

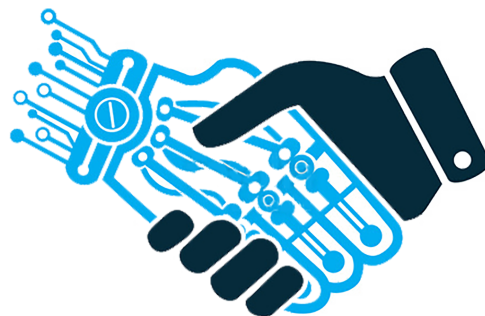
- Lecture Notes -

Industry 4.0 - Digital Transformation TWIE24

Industrial Engineering and Management Program

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INDUSTRY 4.0

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Preface

This script is intended to accompany the lecture and help the listener work through the material in self-study alongside the online sessions. The exam will contain questions exclusively on selected chapters of this script. The literature listed is intended to support a deeper understanding. Online knowledge checks additionally offer the opportunity for self-assessment.

Course content:

After attending this lecture, students should know the concept of Digital Transformation and be able to place it within the context of Industry 4.0. They should be able to trace the development of digital technologies from AI through Big Data to Blockchain.

Core literature:



- Oswald, G. (2018): Digitale Transformation, Springer Gabler, Wiesbaden [?]
Free download: <https://link.springer.com/content/pdf/10.1007%2F978-3-658-22624-4.pdf>

Links:

- <https://www.plattform-i40.de>
- www.Freiwilligschlauwerden.de



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CHAPTER 1

Digital Transformation

Learning Objectives

After working through this chapter, you will know...

- ... what distinguishes digital transformation from digitalization.
- ... what enabler technologies are.
- ... how digital transformation can be implemented within a company.
- ... through which levers digital transformation operates.
- ... which challenges digital transformation brings with it.

Introduction

Digital transformation describes the networking of actors within the economic cycle across all stages of the value chain. Because of the high transparency of information, traditional business models are being changed or entirely new business models are being created. This is changing our understanding of the world of work, and corporate hierarchies are being revolutionized. Machines are taking over tasks from humans, and startups can turn entire markets upside down. However, the effects of digital transformation extend beyond the corporate world. It influences politics just as much as our society and ultimately affects every individual.



Figure 1.1: Progressive digitalization [?].

1.1 Digital Change

Digital change is a phenomenon that influences almost all areas of life and work. In private life, digital services or products can be used everywhere: apps make everyday life easier, and with smart homes, people even live in complete symbiosis with the digital world. In the medical field, treatment and diagnosis can be improved through the targeted **networking** of data. In education, conventional learning is being supplemented or replaced by **digital media**. In addition, the speed at which existing knowledge is superseded by new insights is increasing. This means that the acquisition of new knowledge and the ability to process **information** quickly are becoming permanently more important.

The term "change" describes a process of transformation over a longer period of time. The following chapter will show that digitalization, as the foundation of digital change, has already been underway for decades. However, this change has taken on a new dimension in the more recent past and is therefore on everyone's lips, both privately and, above all, in the corporate environment. On the one hand, this is due to the circumstances described above—that this change has influenced all areas of life and that the pace of change is steadily increasing. On the other hand, it is the **Digital Transformation**¹ actually taking place in industry that is responsible for this. It represents a fundamental change to the entire corporate world. Enormous amounts of data (**Big Data**)² are being linked together into **Smart Data**³, leading to new products, services, and business models. Through networked production, **value chains** can be redesigned.

Because digital transformation also influences employment relationships and the labor market, it is often described in the corporate environment as having a **disruptive character**.

Digital transformation can be divided into three different stages in which it takes effect from a company's point of view.

Stage 1: Digitalization of the value chain

Stage 2: Digitalization of products

Stage 3: Introduction of new business models based on value-added data services

With the digitalization of the value chain, **Smart Factories** emerge. In these, productivity and quality can be improved while simultaneously increasing the variety of variants. Through the digitalization of products, the second stage gives rise to **Smart Products**. By recording data and communicating with other Smart Products, these also make an increase in productivity possible. Finally, the third stage leads, on the basis of value-added data services, to **Smart Services**, which provide the user with information from processes and products and automatically evaluate it [?].

One of the reasons digital transformation is taking place right now is the **enabler technologies**⁴. They emerged in the course of digitalization and represent the technical prerequisite for digital transformation. However, in addition to the technologies of digitalization, there is an even more important reason for the start of digital transformation. The trend of "**focusing on the customer**" places the customer's expectations at the center. Technologies are meant to adapt increasingly to people's needs and deliver high value. For industry, this means that

1 **Digital Transformation** is understood as the exponential and permanent change of society and companies on the basis of technology.

2 **Big Data** describes extensive amounts of unstructured and semi-structured data.

3 **Smart Data** is processed data from which immediately usable knowledge can be derived.

4 **Enabler technologies** are technologies that represent a significant leap in performance and capability for a user.

products must become ever more individualized and the variety of variants must increase [?].

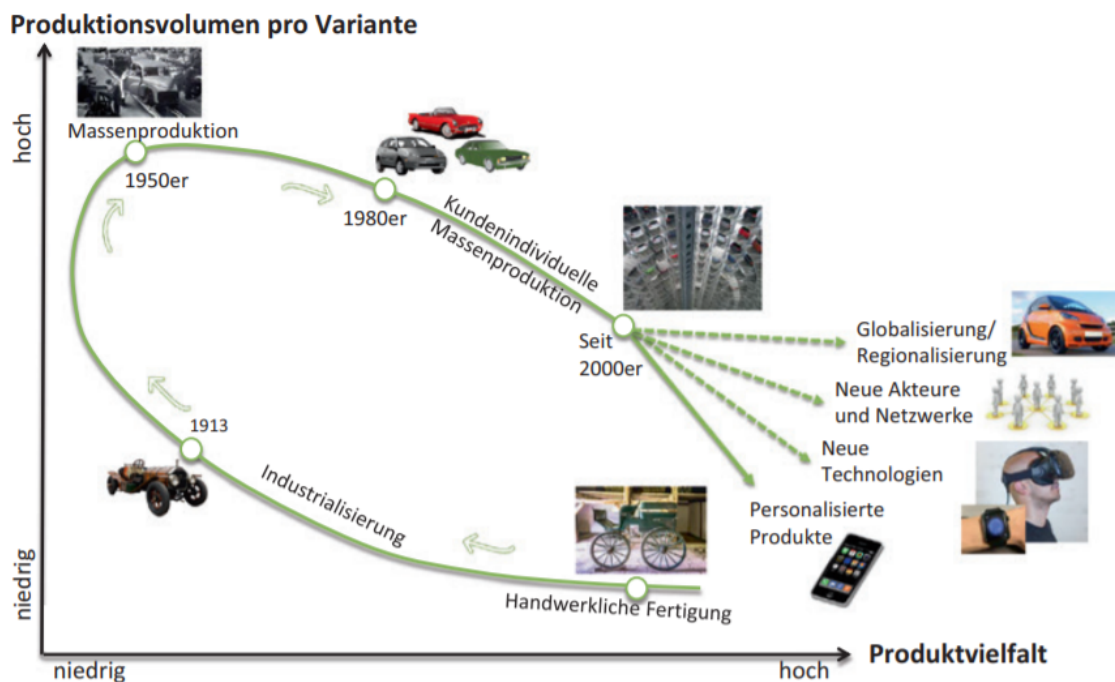


Figure 1.2: Variability at a low price [?].

1.2 Digital Transformation and Digitalization

The term **digitalization** describes the conversion of analog quantities into digital values. The underlying reason is that values need to be stored and processed, which is only possible if they are available in digital form. The beginning of digitalization, however, dates back decades, and the collection of digital data has, in its simplest form, been underway for almost 100 years [?].

The most common examples of digitalization are photos or music files, in which analog content is stored in digital units.

When it comes to digitalization in the corporate environment, this likewise merely describes the mapping of a company's operations, together with its products, processes, and workflows, by digital means. Here, however, digitalization can make a valuable contribution to optimizing and automating processes or developing new technologies.

The concept of **digital transformation** goes significantly further. With digital transformation, processes are not merely adapted to new technologies; they are also questioned in terms of their *raison d'être*. Solving problems is the central focus, in order to maximize customer value. Digitalization can therefore be described as the foundation for digital transformation, but the starting point for digital transformation is, as noted, the customer-centric solution.

Digital transformation stands out from digitalization above all through its far-reaching dimensions. It influences our corporate culture, politics and state institutions, and even our society and behavioral patterns.

1.3 Enabler Technologies

Enabler technologies make digital transformation possible in the course of digitalization and serve as the foundation for new digital business models.

Examples of enabler technologies include:

Internet of Things

The Internet of Things encompasses the trend in which **embedded systems**¹ support people in their work without disturbing them or restricting the actual work. The goal to be achieved with the help of the Internet of Things is to close the **information gap** between the real and the virtual world. The state of a product in the real world can be made available, via embedded systems, for further processing within the network.

Ideally, within the Internet of Things, machines can communicate with machines (M2M), control one another, and humans no longer need to actively intervene in production control. In addition, the information provided by embedded systems enables the early detection of maintenance work, which can be used to reduce defective parts or to save energy.

The growth of the Internet of Things is enormous; the number of devices communicating with one another worldwide is rising at an almost exponential rate.

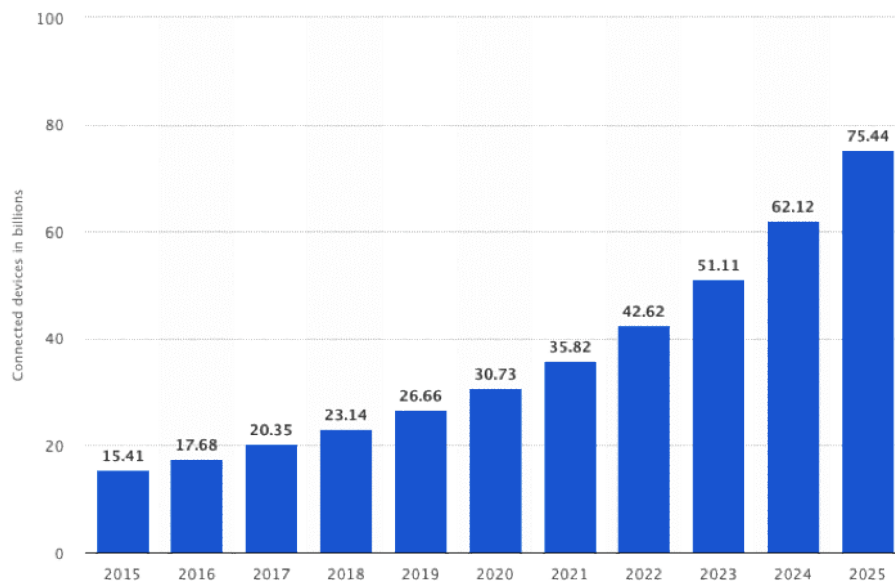


Figure 1.3: Number of devices connected to the Internet worldwide (SAP/Statista, 2020).

¹ An embedded system is a computer system that is integrated into a surrounding technical system and interacts with it.

Internet of Value

The Internet of Value is a **logbook** for transactions of every kind. Here, a database that is encrypted and distributed across multiple computers allows transactions between companies, authorities, and private individuals to be documented digitally. The transactions are registered in a tamper-proof manner and can no longer be altered afterward. This means the Internet of Value creates **maximum transparency** for all transactions.

In the corporate environment, the Internet of Value offers, among other things, the possibility of **smart contracts**. With these, compliance with a contract is automatically ensured through verified transactions. One application example is car rental, in which the user is only granted access to the interior of the vehicle once the rental payment has been made.

Computing Power

Computing power is concerned with the processing power required to process, generate, and collect the enormous amount of data needed. Looking at the increase in computing power over the past decades, an exponential rise can be observed here as well. If the current rate of development in computing power per second continues, the capacity of the human brain could already be reached by the year 2025 [?].

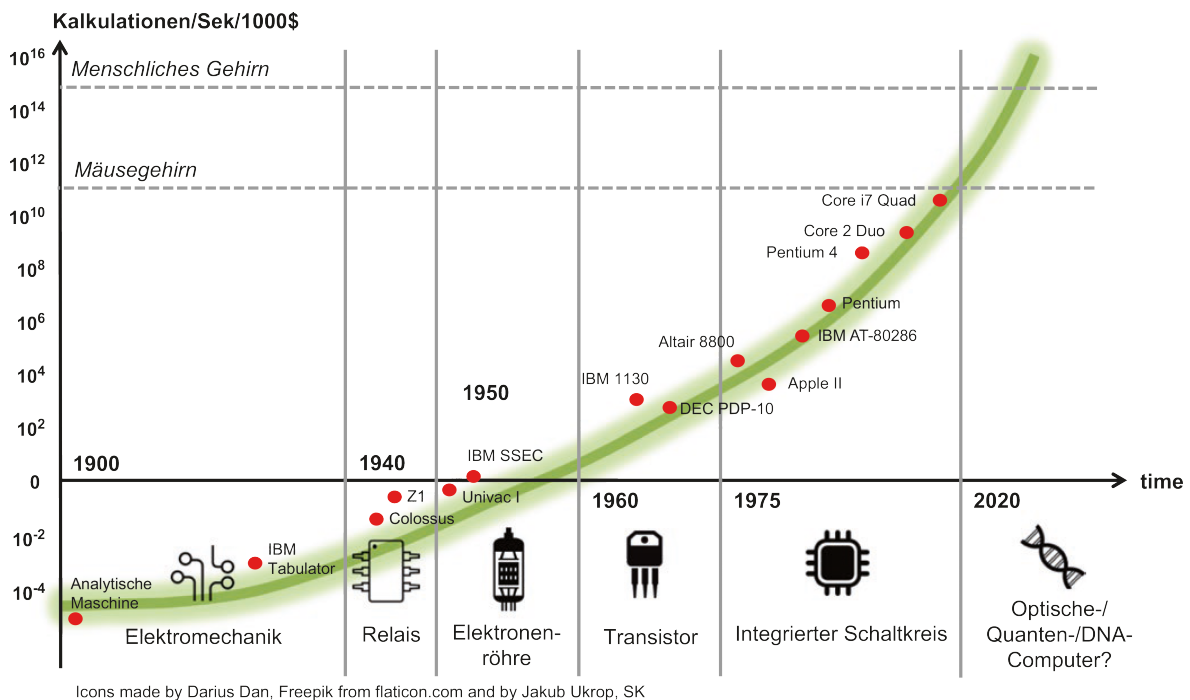


Figure 1.4: Development of computing power per US\$1000 (Schallmo, 2018, [?]).

This enormous computing power enables machines to learn independently and act predictively. Ultimately, these powerful algorithms lead to **artificial intelligence**, which will one day be superior to human intelligence.

1.4 Implementing Digital Transformation in Industry

In recent years, customers have gained increasing influence over what the market has to offer. Through digital transformation, customer demand decisively shapes the market. This development will continue and requires providers to align their business model entirely with the customer and to digitalize it. A **digital business model** answers the same fundamental questions as a conventional business model, but from a different perspective. Here, **customer value** and customer requirements are placed at the center. Information is generated in every area within a value chain.

In digital business models, this information is put to use by collecting and systematically analyzing it. This makes it possible to automate process steps and streamline process chains. This in turn leads to greater efficiency and increases customer value.

The successful implementation of digital transformation poses a challenge for many companies. This is mainly because new paths have to be taken and there is no one-size-fits-all recipe. Every company must develop an **individual strategy** for this.

Nevertheless, there are indeed approaches to a roadmap that can at least increase the probability of successful implementation: In the first step, the **digital reality** is sketched out by describing the company's own business model. This is because business models can only be digitalized once there is an understanding of the existing business model [?]. It is important here that the analysis is not limited to examining the company's own activities alone, but that the view also extends beyond the boundaries of one's own company. By examining the horizontal value chain and its actors, the **degree of digitalization**¹ of the entire industry can be assessed.

Building on this, the next step is to formulate the **digital ambition**. For this, objectives are determined that are set for the implementation of digital transformation. These goals may relate, for example, to time (reducing lead times), finances (reducing logistics costs), or quality (improving the customer experience).

In the third step, it is examined which **digital potentials** exist for the business model. This again requires examining other companies within the industry and identifying **best practices**. Also decisive for these potentials are the enabler technologies, without which it is not possible to realize new applications or services. From the insights gained about the digital potentials, options for the future business model can be derived.

In the next phase, **digital fit**, suitable combinations of options for the business model are evaluated. In this evaluation, what matters is whether the new options fit with the existing business models, whether they meet customer requirements, and whether they can achieve the goals formulated in the digital ambition.

In the final step, the **digital implementation** of the most promising business model takes place.

¹ The **degree of digitalization** indicates the extent to which IT replaces manual work.

A basic prerequisite for implementation is a business model that...

... describes the future **SoS (System of Systems)**¹

... defines the necessary technical infrastructure.

... determines the customer journey.

... depicts the horizontal and vertical value creation network.

The last aspect is the most important here, as it is where the company determines the role it will take on within its SoS.

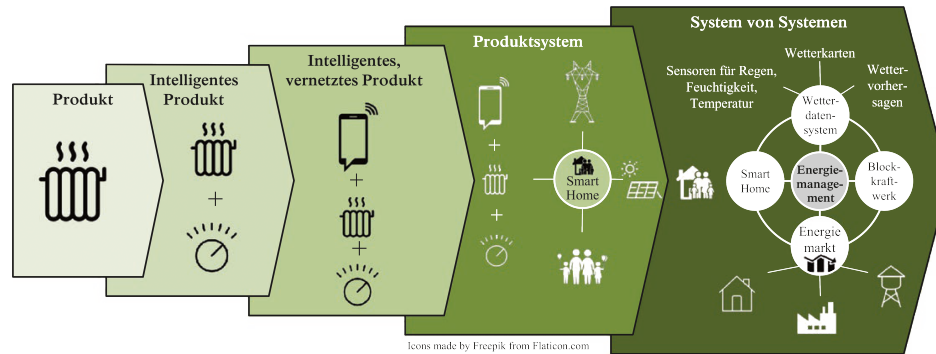


Figure 1.5: SoS, System of Systems [?].

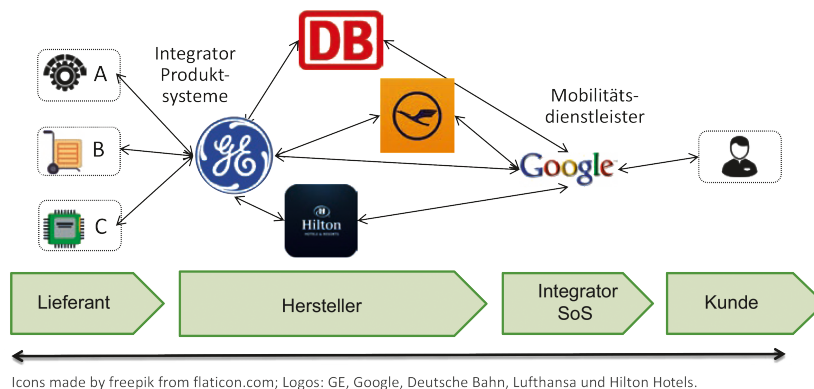


Figure 1.6: Integrated value creation network of systems of systems [?].

In addition to a suitable strategy for implementing digital business models, there are further factors that are decisive for successful implementation:

- Establishing an open innovation culture
- Providing sufficient resources
- Cooperating with suitable partners
- Testing with prototypes to minimize risk

An example of a successful digital business model is ThyssenKrupp Elevator MAX. ThyssenKrupp is a German company with various business divisions; among other things, the company manufactures passenger and freight elevators. In addition to sales and installation, maintenance services are also offered. As the number of elevators in high-rise buildings in cities increases, so too does the amount of maintenance work. Due to intense competition in the maintenance

¹ A **System of Systems** is a collection of specially task-oriented systems that pool their resources and capabilities to create a new, more complex system that offers more functions and higher performance. role it wants to take on.

business, however, this line of business turned out to be time-consuming and low-margin for ThyssenKrupp.

For this reason, the company introduced ThyssenKrupp MAX, an elevator monitoring system that identifies possible causes of failure early and shortens the duration of maintenance work. To this end, various elevator components were equipped with sensors that continuously supply information.

This information is evaluated using **predictive analytics**¹. This enables ThyssenKrupp to carry out maintenance predictively and significantly reduce elevator downtime. In this way, the company can set itself apart from the competition and has successfully revolutionized its own business model [?].

1.5 Levers of Digital Transformation

The effects of digital transformation can be organized along four levers that act on industrial value creation. With these, disruptors are able to break down existing **value chains** into their smallest components and reassemble them through lower transaction costs. Splitting up the value chain also makes it easier for new players with little capital to enter the market, since barriers to market entry are lowered. This leads to the transformation of business models and the restructuring of entire industries. The four levers of digital transformation are:

Digital Data

By collecting, processing, and evaluating digital data, the **efficiency** and **effectiveness** of processes can be increased. In addition, better forecasts and decisions can be made on this basis. This is also why digital data is now produced and traded in the economy like goods, making it a commercial commodity.

Automation

By combining technologies with artificial intelligence, autonomous, self-controlling systems emerge. This generally makes it possible to increase **process speed** while simultaneously reducing operating costs and error rates. However, the decisive advantage is that unit costs can be lowered, bringing companies closer to a batch size of one.

Networking

Through fast internet connections and modern network protocols, an increasing number of objects can be virtually networked. With the help of these technical prerequisites, entire **supply chains** can be **synchronized** with one another and coupled directly to demand. Networking thus increases the flexibility of companies and, through the exchange of information, promotes a shorter innovation cycle.

Digital Customer Access

Through the internet, new players gain direct and scalable access to consumers, something that was previously often reserved for only a few providers. Because of the **complete transparency** of consumer behavior, providers can offer a level of service never seen before. To make this possible, intermediaries are needed above all, who bring providers and demanders together and ensure the exchange of information. As these intermediaries increasingly gain control over customer interfaces, they in turn help shape the entire market structure.

¹ **Predictive analytics** is the analysis of data that makes it possible to predict future results and events.

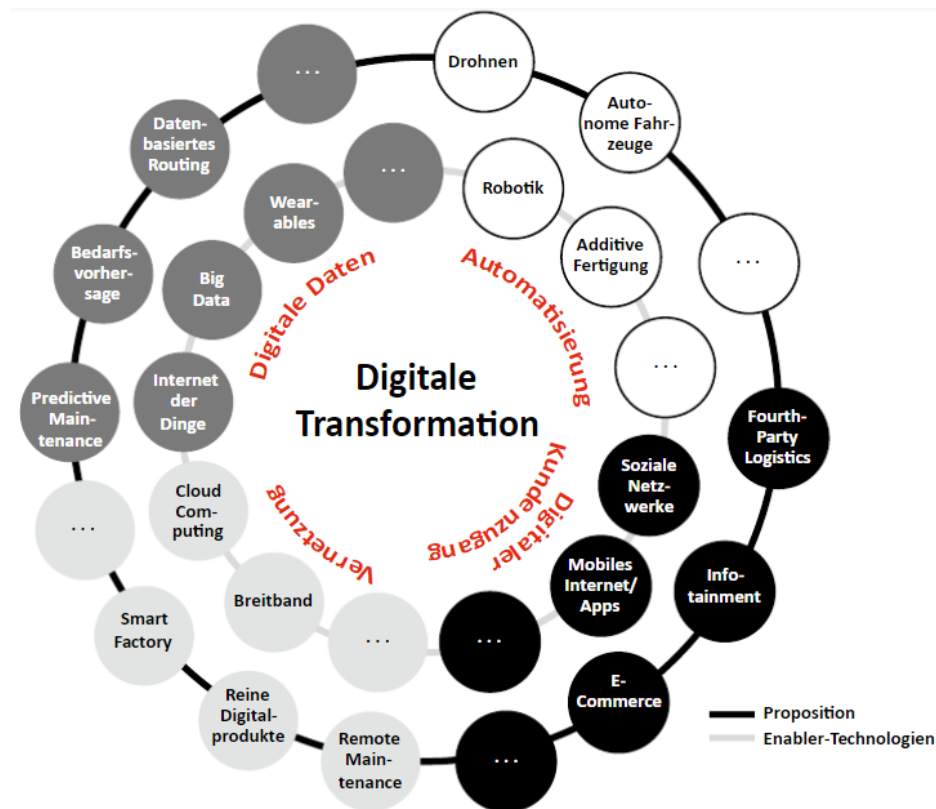


Figure 1.7: The four levers of digital transformation (Wallmüller, 2017)

These four levers can be used to explain the entire logic of digital transformation. With this understanding, companies are able to assess the threat posed by new disruptive technologies in their own industry, or to develop such technologies themselves. This makes the four levers of digital transformation of enormous importance [?].

1.6 Challenges

Digital transformation brings progress and prosperity. On the other hand, both companies and society face challenges that arise from digital transformation.

Although companies are making an effort to incorporate digital transformation into their corporate strategy, not even half of German businesses pursue a cross-company strategy. This poses enormous challenges for them, particularly given the growing diversity of digital interaction channels and the focus on the customer in business models.

Many companies acknowledge that, given their current level of innovative capability, they risk being overtaken by new technology leaders. A role is also played here by the fact that in many industries, the leading company within a market now holds a global monopoly position, leaving little room for competition. On the other hand, even established market leaders cannot be certain of their dominant position.

In the USA, half of the 500 highest-revenue companies have disappeared since the year 2000 [?].

In addition to the new competitive conditions arising from digital transformation, industry also faces the challenge of ensuring the technical prerequisites for this change in the future as well. It must be guaranteed that the enormous amounts of data generated in the future can be stored and processed securely.

For society, digital transformation will mean that existing **income inequalities** will be further reinforced. The state will be called upon above all to support those who lose their jobs due to digital transformation. For these people, financial support is needed in the first instance.

Furthermore, through **education and training**, they must be kept up to date with current knowledge even without a job. This is because, in a rapidly changing world of work, there is a great risk that they would otherwise lose touch with current technologies. In the more distant future, society will likely then be faced with the challenge of developing a completely new social model. For if only half of the population is gainfully employed because the majority of tasks are taken over by machines, digital transformation means more than just structural change.

1.7 Summary

Digitalization is a long-running process that has long been established both in industry and in private life. Digital transformation is a new development that was made possible by the technologies (enablers) developed in the course of digitalization. However, the starting point for digital transformation has been the fact that the customer and customer value have increasingly moved into the focus of companies.

In order to satisfy the customer, new business models are emerging, the variety of variants is increasing, and products are being individualized. Digital transformation describes these processes. Through its enormous scope and disruptive character, it represents a new dimension compared to digitalization.

There is no one-size-fits-all recipe for the successful implementation of digital transformation in a company. However, there are approaches and success factors that companies should take into account in order not to be left behind in the market. Understanding the four levers through which digital transformation operates is also essential, since this makes it possible to understand the entire logic of digital transformation.

Digital transformation will decisively shape the future on many levels. Since there cannot only be winners, it will present both companies and the state with challenges alike.

CHAPTER 2

Disruptive Technologies

Learning Objectives

After working through this chapter, you will know...

- ... what disruptive technologies are.
- ... how they differ from other technologies.
- ... how digital transformation can be implemented within a company.
- ... how established companies should deal with disruptive technologies.
- ... what alternative model exists alongside disruptive technologies.

Introduction

Disruptive markets and disruptive technologies are being reported on ever more frequently. In fact, the word **"disruption"** was named Business Word of the Year 2015 by the "Frankfurter Allgemeine Zeitung" [?].

Unfortunately, the word disruption is used in virtually any context without a real understanding of its actual meaning. Yet understanding disruptive innovation is essential to ensuring a company's long-term success.

2.1 Definition

The term disruption originates from the Latin word "*disrumpere*". According to common encyclopedias, this translates to "*to break apart*", "*to burst*" or "*to tear apart*".

This already describes what characterizes disruptive technologies:

They break apart and transform markets as well as business models.

"The electric light did not come from the continuous improvement of candles."
- Oren Harari¹-

¹ **Oren Harari** (July 30, 1949 - April 10, 2010) was Professor of Business Administration at the University of San Francisco and the author of numerous books on management.

The term **disruptive technologies** can be traced back to **Clayton Christensen**¹, a former professor at Harvard University. He first used the theory of disruptive technologies in 1997 in his work "*The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*" and is regarded as the founder of this theory. In his later works, he continues to develop the theory of disruptive technologies and also uses the term **disruptive innovations** as a synonym. Both terms are therefore to be regarded as having the same meaning.

According to Christensen, disruptive technologies are triggered by resource-poor companies or start-ups (engl.: **entrants**). With their new innovation, these companies attempt to push already established companies (engl.: **incumbents**) out of the market. In doing so, structures within the market are disrupted or destroyed entirely. Disruptive technologies are therefore also referred to as **breakthrough innovations** [?].

The (then) German Federal Ministry for Economic Affairs and Energy (**BMWi, 2005-20213**) assumed that Industry 4.0 projects in particular would lead to disruptive innovations. The ministry found that Industry 4.0 would revolutionize not only the digitalization and networking of horizontal and vertical value chains, but also companies' product and service offerings. This results in the implementation of new, often disruptive digital business models [?].

2.2 Model According to Clayton Christensen

As mentioned at the outset, virtually any innovation is mistakenly labeled as disruptive. Yet as early as the beginning of the "Disruptive Innovation Theory," published in 1997, Clayton Christensen distinguished "conventional" innovations from disruptive innovations. The former generally do not substantially change a market but merely develop it further. Disruptive technologies, on the other hand, are characterized by **aggressive changes** to the market and its participants.

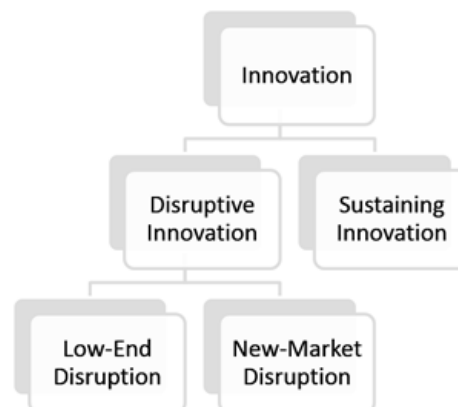


Figure 2.1: Types of technology according to Clayton Christensen.

¹ **Clayton Christensen** (born April 6, 1952 in Salt Lake City, Utah; died January 23, 2020 in Boston, Massachusetts) was Professor of Business Administration at Harvard Business School and is considered the world's leading expert in the field of innovation and growth. He authored many books and several hundred articles. In his first book, "The Innovator's Dilemma" (1997), he addressed the theory of disruptive innovation for the first time. He also founded several companies.

■ Sustaining Innovation

Sustaining innovation (German: *erhaltende Innovation*) refers to technologies that continue to pursue an already existing development path. This is typically promoted by already established companies through internal research and development. The goal pursued here is to "continuously further develop and improve" the products and services already accepted by and established in the market [?].

An example of a sustaining innovation is a new vehicle model from an established automobile manufacturer that is developed by improving known performance dimensions, such as engine power in horsepower. However, the **existing market remains intact** when this new model is introduced. These innovations offer established companies the advantage that, thanks to their prior innovations, they have already been tested in the market and adapted to customer requirements. Most innovations and technologies in today's market fall into the category of "sustaining innovations".

Tesla, for example, currently (still) falls into the "**sustaining innovation**" category, because it has taken market share away from established companies in the luxury segment with electric vehicles (Model S, Model X). With the Model 3 and Model Y, Tesla is well on its way to competing in all markets (including the future truck market).

In a less formal sense, however, it is unmistakable that Elon Musk is shaking the automotive industry to its foundations with Tesla. According to a digital manager at BMW, this is due less to the electric drivetrain of these vehicles than to the fact that they are designed from the ground up as software products.

■ Disruptive Innovation

Unlike sustaining technologies, the following two types belong to disruptive innovations, which cause a **complete restructuring** or **breakup** of an existing **market**. Although the number of disruptive innovations is increasing in the age of digitalization, they still represent only a fraction of all new innovations. The distinction between **low-end** and **new-market disruption** is important because established companies are alerted to differing degrees regarding the potential dangers, and the uncertainty of market creation likewise differs.

- Low-End Disruption

If a sustaining technology is continuously developed and improved further, the likelihood of a low-end disruption increases. Due to the upward trend of the sustaining technology, customer segments with lower requirements are no longer served, since the performance of the constantly improving technology exceeds the actual requirements of the low-end market segment.

It is in this no-longer-served low-end market environment that low-end disruption begins, because this type of disruption is characterized by the introduction of a technology with initially lower performance. At the start of its introduction, this new technology is often far inferior to existing technologies and does not appeal to the main market. However, these technologies offer particular value to customers in the low-end market¹. If this technology is then further developed, it can also become attractive to customer groups with higher performance requirements [?].

¹ A **low-end market** consists of low-cost products suitable for customers who are unwilling or unable to spend large sums of money, or who do not need the full performance of a product.

Not every low-end disruption manages to make the transition from the lower customer segments to the main market. However, if it does, this ultimately leads to the established company suffering significant customer losses. An indication of this is when an established company increasingly moves away from its actual core business and focuses on other business models, because a competitor with **newer technology** is attacking its main business.

It is important for the established company to compensate for the customer decline in its previous core business within the new high-end market segment and to at least hold its position there. However, past experience confirms that only a few established companies have been able to compensate for the customer decline triggered by a disruptive technology.

- New-Market Disruption

Unlike low-end disruption, new-market disruption occurs in a **completely newly created market environment**. Christensen also refers to this as the introduction of an innovation into a **niche market**. While low-end disruption targets and serves competitors' customers, new-market disruption appeals to previous **"non-consumers"**. These are customers whose preferences and needs could not be met by the existing market offering and who therefore deliberately decided against a purchase.⁸

However, the newly introduced innovation has a product criterion that is of great importance to this customer group. As with low-end disruption, these products are significantly inferior to sustaining technologies in terms of performance during their introduction phase, and so initially they remain limited to the customer group they themselves created, the "nonconsumers". Through continuous performance improvements in "the traditionally desired properties of the product"⁸, the new technology can also become attractive enough for customers from the established market segment.

As with low-end disruption, it is initially the **lower customer segments** that become aware of the new technology, before it is further developed enough to win customers from the high-end market environment.

New-market disruptions pose a particular danger for established companies, as they are often **recognized very late**. The reasons for this failure to recognize new-market disruption in time are as follows: the new technologies build up their own market environment and initially grow within it. Another contributing factor is that established companies do not initially lose any customers, since it is only the "nonconsumers" who first become aware of the new offering.

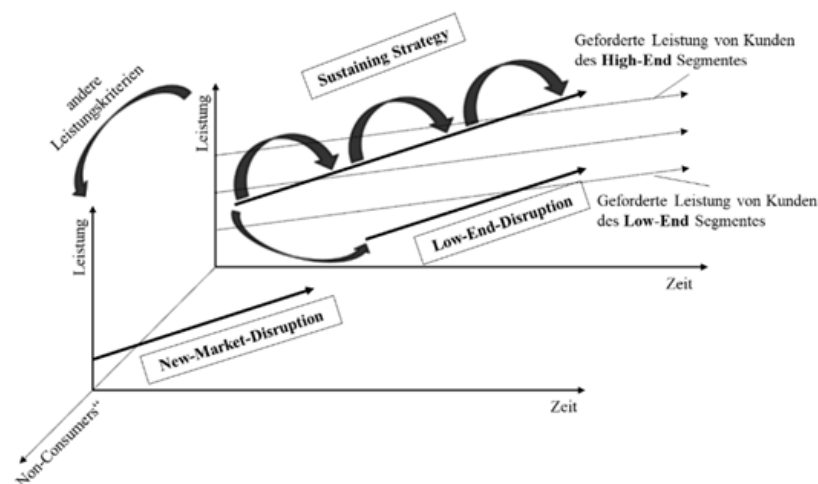


Figure 2.2: Graphical comparison of technology types.

2.3 Examples of Disruptive Innovations

Probably the best-known example of disruptive innovation is the digital camera, which spelled bankruptcy for the company **Kodak**. This example is well suited to illustrating low-end market disruption in practice. In 1996, Kodak was the fourth most valuable brand in the world and sold cameras. Its main business was dominated by the sale of analog cameras. Kodak itself developed the first digital camera in 1975 but saw no reason to invest further in it. Instead, they continued to focus on the further development of analog cameras. Competitors discovered the new technology of digital photography for themselves, even though the digital camera initially offered considerably less performance than the analog camera.

Through continuous further development of and investment in the digital camera, the new technology was successfully established in the market. While the share of digital cameras among all cameras sold was still around 12 percent in 2000, ten years later their share was over 99 percent. As a result, Kodak's revenue also collapsed enormously. Despite numerous restructurings and changes to its business model, Kodak failed to compensate for the lost revenue from analog cameras and filed for bankruptcy in 2012. In 2013, Kodak made a fresh start in the printing business, but has never since been able to regain its former scale [?].

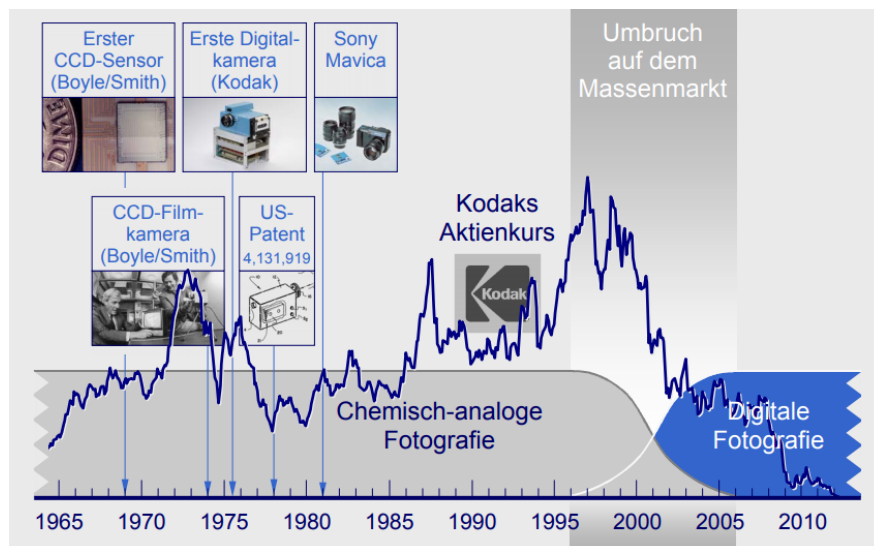


Figure 2.3: Example: Kodak.

Another disruptive innovation that did not, however, originate in a low-end market is the **drone**. Here we can speak of a new-market disruption. Drones were initially developed solely for military purposes. The United States of America, for example, used the unmanned aircraft for espionage and reconnaissance purposes in the 1960s. As drones were continuously developed further in terms of their efficiency, it became possible to build small, powerful, and low-cost drones. This was an important milestone for the deployment of drones, as they could now be established in the mass market.

Today's fields of application are diverse and disruptive. For example, **Amazon's** CEO Jeff Bezos plans to deliver small packages by drone. This "Prime Air" service, as he named it, will take market share away from already established shipping companies such as DHL, DPD, Hermes, or UPS — or even push them out of the market entirely.

A Harvard Business Review article analyzed several examples of disruptive technologies. The following table shows further examples of current disruptions in the market [?]:

Established Technology	Disruptive Technology
Local storage	Cloud storage
Local shops	eCommerce
Money transfer	Blockchain (Bitcoin)
Mechanical watch	Smartwatch
Travel agencies	Online booking

Examples of well-known disruptors:



Figure 2.4: Examples of disruptors.

2.4 Examples of Sustaining Innovations

As already mentioned, **Tesla**, **Uber**, and **Airbnb** are, by contrast, not classic disruptors. They do not meet the conditions for low-end or new-market innovations. They are undoubtedly highly innovative, but not disruptive in the sense of Christensen's definition.

Uber has changed the way taxis operate. The company owns no cars and employs no drivers, and therefore has no fixed costs. Likewise, Airbnb owns no hotels and has no staff. Their business model consists of using existing resources differently. But this is not a disruptive innovation — it is a sustaining or incremental one.

2.5 Dealing with Disruptive Technologies

As already made clear in the preceding chapter, many established companies fail to successfully return to the market after being displaced by a disruptive technology. **439 of the 500 companies** listed in the S&P 500 stock index in 1955 are no longer listed in that index today [?]. For this reason, established companies cannot afford to neglect the proper handling of

disruptive technologies. It must be noted that there is no perfect plan to protect a company from disruptive innovations. Nevertheless, there are various approaches that can help protect established companies.

▪ **3 questions established companies should ask themselves when facing new competition:**

- Does the new idea have low-end potential?
- Does the new idea have new-market potential?
- Does the new idea have an impact on all established companies?

▪ **"The products, not the profits, were the motivation" – Steve Jobs [?]**

The first approach can be found in the Harvard Business Review article "Steve Jobs Solved the Innovator's Dilemma, by HBS Professor Clay Christensen". It refers to the biography and mindset of Apple's former CEO, Steve Jobs. Established companies that already hold a monopoly believe they can no longer grow through product improvements. Instead, they focus on sales and marketing. According to Jobs, this is a mistake, because the focus shifts to profit rather than innovative products.

Visionary thinking and the importance of good products — the very things that led these companies to market dominance in the first place — are undermined by sales and marketing. A focus on profit rather than on new, innovative products increases the likelihood of being displaced from the market by a new technology.

▪ **Acquisition**

Another method of protecting against disruptive innovations is to acquire disruptive companies at an early stage. Every established company's innovation management should search the market for disruptive innovations and identify them early. Through a constant readiness of liquid funds, the company can act quickly and acquire the disruptive company at an early stage. A good example of this is Alphabet Inc., whose subsidiary is Google. In its 2019 balance sheet, Alphabet reported cash reserves of over 117 billion US dollars and is known for its numerous acquisitions each year. Well-known Alphabet acquisitions include YouTube, HTC, and Fitbit.

▪ **Spin-Off**

A very popular approach for protecting against disruptive technologies, but also for creating them oneself, is a spin-off. In this approach, already established companies found a new, independent start-up. These start-ups typically have nothing to do with the established company's core business. They operate entirely independently of their parent company and can thus respond more quickly to market changes.

A further advantage over other start-ups is the ability to draw on the resources of the established company. The parent company usually makes liquid funds as well as patents freely available. As a spin-off of **MIT** (Massachusetts Institute of Technology), the company **Boston Dynamics** succeeded in becoming a pioneer and the world market leader in autonomously walking robots.

Since 2013, Boston Dynamics has continued to operate independently, although it was acquired by Google. Another current example of a spin-off is likewise a Google subsidiary. Under the motto "*We create radical new technologies to solve some of the world's hardest problems*", the start-up "Google X – The Moonshot Factory" pursues the goal of developing new technologies and innovative products [?].

2.6 Alternative Model

Alongside the theory of disruptive technologies, the **S-curve model** by **Richard Foster** is another instrument of strategic innovation management.

Like Clayton Christensen's theory of disruptive innovation, the S-curve model also addresses technological leaps from old to new technologies. Similar to disruptive innovations, a new technology forces change upon the market, with the old technology ultimately being displaced from the market in the long run. This model states that every technology passes through various stages of development before it reaches its performance limit. This is then followed by a technological leap triggered by a new technology.

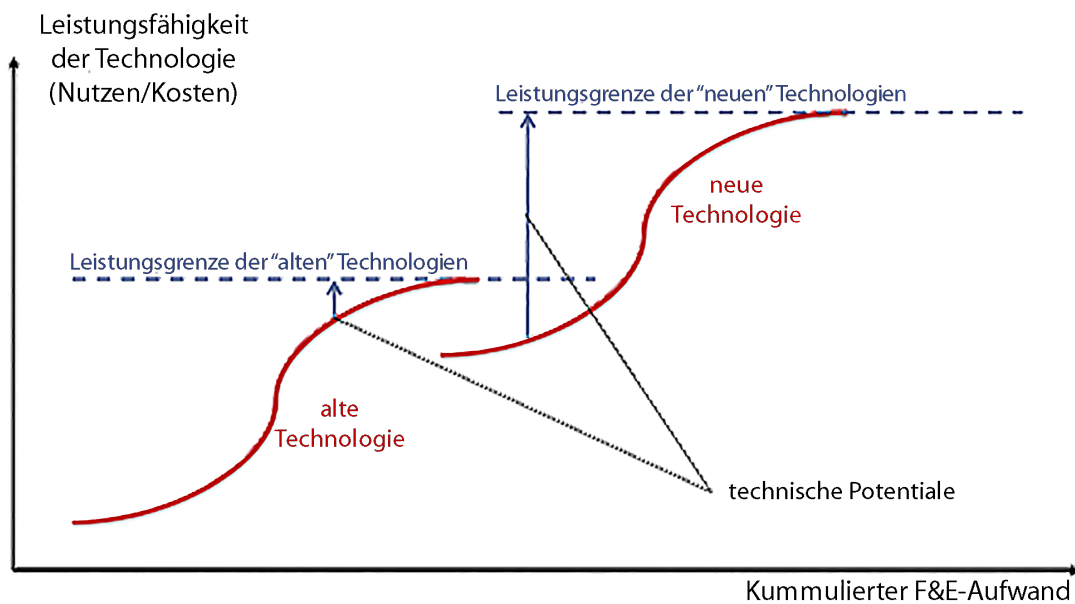


Figure 2.5: S-curve model according to Richard Foster.

This new technology may initially exhibit lower performance capabilities, as it has been barely tested and developed. Thus, only a fraction of its potential performance capability is present in the early stage. However, through continuous further development of the new technologies, considerable progress in performance capability can be achieved. The outdated technology, by contrast, can only produce marginal performance improvements even with high research and development costs, and ultimately becomes obsolete for the market.

A suitable example to illustrate the process of the S-curve model is the current technology shift in the **automotive industry**. As early as the 19th century, the first internal combustion engine was developed by Nicolaus Otto [?]. As is typically the case with such major technological developments, this was followed by more than a century of smaller improvements. Fuel consumption, for example, was continuously improved through incremental advances. However, the engine that is used today in a saturated market now has hardly any potential left for improvement.

The automotive industry has already initiated the technological leap to new technologies, and the first electrically powered motors are being offered on the market. Although the electric motor is currently in the early stage of its life cycle, it has already effectively caught up with the internal combustion engine in terms of energy consumption.

For example, an electric car equivalent to a gasoline-powered car with a consumption of 5 liters would need to consume 42 kWh of energy to match it. A corresponding electric car, however, consumes only about 14 kWh [?]. Considering the long-term potential that could

be achieved through further improvements, it can be assumed that the internal combustion engine will become obsolete in the coming years.

2.7 Summary

Disruptive technologies will bring about many changes in the market, particularly in the age of digitalization. Past examples such as Kodak and Jeff Bezos's plans for drone deliveries confirm this. But it is not only the past from which a shift in the market can be inferred. Due to increasingly shorter product life cycles and the digitalization mentioned above, market processes are accelerating.

Future projects such as virtual reality, artificial intelligence, or blockchain will bring about future restructurings in the market. Nevertheless, in order to purposefully guide and plan a company, sustaining innovations should be distinguished from disruptive innovations.

CHAPTER 3

Artificial Intelligence

After working through this chapter, you will know...

- ... what is understood by artificial intelligence.
- ... the connection between Artificial Intelligence and Industry 4.0
- ... which disciplines AI is composed of.
- ... which ethical questions AI raises.
- ... what weak and strong AI are.
- ... future perspectives of artificial intelligence

Introduction

Artificial Intelligence (KI/AI)¹ – What is it? An artificial intelligence can solve a range of tasks which, when solved by humans, require intelligence. For this purpose, artificial intelligence uses a range of methods that enable a computer to solve precisely such tasks. Using artificial intelligence is considered a key **driver of innovation** for implementing projects within the scope of Industry 4.0.

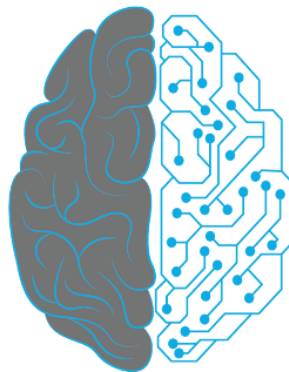


Figure 3.1: Artificial Intelligence (abstract representation).

¹ German: **AI** = Artificial Intelligence

3.1 Defining the Concept of Artificial Intelligence

The term artificial intelligence is contested, as it is understood as the simulation of intelligent human thought and action. The problem with this definition is that neither intelligent human thought nor intelligence itself is clearly defined. Moreover, the human being alone is used as the yardstick of intelligence, even though evolution has produced a multitude of organisms with widely varying degrees of intelligence.

The Mainz-based researcher Wolfgang Ertel therefore proposes, in his book "Künstliche Intelligenz – Wann übernehmen Maschinen?" ("Artificial Intelligence – When Will Machines Take Over?"), the following working definition of intelligence, which is independent of humans as well as of measurable system quantities.

Working definition: A system is called intelligent if it can solve problems independently and efficiently. The degree of intelligence depends on the degree of autonomy, the degree of complexity of the problem, and the degree of efficiency of the problem-solving procedure.

The attribute "artificial" brings additional associations with it. It implies that an attempt is being made to understand, model, and replicate the highest good of humankind: intelligence. Elaine Rich, an American computer scientist, provided a fitting definition of this.

Definition: Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better.

Here, Rich characterizes what scientists and researchers have been doing in AI research for roughly seventy years. According to Ertel, this definition of artificial intelligence will still be current in 50 years [?].

3.2 History of Artificial Intelligence

The history of AI began in the middle of the twentieth century. The founding year of AI is dated to 1950, when the British theorist **Alan Turing (1912-1954)** published his famous paper "Computing Machinery and Intelligence." Turing developed the test named after him, the "**Turing Test**." In this test, a machine is credited with artificial intelligence as soon as it is capable of communicating in such a way that a human cannot distinguish whether they are communicating with another human or with a machine.

For this purpose, the human communicates with a machine via a terminal (e.g., monitor and keyboard). As an example of such a test, the following sample dialogue serves as an illustration, using sample questions and sample answers from various application areas. The example dialogue also makes clear that even the answer to the question about writing a poem could itself be a typical human answer. Turing remarked on this:

"Who among humans is truly creative and able to write poems?" [?].

Q: Please write me a poem about the Firth of Forth Bridge.

A: I have to pass on that one. I could never write a poem.

Q: Add 34,957 to 70,764.

A: (waits about 30 seconds, then gives the answer) 105,721.

Q: Do you play chess?

A: Yes.

Q: My king is on e8; otherwise I have no pieces left. You have only a king on e6 and a rook on h1. It is your move. What do you play?
 A: (after a pause of 15 seconds) Rh1-h8, mate.

Research distinguishes four development phases of AI.

