Industrie 4.0

Controlling in the Age of Intelligent Networks

Dream Car of the Dream Factory of the ICV 2015

In cooperation with

IPRI INTERNATIONAL PERFORMANCE RESEARCH INSTITUTE

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Management Summary

Industrie 4.0 stands for the **intelligent networking** of products and processes along the value chain and is seen as an important factor in ensuring Germany **remains a key production location** in the future. There are many indicators that the paradigm shift long prophesized will not happen overnight but step-by-step. In this context, there will be both opportunities and challenges for management accounting and controlling (hereafter controlling).

Industrie 4.0 has three main characteristics: Horizontal integration through value networks, end-to-end digital integration of engineering across the entire value chain, and vertical integration and networked manufacturing systems. Industrie 4.0 is made possible through the use of **cyber-physical systems**. These consist of physical, intelligent and network-capable components which come together to form an internet of things where each object in reality is allocated a virtual image. Utilized in the manufacturing environment, we call them cyber-physical production systems, and they use intelligent networking as the basis for the **smart factory**, **smart products** and **smart services**. The main objective behind smart factories is to optimize production processes, while smart products and smart services should enhance customer benefit with novel products and services. The implementation of Industrie 4.0 holds enormous **economic potential** for increasing gross value-added.

For this reason, Industrie 4.0 is a topic of interest in politics, with research around it constituting one of ten **future initiatives** within the **High-Tech Strategy** of the German government. Similar research initiatives also exist in other industrial countries such as the USA and China.

Alongside the opportunities, there are also risks and challenges associated with Industrie 4.0. These include setting up a comprehensive broadband infrastructure for industry or protecting against sabotage and industrial espionage. Some of the challenges, such as **quantifying the potential benefits**, require the active help of the controller.

A look at the real-world of business shows that companies have already started to implement Industrie 4.0 solutions. Examples range from visualized real-time productivity to mobile assistance systems to mapping faults and breakdowns in production.

There is a wide range of opportunities for the controller to **improve process performance management** or identify **new causal links**. The demands upon controlling will increase in the future. In order to select the right data from a huge pool of data, the controller will need an even **better understanding of business**. Additionally, controllers will have to master new analysis methods from the fields of predictive analytics or data mining. While they will still need to be a **business partner** who provides analytical support for the decisions of the management, they will also increasing slip into the role of **change agent**. Here, controllers will have to actively shape changes in the company.

Preface

The aim of the **Dream Factory of the International Controller Association ICV** (“*Ideenwerkstatt” im ICV*) is to systematically observe the field of controlling and recognize major trends. From this, the Dream Factory develops the “dream cars” of the ICV, thereby making a major contribution to ensuring the **ICV is seen as the leading voice in the financial and controller community**. Ideas and findings are transformed into concrete, working products in ICV work groups or other project groups. Members of the Dream Factory are renowned representatives of the field of controlling from the corporate world and academia.

The Dream Factory always strives to tackle the most relevant and innovative topics that provide new food for thought for the controlling community. After scrutinizing the topics of Green Controlling, Behavioral Orientation, Volatility and Big Data in recent years, we wish to carry on making controllers aware of new developments and thus provide new stimuli for the ongoing development of controlling.

This year we decided to select "Industrie 4.0" as the main topic as its importance for industrial manufacturing has increased tremendously during the last couple of months. The term stands for the intelligent networking of products and processes along the value chain. For many experts, this development will bring about fundamental changes in corporate management, and this will inevitably also have a significant impact upon controlling. Hence, the goal of this year’s Dream Car report is to show you what is meant by Industrie 4.0, what opportunities and risks it offers, and what consequences it will have for the controller.

The heads of the Dream Factory are:

- Prof. Dr. Dr. h.c. mult. *Péter Horváth* (*Horváth AG*, Stuttgart, Vice-Chairman of the Supervisory Board; *International Performance Research Institute gGmbH*, Stuttgart, Vice-Chairman of the Supervisory Board)
- Dr. *Uwe Michel* (*Horváth AG*, Stuttgart, Member of the Board)

Contributors to the core team of the Dream Factory are:

- *Siegfried Gänßlen* (*Hansgrohe SE,* Schiltach, Executive Advisor to the Supervisory Board*; Internationaler Controller Verein e.V.,* Wörthsee, Chairman of the Board)
- *Prof. Dr. Heimo Losbichler* (*FH Oberösterreich,* Steyr*; International Controller Association e.V.,* Wörthsee, Vice-Chairman of the Board; *International Controlling Group ICG,* Chairman of the Board)
- *Manfred Blachfellner* (*Change the Game Initiative,* Innsbruck)
- *Dr. Lars Grünert* (*TRUMPF GmbH + Co. KG,* Ditzingen, Member of the Management Board)
- *Karl-Heinz Steinke* (*International Controller Association e.V., Wörthsee,* Member of the Board*)*
- *Prof. Dr. Dr. h.c. Jürgen Weber* (*Institute for Management and Controlling IMC at the WHU – Otto Beisheim School of Management*, Vallendar, Director)
- *Goran Sejdić* (*International Performance Research Institute gGmbH*, Stuttgart, Research Fellow)

This year we have also complemented the considerations and consultations of the participants throughout with real-world examples in the form of expert interviews. The following leading Industrie 4.0 experts provided valuable insights:

- *Klaus Bauer* (*TRUMPF Werkzeugmaschinen GmbH + Co. KG*, Ditzingen, Head of Basic Technology Development)
- *Erik Roßmeißl* (*WITTENSTEIN AG*, Igersheim, Commercial Manager)
- *Dr. Kai Scholl* (*EUCHNER GmbH + Co. KG*, Leinfelden-Echterdingen, Commercial Manager)
- *Dr. Maximilian Bode* (*Horváth & Partner GmbH*, Düsseldorf, Senior Project Manager)

We would like to take this opportunity to give our sincere thanks for their willingness to support the work of the Dream Factory of the ICV and for their contributions to this Dream Car report.

Our special thanks go to *Goran Sejdić* for his editorial efforts for this report and for his coordination of the core team of the Dream Factory.

We hope you enjoy reading this report and that you gain new impetus for your daily work in controlling.

Best regards,

Siegfried Gänßlen Prof. Dr. Heimo Losbichler

representing the Board of the International Controller Association

Prof. Dr. Dr. h.c. mult. Péter Horváth Dr. Uwe Michel

representing the Dream Factory of the International Controller Association

1 “Industrie 4.0”: The Future Initiative

> *It is fundamentally true that economic growth in Germany can only be secured by innovations if we are an integral part of the main trends in the global economy. Here, it is particularly important that we pioneer and shape the development known as Industrie 4.0.*
>
> Angela Merkel, German Chancellor

In August 2006, the German federal government for the first time passed an overarching total concept with the explicit aim of fostering Germany’s ambitions to become world innovation leader and thereby secure its strong competitive position: The **High-Tech Strategy**. Since then, this concept has been updated and further developed continuously. In its current incarnation, the High-Tech Strategy focuses on ten so-called future initiatives (cf. figure 1) which tackle both social and technological developments, formulate future guidelines for different areas in life, and bundle the necessary research activities in initiatives.

Industrie 4.0 is one of these ten initiatives and describes the industrial production of the future.

Industrie 4.0 is one of ten future initiatives of the High-Tech Strategy

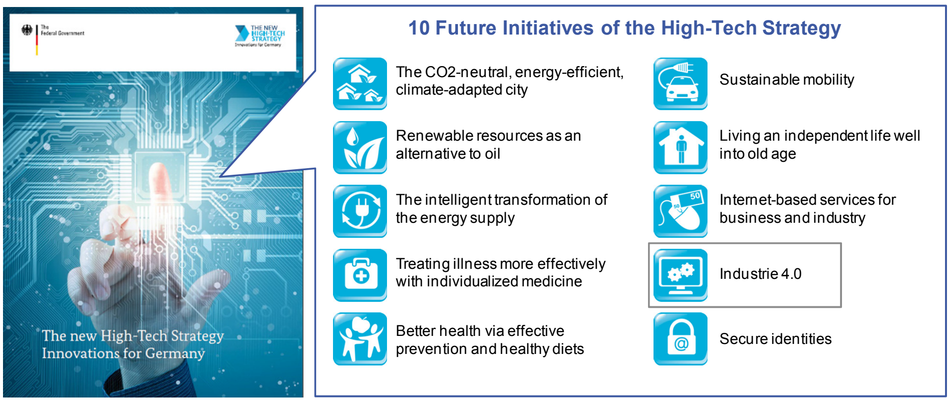


Figure 1: The future initiatives of the High-Tech Strategy (Source: BMBF 2014, p. 50)

In the main, Industrie 4.0 encompasses the development and integration of innovative information and communication technologies for use in industry. To this end, a working group coordinated by the National Academy of Science and Engineering (acatech) has already developed initial implementation recommendations (Kagermann et al., 2013). The aim is to foster the **intelligent networking** of products and processes along the value chain. The overriding objective is to create more efficient processes in the **creation of goods and services** and to enhance customer benefit by **providing novel products and services**. The associated changes in the industrial sector are seen as a comprehensive paradigm shift which causes people to talk about a fourth industrial revolution: Industrie 4.0.

