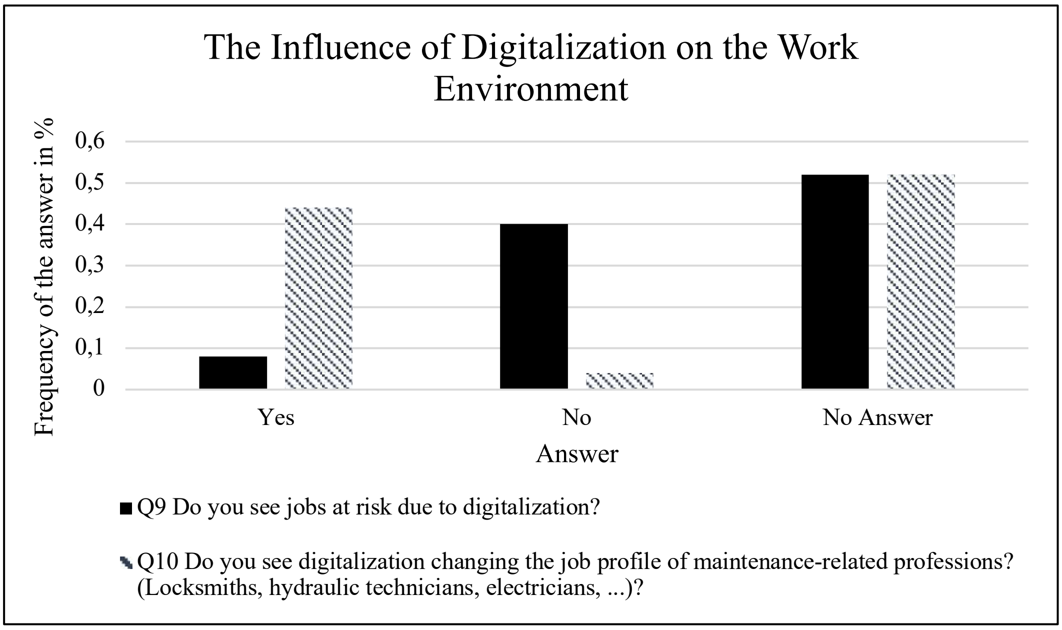

Figure 19: Own figure showing the results of Q9 and Q10

The fourth section investigated questions about the maintenance tasks and processes. The influence of standards and regulations on the work of maintenance employees was reported by 16% as high, and 12% declared the impact as very high. This is quite interesting if compared to the 28% of the participants stating that a high amount of work within the maintenance department is reoccurring work, such as maintenance plans which must be done to some extent because of regulations. On the other hand, 44% percent do not see the potential of automation exceeded within their departments and do see much potential in further investing in digitalization. An interesting finding is that 40% of the participants stated there are prerequisites for interfaces to digital monitoring systems for components, and 40% state using those interfaces already. The other 60% are either not using their interfaces or do not have prerequisites for such. Another relevant finding is that over 32% believe that their IT landscape is not flexible enough to adapt to changes fast, hindering them in further digitalizing. Over 40% of the participants answered the question if, for communication between departments and colleagues, any analog tools are used with “No.” At the same time, only 32% are regularly using a tool such as Teams, which is in times of the pandemic not much. In this section, questions 15-25 were asked.

The fifth and last section focused on data usage and data management. Those questions are important to understand the greater picture of the current digitalization status of maintenance departments in the pulp and paper industry, as big data is the key to a successful digital transformation. When asked about the data availability and data quality in their companies, only 4% of the participants answered "very good," and 28% stated that the availability and quality of data are "good" (Figure 20). When asked if they think real-time data management is necessary for their company, about 20% believe this is somewhat necessary compared to 12% saying it is unnecessary. Also, 20% of the participants already use cloud tools for real-time data analysis. Additionally, 28% of the participants do not think that further investments are needed in this area. This is an exciting finding, as in today's maintenance department's fast reaction in case of breakdowns and preventing breakdowns is a key competency and