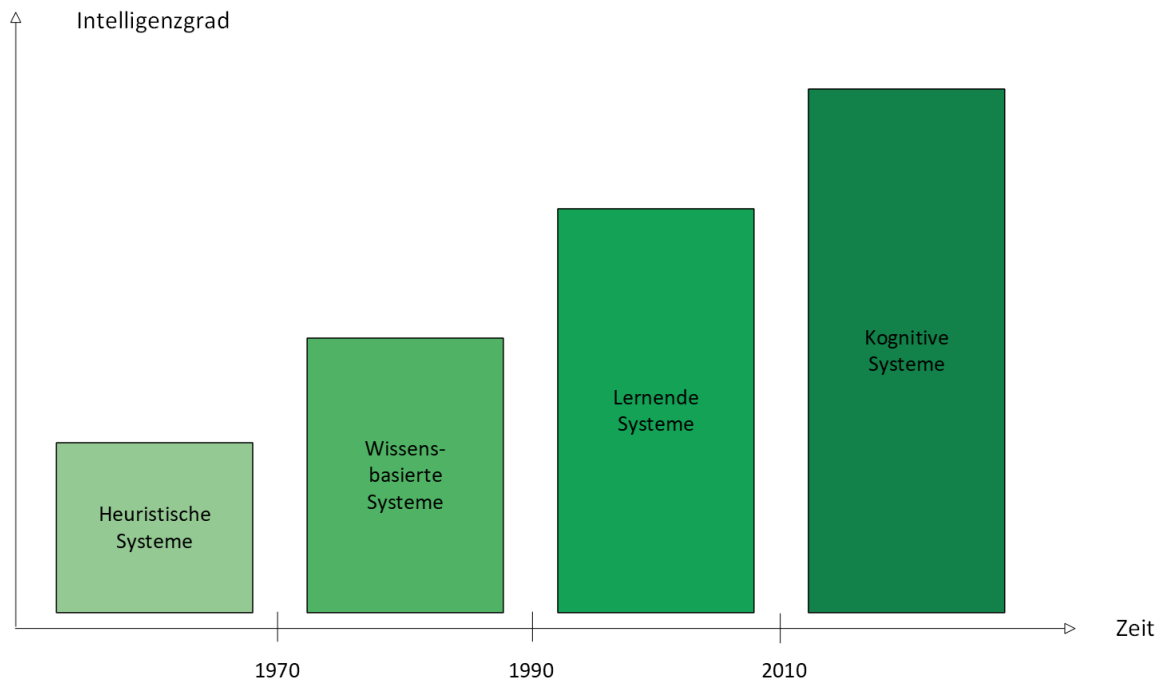


Figure 3.2: Four phases of AI research (based on [?])

Phase 1: Heuristic Systems (1956-1970)

In 1956, the term "Artificial Intelligence" was introduced by John McCarthy (1927-2011) at a conference at Dartmouth College. The first phase of AI research is marked by high expectations of the new technology. The aim was rather to define general problem-solving procedures for computers. At the time, however, this was not successful, whereas research in the area of specialized programs was able to record major successes. It became clear that good AI programs depended on a suitable database and a fast retrieval procedure.

These methods are based on a **heuristic approach** to problem-solving, in which reasoning itself is also regarded as a search process. The goal was to understand human problem-solving behavior. An early application example was playing chess.

Phase 2: Knowledge-Based Systems (1971-1990)

In the second phase of AI, an increased focus on specialized programs can be observed. A widely known programming language, "MACSYMAL," which represented a collection of specialized programs in customary mathematical notation, became established. Typical tasks for these programs were integration and differentiation, which are still needed today.

Knowledge-based systems process knowledge by means of a knowledge base and an inference component. They draw logical conclusions from existing information and are regarded as an important aspect of intelligent systems.

A well-known example is the medical expert system MYCIN, which was developed in the 1970s for diagnosing bacterial infections.

Phase 3: Learning Systems (1991-2010)

Learning is regarded as a central characteristic of intelligence. **Machine Learning** is defined by two fundamental properties: first, it requires input data, referred to as training data. Second, the process consists of gaining experience from this training data and transferring that experience into a model. Such a model is often additionally dependent on further parameters.

In the 1990s, investment in artificial intelligence research increased significantly. In 1997, the first international RoboCup, featuring football-playing robots, took place. In the same year, IBM's AI "Deep Blue" defeated the reigning world chess champion Garry Kasparov 3.5 to 2.5, impressively demonstrating what AI is capable of.

By the late 1990s, existing Go programs had a playing strength that barely exceeded that of ambitious human beginners.

Phase 4: Cognitive Systems (since 2010)

Cognitive systems combine the learning methods from Phase 3 with the knowledge-based methods developed in Phase 2 [?].

Service robotics is developing into a dominant field of AI research. In 2010, Google presented the first self-driving car on a freeway in California.

In October 2015, AlphaGo competed against the reigning European champion and professional Go player Fan Hui. AlphaGo won the match 5:0.

In 2018, the Google company DeepMind introduced the AI AlphaZero. Within a few hours, it learned to play chess, Go, and Shogi in succession and subsequently outperformed every piece of software developed up to that point, becoming vastly superhuman.

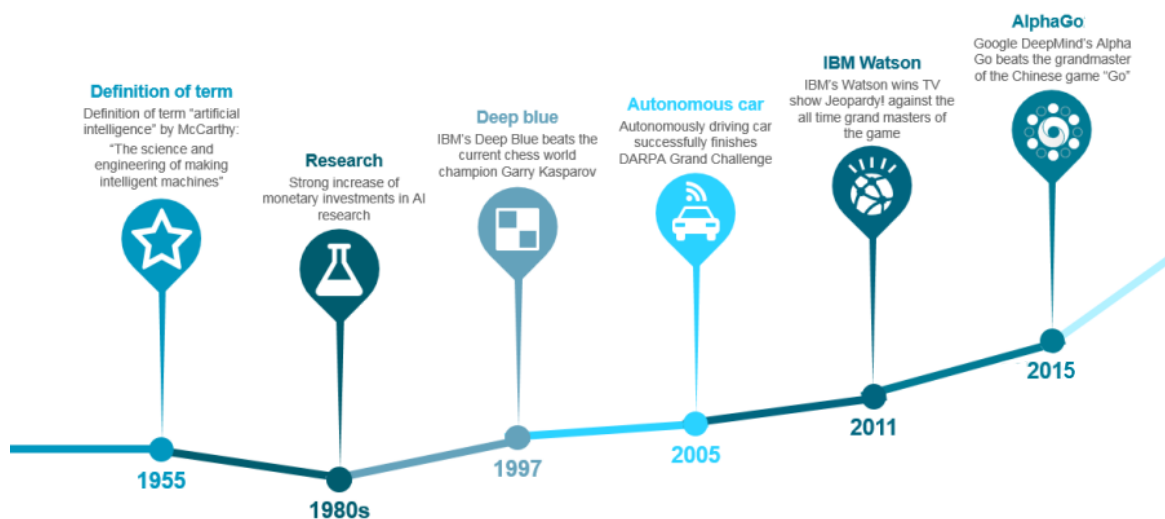


Figure 3.3: History of Artificial Intelligence

3.3 The Connection Between AI and Industry 4.0

Industry 4.0 stands for the fourth industrial revolution, characterized by digitalization and automation. AI plays a central role in this by analyzing large volumes of data, making machines more intelligent, and controlling processes autonomously. Applications such as predictive maintenance, intelligent robotics, and optimized supply chains enable networked, flexible, and efficient production [?].

Automation Influenced by AI

AI enables systems to learn and solve problems independently within defined limits. It plays a particularly central role in the autonomous control of industrial processes, whereby the level of autonomy determines the degree of independent action.

The autonomy of a system depends on the complexity of the task and the role of the human. To achieve higher levels of autonomy, AI systems must be further developed, since their decision-making ability is based on experiential knowledge. AI is thus decisive for the development of intelligent, autonomous systems.

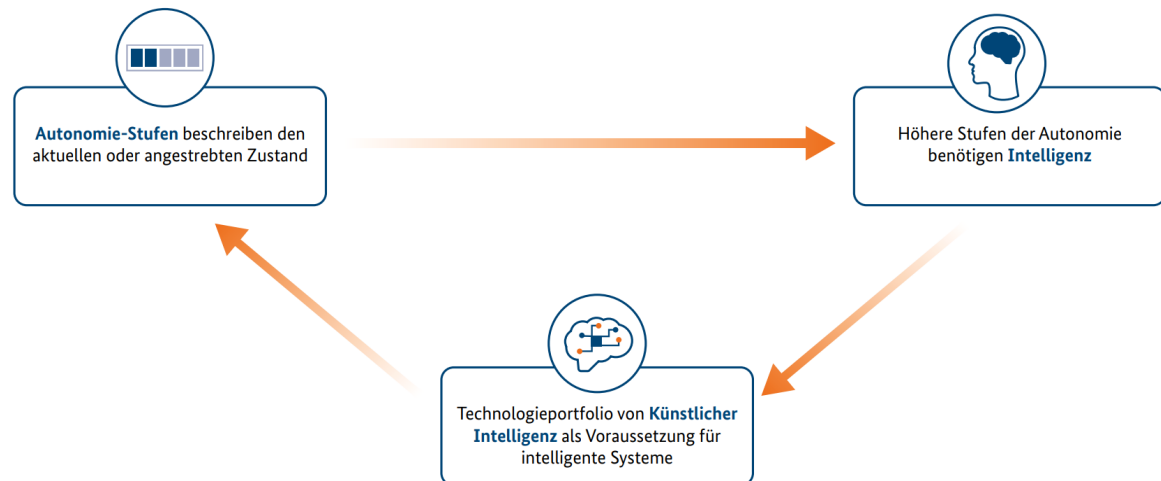


Figure 3.4: General relationship between autonomy and AI [?]

Industrial production encompasses the entire lifecycle of a plant – from planning through operation to maintenance and decommissioning – with all areas interconnected.

A graduated model of autonomous action is important, since not every system requires the same degree of autonomy. Different areas such as process control, planning, and maintenance have different levels of automation. The following figure shows the stepwise achievement of higher levels of autonomy.

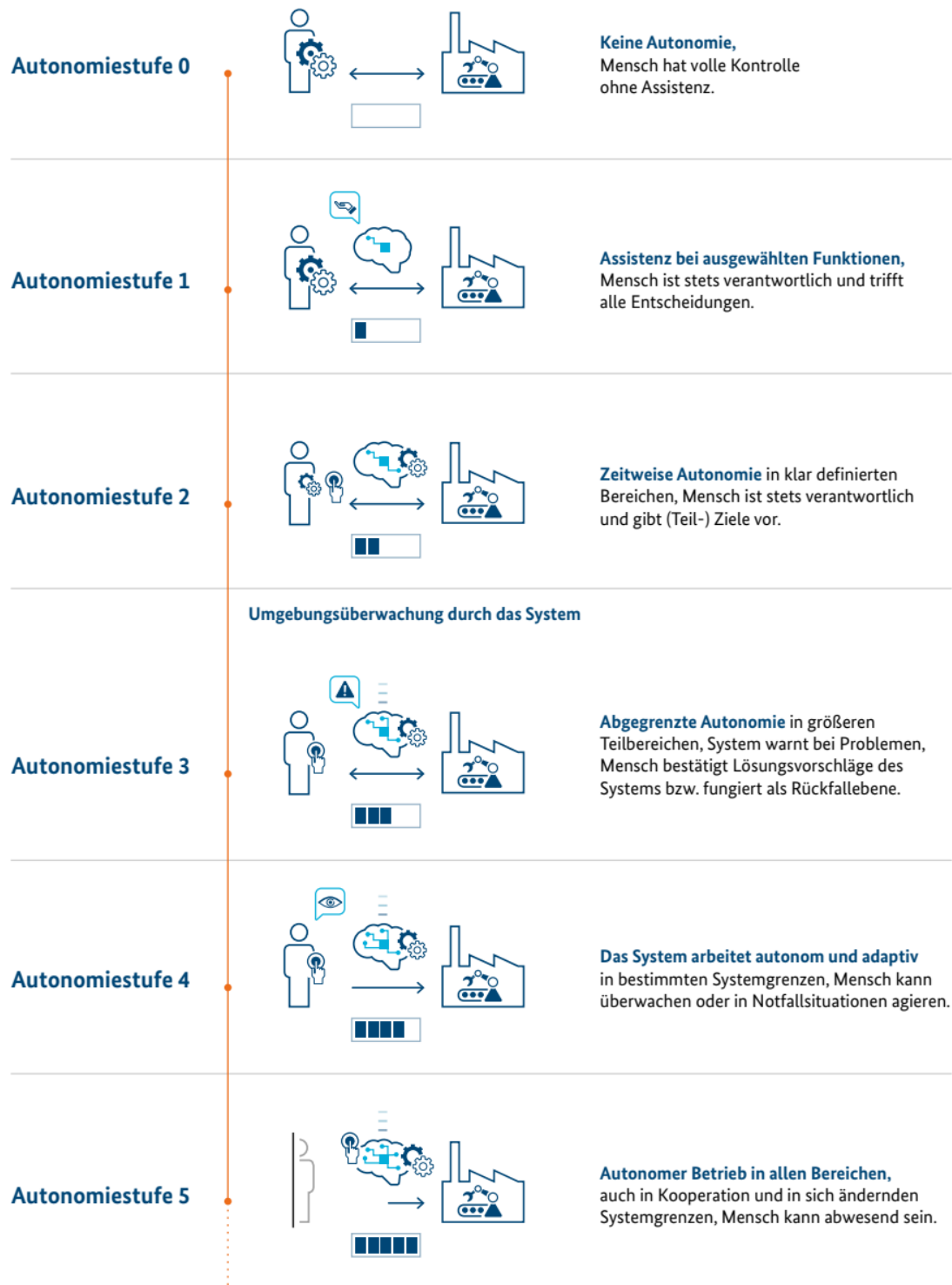


Figure 3.5: Overarching definition of AI-influenced autonomy levels in industrial production [?]

The most important areas of artificial intelligence are Machine Learning, Neural Networks, Deep Learning, and Data Mining [?].

3.4 Machine Learning

In Machine Learning, an artificial system or a computer learns from experience and, after a training period, is able to solve tasks for which the system was not explicitly pre-programmed [?].

The learning process is more successful the more data is available to the system. During the learning process, the data is first divided into training data, validation data, and test data. With the help of the training data, the system is able to recognize patterns and regularities and thereby develop a model with decision rules and various parameters. With the help of the validation data, the correctness of the model can be checked, and afterward the accuracy can be determined using the test data.

In principle, there are three different forms of Machine Learning:

- **Supervised Learning**
- **Unsupervised Learning**
- **Reinforcement Learning.**

In **supervised learning**, training data is provided in which the input and the corresponding output, i.e., the result, are known. In this type of Machine Learning, the correctness of the available data is of particular importance, since otherwise incorrect relationships are learned.

Unsupervised learning differs from supervised learning in that the correct output for the training data is not known to the system. The data is analyzed for patterns and grouped according to various features.

In the third form of Machine Learning, **reinforcement learning**, the system is confronted with problems and repeatedly receives positive or negative feedback on the solution path it has chosen. The system thereby learns strategies that maximize rewards [?].

Machine learning processes already have numerous applications in our everyday lives today, such as facial recognition software in laptops and smartphones, or personalized product recommendations. Machine learning processes can facilitate the handling of large volumes of data across many environments and industries. For example, such systems can be used in manufacturing companies for quality control, to detect deviations from the norm. Predictive maintenance models enable companies to use resources effectively by predicting the point in time at which production facilities and machines will fail.

The **financial industry** also offers many possible applications for the technology described here. For example, risks can be assessed more realistically, or portfolios can be optimally aligned with investor objectives. Furthermore, **healthcare**, and in particular diagnostic possibilities in the event of illness, could be revolutionized through the targeted use of Machine Learning. By analyzing patient data, individual therapy options can also be identified and applied.

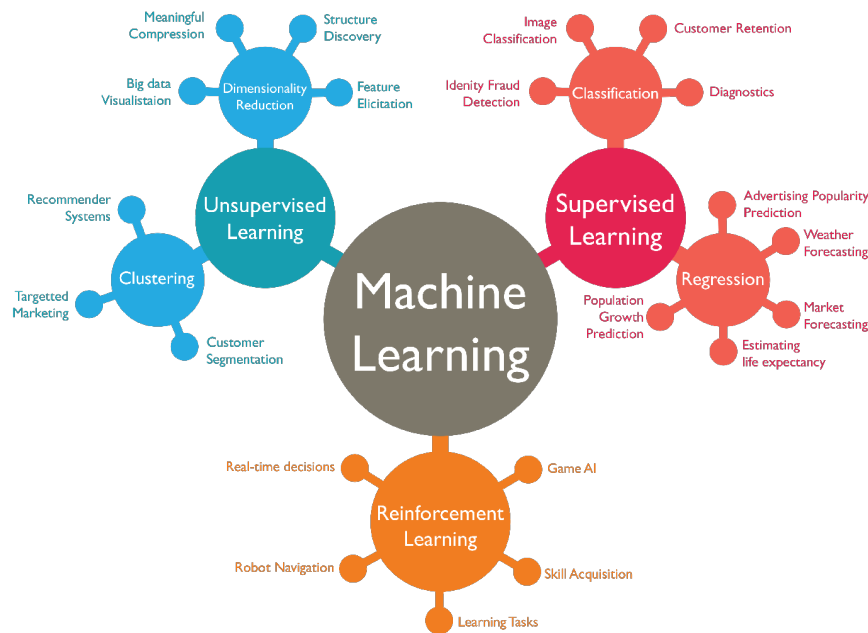


Figure 3.6: Machine Learning: various learning methods.

3.5 Deep Learning

Deep Learning and Machine Learning are two very similar methods of data evaluation. Deep Learning is used primarily for large, multidimensional data, whereas Machine Learning is used more for small datasets that can be processed quickly and with fewer resources. The foundation for Deep Learning is also formed by Neural Networks (see Chapter 3.6), which continually create new connections during the learning process, thereby enabling a machine to learn. This puts a machine in a position to improve its abilities independently and without human intervention. This is achieved by evaluating existing data, in which patterns are recognized, extracted, and subsequently classified. The findings are related to the data in order to link them within a broader context. The machine is then able to make decisions based on the connections between the data.

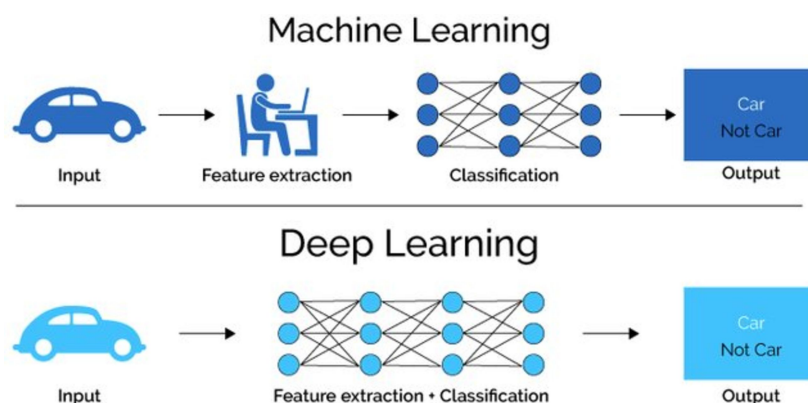


Figure 3.7: Machine Learning vs. Deep Learning

Through the continual questioning of decisions, certain information links receive different weightings. If, for example, a decision is confirmed, the weighting of the connection increases, and vice versa. As a result, more and more intermediate layers and connections form between the input layer and the output layer. The output is then determined by these intermediate layers (Fig. 3.8).

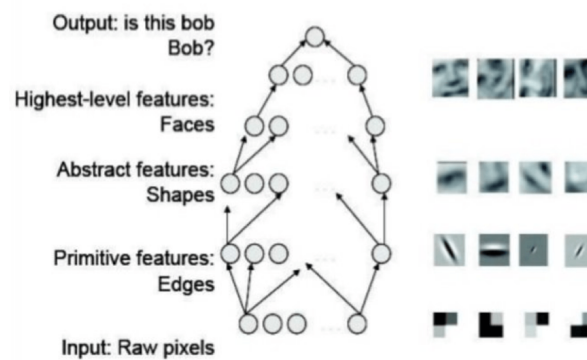


Figure 3.8: Deep Learning feature hierarchy in image processing

Due to the very large volumes of data involved, Deep Learning requires more computing power. Classical processors (CPUs) are therefore not sufficient; instead, powerful graphics processing units (GPUs) are used. This is mainly because training a Deep Learning model, depending on its complexity and size, can take up to several weeks. One problem with Deep Learning is its **lack of transparency**. Without additional effort, it is not possible to trace how a prediction came about. This is because the neural network of a Deep Learning model learns, through the data during training, how decisions are made. For this reason, Deep Learning models are, for example, deliberately avoided in **financial sectors**, with Machine Learning models being used instead.

3.6 Neural Networks

Neural networks are networks of nerve cells in the brain of every living creature. In humans, neural networks are responsible for complex interconnections and for the adaptivity that enables our intelligence as well as a wide range of motor and intellectual abilities. The field of artificial neural networks takes nature as its model.

Figure 3.9 shows, respectively, a representation of a natural neural network and an artificial neural network. A single neuron (green) has many inputs (synapses) at which signals can arrive. When the synapses of the neuron reach a threshold value, the neuron in turn emits a signal via the axon. In reality, however, neurons are interconnected in a far more complex way. In order to apply this principle to artificial intelligence as well, the system is simplified and represented in multiple layers.

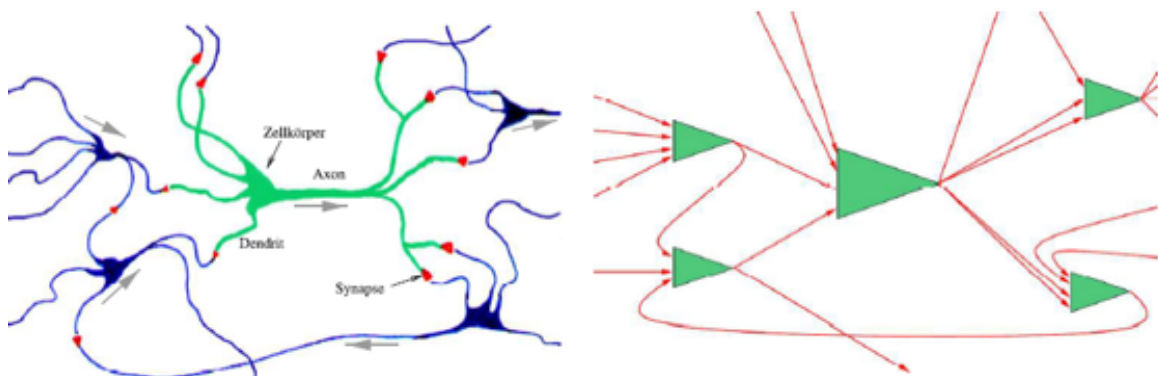


Figure 3.9: Natural neural network and artificial neural network

A simple example of artificial neural networks is image recognition. Suppose an image with 128 pixels depicting a cat is to be classified (Fig. 3.10). In the first step, all 128 pixels are

connected to the inputs of a neuron. Each neuron has 4 inputs, which results in 32 neurons in the first layer of the neural network. Since each pixel essentially has a numerical value, this numerical value is passed on to the inputs of the neurons. Once the inputs of a neuron reach a certain threshold value, the neuron passes on an output value [?].

The weighting of the individual pixels and neurons also plays an important role. For example, the pixels have different weightings, since some are located at the edge and others more toward the center. In the next step, the threshold value of the neurons can also be changed. For instance, one neuron passes on an output value even at a low input value, while another does not.

It is therefore of immense importance for the neurons to take into account the two parameters of weighting and threshold value. A second layer would now be placed on top of the first layer of the artificial neural network, with 8 neurons, each again having 4 inputs. The process of image recognition then passes through more and more layers up to the highest level of abstraction, at which point the output value "cat" is produced. In order for this to also be recognized in as many different images as possible, the neural network can be further trained. To do this, the individual parameters are adjusted until every cat is recognized. This is based on the supervised learning approach within Machine Learning, in which the input and output values are already known.

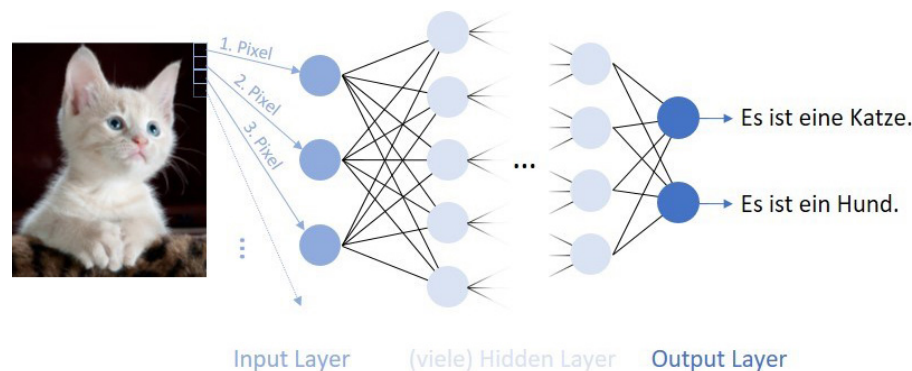


Figure 3.10: Illustration of image recognition.

3.7 Data Mining

Data Mining is the process of analyzing large volumes of data from various data sources in order to gather usable information. This is done by discovering previously unknown patterns, anomalies, and correlations. All of these are later used to predict future outcomes. Data Mining is based on three main types of modeling.

- **Descriptive modeling**
- **Predictive modeling**
- **Prescriptive modeling**

Descriptive modeling uncovers commonalities or groupings in historical data in order to determine the reasons for success or failure, such as categorizing customers by product preference or sentiment. Example techniques for descriptive modeling include clustering, which groups similar datasets, as well as association rule learning, which describes the identification of relationships between datasets [?].

Predictive modeling goes deeper, classifying future events or estimating unknown outcomes – for example, with the help of **credit scoring**, to determine the probability that a person will repay a loan. Predictive modeling also helps uncover insights into matters such as customer

churn, campaign responses, or loan defaults. Example techniques include decision trees, in which each branch represents a probable event.

In **prescriptive modeling**, internal and external variables and constraints are considered in order to provide one or more recommended courses of action – for example, determining the best marketing offer to send to each customer. Example techniques include marketing optimization, which simulates the most advantageous media mix in real time for the highest possible return on investment (ROI), as well as predictive analytics, which describes the development of "if-then" rules from patterns and the prediction of outcomes.

With the increase in unstructured data from the internet, comment fields, books, emails, PDFs, audio, and other text sources, the relevance of text mining as a related discipline of Data Mining has also grown considerably.

Data Mining requires the ability to successfully **parse**¹, filter, and transform unstructured data in order to incorporate it into predictive models for improved forecasting accuracy. Ultimately, Data Mining should not be viewed as a separate, standalone unit, since preprocessing (data preparation, data exploration) and postprocessing (model validation, scoring, model performance monitoring) are equally important.

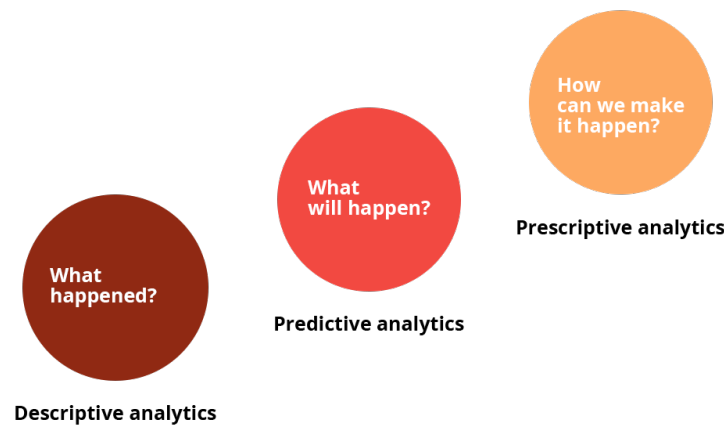


Figure 3.11: Data Mining modeling types

¹ **parse:** to analyze the syntax of a formal language [?].

3.8 Ethics and Impact on the Labor Market from the Use of AI

A contentious part of AI research concerns ethical clarification. A key point of contention is the question of whether, and how many, jobs will be replaced or rendered redundant by the use of artificial intelligence. According to a study by the German Federal Ministry of Labour and Social Affairs, the automation potential of jobs in Germany is 12%. Occupations such as office and secretarial staff, office workers in finance and accounting, machine operators, and unskilled workers are particularly affected [?].

A study by the American investment bank Goldman Sachs from March 2023 shows that AI tools such as ChatGPT could replace up to **300 million** full-time jobs worldwide through artificial intelligence (Briggs/Kodnani 2023), with administrative and legal functions among those most strongly affected.

According to an also recent McKinsey study, companies are using generative AI to significantly increase their productivity and reduce costs. This technology makes it possible to make various business processes more efficient while realizing significant time and cost savings.

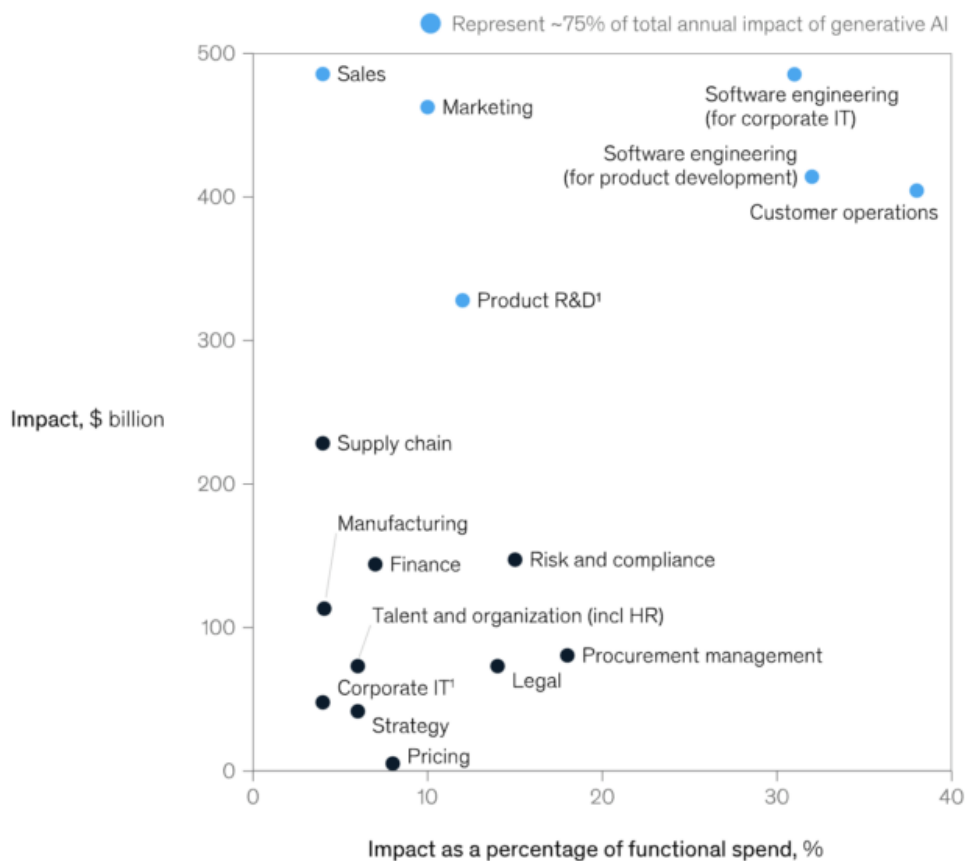


Figure 3.12: Impact of generative AI on the labor market (McKinsey, 2024).

Generative AI can take over tasks that previously required human judgment, thereby increasing productivity by 60-70%. Particularly in software development and customer interactions, AI enables faster workflows and lower operating costs. This leads to a considerable competitive advantage and better resource allocation for companies.

3.9 Ethics and Law in the Use of AI

The increasing complexity and autonomy of AI pose new challenges for ethics and law. AI systems often make decisions that are difficult to trace, which complicates their evaluation and approval. Furthermore, questions arise regarding the decision-making authority of machines and regarding responsibility. A central problem is the attribution of decisions: humans are often held responsible even though they can hardly resist machine-generated suggestions. These developments call for new ethical and legal debates.

AI is changing many areas of life and brings both benefits and risks. Ethics and law must address these questions in order to secure trust and prevent harm. In particular, the autonomy of modern AI, which learns and makes decisions independently, places new demands on transparency, data protection, and liability. AI decisions are often based on correlations, which is legally problematic, since they are not traceable. This autonomy requires its own ethical and legal assessment, one that challenges classical concepts.

The further development of AI carries risks such as malfunctions and incorrect diagnoses. Responsibility in the case of autonomous systems is difficult to clarify, since misbehavior is often unpredictable. Data protection is also a challenge, since AI often accesses and links personal data. Furthermore, AI can foster discrimination when decisions are based on non-transparent criteria. These challenges call for continuous regulation of AI [?].



Figure 3.13: Examples of potential misuse [?]

An example of AI-generated content is the viral images of Donald Trump during a supposed arrest, Pope Francis in a white puffer jacket, or Emmanuel Macron as a garbage collector. These images, created with generative AI models, spread quickly. While the images of the Pope and Macron were received with humor, the Trump image led to controversy, as it was mistaken for genuine news.

These examples illustrate the ethical challenges of AI-generated content, particularly with regard to transparency, fairness, and non-maleficence.

- **Transparency:** It must be clearly recognizable whether content was generated by AI, in order to prevent misinformation. Companies and platforms are called upon to introduce appropriate labeling or watermarks.
- **Fairness:** The spread of deepfakes can lead to distortions in public perception and can be deliberately used for manipulation. This becomes particularly dangerous in political and social contexts.
- **Non-maleficence:** The use of AI for deliberate deception or defamation can cause considerable harm. For this reason, regulatory measures and technical protective mechanisms are necessary to curb misuse.

AI raises societal questions, such as the fear of job loss and diminishing interpersonal interaction. This calls for adjustments to legal and moral norms. Experts emphasize that concepts of guilt and responsibility need to be reconsidered, particularly with regard to assigning responsibility for AI decisions.

Ethical aspects of AI are thus increasingly moving to the center of attention, as algorithms intervene ever more deeply in societal contexts and are no longer confined to specific applications. Artificial intelligence is changing value-creation processes, private interpersonal communication, and human interaction.

Weak and Strong AI

This influence of AI becomes particularly clear when the step is taken from a **weak AI**¹ to a **strong AI**². It is therefore all the more important to find answers, proactively, to questions concerning the transformation of our society brought about by this key technology.

In questions concerning responsibility, social cohesion, or individual personal development, the core discourse on ethics and artificial intelligence continues. AI does not raise fundamentally new ethical questions as such. However, AI does lend new weight to these fundamental debates.

Integrating ethical and legal requirements into AI systems is complex, since they cannot simply be translated into algorithms.

The debate on the ethics of AI is thus far from exhausted; alongside technological progress, it requires a proactive debate, grounded in ethical discourse, on the design and regulation of AI.

1 **Weak AI:** Systems that act intelligently within a specific, narrowly defined context and may even surpass human abilities there.

2 **Strong AI:** Hypothetical AI systems that possess at least human-like intelligence performance in all areas, not only in narrowly defined application fields.

3.10 Model of AI Ethics Principles and Recommendations for Action

A model for the ethical use of AI combines the central principles of existing approaches: beneficence, transparency, non-maleficence, autonomy, justice, and data protection. These serve as the foundation for development and application, with context-dependent weighting.

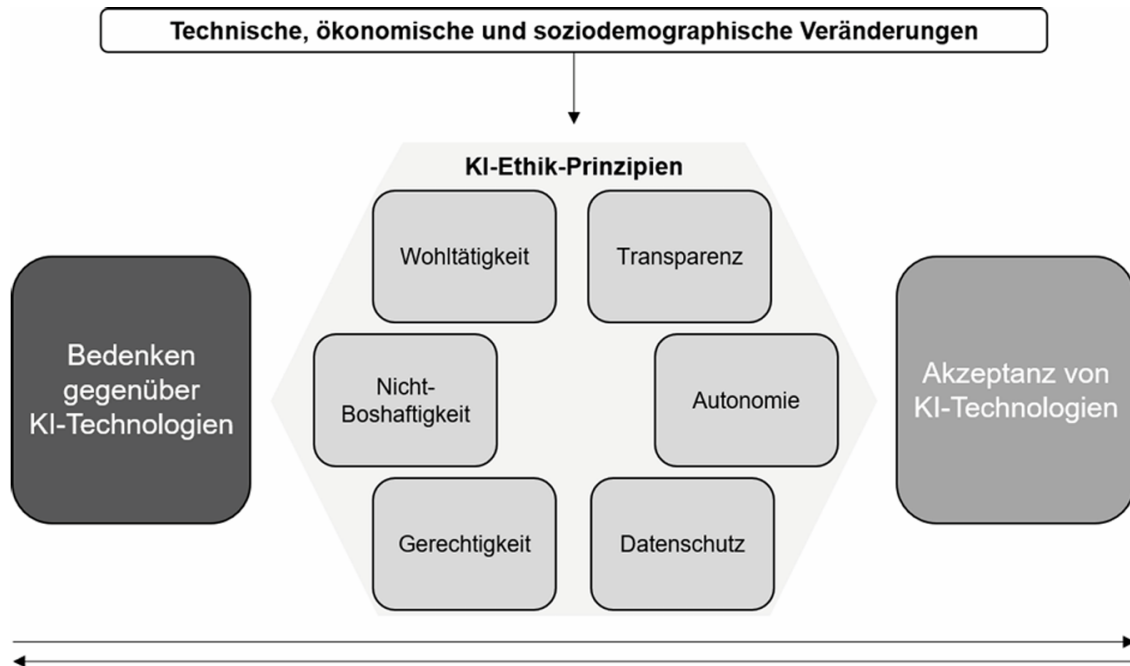


Figure 3.14: Ethical principles in the age of AI [?]

Beneficence means using AI for the good of society, for example to improve quality of life. Transparency ensures traceability, and non-maleficence protects against harm. Autonomy preserves freedom of decision, justice prevents discrimination, and data protection safeguards personal data.

Implementing these principles requires measures such as aligning AI with human values, clear communication, and protective mechanisms. Training strengthens autonomy, fairness requires diverse datasets and participation, while data protection builds trust.

The challenge lies in reconciling ethics and innovation. International standards and national regulations could help secure ethical principles without slowing down progress [?].

CHAPTER 4

Autonomous Driving and Risk Ethics

Learning Objectives

After completing this chapter, you will know ...

- ... which levels of automation exist in automated driving
- ... what motivates the research into autonomous driving
- ... how the human-machine interface (HMI) is changing
- ... how learning systems can be used in autonomous vehicles
- ... what criticism exists regarding the concept
- ... why ethical aspects must be taken into account during development

4.1 Introduction

The invention of the first automobile, the “Benz Motorwagen,” set in motion a development history that continues to this day, beginning in 1886. Over the years, the various automobiles evolved into the passenger cars we know from everyday life. Recent years have been characterized by the digitalization of the automobile, and above all by the development of supporting technologies that assist the driver.

Development has now progressed to the point where self-driving cars, in the form of “autonomous driving,” are set to become part of our everyday lives. This chapter addresses the motivation behind research into autonomous driving, use cases, and the topic of risk ethics of self-driving automobiles.



Figure 4.1: Benz Patent-Motorwagen 1886 - Autonomous Driving in the Future

4.2 Definition

The term autonomy, as it relates to “autonomous driving,” is defined as “self-determination within the framework of a superordinate (moral) law.” In the field of autonomous driving, it is the human being who sets out this moral law by programming the vehicle’s behavior. Through this human programming, the vehicle learns to make certain behavioral decisions in traffic. [?]]

Fundamentally, a distinction is made between six different levels in autonomous or automated driving. The individual levels are shown and explained in Figure 4.2.

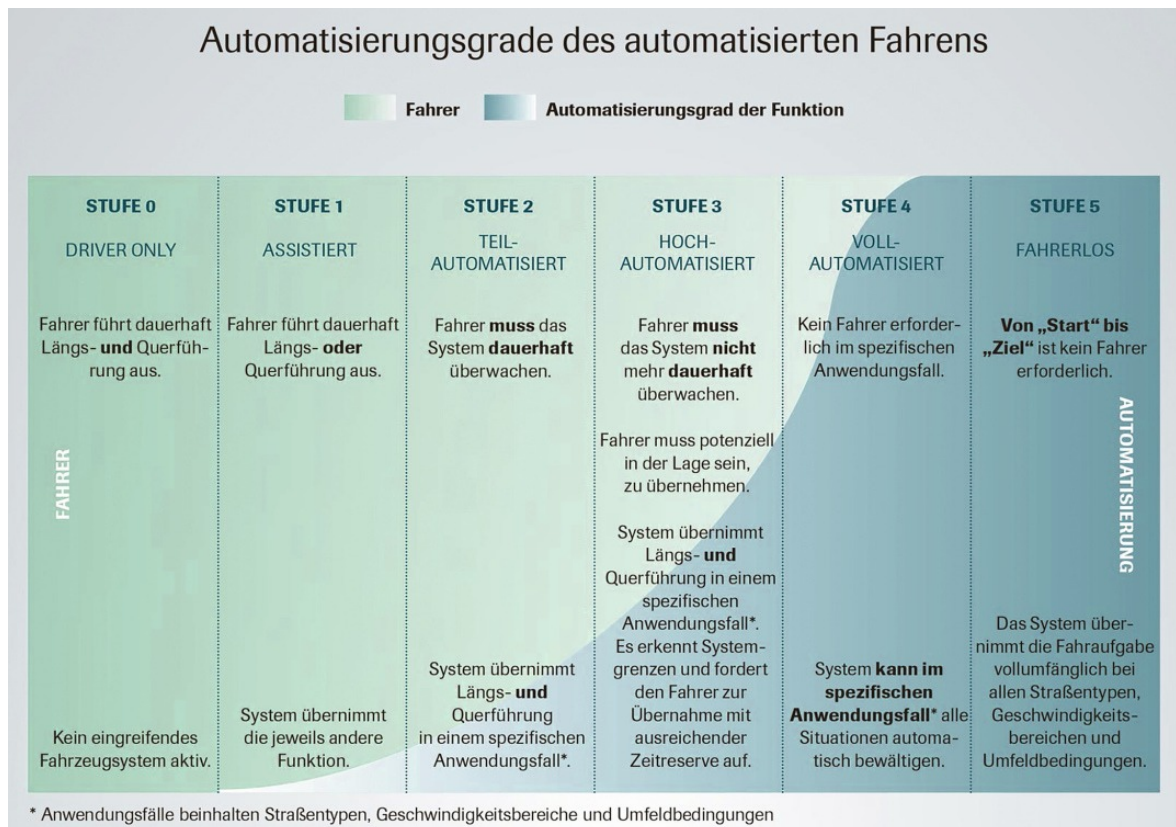


Figure 4.2: Levels of automation in automated driving [?].

4.3 Motivation for Research into Autonomous Driving

According to the German Federal Statistical Office, more than 2.2 million traffic accidents were recorded by police across Germany in 2020.

According to an article published in September 2020 by the campaign “Runter vom Gas” (“Get Off the Gas”), the cause of an accident lay in human error in 94.4 percent of cases [?].

Figure 4.3 shows the average annual number of road fatalities in Germany. A very clear trend can be seen: since the peak in 1970, the number of road fatalities has declined significantly. This decline can be attributed to improvements in the safety of automobiles. A distinction must be made here between requirements imposed by traffic regulations and individual driver assistance systems.

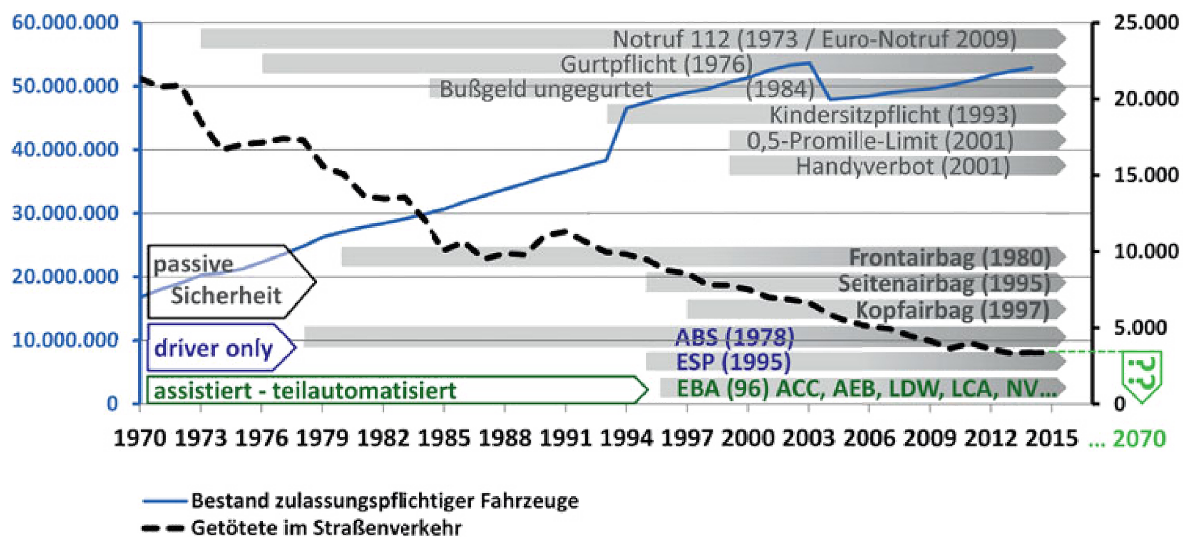


Figure 4.3: Passenger car registrations and road fatalities in Germany since 1970 [?].

Requirements for reducing road fatalities include, for example:

- 100 km/h speed limit on rural roads
- blood alcohol limits
- mandatory seatbelt use

In addition to these requirements, there is an increasing number of **digital driver assistance systems** in automobiles:

- emergency brake assist
- lane keeping assist
- distance assist

The motivation for researching autonomous driving therefore lies almost exclusively in making road traffic safer. The focus here is on the total number of accidents and, in particular, on accidents with fatal outcomes. The trend shown in the graph in Fig. 4.3 is meant to be further influenced by autonomous driving so that it continues to decline.

4.4 Use Cases

There are a great many possible applications of autonomous driving, though this chapter is limited to four different use cases.

Highway autopilot with standby driver – Highway Pilot

This form of autonomous driving is limited to a driving robot that fully takes over the driving task exclusively on highways or similar expressways. In this application, the driver becomes a passenger – still seated behind the wheel, but able to take their hands off the steering wheel, their feet off the pedals, and even engage in another activity.

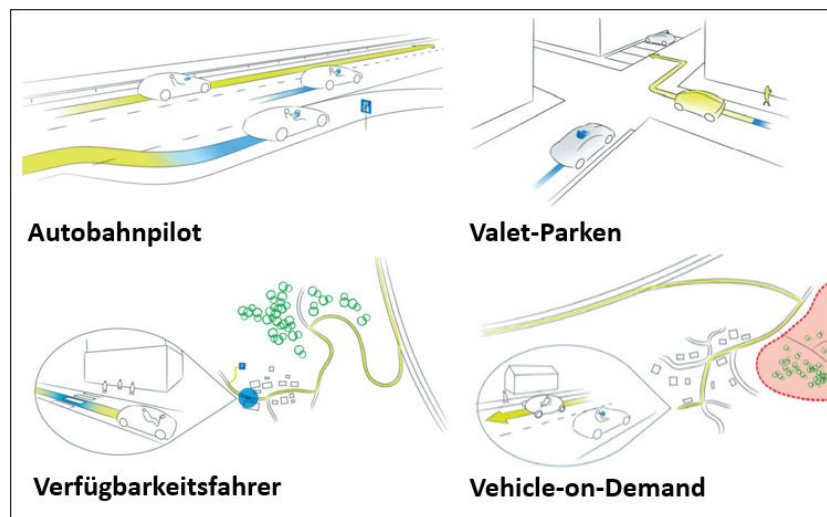


Figure 4.4: Use cases for autonomous driving [?].

Full automation with standby driver

This use case is very similar to the previous one, except that it can also be used outside of highways or similar roads. For the driving robot to be used, the vehicle merely needs to be located within an approved area. Non-approved areas can, for example, include a changed road layout or a construction site. Furthermore, certain areas may fundamentally be unavailable for autonomous driving, such as areas with high pedestrian traffic.

Autonomous Valet Parking

This use case is very easy to understand if one thinks of the situation outside certain hotels. Here, the car is often left with an employee who parks it for the guest. Valet parking follows the same principle, except that no human is needed to steer the vehicle. Once the passengers have exited, the driving robot parks independently and is even capable of re-parking on command, as well as leaving the parking space and picking up the passengers at any chosen location.

Vehicle-on-Demand

With Vehicle-on-Demand, the driving robot moves the vehicle completely autonomously in all scenarios, regardless of whether it is carrying passengers, freight, or cargo. The driving robot is given its destination (by passengers, users, or service providers) and then moves autonomously toward it. Passengers have no opportunity to take over the driving task themselves in any situation. The only options available are to change the destination or to activate the so-called **Safe-Exit**¹ [?].

The use cases just described can accordingly be divided into two different categories. In the first two applications, driving is only carried out autonomously in certain situations; here, the driver still has the option to steer the vehicle themselves, or to intervene in critical situations. The other two use cases, by contrast, are different: although there are sometimes occupants present, they are passengers and only have the option of actively influencing the driving process through instructions such as specifying the destination.

This raises a great many questions from various perspectives:

- Who is at fault in a traffic accident?

¹ The **Safe-Exit** is a special driving maneuver. It brings the vehicle, by the fastest possible route, into a state that allows the passenger to exit the vehicle safely.

- Who is responsible for a vehicle when it is driving without occupants?
- What ethical considerations play a decisive role in the use of AI in automobiles?

4.5 Human-Machine Interface: The Change in Autonomous Driving

Unlike other fields, the human-machine interface (**HMI**) in automobiles has changed very little over time. For more than 100 years, hardly anything has changed here – the motor vehicle is still steered by pedals and a steering wheel. Even the addition of assistance systems, touchscreens, or displays has not changed the actual interface [?].

It therefore seems reasonable to change the interfaces and turn the human into a passive passenger. Contradicting this, however, is a statement by Philipp Slusallek (German Research Center for Artificial Intelligence):

„We humans are not good at supervising a system that feels like it is constantly working correctly. It bores us, and we become inattentive.“ [?].

There is thus a contradiction between proponents of autonomous driving and various research institutions, which, as just described, share the finding that humans are poor at merely supervising an independently operating system.

What the human-machine interface in the field of autonomous driving may look like in the future is shown by the Fraunhofer Institute for Integrated Circuits. Under the name „**Semulin**“, a self-supporting concept for autonomous driving is being developed here, which works with multimodal input and output modalities such as facial expressions, gestures, gaze, and speech.

The developers place great importance on high usability, both because of the increasing complexity and, not least, because of the high relevance of this interface in autonomous driving. The challenge lies in taking into account the limitations of already existing interactions between humans and machines and combining them in a meaningful way.

To realize this human-centered interface, which is also intended to take the overall context into account, already established technologies are being drawn upon. AI-supported methods are used to relate all data to one another, and novel approaches even aim to have the system learn interactively and adapt to the individual needs of the respective user. An overview of this interface is shown in the following figure [?].