The **first industrial revolution** began with the development of the steam engine and the introduction of mechanical manufacturing equipment. The defining characteristic of the **second industrial revolution** was the use of electricity, which enabled the introduction of the conveyor belt and the assembly line. The **third industrial revolution** was characterized by the automation of production processes through the increasing use of electronics and information and communication technologies. According to this development, the defining feature of the upcoming **fourth industrial revolution** will be intelligent networks based on cyber-physical systems (cf. figure 2). Cyber-physical systems comprise the integration of embedded information technologies in objects, materials, and machines, as well as logistics, coordination and management processes, and networking them together (cf. Kagermann et al. 2013, p. 18).

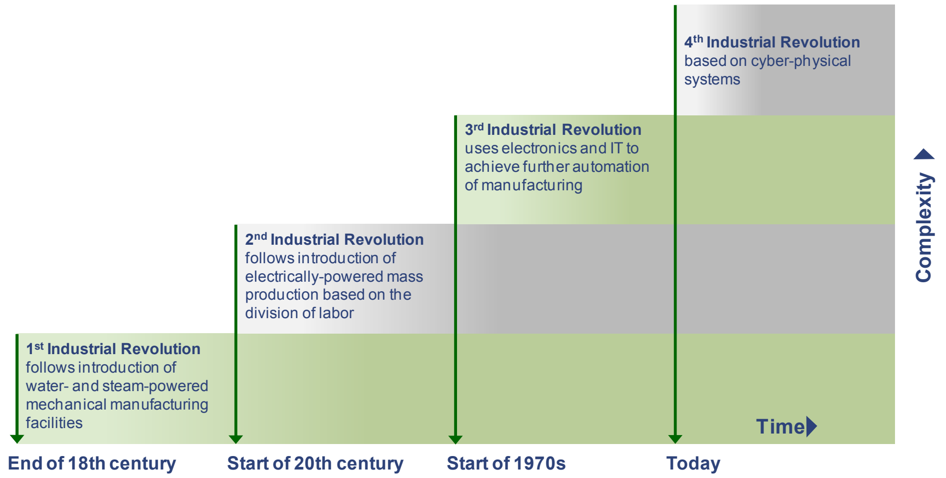


Figure 2: The four industrial revolutions (Source: Kagermann et al. 2013, p. 17)

Regardless of whether Industrie 4.0 can be seen as a revolution or as an evolutionary development, we can expect a **paradigm shift** relating to the possibility of real-time performance management of operating processes. We need to utilize possibility in the design of controlling processes, systems and instruments. The task facing controllers is to actively shape the developments which arise from Industrie 4.0. Thus, the introductory statement from German Chancellor Angela Merkel can also most definitely be regarded as a challenge to the controller community.

Structure of the Dream Car report

In this Dream Car report **"Industrie 4.0 | Controlling in the Age of Intelligent Networks"** we want to provide important impulses for the creative design process required and to make the controller community more aware of what Industrie 4.0 really means.

- First, we analyze what is meant by the term Industrie 4.0 and the associated technologies, opportunities and risks. Additionally, we look at how the topic is handled on an international level (**Chapter 2**).
- Based on concrete implementation examples, we then derive implications of Industrie 4.0 for controlling (**Chapter 3**).
- Further, we show the impacts of Industrie 4.0 on controlling and the extent to which the controlling community has already started to deal with the topic of Industrie 4.0 (**Chapter 4**).
- Finally, we provide a set of recommended actions for tackling the development of Industrie 4.0 as it relates to controlling (**Chapter 5**).

The report also includes recommended reading for those who wish to dig still deeper into the topic Industrie 4.0.

2 Industrie 4.0 Compact!

2.1 Background to the term “Industrie 4.0”

The term “Industrie 4.0” has become a real hype

Everyone is talking about “Industrie 4.0”. In publications, at specialist conferences and at trade fairs the term’s use is almost inflationary. But what does the catchword “Industrie 4.0” really mean?

The first instance of mainstream use of the term was at the Hannover Fair in April 2011. There, the Communication Promoters Group of the **Industry-Science Research Alliance** presented their vision of the industry of the future. From 2006-2013, the Research Alliance was the central advisory body on innovation policy which accompanied the implementation and ongoing development of the German federal government’s **High-Tech Strategy**. The Research Alliance consists of 28 representatives from economics and academia. In November 2011, the federal government adopted the project Industrie 4.0 as part of the action plan for its High-Tech Strategy.

At the same time, the Communication Promotors Group initiated the **Working Group Industrie 4.0**. This working group consisted of over 80 experts from business, academia and associations and was headed up by Dr. Siegfried Dais, Deputy Chairman of Robert-Bosch GmbH, and Professor Henning Kagermann, President of the National Academy of Science and Engineering (acatech). First implementation recommendations on Industrie 4.0 were developed by the working group from January to October 2012 and the accompanying final report containing the recommendations was presented to the German Chancellor Angela Merkel at the Hannover Fair 2013 (see photo 1).

Photo 1: Professor Kagermann handing over the implementation recommendations for Industrie 4.0 to the German Chancellor Angela Merkel (Source: Federal Press Office)

The final report defined eight important fields of action for implementing Industrie 4.0 (cf. figure 3). However, the report pays too little attention to aspects relating to business management, thus making it even more important to tackle those issues here and to develop solutions which focus on networking and real-time.

At the same time as the implementation recommendations were handed over, **Industrie 4.0 Platform** began its work. This initiative continues the work of the Research Alliance and is currently developing concrete solutions for the eight fields of action defined in the report. The Industrie 4.0 Platform is a joint project by the German Association for Information Technology, Telecommunications and New Media (**BITKOM**), the German Engineering Association (**VDMA**) and the German Electrical and Electronic Manufacturers' Association (**ZVEI**). The platform uses a cross-industry exchange to develop technologies, standards and business and organization models and to foster their practical implementation. It is the main touchpoint on the topic of Industrie 4.0 and it consists of representatives from numerous leading companies from a wide range of industries. Additionally, a scientific council made up of renowned professors advises the platform on scientific research issues.

Eight fields of action for implementing Industrie 4.0

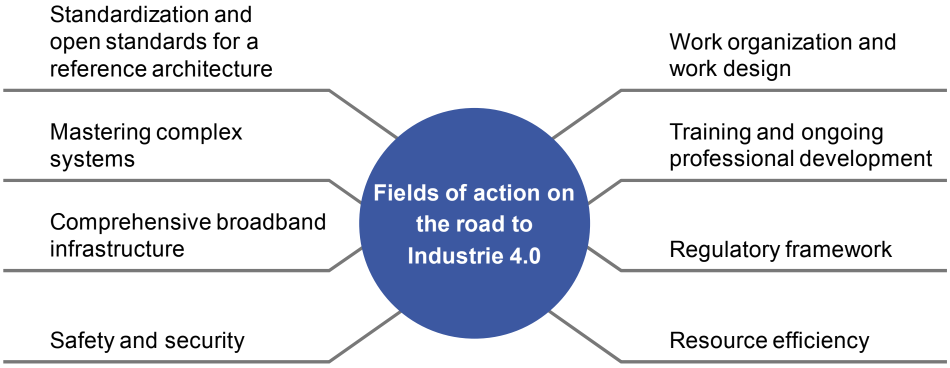


Figure 3: Fields of action for implementing Industrie 4.0 (based on: Kagermann et al. 2013, p. 5)

There are more than 100 different definitions of the term Industrie 4.0 (cf. Bauer 2014, p. 18). To create a uniform understanding of the term, the steering committee of the Industrie 4.0 Platform has approved a definition and vision for "Industrie 4.0". As the leading institution in the field, the platform brings together the most important representatives from business and research. As a result, the Dream Car report also uses this definition:

> ***» The term Industrie 4.0 stands for the fourth industrial revolution, a new level in the organization and performance management of the entire value chain across the lifecycle of products. This cycle focuses on the increasingly individualized desires of customers and encompasses all stages from idea, through development and production order, to delivery of the product to the consumer and recycling, including the associated services.***
>
> ***It is based on the availability of all relevant information in real-time through the networking of all involved instances along the value chain and the ability to derive the optimum value stream at all times from the data. Connecting man, objects and systems creates dynamic real-time-optimized and self-organizing, overarching value networks which can be optimized according to different criteria, such as costs, availability and resource consumption. «***
>
> Source: Industrie 4.0 Platform

2.2 Main characteristics of Industrie 4.0

Implementing Industrie 4.0 will have an impact upon the entire value chain. Intelligent networking leads to increased integration of all the players involved. This vision of the production of the future can be described in more detail using three main characteristics (cf. figure 4), all of which are linked together by one shared characteristic: The performance management process can take place in **real-time** (see below).

