2 The Basics

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Abstract
Even five years after the official start of the initiative, most people are not familiar with the term “Industrie 4.0”. Those who have addressed the topic even have trouble producing a relatively plausible explanation for it. Thus, this chapter deals with the basics: the official definition of Industrie 4.0, its position in the larger context of digitalization, the terms “smart product” and “smart product development,” as well as with the platform and the ecological system. Finally, the initiative’s explosive force on society will be analyzed.

2.1 What Is Industrie 4.0?

When this editor’s first book was published, there was no official definition. The German *Plattform Industrie 4.0*—at the time still led by three industrial associations, Bitkom, VDMA (the German Mechanical Engineering Industry Association) and ZVEI (the German Electrical and Electronic Manufacturers’ Association)—then supplied such an official definition. This definition can be found in the implementation strategy submitted to the platform in April of 2015, whose leadership was taken over by the German federal administration. Its core message states:

> The term Industrie 4.0 stands for the fourth industrial revolution, a new level of organization and control of the entire value creation chain during the life cycle of products. This cycle is oriented toward increasingly individualized customer demands and stretches from the concept, to the order, to development and manufacture, to the delivery of a product to the end user, right up to the recycling process, including the associated services [1].

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The fourth industrial revolution thus indicates a new level in the "organization and control of the entire value creation chain." So as to leave no doubts about just what is included, this value creation chain is specifically and comprehensively defined, from its inception to the services connected with the products. This makes clear that we are dealing with a fundamental transformation in industrial production methods, and not simply a change of any single part of those methods.

Nevertheless, ever since the initial debates, including the discussions of the team having founded the Initiative, composed of acatech (the German National Academy of Science and Engineering) and a research union, pivotal links in the value creation chain have been repeatedly pushed aside or completely negated, as if they were not so important. Mostly, the debate concentrates on changes in production, that is, in manufacturing products. Neither the path from idea to product nor its development, design, or engineering, seem important. In addition, even services and new business models based on them, as well as new value creation paths, all too often fall by the wayside.

For instance, on the homepage of acatech itself under "Dossier on the Future of Industrial Sites," it reads: "With the entrance of the Internet of Things, Data and Services onto the production scene, a fourth industrial age has dawned" [2]. After this statement, there is a picture and a quote from both German Chancellor Dr. Angela Merkel and from the president of acatech, Prof. Henning Kagermann. According to that statement, the Internet of Things, Data and Services is only "entering the production scene," but not that of industry and its overall value creation.

Such statements—of which, unfortunately, there are plenty—represent an inadmissible simplification and reduction of the definition, with broad consequences. You see, those who have nothing to do with industrial manufacturing can relax and move on to other topics; if it only involves production, it is none of their business.

This narrow view limited to production has several causes, and one can presume that those individuals who use such arguments do not do so consciously, and certainly do not mean it in a malevolent way. Let us not forget that all previous phases of industrial development primarily affected production. The fact that this is no longer the case is one of the great peculiarities, and it is time we understood this phenomenon with all of its facets. Secondly, production is that link in the industrial value creation chain that costs the most money. That is why, in past centuries, a primary objective was to optimize, rationalize and save, especially in the realm of production. Thirdly, Industrie 4.0 really does affect production, and it will lead to another boost in productivity which will make a difference. To the extent to which it is possible to bestow components of machines and systems, drives, connection assemblies, and conveyor belts with so much "intelligence" that they can act increasingly autonomously, it is not only the case that human labor will be reduced and other routine jobs made redundant; completely new partnerships and networks are possible, out of which the familiar factory can be turned into a factory network. The effects of Industrie 4.0 on production are indeed tremendous.

If, however, the limitation to production were true, the significance of the overall initiative would hardly be so extensive as to require the attention of greater parts of society. It would be fairly similar to the third industrial revolution, which of course was only called that in retrospect. When programmable logic control was used for IT-supported automation, nobody but manufacturing firms cared. And, except for specialized media, hardly anyone noticed. Yet what is so special about the fourth industrial revolution is that it is actually calling into question and altering production methods on the whole—prompting consequences extending far beyond manufacturing companies.

Industrie 4.0 is changing our industry overall—starting with the concept itself, because it no longer exclusively and predominantly stems from the brain of an inventive engineer, but via the internet from the market, from customers, partners, the competition, from all around the world; through product development, design and programming, via tests and the simulation of digital product models, up to virtual commissioning, because data from manufacturing can be used with data from engineering to accelerate and optimize these process steps. It is also changing services, which no longer only refer to customer service, repair and replacement parts delivery, but rather a number of new services, from preventive maintenance to optimized operation, for instance involving hourly billing.

What serves as the basis for this? The second sentence of the official definition answers the question in the respective section of the implementation strategy:

> The basis is the availability of all relevant information in real time through the networking of all instances taking part in the value creation chain as well as the ability to use the data at any time to derive the optimal value creation flow. By connecting people, objects and systems, dynamic, real-time optimized, self-organized and cross-corporate value creation networks are created, which can be optimized according to various criteria, such as costs, availability and resource consumption [1].

This is difficult for non-specialists to follow. What does "all relevant information" mean? How is it made available in real time? What is so different about the networking and connection of people, objects and systems that alters the entire value creation flow?—Because all machines and systems were already interconnected for automation; people were already able to obtain all relevant information from the devices, rapidly in the moment such information was needed.

There are three main factors which have changed in recent years:

1. Digital components such as sensors, actuators, cameras and microphones nowadays are so small and can be produced so inexpensively that we can use them to teach things to see, hear and feel. By the way, several German producers are leaders in the world market for such products.
2. Since the 2010s, an internationally applicable protocol, IPv6, has existed which enables almost everything to be supplied with its own internet address. This enables a device to establish contact to other devices and people as well as send and receive data.
3. Finally, information science as an engineering discipline has matured and is on the way to become the most important discipline of all. It is used to help networked, sensitive things to act in a sensible and increasingly autonomous manner.