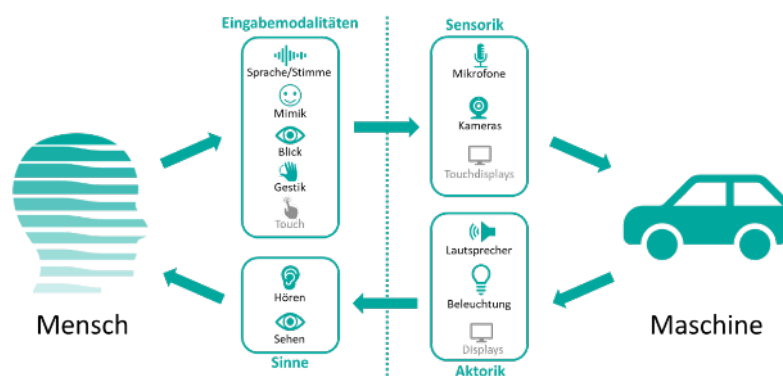


Figure 4.5: Semulin [?].

With this novel interface, artificial intelligence is being used increasingly, which is intended to replace the human within this system. The statement by researcher Philip Bethge therefore points to an ethical discussion.

The question arises as to whether human beings, as thinking creatures, are even capable of functioning meaningfully and safely within such an interface. Beyond the field of autonomous driving, this statement can further be transferred to all areas in which artificial intelligence is applied. The ethical and societal question of whether – and above all how – humans can make meaningful and safe use of artificial intelligence arises again and again.

Learning Systems

A distinctive feature of artificial intelligence, particularly of the Semulin interface described above, is its ability to learn. Considering both sides of the interface, the human being is fundamentally a creature that possesses the capacity to learn and whose performance changes through learning. Machines, on the other hand, fundamentally lack this ability. However, highly automated and connected machines – in this case, vehicles – can possess this capability through the use of the latest technology, thereby gaining the ability to improve functions over time and to learn the behavior and preferences of users.

Through autonomous driving, human abilities such as the capacity to learn and to adapt fall away – but would be compensated for through the use of learning systems. Furthermore, advantages would arise from individualizing vehicle control and optimizing fully automated driving.

The greatest advantage lies in the **collective application** of learning systems, since the exchange, or copying, of what has been learned between systems takes place much faster than in the human process. Due to the heightened safety concerns surrounding autonomous vehicles, the use of learning systems is a **particularly great challenge**.

The focus here is on both road safety and data security. Because there is currently no adequate measure of risk with regard to road safety, the preliminary application must be **fault-tolerant**. Learning systems in autonomous vehicles must therefore initially be supplemented by redundant conventional systems that check the safety of the learning system and, if necessary, intervene [?].

4.6 Risk Ethics of Autonomous Driving

Criticism of the Concept

„In our modern society, undergoing constant change due to advancing digitalization, the impending changes in the field of mobility expected as a result of the introduction of autonomous vehicles into road traffic have increasingly come to the forefront in recent years“ [?].

The criticism is based primarily on accidents that have occurred in connection with self-driving vehicles, some of which have had fatal consequences. As a result of the ensuing media discussions, autonomous driving has increasingly come under criticism.

Headlines are repeatedly seen reporting that people have died in an accident, allegedly caused by a driverless car¹. This criticism stands in contrast to the fundamental idea behind autonomous driving, namely making the roads safer.

1 <https://www.handelsblatt.com/unternehmen/industrie/tesla-zwei-tote-bei-unfall-mit-wohl-fahrerlosem-elektroauto/27108214.html>

Paradoxically, the safety of autonomous vehicles is being criticized here, even though safety is precisely their intended goal. Looking at Figure 4.6, it becomes clear that currently 93.5% of all traffic accidents are based on **human error**, which could in principle be eliminated through the use of autonomous vehicles.

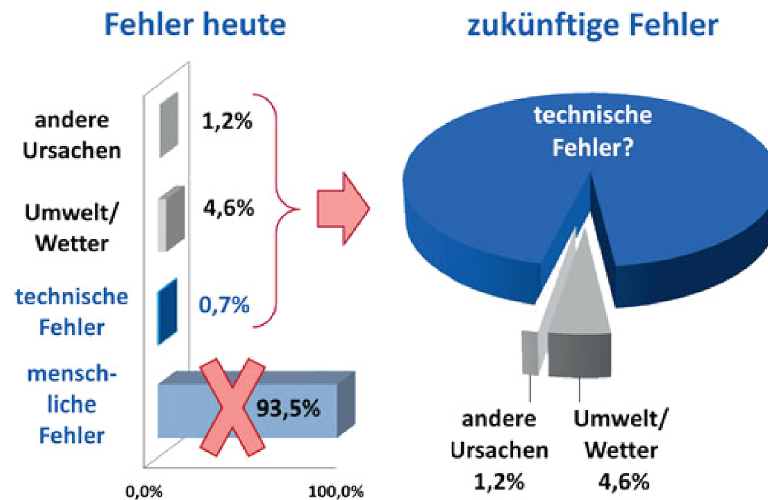


Figure 4.6: With full automation there would be no more human error. However, the share of technical errors could in the future be perceived as significantly larger [?].

The criticism and concerns therefore also relate to the question of what kinds of errors will replace human errors. This question gives rise to an ethical, but also a legal, dilemma, which is described and explained in more detail below.

Ethical Aspects

There is no question that a person participating in road traffic takes on a certain amount of risk and, in doing so, also poses a risk to others. These risks are socially accepted – in other words, **risk in road traffic is socially accepted**. However, an ethical conflict arises in the context of autonomous driving. Through the use of autonomous vehicles, the nature of decision-making will change, and a distinction is then made between two different types of decision-making:

Intuitive-situational: this form of decision-making describes the decision, or rather the reaction, of a human being in a dangerous situation.

Example: a pedestrian steps onto the road, and the driver performs an emergency stop.

Deliberate, conscious: this form of decision-making describes the planned, programmed decision in a dangerous situation.

Example: a pedestrian steps onto the road, and the autonomous vehicle takes into account all parties involved in the dangerous situation and follows the decision predetermined by its programming [?].

The ethical aspect relates to the second form of decision-making, which is the one that applies in autonomous vehicles. As already described, the fully automated autonomous vehicle is controlled by artificial intelligence, which means that every action or decision made by an autonomous vehicle is based either on its programming or on the system's learning capability. The ethical discussion is usually based on the following, or a similar, scenario:

The autonomous vehicle finds itself in a dangerous situation in which it must either endanger a 10-year-old child or, by taking evasive action, endanger an 80-year-old person.

Faced with a serious accident, the autonomous vehicle in this example would have to decide between two lives – a decision that is extremely difficult to justify on moral grounds. One aspect commonly used to justify such a decision in this ethical discussion is the age of those involved.

In this example, the justification could be that the child still has an entire life ahead of them, whereas the older person has already lived a fulfilled life. Another aspect in justifying a decision could be the life experience of those involved. It could be argued that the older person, contrary to their own experience, put themselves in the dangerous situation, whereas the child, due to their lack of experience, ended up in this situation by chance or through no fault of their own [?].

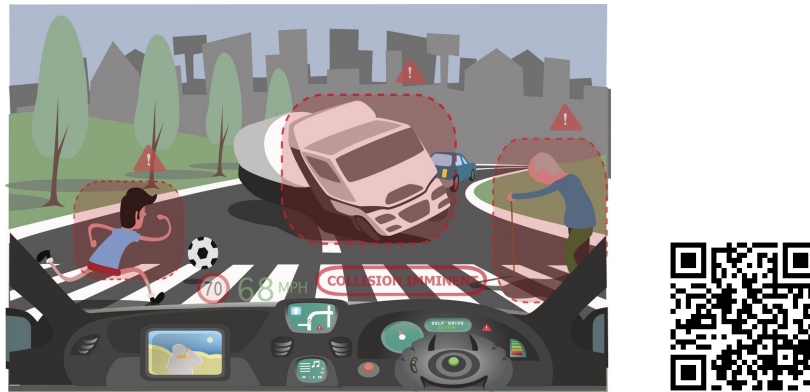


Figure 4.7: Moral Machine¹.

The aspects just described may well be justifiable for some people; however, when considering the **code of ethics**² of the IEEE (Institute of Electrical and Electronics Engineers), neither of the two options would be ethically correct. Deciding on the basis of a person's age would, according to the code, constitute **discrimination**. Even under German law, such a decision would not be lawful, since the first two articles of the German Constitution (Grundgesetz) already establish a fundamental right to life and human dignity. This also fundamentally raises the question of how influential German automobile manufacturers could even be granted the opportunity to bring fully automated cars to market at all. One way of avoiding such a decision would be to leave it to chance whenever such moral options are on the table [?].

Opinions on this aspect also diverge widely, and it becomes clear once again:

Ethics plays a decisive role in the development of autonomous vehicles.

This or similar ethical dilemma situations raise the question of whether autonomous vehicles, rather than having to make a decision themselves, should hand control back to the driver. This consideration only serves as a solution to the problem if control can be handed back quickly enough, or at all. In autonomous driving modes such as Vehicle-on-Demand, this solution would not be possible if the car is driving without occupants.

Even if the presence of a driver makes it possible, in principle, to hand over control in a dangerous situation, this represents an unacceptable risk. Contrary to one of the advantages of autonomous driving – namely that the occupant can attend to other activities – the occupant would now have to make a decision without possibly having any knowledge of how the situation arose. Simulations and experiments have been used to test and measure how

¹ <https://www.moralmachine.net/>

² **IEEE Code of Ethics:** To treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression.

long it would take to safely hand control back to a human. Depending on the so-called **distracting activity**¹, this transition time can take **up to 40 seconds**. However, the time available to react to a dangerous situation, as just described, requires a reaction **within 1 to 2 seconds**.

This comparison therefore shows that it is unavoidable to leave the decision in moral dilemma situations to the autonomous vehicle.

So far, the ethical aspect considered has been one in which a decision is made between a collision involving two people. However, the collision of two vehicles (**V2V**)² must likewise be considered with regard to a programmed decision by the autonomous vehicle. In deciding on accidents, it matters whether priority is given to the well-being of the occupants or of the other parties involved. This is referred to as so-called **crash optimization**.

If, for example, the well-being of one's own occupants were given top priority, the decision would have to favor a collision with the lightest object. If, however, priority is given to the well-being of other road users, the collision should be chosen with the safest other road user. Given the construction of both vehicles, an SUV would sustain less damage in a collision than a small car or a motorcycle.

Important for such decisions is the communication of the autonomous vehicle with other vehicles (**V2V**), with the infrastructure (**V2I**), or, taken together, communication with all parties involved (**V2X**).

For safe implementation, the autonomous vehicle must be able to recognize and classify all objects. For example, it must be able to distinguish a boulder from a plastic bag, since an evasive maneuver is only necessary in one of the two cases.

Furthermore, for the V2V interface, the autonomous vehicle would need to be able to classify the other vehicle in terms of its construction, or even, through advanced artificial intelligence, be able to obtain the make, model, and technical characteristics of the other vehicle.

Legal Aspects

In principle, the person driving is always responsible for their vehicle in road traffic. This has already been regulated since 1986 in an international treaty, the **Vienna Convention on Road Traffic**. A first decisive amendment followed in 2014, permitting systems to support the driver and thus covering driver assistance systems as well as automated driving functions. This amendment came into force in Germany in March 2016 [?].

For the use of assisted driving, the driver in Germany is required to be able to retain control of the vehicle at all times. Accordingly, the driver is responsible for all traffic violations and accidents. A law on autonomous driving was successfully passed in May 2021, according to which autonomous vehicles in Germany can participate in public traffic without a physically present driver. For the time being, this law is currently limited to defined and pre-approved operating areas.

The law furthermore stipulates that continuous monitoring by a natural person must be guaranteed. For this reason, in addition to the vehicle owner's liability insurance, liability insurance for the technical supervisor is also required.

Criminal liability for traffic violations and accidents involving the autonomous vehicle must be determined on a **case-by-case** basis. In addition to individual fault on the part of the

1 **distracting activity**: describes an activity that distracts occupants while the vehicle is being driven autonomously. Examples include reading or sleeping.

2 **V2V**: Vehicle to Vehicle, collision between two vehicles

supervisor, organizational failure on the part of the manufacturer or operator may also be considered.

At present, this law is not yet comprehensive enough, and more precise regulations are still needed before autonomous vehicles can be deployed in regular operation [?].

4.7 Summary

Autonomous driving is an important step that will contribute to road safety and, moreover, reflects the current state – and particularly the further development – of technical capabilities. Although there is still a long way to go before autonomous vehicles are deployed in regular operation, we are already on that path. Assistance systems, as well as functions such as automated parking, have become second nature to us, and we know how to handle them. For this reason, the transition to autonomous vehicles should not pose a problem for people. Only societal acceptance, and the ethical and moral discussions arising from it, still stand critically in the way.

A solution must therefore still be found regarding some ethical and moral viewpoints in order to secure societal, and in particular moral, acceptance. Regardless of this, the final decision will be made in legislation, since alongside responsibility and liability, risk ethics also plays a role here. Only once the law can provide a comprehensive and clear solution will the way be clear for autonomous vehicles. Independent of the law, the moral question will continue to remain, as a machine – rather than a human – makes a decision and possibly learns from it.

CHAPTER 5

Extended Reality (XR)

Learning objectives

After working through this chapter, you will know...

- ... what is meant by the term Extended Reality (XR).
- ... how AR, VR and MR are distinguished from one another.
- ... in which fields of application XR is used in industry.
- ... what advantages result from the use of XR in industry.
- ... what risks must be taken into account when applying XR.

5.1 Definition and Distinction

Extended Reality (XR)

Reality [?] means "that which actually is" or "the totality of what is real" and derives from the Latin adjective "realitas" and the noun "res" meaning "thing, matter." Reality encompasses everything that a human being can see with their own eyes and interact with, without being additionally influenced by any technology.

Through various technologies that are grouped together under the term "Extended Reality (XR)", reality can be influenced to varying degrees. These range from an extension of reality all the way to its complete replacement.

The term **Extended Reality (XR)** comprises **three gradations of influence on reality** that can be created between reality and virtual reality through technological progress.

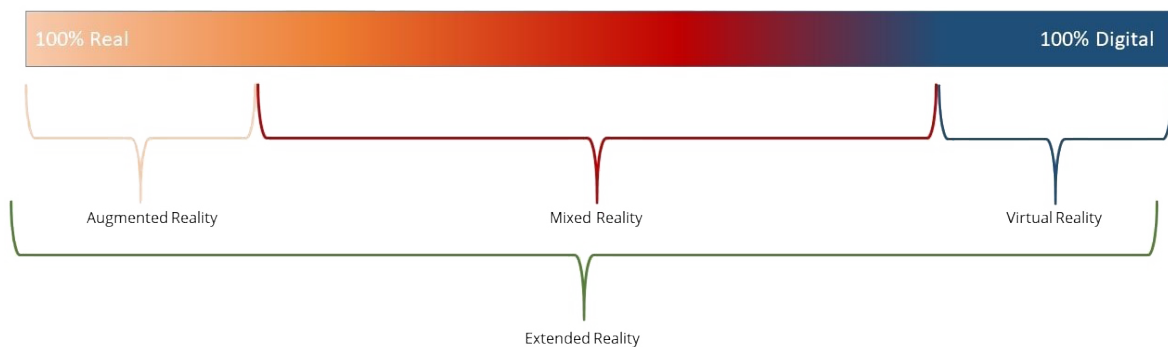


Figure 5.1: Extended Reality (XR) Spectrum

Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) are all part of XR and differ in the ratio of reality to virtuality [?].

Augmented Reality (AR)

With Augmented Reality (AR)¹, the user continues to see the real environment. However, this is extended with additional information in the form of text, graphics, images or videos, so that a combination of virtual and real components is created. The additional elements are projected into the real environment, overlaid onto it, or anchored statically within the image.

Virtual Reality (VR)

Whereas AR extends reality, Virtual Reality (VR)² replaces reality entirely. For this purpose, a computer-generated 360° environment is created with which the user can interact.

Mixed Reality (MR)

Mixed Reality (MR)³ combines aspects of both AR and VR technology. This combination enables simultaneous interaction with both the real and the virtual world.

Representation

The differences in visual representation become clear when the same object is viewed using the various technologies. In VR (*see Fig. 1.2, left*) the real environment is replaced by a virtual image in which the object appears. When using AR technology (*see Fig. 1.2, center*) the object is displayed within the real environment. MR technology (*see Fig. 1.2, right*) enables a further step, in which the object can be placed within the environment and thus fitted into reality. As a result, the user can interact with the object.



Figure 5.2: Representation in VR, AR and MR

1 Augmented Reality = extended reality

2 Virtual Reality = virtual reality

3 Mixed Reality = mixed reality

Mode of Operation

To access the technology, the user requires various media in the form of hardware (HW) and software (SW).

With **VR technology**, virtual realities are created with the help of software, databases and a powerful VR engine, and are displayed to the user on a headset.

The user is meant to be immersed in a virtual world that is as realistic as possible. Via a connected input device (e.g. a motion-controlled controller), the user can influence the virtual world that is displayed to them through a special VR headset. This shields the user from the real world and is able to translate the head and even body movements of the wearer onto the virtual camera and thus onto the virtual display.

A **VR engine** calculates the necessary computer graphics and the necessary adjustments within the virtual environment in real time. Photorealistic effects enable complete immersion in virtual reality, whereby the user perceives the simulated reality as "real". This effect is referred to as **immersion** [?].

In contrast, **AR technology** aims to extend existing reality. For this purpose, the integrated cameras of an AR-capable display device are used to capture images from the user's perspective, on the basis of which tracking algorithms permanently determine the user's position [?].

With the help of this positional information, the virtual content, which is calculated similarly to VR via a real-time-capable engine, can be inserted into the displayed environment. The resulting augmented reality can be output, for example, via a smartphone, a tablet or AR smart glasses.

MR technology combines both technologies with one another. Here, the user looks directly through special **MR glasses**, which use various sensors and cameras to capture the space three-dimensionally, calculate the position and orientation of objects in the space, and place the objects at the corresponding locations in the space.

Thanks to the special features of the MR glasses, the user is able to influence the displayed information (e.g. overlays) through natural impulses such as eye movements, gestures or speech. In addition, external influences, such as objects, are captured directly and are immediately available for further processing.

The goal of MR is to blend the user's natural perception with virtual aspects, thereby extending perceived reality and enabling simultaneous interaction with both the virtual and the real environment.



Figure 5.3: Representation in VR, AR and MR

5.2 Establishment of XR as an Industrial Application

The origin of XR technology lies in the field of multimedia and gaming. Through continuous technological progress, VR technology, compared to its beginnings in the 1990s, has become steadily more affordable and thus a marketable product for the consumer market. The establishment of the smartphone on the market, as well as the use of tablets, played a significant role here.

The first VR headset was already available for purchase on the consumer market in 2014. [?]

AR technology achieved worldwide recognition in 2016 on the consumer market through the game "Pokemon Go". By 2018, it had been downloaded one billion times. [?]



Figure 5.4: AR on trend - Pokemon Go

Over the years, AR technology has become increasingly integrated into the usage behavior of private individuals. Through it, users experience relief in everyday tasks and new possibilities for interaction. A popular special feature in cars is the head-up display, which projects important data, such as speed or navigation instructions, onto the windshield. This technology, which originally comes from aviation, allows the driver to take in important driving data without having to take their eyes off the road.



Figure 5.5: Use of AR in cars: head-up display

The possibilities offered by XR are now being used not only in the commercial sector but also in industry. They are considered future technologies with broad potential for application. In 2018, revenue from XR technology in the business-to-business (B2B) sector amounted to 521 million euros, with a projected revenue increase of more than 50 percent within two years.

5.3 Industrial Fields of Application for VR

The advantage of VR technology is the creation of a parallel reality. Precisely in an industrial environment, this makes it possible to represent objects that do not (yet) exist. For the first time, this enables simple analysis and testing of earlier designs, since the required data can be quickly bundled and represented.

Factory Planning and Production Development

Important success factors for efficient production planning are a well-thought-out layout and well-coordinated processes. The approach taken during the planning phase of a new factory or machine determines how efficiently a plant can later be used for its intended purpose during operation.

The use of VR can significantly improve this planning phase, since factories and plants can not only be drawn on paper or on a computer, but can also be virtually walked through. This allows the factory to be viewed from all angles in advance, and walkways as well as machine placements can be optimized and hazardous areas identified.

In addition, it is possible to simulate and evaluate various scenarios for the installation of storage areas, in order to optimize the planning process. Through the use of 3D objects and virtualized data, the complex processes of mechanical engineering, electronics and software development can be mapped within the planning phase, allowing them to be designed in a time-optimized and efficient manner.

The fast and comparatively simple ability to experiment enables extensive data collection. This data can be evaluated and used, for example, in a continuous improvement process. The use of VR technology enables early identification of potential improvements; in addition, layout errors can be detected early and corrected before implementation. This leads to a considerably more efficient use of funds, time and labor costs. In addition, error costs during planning decrease, potential rework costs are avoided, and production reaches full operational capacity more quickly after commissioning.



Figure 5.6: Factory planning with VR

Product Development

Through the use of VR in **prototyping** of products, the people involved are able to virtually view the current state of development of a product, including its existing features. A realistic representation of the product requires a high volume of data. The use of Computer-Aided Design (CAD) models can help with this.

The CAD models are converted into a VR prototype using special software and integrated into a VR application. Complex technical drawings that were previously not tangible can now be grasped by the user with just a few glances.

This approach can support the product concept as early as the "pre-design"¹ stage and avoid

¹ Pre-design = an early design phase

possible malfunctions or design flaws. The engineers, designers and developers involved can interact with the prototype and check possible use cases in advance.

Within the framework of User Centered Design (UCD), the customer can not only be involved in the development process but can become part of it. In addition to the ability to test various ideas or gain a holistic impression of the prototype, ergonomic product adjustments or overall concepts can be reviewed, tested and adapted precisely according to the customer's wishes.

Compliance with the requirements documented in the specification sheet [?] ¹ can be verified, and functionality can be validated by means of tests and simulated practical applications. Through the use of VR prototyping, physical prototyping can be partially or entirely replaced. This leads to enormous savings, since a physical prototype no longer needs to be produced in a laborious and time-consuming manner. The customer benefits from early and intensive participation in their product.



Figure 5.7: VR Prototyping

Trade Fairs and Customer Presentations

The size of a medium-sized trade fair booth is approximately 25 m². The exhibitor usually pays for this per square meter.

In reality, the exhibitor is bound by the physical size of their booth, and consequently the number of exhibits is limited. In advance, careful consideration must therefore be given to which products from the portfolio should be taken to a trade fair, and how many.

The possibilities offered by VR at least partially remove this restriction. Through virtual trade fair booths that can be designed in any way desired, a company can present every product to the visitor and even simulate its function. Thanks to the nearly limitless possibilities within the virtual space, the setting and other sales-promoting effects can also be freely chosen. Visitors can change the perspective and viewing angle as they wish and, within virtual reality, are not bound by normal physics. This allows a product to be examined from every angle, from the inside, and even zoomed in on.

¹ According to the Wirtschaftslexikon, the specification sheet ("Pflichtenheft") is a written document that contains all the technical, economic and legal details of a tender.

While a classic trade fair booth represents a considerable logistical challenge, comparatively little technology is needed for a virtual trade fair booth. This is easy to transport and can therefore be used not only at trade fairs. VR can thus also be used, for example, for sales events or product demonstrations. Especially for larger products, such as production plants, cars or aircraft, this results in considerable time and cost savings. In addition, an interactive product presentation offers the potential customer a more lifelike experience than classic slides or brochures [?].



Figure 5.8: Product presentation with VR

Training

By integrating VR into training concepts, entirely new, varied and interactive training programs can be designed. Because it is decoupled from reality, resources are not tied up for training purposes, and the trainee can act independently of time and place. The trainee is placed in a realistic situation without the company having to create the actual physical conditions. Critical situations with a high risk potential can be trained without exposing anyone to danger. In addition to particularly critical situations, very rarely occurring situations can also be trained with a high degree of realism and low effort, without the need for extensive preparation or any loss of training depth.

The reduction of risk in hazard exercises enables the trainee to complete training more independently. Training for certain content no longer requires a supervisor, since training content runs in an automated manner and the risk potential is reduced. The training simulations can be repeated as often as desired, which allows for adaptation to the individual's learning pace. In addition, the trainee need not worry about mistakes and their consequences, since the simulation has no effect on reality and ongoing company operations therefore remain unaffected.

Ultimately, capacities in other areas are not lost and can be used more efficiently through the use of AR, which reduces personnel costs within the training area.



Figure 5.9: Training with VR

Example from Industry

Bell Helicopter was the first to design the FCX-001 (see Fig.: 1.12), the company's first helicopter, using VR technology. Normally, it takes five to seven years to design a helicopter. Through the use of VR technology, Bell Helicopter succeeded in conceiving the FCX-001 in less than six months. From the very start of the conceptualization process, the engineers were able to work with the complete virtual model and draw on the experience and assessment of test pilots.

Feedback from the test pilots regarding the virtual model could already be obtained, captured and implemented in the early stages of development. The use of VR technology resulted in enormous time and cost savings for Bell Helicopter.



Figure 5.10: Conceptualization with VR

5.4 Industrial Fields of Application for AR

Production and Assembly

Within production and assembly, AR is used to display a virtual dashboard in the employee's field of view, on which, for example, the next work steps can be listed. Employee input is provided via gesture control. This form of operation allows employees to use their hands exclusively for the tasks within the assembly and production process. The execution of each individual step is recorded in real time and documented as completed once carried out.

The reduction of information to the aspects relevant at each given moment prevents distractions, promotes concentration, and prevents work steps from being overlooked. The need to confirm warning notices, such as "protective clothing required" or "hazardous area", brings possible hazardous situations to the employee's attention and sharpens their awareness of them. The advantage lies in the fact that the assembly worker has the work steps in detailed view, which they would normally not look up in conventional documentation. A consistent way of working and approach is established within the company, leading to consistently high quality. If a new process or a modification to the approach is introduced, it only needs to be implemented once and is thereafter integrated into the "instructions" for all employees.

Onboarding New Employees

Through the use of AR, the onboarding time for new employees into processes can be significantly shortened, since detailed instructions for the various procedures can be accessed via AR. The best practices were previously stored in the form of step-by-step instructions, based on the documentation. Employees with specialized knowledge regarding a particular product or project, who change department or company, can record their approach in the form of instructions. By building up such a knowledge database, this knowledge can be made available to all employees at any time.



Figure 5.11: Production with AR



Figure 5.12: Onboarding with AR

Production Controlling

Using AR, production employees have the ability to display status, diagnostic or parameter data of the machines virtually and in real time. Inconsistencies, deviating production figures and problems are brought into focus and identified more quickly. Malfunctions become visible from a greater distance when inspecting the plant, for example from an elevated vantage point.

In addition, the displayed information can include service notices, such as upcoming maintenance and the contact details of the service partner, to enable quick and smooth interaction and to reduce downtime [?].

Example from Industry

Technicians at aircraft manufacturer Boeing use AR systems to display the wiring diagrams of the aircraft cabling in their field of view. This approach allows them to keep their hands free for the cabling work and to focus on their task. Through this measure, working time could be reduced by 25 percent and productivity increased by 40 percent.

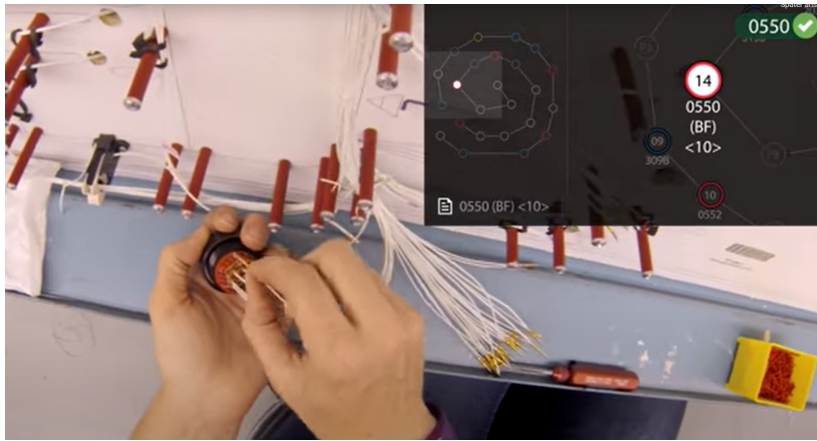


Figure 5.13: Aircraft cabling with AR

5.5 Industrial Fields of Application for MR

Installation, Commissioning, Maintenance and Repair

MR enables a company to pool the knowledge of its employees and deploy it efficiently. During installation, commissioning and maintenance, the company's employee is able, in the event of problems or questions, to bring in an expert or engineer from within the company via MR. This person can view the situation through the employee's eyes, analyze it, and mark the necessary steps in the employee's field of view using symbols such as arrows. The expert can guide the employee step by step through the situation, until the employee resumes their task.

By handling such situations with MR, either a cumbersome explanation of the situation over the phone is avoided, or an inadequate assessment of the problem, e.g. from just one camera perspective, is prevented. The goal should be the highest possible level of information, in order to initiate an efficient approach, minimize downtime, and avoid personal injury and property damage.

In addition, it is not necessary for the expert to travel along for more complicated incidents, thereby being unavailable for other projects and incurring additional travel costs. Experts are only involved when needed, and personnel can be deployed more efficiently.



Figure 5.14: Maintenance with MR

Logistics

If appropriate SW, HW and a tracking system are available in the warehouse, MR can assign

each product to its respective storage location. The picker is navigated along the most efficient route through the warehouse to the corresponding storage location of the product. The location, the time delta and the viewing angle are captured, and situation-relevant information is integrated into the picker's field of view in the form of virtual objects.

Navigation arrows guide the picker along the optimal route to the storage bin and continuously adjust to the viewer's viewing angle in order to keep pointing them toward the corresponding storage bin. The storage bin is highlighted, for example, by a red marker. The use of MR in logistics replaces pick-by-light technology, which requires an elaborate implementation of the technology in the warehouse.

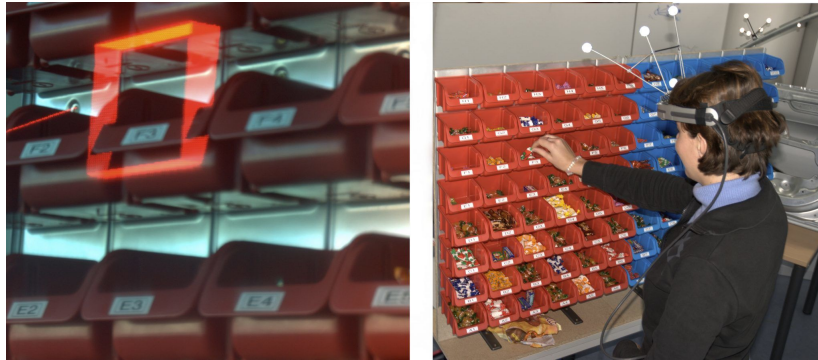


Figure 5.15: Warehouse logistics with MR

In packaging logistics, MR can also provide benefits, since bulky parts for which no standard packaging exists can be measured by the integrated cameras. The search for a suitable container is initiated automatically, and the available packaging is matched against the object's dimensions. If no packaging is compatible, an order for new production can be triggered. The process is accelerated, since the cumbersome manual measuring and documentation becomes obsolete.

Training

MR technology is well suited for training sessions in which the trainer and the trainee are located in different places. Controlled training is possible, since the trainer sees on their tablet exactly what the trainee is seeing through their eyes at that moment. The trainer can give the trainee instructions by drawing virtual objects into their field of view, thereby training them for a wide variety of tasks.

This concept significantly reduces travel costs and enables extensive and flexible training concepts, despite any travel restrictions.

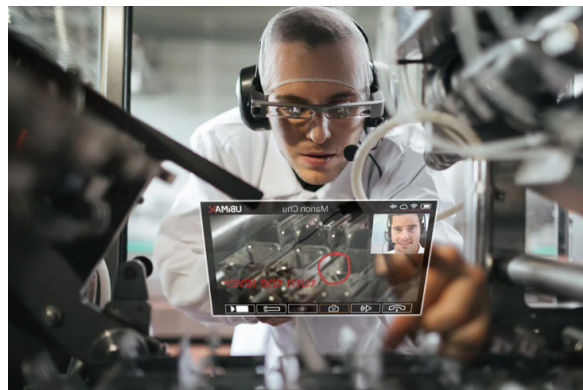


Figure 5.16: Training with MR

Example from Industry

Thyssenkrupp equips its elevator service technicians with MR glasses in order to reduce elevator maintenance time. With the help of MR, service technicians can visualize the specific characteristics of an elevator to be serviced in advance. On site, the service technicians have access to the elevator's real-time technical data and can, if problems arise, request support from the company's experts at any time via video call.

According to the company, the use of MR led to a significant reduction in maintenance time. After successful testing, a large number of buildings, such as the One World Trade Center in New York, were equipped with the technology.



Figure 5.17: Elevator maintenance with MR

5.6 Opportunities and Risks of XR

The use of XR offers new opportunities on the one hand:

- **Communication:** Actions that are difficult to explain can be visually depicted step by step (AR). Understanding of plants and machines can be taught more quickly and in greater detail.
- **Efficiency:** More sense organs are addressed simultaneously, and data is already visually represented in relation to one another (XR). Mechanical and electronic processes can be grasped more quickly (AR).
- **Cost Savings:** Products and systems do not need to physically exist or be present on site in order to be viewed.
- **Quality:** A detailed representation of data, design and interaction is possible during the planning phase. Errors can be detected early and reduced in frequency (VR). The detailed presentation of instructions in the field of view allows the assembly worker to act with their hands free and to strictly follow the instructions (AR).
- **Safety:** Overlaid warning notices in the field of view signal directly before a hazardous situation that caution is required (AR).
- **Employee Recruitment:** New and exciting technologies increase the employer's attractiveness as well as employee satisfaction and retention [?].
- **Reduction of Travel:** Many actions can be explained, demonstrated or simulated remotely using XR. The low need for travel significantly reduces the resulting travel costs on the one hand, and enables more flexible deployment of employees on the other.

However, these advantages of XR are also opposed by a number of risks:

- **Acceptance:** Employees may have problems with the new technology, may not want change, and may reject the new possibilities. This particularly affects older individuals or those with limited technical background. If acceptance of XR technology is not present among all employees, the opportunities and advantages cannot be fully exploited. Measure: Show employees the advantages that result for them from using the technology, and involve them early on, for example by jointly defining newly emerging processes. Training all employees in the use of the new technology and the new processes is essential.
- **Data Protection:** Employees might develop the feeling of being monitored. Measure: Explain to employees in detail what data is recorded through the use of the technology, take their concerns on board, and find solutions together.
- **Technical Infrastructure:** Implementing the new technology requires that appropriate WiFi coverage and server infrastructure be in place, as well as high computing power. Measure: Involve the IT department in the planning process early on, so that in the event of insufficient infrastructure, measures can be taken in good time.
- **Legal Aspects:** When using XR for service offerings, legal gray areas can arise, since such occurrences are not defined in the contract. Measure: Before introducing XR technology in the service sector, contracts must be reviewed and revised in order to define the approach to be taken in connection with incidents related to XR technology.

5.7 Summary

Extended Reality (XR) encompasses and describes all gradations between reality and virtuality. Within XR, the technologies of Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR) can be distinguished from one another. In VR, objects are represented within a virtual environment. This technology can be used in industry to represent, convey or analyze information, products or processes that do not (yet) exist or are currently **not present**.

With AR technology, virtual information is projected onto the real world. It is applied in industry when **existing** data needs to be conveyed and analyzed compactly and in a situation-dependent manner. Mixed Reality combines aspects of both VR and AR and enables interaction with the real and virtual world at the same time.

The use of MR is well suited for optimized communication between two parties and for guidance, since it allows one to look through the user's eyes and place virtual elements in their field of view. All three technologies have different fields of application within industry.

The opportunities of XR lie in the area of fast and targeted data capture, analysis and communication, as well as cost and effort reduction. With regard to industrial use, these technologies are often referred to as "the future" and, through new forms of interaction, open up novel possibilities throughout the entire product development process.

Risks can be expected in the areas of acceptance within the company, technical infrastructure, and undefined procedures for handling discrepancies between the company and the customer. These, however, can be counteracted through forward-looking and prudent handling.

CHAPTER 6

Blockchain Technology

Learning Objectives

After working through this chapter, you will be able to: ...

- ... define blockchain and explain its role for digital trust
- ... explain hash functions, digital signatures, and Merkle trees
- ... compare the consensus mechanisms Proof of Work and Proof of Stake
- ... describe use cases of blockchain in Industry 4.0
- ... name key opportunities and risks of blockchain

6.1 Introduction

Digital systems in which many participants interact with one another require a high degree of trust. Blockchain technology provides a technological foundation for this, since it stores data securely and transparently while dispensing with a central authority. A blockchain consists of a chain of data blocks. Each block contains information that can be verified and traced [?]. The basic principle was already developed by researchers in 1991. Their goal was to timestamp digital documents so that later modifications would remain detectable. In 2009, Satoshi Nakamoto took up this idea and put it into practice for the first time with the digital currency Bitcoin. Technically speaking, the blockchain is a continuously growing list of entries [?]. These are organized into blocks, cryptographically linked to one another, and stored decentrally across the network. Before a new block is added, the network must confirm its validity. Once stored, the content can no longer be altered without detection.



Figure 6.1: Visualization of a simplified blockchain

Figure 6.1 shows in simplified form how the blockchain works. Each block contains a timestamp, the hash of the previous block, and transaction data. If a block is tampered with, the hash no longer matches and the manipulation becomes visible. Today, the use of blockchain technology extends far beyond digital currencies. It is applied in industrial data structures where secure data processing, automated processes, and collaboration between companies [?]. are required. In the industrial environment, blockchain opens up new possibilities. Machines can execute contracts automatically. Components can be tracked across their entire lifecycle. Companies can securely exchange sensitive information, even across borders and without prior trust.

6.2 Fundamentals

Blockchain technology is based on fundamental technical concepts that provide security, trust, and traceability in digital networks [?]. These include, among others, distributed data structures, cryptographic methods, and digital signatures. Taken together, they enable a system in which information can be stored and processed in a decentralized manner.

6.2.1 Distributed Ledger Technology (DLT)

A distributed ledger is a shared database that does not reside on a single computer but is distributed across many computers in a network. These computers are referred to as nodes. Each node stores a complete and identical copy of the ledger. When new data is added, all nodes must agree to the change. This process is called consensus.

Unlike centralized databases, which are controlled by a single entity, a distributed ledger operates without central control. This increases transparency and protects the system against manipulation. Even if the participants do not know or trust one another, the network still functions securely and reliably [?].

The blockchain is a specific form of distributed ledger. Here, data is stored in blocks that are cryptographically linked to one another. There are also other forms of distributed systems, such as so-called **Directed Acyclic Graphs**¹ (DAG). These offer a more flexible structure and are particularly suited to applications with many small transactions, such as communication between machines [?].

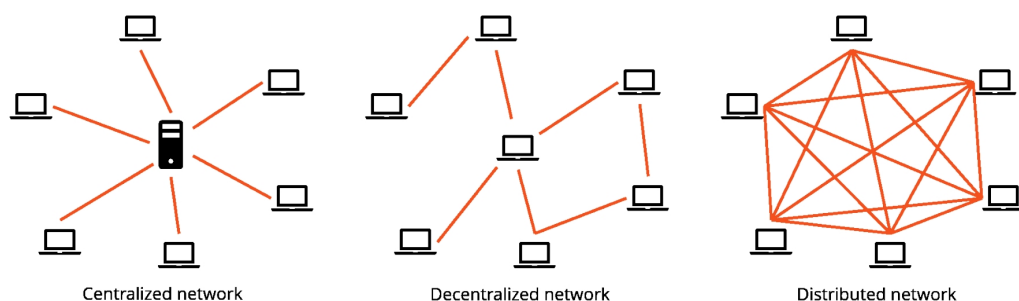


Figure 6.2: Network topology [?]

¹ A **Directed Acyclic Graph** links transactions directly with one another without bundling them into blocks, thereby enabling faster and parallel validation in blockchain systems.

6.2.2 Hash Functions

Hash functions¹ play a central role for the integrity of data within blockchain technology. They transform input data of any length into outputs of fixed length, so-called hash values. These serve as digital fingerprints of the original data. Even the smallest change to the input leads to a completely new hash value. This behavior is referred to as the **avalanche effect**² and forms the basis for the tamper resistance of block-based systems [?].

For a hash function to be considered secure, it must fulfill certain criteria:

- **Determinism:** The same inputs always produce the same hash value
- **Efficiency:** The computation must be quick to perform
- **Collision resistance:** Different inputs must not produce the same hash value
- **Pre-image resistance:** It must be practically impossible to infer the original input from the hash value
- **Avalanche effect:** Small changes to the input alter the entire hash value

In the blockchain, each block contains both the hash of the previous block and the hash of its own transaction data. This creates a continuous hash chain in which every change becomes visible. If a block is altered, the hash value no longer matches and the link to the rest of the chain is broken. This is illustrated in Figure 6.3. It shows how each block references the preceding one via a hash value while simultaneously securing its own contents. This creates a verifiable and consistent data structure. Any subsequent manipulation would damage the entire chain and would therefore be immediately noticeable.

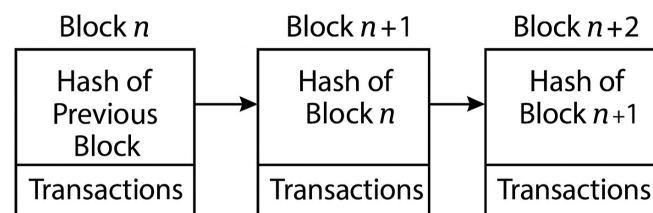


Figure 6.3: Structure of a hash chain

1 A **hash function** is a mathematical function that converts data of arbitrary length into a code of fixed length, serving as a digital fingerprint.

2 The **avalanche effect** describes a property of cryptographic functions whereby even a minimal change to the input data leads to a completely different output value.

6.2.3 Merkle Trees

Merkle trees are a fundamental data structure within blockchain technology. They make it possible to verify large volumes of data efficiently and reliably. They are especially useful for so-called **lightweight clients**¹, which do not need to store the entire blockchain [?]. Building a Merkle tree involves several steps. First, each transaction is hashed individually. These hash values are then combined in pairs and hashed again. This process is repeated until only a single hash value remains — the so-called Merkle root. This root is stored in the block header and represents a compact summary of all transactions contained [?]. A major advantage is that individual transactions can be verified independently. If a transaction is tampered with, the corresponding hash path changes and the Merkle root no longer matches. This makes every change immediately detectable. The following Figure 6.4 shows how Merkle trees are used in the blockchain. They link transactions hierarchically via hash values and create an additional layer of security within each block. At the same time, this structure increases the efficiency of data processing. Merkle trees are especially advantageous in industrial applications with limited resources such as bandwidth or computing power. They enable data to be verified without large volumes of data having to be transmitted or stored. In combination with other cryptographic methods, they help build secure and verifiable blockchain networks.

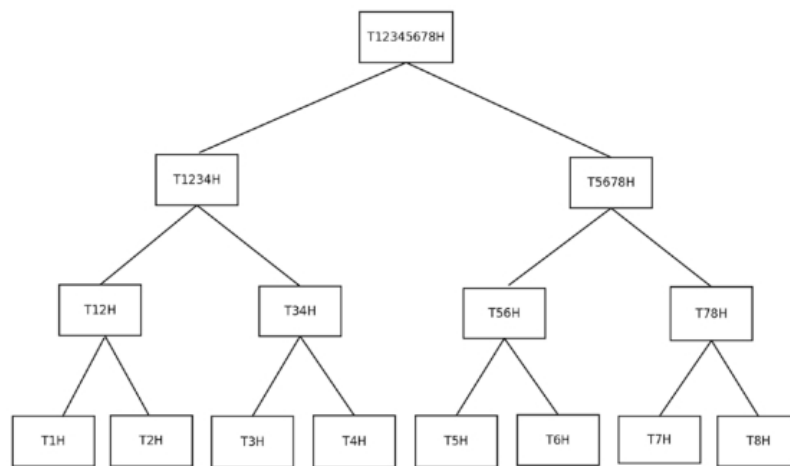


Figure 6.4: The Merkle tree for eight-block transactions [?]

6.2.4 Digital Signatures and Asymmetric Cryptography

Digital signatures are based on **asymmetric cryptography**² and secure the authenticity of data and identities within blockchain technology. Participants in the network use a key pair consisting of a private and a public key [?]. The private key is used to sign a transaction. The public key serves to verify this signature by other network participants. When a transaction is created, a hash value of the data is first generated. This is encrypted with the sender's private key. This produces a digital signature. Anyone with access to the sender's public key can verify whether the signature matches the message. This makes it possible to confirm that the message has not been altered and actually originates from the stated sender. In industrial applications, this method is frequently used in conjunction with smart contracts. The private

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- 1 **Lightweight clients** are blockchain applications that operate with reduced storage and computational overhead. Instead of downloading the entire blockchain, they access targeted, central data structures.
 - 2 **Asymmetric cryptography** is a method that works with a key pair consisting of a public and a private key to enable secure communication and authentication.

key is of central importance here. If it is lost or stolen, access to the associated digital identity and the data is irretrievably lost. For this reason, private keys are often stored in specially protected environments, such as hardware wallets, or additionally secured through biometric methods. Figure 6.5 shows the process: the sender creates a hash value of the message and signs it with their private key. The recipient uses the public key to verify the signature and confirm the authenticity of the message.

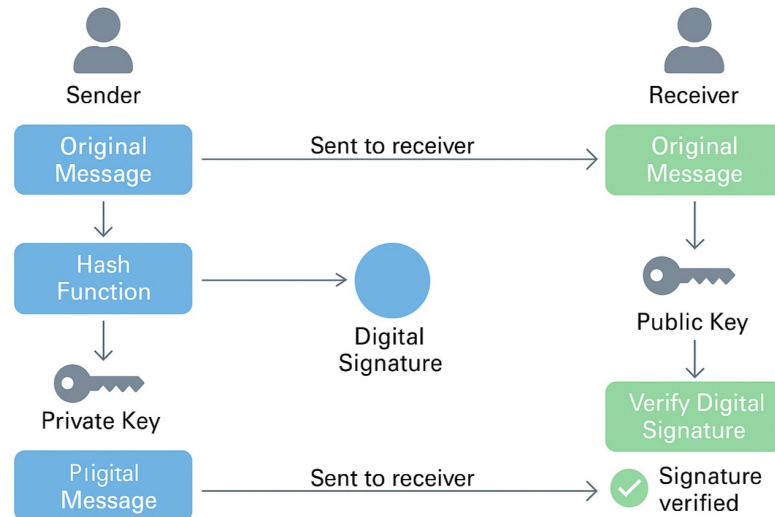


Figure 6.5: Process of a digital signature

6.3 Consensus Mechanisms

What is Consensus?

Consensus describes the process by which all participants in a blockchain network agree on the current state of the data. In this process, the system can function reliably even if not all nodes are trustworthy or behave incorrectly¹. In blockchain systems, this mechanism replaces classical centralized control. Instead of an authorized entity, an algorithmic procedure determines whether a transaction is valid [?]. Trust is thereby shifted to the level of the protocol.

A consensus mechanism fulfills three fundamental tasks:

- It ensures that all network nodes agree on the same state of data.
- It protects the consistency and integrity of the stored information.
- It prevents fraud, double spending, and manipulation.

Consensus is an indispensable foundation for trustless systems. It enables independent entities to work together with the same data without needing to know or trust one another. Even in open networks without central control, security remains guaranteed [?].

¹ **Untrustworthy nodes** are participants in a blockchain network whose behavior cannot be verified in advance.

6.3.1 Proof of Work

Proof of Work is the original consensus mechanism, which became well known with the introduction of Bitcoin. In this model, so-called **miners**¹ compete against one another to solve a mathematical problem. Whoever finds the solution first is allowed to add the next block to the blockchain and receives a reward for doing so. The procedure requires a high amount of computation and thus considerable energy. It is precisely this effort that protects the blockchain against manipulation. Anyone wishing to retroactively alter data would need to recompute not only the affected block but also all subsequent blocks, and would need to do so faster than all other participants in the network [?].

This makes attacks practically impossible. Proof of Work offers a high degree of security and decentralization. The validity of transactions does not depend on identities or amounts of money deployed, but solely on the computing power invested. However, this procedure also has weaknesses. Transaction throughput is limited and energy consumption is very high. Despite these disadvantages, Proof of Work has established itself as a robust procedure in public blockchain networks such as Bitcoin. It protects the system even when participants do not know or trust one another.

6.3.2 Proof of Stake

Proof of Stake is an alternative consensus method that is based not on computing power but on financial stake. Instead of complex computations, so-called **validators**² are selected who deposit a certain amount of **tokens**³ in the network. The higher the stake, the greater the probability of being selected as the block creator. This model significantly reduces energy consumption compared to Proof of Work while also improving scalability [?].

Anyone who does not behave in accordance with the rules risks losing their stake. This principle creates economic incentives for honest behavior and contributes to the security of the network. A well-known example is the Ethereum network. In 2022, Ethereum switched from the Proof-of-Work to the Proof-of-Stake procedure. This update, known as "The Merge," reduced the network's energy consumption by more than 99 percent, according to the Ethereum Foundation.

Alongside its advantages, Proof of Stake also brings new challenges. There is a risk that participants with large token holdings gain disproportionate influence. To offset this, well-designed protocols and strong security mechanisms are required.

1 A **miner** is a participant in a Proof of Work system who validates transactions by solving computationally intensive problems and is rewarded with new units of the cryptocurrency for doing so.

2 **Validators** are participants in a Proof of Stake network who are responsible for verifying and confirming transactions.

3 A **token** is a digital unit of value that exists on a blockchain and can fulfill various functions.

Comparison of PoW and PoS

Proof of Work and Proof of Stake are the most widely used consensus mechanisms within blockchain technology. Both pursue the goal of establishing agreement within the network, but they take different approaches. Proof of Work relies on computing power. Participants invest energy and hardware to solve cryptographic tasks. This procedure offers high security and decentralization but is frequently criticized for its inefficiency and environmental impact.

Proof of Stake, by contrast, is based on economic stake. Anyone who deposits a share of their tokens receives the chance to validate new blocks. This procedure saves energy and scales better but requires additional protective mechanisms to prevent excessive concentration of power.

The following table summarizes key differences:

Table 6.1: Comparison of PoW and PoS

Criterion	PoW	PoS
Validation principle¹	Computational effort	Financial stake
Energy consumption	Very high	Very low
Transaction capacity	Limited	Higher scalability
Incentive model	Reward through mining	Reward through staking, penalties for fraud
Example networks	Bitcoin	Ethereum, Cardano, Solana
Main risks	Environmental impact, hardware centralization	Wealth concentration, protocol complexity

Proof of Work remains particularly suited to systems in which security and immutability are the priority. Proof of Stake, on the other hand, is attractive for applications with high efficiency requirements and a focus on sustainability.

6.4 Blockchain in Practice

Blockchain is no longer merely a theoretical concept. In industrial practice, it is already being used to enable transparency, traceability, and autonomous processes. These properties make the technology particularly valuable for complex and decentrally organized systems in the context of Industry 4.0 [?].