Real-time as key characteristic

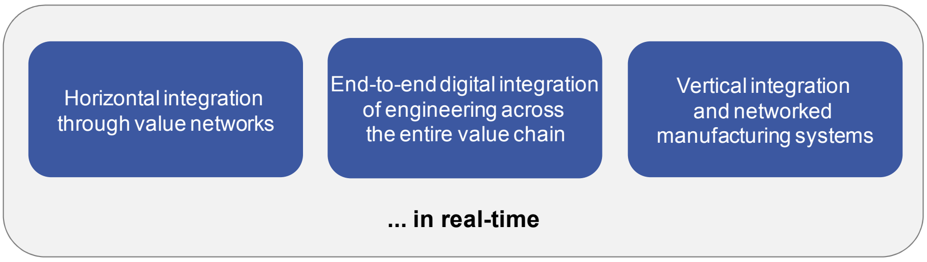


Figure 4: Main characteristics of Industrie 4.0
(own portrayal based on Kagermann et al. 2013, p. 6)

The first characteristic is **horizontal integration through value networks**. This is integration takes the form of networking all the process steps in the value chain. In production, for example, this would mean linking inbound logistics, production, outbound logistics and sales, as well as downstream services, to form an end-to-end solution. However, this linking does not stop at the internal boundaries of the company but also includes suppliers, customers and other external partners, transforming the value chain into a value network. As can be seen in figure 5, this consists of many autonomously acting participants. In a fully implemented Industrie 4.0, different factories, suppliers, external partners, customers and even the energy utility companies are included. The processing of materials, energy and information flows can be standardized. The comprehensive networking promises to considerably increase flexibility and resource efficiency. However, there are many issues which need to be resolved before these hopeful promises become a reality. The lack of standardization concerning cross-company networking or the protection of knowledge or ownership in such scenarios are just some examples of the challenges which need to be mastered during implementation.

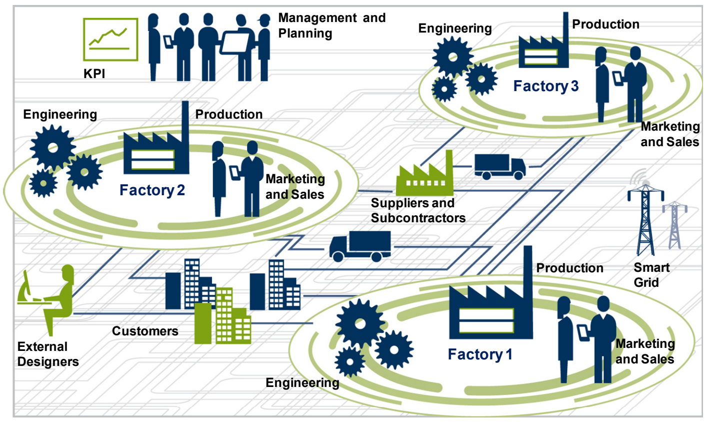


Figure 5: Horizontal value network
(Source: Kagermann et al. 2013, p. 26)

The second characteristic is **end-to-end engineering across the entire value chain**. The aim here is full digitization and thus a virtual portrayal of the real-world. Figure 6 shows how the current situation with many interfaces should be transformed into an end-to-end system engineering solution. We can use this and new possibilities of modeling to master the increasing levels of complexity in business. End-to-end, digital system engineering should allow customers in the future to combine their desired product themselves from individual components and functions instead of having to depend on the product portfolio defined by the manufacturer. The entire value creation process should be mapped, from customer requirements, through product architecture to production.

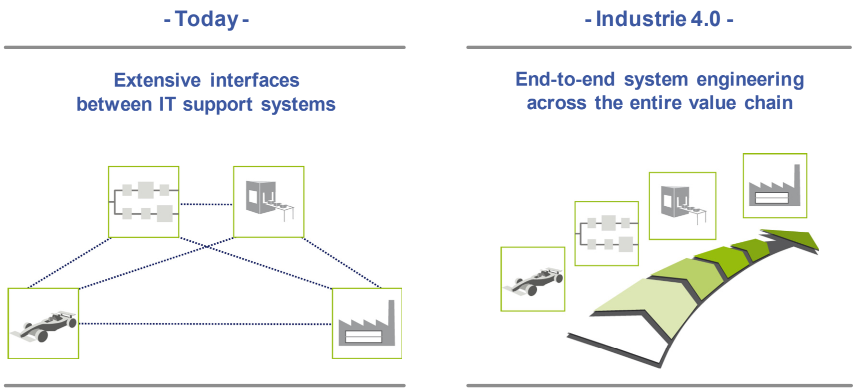


Figure 6: End-to-end system engineering along the entire value chain (Source: Kagermann et al. 2013, p. 35)

The vision in production is of individual, tailor-made products. Customers virtually design the product themselves. Once again, however, we are still far from the finishing line here. The main requirement is to create possibilities of modeling in order to be able to master the increasing complexity of the technical systems. Additionally, we need to train all those employees involved in production appropriately to enable them to see the big picture.

Constant exchange of data between the hierarchy levels

The third characteristic is **vertical integration and networked production systems**. The different hierarchy levels in the company, and especially in production, should be networked using integrated IT systems (cf. Figure 7), for example with the actuator, sensor, performance management, production control, manufacturing, and corporate planning levels being linked together to create an end-to-end solution. This fosters the aim of more flexible and dynamic planning and performance management in production.

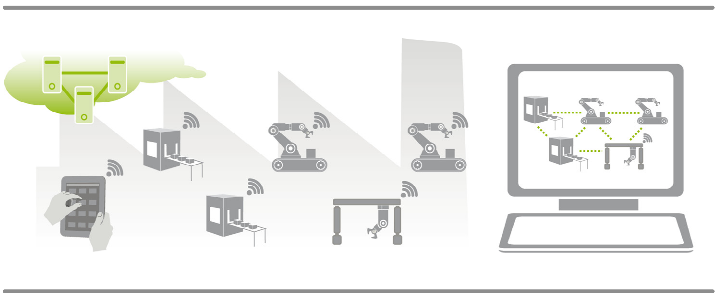


Figure 7: Vertical integration and networked production systems (Source: Kagermann et al. 2013, p. 36)

In the so-called **smart factory** production structures are no longer rigidly defined; instead it should be possible to alter the objects, processes and procedures case-by-case. The individual components of the smart factory continuously exchange information. This exchange takes place in real-time, automatically and across the boundaries of hierarchy levels. There are, however, also challenges which still have to be mastered. Companies need to create an end-to-end and secure infrastructure. The development of modular production systems is a prerequisite for the flexible use of machines. Last but not least, the machine operators will need to be trained to understand the impact of these approaches on the running and operation of the manufacturing system (cf. Kagermann et al. 2013, p. 35).

The one characteristic that the other three all have in common is that of **real-time**. Participants in the horizontally integrated value networks synchronize their data continuously. This allows them to update their production processes at any time across the entire value network and optimize them according to different criteria, such as costs, availability and resource consumption. The information from the system engineering processes are also available in real-time; required data such as customer requirements and their derived construction data feed directly into the production processes. This consistent transparency facilitates the early substantiation of draft decisions in engineering. Vertically networked business and operations processes are synchronized permanently and create an up-to-date image in real-time of the processes and procedures in the factory. For production this means being able to react more flexibly to faults and interruptions (cf. Kagermann et al. 2013, p. 20).

Industrie 4.0 Scenario: Horizontal and vertical integration

The **KSB Group** has approx. EUR 2.2 billion and is one of the leading producers of pumps, valves and related services. More than 16,000 employees around the world work for maximum customer satisfaction in building services, industry and water utilities, the energy sector and mining.

Horizontal and vertical integration at KSB AG

Figure 8 shows how **horizontal and vertical integration** is implemented at KSB AG. On the horizontal level, integration takes place on the one hand in the customer value network and on the other hand in the internal KSB value network. Vertical integration occurs across both of these networks and includes suppliers (cf. Paulus and Zeibig, 2015).

