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From Digital to Smart

The use of digital and smart solutions in Industry Development of a recommendation for a German Industry Company

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Abstract

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Nowadays, companies must pursue the goal of developing their own strategy on the path to digitization in the course of Generation Industry 4.0. Whether without any digital infrastructure or already partially existing systems, the change from digital to smart factory is no longer absent. Accordingly, the use and implementation of digital technologies is becoming necessary.

The aim of this paper is to answer and show which core technologies Industry 4.0 offers and what they mean and then to show the way from a digital to a smart factory. This topic is then embedded in a special internal company recommendation for action.

Principle of Equality

For reasons of better readability, the use of gender-specific wording has been dispensed with in this bachelor thesis. However, it should be explicitly stated that the masculine forms used are to be understood for both genders.

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IV Abbreviations

3D	3 Dimensional
ACATECH	Deutsche Akademie der Technikwissenschaften
AGCO	Allis-Gleaner Corporation
AR	Augmented Reality
DAS /DAQ	Data Acquisition System
DXF	Drawing Interchange File Format
EClass	Data standard for the classification of products and services
I4.0	Industry 4.0
IBM	International Business Machine Corporation
IDC	International Data Corporation
IDC	International Data Corporation
IIoT	Industrial Internet of Things
IoT	Internet of Things
IP	Internet Protocol
IT	Information technology
KNX	short form of Konnex (lat.: connexio)
LTE	Long Term Evolution
NFC	Near Field Communication
PLC	Programmable Logic Controller
RoM	Return on Maintenance
MM	Market department
SCP	Secure Copy Protocol
SEaP	Smart Engineering and Production
SQL	Structured Query Language

TAB	Technische Anwendungs-Beratung
TCP	Transmission Control Protocol
VR	Virtual Reality
WI-FI	Wireless Fidelity
XML	Extensible Markup Language

1 Introduction to the Topic

When people talk about digitization and the integration of the industrial value chain, they end up with what is now understood as Industry 4.0. Combining information and communication technologies with automation technology towards the Internet of Things offers a higher degree of networking within and between production sites and on the way between suppliers and the customer. The digitalization of products and services is also part of this. This results in new business models. Finally, Industry 4.0 realizes the smart factory in the digital value network.[1]

More and more companies, whether in the automotive sector or the electrical industry, such as switchgear construction, are subject to the change of digitalization. Therefore, it is crucial to deal with these topics and build up a basic understanding. The Figure 1 shows the classification of the named issues in a Venn diagram.

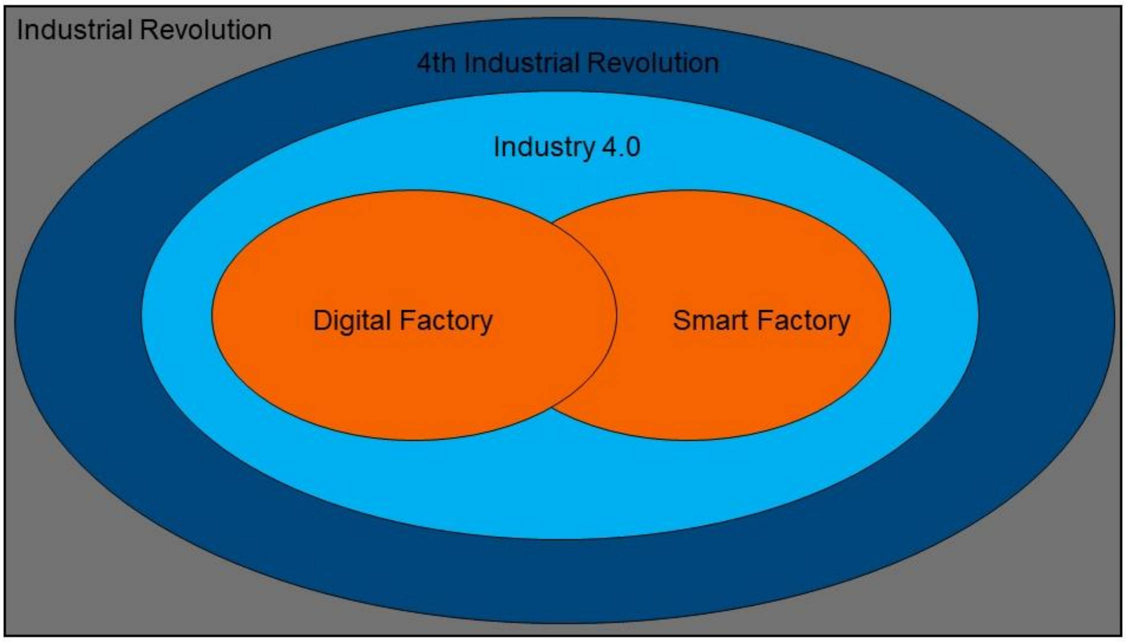

Figure 1: Placement in the context of the industrial revolution[2]

[1] Cp. (ZVEI e.V., n.d.)

[2] Own illustration

Figure 1 shows a precise classification starting with the industrial revolution, from the 4th to Industry 4.0. It then leads to the topics of interest to industry, namely the ‘Smart factory and the Digital factory’.

What these development steps look like will be explained and defined in the section 1.1.

1.1 Research Question, Methodology, and Structure

As previously mentioned in the introduction, the industry, in particular, is transforming digitalization (Figure 1). In a volatile, fast-advancing development of technologies, companies have to face the challenges of Industry 4.0 and make adjustments.

Due to the extended scope of the prospective answer and the limited coverage of this paper, the more precise goals are broken down as can be seen in Figure 3:

- *Industry 4.0*
- *Internet of Things, Big Data, & Augmented Reality*
- *Digital Factory vs. Smart Factory*
- *Practical Application for a German Company*

Based on this, the theoretical foundations of the industrial revolution and, therefore, the current Industry 4.0 will be explained and defined using intensive literature research. Furthermore, this thesis deals with the three core topics **Industrial Internet of Things, Big Data, and Augmented Reality** in the context of industrial application. These were deliberately chosen in the logical and theoretical order they build up.

Using a target analysis, the current state of a German company has to be analyzed in the last chapter, and a recommendation for adjustments should be given. The following theory and the topics of the first chapters, related to technical literature, serve as a basis for all solution proposals and concepts.

1.2 Industrial Revolutions and Their Significance

Before directly starting with Industry 4.0, it is first essential to recognize the historical origin. Therefore, as shown in Figure 1, we will first briefly review the steps and stages of the industrial revolutions with a transition to the 4th industrial revolution.

Starting in the 19th century, the industrial revolution heralded a historic turn. The steam engine, railroad, electrical engineering and other inventions fundamentally changed the world of work. This enabled and realized an enormous economic upswing. At the same time, there was a transition from an agrarian society to an industrial society.[3]

To understand how the revolution has affected our current understanding of the industry, it is first necessary to trace the development and stages of the first to fourth industrial revolution. The timeline in Figure 2 should shortly give a basic understanding of it.

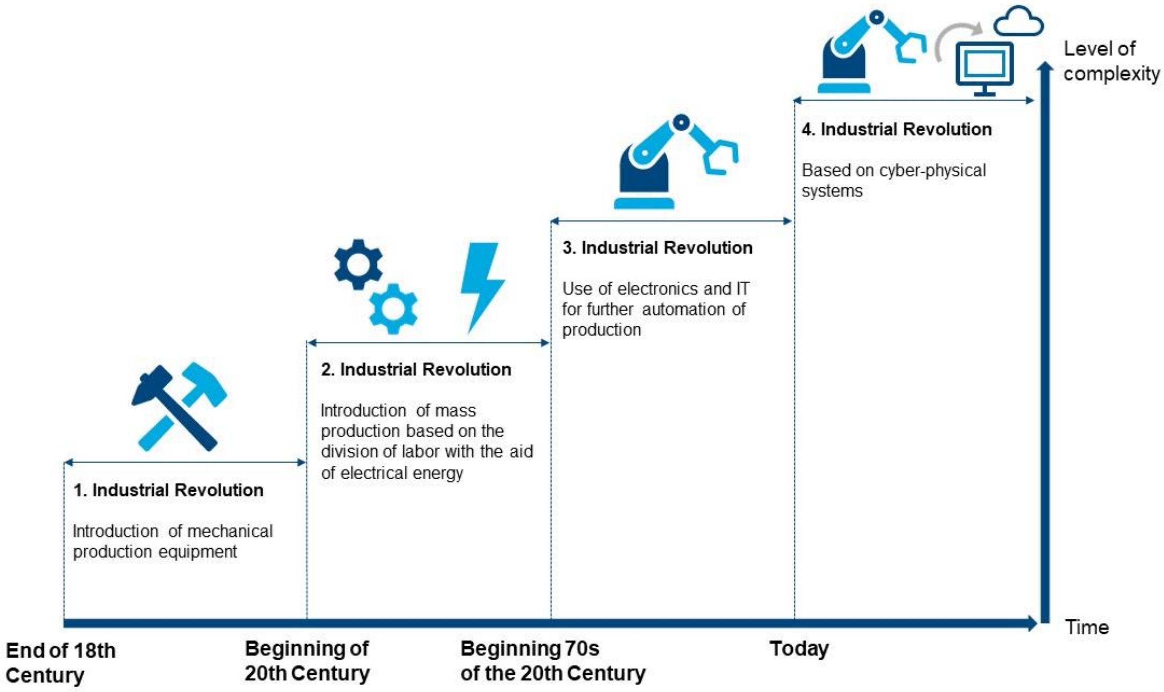

Figure 2: The four phases of the industrial revolution[4]

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[3] Cp. (Schwabe, 2021)

[4] Own representation based on (Becker , et al., 2019, p. 7)

What we can see in Figure 2 are the industrial revolutions divided into four sections. It should be noted that no step-by-step plan was made at this time, and these industrial steps were not planned in areas. Instead, these phases can be divided today and provide us information about the technical progress made. Therefore, in the upcoming section, a summary of the industrial revolution should adequate general insight to allow the later described Industry 4.0 in section 1.3 and the following chapters to be understood.

1st Industrial Revolution:

The first industrial revolution, describes the first use of machines for production, as can be seen in Figure 1. However, by starting around the 18th century, this early industrialization also includes the first railroads, coal mining, and heavy industry.[5]

2nd Industrial Revolution:

Characterized by the use of electricity as a driving force, this was the starting signal for the 2nd phase, which began with the end of the 19th century. Production facilities were further automated, and mass production was introduced. The first steps towards globalization were also taken, which paved the way for the next industrial phase.[5]

3rd Industrial Revolution:

The first functional computer, built by Konrad Otto Ernst Zuse, is a core element of this industrial development. Above all, further developments in electronics and IT were the focus from the 1970s onwards. Slowly but steadily, personal computers established offices and formed a new branch of industry.[5]

4th Industrial Revolution:

The increasing digitalization of analog technologies and the use of cyber-physical systems form the basis of the current fourth industrial revolution in which we find ourselves today. Production on demand and not in stock and just-in-time production are just a few examples of this phase. **Digital Revolution** and **Industry 4.0** are terms that come up in connection with this.[5]

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[5] Cp. (Frick, 2017)

Through increasing automation and smart machines and smart factories, informed data is helping to produce goods more efficiently and productively throughout the value chain. As a result, much greater flexibility is possible, allowing manufacturers to better meet customer requirements by performing individualized mass production (mass customization) - ultimately seeking to achieve high efficiency at a batch size of one. In addition, a smart factory can achieve information transparent and better decisions by collecting more data from the factory and combining it with other company operational data.[6]

As we can see, the fourth industrial revolution represents the current phase of development in which we find ourselves. This is the reason why it is crucial to define 'Industry 4.0' in a single chapter.