6.4.1 Block Chaining and Supply Chains

Blockchain technology offers a reliable way to securely document every step within a supply chain. Each block contains the hash value of the previous block. This creates a chained structure that cannot subsequently be altered without detection. In practice, this means that the entire journey of a product can be traced via the blockchain [?]. Each station generates a new block with relevant information such as timestamp, location, and a reference to the previous block. If a single entry is tampered with, the hash value changes and the discrepancy becomes visible across the entire chain. Figure 6.6 shows, by way of example, how this process documentation works. The blockchain secures every stage of the value chain and makes subsequent changes verifiable. This procedure offers numerous advantages. Companies can quickly identify the cause of quality problems or delivery delays [?]. At the same time, consumers and authorities benefit from transparent origin tracking, for example in the area of food safety or the pharmaceutical industry. Blockchain thus enables complete traceability and strengthens accountability among the parties involved. It supports certifications such as organic or Fairtrade and increases trust in the quality and origin of products.

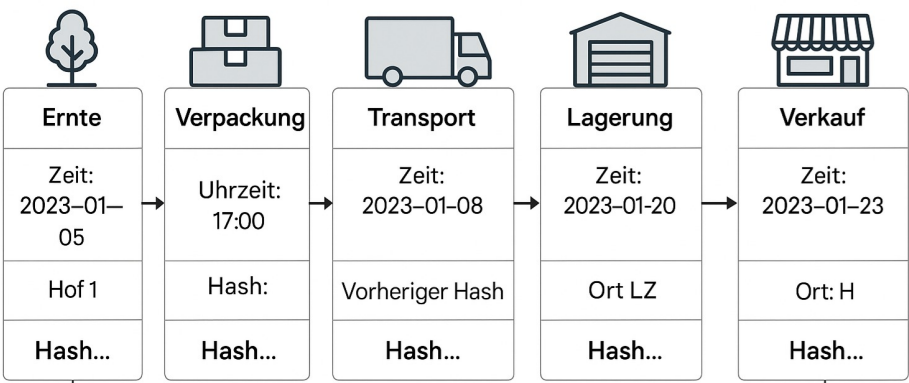


Figure 6.6: Example of a blockchain in food safety

6.4.2 Permission Structures

Blockchain networks can be distinguished by two central characteristics: access to the network and the rights to validate transactions. These structural characteristics determine who is allowed to participate and who can verify and confirm information. The choice of permission structure has a direct impact on transparency, scalability, and data control. In permissionless networks, anyone can participate in the system and validate transactions. These systems are fully open and promote decentralization and censorship resistance [?]. A well-known example is the Bitcoin network. By contrast, permissioned networks restrict validation access to specific, trusted participants. Such models are frequently used in enterprise networks, where it must be controlled who is allowed to process and view data. A further distinguishing feature concerns the accessibility of the blockchain itself. Public blockchains are visible to everyone. Private blockchains, on the other hand, restrict access to selected users. They

are often used in company-internal or regulatorily sensitive areas, where confidentiality and data protection are the priority. These characteristics can be combined, resulting in different types of networks, each suited to particular industrial requirements. A typical example is a private, permissioned network suited to partner companies within a supply chain. Here, only authorized participants receive read and write rights.

		Validierung	
		Permissionless	Permissioned
Zugriff	Public	Jeder darf lesen und validieren.	Jeder darf lesen, nur Berechtigte validieren.
	Private	Nur Berechtigte dürfen lesen, jeder darf validieren.	Nur Berechtigte dürfen lesen und validieren.

Figure 6.7: Classification of permission architecture [?]]

Application Areas

Blockchain technology is already being used in many industrial and societal contexts. Its ability to ensure transparency, data integrity, and automation makes it an important tool for digital transformation within Industry 4.0.

Supply Chains and Logistics

Blockchain enables tamper-proof documentation of the flow of goods across the entire product lifecycle [?]. From raw material to delivery, all transactions are stored securely. This improves traceability, optimizes warehouse management, and speeds up responses to product defects or recalls [?]. In addition, data from IoT sensors can be incorporated, capturing, for example, temperature or location in real time. This makes it possible to ensure the quality of sensitive goods such as food or medication.



Figure 6.8: Blockchain in supply chains

Digital Identities and Public Administration

Blockchain enables digital identities to be managed in a decentralized manner. Individuals and organizations retain control over their data without being dependent on central authorities. Identity credentials on the blockchain are secure, verifiable, and difficult to manipulate [?].

Figure 6.9 shows how institutions such as governments, banks, or employers can validate identities without directly disclosing personal data. Decentralized identities can be used not only for people but also for machines or companies. This facilitates secure interactions and simplifies regulatory processes, especially in international supply chains.

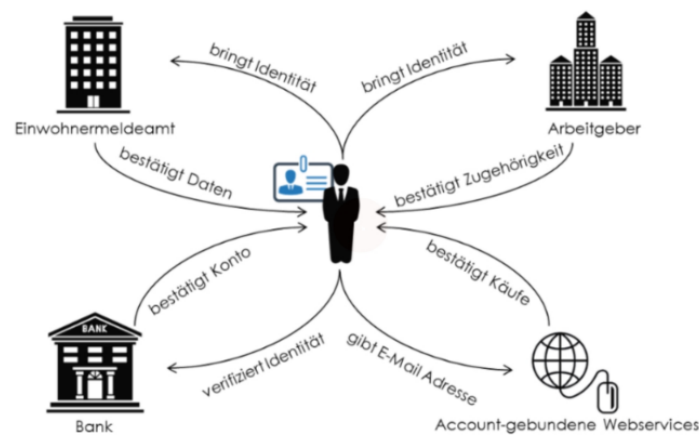


Figure 6.9: Blockchain technology secures identity

Smart Grids¹ and Energy Trading

In the energy sector, blockchain is used to manage decentralized power grids more efficiently. Instead of sourcing energy exclusively from large utility providers, households with solar installations can trade directly with neighbors. Within a local network, energy flows between producers and consumers. Every transaction is securely documented and processed in real time. This model improves energy efficiency, supports sustainability goals, and opens up new business models for peer-to-peer energy trading [?].

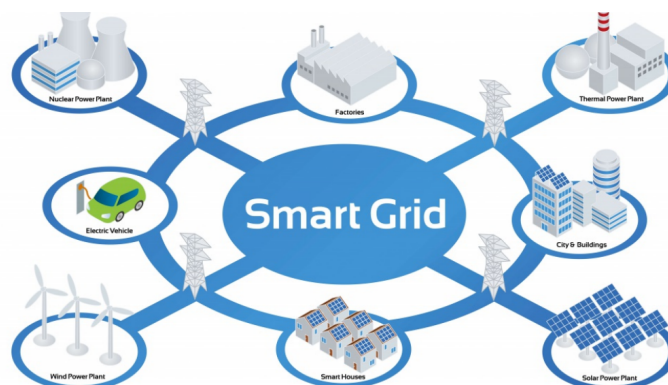


Figure 6.10: Blockchain technology in the energy sector

Further application areas include:

Sustainability and CO_2 Tracking

Environmental data such as emissions or energy consumption can be stored on the blockchain. CO_2 certificates or sustainability credentials can be represented in the form

¹ **Smart grids** are intelligent energy networks in which participants not only consume energy but can also generate it themselves and trade it directly with one another.

of digital tokens. This creates transparency and helps companies meet regulatory or voluntary environmental targets.

Digital Assets and Intellectual Property

Blockchain enables secure proof of ownership of digital goods such as designs, patents, or creative works. Non-Fungible Tokens (NFTs) can be used to unambiguously prove authenticity and ownership. This allows creators to be fairly compensated and intellectual property to be better protected.

Smart Contracts

Smart contracts are digital agreements that execute automatically once predefined conditions are met [?]. They can trigger payments, forward data, or control machines — entirely without human intervention. In industrial systems, this enables autonomous process control, for example in maintenance or reordering.

6.5 Opportunities and Risks

Blockchain technology offers potential for improving security, transparency, and efficiency in industrial systems. At the same time, its introduction brings technical, legal, and organizational challenges [?]. This section provides a structured overview of the key advantages and limitations of the technology.

Opportunities

Blockchain supports central goals of digital transformation. These include high availability, reliable data integrity, automation, and integration with other digital technologies.

Table 6.2: Opportunities of blockchain technology

Opportunity	Description	Relevance for industry
Availability	Data is stored decentrally across many nodes	Higher fault tolerance and permanent access to critical information
Integrity	Data is cryptographically secured and cannot be altered without detection	Reliable quality management and protection against manipulation
Decentralization	Trust arises through distributed consensus rather than central control	Cooperation between autonomous systems and independent organizations
Transparency	Transactions are verifiable and traceable	Facilitates audits, legal reviews, and strengthens customer trust
Automation	Smart contracts execute processes automatically as soon as conditions are met	Optimizes M2M processes and reduces manual intervention
Interoperability	Standardized interfaces enable integration with IoT, AI, and other technologies	Promotes the networking of complex industrial environments

Risks

Despite its advantages, blockchain technology also brings challenges that should be thoroughly assessed prior to adoption. These concern, among other things, environmental aspects, technical complexity, and legal uncertainties.

Table 6.3: Risks of using blockchain technology

Risk	Explanation	Impact on industrial applications
Energy consumption	Proof-of-Work systems require significant computing power and electricity	Increased operating costs and limited environmental sustainability
Scalability	Public blockchains reach limits with regard to transaction volume and speed	Complicates use in real-time scenarios or at high frequency
Legal uncertainty	Regulatory requirements are inconsistent and often subject to change	Increases risk in international projects and complicates legal safeguarding
Data protection	The transparency of the blockchain is partly in conflict with data protection laws such as the GDPR	Requires privacy-friendly architectures and governance structures
Technical complexity	Development, operation, and maintenance require specialized expertise	High investment needed in personnel and infrastructure
Irreversibility	Once executed, smart contracts cannot easily be modified	Can lead to operational disruptions or financial losses if errors go undetected

The risks outlined above show that using blockchain is not universally advisable. A well-founded risk analysis and adapting the technology to the respective use case are essential. Possible countermeasures include more energy-efficient consensus methods, privacy through selective disclosure of data, or targeted training within the company.

6.6 Summary

Blockchain technology is a fundamental innovation that enables trust, transparency, and automation in distributed digital infrastructures. In the context of Industry 4.0, it provides a reliable technical foundation for secure collaboration between autonomous systems, companies, and machines. This chapter has explained the central principles of blockchain technology, including its technical components, consensus mechanisms, and industrial application possibilities. Both the potential and the challenges of the technology have been examined.

Blockchain enables decentralized trust, as it dispenses with central intermediaries. Its functioning is based on distributed ledger structures, cryptographic methods, and consensus algorithms such as Proof of Work or Proof of Stake. These elements secure the consistency and traceability of data. They form the foundation for trustworthy systems in which even unknown actors can access shared information.

In practice, blockchain technology is already in use. Application examples can be found in supply chain traceability, digital identity management, automated contract execution, environmental data collection, and decentralized energy trading. In doing so, it improves data quality, supports autonomous processes, and facilitates the networking of different systems. At the same time, open questions remain. These include the high energy demand of some consensus methods, limited scalability, legal uncertainties, and challenges in data protection. These aspects must be addressed so that the technology can realize its full potential in industrial environments.

CHAPTER 7

Cryptocurrencies

Learning objectives:

After completing this chapter, you will know...

- ... what is meant by cryptocurrencies.
- ... what the monetary system is and what functions it has.
- ... how the technology behind cryptocurrencies works.
- ... which cryptocurrencies currently exist.
- ... which fields of application exist for cryptocurrencies.
- ... which opportunities and challenges exist with cryptocurrencies.

7.1 Introduction

In recent years, a new component has established itself worldwide within the familiar monetary system: cryptocurrencies. Once conceived as a technical experiment, it is today a multi-billion-dollar industry and is regarded by many as the future of the monetary system.

On November 1, 2008, in an article titled „Bitcoin: A Peer-to-Peer Electronic Cash System“ Satoshi Nakamoto presented the concept for cryptocurrencies [?]. Two months later, on January 3, 2009, at the height of the financial crisis, Bitcoin was introduced as an alternative to the centralized monetary system. Today, in addition to Bitcoin, there are around 10,500 other cryptocurrencies (as of: January 2025) [?].

But what are „cryptocurrencies, and what makes them so successful?

Cryptocurrencies are digital means of payment based on blockchain technology. Blockchain technology makes it possible to store data immutably in decentrally distributed networks that are not managed by a central authority [?]. The name cryptocurrency colloquially refers to the cryptographic encryption methods on which the concept of the technology is based [?].

7.2 Origin and Functions of Money

7.2.1 History of Money

The history of money began around 10,000 years ago with the first bartering. People tried to exchange goods or services with one another - for example, livestock for grain.

However, this form of trade brought with it a central problem: the so-called double coincidence¹ of wants.

For a trade to come about, both parties had to possess exactly what the other was looking for. To solve this problem, commodity money or natural money² first developed.

Around 4,500 BC, silver was used as money for the first time [?]. The first minted coins, which served as official legal tender (see Figure 7.1), emerged around 700 BC.



Figure 7.1: First minted coinage from the 7th century BC. [?]

Paying larger amounts with coins often proved to be cumbersome. For this reason, printed paper was first issued as a means of payment in China in the 9th century AD. This paper had a physical connection to a precious metal and was thus considered „backed“ [?]. One could exchange the paper for a tangible economic good, such as gold.

This system was later replaced by „**fiat money**“.

Fiat money has no physical backing and thus no intrinsic value anymore. The value of this money is determined by the collective belief of market participants and controlled by the government and the central bank.

Today, there is „book money“ or „deposit money“. These terms refer to demand deposits available at all times in accounts held at credit institutions (for payment transaction purposes) [?]. Deposit money today accounts for around 80 percent of the money supply in circulation in the eurozone [?].

7.2.2 Functions of Money

Economics defines money indirectly: money is whatever fulfills the functions of money [?]. A distinction is made between three basic functions of money [?]:

- **Medium of exchange/means of payment:**
Money facilitates the exchange of goods and services by serving as a generally accepted means of payment.
- **Store of value:**
It makes it possible to separate purchase and sale in time, so that wealth can be saved and used for larger acquisitions.

1 Coincidence refers to the simultaneous occurrence of two events.

2 Natural money could take the form of plant, animal, or mineral products of high value, long shelf life, and good storability. Particularly popular were shells, snail shells, and tea [?].

- **Unit of account:**

Money simplifies economic transactions by providing a uniform basis for valuation. Instead of 4,950 possible exchange ratios among 100 different goods, there are only 100 price tags [?].

7.3 Technology

Cryptocurrencies rely on blockchain technology and are thus stored in a decentralized manner in a peer-to-peer network¹.

As soon as a user wants to send their cryptocurrency, for example as part of an exchange, a transaction is initiated. This transaction typically includes information about the amount of cryptocurrency and the recipient's address. These are then transformed into a hash value by a hash function, which converts any amount of data into a fixed character length. The hash value is then encrypted cryptographically. In the encryption method, a distinction is made between the user's private and public keys.

First, the hash value is encrypted with the sender's private key. This key remains secret [?]. The encrypted hash value is then attached to the transaction as a digital signature. If the data is subsequently changed, the signature and thus also the transaction become invalid.

The transaction is then transmitted to the network and checked for correctness by every node using the sender's public key [?]. In the blockchain network, a node represents a point that holds a copy of the blockchain and thus keeps the network running.

As soon as the transaction has been verified as correct, it is added to a block of the blockchain along with other transactions. The number of transactions in a block depends on the size of the block. A new block of a blockchain always contains the transactions and the hash value of the previous block, so that the blocks form a chain.

The new blocks are then verified using a consensus mechanism to ensure that all participants agree on a consistent and valid version of the block. The two best-known consensus mechanisms are **PoW!**² and **PoS!**³. With PoW, so-called miners must solve complex mathematical puzzles in order to validate a transaction. In this process, the new block additionally contains a so-called nonce, which serves to validate the block [?]. With PoS, transactions are validated by validators based on the amount of cryptocurrency they own or „stake“.

As soon as the block has been appended to the blockchain, the transaction is considered complete and the recipient can dispose of the cryptocurrency received.

¹ In a peer-to-peer network, equal-status users (peers) can communicate directly with one another or exchange resources, without intermediaries.

² **PoW!**

³ **PoS!**



Figure 7.2: Cryptocurrencies

New coins of cryptocurrencies can be created in different ways, depending on the consensus mechanism.

With PoW, new coins are created through so-called mining. Miners receive new coins as a reward for their work in the validation process.

With PoS, new coins are created through staking. Validators put up a certain amount of their own coins as collateral in order to validate transactions. The more a validator stakes, the higher its chance of validating a block and receiving a reward. For this reason, PoS also does not require extensive computing power.

New cryptocurrencies can also be created via **ICOs**¹. Here, the developers of the cryptocurrency offer coins in order to raise capital.

Cryptocurrencies fulfill the functions of money defined in Chapter 7.2 and can thus be regarded as money. As a medium of exchange or means of payment, cryptocurrencies are used as an alternative to classical currencies and enable fast and low-cost payments. No physical value is deposited as backing, meaning this type of currency is a form of fiat money.

The value of a unit of cryptocurrency is determined by the trust of participants and their willingness to pay. Cryptocurrencies also serve as a form of investment with the potential for high returns and thus as a store of value. As a unit of account, so-called stablecoins² are particularly suitable. For other cryptocurrencies, the high value fluctuations pose a problem for their use as a unit of account. Unlike „normal“ currencies, this is regulated by central organizations such as central banks. Cryptocurrencies, however, are detached from such institutions and are organized in a decentralized manner [?].

¹ **ICOs!**

² A stablecoin is a cryptocurrency that is pegged to the value of another asset, usually a fiat currency.

7.4 Current Currencies

The following table shows the five largest cryptocurrencies by total market value in US dollars available on the market in March 2026 (Bn. $\hat{=}$ US Billion, Tn. $\hat{=}$ US Trillion).

ID	Name	Total Market Value in \$	Price/Coin in \$	Circulating Coin Supply
1	Bitcoin 	1.44 Tn.	71,868	19.9 M.
2	Ethereum 	225 Bn.	2,218	120 M.
3	Tether 	184 Bn.	1.00	184 Bn.
4	Binance Coin 	90 Bn.	664.12	136 M.
5	XRP 	86 Bn.	1.41	61 Bn.

Table 7.1: The 5 largest cryptocurrencies in March 2026 by total market value [?]

Bitcoin:

Bitcoin was the first cryptocurrency and is currently the strongest on the market worldwide. On January 3, 2009, „Block 0“, also called the genesis block, was created, giving rise to the first 50 Bitcoin. The coinbase¹ contained the message: „The Times 03/Jan/2009 Chancellor on brink of second bailout of banks“. This message reflected Satoshi Nakamoto’s stance against the current financial system.

The exchange rate started at 1 Bitcoin for 0.07 US dollars. By April 2013, Bitcoin had already reached over 200 US dollars. By the end of 2017, Bitcoin had reached a level of approximately \$14,000. By November 2021, BTC continued to rise, reaching a high of \$58,348. In 2022 and 2023, Bitcoin lost value again and fell below the 16,000-dollar mark. The approval of Bitcoin trading on the US stock exchange in January 2024 triggered a sharp rise to over \$70,000. With Donald Trump’s election as the new US president, this rise intensified, and Bitcoin reached a new all-time high of \$125,008.



Figure 7.3: Development of Bitcoin since its inception [?]

<https://www.blockchaincenter.net/bitcoin/bitcoin-kurs/>

¹ The coinbase is the first transaction recorded in a block of a blockchain.

Bitcoin uses the energy-intensive PoW consensus mechanism. The current block reward¹ for miners has stood at 3.125 Bitcoin per block plus mining fees since the fourth halving².

Bitcoin started with a block size of 1 megabyte. With the implementation of Segregated Witness (SegWit) in 2017, a block can be up to 4 megabytes in size [?].

A block is mined and appended to the blockchain approximately every 10 minutes, which, given the current block reward, means that 450 new Bitcoin are created every day. However, the Bitcoin blockchain only manages around seven transactions per second [?]. The number of transactions per block varies depending on its size. On average, a block contains between 2,500 and 3,000 transactions. Bitcoin transaction fees depend on network load and average between \$1 and \$4 [?]. The currently circulating amount of Bitcoin is over 19.8 million³, which accounts for more than 94% of the maximum total supply of 21 million Bitcoin.

Bitcoin mining can be carried out worldwide by anyone with a computer and a LAN connection. In 2024, over 40% of global hashrate was accounted for by the United States. A large portion of the hashrate comes from huge mining farms⁴ as well as from large mining pools⁵.

The company Riot Platforms Inc., for example, has built one of the largest facilities in the world for Bitcoin mining in Rockdale, Texas, USA, with a maximum capacity of 700 megawatts [?].



Figure 7.4: Mining farm in Rockdale, Texas, USA

In addition to the large Bitcoin farms, the trend toward mining pools continues to grow. In 2024, 38% of the US share of Bitcoin hashrate was accounted for by the mining pool Foundry USA. This is also currently the largest pool in the world⁶.

Worldwide, according to the Cambridge Bitcoin Electricity Consumption Index, Bitcoin mining consumed 121.13 TWh in 2023 [?]. As a point of reference, around 14 nuclear power plants

1 As of: March 2026

2 A Bitcoin halving automatically reduces the block reward once a specified number of blocks have been mined. It happens every four years.

3 As of: March 2025

4 A mining farm is a data center that has been technically equipped to mine Bitcoin or other cryptocurrencies [?].

5 A mining pool is an association of crypto miners that pools computing power in order to contribute more effectively to the validation of transactions.

6 As of: January 2025

with a capacity of one gigawatt each would need to run continuously for an entire year to cover this energy demand. According to one study, the generation of electronic waste through Bitcoin mining is estimated at around 30,700 tons annually [?].

Despite the negative headlines, Bitcoin remains very popular as a currency and as an investment. It is referred to as the gold of the modern era. With its supply cap, Bitcoin is protected against inflation like gold. In Germany, around 12% of the population own Bitcoin [?].

Bitcoin is the best-known cryptocurrency and currently the most valuable. However, other currencies have overtaken Bitcoin in a few respects, such as reducing environmental impact or increasing transaction speeds. In the future, however, projects such as the planned Bitcoin Lightning Network could bring improvements.

Ethereum:

Ethereum stands for a digital platform that operates with its own blockchain. The platform was released in 2015 by Vitalik Buterin, on which developers can create and offer decentralized applications, so-called Dapps¹. The platform's blockchain (Layer 1) currently consists of 5,962 nodes that are synchronized with one another² [?]. Layer 2 blockchains are separate blockchains that periodically write their data to the Layer 1 blockchain in order to enable higher throughput and faster transaction speeds.

Within the platform, the platform's own cryptocurrency called Ether is used for transactions. Once a transaction is completed, a transaction fee called „gas“ must be paid. The amount of the fee depends on the size of the new block in the chain. Ether is arguably the best-known alternative to Bitcoin and thus the largest altcoin³.

Ethereum was introduced by the programmer Vitalik Buterin in 2015. Like Bitcoin, Ether operates in a peer-to-peer network that is completely free of state oversight and interference.

With the Merge in September 2022, Ethereum switched from the PoW to the PoS consensus mechanism in order to move away from mining and become more environmentally friendly. According to an estimate by the Crypto Carbon Ratings Institute (CCRI), Ethereum's electricity consumption is over 6 GWh, which corresponds to about 2,000 tons of CO₂ [?].

Another difference between Ethereum and Bitcoin is that the total supply of Ethereum is not capped. A new block is generated approximately every 12 seconds. The currency Ether had a value of \$1 in January 2016, broke through the \$1,000 mark two years later, and reached an all-time high of over \$4,800 in November 2021.

Tether:

USDT⁴ is a stablecoin. A stablecoin is pegged to the US dollar in order to guarantee a relatively stable value, unlike most other cryptocurrencies. This means that 1 USDT is generally worth approximately one US dollar [?].

Tether was launched in October 2014 and is still controlled today by the company Tether Limited. According to its own statements, Tether Ltd. backs every newly created USDT with one US dollar, but does not offer a direct exchange of USDT into US dollars. This statement

1 Dapps are open-source software based on blockchain technology.

2 As of: February 2025

3 Altcoin stands for „alternative coins“ and refers to crypto coins that were released as alternatives and successors to Bitcoin. The term thus encompasses all cryptocurrencies except Bitcoin.

4 **USDT!**

can also be referred to as Proof of Reserves. This means that reserves must at all times be equal to or greater than the USDT in circulation.

In January 2015, the company iFinex approved the trading of Tether on its exchange platform Bitfinex. As a result, the volume of Tether in the blockchain network rose rapidly. US dollar transactions were routed via Taiwanese banks to Wells Fargo¹. On April 18, 2017, these transactions were blocked by US banks due to a lack of transparency.

The volume of Tether issued nevertheless rose to 2.8 billion dollars [?]. In April 2019, the New York Attorney General filed a lawsuit against iFinex and Tether Limited for misappropriation of reserve funds. Two years later, iFinex and Tether Limited agreed to pay a fine of 18.5 million dollars.

Despite these negative events, Tether is still mainly used today on crypto exchanges to quickly switch between cryptocurrencies and a stable currency.

XRP:

The cryptocurrency XRP, also known as Ripple, is the native cryptocurrency of the Ripple network. Both the network and the currency were introduced in 2012.

The Ripple network is an open-source platform of the company Ripple Labs, on which fast transactions of currencies, foreign exchange, and other assets can be carried out. The platform was founded with the aim of handling all international transactions worldwide. Banks and other payment service providers are meant to be able to use the software to process transactions. Ripple and the cryptocurrency XRP are therefore not in direct conflict with the current banking system, but rather represent an updated version of the SWIFT transfer system currently in use².

The platform and thus also its cryptocurrency use a different technological approach than blockchain technology. With Ripple, transactions are processed via so-called validation servers, which reconcile the received data with a decentralized database (ledger). Consensus-finding also works differently on the Ripple network.

The so-called HashTree method is used, in which only a single value (hash), which serves as a summary of the data, is compared. This technology not only requires less energy and computing power than, for example, Bitcoin, but also enables a high transaction speed of three to five seconds.

The cryptocurrency XRP is used on the platform mainly for the transfer of value. 100 billion XRP coins were mined in total, of which only 58 billion are in circulation³. Despite the decentralized ledger, many critics accuse Ripple Labs of having too much control over XRP. Ripple Labs not only owns over 40 percent of the XRP supply, but many validation servers also come from Ripple or its close partners.

Nevertheless, Ripple, or XRP, remains an important player in the crypto sector, especially as an alternative to SWIFT transfers.

Binance Coin:

Binance Coin (BNB) is the currency of the crypto exchange Binance. The exchange was founded in June 2017 and today, with over 263 million users, is the largest crypto exchange in the world [?]. The spot trading volume of the last 24 hours⁴ on the exchange amounts to

1 Wells Fargo is a US bank classified by the Financial Stability Board as globally systemically important.

2 The SWIFT transfer system has used the Business Identifier Code (BIC) since August 2014 to uniquely identify the participating banks and institutions and thus also for all international transfers of assets.

3 As of: March 2025 [?]

4 The spot trading volume refers to the total amount of cryptocurrencies traded on the spot market within a given period.

about 11.3 billion US dollars, with Bitcoin accounting for more than 13% at just under 1.5 billion US dollars¹ [?]. The platform operates a dual-chain system. Two separate blockchains are connected to one another, which reduces the load on the chain, thereby increasing the speed and flexibility of the applications.

At Binance, cryptocurrencies are mainly traded on the fast BNB Beacon Chain. Smart contracts and applications from the decentralized finance system are supported on the somewhat slower BNB Smart Chain.

The currency has a cap of 200 million BNB. However, there are so-called quarterly BNB burning events, in which BNB coins are taken out of circulation in order to reduce the BNB supply to 100 million units and thereby generate an increase in value through a decreasing supply. The number of coins to be burned is determined by a mechanism that is based on the BNB price and the number of blocks generated on the BNB Chain. BNB is mainly used to pay for various types of fees, such as trading or transaction fees on the Binance platform, since investors receive a 50% discount on trading fees when using BNB.

Since BNB is closely tied to Binance, its success depends heavily on the platform, which is also under regulatory scrutiny worldwide.

Other Coins:

In addition to the classic crypto coins, there are also so-called meme coins and **AI!**² coins. Meme coins are cryptocurrencies inspired by internet memes³ or trends, often with little or no fundamental utility.

The first and probably best-known meme coin is Dogecoin (DOGE). This currency is based on the famous Doge meme featuring the Shiba Inu dog.



Figure 7.5: Logo of Dogecoin [?]

DOGE was created in 2013 by Billy Markus and Jackson Palmer as a parody of Bitcoin. Unlike Bitcoin, DOGE has no supply cap, which increases inflation and price fluctuations.

DOGE reached its highest value in June 2021 at €0.54/coin. Currently, the currency has a value of €0.16⁴. Despite support from Tesla CEO Elon Musk, DOGE is mainly used for payments, tips, and donations, and not as an investment.

A second example of meme coins is the Trump Coin, released on January 17, 2025. Three days before the inauguration of US President Donald Trump, 200 million coins of this currency were made accessible to the public.

1 As of: March 2025

2 **AI!**

3 Memes are funny photos or videos on the internet that are spread through media attention and are provided with further humorous comments by users [?].

4 As of: March 2025

The value of this coin currently stands at \$10.95¹. Further examples of meme coins include:

- Shiba Inu Coin: Competitor to Dogecoin.
- Pepe Coin: Based on the „Pepe the Frog“ meme
- Floki Inu Coin: Named after Elon Musk’s dog.

AI coins are cryptocurrencies that are connected with artificial intelligence (AI). They support the development of AI applications and the provision of AI services. To this end, the coins are components of decentralized AI platforms, which use the blockchain to process data securely and transparently. Through the release of ChatGPT on November 30, 2022, public interest in AI has risen considerably, which has made AI coins an interesting investment opportunity. There are currently just over 80 currencies in the „Artificial Intelligence“ category [?]. The three largest AI coins by total market capitalization are currently NEAR Protocol, Internet Computer, and Bittensor.

7.5 Applications

Cryptocurrencies have long since evolved beyond their original function as a digital means of payment and investment.

DeFi!²:

As an alternative to well-known financial systems, DeFi is one application of cryptocurrencies. DeFi refers to systems based on the blockchain that give every user access to financial products such as cryptocurrency credits or loans without central institutions such as banks and that are accessible from anywhere in the world [?].

These systems are usually managed democratically, whereby every holder of cryptocurrency receives a voting right. For DeFi applications, **TVL**!³ is an important indicator of size. TVL refers to the total value of assets deposited within the entire DeFi ecosystem.



Figure 7.6: The development of TVL in DeFi since 2018 [?]

The maximum TVL in DeFi currently stands at over 178 billion US dollars, which was reached in November 2022. In January 2025, TVL amounted to about 120 billion US dollars [?]. The two largest areas of DeFi are:

¹ As of: March 2025

² **DeFi!**

³ **TVL!**

- **Borrowing and Lending:**

By TVL share, borrowing and lending is the largest application of DeFi, with a share of over 40% in January 2025 [?]. Users can provide their cryptocurrencies to a protocol, which then automatically lends them out further, with the lender earning interest [?]. In contrast to conventional borrowing and lending, the barriers here are significantly lower, since only registration with a crypto wallet¹ is required to participate in the system.

- **DEXs!²:**

With a TVL share of over 15% in January 2025, DEXs are the second-largest application of DeFi. DEXs allow their users to trade cryptocurrencies anonymously and, unlike classic crypto exchanges, directly with one another.

Smart Contracts:

A central field of application for cryptocurrencies are so-called smart contracts. A smart contract consists of program code and algorithms that are stored on a blockchain. These codes often contain simple „if-then“ logic, meaning that the contracts are executed automatically when certain events occur [?]. These contracts are irrevocably secured on the blockchain and can no longer be changed afterward.

One example would be the insurance sector. Currently, the conventional processing of claims often takes a long time, and the payout conditions are often complex. With smart contracts, clear conditions could be defined in the if-function, and in the event of occurrence, the claim would be paid out automatically.

Smart contracts would increase contractual security.

NFTs!³: NFTs are unique crypto tokens on a blockchain that are one-of-a-kind and not interchangeable [?]. Ownership can be proven flawlessly with NFTs. NFTs are used mainly in art and gaming. The most expensive NFT ever is The Merge by the artist Murat Pak. Of it, over 312,000 pieces were purchased by 28,983 collectors for a total value of \$91.8 million.

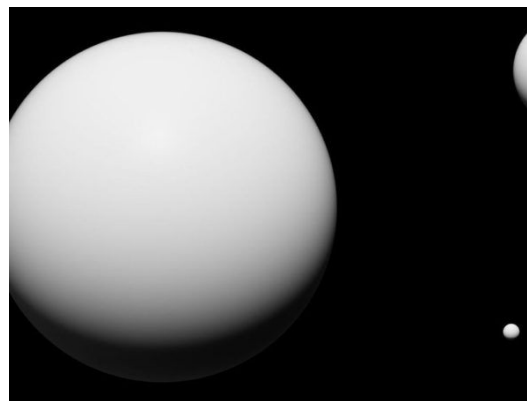


Figure 7.7: The Merge by Murat Pak

In gaming, NFTs are used primarily in blockchain gaming for unique items, avatars, or skins.

Supply Chain Management:

Blockchain technology and cryptocurrencies also find application in supply chain management and offer considerable advantages there.

¹ A crypto wallet stores the user's private keys and thus access to their cryptocurrencies.

² **DEXs!**

³ **NFTs!**

In traditional supply chains, the lack of traceability of the movement of goods represents a central problem that can lead to inefficiencies, fraud, and counterfeiting [?].

Through the decentralized and tamper-proof storage of transaction data on a blockchain, every movement is documented seamlessly and can be checked at any time.

This significantly improves traceability, for example regarding the origin of raw materials or food.

The use of smart contracts also enables the automation of important processes within the supply chain, while cryptocurrencies as a means of payment can reduce high transaction fees and exchange rate risks in international trade.

Overall, blockchain technology helps to increase the efficiency of supply chains, reduce costs, and strengthen trust between trading partners.

The various application possibilities of cryptocurrencies show their enormous potential to transform traditional systems, open up new markets, and drive digitalization forward in numerous industries.

7.6 Opportunities and Challenges

Cryptocurrencies offer numerous opportunities for the economy, technology, and cybersecurity, but at the same time they are also associated with challenges that still need to be overcome.

Opportunities:

- **Efficiency:**

With the help of blockchain technology, cryptocurrencies enable international transactions in seconds at low transaction costs. Transfers within the SEPA area¹ can take banks up to four business days. Outside the SEPA area, transfers take significantly longer. In addition, a fee of 5 to 10% of the transfer amount is charged [?]. For Bitcoin, the transaction fee currently amounts to just under 1.30 US dollars², and the average speed is about 10 minutes [?].

- **Anonymity:**

Without the involvement of a central authority, cryptocurrencies improve data security. Financial transactions can be carried out without central oversight.

- **Decentralization and Transparency:**

Through the decentralization of data via the blockchain, there is no longer a central point of attack for hackers. This data can also no longer be manipulated afterward. All transactions within a cryptocurrency must be recorded on the blockchain, which strongly promotes transparency.

- **Innovation:**

Cryptocurrencies provide a platform for new, innovative technologies, such as smart contracts, which automate and optimize processes.

¹ The SEPA area (Single Euro Payments Area) refers to the unified euro payments area.

² As of: March 2025

- **Independence:**

With independence from central institutions, cryptocurrencies and trading in cryptocurrencies are independent of location and opening hours. One can access and trade one's cryptocurrencies from anywhere in the world around the clock and does not have to wait until an exchange opens for trading on a given day.

Challenges:

- **Environmental Impact:**

The biggest challenge with cryptocurrencies is the high energy demand of PoW-based currencies. Many of the first cryptocurrencies use the PoW mechanism. Bitcoin, for example, has a larger energy consumption than some countries. However, the first currencies are already switching from PoW to PoS, which could represent a solution to the environmental impact of cryptocurrencies.

- **Blockchain Trilemma:**

The blockchain trilemma consists of scalability¹, security, and decentralization. These three properties of a cryptocurrency conflict with one another and represent central challenges of the technology. A high number of nodes in the crypto network thus poses a challenge to scalability. Each node must verify the transaction, which slows down the speed. With fewer nodes, however, decentralization decreases, and with it the security of the data or of the cryptocurrency.

- **Volatility:**

Cryptocurrencies are characterized by strong value fluctuations, which makes them rather unsuitable as a means of payment and poses a challenge for many as an investment asset. For example, Bitcoin has shown an average volatility² of between 50 and 80% over the last five years. The Dow Jones, by contrast, only about 19% [?].

- **Legal Challenges:**

There is still no uniform legal framework for cryptocurrencies. Some countries promote cryptocurrencies, others restrict them heavily by law or ban them entirely. In nine countries worldwide, the use and trading of cryptocurrencies are completely banned³ [?].

- **Quantum Computers:**

Due to their revolutionary approach to data processing, quantum computers could in the future pose a major threat to the security of blockchains and thus also to cryptocurrencies. They have the potential to solve complex mathematical problems much faster than conventional computers. It would thus be possible for quantum computers to break cryptographic encryption and deduce a user's private key from their public key [?].

7.7 Summary

Since the introduction of Bitcoin, cryptocurrencies have developed into a significant and disruptive technology. They could significantly shape the financial system of the future - whether through the optimization of existing structures, as with Ripple, or even through the replacement of the traditional system. The extent to which they establish themselves as a widely used means of payment depends significantly on their societal acceptance and the legal framework conditions of the coming years. A growing challenge for their security and stability is posed by the development of quantum computers, which requires new solutions.

¹ Scalability refers to the ability of a crypto network to handle an increasing number of transactions.

² Volatility refers to a measure of price fluctuations.

³ As of: March 2025

Moreover, closely related technologies such as smart contracts offer great potential for increasing efficiency and automation in various industries, especially in financial services, industry, and insurance.

Overall, cryptocurrencies will continue to undergo an exciting and potentially revolutionary development. With technological advances and possible regulatory adjustments, they could sustainably transform the financial system and promote an increasingly digital, decentralized economy.

CHAPTER 8

The Working World of the Future - Work 4.0

Learning Objectives

After working through this chapter, you will know ...

- ... what Work 4.0 means.
- ... how Industry 4.0 is influencing the working world of tomorrow.
- ... which challenges employers and employees can expect.
- ... how a socially sustainable transition to Work 4.0 can succeed.
- ... what contribution concepts such as the unconditional basic income can make.

Introduction

In the course of technical progress and digitalization, a major structural transformation is taking place in almost all areas of life. This also applies to the working world, which confronts both companies and employees with challenges, but also offers great opportunities.

8.1 The Industrial Revolutions

Driven by profound technical as well as societal changes, several so-called industrial revolutions occurred within Europe starting in the second half of the 18th century. Each of these phases brought new ways of working with it and thus led to major changes in the working world, which in turn always resulted in a reorganization and restructuring of the previously existing social and economic conditions. New and improved technologies and advances in science continuously drove this development forward.



Figure 8.1: Development of work.

Figure 8.1 provides an overview of the working worlds that emerged in the course of the four industrial revolutions, which are briefly outlined below.

Work 1.0: At the end of the 18th century, the revolution began in Western Europe and England. Machine-based production in large quantities. Wage laborers had no rights whatsoever. Labor organizations emerged.

Work 2.0: At the end of the 19th century, the second industrial revolution brought electrification and mass production. Work was broken down into sub-processes (division of labor). Working conditions improved.

Work 3.0: In the middle of the 20th century, the third revolution of the working world began. Computers and robots support human labor. New forms of automation. Qualification of employees as knowledge workers. Introduction of the social market economy and an increase in employee prosperity.

At the end of the 20th century, the widespread adoption of computers and internet connections led to a further profound transformation, referred to as Working World 4.0. Among other things, this is characterized by globalization and networking.

8.2 Work 4.0 – An Overview

The technical progress of recent decades has revolutionized industry (cf. Industry 4.0), and in the course of this the working world too has been affected by numerous upheavals. The resulting changes are manifold and are discussed under the keyword Work 4.0. Some important aspects of this subject area are shown schematically in Figure 8.2 and are discussed in more detail in the following chapters.



Figure 8.2: Important aspects of the Work 4.0 concept.

8.3 Drivers of Change

In addition to technological innovations such as digitalization and automation, the transformation of the working world is also being driven forward by employees themselves. Among other things, the generational change is bringing about a shift in prevailing values and new demands on the working world.

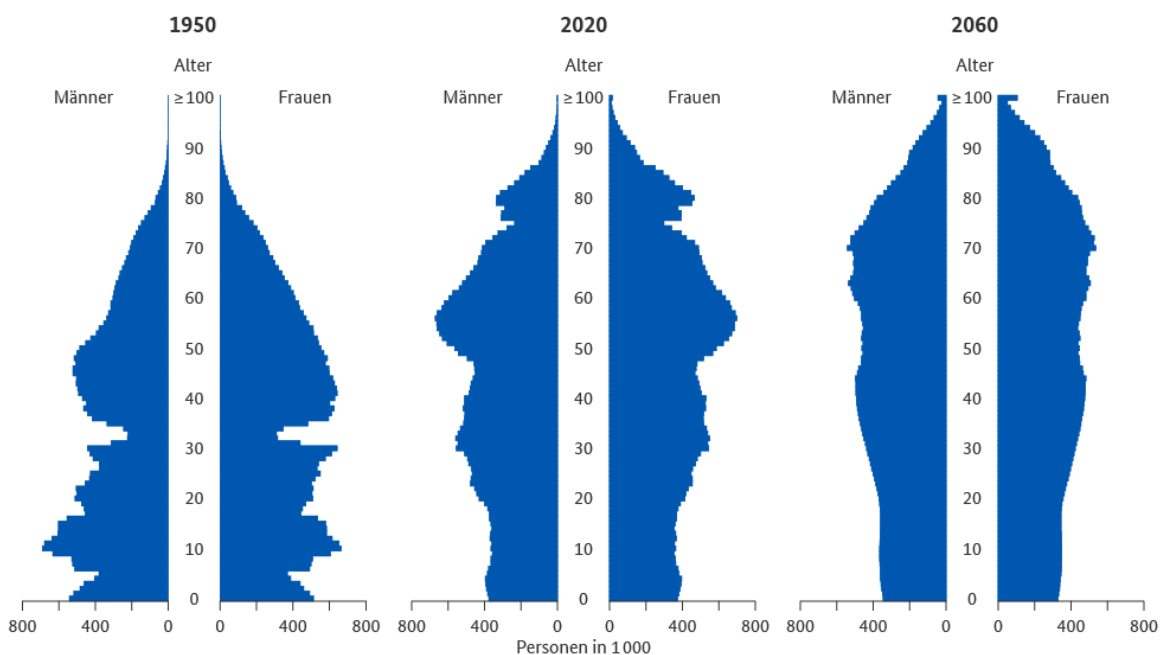
Technical Change/Digitalization

The technical progress of past decades has long since found its way into today's working world, and many jobs will continue to be replaced by automation. Production lines are already automated to an increasingly high degree, which is also leading to new requirement profiles, particularly for skilled workers. Through the use of networkable machines, systems can already be monitored in real time and coupled and controlled on the basis of the data collected. This gives rise to large volumes of data, the handling and analysis of which is creating entirely new branches of the economy, but even outside specialized companies the **need for employees** with specific information-technology qualifications is growing [?].

Demographic Change and Shifting Values

In addition to technical progress, the demographic change that is already foreseeable today will also have a serious impact on how work is organized in the future. Particularly in industrialized nations, population figures are tending to decline and an **increasing aging** of society is becoming apparent.¹

Altersstruktur der Bevölkerung, 1950–2060



2060: 14. koordinierte Bevölkerungsvorausberechnung, Variante 2
Datenquelle: Statistisches Bundesamt
Bildlizenz: CC BY-ND 4.0 (Bundesinstitut für Bevölkerungsforschung 2021)

BUND-LÄNDER
DEMOGRAFIE
PORTAL

Figure 8.3: The aging of the population manifests itself in two developments: in the increasing number of people of retirement age and in their growing share of the total population.

¹ <https://www.demografie-portal.de/DE/Fakten/bevoelkerung-altersstruktur.html;jsessionid=A0C58BF8469792442ED0513A7AB36396.internet272>

Against this backdrop, it is to be expected that widespread **shortages of skilled workers** will occur - this presents various industries with major challenges. While manufacturing sectors, as can already be seen today in the example of the automotive industry, are relying on robots and successfully replacing human workers with them, there are other areas with lower substitution potential.

These include, for example, occupations with an engineering background, which will continue to be required in the medium term for the design, maintenance, and improvement of the machines in use. Also, and especially, in the healthcare and social welfare sectors, where interpersonal interaction is irreplaceable, technical solutions offer only limited scope to compensate for the shortage of personnel [?].

A decline in the working-age population also undermines existing concepts of social security, which becomes particularly apparent in the example of the **pension system**.

The pyramidal age structure that has existed until now (Fig. 8.3), in which the burden of financing pensions was spread across a broad, young base, is increasingly being reversed. As a result, covering existing as well as expected pension claims is becoming increasingly difficult. In order to enable a resilient working world of the future in the spirit of the social market economy, **new approaches** must be discussed here, even beyond existing concepts such as state-subsidized private pension provision.

Furthermore, it should be noted that in regular waves, **new generations** enter the labor market, whose competencies as well as expectations sometimes differ significantly from those of their predecessors. The working world, and thus employers, must accommodate these expectations to a certain degree. Figure 8.4 provides an overview of the generations currently participating in the labor market as well as their prevailing attitudes.

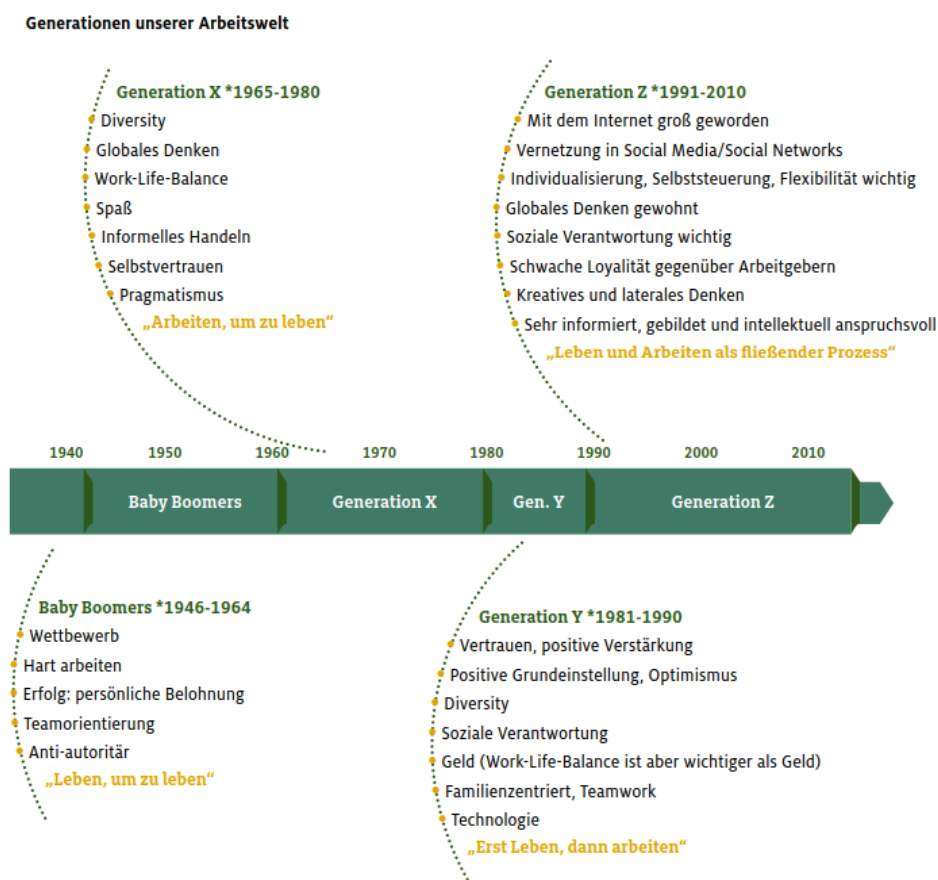


Figure 8.4: Employee generations [?].

8.4 Changes to Jobs and Requirements

As the automation of jobs progresses, monotonous or physically demanding tasks in particular are increasingly being replaced. This trend is already strongly pronounced, for example, in body-in-white manufacturing within the automotive industry, and mainly affects production employees. In these areas, humans are then mainly needed to control the production processes. Higher qualifications will presumably be required for future fields of employment here.

Office workplaces, on the other hand, are less affected by automation but more so by digitalization. Through better networking (the internet, etc.), employees can collaborate independently of one another regardless of location and time. This allows new freedoms with regard to working hours and workplace, and leads to flexible forms of work and organization.

8.5 Flexibility in the Performance of Work

Thanks to mobile devices, the availability of broadband internet connections, and the ability to access projects from various devices via cloud data storage, it is now technically possible to work in teams independently of location and time.

Already familiar solutions include, for example, **mobile work** or the **home office**, which experienced a surge during the Corona pandemic of 2020/21. The flexible choice of workplace can offer advantages for employees, for example by making it easier to reconcile employment and family life. At the same time, however, there are also disadvantages, particularly through the looming erosion of boundaries due to a (perceived) expectation of constant availability.

For employers, the new work arrangements bring challenges arising from statutory requirements. Here, a distinction must first be made between mobile work and the home office. The home office refers to a permanently set-up workplace outside the company premises where work is performed, and since 2016 it has been defined by the legislature in the Workplace Ordinance under the term "**telework**" (Section 2, Paragraph 7 ArbStättV). The employer is responsible for setting up the fixed workplace in accordance with applicable occupational health and safety as well as data security guidelines.

By contrast, the term "mobile working" has not to date been defined by law. In general usage, it is understood to mean that employees perform their work with the help of mobile devices from various locations that need not meet the requirements for a fixed workplace.

In the future, it is to be expected that such and similar **flexible work models** will continue to gain acceptance and be used more frequently. This gives rise to new challenges, within the scope of which the responsibilities, rights, and duties of employees and employers must be clearly defined.

When work is performed permanently outside the company premises, questions must be clarified such as occupational health and safety and insurance coverage. Employees have a **right to protection of their physical integrity**, while employers, given constantly changing workplaces outside their sphere of access (e.g., in mobile working), have no realistic way of setting these up in accordance with occupational health and safety requirements.

Federal Minister of Labour Hubertus Heil has repeatedly advocated in the past for a general right to a home office, most recently in 2020 in connection with a proposed legislative amendment. Since January 2021, employers have also been temporarily obliged, in the context of the Corona crisis, to offer mobile work wherever possible.

8.6 Qualification

The structural changes in the working world caused by advancing automation and digitalization are, according to forecasts, expected to lead to the loss of many jobs, for example in the production sector. In this context, reference is frequently made to so-called technological unemployment, a term introduced in 1931 by John Keynes [?]. Proponents of this thesis fear that jobs will be eliminated without replacement due to the increased use of machines such as computers and robots. The economists Frey and Osborne, for example, already predicted in 2013 that within the following two decades, 50% of jobs in the US labor market would become replaceable due to automation and digitalization.