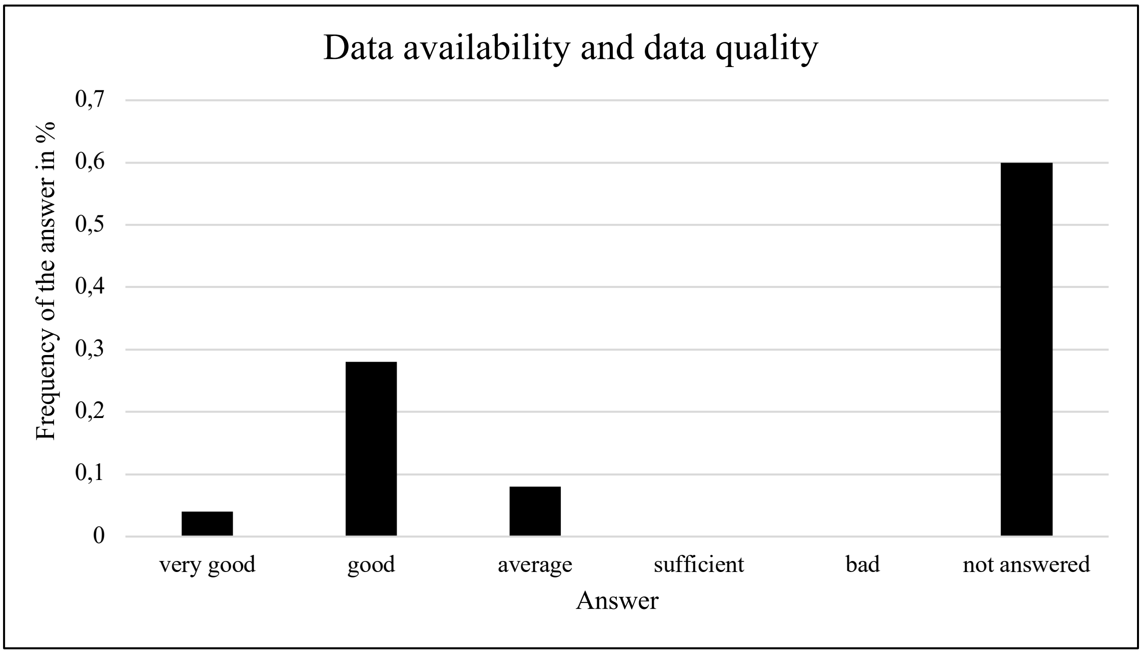

Figure 20: Own figure showing the results of Q26: How do you assess data availability in terms of data quality in your company?

To fulfill this, the management of real-time data is needed and indispensable. When asked about the security of the used tools, 12% stated they do not have an operation technology security officer (OT-Security), and another 16% were not aware of this position. This could explain why so many companies hesitate to implement more digital interfaces and, in general, digitalize more of their processes as they do not know how to make them secure and protect themselves from being hacked.

Evaluation of the survey "Digitalization in the Maintenance Departments of the Austrian Pulp and Paper Industry."

Section 1: General Information					
Q1 In which division of the pulp and paper industry do you operate?					
Pulp	**Graphic Paper**	**Recycled Paper**	**Hygiene Paper**	**Not Answered**	
8%	40%	40%	4%	8%	
Q2 How many employees work in your company?					
1-100	**101-200**	**201-300**	**301-400**	**401-500**	**>500**
0%	4%	12%	44%	24%	16%
Q3 What position do you occupy in your company?					
Management	**Head of Maintenance Department**	**Foreman**	**Work preparation**	**other**	**Not Answered**
8%	68%	8%	7%	8%	4%
Q4 Is your company or branch located in Austria?					
Yes	**No**	**Not Answered**			
96%	0%	4%			
Q5 How large is your maintenance department					
<15	**16- 30**	**31- 45**	**> 46**	**Not Answered**	
0%	8%	8%	32%	52%	
Section 2: Budget					
Q6 What is your annual maintenance budget?					
< 1 Mio.	**>1-5 Mio.**	**6-10 Mio.**	**11-15 Mio**	**Not Answered**	
4%	4%	16%	8%	60%	
Q7 How much of your budget do you spend on digitization projects?					
0%	**1-5%**	**6-10%**	**Not Answered**		
8%	24%	8%	60%		
Q8 If not included in your budget, are there extra budgets for digitalization?					
Yes	**No**	**Not Answered**			
20%	8%	72%			
Section 3: Digitalization					
Q9 Do you see jobs at risk due to digitization?					
Yes	**No**	**Not Answered**			
8%	40%	52%			
Q10 Do you see digitization changing the job profile of maintenance-related professions?					
Yes	**No**	**Not Answered**			
44%	4%	52%			
Q11 Do you use a tool for digital time recording (employee clocks in and out independently on orders)?					
Yes	**No**	**Not Answered**			
16%	28%	56%			
Q12 Do you use mobile devices (smartphones/tablets) to manage maintenance activities?					
Yes	**No**	**Not Answered**			
28%	16%	56%			
Q13 If Yes does each MA own one?					
Yes	**No**	**Not Answered**			
8%	28%	64%			
Q14 If no, do you see more need here?					
Yes	**No**	**Not Answered**			
40%	4%	56%			