These factors now make the step that separates the third from the fourth revolution possible. It is a bit like the difference between a smartphone and the first generation of mobile telephones. A mobile phone allowed people to connect, send and receive text messages, and communicate with anyone. With a smartphone, you can access the internet, and via the smartphone, services such as GPS navigation and updates are offered without having to be actively queried about or request such services. In industry, the difference is that, until now, devices were programmed, connected via an intranet or directly to one another and controlled by a program to perform certain steps, and existing data could be retrieved. In the future, devices can make data available via the internet, trigger actions using their data, or perform an operation themselves based on data, without the need of involving humans.

That is precisely what is meant by the Internet of Things, which we will subsequently examine in more detail. All things can become nodes and terminals on the internet, even machines and systems, but also washing machines, central heating systems, air conditioners, cars, bicycles, watches and eyeglasses.

The great task posed to industry is the development and production of such internet-capable, communicating products, which can be turned into data storage devices, such as smartphones or tablets; and beyond this, developing services and business models that allow additional value creation with these novel products. And ultimately, industry itself must utilize the new opportunities via the internet and the data of things which then gradually become available, in order to optimize its own processes and adjust to new technologies.

Let us use an example with which everyone is familiar: the printer. In recent years, a generation of devices has appeared on the market that serves not only as just a printer, fax machine and scanner. These devices can also connect to the internet with their own IP addresses. If an ink cartridge is running low on ink, the device warns the user and recommends a new cartridge, from the printer's manufacturer, of course. With a click of a mouse, the cartridge is ordered and soon delivered before the installed cartridge is completely empty. None of the printer manufacturers makes any noteworthy profit from selling printers themselves. Printer manufacture is typically undertaken by suppliers, is reduced to an absolute minimum of work and other expenses and costs are brought down as much as possible. The printer providers, who are no longer genuine printer manufacturers, make their actual turnover with the accessories that the customer needs: especially ink cartridges, paper, photo paper, and specialty papers. A connection to the internet enables an increased access to the customer and thus a closer customer connectivity than is possible via a normal retail store.

To be able to offer such printers, these devices must thus be "intelligent." They must be networked and possess the capability of not only measuring the existing volume of ink in the individual cartridges and displaying a respective warning at the right moment, but they also have to automatically offer a suitable replacement and trigger the purchasing process. It is most likely these features harbored in the software of such devices that make the difference between competitors on the market today. Perhaps these features represent the most important components of the products that former printer manufacturers can still develop themselves. And the bigger the customer and corresponding number of printers in use, the larger the profit that is generated by these services, and the greater the advantage is to corporations, for instance, based on the smooth operation of all printers in all departments. The printer production itself—and here we come back to the previously mentioned unjustified limitation of the topic of Industrie 4.0 to manufacturing—the production itself has become a secondary element for printer providers.

If you can understand Industrie 4.0 in this way, you will immediately realize that the fourth industrial revolution is not only changing production methods and industrial processes, but also the products of daily life and the way we use them: in short, our lives and work.

Thus, Industrie 4.0 is not only about what digitalization is doing to industry and is not just of interest to industry. Industrie 4.0 is part of the digitalization of the entire human society, which will trigger even greater changes in our daily lives than the smartphone, because it is being increasingly incorporated into all objects of our lives.

2.2 A Short History of Digitalization

Although the term “digitalization” has been around for a while, and although it has been advancing for more than half a century, it has only been in recent years, after the start of Industrie 4.0, that public debate about it has begun which has reached and interested broader levels of society. We are still at the beginning of the clarification process of what digitalization means for society and its economy, for humans and their lives and work; yet meanwhile there is no doubt, that it will change all of life on this planet.

On Wikipedia, you can find the assumption that in 2002, for the first time, humankind was capable of storing more information digitally than using analog means, such as on hard drives instead of in file folders. Wikipedia estimates that the global technological information capacity in the year 1993 was only 3% digital, but in 2007, just 14 years later, it had reached 94%. These assumptions are based on a publication by Martin Hilbert and Priscila López in Science Magazine in 2011 [3]. The beginning of the so-called digital age is often dated to the end of the 20th century.

However, the digitalization of information did not begin until shortly before the mid-20th century. In Germany, Konrad Zuse built the first functional, fully automatic and freely-programmable computer in the world, the Z3, in 1941. As early as the last years of the Second World War, the first freely-programmable computers also appeared in England and the USA.

The goal of these machines was to calculate. In the 1980s, a professor of electrotechnology in Heilbronn used to refer to computers in his lectures as “high-speed idiots.” Nobody—not even an autistic person—can solve mathematical problems as quickly as a calculating machine. The only thing the computer needs is for information to be reduced to 0 or 1, black or white. That is all that compilers, or translation programs, do: They convert a program written in a higher programming language, the source code, into a bunch of zeroes and ones, the machine code.

The purpose of higher programming languages is for people to be able to abstract from concrete details and describe tasks in a more general form. The science that teaches this process is known as informatics, or information science. It was created in the late 1960s. Its early years generally took the form of courses of study which crystallized from departments of mathematics. The first course of study in information science in Germany was offered at the Technical University of Munich in 1967.

Whereas early computers were large mechanical machines driven by giant electron tubes, Zuse was able to create the first fully electronic computer with his Z3. Texas Instruments and Intel, among others, put the first commercial microprocessors with integrated circuits on the market in 1970/1971. The incredible tempo at which the progressive miniaturization, especially of electronics, then took place was the prerequisite for mainframe computers to be replaced initially by midrange computers, then PCs. Today, every smartphone boasts a performance capability and storage capacities (some, depending on the respective contract with a telecommunications provider, even at no extra charge) which, in the 1980s, corporations could hardly finance for their computers. A computer at a machine builder company in Neckarsulm, Germany, on which an internally-programmed CAD system ran in 1980, cost almost one million Deutschmark and had a main memory of three megabytes. Moore's law, named after Gordon Moore in 1970 and still repeatedly proven true today, predicts that the complexity of integrated circuits, having minimal component costs, will double every one to two years. The smaller and more powerful the necessary hardware was, the more it could calculate and the faster practical fields of application and programming developed.