Against this stands the fact that similar predictions have not come true in the past. It has been observed that technological change has repeatedly created **new markets** as well, meaning that, viewed on a larger scale, technological change has had a neutral or even positive effect on the labor market.

For employees directly affected by job losses (cf., for example, miners/steelworkers in the Ruhr area), the new markets do not necessarily offer follow-up employment; here **social safety nets** are called for, which economically support those affected, among other things. Considered from the perspective of the economy as a whole, however, it is ultimately only relevant whether a macroscopic **balance between labor supply and demand** is maintained.

In the future, it must be expected that the newly emerging markets will demand different qualifications from employees. It is expected that available jobs will shift toward those with **higher qualification requirements**. Due to the increased integration of technical systems in all areas, so-called **digital literacy** - the competence to use technology and IT systems - will receive increased attention.

Because innovation cycles are becoming shorter as a result of new technologies, it is also likely that the qualifications required at any given time will change ever more rapidly, which demands flexibility and a willingness toward **lifelong learning** from employees. Education systems will also have to meet this demand in the future.

Occupational fields that remain non-substitutable will continue to include those based on **creativity** or **social interaction**, as well as **complex cognitive activities**.

8.7 Redesigning Forms of Work – Putting People at the Center

While there is general consensus that technological change will lead to an upheaval and redesign of the working world, there is little agreement on what the result will look like. Everything has already been described, from dystopian scenarios of mass unemployment and people living under the dictates of technology, to utopian visions of a humanity freed from physically demanding labor that can enjoy the benefits of technical progress without existential fears (e.g., [?]).

Scientific studies as well, which seek to depict the current state of affairs and to develop perspectives for the further development of the working world, consistently paint a **heterogeneous picture** of the future. What becomes clear from this is, on the one hand, the complexity of the situation and, on the other, its open-ended outcome, which can and must be shaped today.

To this end, it is important that employees, employers, and stakeholders from the political sphere join forces in order to proactively set the course for a future that is desirable for everyone. Beyond purely profit-oriented considerations, it is necessary here to place people at the center. This opens up a multitude of possible starting points across several dimensions, which are shown schematically in Figure 8.6 [?].

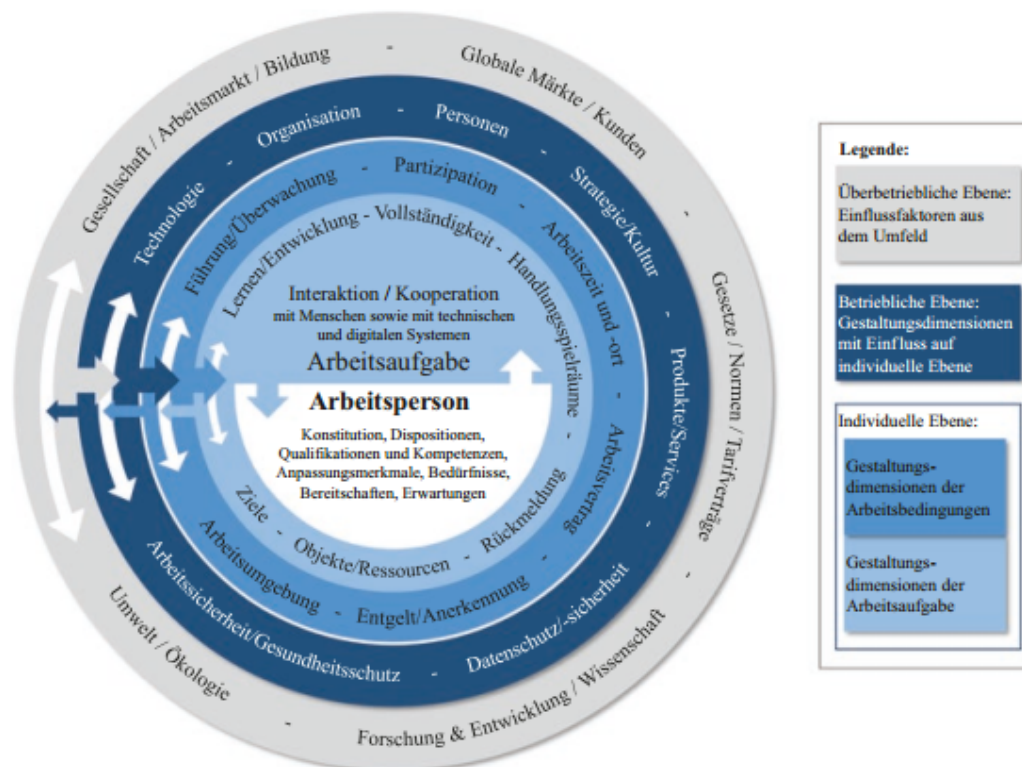


Figure 8.5: Illustration of the various influencing factors and dimensions of human-centered work design in companies.

The diagram shows that the possibilities for shaping this range from the individual position of each worker, through the operational level of the company, all the way to the broader societal environment, and makes clear that an economically as well as socially satisfactory solution can only be achieved by taking **all areas** into account.

8.8 Socioeconomic Aspects

Working World 4.0 is associated with both hopes and fears. While on the one hand advancing automation can physically relieve people, on the other it is foreseeable that entire fields of activity, particularly in the manufacturing sector, will be eliminated without replacement.

As already described above, there is consensus among experts that people, particularly in the context of specific restructuring measures, will lose their jobs, and that adequate follow-up employment - whether within or outside the company - will not always be possible. While in the short term this may possibly still be addressed through bridging assistance and severance payments from companies, in the long term it is to be feared that the labor market will permanently offer only few, or at least significantly different, employment opportunities for **low-skilled workers**.

The social market economy prevailing in Germany and the associated model of **social partnership**, established for decades, are confronted with major challenges by the impending transformation. In a situation in which an ever-increasing share of products is manufactured by machines, fewer and fewer people are involved in the corresponding value chain. **The profits generated are then distributed among a smaller group of people**; on a societal level, this creates the risk that the gap between rich and poor will widen further, giving rise to far-reaching social consequences.

The often-cited maxim "**one must be able to live from one's work**" is thus called into question within the currently existing system.

A way out of this situation is offered by approaches in which an individual's income no longer derives primarily from wages for work performed, whether self-employed or employed - a topic much discussed in this context is in particular the **unconditional basic income**. This is a socio-political concept in which a previously fixed government transfer payment is regularly paid out to all citizens without a means test. Both nationally and internationally, its concrete design has been under discussion for years and has already been tested in part in pilot projects (most recently, for example, in Norway). In the general understanding of the concept, the agreed payments should be set at a level sufficient to cover recipients' basic needs, i.e., to secure the subsistence minimum.

Opponents of the unconditional basic income frequently argue that the concept is not financially viable and, moreover, no longer creates incentives to work, which would have a detrimental effect on a productive society. Low-paid activities might then no longer be carried out for lack of financial incentive. Furthermore, a very small group of working people would have to bear the cost of covering the community's needs, which is perceived as unjust and as undermining the principle of **subsidiarity**.

Financing the basic income does indeed pose a challenge, one that in the medium and long term requires a restructuring of the existing tax and social security systems. If one assumes an unconditional basic income from birth, then, for example, social benefits such as parental and child benefits would be eliminated, and pensions or unemployment benefits would eventually become obsolete as well [?].

Through this significantly simplified social system, the state would already incur considerably lower administrative costs, and the resulting surplus could then be used to fund the basic income. Further financing options exist, for example, in an increase in income tax, the introduction of a financial transaction tax, or the levying of new taxes on consumption or natural resources.

For proponents of the unconditional basic income, a robust financing of the model is thus realistically achievable, and the anticipated benefits outweigh the costs. They expect, for

example, that financial security will alleviate existential fears arising from actual or anticipated unemployment and help to level out social inequalities.

Thanks to a basic level of funding covering each individual's basic needs, greater educational equity would be achievable. The choice of occupation could, if desired, be made more freely and independently of financial incentives, which could increase subjective satisfaction in the long term.

Employees would be better equipped for the challenges of Working World 4.0, such as the constant need for further training; career reorientations involving renewed periods of education might also be received more positively if they did not come at the expense of one's own financial security.

An unconditional basic income for all would also benefit people who perform caregiving activities in the private sphere, such as raising children or caring for relatives - activities that serve the common good but have to date gone unpaid and have often led to personal losses, at the latest in retirement age. Since women have so far been disproportionately affected by this, the basic income also represents a measure toward gender equity and equal opportunity.

The following graphic reflects the **subjective opinion** of the population. However, these factors cannot readily be transferred to reality. For instance, it is not guaranteed that poverty would be reduced by this, since the basic income could at some point fall below the poverty line.

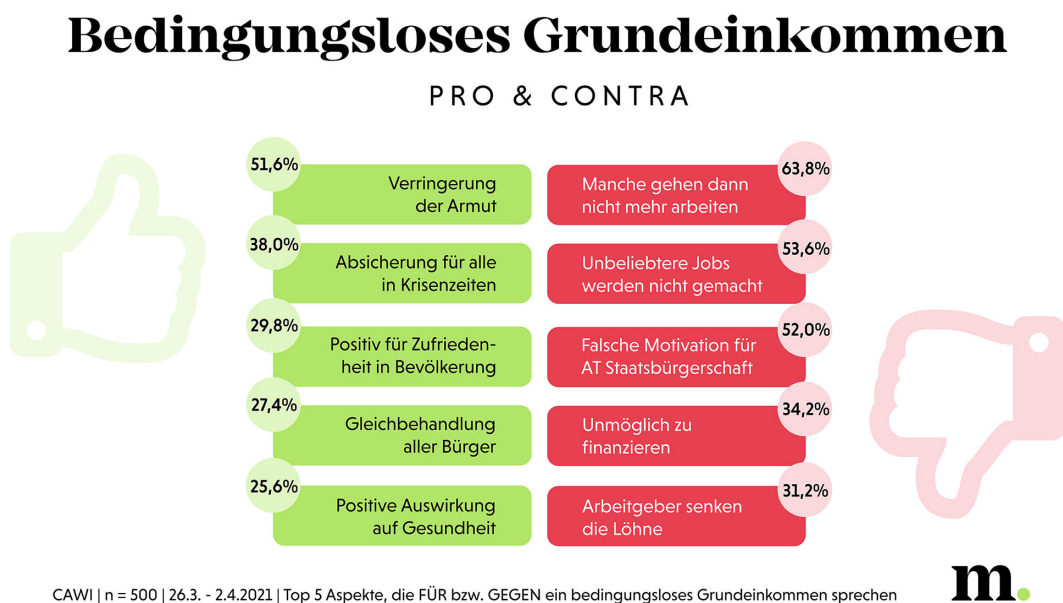


Figure 8.6: Pros and cons according to a Marketagent survey (Austria).¹

¹ <https://www.pressetext.com/news/bedingungsloses-grundeinkommen-polarisiert.html>

There is a multitude of different ideas and models for the UBI (unconditional basic income), all of which nonetheless share the desire for a change to today's system. The three most widely discussed proposals:

- **Unconditional Basic Income:**

As probably the best-known and most publicly discussed model, the concept of entrepreneur Götz Werner is presented below. In his concept, Werner envisages a guaranteed monthly amount of approximately 1,000-1,500 euros for every person from birth to death, which would make a dignified life possible without gainful employment. All taxes would be abolished; the sole source of state revenue and basis for financing the UBI would be a newly introduced high consumption tax. (Werner 2008)

- **Basic Income Concept of the Federation of German Catholic Youth (BDKJ)**

Distinctive feature: the BDKJ advocates for a certain degree of conditionality in the basic income: all recipients of the proposed 600 euros would be obligated to perform 500 hours of community service per year. This is intended to achieve recognition and support for activities beyond paid employment. (Hellmeister et al. 2007)

- **Negative Income Tax:**

The best-known model was created by Dieter Althaus (CDU), the former Minister-President of Thuringia. It grants all adults a citizen's allowance of 800 euros. The higher one's earned income, the higher the tax deductions and the deductions from the basic income become. Althaus advocates for a citizen's allowance that merely secures subsistence, whose central goal is employment for all, which should be promoted accordingly (further details at <http://www.solidarisches-buergergeld.de/index.php/de/konzept>).

There are implementation problems with all models of the UBI. Very few models present clear financing proposals, and implementation against international economic interests is extremely difficult. Furthermore, one essential question remains: **who determines the amount of the basic income?**

Under a UBI, conditions could change such that the basic income falls below the poverty line. In that case, a de facto compulsion to work would effectively reemerge. However, since wages could be expected to be much lower under such conditions, large segments of the population could slide into poverty.

Nevertheless, this should not be a reason to refrain from thinking about a UBI and to instead accept the prevailing unjust and undignified conditions. Whether a UBI is in fact a realistic alternative on the path out of poverty remains, for now, unanswered. Continuing the discussion on this topic is, in any case, to be welcomed.

8.9 Summary

Automation and digitalization are expected to lead to far-reaching changes in the working world, although not every job will be affected to the same degree. In order to do justice to these diverse changes, policymakers must respond to the new and increasingly complex reality of many employees with adequate regulations in the form of a legal framework. It is important here, especially for the new, more flexible forms of work, to find control mechanisms that safeguard employees' rights.

In addition, the concepts of the existing social market economy must be rethought in order to provide room for the increasing flexibilization of career paths and to create a basic economic security for everyone. Proposals such as the unconditional basic income are being discussed as potential solutions, though its immediate introduction in Germany is not yet foreseeable.

CHAPTER 9

Big Data

Learning Objectives

After working through this chapter, you will know ...

- ... what Big Data means
- ... which characteristics Big Data possesses
- ... what challenges, opportunities, and risks Big Data brings with it
- ... where Big Data is applied

Introduction

Due to the development of computers, television, and the internet, the second half of the 20th century was already considered the information age. Processor computing power has increased continuously since the beginning of its development. According to **Moore's Law**, the number of transistors per unit area, and thus computing power, doubles approximately every 18 months. While the first integrated circuits available on the market in 1965 consisted of 30 transistors, the first single-chip microprocessor, Intel's 4004, already had 2300 a few years later, and its successor, the Intel 8008 of 1971, already had 4500.

Today's current processors, such as the Intel Core i7, already have 1.5 billion transistors, with the next processor generation expected to reach 5 to 10 billion transistors. Due to the increasing computing power, the associated digitalization, artificial intelligence, technologies such as RFID (radio-frequency identification), ambient intelligence, smartphones, and the ever-growing acceptance and use of social media applications such as Facebook, Instagram, blogs, and forums (cf. Figure 2), there has been a worldwide **explosive increase** in the volume and diversity of data.

Every purchase, every flight, every phone call—nearly every activity, whether carried out by humans or by machines—generates data. In 2015, every person already produced between 600 and 700 megabytes of data per day; by 2020, this figure had risen to 1.5 gigabytes. According to a forecast from a market study financed by Seagate, the global data volume is expected to grow from **33** to **284 zettabytes** (1 zettabyte = 10^{21} bytes) between 2018 and 2027 (cf. Figure 1). The average growth rate is about 27 percent. Video applications, metadata, the Internet of Things, and social media account for a third of this growth. This enormous quantity and diversity of data requires new tools and algorithms in order to continue extracting information from the data. This phenomenon is referred to by the term “Big Data.”

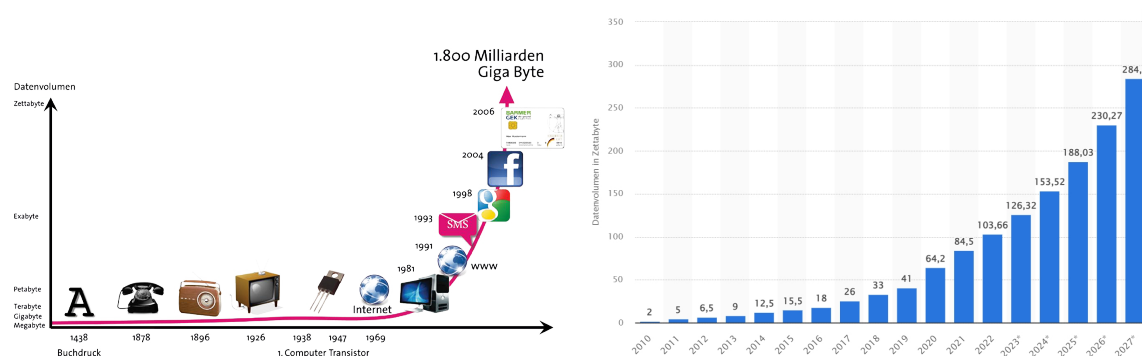


Figure 9.1: Growth of data volume over time

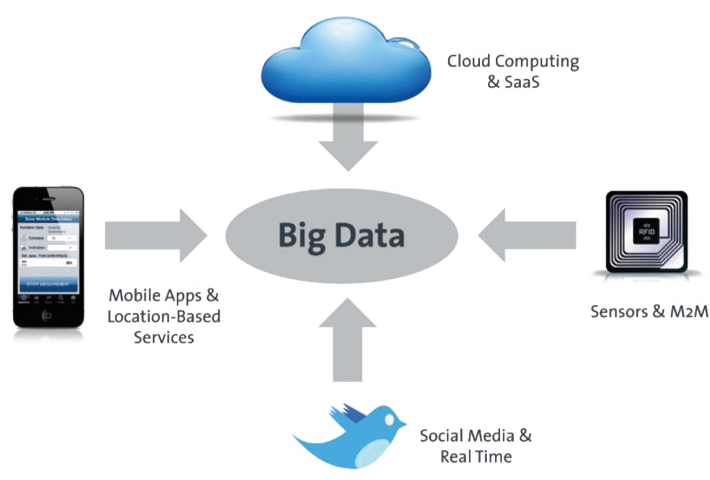


Figure 9.2: Information technologies responsible for the emergence of the Big Data phenomenon (Source: BITKOM 2012, p. 11)

9.1 Definition

The term “**Big Data**” originates from English and is a synonym for the enormous flood of data that today occurs in private and public life. Big Data refers to all types of data and information for which storage in a database or another special data structure is not possible and which cannot be evaluated using conventional data-processing methods, because they are too large, too complex, too fast-moving, or too weakly structured. These **unstructured** data are far more heterogeneous than classical data and can occur in various forms such as e-mail messages, PowerPoint presentations, text files, or similar. The data originate from the most varied fields and applications, such as the financial industry, the energy sector, healthcare, mobile telephony, the internet, credit cards, surveillance cameras, flight and travel data, social media, and many others.

However, Big Data does not merely reflect complex, sometimes intangible volumes of data; it is also often used as a collective term for digital technologies that are employed to automatically collect, manage, and analyze these data.

There are various definitions of Big Data. Edd Dumbill, for example, defines Big Data in terms of processing:

„Big Data is data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the structures of your databases architectures”.

Another definition, from Bitkom, refers to the various facets of Big Data:

„Big Data refers to the use of large volumes of data from diverse sources, at high processing speed, to generate economic value“.

Gartner's definition of Big Data also includes the “**three Vs**” of Big Data:

*“Big data is **high-volume**, **high-velocity** and **high-variety** information assets that demand cost-effective innovative forms of information processing for enhanced insight and decision making”.*

The extended five Vs describe the following properties of Big Data:

Volume

Volume refers to the enormous size of the data. Big Data data sets are very extensive and range from the terabyte to the zettabyte order of magnitude. (Megabyte = 10^6 byte, terabyte = 10^{12} byte, zettabyte = 10^{21} byte). Whether a given data set is considered Big Data thus depends on its **data volume**. Due to the explosive growth in data volume in recent years, this is the best-known characteristic of Big Data. The large quantity of data creates the problem of how to store it. After all, the greater the volume of this data, the more storage space is required to continue storing the data efficiently.

Velocity

The last of the original three Vs, Velocity, refers to the high **speed** at which data is generated, produced, created, or updated; processing in real time is frequently required as well. In order to process data as quickly as possible, work must take place in main memory rather than, as is usual, on hard-disk storage. Processing these volumes of data poses a challenge with respect to processing speed, since slower processing speeds result in noticeable performance losses. The data must also be as current as possible in order to react promptly to changes. Processing speed plays a decisive role, particularly for real-time decisions. Data must not be outdated, as this can lead to incorrect interpretations. In addition to the 3Vs of Big Data, some experts also speak of information capital or asset value. For this reason, two further characteristics are often added to the definition of Big Data:

Variety

When dealing with Big Data, one does not encounter only structured data. Increasing amounts of data are being generated that originate from the most varied sources and exhibit different structures. Variety thus refers to the nature of the data—the form in which it exists. **Structured** data is essentially organized data. It has a defined length and a clear format. It causes no problems for database systems and can be processed efficiently in tabular form. **Semi-structured** data can contain both unstructured and structured data. **Unstructured** data, on the other hand, does not fit into the traditional row-and-column structure of relational databases. Examples of this include text, images, graphics, videos, and similar. The more diverse the data, the more complex its storage and processing become. Many systems are suited only to storing and analyzing structured data. Big Data therefore requires new storage and processing capabilities.

Veracity

Veracity (**reliability**) is one of the unfavorable characteristics of Big Data. While the characteristics named so far have a positive influence, Big Data reduces the accuracy, correctness, completeness, and reliability of the data. Much of the data is vague

or imprecise. Quality and accuracy are sometimes difficult to control, and therefore inaccurate or questionable data must be removed from processing in time, or accounted for appropriately during evaluation, since the quality of the data has a decisive influence on the quality of the analysis result. It is becoming ever more difficult to verify that the data is complete and correct. For this reason, **specific algorithms** must be used to assess the significance of the results.

Value

The last, but probably most important, characteristic is **Value**. Big Data is meant to provide concrete answers to concrete questions, in order to then generate **added value** from them. The other characteristics are meaningless if Big Data cannot increase the value of the enterprise. Applying Big Data develops a **better understanding of the customer**; the enterprise aligns itself accordingly with the customer, processes are optimized, and overall company performance can be improved. Before a Big Data strategy can be developed, however, the potential of these demanding characteristics must be understood and one's own objectives clarified, since investments should only be made where added value can be generated. Besides these five characteristics, Big Data is also attributed further characteristics such as **Vulnerability**, **Visualization**, or **Volatility**. Big Data is so extensive and finds application in so many fields that no generally accepted definition exists, and consequently various characteristics are attributed to it. The five characteristics named above—Volume, Veracity, Variety, Velocity, and Value—are, however, the main properties of Big Data.

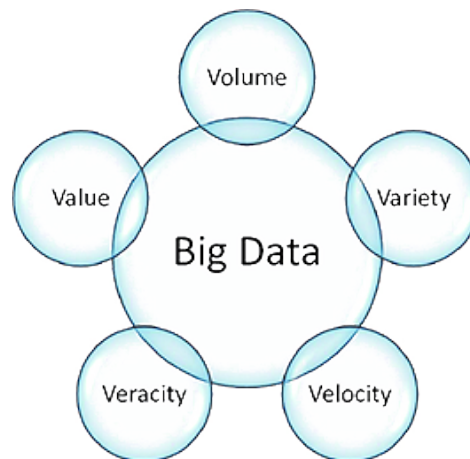


Figure 9.3: The main characteristics of Big Data (Elragal 2014)

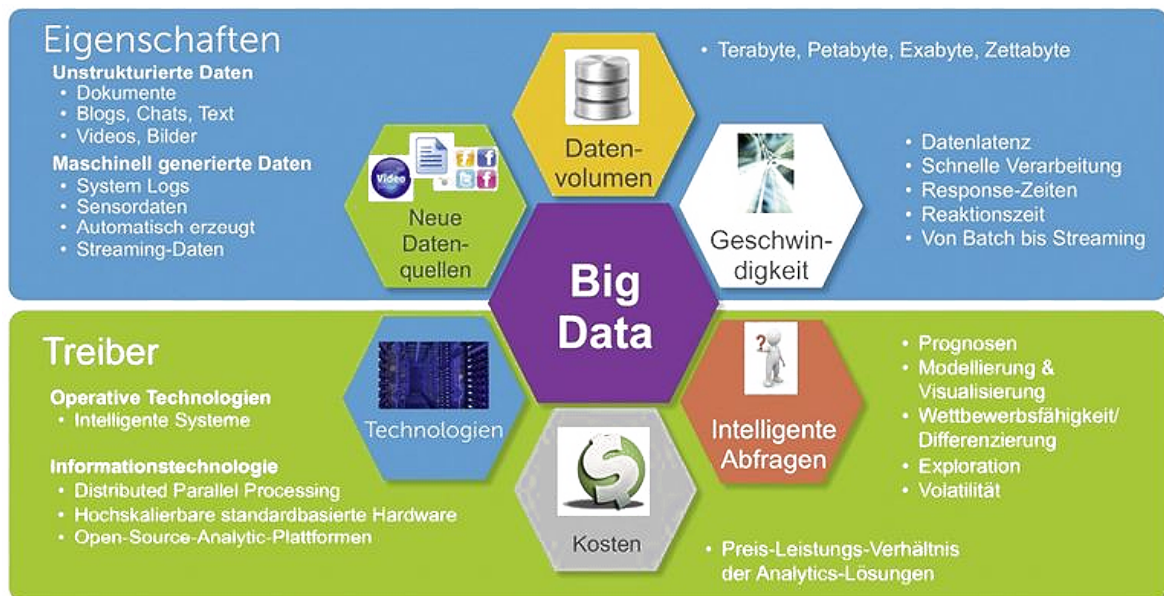


Figure 9.4: Big Data overview (Zeman 2016)

9.2 Big Data Analytics

Data has become an important asset for companies today. To handle the rapidly growing and increasingly complex volume of data, Big Data provides concepts, technologies, and methods where conventional approaches to information processing reach their limits. Through the collection, management, analysis, validation, preparation, and visualization of data, companies obtain important data material, such as information about customers' **purchasing behavior**, insight into the **performance** of production machinery, the likely **success of new marketing campaigns**, and much more. This information forms the basis for making the right business decisions. One can therefore say that Big Data Analytics is essentially a **management method**.

The most important subfields of Big Data Analytics are:

- Acquiring data from various sources by means of search queries
- Evaluating and preparing the data obtained
- Analyzing the data and visualizing/presenting the results



Figure 9.5: Big Data Analytics process (Intellipaat 2017)

Algorithms are needed as the basis for collecting and analyzing data. These algorithms often operate at a level that we, as humans, are not even consciously aware of.

Algorithms were used long before the computer age. The Egyptians, for example, used algorithms to calculate with hieroglyphics. An algorithm is a defined procedure for eliminating

a problem or accomplishing a particular task. This process is always meant to proceed in the same, previously defined way. A prerequisite for the rise of algorithms was the enormous **increase in computing power** of computers in recent years (cf. Introduction). Only this made it possible to process even complex algorithms. The **increasing networking** of individual devices and systems likewise favored the development of algorithms, since these are needed for efficient and meaningful networking.

Today, algorithms are used, particularly on the internet, to determine users' click, search, and purchase behavior, in order to then be able to offer personalized content. Algorithms are therefore also the reason why two different people can receive two completely different search results for the same Google search query. This is because the results are based on the users' previous click and search behavior.

Complex algorithms are also prepared for the various scenarios that can occur. If circumstances change, the solution path adapts accordingly. For example, navigation systems change the selected route during a journey when new traffic jams arise. Furthermore, algorithms can be **capable of learning** and can independently recognize new relationships. Using photos of pets with corresponding labels, for example, an algorithm can learn what dogs and cats look like. After some time, the system is then able to correctly classify new photos by animal species, since it has learned the distinguishing features.

Key technologies for Big Data Analytics

Big Data applications are not based on a single technology. There are, of course, advanced analytical methods that can be used to analyze Big Data. However, Big Data Analytics is in reality an **interplay of multiple technologies and innovations** aimed at extracting the greatest possible benefit from the data. The most significant of these are listed below:

Machine Learning. Machine learning is a subfield of artificial intelligence (AI). It enables systems, based on algorithms and existing data sets, to recognize patterns and regularities and automatically build models that analyze larger and more complex data and deliver fast, accurate results. Solutions are also developed to match the results. The advantage for companies lies in avoiding as-yet-unknown risks, while the likelihood of identifying profitable opportunities and chances increases.

In machine learning, **artificial knowledge** is generated **from experience**. Data Management. Before data can be reliably analyzed, it must be of high quality, well maintained, and organized. Data is constantly flowing into and out of companies. It is therefore important to establish recurring, traceable processes in order to create and maintain certain standards for data quality.

Data Mining. Data mining is a methodology for **analyzing and examining large volumes of data** in order to discover patterns, insights, and knowledge within the data. This information can then be used for further analyses to answer complex business questions. With the help of data mining software, the chaotic and repetitive tangle of data can be searched, the most important points identified, the possible results evaluated, and the decision-making process thereby accelerated.

Hadoop. This **open-source software framework** can store large volumes of data and enables parallel data processing on highly scalable cluster servers. Because of the ever-growing volume and diversity of data, and its computing model that processes Big Data quickly, Hadoop has become a key technology in the business world.

In-Memory Analytics. By analyzing data directly from **main memory** instead of from disk, insights can be derived immediately and reacted to quickly. This saves time on data preparation and data processing. In-memory analytics is, for companies, not merely a simple way to remain

agile and make **better business decisions**, but it also enables the execution of repetitive and **interactive analysis scenarios**. **Predictive Analysis**.

This technology uses data, statistical algorithms, and machine learning methods to determine the probability of future outcomes based on historical data. The aim is to obtain the best possible estimate of what will happen in the **future**. Companies should thereby be able to feel confident, when making decisions, that they have made the best possible choice. **Text Mining**.

Text-mining technology can be used to analyze text files from the web, from comments, from books, and from other text-based sources in order to uncover previously undiscovered insights. Text mining uses machine learning or natural language processing to examine documents such as e-mails, blogs, Twitter posts, surveys, competitive information, and similar, in order to analyze large volumes of information and discover **new topics** and **relationships**.

9.3 Opportunities and Advantages of Big Data

The increase in technical capability to process and generate large amounts of information at high speed opens up many opportunities and advantages. The most significant of these are listed below:

Customer Understanding

Big Data enables companies to better understand their customers and target markets. By analyzing customer data, particularly customer preferences and demand, their behavior and preferences can be identified. In this way, companies can align themselves with customer needs and offer suitable products and services.

Furthermore, **future trends** and market movements can be predicted, which is of great importance in research and development. Based on these insights, companies can respond and develop new products in line with trends, expand existing product lines, modify existing products, or develop new marketing strategies for already-existing products. Companies can act proactively rather than merely reacting to changes. Overall, this shortens **time-to-market**, and products can be brought to market more quickly. Big Data helps companies to serve their customers as effectively as possible.

Optimization of Business Processes

The insights gained from data analysis make it possible to optimize business operations and secure advantages over competitors. Big Data arises in all areas of a company, and powerful analytical systems can process these large volumes of data, detect hidden patterns, and relate them to one another. This allows processes within the company to be optimized and made more efficient. One example of this is the transport of goods by truck. Many different data points, such as traffic-jam data, weather data, or fuel prices, play a role in transport, and most of these are measurable. Analytical systems can evaluate all of this data, determine the optimal routes for trucks, and thereby save time and costs.

Decision-Making

The flood of data and information that companies face daily is immense. New forms of data evaluation and aggregation generate information with a level of specificity never achieved before. Based on this newly gained information, companies can make decisions that are crucial to their continued success. Big Data can also help companies make preventive decisions. For example, machine data can be evaluated to identify the intervals between machine failures. By deploying **additional sensors**, the dependency between various factors and failures can

also be determined. Based on this information, preventive measures can then be defined, such as specific maintenance intervals before a renewed failure occurs.

Optimal Use of Resources

The optimal use of resources plays a major role for companies. Big Data allows intelligent buildings to be combined with automated production facilities, significantly reducing resource consumption. Thanks to these savings and the shortened production time for individual parts—made possible by more strongly networked production processes—companies can remain competitive worldwide. Big Data thus plays an important role in the smart factory through the processing and evaluation of large volumes of data.

9.4 Challenges Associated with Big Data

In addition to the challenges posed by the five characteristics Volume, Variety, Veracity, Velocity, and Value (see Chapter 9.1), Big Data gives rise to further challenges. Companies must face these challenges and develop answers to the questions associated with them.

Total Cost of Ownership

Big Data projects are generally associated with high costs. Heterogeneous and complex information landscapes lead to high operating costs. In addition to acquisition costs, there are also costs for new employees, software configuration, software maintenance, training, and so on.

IT Security

As the volume, complexity, and value of data increase, greater attention must be paid to preventing fraud and manipulation. Cybercriminals can feed false data into the data pool and thereby manipulate the results. In addition, sensitive data is often left unencrypted, since the constant encryption and decryption of large volumes of data results in a loss of processing speed. Data governance must be established—that is, a set of rules must be created that regulates the proper management of digital data—in order to prevent fraud and manipulation.

Transparency

Suitable data structures are of great importance given the large volume and diversity of the data. Regulated and clear data structures and workflows form the basis for interpreting the data, for information flows, and for responsibilities. Only in this way can an overview of the data tangle be created and transparency made possible.

Data Loss

All essential data and information must be captured and must not be lost. Storing and processing large volumes of data presents a problem here, since data volume is constantly growing and the capacities of existing technologies are reaching their limits. Data integrity, performance, and availability must not be compromised. Infrastructure Procurement, commissioning, maintenance, and operation differ for Big Data compared with conventional infrastructures. Particular know-how is therefore required here.

9.5 Risks Associated with Big Data

Privacy and Data Protection

The greatest risk of Big Data is the intrusion into people's privacy. Even large companies such as Yahoo and Facebook have already been involved in this issue. By analyzing the data they collect, companies can gain deep insights into people's habits and personality traits. When browsing the web, every person leaves a trail of data behind them.

Cookies, in particular, allow users' browsing behavior to be analyzed and their movements on the web to be recorded. This records which pages were visited, which products were viewed, or which products were added to the shopping cart. Through decryption and analysis of these traces, a person can be linked to the data, causing them to lose any kind of **anonymity**. People's data must be kept inaccessible in order to guarantee people's security and anonymity.

In most cases, however, there is no consent from those affected regarding the use of their data. Rather, users must explicitly state that they refuse to allow the use of their data. Not infrequently, this decision then also denies users certain functions. Opting out of data collection is therefore often practically impossible.

This results in a **normalization of data collection** in society. Even if it does not appear so at first glance, Big Data leads to a restriction of user behavior for people worldwide. Even though users are generally not aware of it, they no longer act according to their own personal opinion, but rather according to the opinion set by society or by companies.

Competitive Disadvantage

Working with Big Data requires companies to make substantial investments. Not all companies are able to cover these costs. It is easier for large companies to make these investments and benefit from Big Data, which creates a disadvantage for smaller companies. It appears that, due to the high costs and the disadvantages and risks of Big Data, only **large** and, above all, **established companies** benefit from Big Data. This widens the **competitive lead** of large companies over smaller companies, which do not have the same opportunities available to them.

9.6 Application Examples

- Connected cars can receive real-time traffic data and thereby avoid traffic jams at an early stage.
- Mobile devices such as smartwatches and smartphones collect fitness and health data and automatically transmit it to the family doctor.
- The US department store chain Target analyzed customers' purchasing behavior. If specific purchase patterns emerged that indicated a pregnancy, customers were made aware of the corresponding products through targeted advertising and coupons.
- The electricity consumption of households can be optimized through smart grids (intelligently networked electricity grids and households).
- Predictive policing—personal data is collected and evaluated in order to predict who is most likely to commit a crime, where, and when. Crimes are meant to be prevented before they even take place.
- Rolls-Royce uses Big Data in the modeling of new aircraft engines. During the design phase, simulations of new jet engines are carried out, allowing the new models to be tested before production.

- Caterpillar investigated, for one customer, how cleaning ship hulls affects fleet performance. The Big Data solution analyzed data from sensors on board ships whose hulls were cleaned or not cleaned. The result was that cleaning intervals had to be shortened, and the associated investments were nonetheless worthwhile. Big Data helped Caterpillar deploy its product correctly and improve the company's image.
- Big Data is also used to detect credit card fraud. Through completed credit card transactions, the algorithm gathers information about the cardholder's behavior and habits. In the case of suspicious transactions—for example, a purchase in China despite transactions in Germany in the days before—the algorithm triggers an alert and automatically blocks the card, or the cardholder is immediately informed of the suspicious transaction.

9.7 Summary

Big Data—a highly multifaceted phenomenon that is perceived very differently by different people. Some are full of expectations and rave about its infinite potential, while others feel their privacy is threatened and view Big Data as “surveillance.”

There are many arguments for both sides, yet development continues to advance and can no longer be halted, since Big Data already plays a role in too many areas of life. It is probably also the right approach to simply let this development proceed, since Big Data offers consumers and companies many advantages and opportunities. The challenge lies in accepting the challenges and seizing the opportunities without letting the risks become too great. It is important, in this regard, that consumers continue to handle their own data mindfully.

CHAPTER 10

Medicine 4.0

Learning Objectives

After working through this chapter, you will know ...

- ... which terms relevant to the topic of Medicine 4.0 are important
- ... why the digitalization of the healthcare system is unavoidable
- ... which changes are taking place in hospitals (Clinic 4.0)
- ... which advances telemedicine brings with it
- ... which challenges and risks arise

10.1 Introduction

Declining birth rates together with the rising life expectancy of the population in Germany are equally leading to a financial burden in the healthcare sector.

Due to medical advances, better hygiene, healthier nutrition, more suitable living conditions, improved working conditions, and rising prosperity, the life expectancy of newborns continues to increase. The current life expectancy in Germany for newborn boys is 78.6 years and for girls 83.4 years.

One way to reduce costs is to reduce the medical necessity in old age through further qualitative improvements in the aspects already described. However, since this option is only possible to a limited extent, further alternatives must be sought.

The digitalization of the healthcare system offers the best solution here. It can make services more cost-effective while simultaneously improving quality. However, it also brings a number of challenges that need to be overcome.

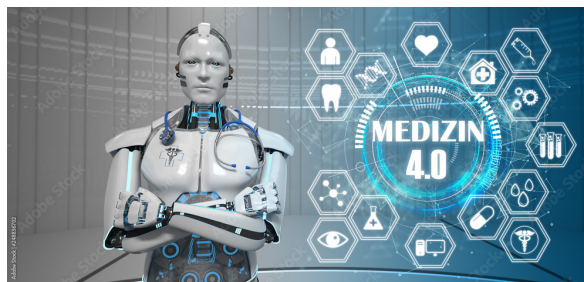


Figure 10.1: Medicine 4.0

10.2 Challenges in the Healthcare Sector

For digitalization to take place in the healthcare system or in the hospital, numerous challenges must be overcome, e.g.

- Digital care network
- Interoperability and isolated systems
- Numerous paper documents and system discontinuities
- Telemedicine
- Market consolidation and skilled-worker shortage
- Patient focus and complexity

The **digital care network** encompasses apps on prescription as well as video consultations. An app on prescription can, for example, be a diary app for documenting blood glucose for diabetics or a companion app for pregnant women. For this purpose, the **Act to Improve Healthcare Provision through Digitalization and Innovation** has been in effect since 19 December 2019. This enables secure round-the-clock access to the data network in the healthcare system. However, security, functional suitability, quality, data backup, and data protection present further challenges for the **BfArM**¹. The healthcare system is an extremely sensitive sector, and therefore data protection in particular, as well as the improvement of patient care, must be fully guaranteed [?].

The next challenges are posed by **interoperability**² and **isolated systems**. At present, no interoperable interaction between individual devices is possible either within or outside a hospital. However, for the digitalization of the healthcare system, it is fundamentally necessary to work with open standards in order to enable interoperability. With the help of open standards, interfaces are created that enable communication between devices within a hospital as well as external communication with other parties. Currently, isolated stand-alone solutions are used for hospital information systems, **PVS** systems³, and the core systems of health insurance funds.

Along with this, the next challenges become apparent: the **numerous paper documents** and the **system discontinuities between outpatient and inpatient care** must be eliminated. Medical history forms, data protection declarations, discharge letters, and other documents that must be filled out by hand are frequently captured on paper. They must subsequently be entered digitally or filled out again at the next visit. These documents also often have to be filled out separately at every station a patient passes through. This process costs a great deal of time and, consequently, money. The same problem arises in the discontinuity between inpatient and outpatient care. Care processes must therefore be optimized with the help of digital and organizational solutions.

Telemedicine is very well suited for outpatient care or medical treatment. Routine check-ups, for which the patient previously had to travel to the practice, can in future take place as tele-visits. Further advantages and possibilities of telemedicine are described in Chapter [10.10 Telemedicine](#) on page [118](#).

The German healthcare system comprises around 1,900 hospitals, which are now subject to considerable cost pressure. At the same time, there is a **shortage of skilled workers**.

1 **BfArM** = Bundesinstitut für Arzneimittel und Medizinprodukte (Federal Institute for Drugs and Medical Devices)

2 **Interoperability** refers to the ability of a system (e.g. a medical device or software) to work together with other systems [?].

3 **PVS** = Praxis Verwaltungssystem (practice management system)

In order to remain competitive, changes must therefore be made and new business models developed. To save costs, **market consolidations**¹ must take place. Hospitals, medical practices, health insurance funds, and all other participants in the healthcare system must work together more closely in future and digitalize processes in order to be equal to these challenges. The digitalization of the healthcare system is thus not an option that can be chosen, but a necessity that must be pursued.

A further challenge that hospitals and physicians will face in future is referred to as **patient centrality** (patient focus). Through general digitalization and networking, patients are increasingly informing themselves independently about the causes of complaints. This behavior must be leveraged by the healthcare system, and digital medical histories must be able to be reliably compiled. In future, patients must be able to do more on their own in order to save costs. To this end, the various stakeholders in the healthcare system must cooperate and network with one another. This makes it possible to offer digital services to their full extent. At the same time, this reduces the **complexity** that arises from the large number of stakeholders.

The first step toward the digitalization of the healthcare system is therefore the introduction of open standards in order to create interfaces. This simplifies internal and external cooperation as well as cooperation with the patient, and further digitalization steps can be initiated and further challenges mastered [?].

10.3 Digitalization in the Healthcare System

Digitalization in the healthcare system can also be summarized under the term **eHealth**. The term eHealth refers to the cost-effective and secure use of **ICT** to promote general health and health-related areas. The term eHealth can be divided into five different areas:

- **eCare** (healthcare provision – e.g. telemonitoring, teleconsultations)
- **eAdministration** (administrative processes – e.g. **eGK**², **ePA**³)
- **ePrevention** (prevention – e.g. age-appropriate assistance systems)
- **eResearch** (research – e.g. genetic research using **AI**)
- **eLearning** (teaching – e.g. blended learning⁴)

Overlaps repeatedly occur among the individual areas, which is why they cannot be completely separated from one another.

The basis for the interaction of the various areas is a secure **TI**⁵. The first steps toward this were taken in Germany in 2015 through the eHealth Act. It is also referred to as the Act for Secure Digital Communication and Applications in Healthcare. It addresses the establishment of a secure telematics infrastructure as well as the introduction of digital medical applications.

1 In most sectors, **consolidation** generally refers to the achievement of stability or the combination of several parts into a whole [?].

2 **eGK** = elektronische Gesundheitskarte (electronic health card)

3 **ePA** = elektronische Patientenakte (electronic patient record)

4 **Blended learning**: a didactic concept that combines online and in-person components of teaching.

5 The telematics infrastructure (**TI**) is the data highway of the healthcare system. It is intended to enable fast and secure communication between physicians, psychotherapists, hospitals, and others.

Further laws subsequently drove the digitalization of the healthcare system forward. A major advance was then brought by the **DVPMG**¹, which came into force on 9 June 2021. It encompasses the further development of the TI as well as the introduction of the **ePA**² and **e-prescriptions**.

The telematics infrastructure connects the various actors (hospitals, physicians, patients, and health insurance funds) as well as the five different areas of eHealth with one another.

In Germany, the foundation for a digital and modern healthcare system has thus been created, and it becomes possible to address its implementation, for example within the hospital (Clinic 4.0), or the precise procedure by means of telemedicine.

Savings Potential in Germany

As early as 2018, up to 34 billion € could have been saved in Germany if the healthcare system had already been digitalized. This corresponds to about 12 percent of the total costs of the German healthcare system, which amount in absolute terms to 290 billion €. The trend in these costs is rising due to demographic change. Costs are estimated to grow by around 4.5 percent annually. A relatively recent study by McKinsey (June 2022) confirms the roughly 12% figure, and the savings potential now amounts to **42 billion euros** per year.

There is still an urgent need for action to reduce costs in order to financially safeguard the healthcare system in future.

In a study conducted by the company "McKinsey", the benefit potential of the 26 digital health technologies currently available was identified. These 26 technologies were divided into six different categories for this purpose:

- Paperless data
- Online interaction
- Workflows/automation
- Outcome transparency/decision support
- Patient self-treatment
- Patient self-service

The results of this study can be seen in Fig. 10.2 "Benefit potential by digitalization measures".

The three areas with the greatest savings potential are paperless data, online interaction, and workflows/automation. In total, 24 billion € can be saved here.

The area of **paperless data** includes the **ePA**, **e-prescriptions**, internal hospital staff communication, and virtual physician assistants.

Online interaction is equivalent to telemedicine. The technologies involved are teleconsultation, remote monitoring of chronically ill patients, and e-triage.

Workflows/automation largely encompasses the digitalization of hospitals (Clinic 4.0). This includes the mobile networking of nursing staff, barcode-based medication administration, tracking by means of **RFID**, monitoring of vital parameters, robots for physiotherapy, automation of simple process steps, and electronic referrals. However, parameters that can be

1 **GSAV** = Gesetz zur digitalen Modernisierung von Versorgung und Pflege (Act on the Digital Modernization of Care)

2 **ePA** = elektronische Patienten Akte (electronic patient record)

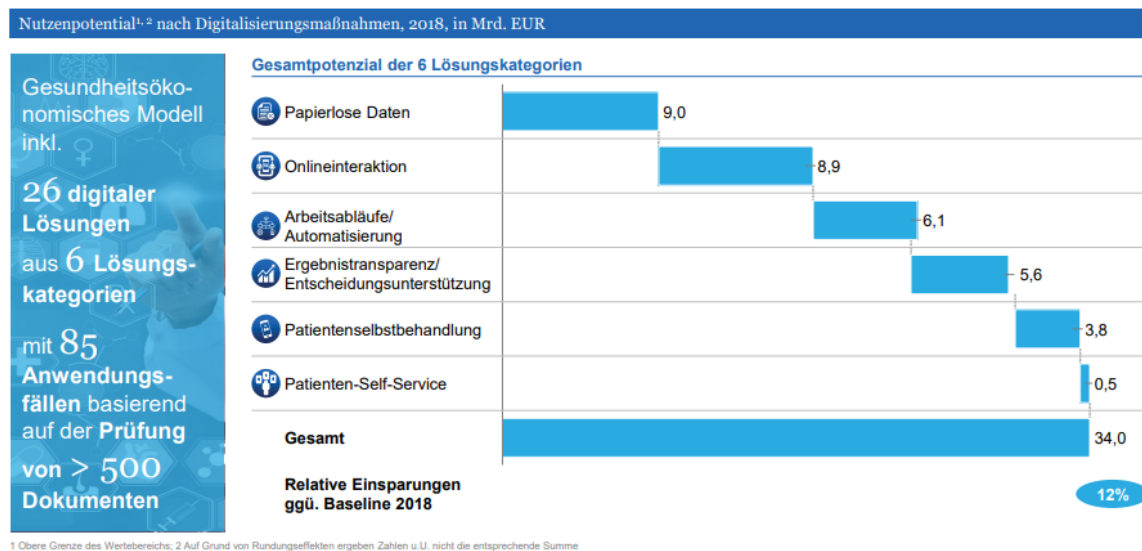


Figure 10.2: Benefit potential by digitalization measures

attributed to Clinic 4.0 are also found in the other categories. These include, for example, the virtual physician assistants from the paperless data category. Of the 24 billion € in savings potential from the three largest areas, around 16 billion € alone can be saved through digitalized hospitals.

Due to the enormous savings potential in the areas of **Clinic 4.0** and **telemedicine**, these are examined in more detail in the following chapters and illustrated with concrete use cases.

10.4 Digitalization in the Hospital (Clinic 4.0)

Digitalization in the hospital, also known as **Clinic 4.0**, refers to the introduction of networked technologies as well as real-time communication.

A look at history shows the changes from Clinic 1.0 to Clinic 4.0:

- Clinic 1.0: Introduction of new **processes** (anesthesia)
- Clinic 2.0: Introduction of new **technologies** (X-ray)
- Clinic 3.0: Introduction of **information-processing and information-storing machines**
- Clinic 4.0: Introduction of **networked technologies** as well as **real-time communication**

The goal of networking the hospital is to provide information to the right person at the right time. This makes decision-making easier and initiates the appropriate processes as a response to an event.

For the degree of digitalization of a hospital, **HIMSS**¹ developed the **EMRAM**. This model has been the worldwide standard since 2015 and divides the degree of digitalization of a hospital into seven different stages. At stage 0, not even the three most important systems of the ancillary departments (laboratory, pharmacy, and radiology) are installed. From stage 1 to stage 6, the degree of digitalization continues to increase. At the seventh stage, the hospital

¹ **HIMSS** = Healthcare Information and Management Systems Society

then runs almost entirely paperless, and all areas are automated to the extent that the current state of technology allows.

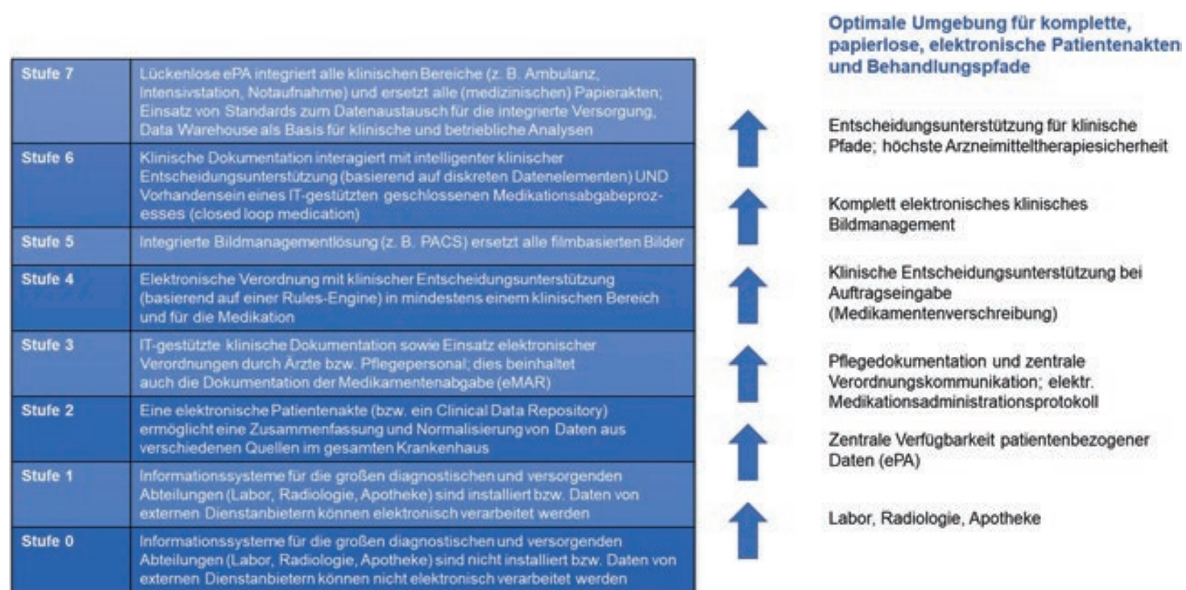


Figure 10.3: EMR Adoption Model (EMRAM), maturity model for the digitalization of hospitals

Hospital Areas:

Figure 10.4 shows the various areas of a hospital. In the graphic, a spatial separation of the individual areas is discernible. In the currently predominant Clinic 3.0, this separation also exists from a technical standpoint.