Section 4: Maintenance Tasks and Processes

Q15 How large is the share of specifications due to standards and regulatory requirements (e.g. DIN, ISO, etc.) in your area of responsibility?

Very high	high	average	low	Not Answered
12%	16%	20%	0%	52%

Q16 How often do you have to use different systems (e.g. ERP, CMS, etc.) to complete your tasks?

1 (seldom)	2	3	4	5 (very often)	Not answered
4%	0%	8%	16%	20%	52%

Q17 Often a process passes through several stations or departments. Which methods do you use to ensure a smooth flow of information? (internal)

	1 (never)	2	3	4 (very often)	Not answered
Courier/ circulation folders	40%	8%	0%	0%	52%
Email	0%	4%	0%	12%	84%
MS Teams	4%	4%	12%	20%	60%
Slack	40%	0%	0%	0%	60%
Chat	12%	24%	0%	4%	60%
Other digital solutions	12%	24%	0%	8%	56%

Q18 How difficult is it to determine the status of an ongoing maintenance/ production process?

	1 (not possible)	2	3	4 (very easy)	Not answered
maintenance	0%	4%	12%	2%	82%
production	0%	4%	4%	2%	90%

Q19 There are regularly bottlenecks in ongoing maintenance processes. How easily can you identify these bottlenecks?

Very easy	Good	Average	Sufficient	Poor	Not Answered
4%	32%	8%	0%	20%	36%

Q20 What is the percentage of similar repetitive tasks in your area?

Very high	High	Average	Low	No repitition	Not Answered
0%	28%	12%	8%	0%	53%

Q21 How high is the flexibility in the IT landscape e.g. to make or implement changes to the running process?

Very flexible	Rather flexible	Not felxible	Not answered
0%	12%	32%	56%

Q22 How high is the automatization/digitalization in your task area?

	1 (insufficient)	2	3	4 (very high)	Not answered
automatization	0%	8%	8%	16%	68%
digitalization	4%	8%	20%	8%	60%

Q23 Do you consider the potential for automation in your area of responsibility to be exhausted?

Yes	No	Not answered
0%	44%	56%

Q24 Do you consider the potential for digitalization in your area of responsibility to be exhausted?

Yes	No	Not answered
0%	44%	56%

Q25 Are there prerequisites for interfaces to digital monitoring systems in the (machine) components (nozzles, pumps, motors, rollers, ...)?

Yes	No	Not answered
40%	4%	56%

Section 5: Data Collection and Data Management

Q26 How do you assess data availability in terms of data quality in your company?

Very good	good	avergae	sufficient	bad	Not answered
4%	28%	8%	0%	0%	60%

Q27 How do you estimate the management of real-time data in your organization?

Very necessary	Rather necessary	Not necessary	Not answered
8%	20%	12%	60%

Q28 Do you see the need to invest more in this area?

Yes	No	Not answered
12%	28%	60%

Q29 Are you already planning or using cloud offerings such as Voith's OnCumulus or others for real-time data analysis?

Yes	No	Not answered
20%	20%	60%

Q30 Do you have an OT-Security (OperationTechnology Security) officer in your organization?

Yes	No	Not answered
18%	12%	60%

Q31 Have you heard of the term OT-Security?

Yes	No	Not answered
28%	16%	56%

5. Discussion

The previous chapters had the aim to identify the status of the digitalization of the maintenance departments of the Austrian pulp and paper industry to get a better understanding of the digital transformation and its enablers, as well as identify possibilities and challenges. In the following chapters, the author likes to discuss her findings.