[6] Cp. (IBM Deutschland GmbH, n.d.)

1.3 Industry 4.0

The term ‘Industry 4.0’ has become concisely a buzzword. Although it was only introduced in the context of the Hanover Fair in April 2013, it is now very common for almost everyone. However, very different images of the future are associated with this term. One group believes that there is nothing fundamentally new behind Industry 4.0. "It's all been there before" is the comment. Production technology will continue to develop evolutionarily, i.e., rather linearly and in smaller steps. The other group associates Industry 4.0 with the potential for fundamental, rather revolutionary changes in the design of value chains. Changes that do not even exist in our current world of imagination.[7]

But what is Industry 4.0 about? The term, although constantly used, seems to be challenging to define. Everything is now "4.0" in some way. In its April 2016 progress report, the Industry 4.0 platform, which is supposed to implement the German government's ideas for industry, understands it to mean the "digitalization of production.”[8]

Germany's Federal Ministry of Research goes even further in its definition of Industry 4.0. In a report from 2016, they defined the term more holistically.

Industry 4.0 describes an economic paradigm shift that brings opportunities to increase efficiency in processes and potential for the development and transformation of value creation and new business models for (industrial) companies. The digital transformation is increasingly breaking up rigid value chains. In their place, highly flexible value creation networks are emerging, platform markets, and innovative smart services. The networking of products, processes, and infrastructures in real time heralds the fourth industrial revolution, in which supply, production, maintenance, delivery, and customer service will be linked via the Internet.[9]

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[7] Cp. (Duis, 2017, p. 259)

[8] Cp. (Hänisch, 2017, p. 9)

[9] Cp. (Bundesministerium für Bildung und Forschung, 2016)

Based on the networking mentioned above through the Internet and the development of new business models, the thesis's most important points of consideration can now be defined in a mind map. The illustrated Figure 3 shows parts of Industry 4.0. Since this is a vast topic, the scope is limited to the more extensive topics marked dark blue and the subchapters light blue. The thesis’s most essential points of consideration can now be defined based on the earlier mentioned networking through the Internet and the development of new business models.

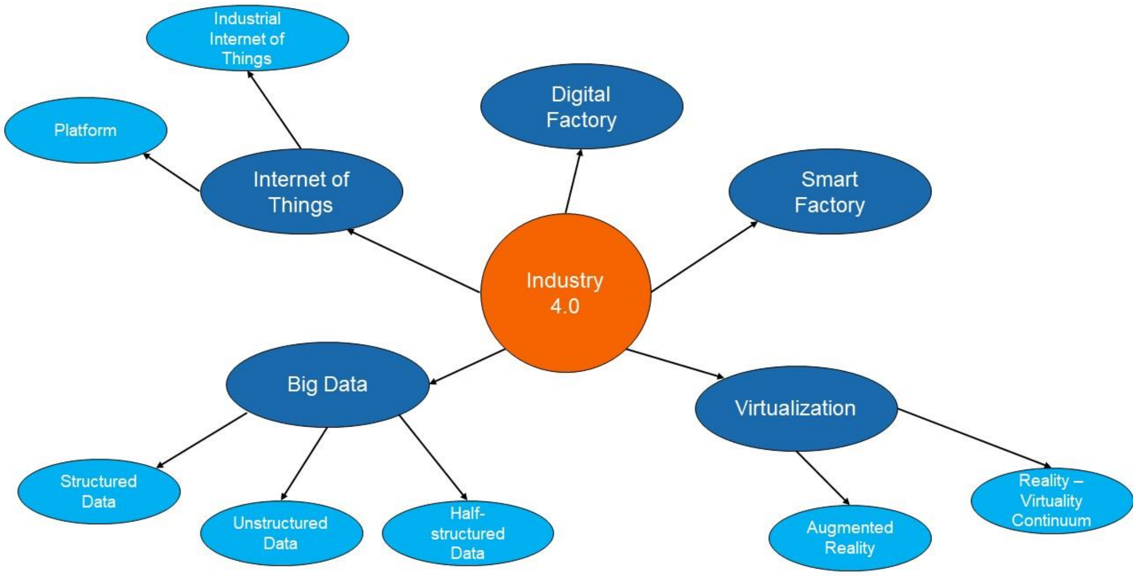

Figure 3: Mind map Industry 4.0[10]

As shown in Figure 3 Industry 4.0 is divided into five core topics: **Big Data, Internet of Things, Digital Factory, Smart Factory,** and **Virtualization**. This mind map shows the topics covered here in the final work. At this point, it should be said that there are many other points of consideration in the context of Industry 4.0. Therefore, the mentioned topics will be broken down in a logical sequence in the following sections.

[10] Own illustration

1.2.1 The Internet of Things

Parallel to the emergence of digital transformation, everyone is talking about the Internet of Things (IoT). But the origins of the IoT go back much further.

Richard Morley first designed programmable logic controllers (PLCs) back in 1968. Later, PLCs formed an important basis for machine-to-machine (M2M) networking. In practice, however, this only came about after the Ethernet standard for computer networks was introduced in 1983, and PLC devices were networked with personal computers (PCs) for the first time in 1986. The decisive impetus for the comprehensive networking of all devices came in 1989 with the conception of the World Wide Web by Tim Berners-Lee and the introduction of the TCP/IP Internet protocol in 1992 - the two solid foundations for the Internet as we know it today. It is not far from the idea of the Internet of Things: the invention of the term for a network of all possible devices and 'things' connected via the Internet goes back to the Briton Kevin Ashton in 1999.[11]

In a shortened diagram of the *wirtschaftswoche*, the most important steps of the Internet of Things can be seen again in Figure 4.

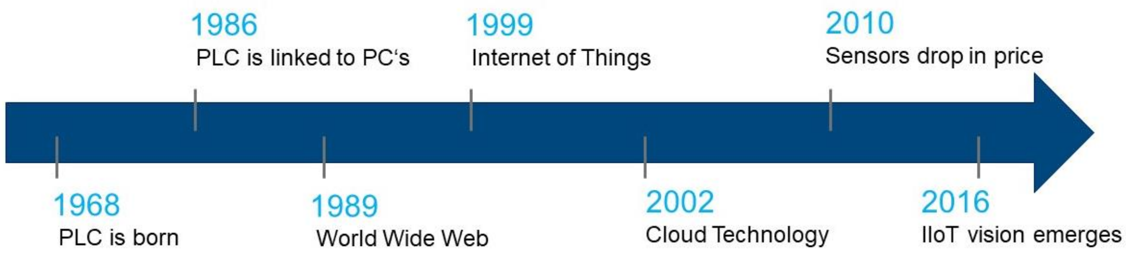

Figure 4: IoT History Timeline[12]

Now that the history of the Internet of Things has been covered, the following section will deal with the definition of the term and its application areas.

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[11] Cp. (Kroker, 2018)

[12] Own representation based on (Kroker, 2018)

The Internet of Things provides the technological platform and, above all, the open standards. These allow the data generated in production to be collected and integrated without great effort. The data obtained in this way can then be used, for example, to 'make' Big Data, i.e., to systematically evaluate the data using statistical methods and thus gain new insights.[13]

A question directly linked to this is networking from the definition above. Jen Clark from IBM makes a clear statement on this.

"In a nutshell, the Internet of Things is the concept of connecting any device (as long as it has an on/off switch) to the Internet and to other connected devices. The IoT is a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them."[14]

Since this work deals with applications in the industry, we will now take a look at where and in which area IoT finds its application. Figure 5 shows various IoT application areas.

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[13] Cp. (Hänisch, 2017, p. 14)

[14] (Clark, 2016)

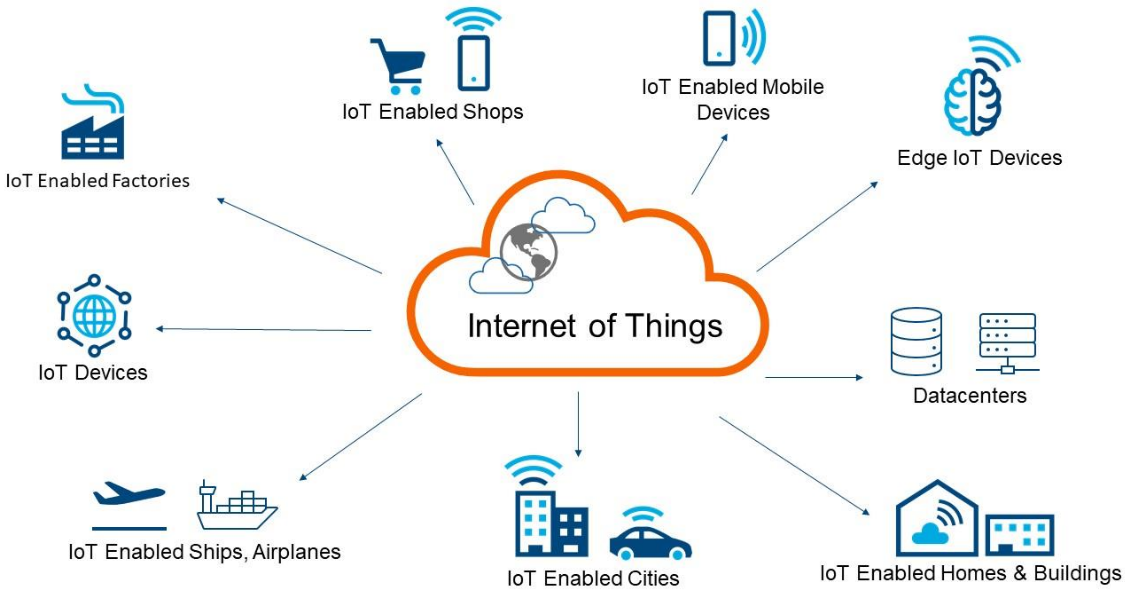

Figure 5: IoT Application Examples[15]

As we can see, there are many different scopes: whether in the private sector, IoT-enabled homes, buildings, or the industrial sector. The Internet of Things, therefore, covers many areas. Regardless of the exact application, the question may arises about how an IoT-enabled factory works, for example. For this very reason, we will now take a closer look at the structure and functionality of such a system. This system is also often understood in the literature as IoT architecture.

IoT Architecture

IoT system architecture is often described as a four-step process where data flows from sensors attached to "things" through a network and eventually to an enterprise data center or the cloud for processing, analysis, and storage.[16]

[15] Own representation based on (TIBICO Software Inc., n.d.)