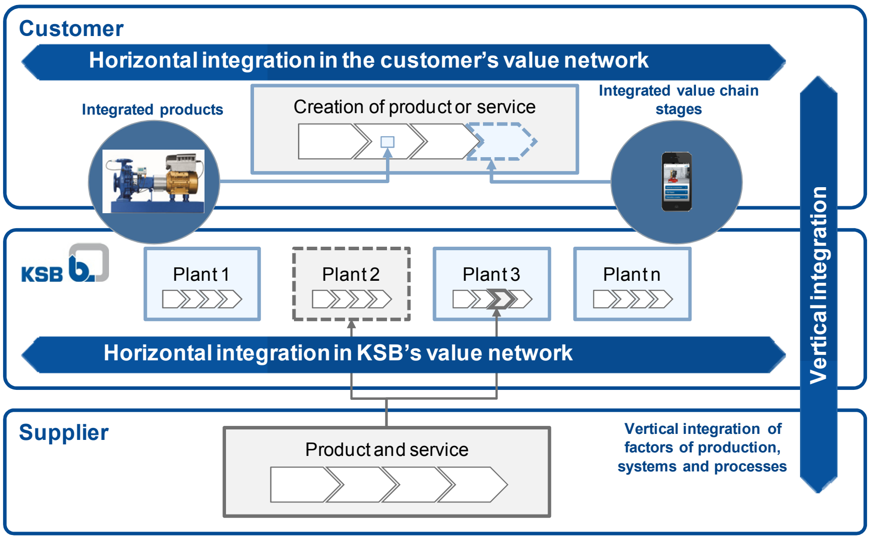


Figure 8: Horizontal and vertical integration at KSB AG (Source: Paulus and Zeibig 2015)

Closer analysis of this specific Industrie 4.0 characteristic leads to reminders of an idea from around 30 years ago. Back then, similar aspects formed the basis for **computer integrated manufacturing (CIM)**. This raises the question of whether Industrie 4.0 is merely a media hype and simply a new label stuck on old and already implemented content ("old wine in new bottles").

Experts: Industrie 4.0 has greater potential and a different orientation than CIM

Prof. Dr. Dr. h.c. mult. August-Wilhelm Scheer, one of the pioneers of CIM, believes the current development has **more potential** than the only piecemeal implemented CIM. CIM describes the comprehensive management of manufacturing plants with the help of computers. Logistics, product development and automation should be supported within an overall concept. He sees the difference in today's availability of the technologies required for implementing such ideas. Integrated database systems, RFID technologies or cloud computing are as available as powerful processors. Now that ideas meet available technologies, the professor emeritus for business informatics prophesizes considerably higher chances of real-world implementation for Industrie 4.0 (cf. Scheer 2012).

Prof. Dr.-Ing. Thomas Bauernhansl, Director of the Institute of Industrial Manufacturing and Management (IFF) of the University of Stuttgart and Director of the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart, identifies several important differentiating features (cf. Table 1). In particular, he sees the employee under Industrie 4.0 in a very different role. Where CIM was based on a factory without people, now humans are the focal point and act as "the conductor of value-added". The orientation of performance management has also turned tail: CIM was based around a central master computer while decentralization of performance management and the communication of autonomous systems are the defining characteristics of Industrie 4.0. He also sees fundamental changes in data management: CIM should record a time-lapsed image in a central database while Industrie 4.0 is based on the availability of real-time data and the digital mapping of the factory, according to Bauernhansl. This allows changes in planning and performance management to be made quickly and sometimes even in the ongoing processes (cf. Fecht 2013).

Table 1: Differentiation between CIM and Industrie 4.0 (cf. Fecht 2013)

	CIM	Industrie 4.0
Role of humans	No operative role	In factory as "conductor of value creation"
Production Planning & Performance Management	Centrally via main computer	Decentral optimization, communication of autonomous systems
Changes in the Production Program	Only possible in the long-term	Possible at last minute, partly during ongoing production process
Availability of Data	Time-lagged portrayal in database	Real-time availability

In summary, there are clearly differences between Industrie 4.0 and CIM. Alongside the technological characteristics listed here, the business management aspects in CIM were thought through in more detail than is the case for Industrie 4.0. There is, for example, the question of what impact the strong customer focus and the associated huge number of variants will have on development and production costs. More attention needs to be paid to such topics in Industrie 4.0 (cf. Mertens, 2014, p. 29) and this task will fall in particular into the remit of the controller. Alongside the differences, however, there are also commonalities: Some ideas from CIM, such as the end-to-end use of information and communication technologies in industry, have been absorbed into Industrie 4.0 and further developed.

Comprehensive networking with the help of embedded systems could change the world of manufacturing fundamentally. The vision of decentralized production planning, continuous data exchange in real-time, and merging together of the real and virtual worlds could give rise to completely new products and services. However, it remains to be seen whether these changes will actually trigger a revolution.

Evolution vs. revolution

For Siegfried Rußwurm, Member of the Managing Board at Siemens responsible for the industry sector, it is clear that these changes will not happen overnight but will develop over decades. He sees this as an evolutionary development and not a revolutionary one. "**No-one is going to be cutting a red ribbon here**" he says, but goes on to say that the innovations which began here could be seen as revolutionary by historians in a few decades (cf. Wirtschaftswoche 2013). Revolutions in the past were also not announced but rather generally recognized as such with hindsight. For this reason, many critics feel it is somewhat of an exaggeration to prophesize the fourth industrial revolution here. They also point out that the technologies used (especially software, electronics, sensors and networking) are not new inventions but have been around for quite some time. Nevertheless, regardless of which term is preferred, there are many indicators that intelligent networks will bring about fundamental change; with hindsight these might really appear to be revolutionary. The past three revolutions also developed over decades. We will have to wait 20 or 30 years to see just how deeply, or even revolutionarily, industry will change (cf. Gausemeier 2014). This makes it even more important right now to develop roadmaps tailored to individual companies which describe in detail the steps the company must take over the coming years to fully tap the potentials of Industrie 4.0.

2.3 Cyber-physical systems as technological enablers of Industrie 4.0

Cyber-physical systems (CPS) are seen as the technological enablers of Industrie 4.0. They connect the virtual (cyber) world with the real (physical) world. Cyber-physical systems in production consist of intelligent (smart) machines, warehouse systems and means of production which can independently exchange information, trigger actions and manage their own performance. They should create intelligent, networked factories and value chains which facilitate more flexible, more efficient and more individually tailored production. As a rule, cyber-physical systems can also be used outside of production and consist of three components:

- Physical components
- Intelligent components

} Embedded systems

- Network components

Physical objects (machinery, buildings, transportation, production facilities, logistics components etc.) which contain an **„intelligent“ component** (sensors, storage options etc.) are described as **embedded systems**. These embedded systems already exist in many forms today. What is new is that they are **networked** both together and via the internet. This networking allows individual objects to communicate with one another.

Developments from different fields are brought together

This communication is made possible thanks to developments from different fields. The interaction between electronics, software engineering, networking and mechatronics are defining characteristics of cyber-physical systems (cf. figure 9).

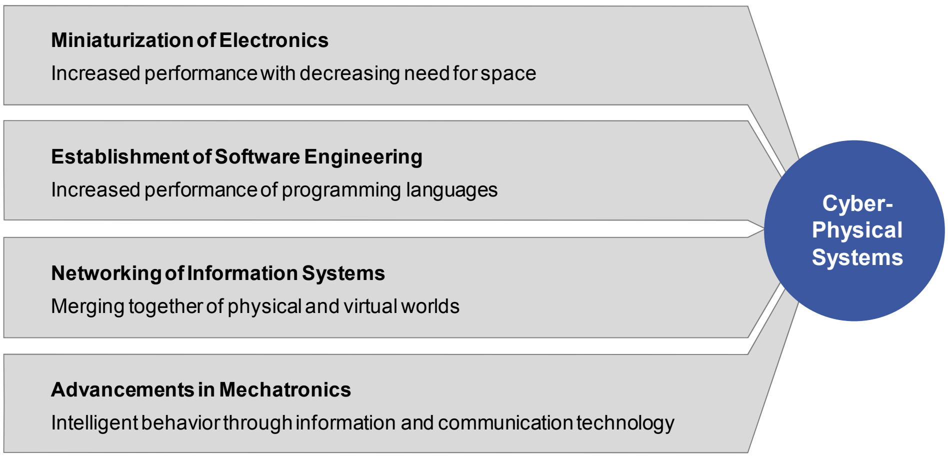


Figure 9: Development towards intelligent technical systems (based on: Fraunhofer IPT, cf. it's OWL 2014)

The trend is to have even more extensive systems with more networked components. At the lowest level we have closed, embedded systems, such as an autonomous airbag. The next development level has two or more embedded systems which are networked, albeit still within a closed system (e.g. automatic parking systems for cars). When the network extends beyond this closed system, we have a cyber-physical system, such as an intelligently networked road junction. This uses data from traffic jam alerts to manage traffic optimally (cf. figure 10).