5.1. Possibilities

The evolution of the maintenance departments from solely seen as cost factors to a value-creating entity within the company is a huge accomplishment and does highlight the importance of maintenance. The maintenance departments needed skilled and well-educated employees to keep seen as the value creator. What distinguishes the employees from external staff is the know-how and expertise of the machines they work on. This is important and should not be neglected as every paper machine does have its peculiarities, and knowing how to handle them saves time and money. In addition, it is essential to keep those knowledge carriers in the company if possible. Today there are many options for qualified employees on the labor market. Incentives are needed which promote working in maintenance and make it more attractive. Fair compensation is essential but investing in new and up-to-date technologies, such as smartphones, tablets, virtual reality glasses, and continuing education programs makes a profession more attractive.

Furthermore, the years of experience and the collected knowledge of employees is priceless and a great opportunity. Therefore, promoting knowledge sharing within the company and gathering the knowledge in databases is another success factor that sets companies apart. As well as keeping the knowledge in the company even after retirement or employees exiting the company. Implementing such a knowledge database seems to have a high investment cost at first sight. Still, this will pay off over a short period as the information is accessible to everyone and not only to a small group of people or even only individuals. The later such a database is implemented, the greater is the opportunity cost. In addition, there is another excellent possibility towards a more digitalized maintenance – the use of the already high volume of collected data. In the survey (chapter 4.2.), participants stated that they were not satisfied with the quality of the available data. It is one thing to collect data but another to provide valuable data. There is much potential to digitalize this data collection and analysis process further to improve the data quality. If we recall the definition of Big Data by de Mauro et al., analytical methods transform collected data into value:

> *"Big Data is the Information asset characterized by such a High Volume, Velocity, and Variety to require specific Technology and Analytical Methods for its transformation into Value."*(de Mauro et al., 2016)

Respecting this, a great benefit of the collected data can be expected. New technologies such as AI methods to automate data analysis are great additions to the current techniques. Once the parameters are set, the data analysis is faster, and if desired, even real-time data management is possible. The management of real-time data is only seen as necessary by 8% (chapter 4.2) of the survey's participants. This is rather interesting as predictive maintenance is the prevailing method used in today's maintenance departments. This method highly relies on historical data, but real-time data is likewise essential. The "alarm" notification that a parameter is off range can only be identified using real-time data. There is an excellent opportunity to expand this further and gain more insight into the machine and its components' behavior. If real-time data is used in greater volume, more unusual behavior can be identified before a breakdown occurs, and the maintenance departments can react proactively.

The maintenance process itself and how the work is performed show significant opportunities to automate further and digitalize. Over 44% of the survey participants stated they do not think the level of automatization and digitalization has been reached yet in their departments. To achieve more automatization, the processes and workflows must be clearly described. No workarounds should be available; one single point of truth must be given throughout the process or workflow. Implementing digital workflows does not provide more transparency but also makes them less error-prone. Further expanding the use of technologies that are already available such as smartphones and tablets, and implementing the digital workflow on those does give the maintenance employee more freedom to access data wherever and whenever needed. This also does save much time as there is less required to walk back and forth between the workshop and the place where the work is performed.

The employee does have all data needed on the device and can also organize more efficiently. Required tools and spare parts are listed for the current and next work orders. Therefore, the employee does not need to make multiple trips to the warehouse and tool issue, as the required items can be collected for both (or more) tasks. This involves the implementation of a digital workforce management system. Only 16% of the survey participants stated that they already use such or similar tools, and 28% do not use such tools. To further expand the use of such devices or installing one is an excellent opportunity to gain a better overview of the available workforce and the capacity of every single employee as the work orders can be assigned to them. Such systems also allow adding of information about an employee's qualifications. This additionally does simplify the planning and setting of work as the responsible person does know who is allowed to perform, e.g., work in ex-zones and who not. This further promotes transparency and is helpful when asked by C-Level management to explain which works are performed and why there is, e.g., is need for a higher budget or additional employees.