[16] Cp. (Jahnke, 2020)

Stage 1: Sensors and Actuators

The process begins with sensors and actuators, the connected devices that monitor (in the case of sensors) or control (in the case of actuators) a "thing" or physical process. Sensors capture data about the status of a process or environmental condition. In some cases, a sensor may detect a situation or event that requires a near-instantaneous response so that an actuator can take corrective action in real time.[17]

Stage 2: Data Collection and Gateway

Data acquisition is the process of signal sampling that measures real-world physical conditions and converts the resulting samples into digital numerical values that a computer can then process. Data acquisition systems (abbreviated by the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:

- Sensors that convert physical parameters into electrical signals.
- Signal conditioning modules to convert sensor signals into a waveform that can be converted into digital values.
- Analog-to-digital converters that convert conditioned sensor signals into digital values.[18]

Stage 3: Analytics

Once the IoT data has been digitized and aggregated, it must be processed to reduce the volume of data before sending it to the data center or cloud. Processing of this type usually takes place on a device close to the sensors, e.g., in an on-site control cabinet.[19]

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[17] Cp. (Jahnke, 2020)

[18] Cp. (Dataforth Corporation, n.d.)

[19] Cp. (Jahnke, 2020)

Stage 4: Analysis via Cloud or in the Data Centre

“The data needs to be stored for further in-depth analysis which is why data storage is such an important stage of an IoT architecture. It helps with follow-up revision for feedback as well. Cloud storage is the preferred storage method in IoT implementations. That's also because more in-depth processing which doesn't require immediate feedback can be carried out in the cloud or at physical data centres. There, more capable IT systems can manage, analyze, and more securely store the data. This is also where sensor data can be combined with other data sources for more detailed insights.”[20]

[20] (Reynolds, 2020)

1.2.2 Big Data

You can't manage what you don't measure. This guiding principle, often attributed to Peter Drucker or W. Edwards Deming, contains more wisdom than may meets the eye. It is about the explosion of digital data and why it is so important. With Big Data, decisions and performance can be made better and more directly based on data.[21]

With this introduction, let us now take a look at the perspective definition of the term and finally determine a definition that applies to the work.

"In recent years, the term "big data" has been used by various major players to label data with attributes. Several definitions of big data have been proposed over the last decade."[22]

These are the beginning words of the authors in the book section *The European Big Data Value Ecosystem*. Like in many other topics, these different definitions mentioned above illuminate various aspects. The overview below lists different big data definitions and approaches.

Big Data refers to large volumes of data originating from sectors such as the Internet and mobile communications, the financial industry, the energy industry, healthcare and transport, and from sources such as intelligent agents, social media, credit and loyalty cards, smart metering systems, assistance devices, surveillance cameras, and aircraft and vehicles, among others, which are stored, processed, and analyzed using specialized solutions.[23]

"Big Data stands for the vast amounts of data available to us every day - data on the order of zettabytes produced by computers, mobile devices and electronic sensors. Using this data, companies can make decisions, improve processes and policies, and develop customer-centric products, services and experiences. Big Data is called "big" not only because of its scale, but also because of the diversity and complexity of its nature[...]."[24]

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[21] Cp. (McAfee & Brynjolfsson, 2012)

[22] (Curry, et al., 2021, p. 5)

[23] Cp. (Bendel O. , wirtschaftslexikon.gabler, 2021)

[24] (SAP Deutschland, n.d.)

"Big data can mean big volume, big velocity, or big variety."[25]

"Big data is high volume, high velocity, and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization."[26]

After looking at the various definitions, we can deduce that there are many ways to understand Big Data. However, a brief analysis shows us that very often the terms volume, velocity, and variety occur. From this, we can deduce that the core of the definition of the word Big Data consists of these. This must now be examined in more detail.

Big Data brings together a set of data management challenges for working with data under new scales of size and complexity. Many of these challenges are not new. What is new are the challenges raised by the specific characteristics of Big Data related to the 3 Vs.

In general, the 3Vs stands for volume, velocity, and variety. In the book *The Elements of Big Data,* Edward Curry and his team describe these 3 Vs related to Big Data. **Volume** describes handling large amounts of data with data processing. **Velocity** is about the data speed. It focuses on managing streams of high-frequency incoming real-time data, e.g., from sensors. **Variety**, the range of data types or sources, means using various syntactic formats, like Spreadsheets or XML.[27]

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[25] (Stonebraker, 2012)

[26] (Laney, 2001), (Manyika, et al., 2011)

[27] Cp. (Curry, et al., 2021, p. 5)

Taking this information, a simplified chart can be created that addresses the three key points.

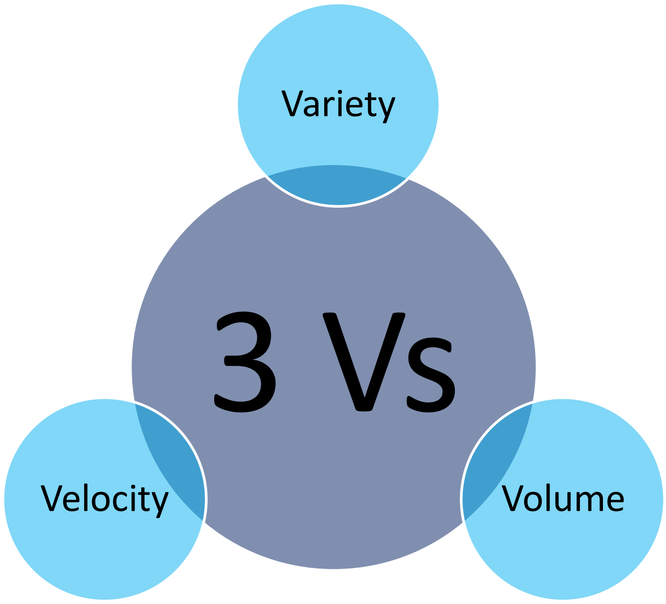

Figure 6: 3Vs of Big Data [28]

Figure 6 shows that Big Data can be described with the 3Vs. Some of the literature adds a fourth one, the veracity, or even a fifth one. However, to not exceed the scope of the bachelor thesis, it focuses on the aforementioned Vs (Volume, Velocity, and Variety). These terms often appear in the professional literature. In connection with big data, requirements can be derived that are very relevant for companies from an economic perspective. Since it is precisely this topic, i.e., the significance for the company, that is the main focus of the thesis, the contents of the 3Vs will be discussed in more detail below.

[28] Own representation based on (Dorschel & Dorschel, 2015, pp. 7-8)

Werner and Joachim Dorschel find suitable descriptions in the book *Praxishandbuch Big Data*.

3 Vs	**Description:**
Volume	According to Moore, if there is talk of Big Data, often the law is mentioned. The primary statement of Moore's Law is that the computing power of IT systems will double (between 12 and 24 months). This rule, established for about 50 years, is still valid today. Therefore, this basis results in the possibility that small, very powerful computer chips can take over control tasks and simultaneously generate digital data.
Velocity	There is no single understanding of 'velocity'. While some talk about the speed at which data is captured, others define it as how data is produced and must be changed. However, it can be said that volume and velocity are interrelated, i.e., the faster data is calculated, the more data is produced in a period of time. Furthermore, velocity means that existing data must be adapted or extended by ever faster-changing circumstances.
Variety	When it comes to the heterogeneity of data formats and data sources, we speak of variety. Data can be stored for entirely different purposes. Often, the predominant data is in an unstructured format (see Big Data chapter) and cannot be assigned to a predefined data model. As a result, it is the task of Big Data to gain knowledge about sources and formats.

Table 1: Characteristics of Big Data[29]

[29] Own representation based on (Dorschel & Dorschel, 2015, pp. 7-8)

If the measures described above do not solve the challenges ahead, there is no way around an alternative approach to data processing, storage, and analysis. In this case, the Big Data approach offers new, expanded possibilities for dealing with large volumes of data. But companies should first check that the expense of the new system does not exceed the added value. There is no one-size-fits-all solution for challenges involving large volumes of data and complex interrelationships - but a little analytical understanding is all it takes to determine when a Big Data system is worthwhile: A individual analysis of the requirements and the existing infrastructure provides a clear answer as to whether the new system is the right approach or not.[30]

But what exactly does Big Data measure, what is data, and what types of data are there in the first place?. These are precisely the questions that will be dealt with in due course.

A rough estimate shows that the Internet is currently around 21 petabytes in size. Expressed in bytes, this corresponds to 21 with fifteen zeros. Unimaginable data that is constantly growing. Estimates assume that the amount doubles every two years. In 2024, the amount of data is expected to increase to 160 zettabytes. It is estimated that by then, 50 billion devices will be connected to the Internet (Internet of Things).[31]

“As unimaginable as it seems today, the Apollo guidance computer took the first spacecraft to the moon with less than 80 kilobytes of memory. Since then, computer technology has grown exponentially - and with it, the amount of data generated. Global technological data storage capacity has doubled roughly every three years since the 1980s. Just over 50 years ago, when Apollo 11 lifted off, the amount of digital data generated around the world would have fit on an average laptop. Today, *IDC* estimates that number at 44 zettabytes (or 44 trillion gigabytes) and predicts that it will grow to 163 zettabytes by 2025.”[32]

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[30] Cp. (Eduard, 2017)

[31] Cp. (Löffler, n.d.)

[32] (SAP Deutschland, n.d.)

From this statement, it can be deduced that as technology and technological advancements increase, data also increases, and Big Data plays an important role. Based on the fact that data is the foundation, especially in IIoT and thus in the Big Data application, it is important to look at the different types of data and classify them. SAP gives a very logical and structured overview of the different data types. They cluster into three main types.

1. **structured data**
2. **unstructured data**
3. **half-structured data**

Structured Data:

Easy organization and searching characterize this data. It is comparable to an Excel table with a fixed layout consisting of predefined columns and rows. This makes it easier for database designers and administrators to search and analyze the data using simple algorithms. However, this data is not suitable for the Big Data approach, even in a larger quantity. The properties described above do not lend themselves to the definition criteria. Traditionally, databases use the so-called Structured Query Language (SQL) programming language to manage structured data.[33]

Unstructured Data:

Unstructured data includes, for example, social media or even images. Obviously, such data cannot be captured in a relational database with columns and rows. Using tedious manual processes, companies have to manage and analyze this data. Data lakes, Data warehouses are rather used for this purpose.[33]

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[33] Cp. (SAP Deutschland, n.d.)

Half-Structured Data:

As the name suggests, this is a mixture of structured and unstructured data. E-mails are a suitable example of this. In addition to the unstructured part (message), there is also a structured part (sender, recipient, subject, etc.). A modern database with AI technology can only enable direct identification and real-time generation for effective management and analysis.[34]

Now that the Big Data approach and its main features have been explained, the question arises, of how this topic can be applied in industry in the context of Industry 4.0. In order to create an understanding of this, case studies are given below.

Big Data: Optimization of Manufacturing Processes

If we take the approach that machines generate a large amount of data in the sense of Big Data, processes and production can be optimized with the help of an analysis of this machine data. Since humans and machines usually work together in production and both are therefore involved in the success, the data mentioned above analysis must be used. With the help of Big Data, these factors can be combined and used to optimize and improve the manufacturing process. Going one step further, the machine data collected can also be used in effectiveness and quality control.[35]

Big Data: Quality Control and Quality Assurance

Another area of application for Big Data is quality control or quality assurance, which in turn can improve the operational and long-term production process. Through a structured measurement of data, an early warning system can be created. If there is an error, it can be detected in time, and the problem can be solved. To improve quality in the long term, companies often use analysis and modeling software. With the help of this software,

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[34] Cp. (SAP Deutschland, n.d.)