It is, of course, no coincidence that hard-wired machine control was able to be replaced by programmable logic controllers (PLCs) at that time as well. In fact, the success of the PLC and automation is seen as a main characteristic of the third industrial revolution. Just as was the case in production facilities, the microprocessor and the free programming of all types of machines prevailed. NC and subsequently CNC machine tools, lathes and milling machines, as well as freely-programmable robots conquered manufacturing plants.

While programs initially were integral parts of computers, at the end of the 1960s, the term "software" appeared to denote them. In the 1970s, the US administration ordered the manufacturer IBM to differentiate between hardware and software on its invoices. In the mid-1980s, Microsoft was responsible for the next big step, the millions of users of the personal computer, the PC. With this step, for the first time on a large scale, hardware was displaced by software, because Microsoft did not offer PCs, but rather the operating system, on the one hand, that is, the software which allowed the computer to process programs, and on the other hand, application software such as the Office programs. The computer itself was sold by partners, who initially only served Microsoft as suppliers. In the computer business, software displaced hardware. IBM experienced a profound crisis in the years to follow, which almost ended in the complete destruction of the company. Luckily, it was able to surmount the transition to doing business with software.

In one fell swoop, companies and entire industries were then exclusively focusing their business on developing and distributing software. In Germany, the firm SAP was established, and internationally, the software industry turned into one of the most important sectors, itself divided into sub-sectors.

IT for information technology and ICT for information and communications technology have become abbreviations that now almost everyone knows. The Center for Office and Information Technology in Germany, called CeBIT, was, from the time starting in 1986 and spanning about two decades, the most important international trade fair focusing on ICT. For several years, it was considerably more important than the Hanover Trade Fair, the world's largest industrial trade show, out of which it developed.

IT quickly came into use for all calculable tasks and work steps in industry. It was used for the digitalization of accounting and order processing, for programming machines and systems and for calculating the durability of products. In construction, computer-aided design (CAD) was responsible for the disappearance of drafting boards; computer-aided manufacturing (CAM) saw the automation of NC programming as derivation of CAD models; 3D modeling enabled the design of product surfaces, such as for automobiles, which was also visual evidence that, in decisive parts of processes, industry was no longer dependent upon handicraft.

The internet enabled software-controlled communication, which would soon connect people around the world in real time via mobile end devices. In addition to the internet and mobile computers, from notebooks to smartphones to tablets, it was miniaturization and the availability of inexpensive components that once again made new business models possible: because using a global positioning system (GPS) and the IP address of very end device, personal and user data of their users could be collected and evaluated, such as preferences for certain locations, shops or products.

The business models of the leading internet companies currently topping the list of internationally successful firms are simple: The company offers certain services, such as internet searches or electronic commerce free of charge or at a very low cost, and in return, consumer goods providers can purchase the respective service as advertising space, with which they offer their products to internet users. Never before have enterprises become such rich companies in such a short time where each individual firm has more financial power than some nations.

There is a significant change which has taken place in the process: Business deals are no longer made by selling software to users, but by selling personal user data to consumer goods manufacturers. To do so, user permission is obtained—if at all—by a single mouse click under endlessly long and rarely read "agreements".

Digitalization first made computer producers such as IBM great. Then, they passed the baton on to software producers such as Microsoft, and information technology hardware makers became suppliers or also switched over to providing software. Ultimately, the suppliers of user data triumphed over hardware and software producers. This not only led to the downfall of most mobile telephone manufacturers. In February 2016, the Google parent company Alphabet, which had been created in the meantime, for the first time was able to topple Apple as the first on the list of the most expensive corporations. In addition to the business model shared by internet enterprises dealing in user data, Apple still offers hardware and software, but Google does not. And Google is the area that finances all other areas of the Alphabet corporation.

It is the way in which internet enterprises have changed consumption, trade and, in fact, a large part of most people's lives with their services, supplied in several free apps, which has only now turned the topic of digitalization into a core topic of society, and on a worldwide basis, no less. Let me repeat very clearly: The foundation of this phenomenon is the internet and the networking of mobile end devices with the internet.

The networking of devices with the internet is also the foundation of Industrie 4.0. As such, the fourth industrial revolution is a part of general digitalization. After software conquered the realm of automation, in industry, too, data and its use via the internet has become a hot topic.

The Internet of Things initially only recognized smartphones and computers as networked things. Now, it is increasingly encompassing all industrially produced things. Just as with the smartphone, these things can become data storage devices with whose data business can be conducted. Just as with the smartphone, it could be the services connected to the respective device that represent the heart of such business transactions.

Digitalization first replaced hardware with software. Hardware became an add-on for the software. Then, the software was enhanced by the internet. Software made access to service offers possible. Today, in many sectors, product and service user data has already become the "material" from which value is created. Software, like hardware before it, has frequently been downgraded to add-on status, partially being offered free of charge, in order to do business with the data.

Considering Industrie 4.0 as a component of the digitalization of our society explains, to some extent, what is meant by the term. But this thought is also frightening, because much of general digitalization, much of what internet companies have innovated, is not only garnering praise, especially in Germany, but certainly also in other parts of Europe and the world. To that extent, it is worth more closely examining where the differences are, and what the digitalization of industry specifically entails.

2.3 Smart Products

At the beginning of the debate about Industrie 4.0, there was great confusion. Was it something other than the Internet of Things or only a synonym for it? Then, in 2014, the Industrial Internet Consortium was established in the USA, and lots of people thought that the Industrial Internet was a better name than the Internet of Things, and much better than Industrie 4.0. After the explanation of digitalization in the previous chapter, we can now try to differentiate them more precisely.

Even if, in the past ten years, The Internet of Things meant nothing more than the internet of mobile computer things, especially with regard to smartphones and tablets, to a certain extent it is the roof under which all other digitalization takes place. Because ever more things can be networked with the internet, ever more things are going to be on the internet. Just as the smartphone, these items, too, are potential data storage media. The term "Internet of Things and Services," which appeared at about the same time as the Internet of Things, additionally alludes to the fact that the networking of things is not an end in itself. Rather, it is the foundation for services that previously did not exist; services that enable new kinds of business—the most frequent reason for something becoming extremely popular on a large scale.