5.2. Challenges

The Digital Transformation in maintenance departments of the Austrian Pulp and Paper Industry has yet not completely arrived, and there is still a lot to do, or in some cases, a first move must be made. The myth that many jobs will be at risk with digitalization is not entirely true, and only 8% of the survey participants believe that jobs will be lost. It is more of a transformation in the maintenance-related professions to observe, which also 44% of the participants agree. I

n Chapter 2.2.2. Evolution of Maintenance the change to smart service engineers as a step of the maintenance evolution is explained. With machines gaining on electrical components and the rise of the Industrial Internet of Things (IIoT) with a need for an increase in interfaces to cloud services, call for employees with mechanical, electrical, and programming and general IT-skills smart service engineers. It is difficult to find such allrounders in the labor market, but there are possibilities to create chances for employees to become smart service engineers through training and knowledge. A difficulty could be that there are not that many employees who like to participate in extra training; to prevent the need for attractive compensations and individual career options for those choosing to participate. With many retirements of the “Baby-Boomer generation” happening in the following years (Chapter 3.1), it might be interesting to implement such training already during apprenticeship training. This is a great way to distinguish one’s company from others in the competitive labor market and be more attractive to young talents interested in working with new and emerging technologies. Another challenge towards digitalization is the flexibility of the IT infrastructure; over 32% of the survey participants stated that they experience their IT infrastructure as inflexible, and adaptation is not easy to make. Whether this is an issue of the structure itself, there are enough employees to fulfill the requests. Nevertheless, there will be an increasing need for employees who have completed training in IT. This remains a challenge as many companies are looking for employees with IT skills, and there is a shortage of skilled employees.

Another challenge is identifying the status of an ongoing maintenance process. Only 2% of the survey participants stated that it is “very easy” for them to an ongoing maintenance process; another 12% stated it is easy for them. There is much potential to improve the data collection on ongoing maintenance processes. As mentioned above in the discussion of the opportunities (Chapter 5.2.), implementing a workforce management system helps identify work order status. As helpful as these systems are, no one solution fits all; most solutions need to be tailored to the company’s needs, followed by high investment costs, which may hinder decision-making. One of the bigger challenges is the management of data. Much data is already collected but managing and analyzing this data to generate meaningful value is difficult. Especially for predictive maintenance systems to manage the data correctly as historical and real-time data is needed. Setting the correct parameters by analyzing historical data and updating those is crucial and requires much experience. Setting one parameter wrong can cause much damage and cause high costs. Additionally, when setting parameters, communication and sharing of experience across departments must be considered as e.g., maintenance and production are highly interconnected. This sometimes can be challenging as both parties do want to see different information of the components, but this discussion is valuable as it ensures the parameters set are thought through and not “random”. Implementing new technologies such as Artificial Intelligence and Machine Learning are possibilities but, at the same time, also a challenge as it is not a miracle tool that works asap; it is more progress over time. Furthermore, employees need to understand this technology if companies do not want to rely on external services. Additional interfaces are needed to the already existing ones if using such tools. As mentioned in chapter 5.2, there is a need to have more interfaces to connect more components to cloud services. This will allow more real-time insights into the machine's behavior. Only 40% of the survey participants are already using such interfaces. But with more interfaces come new problems, such as ensuring the security of these interfaces. It does take many human resources regular maintenance to keep those interfaces safe. Surprisingly only 18% of survey participants already have an operational technology security employee (OT-Security). More surprisingly was that 16% of the participants did never hear of this position. When everything is getting digitalized, not employing someone with the expertise to keep everything safe and protected is a high risk. As being hacked is not an unbreakable risk, hacking attacks on companies have increased in the last few years. This might also be one of the reasons why companies hesitate to invest in the digitalization of their processes. Increasing the percentage of budget spent for digitalization, even better, providing a budget solely to digitalize the maintenance department allows for safely driving the digital transformation. The survey participants stated that 24% invest 1-5% of the maintenance budget into digitalization. Only 20% stated having their digitalization budget, and 8% did not have a budget solely for digitalization topics (Chapter 4.2.). Proposing higher spending for the digital transformation of the maintenance departments might be a challenge with the C-Level management. Still, it is an important discussion that must be done to stay competitive. Furthermore, such a process does need preparation, it can't be implemented at once, and therefore budgets are needed. One of the most important aspects is preparing, including, and educating the employees. In chapter 3.2.2. where steps for a successful implementation of a digital structure are given are educating and informing important points. If implementing a digital structure and the accompanying change is to go well, the employees must be won over by these plans. Since change is usually met with resistance, it is crucial to provide information about it (not too early, but not too late either – this is a whole challenge on its own) and allow employees to help shape this change. Older employees, in particular, may find it difficult to accept this change in structure. Statements such as "we have always done it this way, why should we change it now? It works!" should be taken seriously and countered with good arguments. implementing a change management process can help overcome this challenge. Additionally, it is important to train the employees on using the newly implemented systems and tools to take the fear of using them and ensure a successful go-live. It does not help to spend millions on new technologies if no one knows how to use them properly.