[35] Cp. (Laroque, 2018)

upcoming processes can be simulated in advance. Furthermore, this test can also be tested under virtual reality or with the help of digital twins.[36]

Big Data: Predictive Machine Maintenance

A question that frequently arises in production is, *when is the best time to service a machine that requires maintenance?*

This approach is described by 'Predictive Maintenance'. This refers to the control of maintenance according to actual maintenance requirements. In order to be possible, continuous data from the ongoing operation are required. With the help of this data, the system constantly learns and receives an interpretation possibility or interpretation functionality. As a result, maintenance deadlines can be specified, which reduces costs and makes the process look smarter. The greater the stress on the machine, the shorter the maintenance intervals and the less machine damage. Any necessary spare parts can also be ordered and installed in good time.[37]

Taking a closer look at the use cases, the word analysis or analytics takes on a strong weighting in the context of Big Data. Only by evaluating the data, can an economic benefit be achieved. Accordingly, it is also important to address this topic here and briefly explain the different processes. It will start in the following Table 2 with a clear definition and comparison of the terms ‘analytics’ and ‘analyses’.

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[36] Cp. (Laroque, 2018)

[37] Cp. (Schmidt & Human, 2019)

"An *analysis* is a systematic study of something. By subdividing or breaking down the object of investigation - in the case of data analysis, that is, the data - into its components, e.g., structures, conspicuous features [...] are to be discovered. Accordingly, analysis is a process in which information [...] is obtained from data."	"*Analytics*, on the other hand, refers to the teaching or art of analyzing, i.e., the performance of data analyses. Thus, the term analytics is also used directly for the set of all analysis methods. It then includes as a superset in particular methods from the areas of statistics and data mining or machine learning."

Table 2: Comparison of Analysis & Analytics in the context of Big Data[38]

As can be seen in the case study 'Predictive Machine Maintenance', there are analytics variants that are characterized by different questions. This is the last point of consideration in the Big Data chapter.

In the upcoming part, these forms are enumerated and ranked in ascending order of complexity and value. (from low to high).

1. Descriptive Analytics

Q: What has happened?

With this method of descriptive analysis, the goal is pursued to produce descriptions or a summary of a fact. The question *'What has happened'* is in the foreground and can be supplemented with the points when and where.

[38] (Lanquillon & Mallow, 2015, p. 55)

2. Diagnostic Analytics

Q: Why has it happened?

Diagnostics analytics describes the method of root cause analysis to answer the question *'Why ultimately?'*. Often correlations can be derived from the collected data, but causal relationships are very difficult to derive.

3. Predictive Analytics

Q: What could happen?

Predictive analysis should give an outlook into the future. Accordingly, it addresses the question *'What could happen?'*. It is important to add that prediction is not limited to the future. Unknown values of the past can also be target values.

4. Prescriptive Analytics

Q: What should happen?

Prescriptive analysis is intended to provide an answer as to which steps can be taken to achieve a goal. Therefore, it deals with the question *'What should happen?'*. This form of analysis represents the highest form of decision support. For companies, in particular, recommendations for action in new, unexpected situations are of particular importance.[39]

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[39] Cp. (Lanquillon & Mallow, 2015, pp. 56-57)

1.2.3 Augmented Reality

„We define Augmented Reality (AR) as a real-time direct or indirect view of a physical, real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it. AR is both, interactive and registered in 3D as well as combines real and virtual objects.“[40]

Despite the fact that the term augmented reality now appears frequently in the literature in particular, it is questionable whether there is a unified definition or even whether one can speak of a unified definition. Although in the previous section AR was defined as a way of supplementing natural feedback to the operator with simulated cues, it must be pointed out that AR is a type of virtual reality that provides a clear and distinct view of the real world. It could be concluded that AR and VR could be related, and it would be quite interesting to consider the two systems together. But by definition, a VR environment describes a purely synthetic world that may or may not simulate the characteristics of a real environment. In contrast, a strict real environment must be clearly described by the laws of physics. However, rather than viewing the two types as pure opposites or mixtures, it seems more useful to view them as kind of opposite ends of a continuum. This is called the reality-virtuality continuum, which is shown in Figure 7 below.[41]

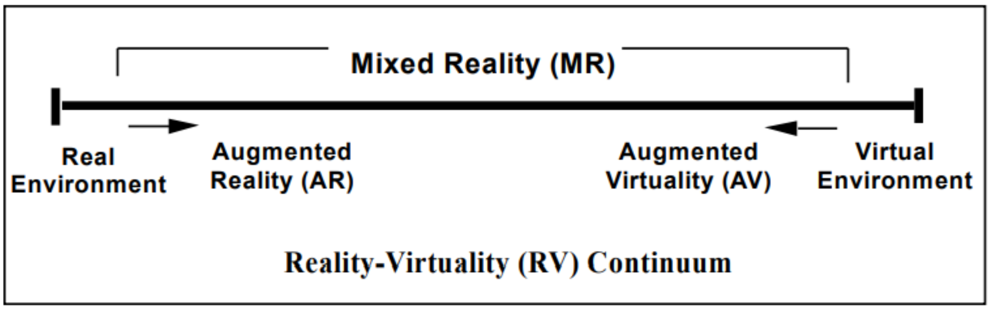

Figure 7: The Reality-Virtuality Continuum[42]

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[40] (Julie & Borko, 2011, p. 3)

[41] Cp. (Paul, Haruo, Akira, & Fumio , 1994, p. 2)

[42] (Paul, Haruo, Akira, & Fumio , 1994, p. 2)

According to Milgram and Kishino, this continuum represents, as already mentioned, a continuum between reality and virtuality. On the one side or the one end is a perfect reality, and on the other side, the perfect virtuality. On the right side, the user is thus in a completely virtual world. The middle area is called mixed reality and is characterized by the degree of virtuality. [43]

Now that the classification of AR and VR has been made in a simple outline, the next section will ask how AR applications and solutions find their place in the industry.

[43] Cp. (Tönnis, 2010, p. 2)

1.2.3.1 Augmented Reality Solutions

In early 2016, the first agencies made it their business to simply offer AR solutions in the form of 3D content and 360-degree videos. As a result, many companies have started their own initial projects. In 2017, larger companies also began to take a more in-depth look at augmented reality. From the middle of the year, there was then a rapid push. Apple ARKit and Google ARCore made AR development for mobile devices possible. Gradually, AR also made its way into top management. Professional articles and magazines show this. One example that should be mentioned here is the article, "Why Every Organization Needs an Augmented Reality Strategy," written by Michael Porter and E. James in a Harvard Business Review.[44]

“AR is making advances in consumer markets, but its emerging impact on human performance is even greater in industrial settings.”[45]

In this context, industrial examples embedded in the AR key capabilities, **visualize, instruct, and guide and also interact** will be presented below. These use cases are also based on the previously cited Harvard Business School article.

[44] Cp. (Adelmann, 2020, pp. 11-12)

[45] (Porter & Heppelmann, 2017)

1st Case: Visualize

A first example, which can be seen in Figure 8, is the new showroom of the Volvo car brand.

Figure 8: Volvo’s AR showroom [46]

With the help of Microsoft HoloLens, customers at the car manufacturer Volvo can use augmented reality (as shown in the picture) to see what their future car will look like. A lifelike hologram of the vehicle is displayed and projected directly in front of the customer. With the help of this method, for example, the customer can test colors in advance and see what they look like. But technical details and functionalities of the vehicle are also displayed.[47]

Since virtual and real worlds partly merge here, this could also be classified according to Milgram in the category of mixed reality.

[46] (Porter & Heppelmann, 2017)

[47] Cp. (Charlton, 2015)

2nd Case: Instruct & Guide

What we can see in the next application and in Figure 9 is the use of informed reality at AGCO.

Figure 9: AR instructions[48]

"Today, AGCO is increasing the efficiency, quality, and safety of its manufacturing programs by pioneering the use of informed reality, a form of augmented reality that uses wearable devices like Google Glass."[48]

As can be seen, companies can use informed reality to show useful information or even entire process steps to employees during assembly or even maintenance. This use case is very interesting, especially for industrial companies with their own production line.

[48] (AGCO Corporation, 2017)

3rd Case: Interact

"Traditionally, people have used physical controls such as buttons, knobs, and, more recently, built-in touchscreens to interact with products. With the rise of SCPs, apps on mobile devices have increasingly replaced physical controls and allowed users to operate products remotely. AR takes the user interface to a whole new level. A virtual control panel can be superimposed directly on the product and operated using an AR headset, hand gestures, and voice commands. Soon, users wearing smart glasses will be able to simply gaze at or point to a product to activate a virtual user interface and operate it. A worker wearing smart glasses, for instance, will be able to walk a line of factory machines, see their performance parameters, and adjust each machine without physically touching it." [49]

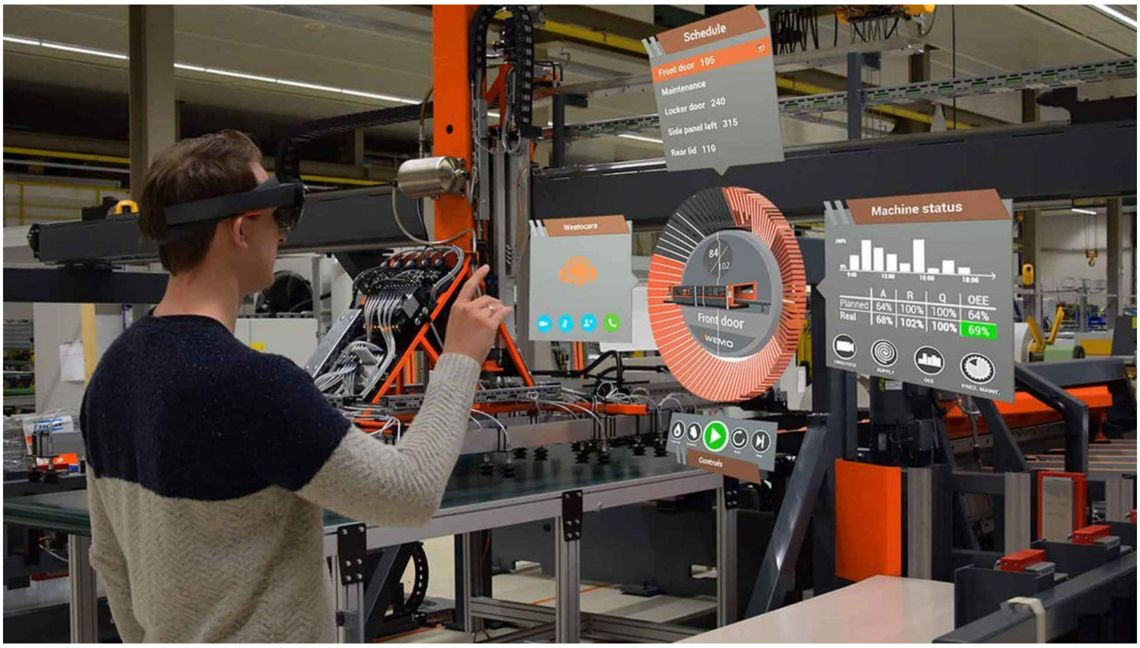

Figure 10: AR panel board via HoloLens [50]

With the help of smart glasses, relevant holograms are projected into the real world. This creates a digital workplace. Through a simple application, the operator gets direct access to data that ensures high efficiency in the areas of analysis, processes, and maintenance.