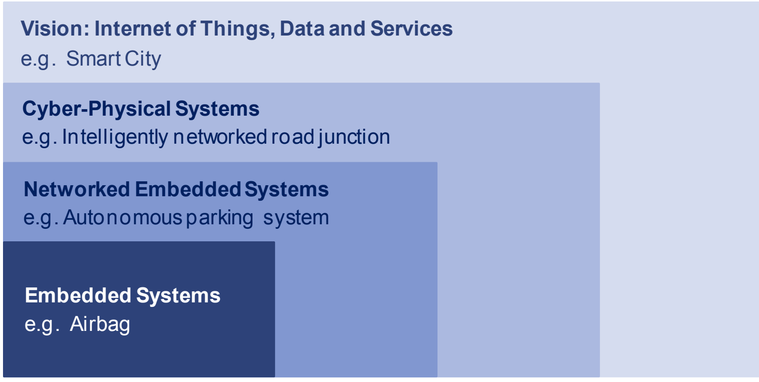


Figure 10: The development stages of embedded systems to the Internet of things, data and services (based on: acatech 2011, p. 10)

Cyber-physical systems communicate via the Internet and use Internet services. They analyze their environment with sensors (e.g. for temperature, pressure, movements) and assess the impressions they receive by accessing globally available data and services. They save data and use actuators (e.g. movements with grapplers, visual or acoustic signals) to influence their physical environment. Humans use man-machine interfaces (e.g. via touch displays) to interact with cyber-physical systems and manage them with voice or gesture control (cf. acatech 2011, p. 10).

Cyber-physical systems are based on autonomous and decentralized networks and optimize themselves within these networks. In an advanced stage, they can intelligently combine their individual functions autonomously and thus develop completely new abilities. On the most fully-developed level, an **Internet of Things** (IoT) is created in which each object in the real-world is allocated a virtual image. This data is all available in real-time and is updated permanently. This system of systems is a vision which still lies some distance in the future. In this form, cyber-physical systems facilitate the **linking together of the three networks**: the Internet of Men, the Internet of Things and the Internet of Services merge together to become one. People are linked together via social networks, as already happens today. Additionally, intelligent objects capable of communication (work pieces, vehicles or machines) join together in networks and use services to connect to one another (cf. Bauernhansl et al. 2014, p. 15).

The Internet of Things offers many possibilities for application

The intelligent networking creates numerous possible applications, for example intelligent power networks (smart grid), intelligent buildings (smart building, smart home) or intelligent traffic systems (smart mobility) (cf. acatech 2011, p. 10).

If cyber-physical systems are deployed in field of industrial production, we call them **cyber-physical production systems (CPPS)**; one example of their application is in **smart factories** (cf. Kagermann et al. 2013, p. 89).

2.4 Potential uses of intelligent networks

The comprehensive implementation of Industrie 4.0 offers a wide variety of potential uses. Here we can differentiate between the **creation of goods and services** (smart production) and the **goods and services themselves** (smart products and smart services). The goal behind smart production is to optimize the entire value chain, while for smart goods and smart services it is to increase customer benefit through novel products and services. In terms of the overall economy, tapping these potentials promises to increase the gross value-added (cf. Bauer et al. 2014, p. 5).

Intelligent production in the smart factory

When it comes to **creating goods and services**, the vision of the future is called the **smart factory**. Man, machines and the work pieces to be produced are connected to one another much as in a social network. Social machines communicate with one another and with intelligent objects in the factory. The overriding objective of this network is to achieve a total optimum of quality, run time and capacity utilization. Crucially, what is new here is that all data is available in real-time, resulting in a permanently updated, virtual representation of reality. This facilitates the improved management of complex processes and procedures (cf. Kagermann et al. 2013, p. 23).

A further major innovation is the **decentralized (performance) management** of the factory, which has brought about a complete revision of the production planning process. In contrast to conventional production which takes the form of a chain of clearly defined steps, production in Industrie 4.0 takes place in dynamic networks. The end-to-end digital engineering between the different levels and resources facilitates vertical integration within the company. The vision: **Intelligent products or work pieces** know their production process and take an active part in the manufacturing process. They are connected to the machines and use information on free capacities to find the one they need. In this way, the smart factory can produce considerably more efficiently with fewer faults or interruptions. Mastery of the complexity means it is possible to produce in small numbers right down to a batch size of one and still be profitable. People also have their place in the smart factory: They receive support through intuitive automation, such as assembly handling assistants for difficult or dangerous tasks (cf. Bauernhansl et al. 2014, p. 16).

Plug & Produce should enable simple retooling or extension of machines or components. Standardized interfaces and protocols permit simple configuration and exchangeability. In the best case scenario, a milling machine can be turned into a lathe simply by replacing one component (cf. Kagermann et al. 2013, p. 105).

Interaction via man-machine interfaces

When people interact with intelligent machines and objects, the **man-machine interface** plays an important role. It must be intuitive and user-friendly, both of which are decisive when it comes to worker safety and the acceptance of Industrie 4.0 technologies (cf. BMBF 2013, p. 28).

Industrie 4.0 Scenario: Automotive production

Today there are **purpose-built production lines** in automotive production. It is a complex process to retool them for new product variants. Software-supported manufacturing execution systems (MES) are usually designed in the same way as the hardware of the production line with a precisely defined range of functions, making them very static. The functionality of the production line also defines the order and the rate of employees' work; as a rule it is very monotonous. Often, **individual customer requirements cannot be satisfied**; for example, it is not possible to install a component from a different product group made by the same company.

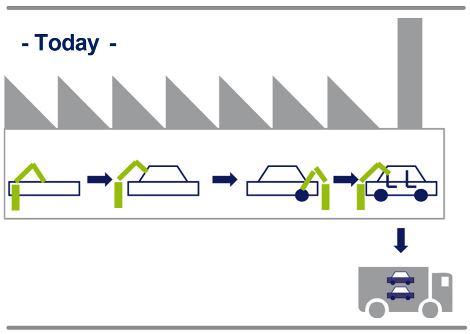


Figure 11: Clocked assembly on production line (Source: Kagermann et al. 2013, p. 68)

These contrast with the **dynamic production lines of Industrie 4.0**. Vehicles within travel autonomously through the factory. The dynamic reconfiguration of production lines makes it possible to mix and match the equipment with which vehicles are fitted; furthermore, individual variations can be implemented at any time in response to logistical issues (e.g. bottlenecks) **without being constrained by centrally prescribed timings**. The manufacturing execution system IT solution now constitutes a central component from start to finish – from design through to assembly and operation. The control system consists of apps based on a manufacturing operation system (MOS) and a federative ICT platform. Apps, MOS and platform combine to form a new and flexible MES. The new dynamism permits the trouble-free integration of **individual elements**. Additionally, assistance systems, such as data glasses, provide support for employees through assembly or picking instructions, making assistance systems an important "enabler" for integrating humans into the factory of the future (cf. Kagermann et al. 2013, p. 68).

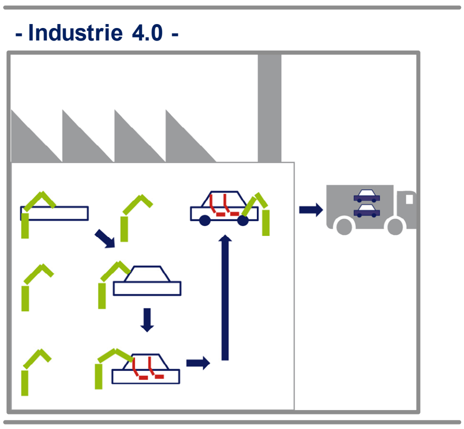


Figure 12: Decoupled, fully flexible and highly integrated production systems

Smart products are appearing in all aspects of our lives

However, this „smartification" does not stop when the products pass through the factory gates. We talk about **smart products** when we refer to intelligently networked products used by customers. This type of products can be found in all aspects of our daily lives, from tennis racquets equipped with sensors which can provide the user with data to analyze the playing technique, to networked systems in agricultural machinery capable of self-managing the work with the help of weather data.

Smart products, in which hardware, software, sensors, data storage, microprocessors and network components are connected to one another, are complex systems. Compared with “conventional” products, they offer an enhanced range of functions and are characterized by three components:

- Physical components (sensors, actuators, control units)
- Intelligent components (processors, software, data storage)
- Network components (wireless, wire-connected)

Smart products should be seen as CPS

Thus, smart products should also be regarded as cyber-physical systems (cf. Chapter 2.3). Figure 13 summarizes the main characteristics of smart products.

Figure 13: Characteristics of smart products (based on: Capgemini 2014, p. 7)

Smart Products are equipped with sensors which make them **aware** of their environment and enabling them to monitor their current use and status. Being equipped with processors, software and data storage makes them **intelligent**. This equipment enables autonomous decision-making and self-learning processes. They are **connected** via network elements to one another and to their environment. This allows them to interact with other cyber-physical systems. Integrated control technology makes them **responsive**, which enables them to adapt to their environment autonomously or based on external commands. Smart products use actuators (e.g. via acoustic or optical signals) to influence their environment.