The internet has remained the same, but its end products, users and to what it interconnects have changed—because now, it is not only people connected to the internet, but also things. According to estimations, we will have nine billion people on Earth in a few years, most of whom will use the internet, but, in fewer than two decades, around 500 billion devices will be networked.

What does this have to do with industry? It is the source of all products, things and devices that are networked and can become the object of services. In order for them to be designed this way and capable of this new role, in order for them to be—and here is another relatively new word—cyber-physical systems, they must be developed and manufactured accordingly. That is the first connection between the Internet of Things and Industrie 4.0. Only things that can be conceived and constructed as interconnectable data storage media can be a part of the Internet of Things. Only if industry manufactures such things can the internet be used with those things. That is quite obviously not an insignificant role. The basis for a functioning Internet of Things is formed by the internet-capable things that industry first must supply.

The prerequisite for the development of the business of internet enterprises was the development of smartphones and tablets. If we are to believe the people in charge at Google, however, neither the development of these devices nor the development of the extremely successful business models based upon them were influenced by any kind of strategy or any plan of any kind. The devices were there, and their interconnectivity made it possible to develop the corresponding business models. In the process, you could say that the users of the devices were taken by surprise. Without being asked, they were given services and functions that brought them advantages. And they only discovered quite a bit later, if at all, just how business was being conducted with their data. Even then, most users didn't and still don't care. The internet, made available in return (almost) free of charge, with its virtually limitless access to knowledge and information and which makes life easier with countless helpful apps—this network was and continues to be so important to people that they barely even want to know about the business underlying it. Nor do they want to know about any abuse being committed with their data, nor about the monitoring possibilities to which their data is susceptible, for intelligence services as well as international corporations.

If the Internet of Things can be theoretically expanded to include all things because industry can design them accordingly with Industrie 4.0, it is no longer comparable to the initial attempts at the Internet of Things via mobile end devices. The basic purpose of networking mobile units was for people to be able to access the internet. This basic purpose does not exist for the other kinds of devices. A device itself is not motivated to use the internet and network. This time, the manufacturers and the customers are the ones who need to understand their own needs and wishes: Who can accomplish what tasks with which device in a different or better way, and who benefits from a particular device connecting to the internet? An additional question of special interest to manufacturers is: Who may be in the position to come between me and my customers with what kind of offer once the device is connected to the internet or could be connected?

The relationships are also quite different regarding the data itself. Basically, we are talking about device data. Whether a personal connection can be derived from that data cannot be answered universally. It depends on the device and its functions. Generally, however, it can be said that the device data is considerably more complex than personal consumer data. Device data can pertain to everything that is related to the usage of a device: its operating data, the purpose of its use, the location of its operation, the ambient conditions, resource consumption, service life and its current "state of health," as well as many other aspects.

Finally, the Internet of Things, conversely, is the technological basis with which industry can use digitalization for its value creation processes. In this way, the cloud, which we will discuss separately, can also become a source of new ideas for products and services, just as internet-based services are used for the optimization of industrial processes.

What exactly Industrie 4.0 means as a component of the Internet of Things (and Services) can only be clarified if we make a more specific differentiation: regarding the business segments and the products. In principle, Industrie 4.0 means something completely different to investment goods manufacturers than to consumer goods manufacturers. Ultimately, every company must decide what it wishes to accomplish within the context of Industrie 4.0 in the course of digitalization for every specific product and every individual service. Of course, it is not possible for us to examine all types of products and companies. But it is worthwhile to have a look at a few examples familiar to most readers.

Let us look at smart products. The association College International Pour La Recherche En Productique (CIRP), the International Academy for Production Technology, at its 23rd CIRP Design Conference in March of 2013, adopted an official definition. The formulation, by Prof. Michael Abramovici from the Ruhr University of Bochum, can be found at SpringerReference:

> Smart products are cyber-physical products/systems (CPS) which additionally use and integrate internet-based services in order to perform a required functionality. CPS are defined as "intelligent" mechatronic products/systems capable of communicating and interacting with other CPS by using different communication channels, i. e., the internet or wireless LAN (Lee 2010; Rajkumar et al. 2010) [4].

Smart products are thus cyber-physical products or systems with integrated, internet-based services. It is not enough that they are mechatronic and “intelligent” or possess a connection to the internet. They also have to have an integrated service that works via the internet or other wireless networks.

Let us first examine what that means in the consumer goods industry, because their products are closer to smartphones than machines or factories, and the effects of Industrie 4.0 in relation to such products are palpable for all people, not only for employees or managers of industry.

Consumer goods are products intended for consumption. Among them, a differentiation is made between short-term or immediately consumed goods, such as food, toothbrushes or shoe laces, and goods that are used for longer periods of time, meaning years or even decades. These include so-called white goods, such as refrigerators and washing machines or household or garden furniture and other furnishings, as well as a large part of clothing and other textile goods. We will leave out automobiles, because they are going to be examined separately.

Often, there is a direct connection between the two categories of short-term and longer-term consumer goods. A coffee machine is used for several years, and in addition to power and water, the consumer also needs ground coffee to make the beverage with the machine, and from time to time, some cleanser and perhaps a replacement part or two.

With such products, associated services can emerge, such as measuring the consumption of ground coffee or the period of machine use. This can result in the ability to make offers for new ground coffee, cleanser and even replacement parts, which either the manufacturer or a business partner has in stock. Especially if we are not simply dealing with a single machine in a single household, but rather hundreds of machines in a corporation or hotel chain, such offers will pile up. This is already happening today. We see it with the aforementioned printers, which signal the user when new cartridges are required and the paper needs to be refilled. Depending on the configuration when installed, this message can also be coupled with an order via the internet and using the fastest delivery method. In such cases, the printer manufacturer has an influence on the selection of supplier and product, and perhaps customers willingly pay more for coffee or ink cartridges, thus financing the additional services offered.

For this kind of product, several scenarios are possible: Example a: The customer does not use the service offered, but continues to purchase the goods in a shop; Example b: The customer—for instance, a large corporation—connects the machines with their own system, which evaluates the device’s messages and connects to another supplier; Example c: The service is only used by so few customers that the development of that service is not worth it for the manufacturer.