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[49] (Porter & Heppelmann, 2017)

[50] (WEMO, n.d.)

With smart glasses, an operator can control the machines from any location. This also applies to visual analysis, direct insight into information such as elapsed or remaining production time, and machine status. With the presence of cameras inside the machine, the process of the production line(s) can be controlled in real time and remotely.[51]

[51] Cp. (WEMO, n.d.)

1.4 To put it in a nutshell

At the beginning of this chapter, a basic understanding of how the **four industrial revolutions** took place was established. Building on this theoretical knowledge, the current **fourth industrial revolution** was introduced, and the core topic **Industry 4.0** was mentioned first. By means of theoretical definitions, the term was presented, and it was explained which contents are particularly important for the industrial sector. These are the **Industrial Internet of Things, Big Data, and Augmented Reality**. In individual chapters, the three core topics were presented by means of scientific analysis, and an attempt was made to embed them in an industrial context. The following findings are summarized once again:

1. Fourth industrial revolution

1.1 Industry 4.0 as the main characteristic

1.1.1 Industrial Internet of Things as the basis of I4.0

1.1.2 Big Data approach

1.1.3 Augmented Reality in industrial use

Thus, the Industrial Internet of Things establishes the networking of devices and communication. By means of the aforementioned platforms and data from the Big Data chapter, these can be evaluated and used with a suitable analysis procedure. Lastly, augmented technology is becoming increasingly applicable in industrial production in particular. As mentioned in the previous chapter, there are various application cases in which data and networking also form the basis.

This logical structure makes clear that this is not an arbitrary selection of topics, but that the structure of the smart factory can now be addressed in the following chapters based on the initial question *Which core components define Industry 4.0, and what does the path to a smart factory look like?*

2 Digital Factory

Now that the basics of I4.0 have been explained, this chapter will focus on the concept of the digital factory and the smart factory based on it. Here, too, the components and core elements must first be named and explained by means of a definition.

The Digital factory is the generic term for a comprehensive network of digital models, methods, and tools, such as simulation, three-dimensional visualization, and virtual reality connection, which are integrated by means of end-to-end data management. The goal of the digital factory is the holistic planning and evaluation as well as continuous improvement of all essential structures, processes, and resources of the real factory in connection with the product to be manufactured.[52]

With this definition and the recognition of the goals of a digital factory, the main characteristics can now be named. The Institute for Integrated Production in Hanover also provides here information about this.

The main features of the digital factory are the data consistency enabled by the standard interfaces and the shared use of virtual models. These virtual factory models support simultaneous work by different departments and thus enable the greatest possible parallelization of processes. In addition, the standard interfaces offer simple data transfer without time-consuming conversion. By avoiding conversion processes, which are usually associated with data loss, the quality of the data is also increased. Furthermore, by introducing shared models, up-to-date data is always used. The guiding principle of "do-it-right-first-time" to reduce effort can thus be implemented on the process side. Another component of the digital factory is the use of digital tools. With the help of this support, the process overview can be significantly increased, and cost and time improvements can be implemented. An improvement in communication and collaboration is also achieved through the redundancy-free mode of operation. The digital

[52] Cp. (IPH - Institut für integrierte Produktion Hannover, n.d.)

methods and tools can be applied throughout the entire product life cycle, from product development to production planning and production startup to production operation.[53]

After the main features have been mentioned, the main focus and application areas of the digital factory can be derived, as shown in the Figure 11 below.

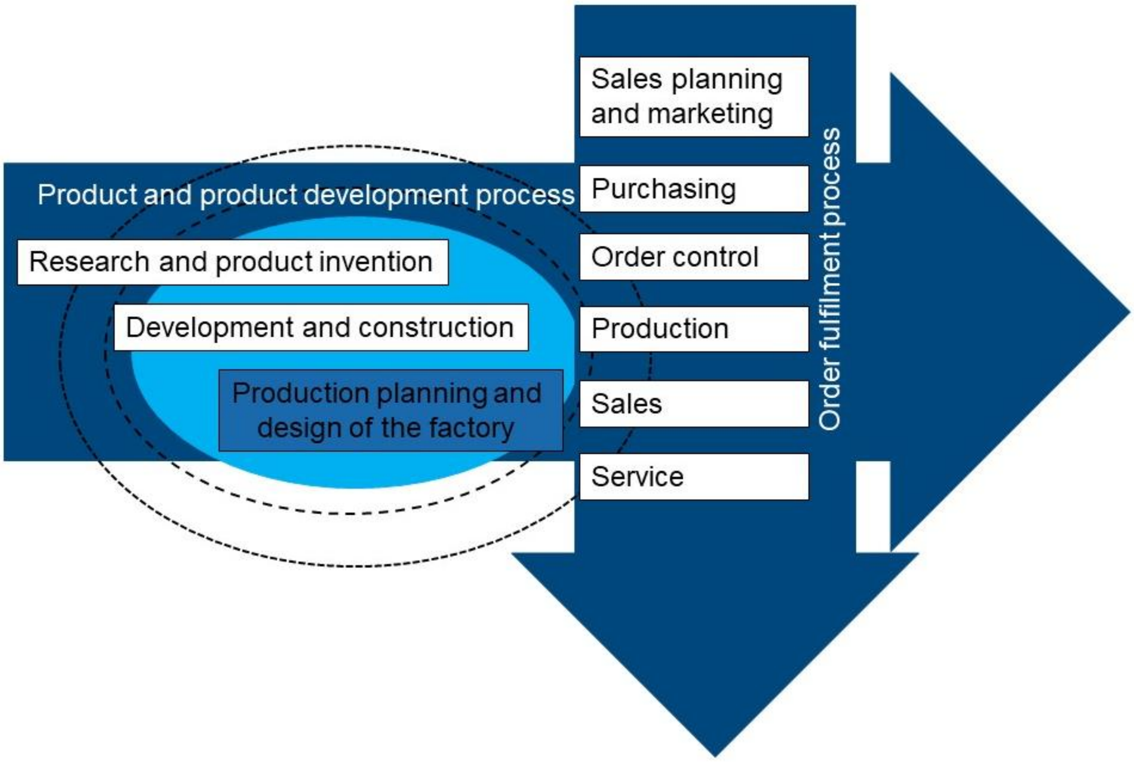

Figure 11: Application areas - the focus of the digital factory[54]

As can be seen in Figure 11, the production planning and design of the factory are highlighted in light blue. Accordingly, this is the main focus.

The digital factory is a link and integrator between product development, planning, and production. It links the product data from development with the planning data and provides tools for modeling and planning manufacturing concepts as well as simulation methods. It also offers visualization techniques and documents the planning progress.[55]

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[53] Cp. (IPH - Institut für integrierte Produktion Hannover, n.d.)

[54] Own representation based on (Bickelhaupt, 2018)

[55] Cp. (Matyscok & Seewaldt, 2019)

The following subsection continues by examining the potential uses of the digital factory in the context of Industry 4.0.

2.1 Digital Factory Embedded in I4.0

Based on the theoretical foundations for the digital factory explained in Chapter 2 and the topic of Industry 4.0 discussed in Chapter 1, both topics will now be brought together. This can be seen in the Figure 12 below.

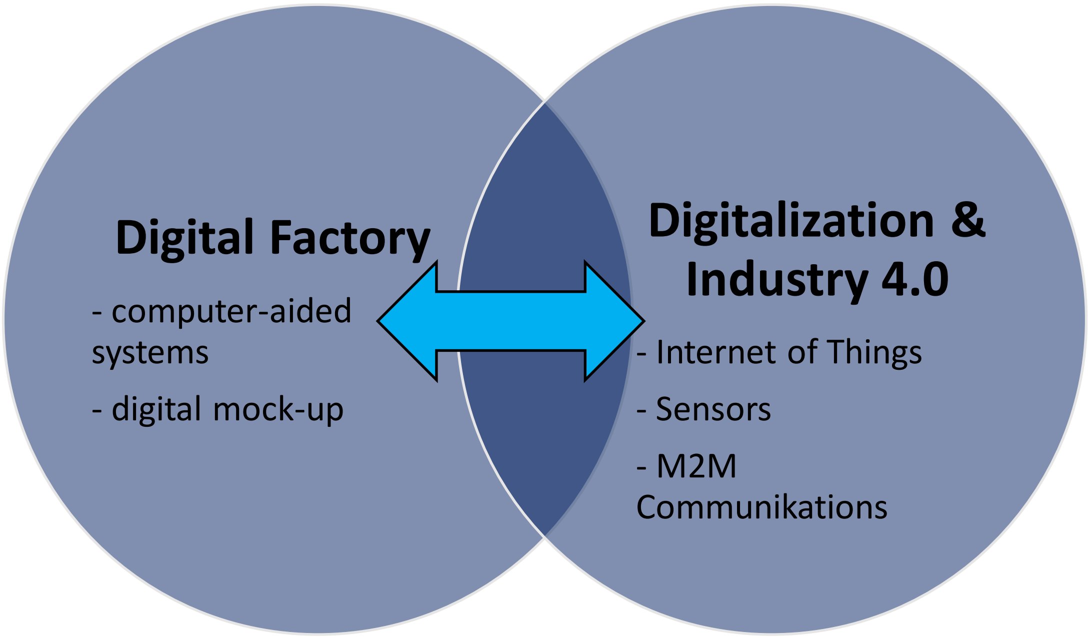

Figure 12: Combination of Digital Factory and Digitalization & Industry 4.0[56]

With the digital factory, which includes digital models, methods, and tools, processes and products can be mapped virtually. This means that products and their production can first be planned and simulated on the computer. The entire production planning can thus be mapped virtually (Figure 11).[57]

The virtual factory is now created. This results in various benefits. On the one hand, a common database can be established that can be accessed by different areas of a company. This data is then digitally secured. On the other hand, the use of standard libraries enables a higher planning speed. Improved coordination processes between development and

[56] Own representation based on (Matyscok & Seewaldt, 2019)

[57] Cp. (Strehlitz, 2016)

production planning mean that more work is done across the board or in parallel. This results in simultaneous engineering.[58]

“After the virtual factory has been converted into reality, it is possible to move from the real factory to the smart factory. In the Smart Factory, all components of the real factory are networked and can communicate with each other.”[59]