In order to be able to take the step from Clinic 3.0 to Clinic 4.0, the individual areas must be able to communicate with one another in real time. There are also a number of approaches within the individual areas themselves that are decisive for digitalization in the hospital.

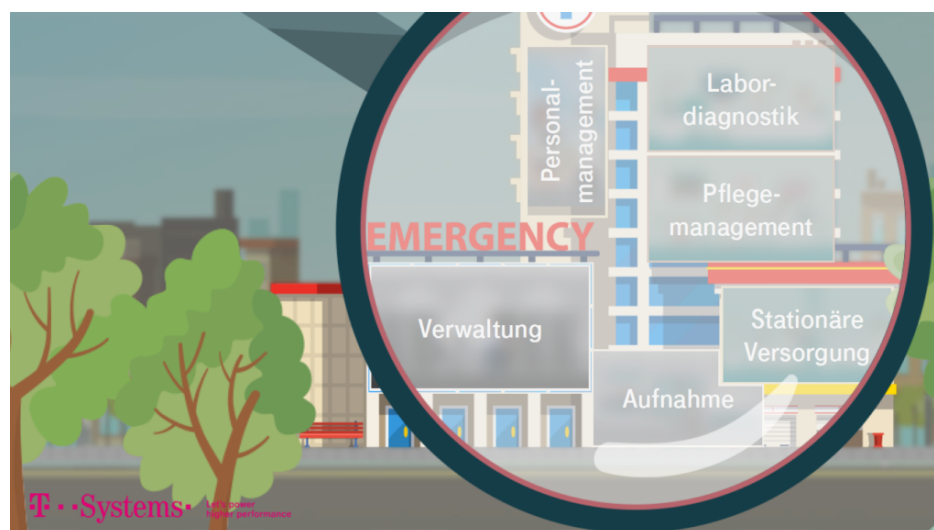


Figure 10.4: Hospital Areas

With the digitalization of the hospital, the individual areas within the clinic undergo a transformation. At the same time, the physician, the patient, and research and teaching continue to develop.

10.5 Physician 4.0

Through the networking of the digitalized clinic, the role of physicians is also evolving. In future, there will be **networks** of a large number of hospitals that cooperate with one another. Different clinics treat different areas of specialization. Cooperation among these different specialist clinics offers the patient the best possible care.

If a patient is admitted with symptoms that the clinic is not specialized in, contact is made with the nearest specialized clinic. The patient's images from **MRI**¹, **CT**², etc., are sent to the specialized clinic. In a **video conference**, both the physician at the current hospital and the physician at the specialized hospital treat the patient together. In this collaboration, the physicians can decide on the follow-up treatment. It can be decided whether the patient can continue to be treated at the current hospital or whether they must be transferred to the specialist clinic. If a transfer is not possible due to a critical condition, the option exists to call a specialist to the current hospital.

Information about pre-existing conditions, medications, etc., is also more easily and quickly accessible. Through the **networking** of general practitioners, specialists, and hospitals, information will in future be available around the clock. Information gaps, information discontinuities, and time losses due to lengthy medical histories or searching for previous findings will be eliminated. The physician has all information about the patient immediately at hand and can therefore inform themselves about the patient before admission. This saves valuable time and increases the chances for critical patients.

The role of the physician will shift with Clinic 4.0 away from a general practitioner toward a **specialist**. They will become a team player who works closely with other physicians. This ensures optimal patient care. The task of the general practitioner will become that of the team leader. They will assemble the best possible network of medical experts for their patient and continuously develop it further [?].

10.6 Nursing 4.0

The nursing staff of a hospital are responsible not only for actual patient care, but also for a great deal of administrative work. For morning rounds, nursing staff often have only 20 to 30 minutes before the first operations begin. During this round, the patient's wounds are examined and the treatment plan for the current day is established. Due to the limited time available, this information is often not entered into the hospital information system but rather written down on a slip of paper. If this slip of paper goes missing, it cannot be determined whether all items on the list have already been completed. **Mobile documentation systems** can provide support here. With these, all hospital staff have an overview of the most important patient information at all times. Furthermore, to-do lists can be created that can then be worked through over the course of the day. This would eliminate the risk of data loss [?].

Patients or staff often have to be searched for over a long time because their exact whereabouts in the hospital are unknown. This can happen in particular when patients have to move independently between wards, for example from the emergency room to the MRI, and lose their way in the process. Other scenarios include visiting the cafeteria due to visitors, or hairdressing appointments, etc. Physicians who are spontaneously called to the operating room are also sometimes searched for at length. **Location systems** that function with the help of RFID chips can provide a remedy here. This process is also referred to as **tracking**

1 **MRI** = Magnetic Resonance Imaging / Magnetic Resonance Tomography → contrast agent for soft tissue

2 **CT** = Computed Tomography → X-ray, 3D cross-sectional images possible

and tracing. The RFID chips are attached to patient wristbands, hospital beds, or hospital objects. This makes it possible to determine the location of missing persons or objects at any time. Time is saved and processes are made more efficient.

In addition to mobile documentation systems and location systems, **electronic order-entry systems** represent an important change in nursing care. In such a system, requests and orders, e.g. for X-rays, are recorded electronically. After the X-ray, the physician receives the X-ray images through the clinical information system. Order-entry systems link the various subsystems of a hospital with one another and thus ensure an uninterrupted exchange of information. If they are connected to the hospital pharmacy, the availability of medications can, for example, be checked and, if necessary, automatically reordered directly. A connection with the further downstream care services contributes to a faster implementation of organizational or structural measures after the hospital stay. Wheelchairs, walking aids, or the conversion of the patient's home can be ordered or arranged before their discharge, so that no avoidable waiting times arise for the patient.

A further point that contributes to improving nursing management is referred to as **hospitality entertainment**. This refers to an entertainment station in the form of a tablet or similar device located directly at the patient's bedside. All kinds of streaming services can be used for entertainment purposes. In addition, non-medical hospital services can also be used. For example, hairdresser visits can be scheduled or meal choices made.

Mobile identity access serves access management. It involves a centralized, digital key management system with which access to the controlled-substances cabinet or other critical areas can be monitored and documented. This prevents the misuse of medications.

Nursing documentation via voice bot greatly facilitates the daily rounds of nursing staff. With the help of voice bots, documentation can be created that is then fully automatically transferred to the hospital information system. Furthermore, the patient can use this voice bot as an assistant. Similar to, for example, Alexa, this voice bot offers the patient entertainment options as well as control of smart devices.

The last area in nursing management is **hygiene management**. Here, sensors can be used to monitor the fill level of disinfection stations. Furthermore, hygiene measures are precisely documented. IoT sensor technology helps to keep the hospital consistently clean throughout. This further relieves the burden on hospital staff.

10.7 Hospital Administration 4.0

In addition to the value-creating core processes, the supporting processes must also be digitalized. These likewise benefit from intelligent networking within the hospital.

Applications, which are now submitted almost exclusively online, can be forwarded to the correct ward within seconds. **Absence planning** is greatly simplified due to electronic vacation requests, training requests, or sick notes. These requests are also, after approval by the supervisor, forwarded fully automatically to the relevant departments.

Currently, a great deal of sensitive data is transmitted via inadequately protected channels, such as WhatsApp. A **staff app** can remedy this. This simplifies communication within a hospital, and data protection regulations are complied with while IT security is ensured.

10.8 Patient 4.0

The development toward Clinic 4.0 changes not only the processes within the hospital and the role of the physician, but also the role and tasks of the patient. The focus of digitalization should not be solely on the monetary possibilities, but rather on the **optimal care of patients**.

The distinction between inpatient and outpatient care is increasingly disappearing. Telemedical methods offer the patient the opportunity to draw on expert knowledge from home or from the nearest hospital. Through **home monitoring** and the wearing of **wearables**, patients may in some cases be spared an inpatient treatment. The required data can be collected remotely, and further treatments can be planned on this basis.

The **ePA** stores all data and information in a central location. For example, X-ray images no longer need to be sent from physician to physician; instead, access is possible at any time. This gives the patient full control over who can view their medical data.

Through **hospitality entertainment**, the patient can access information about their upcoming appointments and the treating physicians, or arrange follow-up appointments online.

The role of the patient is changing, and the patient becomes master of their own affairs. They are actively involved in the treatment and can help shape and manage their own course of treatment. This gives them responsibilities that they did not have before, but in return they gain all the described advantages of a digitalized healthcare system.

10.9 Research and Teaching 4.0

The further development of medicine represents an enormously beneficial side effect of the digitalization of hospitals. The training of new physicians is also being facilitated.

By using cross-hospital **video conferencing systems**, students can virtually participate in operations. **VR** and **AR** offer the opportunity for aspiring physicians to practice their first operations in a simulation. This allows them to gain experience without putting patients at risk. Experienced physicians can also use these techniques to train for complex operations or rare complications.

Algorithms based on **AI** or **machine learning** advance medical research. To gain new insights into certain diseases, large amounts of data (**big data**) are required. The data needed for such algorithms is often available in individual hospitals, but cannot easily be combined. Networking hospitals would eliminate this problem. With the help of **big data analytics**, this data can be analyzed and new insights gained. This information not only serves medical research but also supports physicians in decision-making for the individual treatment of, for example, tumors. In the case of such a disease, there is a large number of treatment options, which is why selecting the best option represents a major challenge for the physician.

Risk Assessment

The greatest risk is posed by **computer viruses**, which manipulate data, render it inaccessible, or publish it. A ransomware virus, for example, encrypts the data on a hard drive, and access can only be restored after a password is entered. Hackers usually demand a ransom for this password. Although the hospital has the option of restoring a backup, this takes a great deal of time. Such a situation can have extreme consequences. Damage running into the millions can occur, since no exchange of information is possible anywhere in the hospital. Furthermore, in a digitalized hospital, such an incident can bring operations to a halt, which in the worst

case can cost human lives. IT security therefore plays a decisive role for Clinic 4.0. If it cannot be guaranteed, the foundation for digitalization is missing.

A similar issue is **data protection**. Patient-related information must under no circumstances reach unauthorized persons. The patient must have full access to their own data at all times and must have the assurance that the data actually only reaches the persons to whom they themselves have granted permission.

This leads to the next risk, namely **liability risk**. If a system fails due to a cyberattack, or if artificial intelligence decides incorrectly about further treatment and a human life is lost, disagreements arise over the attribution of blame and liability. Who is liable in such a case must be clarified before the deployment of state-of-the-art technologies.

In summary, it must be said that the risks arising from Clinic 4.0 represent a significant threat. Nearly all new risks are based primarily on software solutions. Therefore, no expense or effort must be spared in development to make every piece of software as secure and reliable as possible. If this hurdle is overcome, Clinic 4.0 offers more advantages than disadvantages. Time and costs are saved, and above all, patient care is improved. Research and teaching are advanced, which will lead to new medical insights and will further reduce mortality.

10.10 Telemedicine

Telemedicine can be defined as medical consultation across spatial distance. In the context of eHealth, it can be assigned to the eCare area. Medical support is provided in the areas of diagnostics, therapy, and rehabilitation. This is done through the use of information and communication technologies.

Telemedicine offers a number of applications, both for the exchange of information between physicians (doc2doc) and for communication between physician and patient (doc2patient). However, such care cannot replace a physician, but rather supplements the treatment in order to increase the quality of care. The various scenarios can be divided into three areas:

- Teleconsultations
- Telemonitoring
- Teletherapy, tele-advice, and e-triage

In **teleconsultations**, several physicians come together and discuss the further treatment of, for example, patients with tumors. The structure of such a teleconsultation is a cooperation among equal participants. Thanks to the intelligent networking of hospitals, the X-ray images are available to every physician, and together – ideally even with the support of artificial intelligence – the best possible treatment option can be defined.

Such a scenario is illustrated in Figure 10.5 "Teleconsultation". The nurse, who takes the patient's vital parameters, is connected directly by video conference to the physician and a specialist. They can see one another as well as the live parameters in front of them. Together, the best treatment strategy can be developed in this case. All information that is discussed can be centrally printed for the patient and the nurse and stored in the ePA.

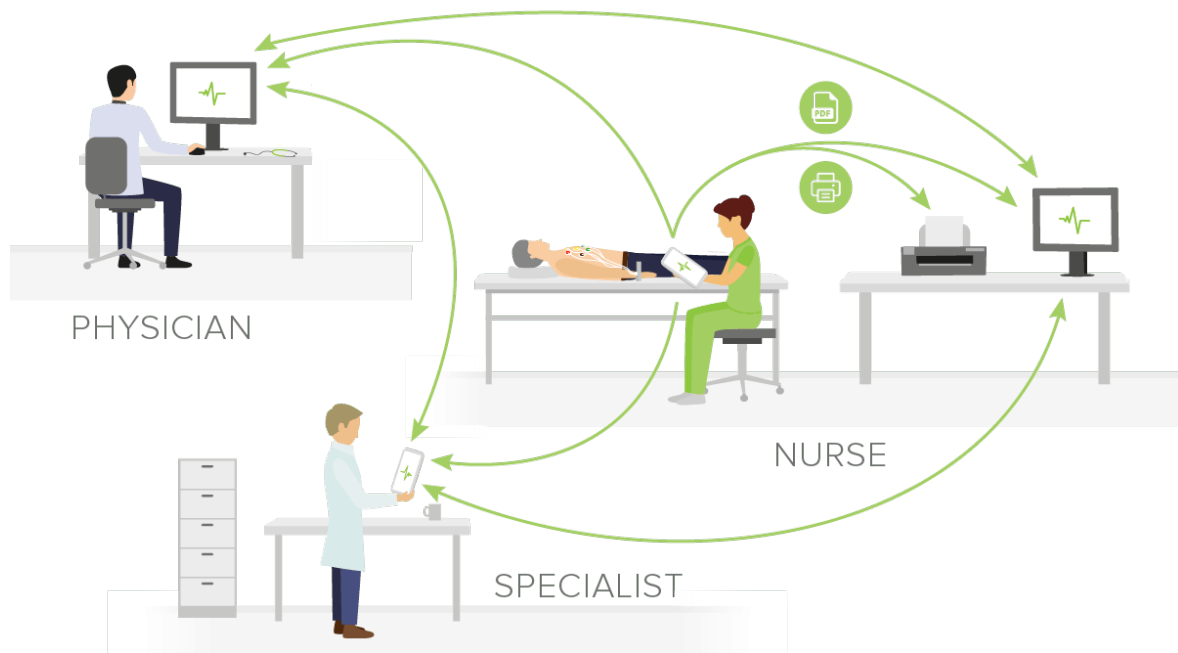


Figure 10.5: Teleconsultation

Telemonitoring serves the continuous monitoring of specific health parameters of the patient. In particular, remote monitoring of chronically ill patients can ease their lives or, in some cases, even save them. Here, wearables and home monitoring help to detect changes in the stage of a disease or emergency situations in time and to initiate appropriate measures [?].

Teletherapy can be used for mental illnesses. Consultations with a psychiatrist can be held online. For physical concerns, **tele-advice** offers good opportunities to save time and money. In tele-advice, a doctor-patient interaction takes place. This option is used primarily for uncomplicated matters and follow-up examinations. **E-triage** is an online tool or telephone service that helps patients assess whether a hospital visit is really necessary. Complaints can often already be clarified remotely, thereby relieving the burden on the hospital.

Tele-Intensive Care Medicine

Tele-intensive care medicine, combining the two areas of teleconsultation and telemonitoring, represents a distinct area of telemedicine in its own right. The special feature of tele-intensive care medicine is that a teleconsultation can be convened around the clock, as needed. The procedure is the same as already described in Figure 10.5 "Teleconsultation". The structural setup of a teleconsultation in intensive care medicine can take the form of either a **hub-and-spoke structure** or a **cooperation of equal intensive care units**.

The most common form is the hub-and-spoke structure. Figure 10.6 "Hub-and-Spoke Structure" illustrates a schematic of such a setup. The core of the hub-and-spoke structure is the tele-intensive care center. It acts as a video conferencing unit and establishes a secure data connection, for example via a VPN server. It is also responsible for the transmission of laboratory values, images, or monitoring data. Furthermore, it is responsible for electronic documentation. The participants in this area are specially trained tele-intensive care physicians as well as further experts. The tele-intensive care center connects with a wide variety of hospitals or partner intensive care units.

Every partner intensive care unit must have a mobile video conferencing unit so that it can connect with the tele-intensive care center at any time. The partner intensive care units are the

places where patients are admitted and treated. A treatment team consisting of physicians and nursing staff is indispensable here. This results in a four-eyes principle for treatment, through which decisions can be made more easily and precisely. If required, additional specialists can also participate in such a round.

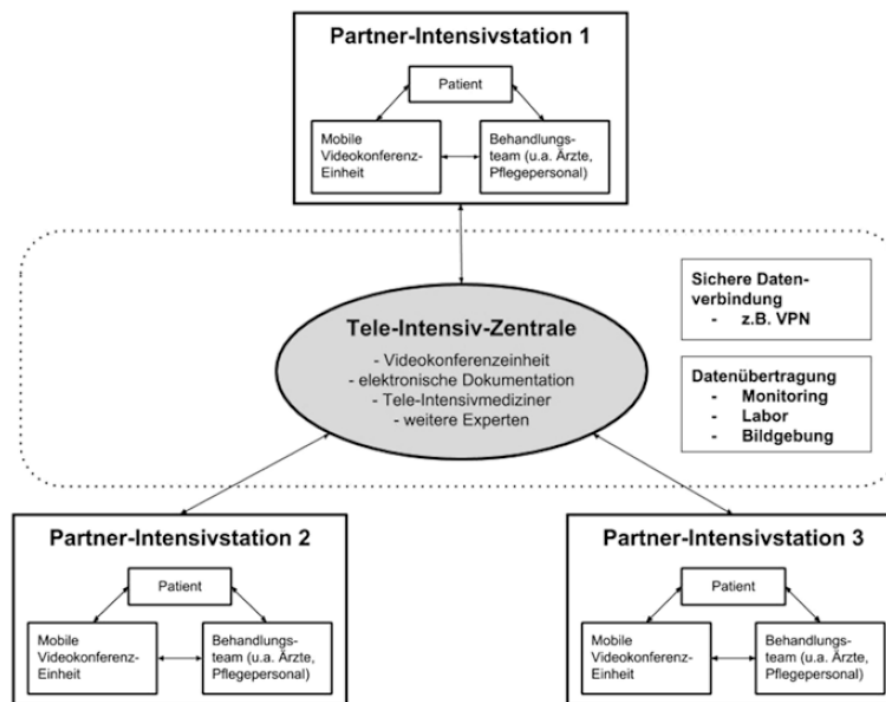


Figure 10.6: Hub-and-Spoke Structure

Effects of Telemedicine

Telemedicine offers a great many advantages and influences the following aspects:

- Influence on mortality and length of stay
- Influence on the implementation of treatment guidelines
- Influence on sepsis mortality
- Algorithms and early warning systems
- Tele-emergency medicine
- Tele-stroke care
- Smartphone applications

Telemedicine, or tele-intensive care medicine, has a positive influence on **mortality and length of stay**. This is due to:

- More frequent consultations
- Earlier analysis of clinical indicators
- Higher treatment adherence
- Faster response in emergencies

mortality and length of stay are reduced. Furthermore, patients need to be transferred less often. This saves the time and costs that would otherwise arise from transports, and the chance of recovery is increased.

The implementation of treatment guidelines is likewise positively influenced. Through telemedicine, specialists from other locations can be consulted. A pharmacologist is often involved in the treatment, who can quickly identify medication non-compliance.

About eleven percent of the roughly 2 million people who are admitted to intensive care units in Germany each year develop severe sepsis (blood poisoning). Once sepsis occurs, there are precise specifications for which measure must be taken at which point in time. If these measures are not initiated, the chances of survival for the patient are relatively low. The implementation of these measures is currently very unreliable. Through tele-visits, the measures can be implemented more effectively, and the chances of survival for patients increase enormously.

Through **algorithm-based monitoring systems**, organ malfunctions can be detected at an early stage. The immediate initiation of appropriate measures significantly increases the patient's chances of survival. Telemedical **early warning systems** are predominantly used in the outpatient setting and enable patients to continue their normal lives. The non-invasively measured vital signs are continuously monitored in a telemedicine center. Changes or abnormalities in this data are detected early, and medical care can begin.

In the event of an emergency response, **tele-emergency medicine** can play a decisive role. All data recorded by the emergency team on site is forwarded via a mobile communication and transmission unit to a tele-emergency physician center. Here, a tele-emergency physician is stationed who can be connected in real time to the scene of the accident. They receive all vital data as well as a live video transmission. In non-life-threatening situations, the tele-emergency physician can delegate to the emergency personnel. In life-threatening situations, the time until the emergency physician arrives can be put to meaningful use. This results overall in a reduction in emergency physician deployments and a relief for the healthcare system.

Especially in rural regions, too much time passes between the occurrence of a stroke and the correct treatment. **Tele-stroke care** provides a remedy here. Immediately after the admission of a stroke patient, a stroke expert is consulted with the help of a telemedical method. Based on their expertise, this expert can then initiate the correct treatment steps and appropriate therapy without having to be on site in person.

Finally, **smartphone applications** can also ease the lives of sick people. Although follow-up examinations should be a matter of course after treatment has been completed, they far too often do not take place. Through smartphone applications, patients can electronically document symptoms in the period following treatment. These can be monitored by the treatment team and specialists. By incorporating an audio-video conference, contact can be maintained and the overall quality of care increased.

In summary, it can be said that telemedicine offers extensive support both in the outpatient care of chronically ill patients and in emergencies. The quality of care is increased, and the chances of survival in particularly urgent cases grow enormously. For this reason, telemedical applications must be focused on and expanded in future. However, this first requires the prerequisites to be created through networking of the healthcare system within the framework of a Clinic 4.0.

10.11 Summary

In light of all the aspects now presented, the digitalization of the healthcare system is a firmly established part of the future of medicine. Demographic change and rising life expectancy are forcing a transformation and confronting the healthcare system with numerous challenges. A digital care network must be developed, and interoperability must be ensured. Paper documents must be eliminated and system discontinuities removed. All actors in the healthcare system must in future work together on a shared platform (the telematics infrastructure). Only in this way can the shortage of skilled workers be overcome, the costs of healthcare provision be kept within limits, and an improvement in patient care be ensured.

In Germany, around 34 billion € can be saved annually through a digitalized healthcare system. Most of these costs can be saved in the area of a modernized or digitalized Clinic 4.0 as well as through telemedicine.

In Clinic 4.0, networked technologies are introduced and real-time communication is enabled. This will allow all areas to continue developing. The physician will lose their role as a general practitioner and take on a role as a specialist within a team. The patient is required to take on more responsibility and independence, but in return gains greater influence over their own treatment process. Nursing care is greatly relieved through mobile documentation systems, location systems, electronic order-entry systems, hospitality entertainment, and further systems. Administration will run more smoothly between the individual departments. Research and teaching can make use of VR and AR to practice operations and rare situations. Through algorithms, machine learning, and big data analyses, new insights will be gained, and previously incurable diseases will be brought under control.

Telemedicine, with teleconsultations, telemonitoring, teletherapy, tele-advice, and e-triage, has a positive influence on many areas of life. For example, mortality and length of stay are positively influenced. People in rural regions can thereby be cared for more quickly, and early warning systems increase the chances for at-risk patients.

Computer viruses, data protection, and liability risks do indeed represent new risks that must be overcome. However, once these have been eliminated, Clinic 4.0, in conjunction with telemedicine, holds a promising future for a better life.

CHAPTER 11

Digital Administration

Learning Objectives

After working through this chapter, you will know...

- ... what is understood by digital administration
- ... which advantages and disadvantages digital administration brings with it
- ... which challenges must be overcome in Germany
- ... which technologies help with this and how they can be deployed
- ... what a fully digital administration can look like.

11.1 Introduction

Among the population, the desire for digital processes is growing beyond the private sector and extending to digital processes in the state sector. The drivers of this affinity for digitalization in the private sector are the large tech companies, which, with their simple, affordable and user-friendly applications and products, have ignited people's enthusiasm for digitalization – whether through smartphones, smartwatches, or the numerous other useful inventions such as Apple Pay.

Moreover, the coronavirus crisis demonstrated impressively how digital networking among German public authorities actually stands, and how much work in relation to digital administration in Germany still needs to be done. Good examples of this are the numerous coronavirus mishaps, which were not previously known to the broader German population to this extent. This includes, for example, the contact tracing of people who had become infected with the coronavirus. Here, health authorities attempted to trace chains of infection via telephone contact. Furthermore, there is the still-existing problem that German public authorities have not managed to create an interface through which coronavirus case numbers could be reported digitally to a central location, without having to resort to the proverbial technological standard of German public authorities: the fax machine.

11.2 Definition

Digital administration, also called e-government, is understood as the simplification of internal as well as external workflows in administrative institutions. This simplification is achieved with the help of **ICT (Information and Communication Technology)**. The use of these modern ICT technologies is intended to enable access to services digitally in the future as well. With regard to internal and external workflows, a distinction can be made between four different relationships. These are: [?]

Government to Government = G2G

Government to Citizen = G2C

Government to Business = G2B

Government to Employees = G2E

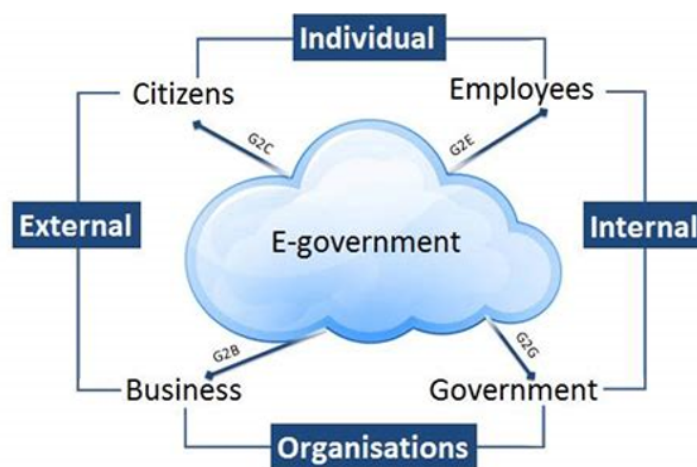


Figure 11.1: The various relationships in e-government [?]

The relationships mentioned above show that digital transformation across the various state institutions offers a multitude of new possibilities for the most diverse interest groups, such as cities, municipalities, communities as well as companies and citizens. Administrative procedures thus become **simpler, more flexible and more transparent** for various interest groups.

11.3 Reasons for Digitalization as well as Advantages and Disadvantages

Due to private-sector digitalization and its **demands on Germany as a business location**, it is in Germany's own interest – for the sake of the attractiveness it wants to represent as an international industrial location – to drive forward the digitalization of processes. Only in this way can a society-wide digitalization process succeed, from which all interest groups can benefit from one another. This results in the necessity of using the freely available opportunities provided by private-sector companies, in order to **fulfil tasks better, more economically and more efficiently**.

The great advantages of e-government arise, on the one hand, from the **constant availability of services**, which can thus be accessed independently of time constraints, and on the other hand from the advantage that in the future, public offices no longer need to be visited in person, but that applications can in many cases be processed online, also **in real time**.

These advantages are not limited to the needs of citizens, but also offer public authorities numerous positive effects, since specialist staff can be saved for many routine tasks, allowing this specialist staff to devote themselves to more challenging activities. Furthermore, electronic data can be handled and stored much more easily, resulting in efficiency gains that can benefit other municipal projects in the future. Another essential aspect is the resulting flexibility that comes into play. Documents can thus be accessed from anywhere, which also enables home-office working in administration – an important factor for the attractiveness of the workplace, since public authorities compete with private companies for qualified staff. All in all, it can be stated that the result is a **leaner, accelerated process**.

The disadvantages of e-government consist mainly of **data protection issues**, which arise from the transmission of citizens' information over the internet. With well-thought-out IT security measures, the issue of data protection can be effectively addressed here. In addition, there is the disadvantage of **incomplete accessibility**, since access to online services requires certain knowledge [?].

11.4 Laws

E-Government Act

The E-Government Act was enacted on 25 July 2013 and came into force on 1 August 2013. The Act serves to promote electronic administration.

"The key points of the Act can be presented as follows: Article 1 is the E-Government Act. The essential provisions are:

- Obligation of the administration to establish an electronic channel, and additionally of the federal administration to establish De-Mail access,
- Principles of electronic file management and substitute scanning,
- Facilitation of the provision of electronic evidence and of electronic payment in administrative procedures,
- Fulfilment of publication obligations through electronic official gazettes and bulletins,
- Obligation to document and analyse processes,
- Regulation for the provision of machine-readable data holdings by the administration ('open data')" [?]

Government Programme "Digital Administration 2020"

The government programme "Digital Administration 2020" was adopted by the Federal Cabinet on 17 September 2014 and constitutes a kind of **action guide** for implementing the E-Government Act [?].

Online Access Act

The Online Access Act, or OZG for short, is the second important law in Germany that enables digitalization in public authorities.

The OZG is a law passed on 18 August 2017 that is intended to guarantee access to all administrative services by the end of 2022. The Act obliges the participating public authorities to make all administrative services accessible electronically via the administrative portal as well. There are exceptions only for a few administrative services which, for particular reasons, cannot be made available digitally. These exceptions are as follows:

citeVorteile

- "factual impossibility (e.g. emptying a rubbish bin),

- legal impossibility (e.g. the issuing of a new identity card, which by law requires the applicant to appear in person), and
- economic impossibility according to the cost-benefit calculation (i.e., for example, the application to operate a new nuclear power plant)."

The **Federal Portal** is a portal in which, in the future, all administrative services of the German public authorities will be mapped. Furthermore, after entering a search term, a status regarding the digitalization progress of the respective service can be retrieved. Here, information is provided as to whether the service can be carried out fully, partially, or not at all in digital form.



Figure 11.2: Home page of the Federal Portal [?]

The following section illustrates, by way of example, the process for a fully automated administrative service.



Figure 11.3: Process of a digital service

As can be seen in the figure, the Federal Portal must first be accessed. The desired administrative service can then be entered into the search field. If this service is available digitally, a login must be carried out using the identity card, which has the eID function activated. The corresponding application can then be filled out and finally submitted.

11.5 Application of Existing Technologies in the State Apparatus

Since digitalization is continuously advancing and the world is in a constant state of change, there are also, in the field of digitalization in administration, constantly new possibilities and technologies that can be implemented in the future.

Science is already engaging today with further additions for the further development of digital administration. Among other things, the term **Smart Government** is mentioned, which is regarded as apt for the future embedding of technologies into digital administration. Technologies such as **blockchain**, **artificial intelligence** and **big data** find application here.

The following graphic illustrates and names the technologies available today and shows examples of application, of how these can be used within the state apparatus.

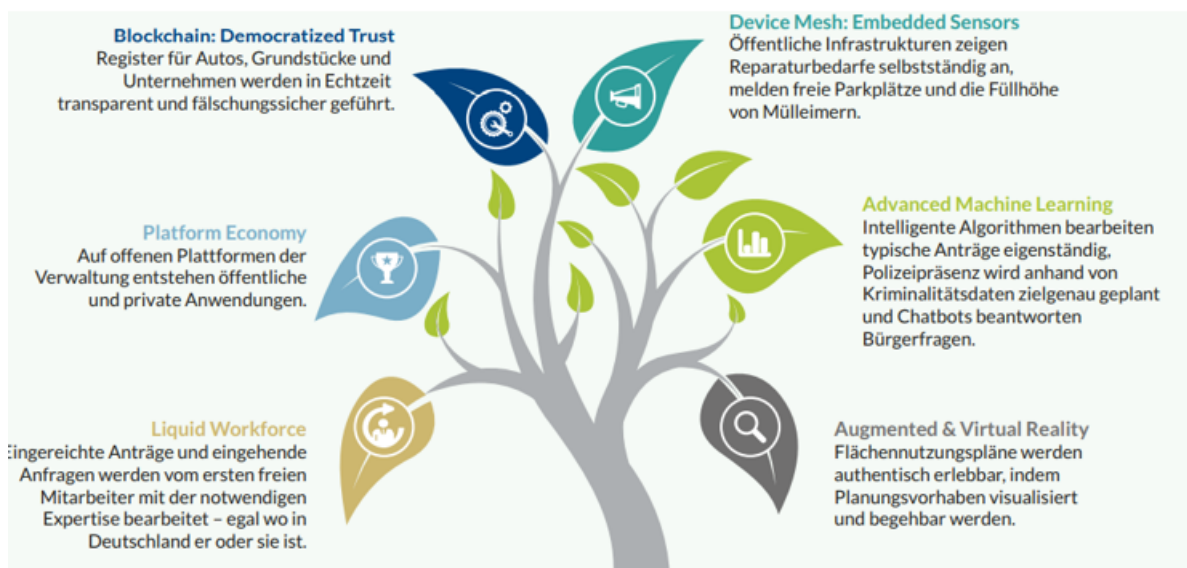


Figure 11.4: Technologies and their fields of application [?]

These technologies, together with their fields of application in state institutions, are presented below. On the one hand, possibilities that are currently not being taken into account shall be shown; on the other hand, active attention shall be given to fields of application that are currently already being implemented.

One of the technologies that administration could make use of is **blockchain technology**. With a view to the tasks of administration, two major thematic blocks can be identified here in particular. On the one hand, within the process landscape of administration, the topic of certifications as well as the various registers plays an extremely important role. This concerns both the maintenance of citizens' data as well as the maintenance of data on motor vehicles and property, all of which make the organization of communal life possible. On the other hand, administration holds the role of a fair, objective and neutral intermediary, which through its presence makes certain processes possible in which trustworthiness plays a central role. For this purpose, administration has developed, over centuries, a multitude of tools such as deeds, seals, stamps, certificates and more, in order to safeguard legal certainty for everyone.

This is where blockchain technology can intervene and **redefine the role of administration**, since blockchain technology is precisely predestined to hold data in a neutral, immutable and decentralized manner. This makes it possible to replace existing registers and certifications. Data storage on the blockchain – such as identity cards, weapons or vehicle data,

patient data as well as birth certificates and land register entries – becomes possible [?].

Augmented Reality can be used in the future to first inspect planning projects virtually. Various different perspectives can be adopted, taking the natural environment into account. A further possibility lies in the measurement of objects, where VR glasses display the dimensions directly to the user [?].

Within the scope of machine learning and artificial intelligence, there is a multitude of use cases that can be covered with the help of the new technology. Various possibilities are shown in the following figure.

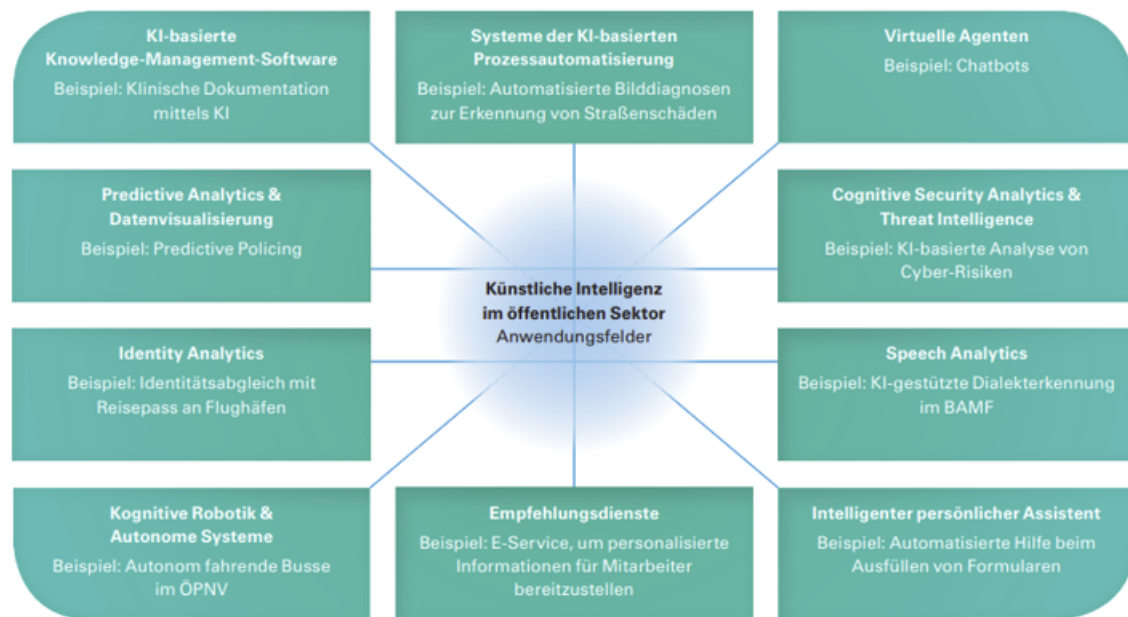


Figure 11.5: Fields of application of artificial intelligence [?]

The technology of the **Internet of Things** will make smart city concepts achievable, which aim at an efficient, technological, sustainable, social and just city. Here, embedded sensors are to play the central role, contributing with their data from the environment to the intelligent management of the city. For this purpose, the sensors record various data in the streets, for example air quality, or the state of empty streets, which then causes the street lamps to switch off in order to save electricity. Furthermore, sensors are already being used today to detect flood and wind hazards at an early stage, so that appropriate measures can be initiated. Traffic measurements on motorways are also already a reality today and attempt to detect hazards and emerging traffic jams at an early stage [?].

11.6 Challenges

In order to harness the transformation potential that digitalization offers to German administration, decisions are needed that release the brakes.

A major **challenge** here is posed by our **federal system**, according to which Germany is organized. Since innovations here often only succeed on a small scale, and the overall system shows little capacity for innovation.

"Joint action is thereby made more difficult because

- political opinion-forming processes are largely decoupled and run in staggered cycles,

- the actors in the departments and IT units, in municipalities, federal states and at the federal level pursue different goals, and
- IT investment decisions from the past continue to have an effect, because different paths were taken that, due to lock-in effects, can only be abandoned with great difficulty." ¹

These challenges are illustrated once again graphically in the following diagram and show the **inertia** with which the **expansion of digitalization in administration in Germany** is taking place.

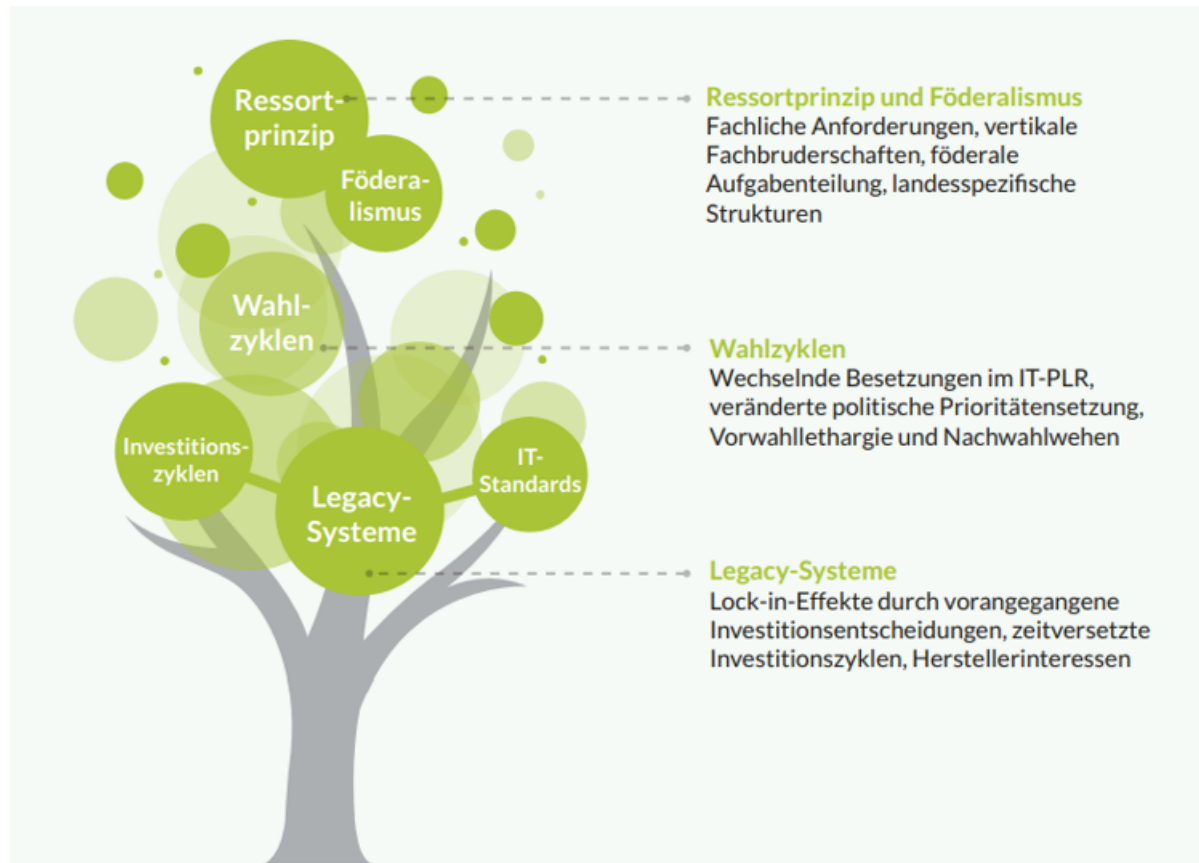


Figure 11.6: Challenges of the federal system [?]

In order to consistently and successfully drive forward digitalization in public authorities, adherence to a strategy is required. First, a **joint consensus** must be found, by which everyone can orient and align themselves. In addition, a shared vision must be formulated. Once this first hurdle has been overcome, the second step of the recommendation pyramid (figure below) can be applied. This involves administration showing itself to be open to innovation, incorporating the ideas of stakeholders, and increasing the **speed of implementation**. In addition, processes must be able to be used across existing organizational boundaries. For this, uniform interfaces and standards must be created. Building on this, it is necessary to ensure secure administration, so that citizens' data is handled responsibly. Furthermore, it must be possible to intelligently incorporate the collected data into decision-making. The foundation of the digitalization system is formed by a legal framework, which must be designed. The laws adopted within this legal framework are needed in order to guide digitalization in the right direction.

1 [? , Beck p. 21]



Figure 11.7: Recommendation pyramid for implementing digital administration

11.7 Example of a Fully Digital State

In the following, the example of Estonia will be used to illustrate one possible approach to digital administration.

In Estonia, a digital proof of identity has long been standard. Unlike in Germany, the identity card in Estonia also continues to serve additional functions, such as those of a driving licence or a supermarket loyalty card. Estonia has created a way for a digital signature to be legally binding. For this, only the identity card and a PIN are needed, with which a digital signature can be formed. No documents therefore need to be signed by hand any longer. The system behind this is called **X-Road**. In Estonia, all data only needs to be provided to a public authority once. That authority can then, in turn, access the data of other authorities if this is compliant with data protection requirements. In this way, all authorities only obtain access to citizens' data that they actually need to work with. The advantage for the citizen here is the **once-only principle**. Any data only needs to be submitted once, so that in the event of a change of address, this only needs to be done once.

To promote trust in the state apparatus, Estonia has created an access point where citizens can look up who accessed which data, for what reasons, and at what point in time. Furthermore, this allows citizens to find out what data the state holds about them.

Data that the residents' registration office in Estonia needs to know following the birth of a child is transmitted directly from the hospital. In addition, immediately after birth, a person receives a personal ID by which they can be identified. State benefits such as child benefit therefore do not need to be applied for, but are transferred automatically. By comparison: in Germany, the birth certificate must be sent by post at least three times to different authorities. According to figures from the Estonian government, 99 percent of administrative procedures can be carried out digitally. Only marriages, divorces and house purchases are not yet possible digitally. For these, even in Estonia, one must still appear in person ¹.

1 [? , cf. Beck p. 16 ff.]

In conclusion, the following figure is intended to impressively show which topics and which fields of action must be observed and taken into account in the transformation towards digital administration in Germany.

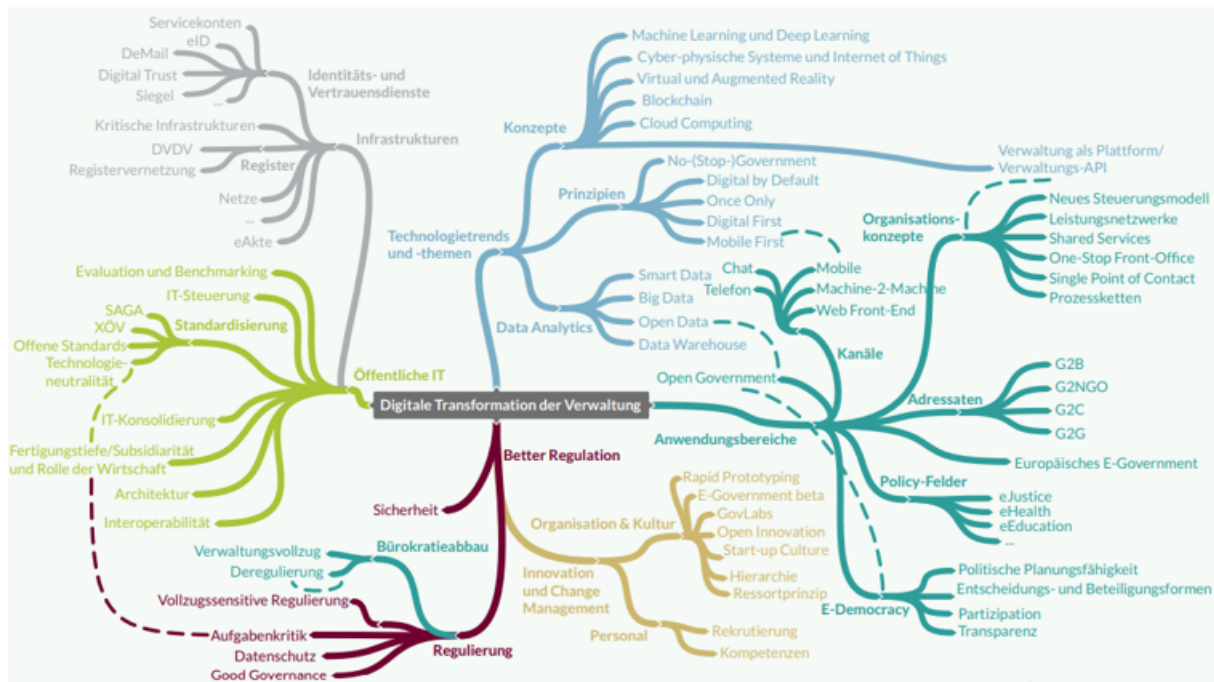


Figure 11.8: Fields of action of digital transformation

11.8 Summary

Digital administration is already being applied today, as was shown using the example of Estonia. Digital administration will, sooner or later, also become established in Germany, although it became clear here that in Germany some fundamental conflicts still need to be resolved before the same administrative procedures found in Estonia can be encountered here. Nevertheless, it was shown what potential can be harnessed with digital administration in Germany, and how it secures Germany as an industrial location. Digital administrative processes promise a much faster, more efficient and more cost-effective alternative for Germany. Not only can a considerable number of positions be saved as a result in the future – no, there is also the advantage that citizens gain with e-government. They can avoid future visits to public authorities and carry them out at a time of their choosing.

CHAPTER 12

Digitalization of Culture

Learning Objectives

After working through this chapter, you will know...

- ... what digitalization means in the arts.
- ... what projects for the digitalization of culture can look like.
- ... what digital art can look like.
- ... what the Fonds Digital is.

Introduction

Cultural digitalization describes the approach of digitalizing culture in as many areas as possible, such as music, theater and works of art. Since this encompasses all aspects of culture, it is also a very wide-ranging topic. It ranges from the digitalization of works of art, through new possibilities for the concepts of cultural institutions, to digitally created art. A large number of projects dealing with digitalization in all of these aspects are already under way, and new ones are added every day.

This chapter gives a first insight into the digitalization of culture and some of the projects that have emerged from it.

First, projects and art forms that have already been implemented are presented, followed by a brief description of the German Federal Cultural Foundation (Kulturstiftung des Bundes) and why it is so important for the promotion of digital culture. The chapter concludes with the funding program Kultur Digital, which describes how projects will be funded and implemented in the future.

12.1 Projects

In this chapter, various projects are presented in order to make the topic of cultural digitalization more tangible and to once again highlight the different aspects and possibilities of digitalization. In general, the projects can be divided into three artistic areas:

1. digitalization of art institutions
2. digitalized works of art
3. digitalization of music and theater productions

12.1.1 Digitalization of Art Institutions

The **Museum als Co-Labor** (Museum as Co-Lab) falls under the category "digitalization of cultural institutions. In Museum als Co-Labor, the project partners are committed to conveying archaeological practice and expertise in a new way by creating digital applications. Museums are supported by an advisory board in the design of **digital serious games**¹ and in the development of digital installations for the various institutions. In game jams and workshops, participants develop digital and interactive formats together and test them. During testing, experiments are conducted with techniques such as:

- Augmented Reality (AR)
- mixed-reality headsets
- LiDAR scanning²
- photogrammetry

The focus is on collaborative, process-oriented and co-creative work. The stated goal of the project "Museum als Co-Labor" is to implement digital applications in exhibition practice on a long-term basis and thereby sustainably shape the transformation of museums into co-labs. The institutions are supported by experts from digital, marketing and consulting agencies, who not only bring technical knowledge but also train staff in working with agile and digital methods. The younger generation will in future be responsible for preserving and passing on history and culture, yet this raises the question of how this is supposed to work if engagement with history and culture is lacking.

Museum als Co-Labor addresses precisely these questions, because the participants have long been aware of the following:

Digitalization is no longer the future, but has long since become the present!

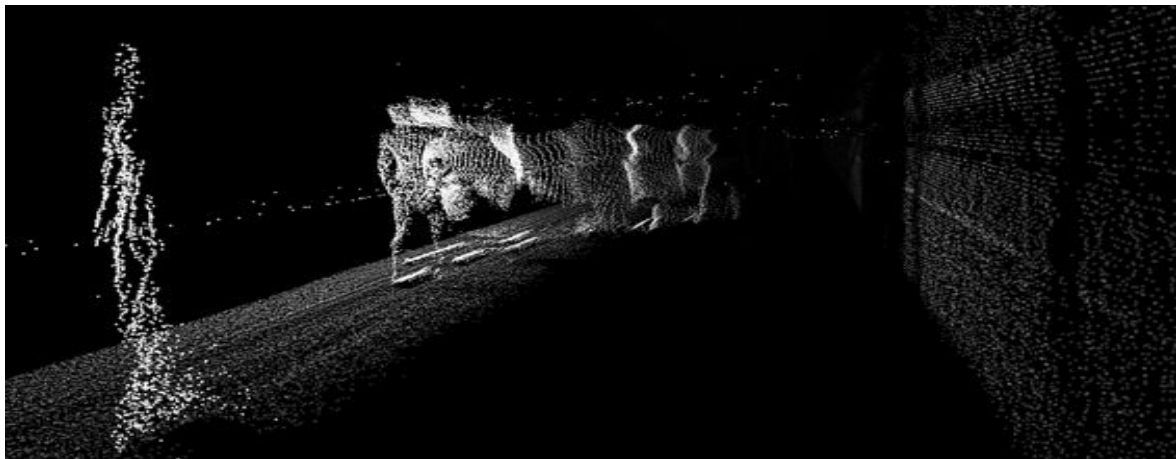


Figure 12.1: Interior of a museum scanned using LiDAR technology

¹ These are games that take place in a hardware- and software-based virtual environment and aim to stimulate the learning of specific, desired content.