This is the category which also includes the much-discussed networking of household devices or components of furnishings and buildings themselves, such as heating systems or doors, to the extent that, for example, they can be remotely switched on and off and regulated using a smartphone. This idea has been around for years. Before the Internet of Things became a reality, they were not achievable, or at least not economically successful. Whether they will be a success remains to be seen. At any rate, it is improbable that customers will voluntarily make their private and operational user data available just for related services, such as they do with smartphones. Services must be developed which are worth it. That is the great challenge for consumer goods manufacturers. The risk for the manufacturers, on the other hand, includes conceivable or even unpredictable service offers from third parties, which may become more important to consumers than the product itself.

In contrast to consumer goods manufacturers, a company in the investment goods industry does not produce for the end customer. Its customer is another industrial enterprise. Under certain circumstances, this customer sells consumer goods, and might be a manufacturer of industrial goods. A seller of electronic motors, for instance, delivers his products to a robot manufacturer, who uses the motors to drive the robotic arms. The robots, in turn, go to a manufacturer of large machines that uses the them for production. In this environment, the smart products are machines of all kinds, robots, manufacturing plants or process industry plants, but also components, assemblies and parts needed for those products. In such situations, possible services need to have a very different character. The most important fields in which examples are known to date involve customer service and logistics.

By connecting industrial products to the internet, their operational data, including ambient data and data exchange with connected devices, can be collected and evaluated on a large scale. Because, in contrast to a household appliance malfunctioning, the failure of a drive can lead to downtime for a plant and thus enormous losses on the part of the operator, the issue of service plays a very different role here. Based on the evaluation of as much data as possible from the respective device and its environment, malfunctions can be more easily predicted. Machine failures or downtimes can be reduced and, in many cases, even prevented. The more devices a manufacturer has on hand to evaluate, the better his analysis and the more reliable are his services. Nevertheless, industrial customers are generally only willing to take advantage of such services under very clearly outlined conditions and based on specific agreements—because, at the same time, data may, under certain circumstances, provide information on the processes that are controlled by the devices, which, in turn, could reveal precisely those competitive advantages that account for a company's lead in the world market.

In logistics, Industrie 4.0 plays a role because connecting transportation systems and the products to be transported to the internet can enable the delivery to be effected with utmost precision. Unnecessary waiting times and detours and excessively early or late deliveries can be avoided; search and retrieval can be automated to a much greater extent than was previously the case. However, despite these immense advantages, here too, such services can only be developed and executed based upon an agreement and explicit order.

Finally, one function rumored to be the primary objective of Industrie 4.0 could actually be conceivable for the distant future: the smart factory, in which a workpiece communicates via the internet with machines, right down to having a machine switch on a drill to supply itself with a threaded hole.

Yet no matter what type of smart product one wants to investigate in the investment goods industry, the questions of real-time capability and security play a very different role than is the case for consumer goods. Here, broadband availability is not a question of convenience, but of survival. The reliability of services has nothing to do with access to a search engine. Either the machine or system does its job or it will be very expensive for all involved parties. A malfunction or a service performed at the wrong time may even cost human lives. To that extent, developing the broadband infrastructure is not only about telecommunications and internet availability for the end user. Without a suitable infrastructure, industrial enterprises have no chance to achieve the necessary transformation.

Even if Industrie 4.0 is an integral part of general digitalization: This part is in no way comparable to the dimensions of what we have previously seen in the world of consumerism; it cannot be compared to the digitalization of music and language, nor the digitalization of communication, nor trade.

A special case among smart products is the automobile. In the past one hundred years, it was the core of private mobility. According to the German Federal Ministry for Economic Affairs and Energy (BMWi), in 2015, the automotive industry, including its large chain of suppliers, was the largest branch of the manufacturing trade in Germany and, based on turnover, the most significant branch of industry in Germany by far. Enterprises in this industry generate a turnover of more than 404 billion euros and directly employ more than 790,000 people. Around the world, the German automotive industry led the pack with its products in almost all product divisions. What role does Industrie 4.0 play in this industry and product? The answer is somewhat complicated.

The automotive industry set the pace for the second industrial revolution with its mass production and division of labor, as well as for the third revolution, with its software-controlled automation. Its production plants are among the most advanced and complex currently in existence. In them, a high degree of individual product variations is manufactured at conditions and prices previously only possible for the series production of identical products. Approximately 150,000 different vehicles roll off the conveyor belts before being followed by one that is virtually identical to a previous vehicle. Now the question is: How is this industry transforming its production to conform to the Internet of Things? How is it achieving the fourth industrial revolution?

If there were a qualifying examination, the automotive industry would not pass the test. Several studies prove that it is lagging behind with regard to digitalization. In November 2015, the BMWi, in collaboration with the ZEW (Centre for European Economic Research) in Mannheim and TNS Infratest, published a study of the German digital economy and degree of digitalization of the German economic sector—with the automotive industry exhibiting an especially poor performance. According to the *Monitoring-Report Wirtschaft Digital 2015* (“Monitoring Report, Economy Digital 2015”) [5], automobile manufacturing, with an index value of 37, together with the health industry and other manufacturing trades (both at 36) are situated in the lowest category of the “deeply below-average digitized” sectors.

Regarding the digitalization of production, the automotive industry is thus facing an extremely large challenge. This is surprising, especially considering that this industry was one of the leaders in the 1990s. Nowhere else was the use of IT in processes as strongly anchored, and nowhere else was the use of modern technologies as advanced as in the automotive sector. Evidently, without anyone noticing, it then fell behind.

And what is the scoop on the automobile as a smart product? It is a consumer good of a special kind. Is it a mechatronic system? For sure. It is a highly complex mechatronic system of mechatronic systems. About one hundred software-controlled systems, from the door lock to the parking assistant, are not unusual for a car. Is this system of systems connected to the internet? For newer vehicles, the answer is also yes. Hardly a vehicle leaves the factory anymore without its own IP address, and the driver can use it to access certain services. Yet precisely at that point, with the integrated, internet-based services that make a smart product what it is: That is where it becomes difficult for the automotive industry.