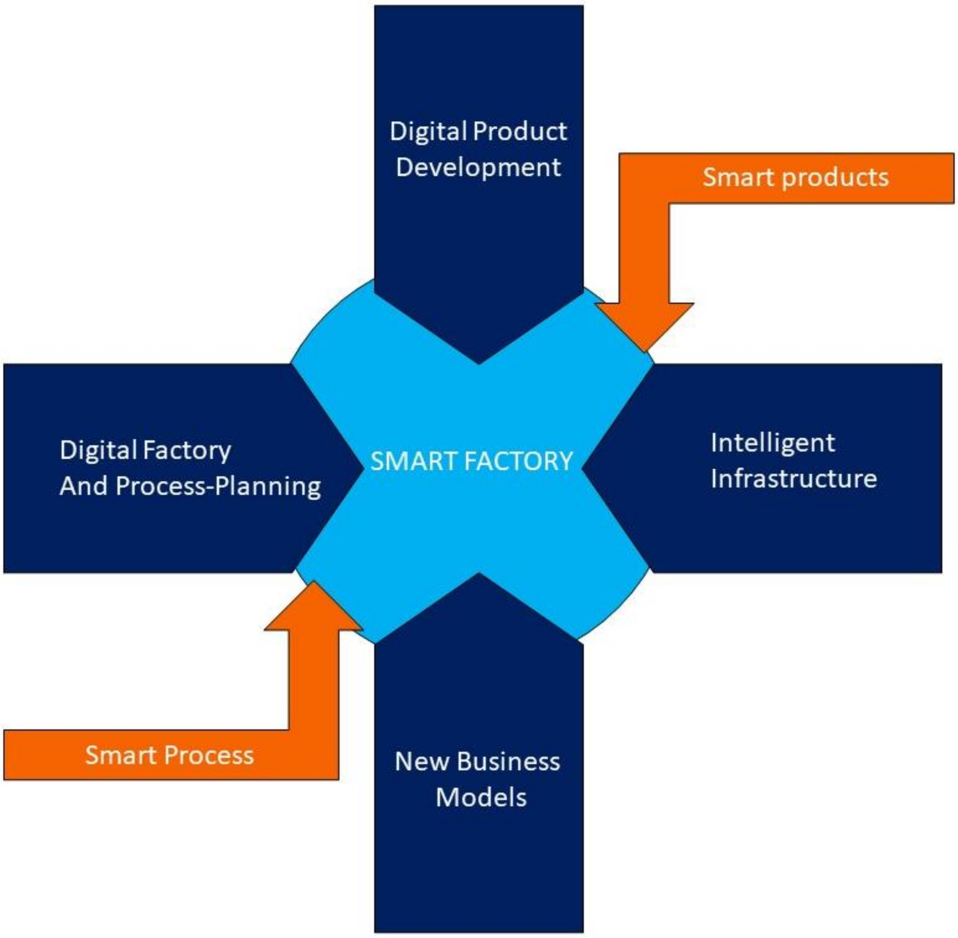

Figure 13: Smart Factory[60]

[58] Cp. (Bickelhaupt, 2018)

[59] (Bickelhaupt, 2018)

[60] Own representation based on (Bickelhaupt, 2018)

If we analyze Figure 13, it can be clearly seen that a basic prerequisite or basis for the path to the smart factory is the upstream digital factory. This is the reason for creating the basic features and the general understanding of the smart factory in the following chapter.

2.2 From Digital Factory to Smart Factory

"Economic conditions have changed significantly since the 1990s and have experienced renewed dynamism since the 2010s. All companies today operate in a global, turbulent environment in which serious market events based on disruptive business models follow one another even more quickly and future developments are more difficult to forecast."[61]

As can be seen, Smart Factory is an important element of the previously described Industry 4.0. Smart Factory masters complexity through the networking and use of the IoT. This results in lower susceptibility to faults and an increase in production efficiency. Communication between people, machines, and resources is a matter of course in the smart factory.[62]

As Bracht and his colleagues have already described above, the requirements profile for companies is changing. A key role is played by information such as production orders, machine settings, or even machine availability. Seamless interaction between information systems is necessary to ensure that cost, time, and quality targets can be met. Accessing the right information at the right time and in the right place is a challenge for companies. They do not only need purely static information about objects. Interrelated information about statuses etc. is also required.[63]

To address the new framework of the fourth industrial revolution, the system of an intelligent factory called Smart Factory is pursued. A Smart Factory is characterized by

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[61] (Bracht , Geckler , & Wenzel , 2018, p. 1)

[62] Cp. (Bracht , Geckler , & Wenzel , 2018, p. 15)

[63] Cp. (Lucke, 2013, pp. 251-252)

the systematic linking of information systems with internal operating facilities, external components, and the external environment.[64]

This link is implemented throughout the entire plant, i.e., production, maintenance, and logistics participate as intelligent components in this system. The goal is to optimize the production environment through improved and accelerated communication of the objects. All objects have individual object properties, which can be understood as the knowledge about their state or their location.[65]

As it has been described in 1.2.1, they are able to store this information and share it with other objects as real-time information. In the process, data is created that exceeds the known scope in terms of frequency, quantity, and required processing speed. In this context, there is also talk of Big Data.

The data exchange of the objects enables a high degree of self-organization and decentralization. Particularly in the production of small batches and customer-specific products, this capability can be benefited from. For example, each variant goes through an individual path during production. Therefore, the products must exchange their knowledge with the machines about production and logistics steps that have already been completed or are incomplete. These products, capable of exchanging information, are also called smart products. The communication with each other, independently decide which product must pass through which station next in order to guarantee efficient production. Production planning and control can be carried out and controlled without significant human intervention.[66]

Since products, machines, or materials can communicate with each other in addition to people in the smart factory, a dynamic network is needed to connect all physical and

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[64] Cp. (Bendel O. , Die Industrie 4.0 aus Sicht der Ethik, 2017, pp. 161-172)

[65] Cp. (Rojas, Rauch , & Matt, 2018, pp. 165-169)

[66] Cp. (Wang, Wan, & Zhang, 2015)

virtual objects. This network is called the Industrial Internet of Things (IIoT) and forms the central starting point for a smart factory.[67]

In principle, the smart factory can be divided into different areas, as can be seen in Figure 13 below. One area is Smart Production, which forms the core of the smart factory with its value creation processes. Another increasingly relevant area is smart maintenance. This ensures that production runs as efficiently as possible in order to ensure the highest possible guaranteed productivity.[68]

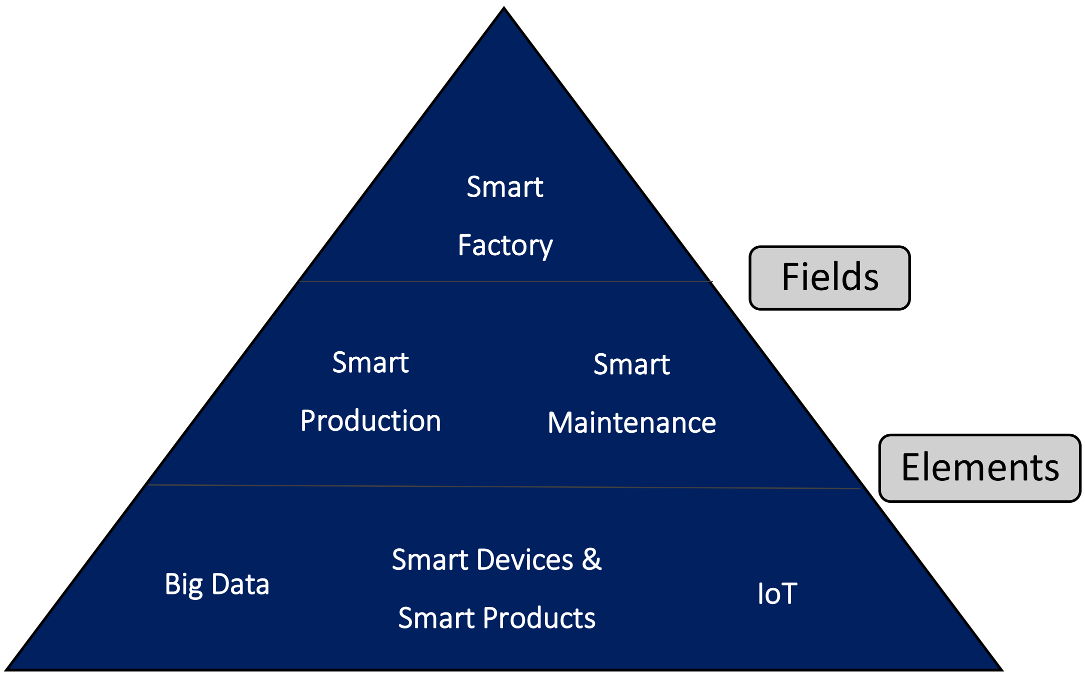

Figure 14: The Smart Factory Pyramid [69]

The Figure 14 shows that the theoretical approaches of the first chapters, big data, smart devices, and IoT, are the basis or elements of smart production or smart maintenance. Both fields ultimately result in a smart factory.

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[67] Cp. (Pollmann, 2017, pp. 257-260)

[68] Cp. (Nikelowski & Wolny, 2020, p. 3)

[69] Own representation based on (Nikelowski & Wolny, 2020, p. 3)

2.3 To put it in a nutshell

In summary, the **digital factory** offers an optimal basis for becoming a **smart factory**. The general digital structure serves as a basis. It was also made clear that the application area is an overarching part of the **product and product development process**.

Furthermore, embedding the digital factory in the context of Industry 4.0 creates the path to the smart factory. Here, too, we have recognized that a smart factory can be created by means of **smart products** and **smart processes** combined with digital process planning, intelligent infrastructure, and digital product development.

In a final step, the path to a smart factory was clarified once again, and the basic structure was addressed. Elements such as **IoT, Big Data,** and, in the application-specific case, **Augmented Reality** are core elements of smart production and smart maintenance. Based on this, they can be clearly clustered as Smart Factories.

3 Application Case

3.1 Introduction to a German Company

The company is a leading supplier of solutions and services for electrical installations in residential, commercial, and industrial buildings.

In 1955 the company was founded. As already mentioned, the company was founded in the early years. In the following decades, the enterprise grew and developed as below in the diagram to recognize, in the '80s the selling always further.

Due to company internal reasons, for this paper the overview of the company growth could not be shown.

With regard to production and sales worldwide, The company can now boast more than 20 production sites in around ten countries. These include Germany, China, France, Great Britain, and India.

To once again draw attention to the increasing sales, the chart below breaks down sales by the market. As can be clearly seen, the focus is on the German market.

Due to company internal reasons, for this paper the overview of the company's turnover could not be shown.

In addition to the above-mentioned monetary figures, The company's personnel strength should also be mentioned. With more than 11,500 employees worldwide, of which more than 3200 work in Germany, The company is one of the larger companies.

But what does the solution portfolio of The company Germany look like?

Basically, the solutions can be divided into seven categories:

1. energy distribution and energy management

2. cable routing and infrastructure

3. switch ranges, building controls, and door communication

Energy distribution and energy management:

To this area, products are understood like pure energy distributions, house energy management systems, small distributors/field distributors, and also energy distributions larger than 630 Ampere.

Cable routing and infrastructure:

In this area, The company offers extensive products such as parapet trunking systems, cable routing systems, skirting systems or also underfloor and room connection systems.