An article in Harvard Business Manager from December 2014 by the renowned Harvard professor and strategy pioneer Michael E. Porter and James Heppelmann shows how smart products will change the entire world of business and economics and are in part already doing so today (cf. Porter and Heppelmann 2014, p. 34).

Porter and Heppelmann describe how intelligent components bring about an increase in the performance of physical components, whereby the network components in turn increase the performance and value of the intelligent components. Thus, a “self-perpetuating cycle of increasing value” is created. This networking has two functions: First, it enables the exchange of data between the product and its operating environment, manufacturer, user or other products or product systems; second, some of the functions of the physical product can be transferred to external servers. The intelligent products differ in the range of their functions. Porter breaks them down into four levels, each building on the previous one: **Monitoring**, **control**, **optimization** and **autonomy** (cf. figure 14).

Four successive functional levels of smart products

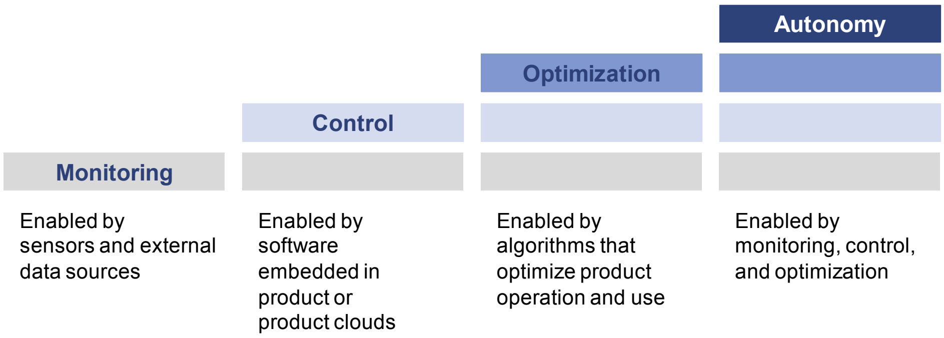


Figure 14: Functional levels of smart products (Source: Porter and Heppelmann 2014, p. 41)

Monitoring is enabled by sensors and external data sources (e.g. from the cloud). Smart products can monitor their operation, environment or the current or past status. If necessary, the product can send out messages or alerts.

Smart, connected products can be **controlled** through remote commands or algorithms (example of reaction rules: “If a sensor recognizes rain, then switch on the windscreen wiper”). Users can control and personalize their products in many new ways.

Monitoring and control functions enable the capabilities and performance of a product to be **optimized**. The combination of data analysis with algorithms makes it possible to continuously improve the performance of a product.

The highest development level is that of **autonomy**. This is reached through the combination and interaction of the other three functions. Self-learning devices adapt automatically to the situation and products can operate in complex environments without human control.

The services which are created in this way are called **smart services** and can take on many very different forms (cf. Riemensperger 2014).

“Data is becoming more important than the physical product”

Based on the findings of the Working Group Industrie 4.0, the follow-up report “Smart Service World – Internet-Based Services for the Economy” was presented to the German Chancellor at the CeBIT Fair in March 2014. Co-chair of the working group, Frank Riemensperger, explains the key message of the smart service world: “It is no longer about the product,” says the Senior Managing Director of Accenture Germany. Instead, in the future what will be more important is how the product is used, which data is created during use, and how we can use that data. He attributes more value to the data than to the physical product itself. The report of the working group believes the business models of both providers and of producers and operators face a revolution in the near future. The combination of smart products with physical and digital services to create smart services will lead to the client demanding them **“as a service”** which is flexible and tailored to specific needs. This will mean that the focus will no longer be on the provider but on the consumer, who expects to receive the right service everywhere and 24/7. These changes can change entire industry structures (cf. Riemensperger 2014).

The report names already digitized markets, such as media, music and advertising, as good examples of both the strength and the disruptive nature of these innovations. Apple or Facebook have established themselves there as new digital market leaders and created completely new business models. In the future, this change is predicted for many more industries (cf. Kagermann et al. 2014 p. 17).

Industrie 4.0 Scenario: Plant operations optimization as a service

Operators of plants within a value chain must constantly economically optimize the plant. **Today,** as a rule this highly complex task is undertaken by the plant operators themselves. This optimization must consider a range of very different criteria (resource consumption, capacity utilization and throughput of the plant, product quality, etc.). One huge challenge is coping with unplanned events. The operator must organize a large number of suppliers and service providers linked to the plant (maintenance, logistics, spare parts etc.).

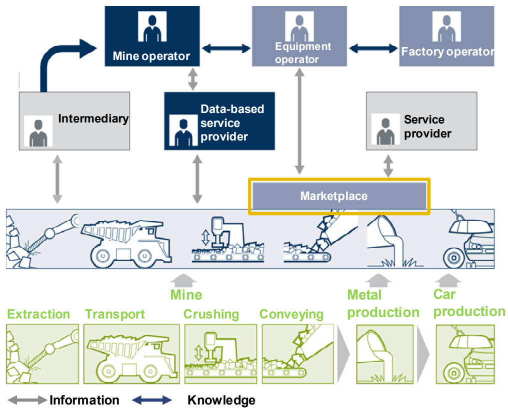


Figure 15: Plant optimization by the operator (Source: Kagermann et al. 2014, p. 34)

As part of **Industrie 4.0,** plant data and digital models can be gathered, maintained and offered as **smart services** on a platform. Process and sensor data are transmitted to this platform and collected there. Service providers use intelligent, data-based services and offer their knowledge in the form of reports (creating transparency), recommendations (early recognition of up-coming faults) or direct interventions in plant operations. Instead of having to commission service providers directly, plant operators can also use information from the service platform to invite tenders via a marketplace and commission services directly. Finally, an intermediary can view the entire value chain and offer new benchmark services which would incorporate a number of different plants (cf. Kagermann et al. 2014, p. 34).

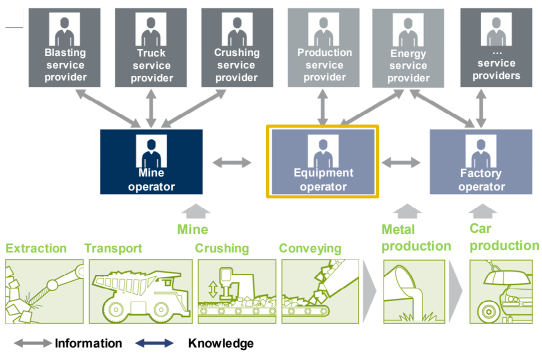


Figure 16: Plant optimization as smart service (Source: Kagermann et al. 2014, p. 34)

Industrie 4.0 is predicted to have enormous potentials for the German economy

Enormous **economic potential** is expected from Industrie 4.0 due to the new possibilities described above for the creation of goods and services and the goods and services themselves. A joint study by the Federal Association for Information, Technology, Telecommunications and New Media e.V. (BITKOM) and the Fraunhofer Institute for Industrial Engineering and Organisation (IAO) called "Industrie 4.0 – Economic Potentials for Germany" investigated six industries concerning their potentials for growth. The industries selected include those which will be particularly early and heavily affected by the merging of production and internet: Plant construction and engineering, electrical equipment, chemicals, automotive construction and parts, information and communication technologies (ICT), and agriculture. The possible increases in productivity in Germany by 2025 amount to approximately **78 billion Euro**. On average, an annual increase of 1.7% of gross value added [1] could be realized each year (cf. figure 17). The industries identified as particularly profitable in terms of Industrie 4.0 were plant construction and engineering, electrical equipment, and chemicals. Here, an additional growth potential of **2.2 percent per year** was calculated (cf. Bauer et al. 2014, p. 30).

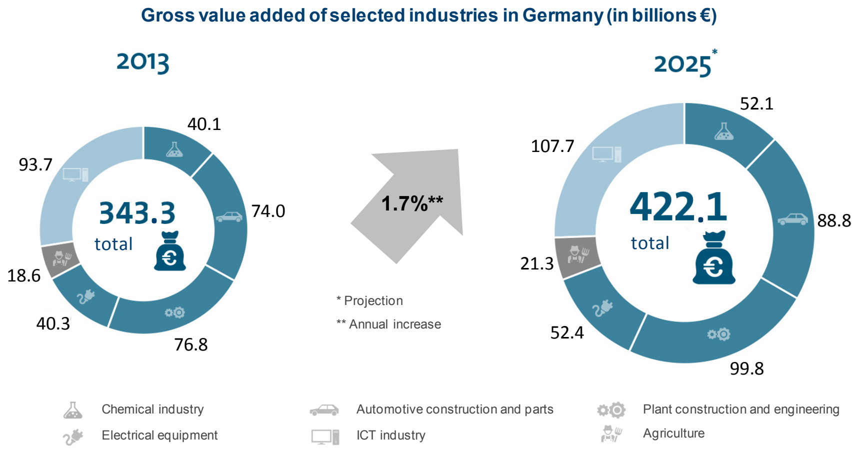


Figure 17: Growth potentials through Industrie 4.0
(Source: BITKOM 2014)

Plant construction and engineering is both user and provider of the technologies linked with Industrie 4.0. The large volumes of operating, current state and environment data should be used for more efficient production. Additionally, companies can equip their own products with Industrie 4.0 technologies. This would open up new business opportunities such as service models. "Industrie 4.0 has the potential to revolutionize our industry in the same way that the Internet did for knowledge work," says Prof. Wilhelm Bauer, Director of the Fraunhofer IAO. However, only a small part of the expected potentials have been classified so far. A crucial aspect will be whether and how the new business models can be implemented in this traditional industry (cf. BITKOM 2014).