6. Summary & Outlook

The paper manufacturing industry has evolved alongside every major industrial revolution since the 18th century. As the industry has developed, so has the manufacturing of paper. The digitalization of communication and media has critically reduced the global need for graphic paper. Besides this, the impact of increasing digital communication and transformative technologies (Chapter 2.) is a challenge but also a great chance to reshape processes. In the beginning, the author mentioned that maintenance departments of the Austrian Pulp and Paper industry do create more costs as % of sales than other industries with similar production complexity. This is a further push factor towards digitalization. This thesis aimed to give an insight into the current digitalization of maintenance departments of plant-intensive productions with a focus on the Austrian pulp and paper industry and identify challenges and possibilities.

There is almost no literature focusing on the digitalization of maintenance departments in Austria's pulp and paper industry. The author performed a survey evaluating the situation within the industry. The aim was to reduce the lack of information, fill a literature gap and give an overview of the evolution of digital maintenance management. According to the findings of the survey there already have been made preparations and small steps toward digitalization and implementation digital structures, but there are still a few challenges ahead (Chapter 4.2.). Following critical implications are identified:

1. There is still a long way ahead for a digitalized maintenance department. First steps have been made, but budgets to further invest are either small or do not exist.
2. More awareness of c-level management towards the need for a digital structure is crucial and must be understood as value-creating and not as cost factor.
3. For implementing a digital structure successfully, it is vital to have excellent data availability, collection, and management (Big Data) as they are the key-value creator and input of most technologies (AI, ERP, etc.).
4. Knowledge sharing within maintenance departments and cross-departmental should be increased and promoted. With interwovenness increasing this is inevitable.

In addition to those implications, the author identified six steps that reoccur when implementing a digital structure and suggests a 4-step process for implementing a digital structure within maintenance departments (Chapter 3.2.). Lastly is say that digital transformation is happening whether companies like to participate or not.

Considering the evolution of maintenance, the next era is on the horizon. The rise of emerging technologies and the further evolution of state-of-the-art tools, like predictive maintenance systems, are happening faster than ever. Keeping up and identifying the right fit tools for one's processes is not easy but must be seen as a core task. The future of maintenance digitalization is strongly intervened with the evolution of production processes and will increasingly affect maintenance processes. Technologies such as Machine Learning and Digital Twins will also be topics that maintenance must deal with and understand. In the context of smart maintenance and the changing job profiles of the maintenance-related professions, new tools will play a more significant role in the future than previously expected. They will become standard equipment to complement traditional tools, such as wrenches.

One of these great new technologies is virtual reality. Some machine manufacturers already offer such systems, but soon, VR goggles in conjunction with digital twins of machines or machine components will play an important role and indispensable. Another technology related to the above-mentioned is the industrial internet of things. This will become a topic more quickly than anticipated, as it is seen as an enabler for VR.

Even further in the future, but already much discussed in the research, are the abilities of materials and machine parts to heal themselves. with these self-healing capabilities, damaged materials should be able to return to their original state within a few seconds. This would mean a further evolutionary step not only in maintenance but for society as a whole.

Abbreviations

Artificial Intelligence	AI
Condition-Based Monitoring	CBM
Computerized Maintenance Management Systems	CMMS
Deep Learning	DL
Enterprise Resource Planning	ERP
Failure Mode and Effect Analysis	FMEA
Fault Tree Analysis	FTA
Industrial Internet of Things	IIoT
Internet of Things	IoT
Life Cycle Costing	LCC
Machine Learning	ML
Operation Technology Security	OT-Security
Return of Investments	ROI
Radio-frequency Identification	RFID
Total Quality Management	TQM

List of Figures

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