Switch ranges, building controls, and door communication:

As the name suggests, The company specializes in their in-house switch program here. Among other things, however, KNX building system technologies, security technology, and door communication systems must also be mentioned. In addition to the standard products, exclusive manufactory solutions, such as refined switches or individualized door communications, are also offered.

The company acts ethically, caring for people, and they respect the environment by taking into account our planet's limited resources in our business activities, offering our customers energy-efficient solutions.

Due to company internal reasons, for this paper the overview of the company's ethical approach could not be shown.

Introduction the market department

In the following, the market department will be presented. The topic of this Bachelor Thesis was determined for and with this department.

The Market department:

- the targeted development of market positioning and our range of solutions
- the reliable coordination and control of market launches, as well as development and management of the associated marketing mix, including sales-related procedures
- the professional transfer of knowledge and application advice for sales teams, business partners, and customers,

and thereby, establishes the **fundamental principles for successful sales**. Market department also works closely with Sales, customer marketing, and Product Management.

Market department plays an important role at the company. It handles a central role in marketing. Below, the significance is shown easily.

Due to company internal reasons, for this paper the overview of the company's central role of the market department could not be shown.

As shown in the Figure, market department serves two important target groups. Firstly, for functional buildings and secondly for residential buildings. Thus, the market department takes over or initializes market requirements and specifically controls the market launch processes.

These ever-increasing market requirements and the digital transformation in the context of Industry 4.0 described in the first chapters of the thesis have resulted in new requirements for the company and, above all, for the Market department.

As already mentioned at the beginning, this concerns, in particular, the area of the construction of control cabinets.

In the following chapters, the current situation will be first described, and then the solutions and theoretical approaches of the beginning chapters will be adapted to the company. The goal should be to work out new solution concepts and to make attention to possibly existing problems. Finally, a recommendation for action with constructive approaches should serve the company The company and, therefore, the market department to prepare and upgrade for the changes of digitalization and progressive networking.

3.2 The Company and Industry 4.0

The company has been preparing for change and digitalization for some time now. In order to follow this digital trend, new technologies and approaches must also be pursued here and remain competitive.

In the first part of this thesis, we have dealt with the theoretical approaches of Industry 4.0 and have presented some components and important approaches and defined them in the possible framework. Now, by means of an inventory and analysis, it is important to see where The company stands in terms of digitalization, which approaches are already being pursued and expanded, and where gaps and problems exist.

Finally, a conclusion with a clear conclusion for possible actions should emerge, which should serve the company The company, and especially the market department, to be best prepared for the industrial requirements in the future.

In the following chapter, we will go into more detail and analyze various individual parts.

Current Status

Before an adjustment can be made, it is important for the company to map the current status. In the context of this thesis, this includes the current status of digitization.

In a further step, the digital processes should be presented. Any problems or missing steps should be mentioned. These are then taken up for a strategic plan for implementation or a recommendation for action.

In order to get a clearer and more delimitable structure, we will limit ourselves to the following The company areas.

- Smart Engineering and Production
    - Digital end-to-end process
- Augmented reality

Smart Engineering and Production:

This topic is also very new for the company and untouched so far. Although the company invests a lot in the area of digitalization, a smart link between engineering and production has not yet been implemented. Since there are no approaches here so far, I would like to present an approach to implementation and make a recommendation.

In order to establish a smooth SEaP process, various interfaces and components must be built. In the following picture, these are shown on the basis of the company cooperation Rittal and Eplan. This unique process should also serve as a basis for the company. The goal of this entire process is to generate a continuous end-to-end process.

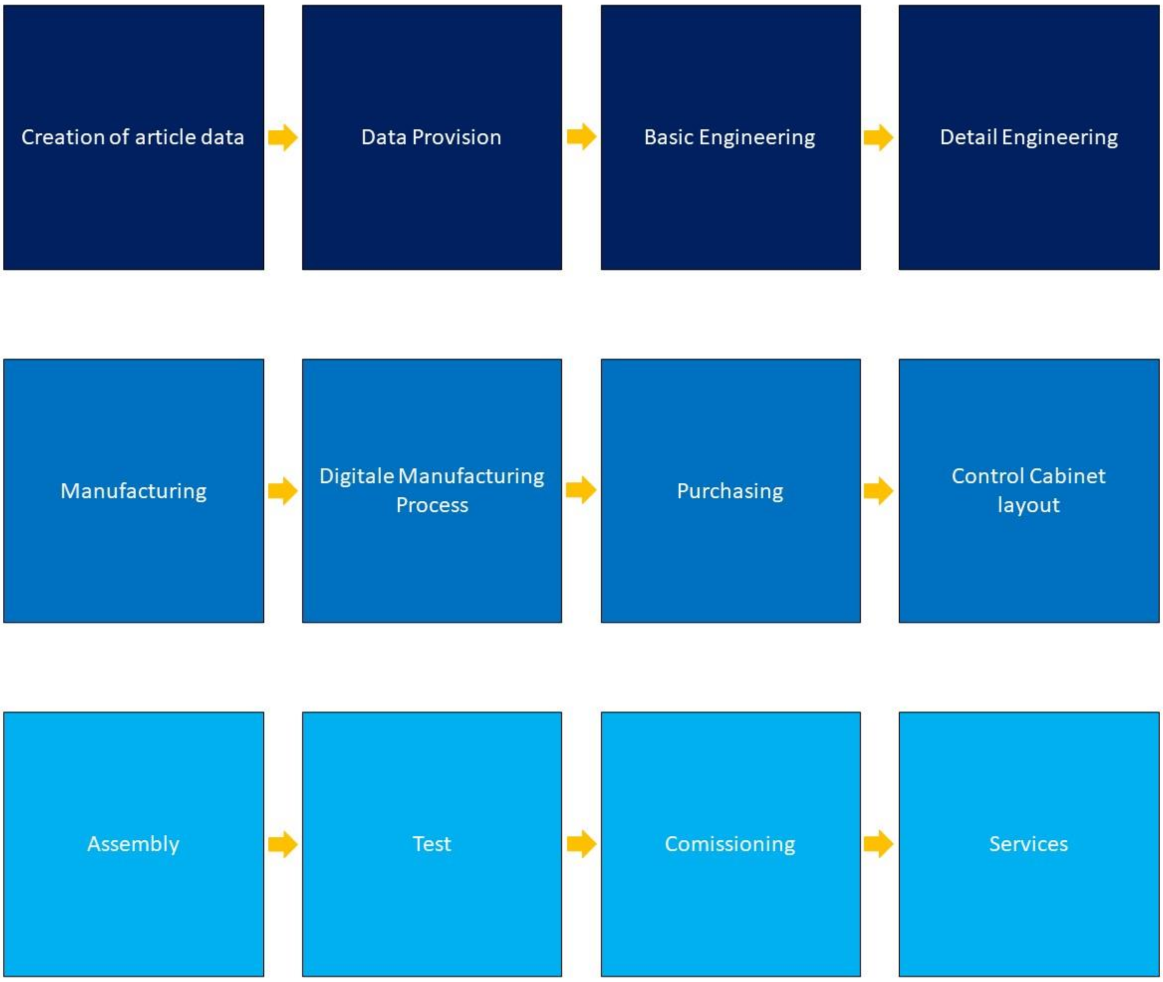

Figure 15: Smart End-to-End process[70]

Figure 19 shows a smart end-to-end process with all intermediate steps that are necessary to create a Smart Engineering and Production process. This process is now to be adapted to the company. In the process, it will also be shown whether and how the digital technologies IoT and Big Data, which were described in the previous chapters, can be applied.

[70]Own representation based on (Phoenix Contact GmbH & Co. KG, n.d.)

1. Creation of Article data

In this first step, item descriptions must be provided digitally. The content should be a detailed description of product- and production-specific features. For the company, the quality of the item description in turn means a simplified process. After an analysis, it was determined that digital item descriptions already exist. These are already equipped with many attributes about the products. What is still missing, however, is an extension with information about the above-mentioned manufacturing process or engineering process. These must be integrated directly into the design process. Therefore, it is advisable to carry out a close consultation between the construction, the production and the market requirements in the future. Now that the digitally enriched article description is available, suitable data formats of the articles must be provided in the further course. The uniform data standard is described here by the so-called EClass format. The company is already optimally positioned in this respect. As of today, all data is mapped in the EClass format. This process step is therefore already in place and does not need to be newly implemented.[71]

2. Data Provision

After the first step has been taken, the article data would then have to be made available holistically and across all processes. Engineering tools can also be used for this purpose. These are also used in e-shops and catalogues. This data provision is also defined by standard formats such as DXF (3D files). A simple way of provision is the use of a portal or a cloud-based platform.[75]

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[71] Cp. (Phoenix Contact GmbH & Co. KG, n.d.)

3. Basic Engineering

The basic engineering ring describes the path from the idea to the product in the end-to-end process. In the area of preliminary planning, the entry of a machine from production into the engineering process is defined here. There is also a very clear link here to the topic of IoT and Big Data. As already described in theory, failures can be avoided in this way. Failures therefore mean an interruption of the process.[72]

After a detailed analysis, it was determined that there is potential for the company to improve this. It would be extremely important to integrate production more strongly into the IoT and to be able to analyze machine data and make statements using Big data analysis. These statements in turn help the SEaP process to run smoothly. Furthermore, there is no direct transfer or interface from design planning to production. This is intended to define the use and estimation of the first components.

4. Detail Engineering

In detail engineering, digital data should move to the forefront of product development and production. By means of engineering software, circuit diagrams are created, which are to represent the automation project. In turn, solutions for further product planning are connected via interfaces.[76]

When it comes to engineering software, The company is already optimally positioned.

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[72] Cp. (Phoenix Contact GmbH & Co. KG, n.d.)

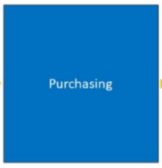
5. Manufacturing

By means of its virtual prototype, manufacturing steps can now be developed automatically. A communication between human machine interface can create machine programs independently. Consequently, manual production becomes smart and therefore digitally supported.[73]

6. Digital Manufacturing Process

Based on a standardized description, a product data model of the control cabinet is provided for subsequent production processes. It contains all the information required for both manual and automated control cabinet construction.[77]

7. Purchasing



After the completion of the planning and the thus complete digital description, the data must now be transferred so that the downstream process of procurement and purchasing can take place. The transfer to an ERP system is important here. This is available at The company and is already used today in a fully digital and smart way.[77]

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[73] Cp. (Phoenix Contact GmbH & Co. KG, n.d.)

8. Control Cabinet Layout

With the so-called virtual prototype from step 5, the next step is the precise control cabinet planning in the third dimension. This model now describes the plant with all the small details and elementary information for the production process. Regardless of whether this is done internally or by an external service provider for The company. This digital image allows economic cost increases and time losses as well as errors to be clearly avoided.[74]

9. Assembly

With a now smart assembly system, the assembly work can also be simplified. Through an adequate and coordinated provision of data, assembly can be carried out according to requirements. For The company, this system is above all product-independent. [78]

10. Test

In this point, according to analysis, The company is very far ahead. By means of a black box model, the products from production are examined very precisely for any defects and, if necessary, rectified. Thus, an optimal inspection of the final product is given and guaranteed.[75]

11. Commissioning

The use of software that is perfectly matched to the hardware used enables rapid commissioning of products. In addition, communication between engineering and manufacturing can be accelerated on the basis of standardized data for individual products. Here, again, I would like to mention that the

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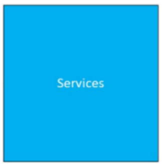
[74] Cp. (Phoenix Contact GmbH & Co. KG, n.d.)