[1] Total value of all goods and services produced minus intermediate inputs

2.5 Risks and challenges

Alongside the opportunities and possible applications described here, there are also many divers risks and challenges associated with comprehensive networking. Some of those risks and challenges are described in this section (cf. figure 18).

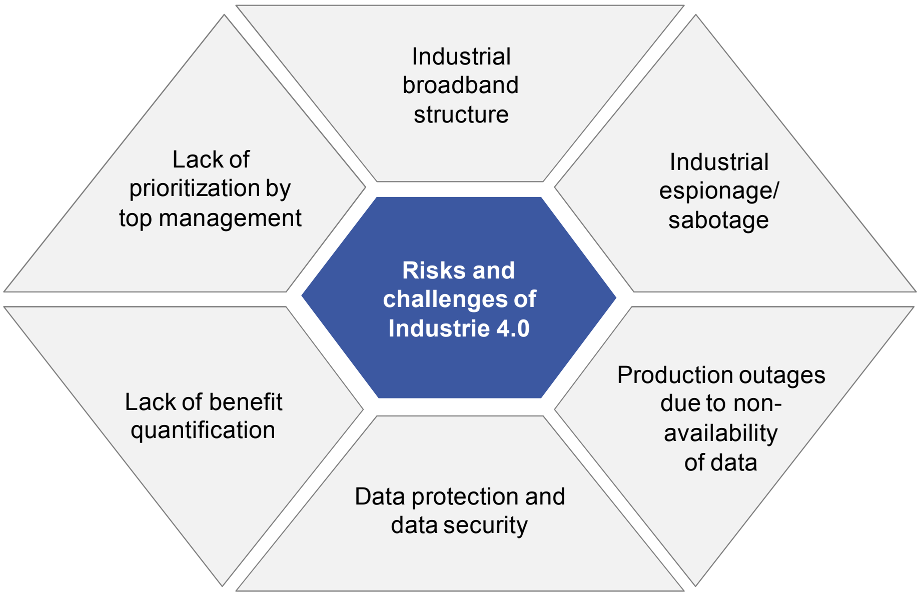


Figure 18: Risks and challenges when implementing Industrie 4.0 (own portrayal based on: PwC 2014 and Kagermann et al. 2013)

In order to be able to use cyber-physical systems across the board, it is necessary to have a high-performance infrastructure in place. The communication networks currently in existence cannot guarantee such a qualitatively and quantitatively high level of data exchange, making the expansion of the existing communication one of the basic requirements for implementing Industrie 4.0. To do this, we need an **industrial broadband infrastructure** which offers guaranteed latency, system stability and quality of services and which does so with a guaranteed, blanket broadband. The overriding demands upon an effective broadband infrastructure which reaches many users are simplicity, scalability, security, availability and affordability (cf. Kagermann et al. 2013, p. 49).

How do we protect against sabotage and data abuse?

Due to the availability of data in clouds and integration beyond the borders of firms and countries, many interfaces are created which offer potential for attacks. These attacks can take many different forms. On the one hand, for example, production data are a valuable and hence also coveted good. It can be assumed that attempts will be made to appropriate this data by means of **industrial espionage**. Additionally, problems can also occur among the users of a cloud. They could take advantage of weaknesses in order to acquire more rights as a user of a platform than were actually intended. On the other hand, attacks can also focus directly on manipulating production (**sabotage**), resulting in the risk of expensive production outages or even a threat to the physical safety of employees. The existing security architectures cannot simply be transferred to Industrie 4.0 technologies. Plants cannot keep on pausing operations in order to load security updates. Additionally, data transfers and control instructions between the cloud service and participants also require secure channels (cf. Fallenbeck and Eckert 2014, p. 397). By saving data in clouds there is a de facto shift in the functions away from the physical devices. This, in turn, means that they need less data storage capacity, calculating capacity and energy

consumption. However, it also means that the individual plants are no longer independent from external data sources. The crux here is that if the cloud goes down or is unavailable, the **lack of access to the cloud's data and applications equates to a complete breakdown in production**. To prevent this, security architectures and protection systems must be created which nullify this enormous risk. The storage, use, processing and dissemination of data from the cloud must be protected. Guaranteeing protection against attack and during operations in what are de facto open and cooperating systems is a major challenge (cf. Fallenbeck and Eckert 2014, p. 397).
From the perspective of **data protection** there are aspects which have to be worked on, for example there is urgent need for action in dealing with employee data. Data about where employees are, movement profiles and usage profiles is being recorded permanently, which constitutes a serious threat to the privacy of employees. The creation and enforcement of underlying data protection is an enormous challenge and it falls to both politicians and companies to create the prerequisites which guarantee the proper protection of this data. This will also play a crucial role in the acceptance of the new technologies among the workforce (cf. Fallenbeck, Eckert 2014, p. 397).

The challenges from the business management perspective are also immense. Technological and non-technological challenges were identified as part of a survey by PricewaterhouseCoopers (PwC). What is interesting from the controlling perspective is that nearly half of the executives from German companies questioned saw the greatest challenges for Industrie 4.0 in the lack of clarity concerning the economic benefits of the high investments. This was the top answer because the implementation of Industrie 4.0 technologies requires enormous investments in plant and equipment, in research and development, and in training and education. However, despite these known investments, the **potential benefits** have yet to be unequivocally and reliably **quantified**. Additionally, the **lack of prioritization by top management** was also identified by the participants as a further hurdle. For the implementation of Industrie 4.0, it is necessary that top management recognize the importance of this topic and handle it as a top priority. This is a fundamental requirement for the development of an internal corporate vision and roadmap for Industrie 4.0 (cf. PWC 2014, p. 36).

Quantifying the benefit is a job for the controller

2.6 International comparison

Good underlying framework for Germany compared to other countries

Germany is regarded both as one of the most competitive industry locations and as the leading plant factory outfitter in the world. Its strong plant construction and engineering industry and its know-how in embedded systems and automation technology mean Germany is well-prepared for the coming change and has the best prerequisites for assuming a leading role in the production technology of the future (cf. Kagermann et al. 2013, p. 5).

Different countries were investigated to identify their ability to implement Industrie 4.0 in a European **"Industrie 4.0-Readiness Check"** by the management consultants Roland Berger. The criteria were the manufacturing share of gross value added and the underlying conditions pertaining to industrial and societal sophistication (cf. figure 19).

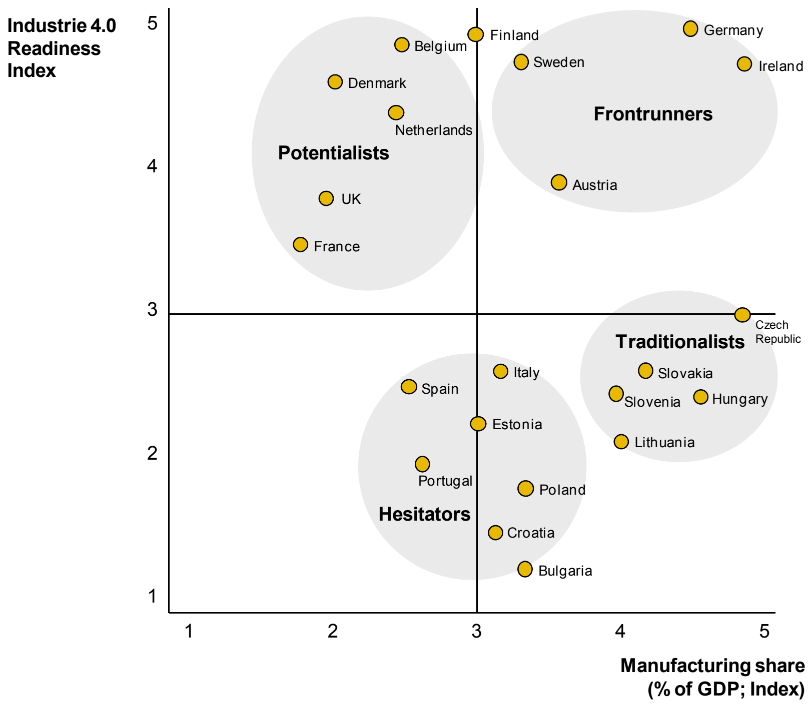


Figure 19: Industrie 4.0 Readiness Check (based on: Roland Berger 2014, p. 16)

The graphic shows an Industrie 4.0 Readiness Index on the vertical axis. This consists of the bundling of criteria concerning technical and societal sophistication (including degree of automation, education system, innovation network, internet sophistication). The horizontal axis represents the traditional industry measure, the manufacturing share of gross value added. The resulting matrix divides the European economies into four major groups.