² A form of three-dimensional laser scanning used for optical distance and speed measurement, as well as for remote measurement of atmospheric parameters.

12.1.2 Digital Art

Digital art can be viewed from various perspectives. These can be categorized into the following five points:

1. historical perspective
2. artistic genre
3. computer science
4. video games
5. computer as a tool

When looking at digital art from a **historical perspective**, one traces the history of the computer and, beyond that, the history of the machine in the service of art.

From the perspective of **artistic genre**, digital art can be found in every field. It exists in the visual arts as well as in the performing arts and in literature and music.

From the perspective of the scientific discipline of **computer science**, digital art spans many areas, ranging from the spectrum of digitalization, through digital humanities, to data archiving. A particular case of digital art from the computer-science perspective is **video games**. Here, entire worlds and landscapes are created, depicted in the most diverse designs and modes of representation.



Figure 12.2: Here one sees an excerpt from the game Ghost of Tsushima, which won the Game Developer Choice Award in the category of visual design

The last perspective is the **computer as a tool**. Here, the diverse range of possible applications in art stands out in particular. The machine is at the same time also an adequate means of making art **contemporary**.

With digital art, it is striking that it has a surprisingly low visibility in museums, archives and artistic discourse.

NFT Art

So-called **NFTs** (non-fungible tokens) are tokens that cannot be replaced. This means that once an NFT has been acquired, it can no longer be sold for the same price. It behaves like an investment, whose value rises or falls depending on market conditions.

An NFT is a purely **digital asset** that exists only in the digital universe. For the buyer, this means that one can only ever **own** an NFT. NFTs can be any digital file. They range from works of art, articles, and music to memes¹.

The boom for NFT art began around April/May 2021. Since then, search terms relating to NFTs have been trending, especially on platforms such as TikTok, Twitter and Instagram. This rightly raises the question: "What influence will the digital form of art sales have on creatives and the industry?" What can already be said is that NFTs are no longer just a **hype**, but rather a **longer-lasting trend**.

With NFTs, there is for the first time a chance to own digital content. Previously, one only downloaded digital content such as songs or sent images without thereby becoming the owner of that content. This has changed fundamentally with NFTs. Artists can now freely decide whether they want to lend, sell, or even exhibit their NFTs. An environment is developing in the **digital space** that is increasingly **converging with reality**.

In order to legally own NFTs, they must first be minted, i.e., turned into a **token**, using a **blockchain**. The advantage of the blockchain is that it is very well protected against **hacking attacks**. This can be particularly important when tracing copyright, since it is very difficult to introduce false information. Simply put, one can say that a digital work of art **belongs exclusively to the artist**, provided they minted it. Currently, however, the legal situation regarding the ownership of digital works of art is being reviewed once again.

The trading of digital art gives artists a new way to categorize their works and also to earn money from their work. The goal of this form of art distribution, from the artist's point of view, is a very **fast and simple** way to produce works and reap their rewards. The great advantage that results from this is that one no longer has to wait for payments from customers, prepare files for printing, or wait for customer feedback regarding adjustments.

In addition, there are **royalties** on NFTs that are collected by the creator. These usually amount to **8-10 percent** if the work is **resold** in the future. The general danger in trading digital art is that its value is based solely on cryptocurrencies. So if cryptocurrencies fall over a long period, the value of NFTs and crypto artworks falls at the same time. The cryptocurrency in which trading takes place is called **Ethereum**².

In order to better grasp the scale of NFT trading, here are a few examples of the currently most expensive NFTs:

- Rank 1: **Everydays: the First 5000 Days**
- Rank 2: **CryptoPunk #7523**
- Rank 3: **CryptoPunk #3100**
- Rank 4: **Crossroad**
- Rank 5: **the first tweet**

At the end of 2021, the **40-billion-US-dollar** mark was broken on the NFT market. In March 2021, the **most expensive NFT artwork** to date was sold for **69.3 million USD**, under the title "**Everydays: the First 5000 Days**". The artwork shows a compilation of the first 5000 digital artworks by Beeple. What is special about the artwork is that the artist

¹ These are creative content, usually images or short videos, that are primarily spread on the internet. The content is usually humorous and lighthearted, sometimes also socially critical and satirical.

² This is an open-source, distributed system that offers the creation, management and execution of decentralized programs or contracts on its own blockchain. It is thus a counter-design to the classic client-server architecture.

Beeple began creating digital artworks as early as 2007. Since that day, he has created a new artwork every day and combined them into the work "Everydays: the first 5000 Days". The compilation contains various styles, content and media. The earliest artworks were definitely not up to date, but through the overall concept, the value of the artwork rose rapidly.



Figure 12.3: In this image of the artwork "Everydays: the first 5000 Days", the individual 5000 elements of the overall work can be clearly recognized

The second most expensive NFT is "**CryptoPunk #7523**". It depicts a pixelated portrait of a fictional figure. Fittingly for the pandemic, he wears a surgical mask, further fueling the hype around blockchain products.

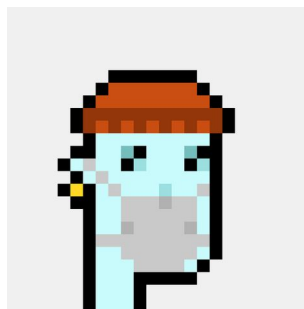


Figure 12.4: CryptoPunk #7523 with his surgical mask

Third place likewise goes to a CryptoPunk. This artwork bears the title "**CryptoPunk #3100**". Whether this one will become the most expensive of its kind in the future is still unclear. The current owner hopes to resell his Punk for **91 million USD**. This would make it not only the most expensive of its kind, but even the **most expensive NFT of all**.



Figure 12.5: CryptoPunk #3100, which is expected to one day fetch record sums

The video "**Crossroad**" was acquired for **6.66 million USD** and is thus the fourth most expensive NFT. On closer inspection, one recognizes a clear **jab** at the former American president **Donald Trump**. In the video, passersby walk past an oversized, fallen Donald Trump figure covered in insults. What is special about this NFT is that it was oriented around the American election campaign. Had the election gone in Trump's favor, the NFT would instead show him **wearing a crown as he walks through hell**.



Figure 12.6: This image is an excerpt from the 10-second video "Crossroad"

The fifth and final NFT on this list is the **first tweet ever written**. It consists of just the words "**just setting up my twttr**". Twitter CEO **Jack Dorsey** sold these words for **2.9 million USD**. He donated the proceeds of this auction to people in need in East Africa. The response from the corporate world followed immediately. The CEO of **Bridge Oracle**, a startup dealing with blockchain technologies, Sina Estavi, commented: "I think years later people will realize the true value of this tweet, like the Mona Lisa painting."



Figure 12.7: Jack Dorsey, founder of Twitter, with the very first tweet

12.1.3 Digitalization of Music and Theater Productions

Theater has always understood itself as a place for reflecting on politics and society. But what does this look like in the digital age? Can cyberspace now also be used as a venue for theater? Are the forms that the internet has developed even usable for the institution of theater at all? Since 2013, discussions and investigations into the consequences of digitalization for theater have taken place in the context of the **Theater und Netz** (Theater and the Web) conference. Topics of the annual discussions include, for example:

- Platform or player? Political art and new activism
- Digital stages of extremism
- Assertion machines: fakes, facts and fictions
- From audience to community
- The innovation screw

In the 14th edition of **Netztheater**, it is described how, due to the coronavirus pandemic, hierarchies dissolve, new workflows emerge, and staff are connected through data streams. At that time, it seemed as though theater in its classical form would have to pause until the coronavirus pandemic was over. In the opinion of some theater practitioners, this was the better solution, rather than offering "bad television" on their own website.

For the Burgtheater in Austria, however, pausing was not an option. Out of the desire to maintain contact with its audience, the series **#MyHomeIsMyBurgtheater** was created. In this series, ensemble members filmed themselves reading **self-chosen texts** that had become important to them at some point in their lives or had accompanied them for a long time. This series reached **50,000** people on Facebook alone in a very short time. The Burgtheater's goal with this alternative program was to maintain customer loyalty and its service to the public.

The great danger at the time was that the internet was being overwhelmed by aesthetically undemanding, self-filmed content. To counteract this, the series **Wiener Stimmung** was created. It significantly raised the artistic bar by awarding 22 paid commissions to Austrian artists. Each of them held a 10-minute monologue, produced with a small team (usually just a sound technician and a camera operator) via video conference due to the crisis. This led to the Burgtheater's **schedule of performances** being replaced by an **online calendar**. The program was also expanded. The formats offered included streams, readings, play instructions, and Zoom workshops. Everything was under the motto **Theater without Theater**.

This gave rise to the Twitter campaign **#vorstellungsänderung** (#changeofperformance).

The idea behind it is that people narrate a performance that exists only in their imagination. In a very short time, 3000 tweets were written under this hashtag, forming a **collective narrative of a theater evening**. What is special here is that the theater neither dictates the content nor intervenes in what happens. With the help of the Twitter algorithm, the hashtag trends in Germany and Austria. The announcement of the fictional theater performance meets the conventional minimum requirements:

1. title
2. genre
3. cast/character setting

Since the art form of theater is very complex, #vorstellungsänderung follows a very simplified and extremely reduced approach: joint play, joint imagination and creation, as well as traditional mechanisms. All participants acknowledge the conventional arrangement of an **evening visit**. The freedom granted by the theater leads to those involved in the series engaging with the following aspects:

- plot
- piece
- implications
- comparison with the sense of the stage
- demands on entertainment and meaning
- emotional involvement

The series **#vorstellungsänderung** is a unique experiment in the tension between art and creativity on the one hand and the possibilities of quantification and commercialization on the other. The goal is not merely to have theatrical performances on a stage in the classical sense, but rather to explore new forms of theatricality in spaces other than the traditional ones, under social restrictions. This raises the question:

“Is the idea that theater takes place in separate rooms already a thing of the past?”

12.2 German Federal Cultural Foundation

In order to better understand the funding program **Kultur Digital** in the further course of this chapter, the significance of the German Federal Cultural Foundation (Kulturstiftung des Bundes) must first be highlighted. This is a foundation whose mission is to promote innovative programs and projects in an international context. For this purpose, it has an annual budget of 35 million euros at its disposal. Since 2002, the German Federal Cultural Foundation has used this to fund around 4,000 projects in the field of contemporary culture. At the center of its efforts, alongside the promotion of art, are cultural exchange and cross-border cooperation. This can be broken down into the following three areas:

1. general project funding
2. program funding
3. cultural lighthouses

Under **general project funding**, projects are funded with up to 10 million euros without restriction by discipline (art, music, theater, etc.). Cultural practitioners can apply for these funds twice a year and, ideally, also receive them. This funding and financial support usually relates to large **international and innovative projects**, such as DOMiDLabs, Jupiter – Performing Arts for Young Audiences, and Kultur Digital.

Program funding runs parallel to general project funding. The difference is that program funding sets **its own priorities**. These can, for example, come from the following areas:

- climate
- digitalization
- structural change
- diversity

The program funding category also includes the funding program **Kultur Digital**, which will be examined in more detail in the following chapter.

The last point funded by the German Federal Cultural Foundation is the so-called **cultural lighthouses**. Here, selected cultural institutions and internationally renowned festivals receive multi-year funding. Through this funding, they above all gain multi-year planning security. Examples of institutions covered by this funding include:

- documenta in Kassel
- the Donaueschingen Music Days
- the Berlin Theatertreffen
- the World Cinema Fund
- the Tanzkongress (Dance Congress)
- ...

12.3 Kultur Digital

Kultur Digital is a funding program that supports cultural institutions in shaping digital opportunities and challenges in a self-determined and public-interest-oriented way. However, to date only a few institutions have developed digital concepts and offerings and advanced their institutions in this direction. The reasons for this include a lack of specialist know-how needed to assess and use the highly dynamic technologies. The Kultur Digital funding program primarily addresses projects that have not yet been implemented, or that are still in the initialization phase. The projects presented here therefore differ from the projects in the previous chapter.

The three-part program **Kultur Digital** fundamentally pursues an **open-access, open-source and open-content** approach.

The components of this program are:

- Fonds Digital
- Kultur-Hackathon Coding da Vinci
- Akademie für Theater und Digitalität (Academy for Theater and Digitality)

12.3.1 Fonds Digital

The **Fonds Digital** is an association of cultural institutions from all artistic disciplines. It is aimed at public cultural institutions that have already developed digital strategies and tested digital offerings. The Fonds Digital is intended to enable cultural institutions to expand their processes of change and advance their institutions with the help of new digital aesthetics and profiling.

Funded projects come from the areas of **digital curation, digital artistic production, and digital mediation and communication**. Each project-based consortium always consists of two cultural institutions and one digital partner, who supports the implementation of the concepts already developed. The partner helps to acquire new digital skills, which the cultural institutions then combine with new content and publish in public networks. To support these institutions and consortia, regular **Digital Labs**¹, as well as colloquia, international excursions and further training courses are planned. In total, the Fonds Digital has 15.8 million euros available.

Projects excluded from the Fonds Digital are those that focus exclusively on the digitalization of collection holdings.

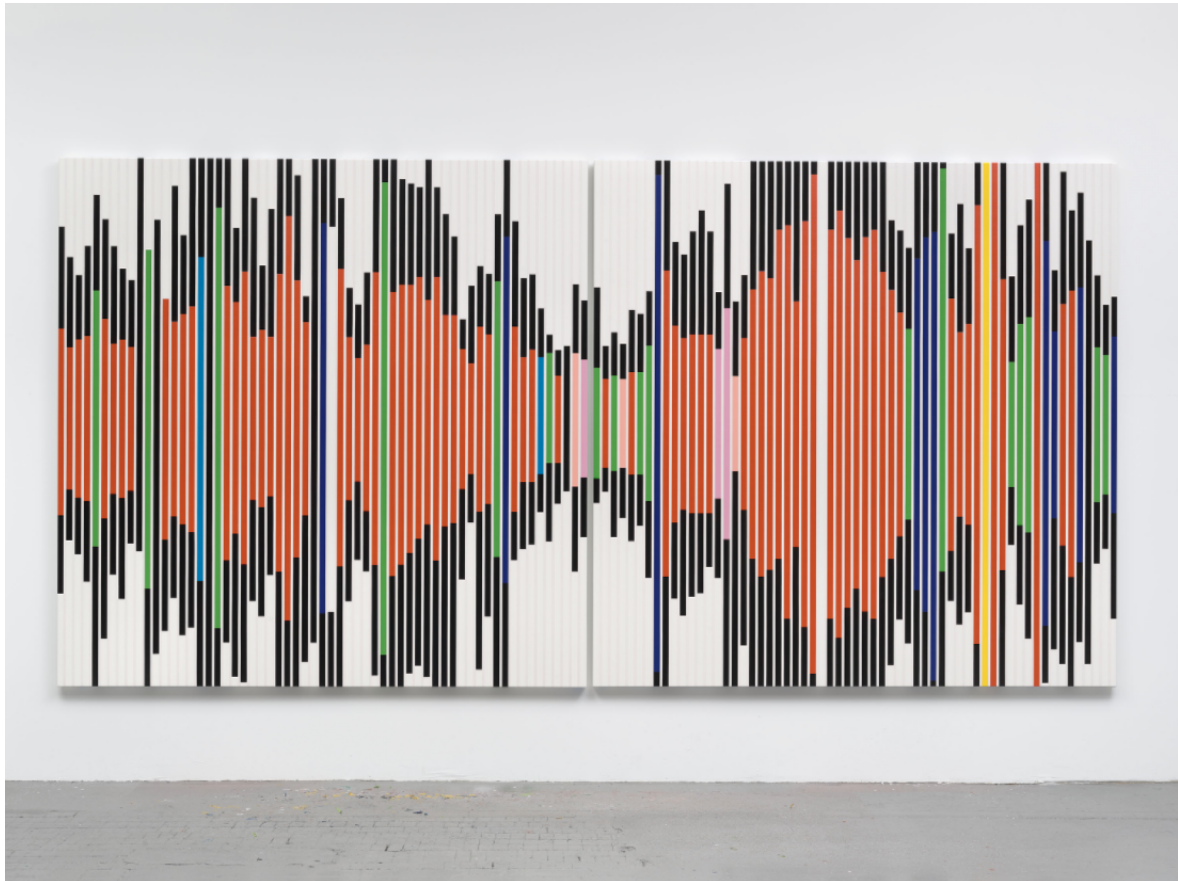


Figure 12.8: The Soundgraph 3.0 emerged from one of the Fonds Digital's projects; it visualizes a digitally composed piece

¹ Academies organized by the German Federal Cultural Foundation to provide institutions with professional guidance and to promote mutual exchange.

12.3.2 Kultur-Hackathon Coding da Vinci

The **Kultur-Hackathon Coding da Vinci** is intended to motivate institutions to prepare cultural data for the public using the possibilities of digital technologies. It is an event format that focuses on further expanding the range of open and freely accessible cultural data.

Coding da Vinci not only supports **digital transformation**, but also creates attractive opportunities for the online community to engage creatively with culture(al data). The Cultural Foundation supports eight editions of the Kultur-Hackathon and cooperates with the founding institutions of Coding da Vinci for this purpose.

In addition, there are scholarships to support participants with ideas that emerged during the hackathon. In addition to 1,250 €/month, these scholarships include participation in coachings and workshops in order to learn new skills relevant to their projects and, where appropriate, pass them on further.

In general, the hackathon is a **joint project** of the German Digital Library (Deutsche Digitale Bibliothek), the Research and Competence Center for Digitalization, Open Knowledge Foundation Germany, and Wikimedia Germany.

12.3.3 Theater and Digitality

This is the third program within Kultur Digital. In the period 2019-2022, 54 artist scholarships will be awarded, each for five months, at the Academy for Theater and Digitality at the theater in Dortmund.

This creates, for the first time for theater in Germany, a place for digital artistic research, cooperation, and the training and continuing education of artistic and technical staff.

Individual research scholarships are funded with up to 1 million euros. A total budget of 18 million euros is available.

Two example projects for Theater and Digitality are:

1. **Das House-Reinventing the Real**
2. **UnBoxing Stages-Digital Practice in Theater**

Das House-Reinventing the Real

This is a virtual reality theater project that engages with the questions: "Whether and how digital spaces can be used by theaters?" as well as the question: "How do theatrical narration and co-presence function in virtual landscapes?". "Das House" invites visitors into atmospheric and enigmatic in-between worlds, built from new as well as existing 3D scans. There are also 3D-scanned avatars of participants. There are now already two episodes of this project: "Das House 0.1" and "Das House 0.2".

Whether this type of theatrical staging will prevail, however, remains to be seen.

UnBoxing Stages-Digital Practice in Theater

This is a cooperation between the Theatertreffen, the Academy for Theater and Digitality, and the Initiative Digitale Dramaturgie, within the framework of Theater virtuell. Due to the coronavirus pandemic, theaters were forced to depart from their typical daily routines. "Theater on the net" was initially a makeshift solution, but it turned out that enormous potential and possibilities were hidden within it. New aesthetics and new modes of narration can captivate new audiences. However, important questions for the future also arise here:

- How should one meaningfully approach theater on the net?

- What risks and potentials lie behind this initiative?
- How can a sustainable engagement with theater on the net and digital technologies succeed?
- Which aesthetics, forms of interaction and presentation modes are on the rise?
- What technical know-how is needed for a sustainably successful production?

The research project "UnBoxing Stages-digital Practice in Theater" engages with all these questions and more, and invites exchange about forms of theater in and via the net.

This is approached through three **panel discussions**, in which all necessary parties are represented. In addition, there is the "**Long Night of the Tutorials**", at which experts hold a series of 60-minute hands-on talks and share their practical knowledge about the combination of the net and theater.

12.4 Summary

To conclude this chapter, here once more are the most important pieces of information on the topic of **cultural digitalization** at a glance. In terms of concrete projects on the topic of cultural digitalization, there is, for example, "**Museum als Co-Labor**", in which archaeological practice and expertise are conveyed in a new way through the creation of digital applications. New technologies such as LiDAR scanning are used in the process. In the field of **digital art**, the whole topic of **NFTs** must not be left out. These are purely digital assets that can only be owned through mining with the help of the blockchain. NFTs are very popular among artists, as they represent a fast and simple way to earn money from their art. The currency used for NFTs is called **Ethereum**.

In the area of **digitalization of music and theater productions**, there has been the conference "Theater und Netz" since 2013. This deals with the topic of how theater can be made digital in the future. Under the hashtags "#MyHomeIsMyBurgtheater" and "#vorstellungsänderung", there have already been successful attempts in this direction. In the long term, the question arises: **Is the idea of theater taking place in separate rooms already a thing of the past?**

In the case of the Kultur Digital funding program, there are still only a few institutions involved. This is due, among other things, to the fact that there are still very few concepts and offerings in this direction. Compounding this is the fact that the institutions are not sufficiently developed in this direction.

Kultur Digital pursues three approaches: open-source, open-access and open-content. The basic components of the program are: "Kultur Digital", "Kultur-Hackathon Coding da Vinci" and "Akademie für Theater und Digitalität".

The **Fonds Digital** is an association of museums, theaters, opera houses and memorial sites. The project teams within the Fonds Digital consist of **two cultural institutions, each paired with one digital partner**. Funded projects come from areas such as: digital curation, digital artistic production, digital mediation and communication. To support these projects, there are regular "Digital Labs", colloquia, international excursions and further training courses.

The **Kultur-Hackathon Coding da Vinci** is intended to motivate people to prepare cultural data for the public using the possibilities of digital technologies. In addition to digital transformation, it aims to create attractive opportunities for the online community to engage creatively with culture(al data).

In **Theater and Digitality**, there are 54 artist scholarships at the Academy for Theater and Digitality. This creates, for the first time for German theaters, a place for digital artistic research, cooperation, and training and continuing education.

CHAPTER 13

Cloud Computing

Learning objectives

After working through this chapter, you will know...

- ... how Cloud Computing fundamentally works.
- ... which Cloud Computing models are available on the market.
- ... how Cloud Computing is technically implemented.
- ... which advantages and disadvantages Cloud Computing offers.

13.1 Basic Concept of Cloud Computing

The steadily growing demand for IT infrastructure among industrial companies, driven by digitalization, has given rise to the solution approach of Cloud Computing (Ger. Rechner- bzw. Datenwolke, i.e. "computer" or "data cloud"). This refers to an infrastructure that gives companies the ability to obtain software, storage capacity and computing power over the internet in a customer-specific, location-independent and on-demand manner. Billing is based on the scope of functionality, the duration of use and the number of users. The importance of a flexible and scalable hardware and software infrastructure has become particularly apparent over the last decade. It is no coincidence that, according to a representative survey by Bitkom Research, two out of three companies in Germany now use this technology [?].

However, making use of cloud services necessarily requires a broadband connection that is fast enough that it no longer makes a difference whether data is stored locally or in the cloud. In the private sector, usage is therefore also tied to the market availability of DSL or LTE connections. Fundamentally, the required bandwidth depends on the respective service model, which will be examined in more detail later [?].

Cloud Computing is essentially defined by five technological characteristics (see Figure 13.1). These were established by the "National Institute of Standards and Technology" (NIST) as follows [?]:

- **On-demand self-service:** When needed, computing capacity such as server time and network storage can be provisioned automatically without further interaction with the provider.
- **Broad network access:** The functions of Cloud Computing are made available over the network and are accessible through standard mechanisms (e.g. web browsers).

- **Resource pooling:** Resources such as storage capacity, computing power and networking are dynamically allocated according to consumer demand.
- **Rapid elasticity:** Virtual resources are scaled quickly and elastically according to demand. From the user's perspective, this scaling appears to be virtually unlimited.
- **Measured service:** Includes the monitoring and control of resource usage. This creates transparency for both provider and consumer, and can also be used for automatic scaling and billing.

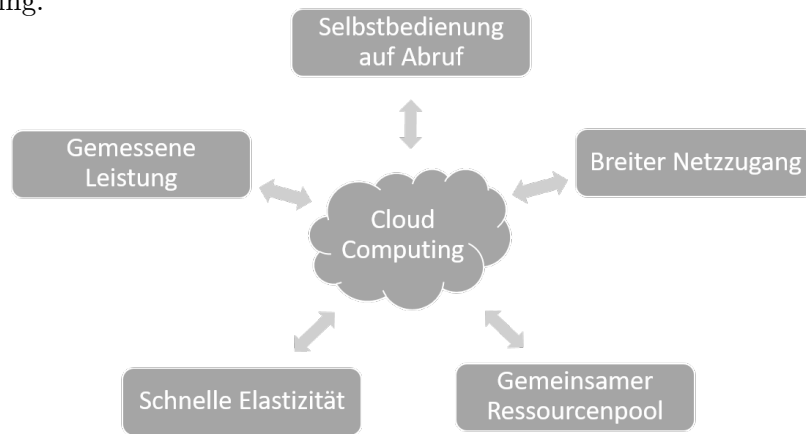


Figure 13.1: Technological characteristics.

A key opportunity offered by the use of Cloud Computing is the increase in efficiency through optimal availability and utilization of IT resources. Performance-based payment for services, combined with the elimination of cost-intensive investments in IT infrastructure, can also lead to a cost advantage, which particularly benefits young companies (start-ups) [?].

On the other hand, there is the inevitable need for a fast internet connection to enable optimal use in the first place. In addition, there is a certain risk with regard to data protection, since the servers of cloud providers are predominantly located outside the EU. Consequently, the data protection laws of the respective country apply, which are generally interpreted less strictly than EU directives.

13.2 Cloud Computing Models

In addition to the characteristics mentioned above, Cloud Computing is also defined by service and deployment models. The available service models are oriented around the three levels of IT infrastructure (hardware, operating system, software). Deployment models, on the other hand, are distinguished by the use of public network structures. The form of the respective model can range from open (public) to completely closed (private).

Service Models [?]

- **Software as a Service (SaaS):** Software and application programs are made available to the user via the cloud. Access is usually via a web browser or a dedicated program interface.
- **Platform as a Service (PaaS):** PaaS is primarily aimed at application developers and system architects. In this service model, the developer is provided with a programming or runtime environment with dynamic computing and data capacity. This gives the user the ability to program their own software as well as to run it on the cloud.
- **Infrastructure as a Service (IaaS):** Describes the provision of virtual computer hardware, such as storage, network and computing capacity. Here, the user is able to design their own virtual computer cluster. They have control over the operating system, storage and applications and can manage these independently.

Deployment Models

- **Private Cloud:** Usage is exclusively by a single organization, which enables easier integration of other business units (e.g. company locations) into the cloud. The cloud platform can be managed (hosted) either internally by the company or by third parties. The organization's exclusive access results in a high degree of customization. This offers advantages in the areas of data security and legal compliance.
- **Public Cloud:** With the public cloud, the provider and the user belong to different organizational entities. In order to achieve the greatest possible economies of scale, the IT infrastructure is made accessible to the general public, meaning a large number of users is characteristic of this model. Payment here is based on actual usage (**pay-as-you-go**).
- **Community Cloud:** This involves an association of organizations with shared interests that can access a common cloud infrastructure. The user base tends to be small and geographically dispersed. Usage costs under this model are distributed among all participating organizations. Examples include: several municipal authorities, universities, cooperatives.
- **Hybrid Cloud:** A combination of public and private cloud, in which certain functions and services are outsourced to a public cloud, which can be drawn upon during peak loads or in the event of a failure. This allows organizations to benefit both from the cost advantage of a public cloud and from the data security advantage of a private cloud.

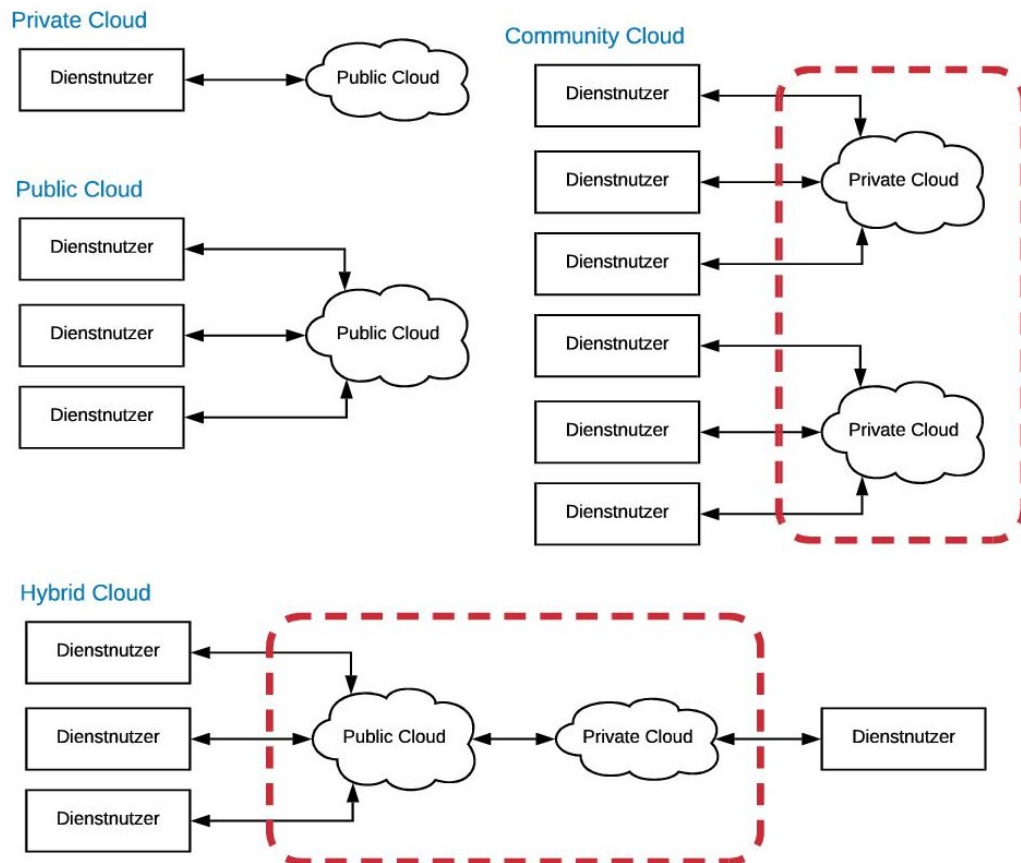


Figure 13.2: Deployment models of Cloud Computing.

13.3 Architecture and Technical Implementation

The architecture of Cloud Computing is best compared to the structure of a computer. Processor cores, main memory, hard drive and programs are components that can be found in similar form in a cloud, which, however, enables enormous scalability. As already explained in Chapter 13.2, there are different models (types) of Cloud Computing. One way to structure the cloud is to divide it into three layers, with each layer representing a degree of abstraction.

- **Application**
- **Platform**
- **Infrastructure**

The layers of the cloud can be used to classify the various Cloud Computing models.

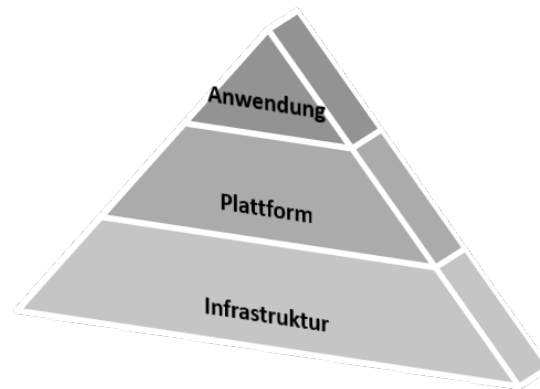


Figure 13.3: Layer model of Cloud Computing.

Application (SaaS)

The Software as a Service model serves the application layer, which is the most abstract layer of cloud services. Here, the user accesses an application offered to them by the cloud. The use case already includes the two underlying layers, but without the user coming into contact with them. This means that scalability and data storage are managed by the cloud service, so the user is not concerned with them.

Typically, an upload speed of 128 Kbit per second is sufficient in this area, since only the information for the respective work step is transmitted, rather than the entire process or the complete document [?].

Characteristics of a SaaS application:

- Modular and service-oriented design
- The load is not predictable, since the intensity of use and the number of users are unknown
- Dynamics and multi-tenancy of the application

The field of application for SaaS ranges from online backup and long-term data archiving to the provision of documents for team collaboration and network drives. Well-known examples of SaaS applications are Apple iCloud, Google Drive and Microsoft OneDrive.

Platform (PaaS)

At the platform level, developers are offered platforms, tools and interfaces for programming or operating applications. The cloud itself serves the developer as a programming interface, through which they contribute exclusively their program logic. The cloud platform then independently manages the distribution of the data to be processed across the processing units (resources). Under this model, the user therefore has no direct access to the compute instances. This abstraction of the technical components is desired here, since the user primarily wants to process data rather than manage the system. Companies typically use PaaS in three central areas:

- Development framework
- Business intelligence or analysis of company data
- Internet of Things (IoT)

Since the PaaS layer performs the computation-intensive operations and a large amount of throughput is generated here due to the high volume of information exchange, a data transfer rate of 10 Gbit/s is required here. Examples of such cloud products are Windows Azure and Google App Engine.

Infrastructure (IaaS)

The infrastructure represents the lowest layer of the architecture. Under this service model, the user has access to the compute instances and can largely manage them independently. The IaaS concept includes storage and messaging services designed to be highly scalable. This does not, however, apply to programs introduced by the user. Compared to a traditional data center, the IaaS model offers the advantage of scalability. This means that the compute instances can be expanded or reduced as required. Infrastructure as a Service is therefore particularly suitable for strongly fluctuating demand for server, network and storage capacity, as is the case, for example, when running tests during application development or when an online shop experiences higher capacity utilization during peak sales periods [?].

Since the largest amount of data is moved and stored at the IaaS layer, the bandwidth requirement is also greatest here, at approximately 100 Gbit/s [?].

The best-known examples in the IaaS area are Amazon Web Services and Open Telekom Cloud. The limits of scalability of IT resources (main memory, number of processor cores, storage capacity) depend on the respective provider.

Main memory	Between 100 and 240 GB
Processor cores	16 - 32
Storage	1 - 2 TB

Table 13.1: Typical scaling limits of IaaS

13.4 Distinction from Other Technologies

The desire to use IT resources collaboratively and thereby utilize them more efficiently has given rise to further technologies alongside Cloud Computing.

Grid Computing

A term closely related to Cloud Computing is Grid Computing. This technology, developed in the mid-1990s, represents an early precursor to the cloud. This technology focuses on the controlled, shared use of decentralized IT resources. Unlike cloud technology, Grid Computing does not take economic criteria such as business and pricing models into account. As a result, the centralization of IT resources (data centers, management, etc.), which is precisely what provides the economic advantages, is not pursued [?], [?].

Edge Computing

The goal of Edge Computing is to process data streams largely on-site (in a resource-efficient manner) while simultaneously benefiting from the advantages of the cloud. By positioning resources (storage, computing power, software) closer to the end devices and using optimal distribution, higher efficiency and lower latency are to be achieved. Only the relevant data is then compressed and forwarded to the central systems.

Fog Computing

This term is sometimes used synonymously with Edge Computing, primarily due to the significant overlap between Fog and Edge Computing. In fact, Fog Computing focuses less on end devices and more on bringing cloud resources closer to the applications. This is achieved through smaller data centers, which perform a partial evaluation of the data before it is transmitted to the cloud.

Comparison of alternative techniques	Grid Computing	Edge Computing	Fog Computing
Goal	Controlled, shared use of IT resources	Data streams are processed at end devices (on-site). Only relevant data is forwarded to the cloud	Similar to Edge Computing. Difference: bringing cloud resources closer to the application.
Advantages	Flexible capacity during peak loads	Reduction of the data volume to be transmitted, leading to lower transmission costs and latency, and at the same time higher service quality	
Disadvantages	Lack of data encryption; dependency on the cloud provider	Irregular computing or storage demand and capacity bottlenecks when processing large volumes of data.	

Table 13.2: Overview: alternative techniques

13.5 Data Security and Data Protection

The greatest challenge in Cloud Computing is ensuring the security of stored information. This concerns not only the protection of company information, but also all customer, partner and employee data. Since the centralized storage of large volumes of data creates a broad attack surface for cybercriminals, the effort required to protect the data against misuse, loss or theft by third parties or even by the cloud provider is correspondingly higher. The key requirement for the protection of personal data is EU Data Protection Directive 95/46/EC of the European Parliament.

Particularly insecure interfaces as well as a shared system environment constitute possible points of attack. It should be noted that data security here is determined by the technology used and the applications used by the provider. Larger cloud providers in particular benefit from economies of scale, since the costs for technical, financial and personnel resources are spread across a larger number of users.

Requirements for the Cloud Provider

Under the German Federal Data Protection Act (§ 3 para. 7 BDSG), the user of the cloud remains externally responsible for the security of the data. Therefore, according to § 11 BDSG, a data processing agreement (Auftragsdatenverarbeitung, ADV) must be concluded with the cloud provider.

The following points in particular must be addressed [?]:

- Engagement of subcontractors: All subcontractors engaged by the cloud provider must be named in full. In addition, the user must be granted a right of objection with regard to future subcontractors, which enables them to terminate the contract in such cases.
- Rights of control: The cloud user has the right to carry out an audit at the provider's premises. Since an on-site audit is difficult to carry out, the cloud provider can also meet this requirement by providing certificates.
- Possibility of switching providers: including transfer of the data to the new provider
- Deletion of the data after termination of the contract
- Ownership rights to the data

Data Transfer to Non-EU Countries

A large proportion of cloud providers store their data outside the EU. Since, in principle, the data protection laws of the respective location apply, and regulations outside the EU are comparatively lax, concluding a data processing agreement (ADV) alone is often no longer sufficient. However, the transfer of data requires a legal basis, and therefore an adequate level of data protection must be established here.

There are two options for this:

- Certification under the Privacy Shield (an informal agreement between the EU and the USA in the field of data protection law, which regulates the protection of personal data)
- EU standard contractual clauses

In both cases, however, supervisory authorities often also require an additional ADV agreement. This additional ADV contract is not, however, negotiable with every provider. In such cases, the only remaining option is to choose a cloud provider that has data centers within the EU [?].

CHAPTER 14

Digital Resilience

Learning objectives:

After working through this chapter, you will know...

- ... how resilient supply chains emerge.
- ... how external effects continually raise the requirements placed on companies.
- ... why the relevance of digital processes keeps growing.
- ... which innovations strengthen the resilience of companies.

14.1 Introduction

The word resilience derives from the Latin „resilio“ and means „to bounce off“ or „to spring back“. Corporate resilience refers to a company’s ability to withstand external shocks and social, economic, or political conditions while adapting to the new circumstances. The resilience of an ecosystem means nothing other than the ability to maintain the organization’s stability despite external effects [?]. Resilient companies use crises as an immediate opportunity to keep growing, rather than falling into a state of shock.

The Corona pandemic in particular showed how important it is to be able to react to unforeseeable situations at very short notice. Companies changed their product offerings, others switched their operations to home office. What matters is that companies with digital processes in place, allowing them to continue steering all workflows independently of the company location, are clearly at an advantage.

Since the European Union also describes resilience as a kind of „compass for future policy“, it is therefore important to understand how a company can become resilient [?].

To be resilient in crisis situations, an expansion of short-time work, loans, and guarantees helps the economy in the short term. In the medium term, however, it is essential to strengthen companies by digitalizing business processes and preparing the workforce for flexible working from home.

Digital resilience encompasses a range of mutually dependent aspects, which is why it is not sufficient to focus on individual points alone. This is why an understanding of complex interrelations is required.

External effects

External effects represent a form of market failure in economics. Here, external influences generate costs or benefits that affect not the party causing them, but the persons or groups involved. External effects can be either negative or positive in nature. However, it is primarily negative external effects that attract attention, as they can cause damage to

companies. Negative effects thus occur when, for example, the production of a company or the consumption of a household indirectly impairs — that is, reduces — the production or benefit of another actor, without this being mediated through markets. If, for example, a delivery fails to arrive, a company can no longer manufacture products and is thereby placed at considerable risk. A positive effect, on the other hand, occurs when the benefit of another actor indirectly grows, that is, increases.

Types of external effects

Typical negative external effects include, for example:

- Environmental disasters
- Health crises (Corona)
- Economic crises
- Cyberattacks
- War

However, there are digital technologies that counteract or mitigate external effects. Innovative technologies can be a valuable tool for avoiding these effects. This work aims to explain digital technologies that will increase the resilience of companies in the future. The following section therefore presents examples that reduce the risk of external effects in the digital age.

14.2 Cyber-Security Solutions

Companies can increase their digital resilience by using firewalls, encryption, and other security measures to protect their systems and data from threats.

Cyber resilience aims not merely to protect individual servers, but to secure the most important business processes in such a way that ICT disruptions triggered by deliberate cyberattacks, force majeure, or even internal errors can be intercepted and withstood.

A resilience strategy aims at three things:

- withstanding an accidentally or deliberately induced IT disruption,
- keeping an interruption as short as possible and returning quickly to normal operations,
- emerging strengthened from the incident — that is, learning continuously and systematically.

To achieve these goals, an international procedural model is now becoming established, comprising at least eight building blocks that are continuously being worked on [?].

1. Identifying and documenting the important business processes,
2. Defining the tolerance for damage,
3. Establishing a mapping,
4. Testing resilience,
5. Conducting lessons learned,
6. Defining communication channels,
7. Information sharing,
8. Conducting self-assessments.

Identifying and documenting the important business processes

The basic requirement is that all business-critical processes must be prioritized and addressed in the event of failures or bottlenecks. This is why the dependencies and relationships between the various processes must already be clear in advance [?].

Defining the tolerance for damage

Since disruptions can cause substantial damage to a company, especially in critical business processes, it is important to know in advance which disruption can be tolerated for which processes.

Establishing a mapping

In this step, all components required for the business process are determined. This also includes information about infrastructure components, IT systems, interfaces, and service providers.

Testing resilience

To be prepared for a real emergency, regular tests are used to check whether the information gathered is sufficient to continue operating normally. It is also checked whether the tolerance for damage is exceeded.

Conducting lessons learned

The insights gained in the previous test phase are systematically analyzed and incorporated into the continuous improvement process. The rehearsed measures must then also be applied to real incidents, so that risk is reduced and the company's resilience is increased.

Defining communication channels

To ensure that it is clearly regulated who must communicate with whom during incidents, a communication channel is defined. The more regularly a test is conducted, the better and more smoothly the communication channels function.

Information sharing

The more frequently incidents are shared with one another, the better they can be handled, since more information is available. It is therefore helpful when the entire industry exchanges information about incidents and the measures taken.

Conducting self-assessments

To always be "up to date", the individual measures should be reviewed and adjusted at regular intervals [?].

With this method, companies aim to become cyber-resilient. However, since cybersecurity encompasses not only the protection of information and data (i.e., data security) but also the protection of non-information-based „assets“ that are vulnerable to ICT threats, ensuring this is becoming increasingly difficult [?].

14.3 Cloud Computing

By using cloud-based solutions, companies can store and secure data and applications in a centralized manner, enabling them to respond quickly to failures and maintain important business processes. The use of cloud computing has increased significantly in recent years and offers a wide range of benefits.

One of the most important benefits of cloud computing is the flexibility it offers. Users can access data and applications from anywhere, as long as they have an internet connection. This makes it easier for employees to work from home or on the go and also increases productivity.

Another advantage is the cost savings that can be achieved through the use of cloud computing. Since users do not need to purchase expensive computers or servers to store their data, savings can be achieved. In addition, upgrading and maintaining hardware is no longer necessary, as this is the responsibility of the cloud service provider. There is also a wide range of security measures that protect the data.

A potential innovation that can be used in warehousing is called „DProdLog“.

14.4 Smart Containers - DProdLog

An alternative that is intended at least to guarantee the availability of inventory has been researched by the Fraunhofer Institute in the „DProdLog“ project. The starting point for this is smart containers equipped with sensors to capture fill levels and position. The containers form a cyber-physical system that independently communicates with a modular service portal realized through a cloud solution. With the help of this service portal, data from the digital containers is then collected, interpreted, and, in the next step, an automated order is placed to replenish the warehouse stock [?].

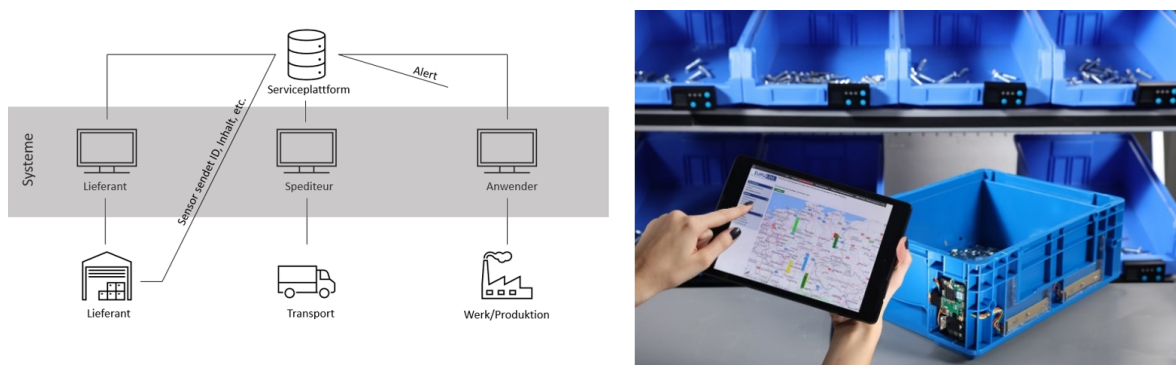


Figure 14.1: Diagram illustrating DProdLog
(Based on [?])

The smart containers thus constitute a new innovation that can avoid error-prone recording and monitoring activities as well as high safety stocks. These containers are particularly important in cases of inconsistent demand, as they trigger replenishment processes and visualize information via a dynamic display. In addition to the containers, the company itself, the respective suppliers, and the carriers are connected to the platform. They communicate digitally and au-

tomatically in real time via the platform. Furthermore, the collected data can then be written directly to the cloud and used there for big data analyses [?].

As soon as the container reports via the service platform that it is nearly empty, the user receives a notification of the current fill level and can then initiate appropriate measures.

In addition, carriers can use a logistics app that informs service providers about the status of the delivery. This makes it possible to guarantee real-time shipment tracking.

The sensors on the containers also serve to optimize energy consumption in operations and thereby reduce energy costs. This can help offset increased energy costs and material prices.

Naturally, this technology is no guarantee of being unaffected by external effects, yet it nevertheless considerably reduces the risk of stock shortages. Depending on how high the reorder point is set, business risk can be minimized during times of supply bottlenecks.

14.5 Intelligent Transport Management

Efficient and flexible logistics play an increasingly important role in the success of companies today. Especially in times of crisis, when supply chains are under strain, an intelligent transport management system (TMS) can play a supportive role. The aim here is to achieve optimal control and monitoring of the transport process using digital technology.

Intelligent transport management includes, among other things, the use of technologies and processes for the efficient management of transport processes. Its main feature is the networking between vehicles and infrastructure in order to optimize logistics processes and find rapid solutions in the event of external effects such as delivery failures.

The use of intelligent transport management systems (ITMS) increases both efficiency and transparency in logistics processes. This is possible because ITMS provide real-time data, thereby enabling faster decisions. In addition, ITMS offer a high degree of flexibility, as they can be adapted to a company's individual needs.



Figure 14.2: Diagram illustrating TMS
(Based on [?])

Another important feature of ITMS is the integration of data from various sources. For example, GPS data, order data, and weather forecasts can be combined to enable optimal route planning. This can lead to a reduction in delivery times and costs.

A study by McKinsey likewise confirms the benefits of ITMS. According to this study, the use of ITMS can reduce the number of unforeseen events, such as delivery delays, by up to 50 percent [?].

14.6 Edge Computing

Companies can also become more digitally resilient through the use of edge computing. Edge computing is an alternative to IoT and offers a decentralized architecture in which data is processed and analyzed directly on the devices or in their vicinity (see figure). Data is thus stored and processed in real time closer to where it originates, instead of being sent over long distances to remote data centers [?]. This makes it possible to reduce latency and enable a faster response speed, which is of great benefit for many processes in industry.

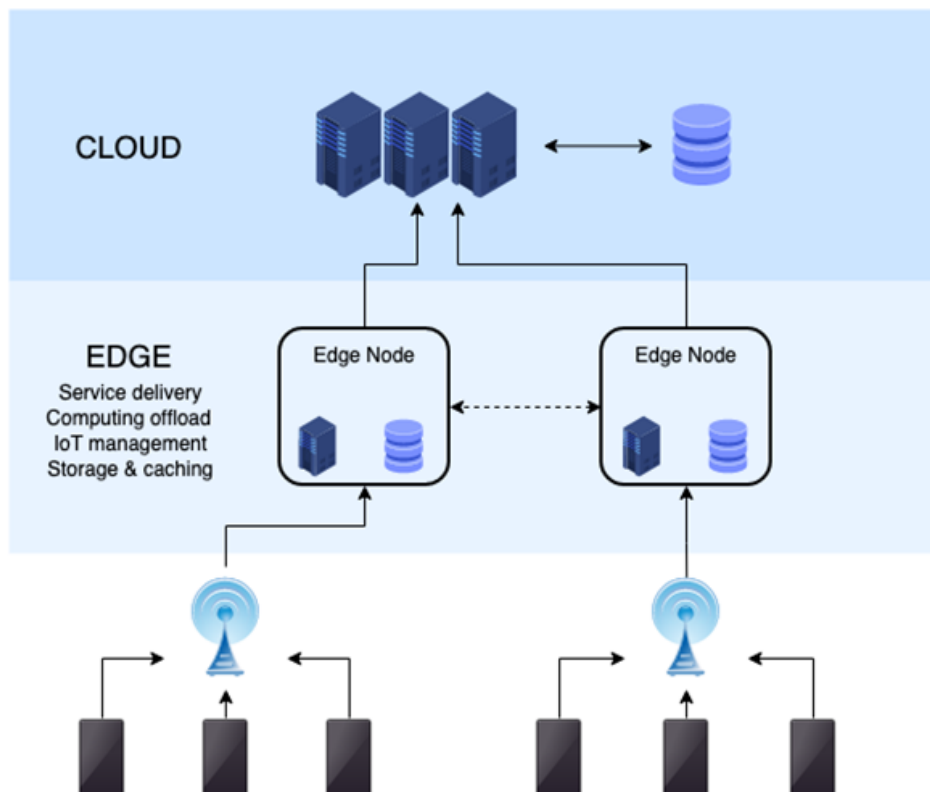


Figure 14.3: Edge computing
(Based on [?])