[75] Cp. (Phoenix Contact GmbH & Co. KG, n.d.)

next section, Augmented Reality, will go into more detail about commissioning with AR solutions.[79]

12. Service



For The company, this will become an increasingly important component in the future. After the actual product come services and support that map the offer holistically. A service or even a service contract tailored to the product, for example a control cabinet, in turn binds the customer to the The company company.

Augmented Reality:

As already explained in the Augmented Reality chapter, this topic is about expanding the range of solutions. In this context, The company also focuses on the AR principle: "I get additional information about the scene".

In order not to lose touch in the very fast-moving digital age, the topic of augmented reality must be taken up and put into practice in the future. In the following, the existing ideas are discussed, and further prospects are given.

Before the company can implement augmented reality solutions, it is important to get an overview of the providers of suitable AR glasses. For this purpose, an overview was set up. This also includes prices for the various models.

Figure 16: Overview of AR Lens Solutions in Industry

Figure 21 shows that the Epson and Vuzix models are the most widely used in the industry. These would also be very interesting for The company in the future to test possible AR solutions. Now that we have a rough overview of the glasses models, the question naturally arises for The company, which AR experience is there, and in which areas can these be adapted to the company’s portfolio. To analyse this, an AR experience circuit was created below.

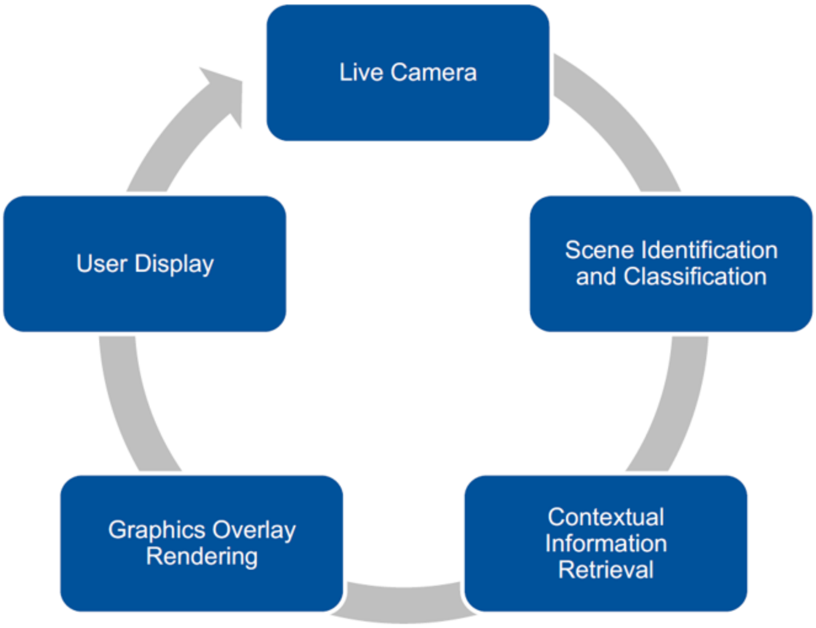


Figure 17: AR Experience Circuit

But how can this cycle be realized?. Here we return to the topic of the Internet of Things. Using IoT, it can use NFC or Bluetooth to perform scene classification or identification, for example. This was tested and analyzed by a project team specially created by The company.

Due to company internal reasons, for this paper the overview of the company's first 3D model could not be shown.

After modeling a product, the question is how to define the scope within the AR Experience loop just shown. For this purpose, first use cases were collected:

1. remote assistance

2. step by step guides

In the following, we will go into each of the three points mentioned and briefly explain how a theoretical process would look like and what it would be needed. Due to the limitation of the thesis, unfortunately, not every piece of information can be dealt with, and not every term can be defined specifically.

1. Remote Assistance:

Figure 18: The company Remote Assistance Example

For The company, remote assistance defines itself as an additional kind of competence centre at work. We have tried to make this clear with the example above. When measuring circuits, for example, the Help Centre can be used to show exactly which contacts are required. This would, for example, simplify the maintenance of distribution and reduce errors.

2. Step by Step Guides

The Step by Step Guide topic is essentially about The company being able to offer assembly instructions via an augmented reality solution in the future. Here, too, the first visualizations were created for testing, and a kind of plan for creating this solution was drawn up. Here, too, we were able to provide images for better comprehension.

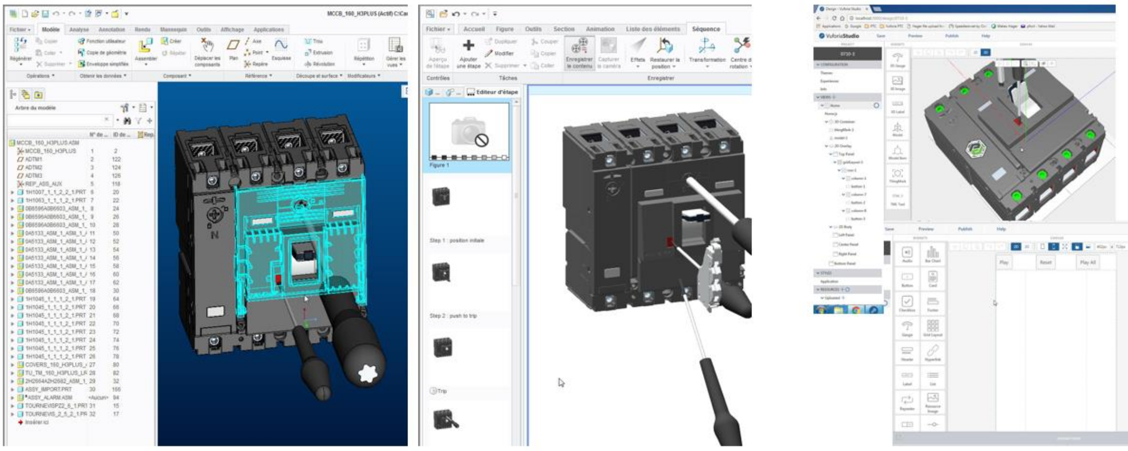


Figure 19: The company’s Step by Step Plan

In order to realize the first solutions, as can be seen in Figure 25, more software is necessary. For this purpose, The company has limited itself to the following in a test project:

- **Creo Parametric** for the creation of the research and development model simplification.
- **Creo Illustrate** for the creation and animation of image sequences
- **Vuforia Studio Experience** for the final creation of the actual augmented reality representation

3.3 Recommendation for action

Since the topic of this thesis is a very large and multi-faceted one, and interfaces and applies across departments, the recommended action is divided into the following headings:

- Economic

- Technical

- Strategic

At this point, I would like to emphasize once again that due to the time constraints and the limited scope, it was not possible to go into more detail on the individual parts in the practical part. Following this work, special working groups must look at the topics that have been touched upon and generate projects for the future.

Economic Recommendation

Economically, many costs come with the switch from digital to smart. I would like to state that the The company sales company has built up a very good basis for a digital infrastructure in recent years. At this point, deeper process steps must now be addressed. In economic terms, this means that investments must be made in the smart factory. A precise estimate of the costs involved can only be made after a more in-depth cost and effort analysis has been carried out with the relevant Digital & Information and Market department. A clear recommendation for action is the creation of provisions for the future. As we have seen, the topic of digitization and the further development to Smart is so rich in detail and facets that larger and faster changes will also arise in the industry and therefore also in the electrical sector in the next 10-15 years.

For the sake of clarity, I have once again highlighted the most important economic advantages for The company:

- Reduction of downtime costs through intensive use of IoT and big data approaches in production

- Revenue generation through smart customer service offerings such as augmented reality for electrical tradesmen

- Lower process costs through simple digital infrastructure and smart interfaces

Technical Recommendation

It is not only economic action that is necessary. I would also like to make technical recommendations at this point. Here, I am referring more specifically to the technical digital and smart infrastructure. Individual technical subcomponents have already been completed, but are not yet integrated into the entire process. In the future, the company and above all the market department should also continue to drive the foundations for the technical infrastructure. In detail this means:

1. increase of smart devices in production

2. use of augmented reality technology in the production lines

3. mapping of digital product twins in order to detect faults in good time

4. building the existing tools into a bidirectional ecosystem

5. Easy and smart data transfer between departments

Here, too, I would like to point out once again that the recommendations for action relate to the next 5-10 years and cannot be implemented at short notice.

Accordingly, I would like to give the clear advice to look at the "digital and smart" market at an early stage and to recognize trends and changes, especially on the technical side. A great deal of emphasis should be placed on market department. Here, too, it is advisable to analyze the individual positions in more detail in a working group and to create initial action steps based on the end-to-end process shown.

Strategic Recommendation

One of the most important steps for market department is strategic positioning and market development in the area of digitalization and smartness.

To make my recommendation for action clear, I have created a figure for this purpose. This figure shows a digital-smart-strategy.

Due to company internal reasons, for this paper the overview of the company's digital smart strategy could not be shown.

In conclusion, I would like to emphasize that it is enormously important to think globally and prepare for the coming years, as the trend towards smart is advancing rapidly. To this end, strategies must be worked out and expanded at an early stage.

4 Future Outlook

Now that I have given clear recommendations for action for the three sub-areas mentioned, I would like to give a Future Outlook, especially for the Market department department, in order to gain a better understanding of the topic of smart and digitization and to raise awareness.

The further the path from digital to smart becomes in the coming years, the more the customer journey will be affected. A new market is emerging with the targeted use of smart devices in production and augmented reality for customers.

Companies should analyze their business models in the future and definitely try to find out what degree of digital transformation is necessary. Hasty action and digital actionism can quickly backfire and destroy a lot of capital. As I have just described, the use of a structured digital-smart strategy is a sensible medium.

When it comes to an analysis, the situation is aggravated by the fact that digitization, digital transformation, IoT, Big Data and Industry 4.0 are often lumped together and no one can really assess whether they are affected by it and what exactly is important for the company.

However, it is clear that every company is affected, regardless of how and in which area. Powerful mobile devices, fast data networks and state-of-the-art data centres are changing consumer behaviour in terms of products, services, communications, etc. In addition, data is collected everywhere and every technical device is networked. This is what the digital future looks like.

I would like to end my thesis with a quote from C. Darwin.

"It is not the strongest species that survives, nor the most intelligent, it is the one most able to adapt to change." (Charles Darwin)

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Declaration

I certify that I have written the thesis independently and that I have not used any aids other than those indicated. This work or a paper with the same or a similar topic has not already been submitted elsewhere.

The supervising lecturer will receive the work in an additional electronic form that allows for a plagiarism check. I agree that the work will be checked with plagiarism software. I understand that upon review, the work may be added to the plagiarism software.

Saarbrücken, 01.03.2022

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Signature Tobias Wunn