Which services should be offered by the automotive companies themselves, and which by partners? Where is it reasonable and beneficial to the business end to take advantage of and integrate services provided by internet enterprises? A quick jump was made to Google and Apple, for instance, in integrating their navigation assistance systems. But in 2015, Audi, BMW and Daimler, in a concerted action, took over the Nokia mapping service Here, in order to free themselves from the products of the large internet firms. It seems that the automobile is a product based on which big league companies are becoming competitors on the internet.

The reason for this is simple: Just as is the case for a smartphone, a car can also use the internet to provide information pertaining to preferred places and other driver preferences, and using the GPS system, it can even be directed to offers of advertisers in a more targeted manner than just with a smartphone. The dilemma of the manufacturers is that their customers are paying a lot of money for the car and its “intelligent” accessories. It is not automatic that they will accept all of their movement data being evaluated for any business idea without question, as is often the case with smartphones. It is even less certain that they will want to opt for services which depend on the manufacturer or dealer of their vehicle that they can otherwise access via a smartphone while driving.

However, even without this dilemma, the automotive industry would still have problems. As an example, there was an Audi A5, built in 2013, for which an update of the GPS system in 2016 cost about 350 euros, according to a dealer. Such an update is wise at least once a year. But the owner has to go to the trouble of finding out if there is an update. The manufacturer does not provide the information, and even the dealer will only inform the owner when asked. On the other hand, a GPS program on a smartphone costs nothing and is kept up to date automatically. Why should anyone use the system integrated in the vehicle? In 2016, automobile manufacturers had not yet realized that a GPS system is not a component like an outside mirror that only needs to be available as a replacement part if damaged, or that a GPS system is a service for which customers require up-to-date data.

And yet the automotive industry will also be faced with additional challenges. The development and marketing of electric cars has stalled, and the combustion engine, whether diesel or gasoline, is becoming less popular, even without such catastrophic mistakes as the software-supported exhaust deception scandal at Volkswagen and, evidently, other auto makers as well. The significance of the automobile as a guarantor of mobility is fading fast. In cities, it is becoming old-fashioned to still be getting around by car. And people are becoming tired of the car as an object of prestige. Nowhere in the world are there more registered users of car-sharing schemes than in Germany. It is true that the automotive industry is active and a driving force in the car-sharing business, but this service probably will not be able to make up for the expected drop in sales for the medium term.

The automotive industry is important for Germany as an industrial location. And it is especially challenged by Industrie 4.0 and the Internet of Things. It will be exciting to observe how it will confront this challenge.

2.4 Smart Engineering

Engineering, the realms of design and product development, of testing and safeguarding, preparation and planning production and its necessary facilities—it has always been one of the most important areas of industry. A widely-known calculation states that, in engineering, about 80% of all production costs are determined by the selection of the materials, processing methods, tools and machines with which the product is manufactured, and by all decisions made in this area. Yet only 20% of production costs are incurred in engineering, because it has the fewest employees and the cost of its own tools are not comparable to the production facilities and materials.

This is an old and well-known calculation. Nevertheless, engineering is consistently disregarded where too much concentration is placed on cutting engineering expenses and not enough on the manufacturing costs, which could be kept lower through engineering. With Industrie 4.0, a whole different level of importance is placed on engineering. The fourth industrial revolution will change engineering earlier and more thoroughly than it will change production.

The truth is: the smart products mentioned above also require smart engineering. Mechatronic devices with integrated, internet-based services cannot be developed in the same way as mechanical or simple mechatronic products. Just as we have seen with the automobile, such mechatronic devices are highly-complex systems of systems. Such systems cannot be developed in the traditional side-by-side and consecutive way in which mechatronics, electronics and information technology were developed. They require systems engineering (SE).

For decades, systems engineering was the domain of aerospace, created out of the compulsion to master complex, large-scale projects with a very large number of participants spanning nations and continents. A new discipline was actually born from that industry: systems engineering.

Today, systems engineering is an issue in the automotive industry and, increasingly, also in mechanical and plant engineering. It no longer matters whether thousands of people are involved in a development project and the project has the dimensions of a space station or passenger airplane. Every machine tool, every processing center, even every drive motor can reach a level of complexity that cannot be handled without methods of systems engineering.

These methods no longer first deal with the individual elements of a new product which are then assembled and tried out. Instead, the entire system is always in focus. Initially, the requirements are determined and defined, then the corresponding system architecture designed. The next step is determining which functions are to be performed by which discipline.

All disciplines—which represent a best-case situation and the goal of systems engineering—work in parallel to implement the requirements to functionality and to develop the logic according to which the system will function. In the reality of modern industry, all disciplines work largely separated from each other, with difficulties in coordinating their results, because all specialized IT systems speak their own language, which is not understood outside of that special area, making data exchange or a common visualization, if not impossible, then only possible with a very large degree of effort.

While electrical, electronic, mechanical and IT specialists work with models, visually depict their development results and perform tests on digital models, that is, are able to simulate the target functions, this is not the case for multi-disciplinary systems. Model-based systems engineering is thus an extremely important topic for scientific and in-factory research and development, which will be examined in more detail in the chapters regarding research. Experts do not yet agree whether it is desirable or even necessary to strive toward a multi-disciplinary model of the overall system, or whether it is a better idea to enable the linkage of specialized models, which would then allow co-simulation.

When systems move their mechanical parts using software, which in turn is stimulated by electronic components, then it should be possible to test the model as if it were connected to the internet and already in operation. The tester would have to virtually give a command or be able to simulate data entry using another device, leading to the system performing the desired function. Only if industry is capable of running such tests in an early development stage can it reach a pace comparable to that of the software and internet industries. To do so, the prerequisites must be achieved via standards or system integration, and IT companies are currently working on that goal.

The other challenge posed to smart engineering looms at least as large: Because the division of labor has been taken to ever further extremes in the past hundred years and longer, and because, today, a specialist is so skilled in his or her area of specialty that there is hardly any more room for improvement, there is a lack of generalists. When mechanics and IT specialists receive a joint project, they often lack a project manager who understands both sides well enough to manage them competently.