A relevant aspect of Industry 4.0 is the interconnection of machines and the associated improvement of manufacturing processes. Edge computing can play a central role here by enabling data processing close to the machines. The use of edge computing in production can help improve the efficiency of manufacturing processes and reduce production costs. For example, sensors and other devices can be deployed on the production line to collect and process data in real time.

In addition, Industry 4.0 enables the digitalization of supply chains and the associated ability to optimize and automate processes. Here, too, edge computing can play a relevant role

by, for example, enabling data to be processed and analyzed in real time along the supply chain.

The use of edge computing can reduce dependence on the equally important form of cloud computing. This means that companies have greater flexibility and a better response to disruptions and failures. In the event of a network outage, for example, companies can rely on the collection and processing of data on local devices instead of being dependent on the cloud infrastructure functioning again.

Since unplanned downtime of machines and equipment causes costly production losses in the highly automated manufacturing industry, the use of machine-driven sensors and AI-based analysis makes it possible to permanently monitor all machine functions [?].

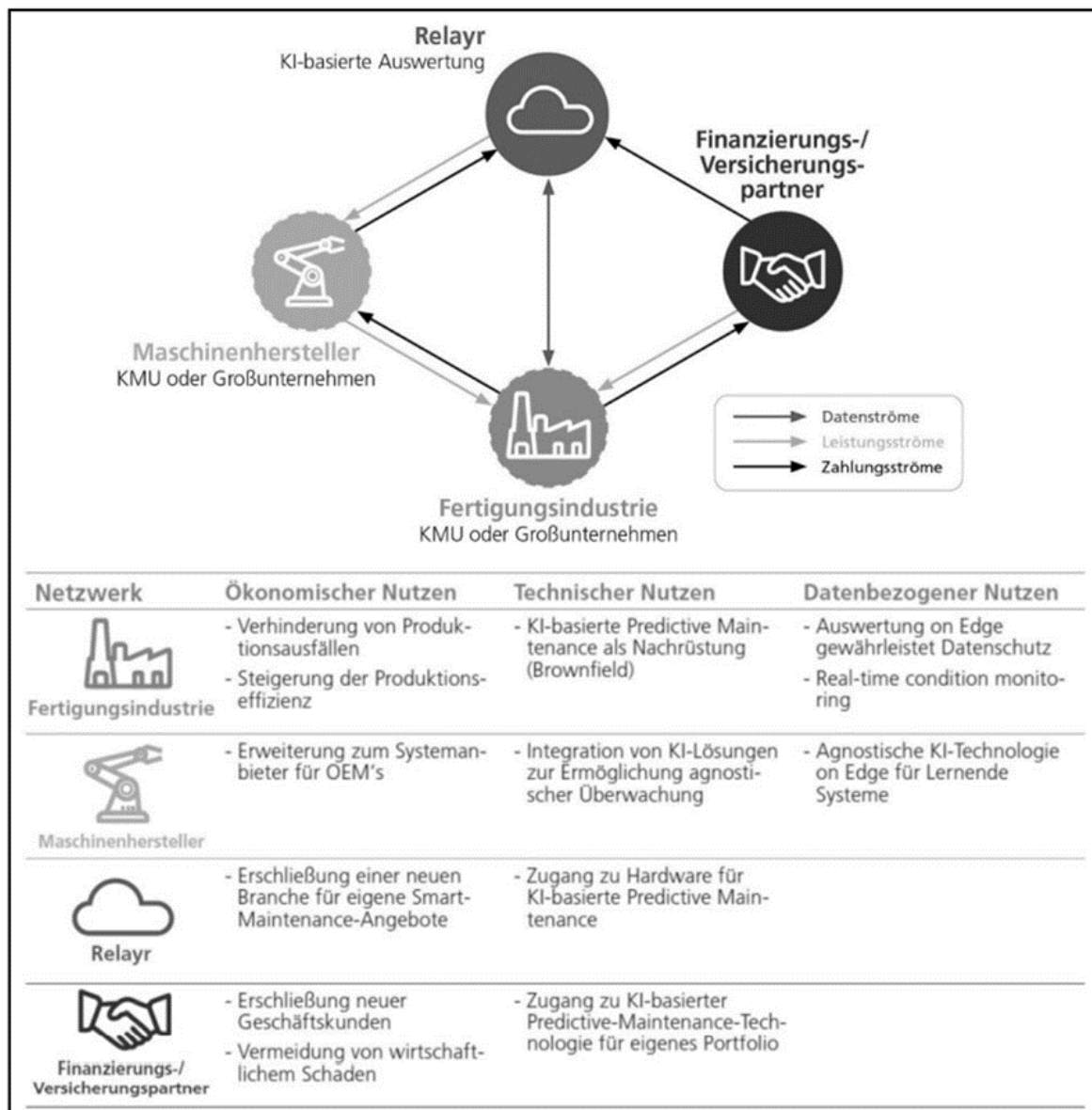


Figure 14.4: AI-based analysis
(Based on [?])

Through AI-based analysis on the edge (directly at the machine) and the decentralized evaluation of machine functions, the volume of data to be processed can be considerably limited, as the following figure shows. The company Relayr has expanded a data-based innovation into a performance guarantee, whereby a financing and insurance partner minimizes the risk of any remaining production downtime through a digital business-interruption insurance policy.

Already in 2014, Guido Jouret, then head of Cisco's Internet-of-Things division, stated: „We waste time and bandwidth when we send all the data from IoT devices to the cloud first and then send the answers back to the network“ [?]. According to a 2018 study by the International Data Corporation (IDC), the share of real-time data is expected to rise to 30 percent of all processed data by 2025. As the spread of IoT continues to advance, the volume of data generated increases, and „the real-time relevance of new data is growing even faster than the volume of data itself“ [?]. As the share of real-time data increases, so too does the importance of edge computing.

14.7 Disaster Recovery and Business Continuity Solutions

Disaster Recovery (DR) and Business Continuity (BC) concepts aim to minimize the effects of disasters, disruptions, or, for example, external effects on companies or organizations.

DR solutions provide protection for IT data and systems to ensure that all data can be restored after an unforeseeable problem. This includes the use of backup systems that are updated regularly, as well as the deployment of redundant hardware and networks to increase the availability of IT systems.

BC systems go a step further and also include activities to minimize the impact of an unforeseen event on business operations. This includes reviewing and revising business processes, establishing emergency plans, and training employees for emergency mode.

The figure shows an overview of the external drivers that are decisive for a company in introducing BCM (Business Continuity Management) [?].

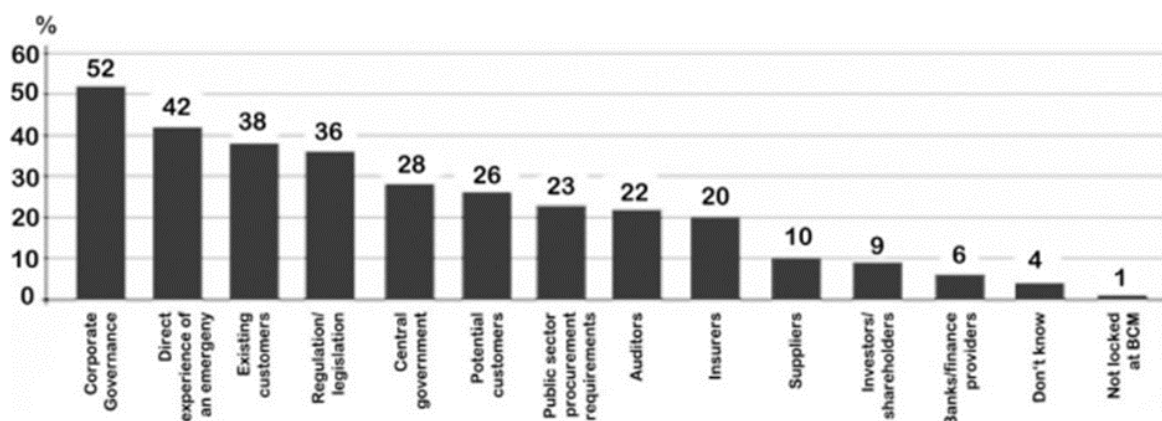


Figure 14.5: External drivers for BCM solutions
(Based on [?])

Together, DR and BC solutions thus form a complete system for minimizing risk following unforeseeable impacts or external effects. These measures are essential, especially for companies that depend on IT systems, in order to maintain their business processes.

14.8 Summary

Overall, it is important to develop and implement a comprehensive strategy for digital resilience and crisis resistance that includes flexible and scalable technologies, robust data security and management, regular review and revision of business processes, employee training and drills, as well as close cooperation and communication with external partners. Since external influences usually affect not just one area of a company but impair a complex, interconnected system, it is therefore important to be able to draw on a broad spectrum of digital innovations.

Cloud systems are becoming increasingly important in this regard, as they can generally be used across interfaces and therefore cover a wide range of applications. The use of sensor technology in the field of warehousing plays an important role here, as it can help ensure a certain level of security in logistics by allowing demand to be met early on. Nevertheless, it is also important to rely on decentralized storage in order to enable faster response times. A good balance should therefore be struck between cloud computing and edge computing in order to increase the resilience of companies.

The optimization achieved through intelligent transport systems also offers the possibility of achieving greater flexibility, efficiency, and safety in transport. This enables companies to respond flexibly to short-term disruptions or crises and make changes to their transport processes. The use of sensor technology is becoming increasingly important, and its connection with IoT is taking on a relevant significance for the transport of the future.

Continuous review and revision of business processes and workflows are likewise important to ensure that the organization can respond effectively to changing needs and challenges. Ernest Hemingway describes it in the following words: „The world breaks everyone, and afterward many are strong at the broken places.“ This quote can also be applied to the resilience of companies, which should grow from external influences and emerge from them strengthened, since the significance of crises and external effects for the development of companies has increased considerably in recent years.

CHAPTER 15

Additive Manufacturing in Industry 4.0

Learning Objectives

After completing this chapter, you will know...

-what additive manufacturing is.
-which process steps are necessary from the file to the finished part.
-which manufacturing processes exist for additive manufacturing.
-what role additive manufacturing plays in Industry 4.0.
-what advantages and disadvantages the technology offers in industry.

Introduction

Additive manufacturing, also known as 3D printing, is becoming increasingly important because it opens up new possibilities in production. It enables the manufacture of complex shapes and individual products in an efficient way. With the growing need for flexibility, rapid implementation, and resource conservation, this technology is gaining importance in many areas.

15.1 Fundamentals of Additive Manufacturing

In a subtractive manufacturing process, material is removed from a block until the workpiece has the desired geometry. This principle has been known for millennia and was already applied by sculptors, for example when creating marble statues or wood carvings.

Modern manufacturing methods such as CNC milling and CNC lathes are also based on the same fundamental principle. Here, tools or workpieces are shaped from metals by means of machining.

Additive Manufacturing (AM), also referred to as 3D printing, describes a process for the layer-by-layer production of three-dimensional objects. In contrast to traditional manufacturing methods, in which material is removed or shaped through milling, drilling, or casting, in additive manufacturing the workpiece is created by depositing material layer by layer, precisely where it is needed. This principle enables particularly resource-efficient, flexible, and individualized production.

Since the 1970s, additive manufacturing has complemented classic production processes and has developed into a key technology of modern industry. The term “3D printing” became increasingly widespread from around 2012 onward, generating great public and media interest. The resulting worldwide hype made the technology known even outside of industry and

contributed significantly to its further development and application in a wide variety of fields.

The core idea of additive manufacturing lies in the direct translation of digital models into physical products. This allows even complex geometries and individual one-off items to be produced efficiently, making the technology an important component of modern, flexible production systems and of Industry 4.0.

15.2 Functional Principle and Process Chain

Additive manufacturing goes through several coordinated process steps, from digital modeling to the post-processing of the physical part. Each of these steps has a decisive influence on the quality, precision, and reproducibility of the final product.

The basis for additive manufacturing is a digital STL file (Standard Tessellation Language), which describes the object to be produced in the form of a polygon mesh, usually made up of triangles. This file can either be created from a CAD program or generated using 3D scanners and other digitization methods. The STL file thus forms the bridge between design and manufacturing.

In the next step, the STL file is processed in slicing software. This converts the digital 3D model into machine code (G-code), which controls the additive manufacturing systems. To do this, the model is divided into many horizontal layers, a process known as “slicing.” Various parameters can then be configured in the slicing software, such as printing and movement speed, temperature, infill pattern, or the positioning of the part in the build volume.

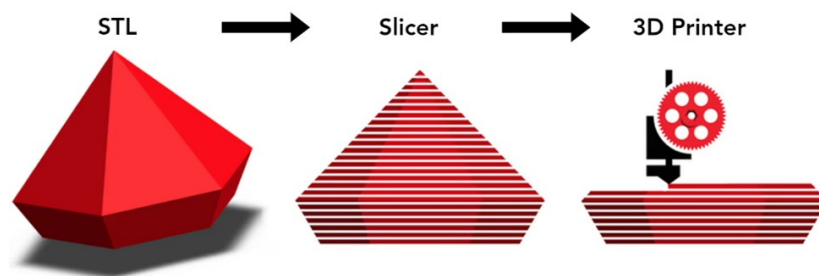


Figure 15.1: Process in 3D printing

Before the actual manufacturing process starts, the software allows a simulation of the build process in order to detect potential errors or collisions and to optimize material usage and time. The finished G-code is transferred to the manufacturing system via various methods, typically via memory card, cable connection, or network (WLAN/Ethernet). The memory card offers advantages such as lower susceptibility to errors and energy savings, whereas the cable connection allows real-time monitoring of the process. During the printing process, the physical object is created layer by layer. Overhangs with an angle of inclination greater than 45° require support structures. These can either be made of the same material as the part and removed mechanically, or of a soluble foreign material that is chemically dissolved after printing.

The level of detail and surface quality depend significantly on the chosen layer thickness (Z resolution) and the nozzle outlet diameter (X/Y resolution). Thinner layers result in a smoother surface, but also increase manufacturing time.

Once additive manufacturing is complete, post-processing follows in order to improve the visual and functional quality of the surface. Especially with FDM/FLM processes, mechanical rework is required, as surfaces frequently show visible layer lines. As a rule, finishing takes place in multiple stages.

Mechanical processing of the surface removes excess powder, staircase steps, and support contours. Optionally, heat treatments can then be carried out.

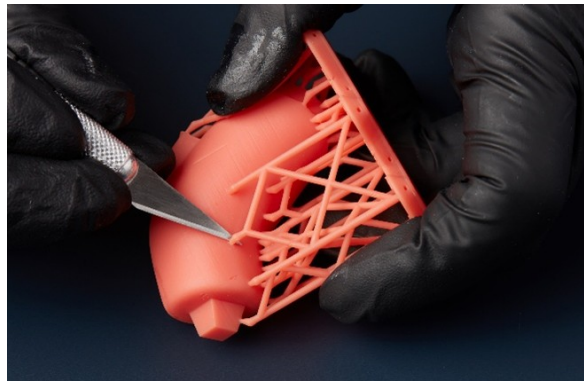


Figure 15.2: Removing the support contour

15.3 Additive Manufacturing Processes and Materials

Additive manufacturing encompasses a wide variety of processes, which differ mainly in the type of material deposition and energy input. In principle, parts are built up layer by layer, with different materials (solid, liquid) being used. The choice of the appropriate process depends significantly on the desired material properties, the part geometry, and the field of application.

One of the most important additive manufacturing processes is **Binder Jetting**. This process is characterized by particularly broad material compatibility, since a wide range of materials such as metals, plastics, ceramics, gypsum, or sand can be processed. It is therefore used both for prototyping and for functional end-use parts.

The printing process begins with the application of a fine powder layer onto a build platform. This plate first lowers slightly while a roller spreads the powder evenly. An inkjet print head, which functions similarly to that of a conventional 2D printer, then moves precisely across the powder bed. In doing so, it selectively deposits the liquid binder in the form of tiny droplets, about 80 μm in size, exactly where the material is to be solidified.

After a layer is completed, the build platform lowers again, and a new powder layer is applied. This process repeats layer by layer until the complete part has been built. After printing, the excess powder that has not come into contact with the binder is removed. This unbound powder can be partially recycled and reused for further printing processes, which improves the economic efficiency and sustainability of the process.

A major advantage of binder jetting is that no additional support structures are required. The powder bed itself acts as a natural support throughout the entire build process, which allows for greater design freedom and more complex geometries.

The strength and robustness of the objects produced depend heavily on the binder used and the subsequent post-processing steps. Untreated parts generally have lower mechanical stability than metal or ceramic parts. However, subsequent sintering, i.e. the thermal densification of the material, can significantly increase strength.

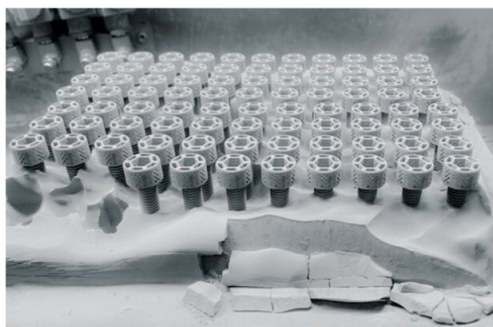


Figure 15.3: Binder Jetting

In **Material Jetting**, a build platform is covered layer by layer with tiny droplets of build or support material, which are applied via print heads. The droplets cure immediately, either through UV radiation or cooling, as is the case with wax materials, for example. After each completed layer, the build platform lowers slightly so that the next layer can be applied. Overhangs and complex structures are stabilized by support material, which is likewise applied in droplet form and removed after printing by melting or dissolving.

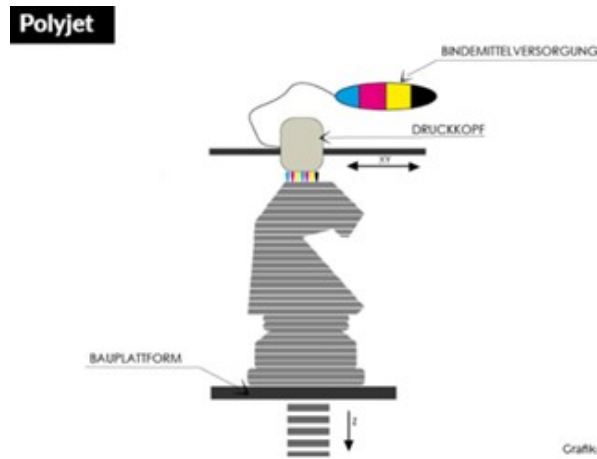


Figure 15.4: Material Jetting

Material jetting is impressive due to its high precision in droplet placement and layer thickness. This results in very smooth surfaces and finely detailed structures. In addition, the process allows a flexible combination of colors, degrees of transparency, and material properties such as hardness or elasticity. These characteristics make material jetting particularly suitable for prototypes, design models, and applications with high aesthetic requirements, for example in medical technology or investment casting.

Limitations arise from the limited strength of the polymers used, which usually do not achieve the durability of classic thermoplastics. In addition, there are high acquisition and operating costs, since both the print heads and the curing system require special environmental conditions and regular maintenance. Furthermore, the build volume of many machines is limited, as the high-precision print heads are difficult to scale up. For this reason, material jetting is rarely used in large-scale series production.

In **Material Extrusion**, a thermoplastic filament or a pasty mass is fed via a feed mechanism into a heated nozzle. There, the material melts or is heavily plasticized and then deposited through the nozzle onto the build platform.

The print head (or alternatively the build platform) moves precisely in the X and Y directions in order to generate the first layer of material according to the specified 3D CAD data. Once a layer is complete, the build platform lowers, or the print head rises, to make room for the next layer. As the extruded material cools rapidly, each layer solidifies, so that a three-dimensional object is created layer by layer.

For a stable bond between layers, precise coordination of key process parameters is required. These include extrusion speed, nozzle temperature, layer height, and feed rate. Only with optimal coordination does a uniform, strongly adhering bond form between the tracks. A characteristic feature of this technique is the visible layer grooves in the parts.

A key advantage of material extrusion lies in its simple technical implementation and the correspondingly low investment costs. The systems are usually compact, easy to operate, and suitable for a wide range of materials, from inexpensive PLA for simple prototypes to high-performance plastics such as PEEK for industrial applications.

Compared to more precise processes such as material jetting, however, material extrusion exhibits lower surface quality and detail resolution. The visible layer lines often remain, and shrinkage or warping effects during cooling can lead to cracking or adhesion problems

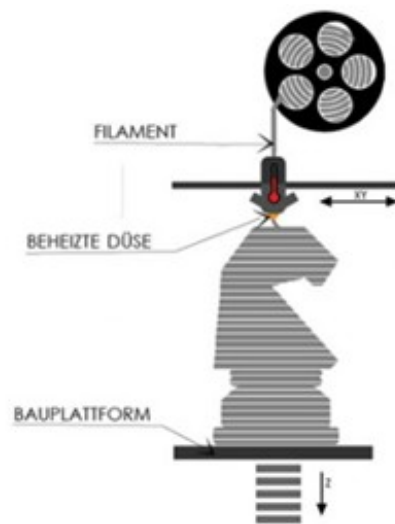


Figure 15.5: Material Extrusion

between layers. The mechanical properties of the parts are also strongly dependent on print parameters, material choice, and build chamber temperature. To improve part quality, post-processing steps such as grinding, polishing, or heat treatment may be necessary.

In **Vat Photopolymerization**, liquid resin is filled into a container, usually translucent (e.g. glass or a special plastic). A light source, such as a laser, projector, or an LCD panel, selectively cures the contour of the part's layer. The build platform or the optical system then moves so that a new layer of resin becomes available. This process repeats layer by layer until the part reaches the desired height. Once complete, the object is removed from the resin bath and is frequently subjected to post-curing under UV light in order to ensure final strength.

The method is impressive due to its very high surface quality and precise dimensional accuracy. The parts often appear almost injection-molded, and thanks to special resins, applications in medical and dental technology, jewelry manufacturing, and design prototyping are possible. In addition, very fine details can be represented, and through transparent or colored resins, a wide range of aesthetic and functional properties can be realized.

Limitations arise from the mechanical properties of the photopolymers, which are often brittle and have only limited heat or chemical resistance. The resins are sometimes expensive and require careful handling (e.g. protective clothing, UV protection). Build chamber sizes are also often limited compared to powder bed fusion or material extrusion processes. Finally, UV post-curing is often necessary to achieve the final material properties.



Figure 15.6: Vat Photopolymerization

In Powder Bed Fusion (PBF), a thin layer of powder is spread evenly onto the build platform. An energy source, usually a laser or electron beam, then selectively melts or sinters the powder grains at the points where the part is later to be formed. After each layer, the platform lowers slightly and a new layer of powder is spread. This cycle repeats until the workpiece has been fully built up layer by layer. The excess powder supports the part during the printing process, meaning that separate support structures are often unnecessary. In polymer PBF processes, it is usually sufficient to remove the finished part from the powder bed and brush or vacuum off the excess powder. In metal PBF processes, support structures are sometimes necessary, for instance for thermal management or part fixation, which can subsequently be removed again.

The process allows for almost unrestricted design freedom, as the loose powder takes on a natural supporting function. In addition, fine details, high resolutions, thin wall thicknesses, and, for metallic parts, high density are possible. Complex internal structures and function-integrated designs, for example for lightweight construction applications, can thus be realized, which would be difficult to achieve using conventional processes.

Disadvantages include the high investment costs for machines and powder materials, as well as the elaborate powder handling, particularly for reactive or hazardous metals. Build speed can be limited for delicate or very large parts. Metallic PBF parts also frequently require post-processing, e.g. removal of support structures, surface treatment, or heat treatment, in order to achieve the desired final material properties.

In Directed Energy Deposition (DED), a focused energy source creates a small melt pool, into which powder or wire is simultaneously fed. The new material fuses with the surface of the base material, so that the part is built up layer by layer. Control is carried out via 3D data, which determine the deposition path and the layer thickness. A key feature of DED is that only the area required for the adhesion of the new layer is melted, thereby reducing thermal stress and distortion.

DED offers particular advantages for repairs and large-volume parts. Damaged areas can be repaired in a targeted manner without exposing the entire workpiece to high temperatures. The process allows high deposition rates and great build volume flexibility, since it is not necessarily bound to a fixed chamber. Some systems use industrial robots to precisely apply material even to complex contours or curved surfaces.

Disadvantages often include relatively rough surfaces and contours, so that mechanical post-processing may be necessary when tight tolerances are required. Powder-based DED systems produce finer layers but require more expensive feedstock material. In addition, coordinating the energy source and material feed requires precise process monitoring and complex machine control.



Figure 15.7: Powder Bed Fusion

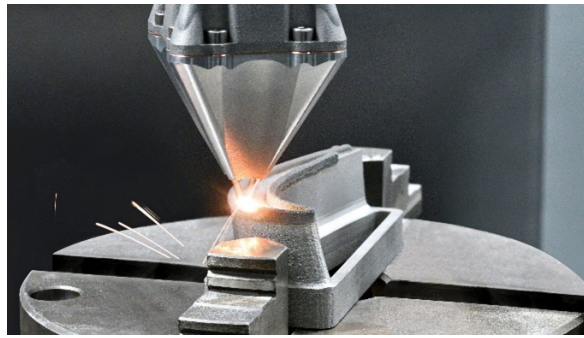


Figure 15.8: Directed Energy Deposition

The following section presents the most important materials used in additive manufacturing. With solid materials, such as powder or granulate, large-format workpieces can be produced, for example in mechanical engineering or aerospace. Processes using liquid substances are suitable for small to medium-sized workpieces, for example in medical technology.



Figure 15.9: Materials for 3D printing

With regard to material categories, four groups are primarily used: metals (e.g. steel, aluminum, titanium), which are used for heavily loaded parts; polymers such as ABS, PA, or PEEK for prototypes and functional plastic parts; ceramics for high-temperature or wear-resistant components; and biomaterials such as hydrogels or collagen, which are used in medical technology and tissue engineering.

Material forms also differ depending on the process. Powder enables precise parts with high accuracy, while granulates are more cost-effective but less precise. Filaments (thread-like plastics) are characterized by ease of handling. Liquid resins produce very smooth surfaces.

Additive manufacturing thus offers a broad spectrum of processes and materials, ranging from the production of fine prototypes to robust metal structures. Through the targeted selection of the appropriate process and material, tailor-made solutions can be realized for a wide variety of industrial requirements.

15.4 Additive Manufacturing in Industry 4.0

Advancing digitalization is fundamentally changing industrial manufacturing and making production processes significantly more flexible and efficient. Through data integration along the entire process chain, from product development through manufacturing to logistics, a high degree of transparency and efficiency is achieved. Additive manufacturing processes in particular help to shorten the so-called time-to-market, i.e. to significantly reduce the period between the development and market launch of a product. Thanks to modern data transmission capabilities, additive manufacturing can be seamlessly integrated into digital production chains, a decisive step toward fully networked and self-controlling manufacturing systems. Another important aspect of digitalization is the concept of digital warehousing. In

this approach, spare parts are not stored physically but digitally, for example in the form of 3D databases. When needed, these parts can be manufactured additively immediately, eliminating storage costs and ensuring the long-term availability of spare parts.

Additive manufacturing is also characterized by a high degree of automation. Digital process chains automatically provide all machine control data, so that the printing process starts at the push of a button and runs largely autonomously. This human-independent production enables continuous 24/7 manufacturing, consistent production rates, and stable product quality.

Nevertheless, manual steps are still required, for example when loading the printing systems, post-processing the parts, or performing quality inspections. In the long term, additive manufacturing is thus becoming a central component of digitalized industrial production. It combines flexibility, individualization, and economic efficiency, thereby strengthening competitiveness compared to conventional series production.

15.5 Fields of Application of Additive Manufacturing

Additive, tool-free manufacturing is particularly well suited to producing products in small quantities. It enables a high degree of individualization, since adjustments can be made directly in the CAD file and transferred to the finished product with little effort. A major advantage is that part complexity has almost no influence on the manufacturing process; even complex geometries can be realized efficiently and precisely.

From an economic perspective, additive manufacturing is particularly worthwhile when small quantities and a high degree of variant diversity are required. It allows for on-demand production and thereby reduces inventory levels and capital tied up in stock. Additive manufacturing can be divided into different categories based on its intended use, reflecting the technological maturity level and the intended purpose of the parts produced. Fundamentally, three main terms are distinguished: Rapid Prototyping (RP), Rapid Tooling (RT), and Additive Manufacturing (AM).

Rapid Prototyping (RP) refers to the fast and cost-effective production of sample or prototype parts. The goal is to be able to carry out design and functional testing in early development phases without relying on elaborate or expensive tools. RP processes thus enable cross-departmental testing and significantly shortened development times.



Figure 15.10: 3D-printed prototype and original part



Figure 15.11: 3D-printed prototype

Rapid Tooling (RT) goes a step further and refers to the manufacture of tools or tool components that are subsequently used in primary or secondary forming processes, such as injection molding or deep drawing. This approach allows for the efficient production of mold inserts, fixtures, or casting molds and contributes to shortening production preparation.



Figure 15.12: 3D-printed mold

Finally, the term Additive Manufacturing (AM) describes the industrial use of additive processes for the series production of marketable end products. In contrast to rapid prototyping or rapid tooling, the focus here is no longer on model building or tool creation, but on the direct manufacture of functional parts or small series.



Figure 15.13: Coin tray: Additively manufactured by Daimler

This classification makes it clear that additive manufacturing has evolved from a pure prototyping technology into a fully-fledged production process. In doing so, it makes a central

contribution to the flexibilization of modern manufacturing processes and to the realization of individualized products in the spirit of Industry 4.0.

15.6 Advantages and Challenges

A major advantage of additive manufacturing lies in its flexibility. It enables individual adaptation of products to specific requirements and is often more cost-effective than many classic manufacturing processes. Development times can be significantly shortened, as results are often available within a few hours instead of days or weeks. In addition, the process allows the production of small batch sizes or complex geometries without high costs.

Clear advantages also arise in the development and testing process. Design concepts can be tested before physical prototypes are built, allowing ergonomic, visual, and haptic properties to be evaluated at an early stage. Functional tests of mechanical, electrical, or aerodynamic properties are also possible. This allows development cycles to be accelerated and design flaws to be identified early.

Another positive aspect is sustainability. Because of the layer-by-layer build-up, only as much material is used as is actually needed, significantly reducing material waste. In addition, the carbon footprint improves through shorter transport distances and the ability to manufacture locally in the sales market. Environmentally friendly filaments made from renewable raw materials, such as PLA from corn starch or sugar cane, further contribute to ecological sustainability. Thermoplastics such as HDPE or PET can be processed multiple times, which also enables the use of recycled materials from bottles, filament waste, or even ocean plastic.

In addition to these advantages, however, there are also challenges. The surface quality of additively manufactured parts is often limited due to the layer-by-layer build-up. Visible stepping effects occur, which, particularly in metal parts, require elaborate post-processing. Mass production also still represents a limitation at present. The printing process takes comparatively long, and production costs for large quantities are still too high to compete economically with classic processes.

Despite these limitations, additive manufacturing offers considerable potential for industrial production. It is individualized, material-saving, and enables designs that would not be feasible with conventional processes. It therefore represents a key technology for flexible, sustainable, and future-oriented production processes.

15.7 Summary

Additive manufacturing has evolved from a technology originally used mainly for prototypes into a central component of modern production processes. It combines the ability to efficiently produce complex geometries and individual parts with the flexibility of digitally controlled manufacturing processes. By directly translating CAD data into physical objects, not only is material saved, but development time is also drastically shortened. Different processes such as binder jetting, material jetting, material extrusion, vat photopolymerization, powder bed fusion, and directed energy deposition each offer specific advantages in terms of material variety, level of detail, mechanical strength, and build volume, thereby covering a broad range of applications, from prototypes and design models to functional plastic and metal parts to highly precise medical or industrial components.

Additive manufacturing plays a decisive role in Industry 4.0, as it increases the efficiency and responsiveness of manufacturing through a high level of automation, digital networking, and flexible production planning. Concepts such as digital warehousing and on-demand production enable a reduction in inventory levels and rapid availability of spare parts, while direct integration into the digital process chain improves the transparency and controllability of the entire manufacturing process. At the same time, the technology opens up new possibilities

for individualization, function integration, and lightweight construction that are difficult to achieve with conventional processes.

Despite its numerous advantages, challenges remain, for example regarding surface quality, production speed for large series, investment costs, and post-processing. Nevertheless, the potential outweighs these challenges. Additive manufacturing enables resource-efficient work, reduces material losses, and at the same time offers a flexibility that is hardly achievable with traditional manufacturing methods. It therefore represents not only a complement to classic production processes, but also has the potential to fundamentally transform production processes and enable new business models. As a key technology of modern industry, additive manufacturing makes a sustainable contribution to individualization, efficiency improvement, and innovative capacity across a wide range of industries and will continue to gain importance in the future.

CHAPTER 16

Data Protection (GDPR) in the Context of Industry 4.0

Learning Objectives

After working through this chapter, you will know ...

- ... what personal data is and how it differs from pure machine data
- ... which legal bases the GDPR provides for data processing in a company
- ... which typical areas of conflict digitalization projects bring with them in Industry 4.0
- ... how the tension between statutory transparency obligations (e.g., the Battery Passport) and data protection can be resolved
- ... what role the works council and the data protection impact assessment play in introducing new technologies

Introduction

In the sense of Industry 4.0, digitalization means, above all: more data, more sensor technology, more networking. Machines, plants, and processes continuously generate data streams from which value creation can be derived – predictive maintenance, AI-supported quality control, or digital twins are inconceivable without this data foundation. However, as soon as these data streams allow conclusions to be drawn about individual persons, for instance operators at a machine, the **General Data Protection Regulation (GDPR)**¹ applies.

Digitalization in the workplace is therefore never a purely technical matter. It is always also a matter of co-determination, compliance, and the trust of the workforce. This chapter shows where classic Industry 4.0 applications collide with data protection law, how these conflicts can be classified, and which processes companies have established to reconcile digitalization and data protection.

As Figure 16.1 shows, the boundary between pure machine data and personal data is often fluid in practice. A cycle-time value on its own is not personal data – however, as soon as it is linked to an operator ID, a personal reference arises within the meaning of Art. 4 No. 1 GDPR.

1 **GDPR** – Regulation (EU) 2016/679 on the protection of natural persons with regard to the processing of personal data, directly applicable law in all EU member states since 25 May 2018.

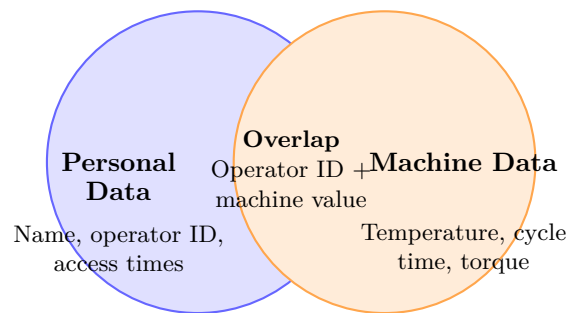


Figure 16.1: Distinction between personal data and pure machine data – the overlap arises as soon as a machine value can be attributed to an identifiable person.

16.1 Fundamentals

16.1.1 Personal Data vs. Machine Data

According to Art. 4 No. 1 GDPR, personal data is „any information relating to an identified or identifiable natural person“. What matters here is not the type of data itself, but its **attributability** to a person. A sensor value (e.g., vibration, temperature, torque) is, on its own, purely machine data. However, as soon as this value is linked to a shift, operator, or employee ID – for instance in an MES¹ log – a personal reference arises, and the GDPR applies.

For operational practice, this means: already at the stage of **system architecture**, a decision must be made as to whether and how machine data is linked with personal data. This decision should not be left to chance but should be part of a deliberate design process (see Section 16.4.3, Privacy by Design).

16.1.2 Legal Bases under Art. 6 GDPR

Every processing of personal data requires a legal basis. For the operational context, three of the six bases named in Art. 6(1) GDPR are particularly relevant.

Legal Basis	Typical Application in Industry 4.0
Art. 6(1)(b) (contract)	Access control for employees to plant equipment under the employment contract
Art. 6(1)(c) (legal obligation)	Documentation obligations, e.g., proof of qualifications on safety-relevant machines
Art. 6(1)(f) (legitimate interest)	Evaluation of operator data for process optimization – requires a balancing of interests
Art. 6(1)(a) (consent)	Voluntary participation in pilot projects, e.g., wearables for ergonomics analysis

Table 16.1: Legal bases under Art. 6 GDPR with typical applications in Industry 4.0.

Of particular importance in the operational context is **Art. 88 GDPR** in conjunction with **§ 26 BDSG**²: the processing of employee data for purposes of the employment relationship is permitted, provided it is necessary – blanket, all-encompassing surveillance generally is

¹ **MES** – Manufacturing Execution System, a process-near IT system for controlling and monitoring production.

² **BDSG** – Bundesdatenschutzgesetz (Federal Data Protection Act), supplements and specifies the GDPR for the German legal system, including in the area of employee data protection.

not.

16.1.3 Data Subject Rights

As data subjects, employees have the same rights vis-à-vis their employer as customers have vis-à-vis a company:

- **Right of access** (Art. 15) – what data is being processed about me?
- **Right to rectification** (Art. 16)
- **Right to erasure** (Art. 17) – with restrictions, e.g., where statutory retention obligations apply
- **Right to object** (Art. 21) – particularly in the case of processing on the basis of legitimate interest

These rights apply regardless of whether the data resides in a classic personnel file or in an MES log. For Industry 4.0 systems, this means: the ability to respond to access requests must be considered from the outset in the system architecture, since retroactively filtering large volumes of sensor data for personal references is technically demanding.

16.1.4 Supervisory Authorities

In Germany, data protection is organized on a federal basis: each federal state has its own state data protection authority, which is responsible for private-sector companies. At the EU level, the **European Data Protection Board (EDPB)** coordinates the uniform application of the GDPR. Violations can be sanctioned with fines of up to 20 million euros or 4% of worldwide annual turnover (Art. 83 GDPR) – a framework that is significantly higher than that of many other economic regulations.

Exercise: An MES logs the operator ID, the name of the machine, and the cycle time for every production order. Assess: Does this constitute personal data? Which legal basis under Art. 6 GDPR is applicable for the evaluation of this data as part of process optimization?

16.2 Conflict Areas Specific to Industry 4.0

The following four areas illustrate, by way of example, where classic Industry 4.0 technologies come into contact with data protection law.

16.2.1 Employee Monitoring through Sensors and MES

Sensors, RFID tags, and MES systems continuously capture process data. When this data is linked to individual persons, monitoring pressure can quickly arise that goes beyond pure process optimization. The central legal distinction is drawn between:

- **Process monitoring** – permissible where it serves plant safety, quality assurance, or maintenance and does not constitute targeted behavioral or performance monitoring of individual persons.
- **Employee monitoring** – behavioral and performance monitoring of individual employees, which is only narrowly permissible under § 26 BDSG and is regularly subject to co-determination by the works council (see Section 16.4.2).

A frequently discussed practical example is worker tracking in the smart factory: positioning systems that are actually intended for material flow control simultaneously allow conclusions about the duration of presence and movement profiles of individual employees. Careful attention to **purpose limitation** (Art. 5(1)(b) GDPR) is essential here: data collected for material flow control may not simply be repurposed for performance evaluation.

16.2.2 AI Training Data and Explainability

AI systems used in quality control – for instance, camera systems for optical defect detection – often also capture persons within their field of view, for example when operators perform manual rework. For such training datasets, the following applies: as soon as persons are recognizable, this constitutes personal data (and, in the case of biometric evaluation, even special category data) within the meaning of Art. 9 GDPR.

In addition, **Art. 22 GDPR** governs the right not to be subject to a decision based solely on automated processing that produces legal effects or significantly affects the person. For Industry 4.0 applications, this is particularly relevant where AI systems contribute to personnel decisions, for instance in automated shift scheduling or performance evaluation. Here, a „right to explanation“ or to human intervention must be provided.

An important interface exists with the EU’s **AI Act**, which classifies AI systems on a risk-based basis (see Section 16.3). Systems for monitoring and evaluating employees regularly fall into the „high-risk“ category there.

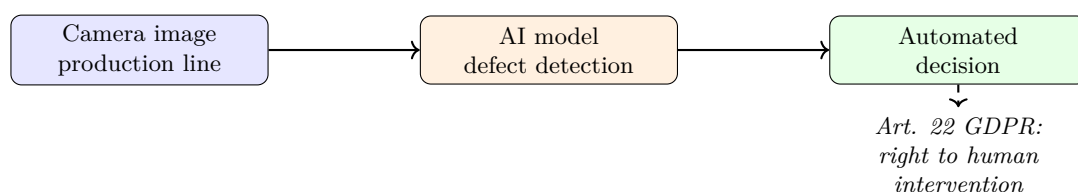


Figure 16.2: Automated decision-making in AI-supported quality control and the right to human intervention under Art. 22 GDPR.

16.2.3 Predictive Maintenance with Personal Reference

Predictive maintenance systems forecast maintenance needs on the basis of historical sensor data. Problems arise when fault causes are attributed to the operating behavior of individual

persons – for instance, when an algorithm determines that a particular operator is disproportionately often „involved“ in faults. This immediately raises the question of **attributability** and **liability**: is the operator actually the cause, or does the fault lie with the machine, the material, or the process?

For operational practice, strict **aggregation** at the machine or shift level is recommended before data is used for analysis – evaluation at the individual-person level should remain the exception and requires its own legal basis as well as, generally, the involvement of the works council.

16.2.4 Cloud and Edge Data Location

Many Industry 4.0 platforms use cloud infrastructures, frequently from US hyperscalers. Where personal data is transferred to third countries in the process, the requirements of Art. 44 et seq. GDPR apply. Since the **Schrems II ruling**¹ of the CJEU (2020), transferring personal data to the USA has become legally more demanding – standard contractual clauses alone are often no longer sufficient; additional technical and organizational measures are required.

Two strategic options result for manufacturing companies:

- **Data localization** – processing exclusively on European or local edge systems, without cloud transfer.
- **European cloud alternatives** – use of providers with an EU server location and a contractual guarantee against third-country access, for instance in the context of the **Gaia-X**² initiative.

Edge computing (cf. chapter on digitalization trends) offers a double advantage here: it not only reduces latency but, through local data processing, can also reduce data protection risks associated with cross-border data transfer.

¹ Judgment of the Court of Justice of the European Union of 16 July 2020 (Case C-311/18), which declared the EU-US Privacy Shield invalid and requires additional safeguards for data transfers to the USA.

² **Gaia-X** is a European initiative to build a federated, sovereign data infrastructure, involving, among others, industrial companies and research institutions.

16.3 Interface with Other Regulatory Topics

The GDPR does not stand in isolation but within a dense network of newer EU regulations that specifically target the data economy. For Industry 4.0, three legislative acts are particularly relevant.

Legislative Act	Subject of Regulation	Relation to the GDPR
GDPR (2018)	Protection of personal data	Foundation
Data Act (2023)	Access and usage rights to machine and IoT data	Applies in addition to the GDPR; where personal reference exists, the GDPR takes precedence
AI Act (2024)	Risk-based regulation of AI systems	Supplements the GDPR for automated decisions (Art. 22)

Table 16.2: Interplay of the GDPR, Data Act, and AI Act in the Industry 4.0 context.

16.3.1 Data Act

The **Data Act** regulates who may access data generated by connected products (e.g., machines, IoT devices) – irrespective of any personal reference. It is intended to secure fair access for users of IoT devices (e.g., machine operators) to „their“ machine data, including vis-à-vis the manufacturer. Where machine data contains personal elements, the GDPR remains the primary legal basis – the Data Act then additionally regulates the economic dimension of access.

16.3.2 AI Act

The **AI Act** classifies AI systems according to risk levels (minimal, limited, high, unacceptable). AI-supported systems for evaluating employees – for instance, in the context of people analytics or automated performance appraisal – generally fall into the „high-risk“ category and are thus subject to additional obligations such as risk management, documentation, and human oversight. These obligations overlap substantially with the requirements of Art. 22 and Art. 35 GDPR (data protection impact assessment).

16.3.3 Battery Passport / Digital Product Passport: The Tension between Transparency and Data Minimization

A particularly illustrative example of the conflict between regulatory transparency obligations and data protection is provided by the **Battery Passport** (Digital Product Passport, mandatory from 18 February 2027 under Regulation (EU) 2023/1542). It requires comprehensive documentation, in part spanning the entire supply chain – CO₂ footprint, material origin, recycling data – which is shared with various actors via tiered access rights.

As soon as this supply chain data also contains information about individual persons – for instance, contact persons at suppliers, inspection personnel, or those responsible for repair processes – the **principle of data minimization** under Art. 5(1)(c) GDPR applies in parallel: only the data necessary for the respective purpose may be processed.

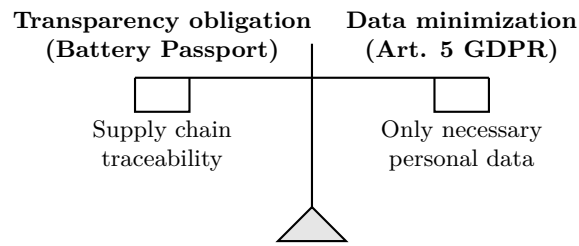


Figure 16.3: Tension between the statutory transparency obligation (Battery Passport) and the data minimization principle of the GDPR.

The practical solution usually lies in the **anonymization or pseudonymization** of personal elements in supply chain documentation: instead of named contact persons, function titles or roles are recorded that are sufficient for traceability without identifying individual persons.

16.4 Practice in the Company

16.4.1 Works Agreements as a Governance Instrument

Works agreements are, in German companies, the central instrument for designing digitalization projects in a manner that is compliant with both data protection and co-determination requirements. They typically govern:

- which data may be collected,
- for which purpose it is evaluated,
- how long it is stored,
- who is granted access,
- and whether and how evaluations may lead to conclusions about individual behavior.

16.4.2 Co-determination by the Works Council

Under **§ 87(1) No. 6 BetrVG**¹, the works council has a mandatory co-determination right in the introduction and application of technical equipment that is *intended* to monitor the behavior or performance of employees. What matters here is not actual use but already the technical **capability** for monitoring – an MES system that theoretically permits personal evaluations can be subject to co-determination even if monitoring is not actually intended.

For practice, this means: digitalization projects in production should involve the works council at an early stage – not only after technical implementation, but already during the concept phase.

16.4.3 Privacy by Design and Privacy by Default

Art. 25 GDPR requires that data protection be taken into account already at the stage of **system design** (*Privacy by Design*) and that data-protection-friendly default settings be chosen (*Privacy by Default*). For Industry 4.0 systems, this can be made concrete as follows:

- Aggregation of data at the machine rather than the personal level, wherever possible
- Pseudonymization of operator IDs in evaluations, with re-identification only for a justified reason
- Role-based access concepts analogous to the tiered access rights in the Battery Passport (cf. Figure 16.3)
- Deletion concepts that are technically embedded already at the system design stage

16.4.4 Data Protection Impact Assessment (DPIA)

For processing operations that are likely to result in a high risk to the rights and freedoms of natural persons – for instance, comprehensive employee monitoring or the large-scale use of AI systems – Art. 35 GDPR mandates a **data protection impact assessment**.

1 **BetrVG** – Betriebsverfassungsgesetz (Works Constitution Act), governs the co-determination rights of the works council in German companies.

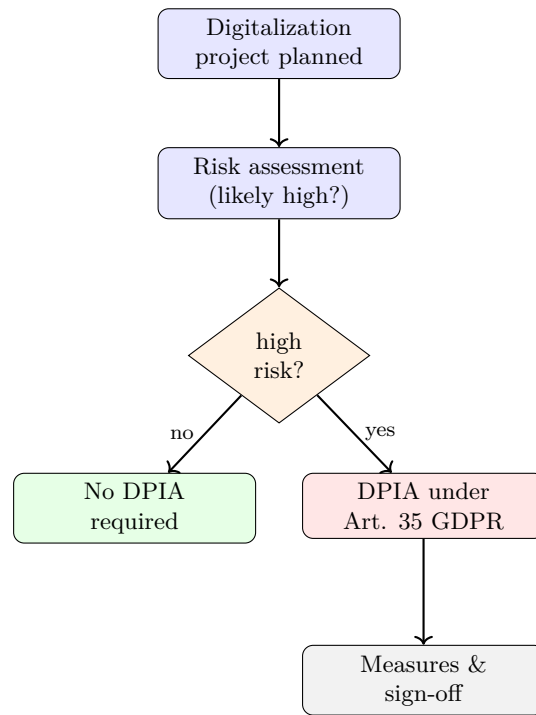


Figure 16.4: Course of the data protection impact assessment for digitalization projects in production.

The works council, the data protection officer, and – in the case of high-risk AI systems – the requirements of the AI Act should be integrated into this process in order to avoid duplication of effort and to produce a consistent compliance picture.

16.5 Opportunities and Risks

Data-protection-compliant digitalization is not merely a cost factor; it can also create competitive advantages. At the same time, considerable risks exist if the requirements are disregarded.

Opportunities

- **Trust of the Workforce**
Transparent, co-determined digitalization projects reduce resistance and increase acceptance of new technologies.
- **Competitive Factor**
Data-protection-compliant systems facilitate cooperation with European customers and partners, who increasingly pay attention to GDPR compliance.
- **Data Quality through Structure**
The obligation of purpose limitation and data minimization forces companies to structure their data models cleanly from the outset – an advantage that also benefits other digitalization projects (e.g., the Battery Passport).
- **Legal Certainty**
Clear works agreements create legal certainty for employers and employees alike.

Risks

- **Fines**
Violations can be sanctioned with fines of up to 20 million euros or 4% of worldwide annual turnover.
- **Co-determination Conflicts**
If the works council is not involved at an early stage, delays or even the invalidity of already-introduced systems may result.
- **Barrier to Innovation**
Unclear or excessively restrictive interpretation of data protection requirements can slow down digitalization projects – an aspect that should also be discussed in the international comparison of business locations (cf. MHP Barometer).
- **Complexity from Regulatory Overlap**
The GDPR, the Data Act, and the AI Act overlap substantively, which can lead to demarcation problems and duplicate reviews in practice.

16.6 Summary

Data protection is not a peripheral topic in Industry 4.0 but an integral part of every digitalization project as soon as machine data can be linked to persons. The central challenge lies in cleanly distinguishing between process and employee monitoring, in choosing a viable legal basis under Art. 6 GDPR, and in the early involvement of the works council and the data protection officer.

With the Data Act and the AI Act, additional legislative acts have been added that regulate specific aspects of the data economy and AI use and are, in practice, closely interwoven with the GDPR. The example of the Battery Passport illustrates how statutory transparency obligations and data protection must be reconciled – usually through consistent pseudonymization and role-based access concepts.

For companies, the principle applies: whoever integrates data protection into the system architecture from the outset (*Privacy by Design*) not only avoids legal risks but also creates the structured data foundation that is needed anyway for further digitalization initiatives – from predictive maintenance to the digital product passport.

Discussion Question: Digitalization in the workplace – where does process optimization end, and where does monitoring begin? Discuss using an example of your own choosing from your professional environment.