The collaboration of the disciplines, which must work together for a modern system to be successful, is also lacking for other reasons. Specialization has led to competition between disciplines. Over several decades, certain power structures have developed in enterprises and between the disciplines which have now begun to falter. It is no longer a matter of course that the mechanical engineers dictate how a machine should be built. In some companies whose development teams ten or fifteen years ago were composed of more than 90% mechanical engineers now have teams with a higher number of electronic technicians and IT specialists. Some companies that dominated the world markets as electronics enterprises are software companies today. This is the case for IBM, as well as for Siemens, to name two of the most well-known examples. Around 20,000 employees at Siemens spend one hundred percent of their working time developing software. This shift in the significance of the disciplines is accompanied by fears of job loss, which are about as difficult to overcome as the media discontinuity between the involved IT systems. (We will not even get into the purely human barriers: A new method to make a task faster and especially more transparent for others may not even be desirable to those who are intended to use it; they may not want to have to be faster).

Yet that is just what industry has to achieve now if Industrie 4.0 is to be a success: The disciplines of engineering must come together and work on a common system model in order to compete with the smart people in the internet companies regarding innovation and speed of development.

2.5 Platforms and Ecosystems

New business models are on the horizon. Intelligently developed products connected in the internet will serve as data storage media to offer new services with the aid of the data. Just as can be done with smartphones today, in the future, apps will be made available through a variety of devices offering integrated, internet-based services. Along the way, there are already signs that the methods of doing business and trade are also changing. Where there previously were simple relationships between manufacturers and customers, this aspect, too, is now becoming more complicated.

Up to now, a manufacturer developed and produced a product, which was then sold on the market by that manufacturer or a retailer. During the development and production phases, business partners of the manufacturer generally supplied parts, components or services, but the basic principle was: The manufacturers sell their products to customers. The more products turn into smart products, the less this basic principle can be upheld.

In the publications and events surrounding Industrie 4.0 and the Internet of Things, two expressions are popping up more and more frequently which seem familiar to us but now stand for something else than they once did. These expressions are the terms “platform” and “ecosystem”.

We already know several types of platforms: those in the automobile industry which enable manufacturers to develop various engines and components for one vehicle platform whose reusability has, however, been secured because they were developed for certain platforms and not for one particular vehicle model; the operating system of a PC is the platform on which the software of various producers can be used; of course, political or social groups also rely on platforms that define commonalities; there are drilling platforms and landing platforms, and the expression has several other meanings. When we speak of platforms in connection with Industrie 4.0, the best comparison is that of a computer operating system.

Just as an operating system on a smartphone can serve as a platform for millions of applications, new platforms are now being developed through which industrial services can be offered. It is not very promising for every product or every product line to program special apps that will only work with that product. It seems much more logical to develop apps for a particular type of industrial service, which then can be integrated with certain products or product types, regardless of who exactly manufactured the product. Such a service could, for example, be the search for and ordering of replacement parts, for products ranging from household appliances to cars. Most likely, platforms will develop on which such apps can run. At this point, it is hard to tell who the suppliers and who the operators will be. It could be leading industrial enterprises, cooperation between branches of industry, associations, ITC suppliers or even entirely new players specialized in this type of business.

Just as it is important for industrial enterprises to find out with which business models they wish to turn a profit relating to their future smart products, so, too, will it be important to identify the correct platform with which to do so.

The description of newly-forming platforms alone sheds light on the second expression that has acquired a new meaning: the ecosystem. To date, many people—especially in Germany—have understood it to signify an ecological system; a system that describes how people, nature and technology can interact to the benefit of the ecology. And internationally, many have understood the English term ecosystem as being the economic system of a country, region or the world. Now the term is surfacing in a new variation. It means the special system which in future will be used for the development, manufacture, distribution and use of smart products on the Internet of Things.

Because in addition to manufacturers of products and their suppliers and dealers, there are now also manufacturers and suppliers of platforms, apps and services, cloud technology and software. The number of participants may not be as large as in an ecosystem of computers and smartphones, but this number will grow considerably and become less well-defined than we have known from traditional industry. There will surely be more ecosystems than those in the environment of the smartphone, because the number of possible types of services extends well beyond what is achievable with smartphones. And everyone who transforms his or her enterprise to orient toward Industrie 4.0 also has to consider what role that enterprise will play in which ecosystem—because it is also clear that the decision will not be in favor of a single ecosystem, but rather most likely several simultaneously. The example of the internet of automobiles as described in Sect. 6.2 could be a typical case. Automobile manufacturers will soon have to network their vehicles in the ecosystem of China as well as in at least one in the western world.

2.6 Social Magnitude

What is the goal of Industrie 4.0? On the homepage of acatech, under the heading *Dossier Zukunft des Industriestandortes* ("Dossier for the Future of the Industrial Location"), in the introduction, which has been quoted elsewhere in this book, there is also the following assessment:

> Germany has the potential to become an international lead market and lead supplier in Industrie 4.0 and the services connected to it. From this transition, a new "Made in Germany" economic miracle can emerge, and value creation and jobs can be generated [2].

Industrie 4.0 is seen by its initiators and the Federal Republic of Germany, which it is pursuing as part of its high-tech strategy, as significant for the future of Germany as an industrial location. Germany could become a lead market and lead supplier, which could lead to a new economic miracle.

Faith is being placed on German industry to play a predominant role in the fourth industrial revolution. A lead market means that the German market would be at the forefront for smart products and related services. A lead supplier means that German industry would be the global leading supplier of products and services based on Industrie 4.0.

After having taken a close look at what type of products and services are involved, it is now clear: The decisive factor is the use of the internet for industrial value creation processes as well as for the use of products and services. With Industrie 4.0, Germany as an industrial site has signaled its demand to play a leading role on the internet in the future. After the beginnings of the internet economy, which focused exclusively on the networking of people with the aid of mobile computing end devices and the exploitation of the resulting personal data, the manufacturing industry has now taken the stage.

We are not talking about a simple expansion of previous economic activity to include data on the internet. We are talking about completely different, industrial and device-related data. And to use this data, suppliers require more than smartphones and operating systems. They need deep knowledge of industrial value creation, software-controlled processes, safe machines and their effective utilization. Internet companies cannot simply purchase this know-how and acquire it in just a few years. However, they may be able to dictate to producers the rules that will be used to do business with industrial data on the internet.

In several branches, German industry has forfeited its leading position. Whether it be the textile industry, consumer electronics, computers and their peripheral devices—this list of industrial branches lost to competitors in the USA and especially Asia is long. On the other hand, significant industries, such as mechanical and plant engineering, automation suppliers and manufacturers of sensors and actuators, the automotive industry and agricultural machines, manufacturers of household appliances and other sectors of the consumer goods industry, have succeeded in leading their global markets with regard to the quality of the mechatronic products. Their goods are so highly valued due to their "Made in Germany" label that even higher prices than competitor products cannot shake their top spot in those markets.

Besides production, Germany as an industrial location also has bred a few leading suppliers, such as SAP, Siemens or Telekom, which directly provide parts of the technology required for Industrie 4.0. Digital support of the value creation processes and cloud platforms top the list. In recent years, several smaller and mid-sized enterprises have begun to expand their IT and internet expertise and rise to join the circle of technology suppliers.

Thus, this claim that Germany as an industrial location has taken a leading role is justified. While this does not apply to all industries, it certainly applies to those which are pertinent to Germany's current global market position.

Whether this will lead to a new economic miracle remains to be seen. It is still unclear just how exactly the business model with an industrial internet will look. Of course, the broad global debate about the fourth industrial revolution is spurring lively competition. It has not yet been determined who will lead the race, and it will differ from one industry to the next.

Should Industrie 4.0 prove successful, "Made in Germany" will have a different significance in the future than has been the case. It will no longer be a stamp on a device indicating that the product was manufactured in Germany. In the future, it will be about the technologies that were employed for the development of a system and its integrated services; it will be about the methods of development, testing, manufacture and service. "Made in Germany" will then include smart engineering, smart products and smart services. Ideally, we would need another slogan than the brand "Made in Germany," since the old brand primarily refers to manufacture, evident in the "Made." Now, it is more about the "How" of the overall processes.

If Industrie 4.0 is successful, not only products and services will find customers around the world. Enterprises and nations will also want to shop at German companies, especially for technology and expertise regarding how this innovative industry works and how to make money with it.

Hopes are high that it will be a success. Germany as an industrial location could be just as important for the global internet economy in this next phase as the USA was in the first phase and still is today. The other possibility, that Germany would primarily produce the hardware while others shape the economy of the future, will not be explored further in this book.

Industrie 4.0 has a significance for industry and Germany as an industrial site that cannot be valued enough. Its success depends on a wealth of jobs—not so much those jobs than can be protected with Industrie 4.0 as the undoubtedly even higher number of jobs that can only be created for and through it. The job situation itself is one of the most important criteria for the prosperity of a society, the financial strength of a nation, and the weal and woe of everyone, including those who work neither in nor for industry. Yet the social magnitude of Industrie 4.0 does not end there.

The new products and opportunities of integrated services offer an incredible amount of possibilities to change our lives. Now that software and device networking offers virtually unlimited technical possibilities, the question is, what will society do with these possibilities? Should insurance companies use personal data for their business? Should the health status of accident patients already be available to hospitals when they are admitted? Which data should be free of charge and which should not? What rights does a person have toward a digitally-controlled, autonomous device? And vice versa? On the other hand: Should machines in the future be so intelligent that they can operate on a minimum of regenerative energy? Should industry use its smart products to contribute greatly to not only halting environmental damage but even enabling the environment to recover?

If anything is technically possible, society has to take on an influential role. What is done with Industrie 4.0 cannot be left to the free market to decide. The risks would be too great that the wrong things will be done, and the chance to achieve great things is far too important. At the same time, a new openness must emerge, in comparison to the past. Start-ups must be fostered, investments must be made easier, barriers to new technologies and services broken down. This is a balancing act that all of humankind must now master. If Germany is to play a leading role as an industrial location, it will have to be a leader in this type of influence as well.

In recent years, the awareness of entrepreneurs and enterprises has grown to recognize that the Earth and nature are not resources that industry can exploit at will. Humans have already damaged the natural environment with their industry such that complete recovery is no longer possible. It is no longer nature, with its millions of years of natural laws, that determines the climate and quality of the environment, but humans. In doing so, however, they have also taken on the responsibility to care for the future development of the natural environment.

A few years ago, just before the topic of Industrie 4.0 became the dominating theme of the Hanover Trade Fair, its motto had been “Greentelligence.” It would be catastrophic if Industrie 4.0 led to a decline in the efforts of industry to pursue environmentally sustainable processes and products. The opposite must be the goal. The incredible opportunities of new technologies must be employed to make industry so “intelligent” that it can virtually autonomously lead to greater resource efficiency and sustainability, lower emissions and less environmental pollution.

From this perspective, the targeted leadership role of Industrie 4.0 in the world is almost more important than from an economic aspect: Only if the further industrialization of the world is done according to the principles of Greentelligence can the world’s billions of people achieve a desired level of prosperity without simultaneously making ill or killing millions with smog and environmental destruction.

Industrie 4.0 has the right stuff to also promote a significant transformation in that sense as well; one that will unleash its effects far beyond industry. High hopes are also held for this aspect of success.

References

1. Umsetzungsstrategie Industrie 4.0, result report of the platform Industrie 4.0, editorial board of BITKOM e. V., VDMA e. V., ZVEI e. V., April 2015, p. 8.
2. http://www.acatech.de/de/aktuelles-presse/dossiers/dossier-zukunft-des-industriestandorts.html. Accessed 12 May 2016.
3. Hilbert, M., & López, P. (2011). The world's technological capacity to store, communicate, and compute information. *Science, 332,* 60 (print ISSN 0036-8075, online ISSN 1095-9203).
4. http://www.springerreference.com/docs/html/chapterdbid/409978.html. Accessed 12 May 2016.
5. Monitoring-Report Wirtschaft Digital. (2015). German federal ministry for economic affairs and energy, report on public relations. publikationen@bundesregierung.de.

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