The **Frontrunners** are characterized by a strong industrial base and modern, forward-looking economies (Sweden, Austria and Germany). Ireland is a special case in this category as several big pharmaceutical companies have settled there and are large contributors to the country's relatively small GDP. The **Traditionalists** are found mainly in Eastern Europe and still thrive on their sound industrial base, but few of them have (thus far) launched initiatives to take industry to the next level. The **Hesitators** lack a sound industrial base. Many of them suffer from fiscal problems, which constitutes a further hurdle. Countries like France and the UK number among the **(High) Potentialists**: Their industrial base has been weakening over the last years but their modern societies and economies offer great potential for innovations and developments (cf. Roland Berger 2014, p. 16).

Germany regards Industrie 4.0 as extremely important. The topic has been included in the government's new High-Tech Strategy as one of ten future initiatives whose objective is to make Germany into the leading innovator world-wide (see Chapter 1). The excellence cluster "Integrative Production Technology for High-Wage Countries" – an interdisciplinary research project of the RWTH Aachen University and the BMBF top cluster "Intelligent Technical Systems Ostwestfalen-Lippe (it's OWL)" – is one of the largest current initiatives for Industrie 4.0. It's OWL is the umbrella term for a cooperation of 174 companies, universities, scientific competence centers, and business-related organizations in the East-Westphalia-Lippe region (OWL) which was founded in 2011 (cf. it's OWL 2014, p. 6). Another remarkable initiative is the Allianz 4.0 Baden-Württemberg. The state of Baden-Württemberg wants to position itself as the leading provider for the topic of Industrie 4.0 and has set up a steering group chaired by Manfred Wittenstein, former VDMA president and current President of the Supervisory Board of Wittenstein AG. It consists of representatives from the Ministry for Economic Affairs and Finance, business, science and academia, and the unions, and its objective is to bundle together all the existing know-how within the Allianz 4.0 Baden-Württemberg (cf. Ministerium für Finanzen und Wirtschaft Baden-Württemberg 2014).

Initiatives also in other countries

Alongside Germany, other countries have recognized the trend towards the industrial use of the Internet of Things and Services. As a result, there are similar initiatives in other industry nations. In mid-2011, the **Advanced Manufacturing Partnership (AMP)** was created in the **USA**. It brings together representatives of the research, business and political communities to chart a course for developing emerging technologies. The AMP Steering Committee is made up of representatives of top universities (including MIT, Stanford, UC Berkeley) and the CEOs of leading US enterprises (including Caterpillar, Ford, Intel). It recommended the establishment of a National Network of Manufacturing Innovation Institutes (NNMII) under which leading research institutes have united in order to improve the global competitiveness of US businesses through innovative technologies. In all, the Obama administration earmarked 2.2 billion dollars for Advanced Manufacturing in 2013 (cf. Kagermann et al. 2013, p. 71).

China is also striving to attain global technology leadership by strengthening its industry. The 12th Five-Year Plan (2011-2015) comprises seven "strategic industries" including High-End Equipment Manufacturing and a New-Generation Information Technology. China's leaders are making a total of 1.2 trillion euros available for industrial development as part of the five-year plan (cf. Kubach 2011, p. 4). In the machine tools sector, one of the priorities is the development of "intelligent manufacturing", while the Internet of Things (IoT) has been a priority since 2010. This can be seen, for example, in the annual conference on the topic established in 2010, research groups on CPS, or an "IoT innovation zone" with 300 companies (cf. Kagermann et al. 2013, p. 71).

3 Best Practices from the Controlling Perspective

Industrie 4.0 is a topic which is heavily driven by technology and it requires the introduction of innovative information and communication technologies. There are numerous projects in progress in the business world whose focus is, in the main, on technology (cf. Table 2).

Table 2: Examples of Industrie 4.0 initiatives (cf. Sauter et al., 2015)

Company	Industry	Industrie 4.0 Initiative	Technology Enabler
Daimler AG	Automotive industry	Optimization of production logistics through traceability	▪ Ad-hoc network capable sensors ▪ Traceability and real-time system portrayal ▪ Interface to existing CPS and logistics chain
Festo AG & Co. KG	Drive engineering	Smart Factory – Flexible just-in-time production at optimum capacity utilization	▪ Interface standards for manufacturing modules ▪ Modular/ self-configuring software ▪ Simulation of order situation and production layout
HARTING Technology Group	Electronic components	Integrated Industry – Next Step	▪ Traceability, real-time responses and M2M/M2W with help of RFID technology ▪ Vertical integration (from field level with RFID and sensors up to SAP back-end system)
Maschinenfabrik Reinhausen GmbH	Power engineering	Manufacturing Execution System (MES) ›MR-CRM‹	▪ CPS ▪ Interface-neutral networking of man and machine (vertical integration of ERP, NC programs and quality assurance)
Siemens AG	Technology	Software and automation solutions for Smart Factory	▪ Totally integrated automation ▪ PLM software ▪ Digital figure of the factory
Würth Group	Joining technology, C-part management	Data transfer from inventory data and optical ordering system based on Kanban	▪ Traceability and M2M communication to transfer inventory data

It is important to use selected projects to demonstrate that the controller must play a vital role as co-shaper and “business conscience” in the implementation of Industrie 4.0. The following best practices are designed to look at this in more detail.

3.1 Visualized real-time productivity at Hansgrohe

At **Hansgrohe** a conscious decision was taken to tackle the topic of Industrie 4.0 in several stages. Back in 2010, the **"BDE online" project** was initiated. Until then, production was more or less an IT-free zone. Production orders were printed out and the shift supervisor was responsible for their scheduling. For their part, the workers noted down the required times on the order documents and handed them back to the shift supervisor upon completion. Shop clerks made sure that the information was entered into SAP.

Hansgrohe SE	
Revenue (Group)	EUR 841m (2013)
Employees (Group)	3,446 (2013)
Products / Business activity	Sanitation (incl. fittings, showers, bathroom equipment)

"BDE Online" changed everything. Now, the workers login with their ID at the respective assembly line. The system is also notified at the start of a production order. To do this, each assembly line is equipped with a card reader and an integrated scanner. For Hansgrohe it was extremely important that the system can be used intuitively and simply as the workers had not had any experience whatsoever with using keyboard and mouse.

Figure 20: Visualization of real-time productivity at Hansgrohe

Productivity in real-time

The **core functionality is that each product manufactured is scanned at the end of the assembly line**. This scanning generates a notification which tells the system what the current productivity is – both for the order itself and cumulatively for the shift. Thus, the workers are informed about actual productivity in real-time. At the same time, the workload for recording this data was reduced drastically. This method was adopted step-by-step for all high-traffic assembly lines at Hansgrohe until the project phase "BDE online" was completed in 2013.

In total, productivity in the affected divisions **was increased by 3%**, which led to a considerable **reduction in costs**. As part of the second project stage "MES" (manufacturing execution system), which began in 2013, all machines in the division Basic Production (processing centers, casting and injection molding machines) were connected together in a central MES system.

Contribution of Controlling

Controlling involved from the very beginning

Controlling was involved in the project from the outset. The **controller** was challenged as a **sparring partner** in both strategy development and in the implementation phase.

On the one hand, there was the question of how much added value controlling could generate through the new systems about to be implemented (phases 1 and 2 in figure 21). In the main, operative topics were discussed here, such as:

- What requirements does controlling have and how can these be fulfilled?
- What benefits does the additional transparency create?
- To what extent is this content considered in reporting?

From the perspective of controllers the following examples of improvements were identified:

- **Timely data** enables direct reactions
- **Clear improvements in the planning process** meant that the total preparation times on the shop floor could be reduced by one day (e.g. elimination of paper, tooling-up processes)

What was much more challenging were the discussions about which **potentials could be tapped in the years after the project through 4.0 technologies**. Here, it is not simply a question of technology aspects but far more that topics such as the Internet of Things, labor organization and qualification, and the trend towards increasing individualization of consumer requirements in society are included. Ultimately, the entire value chain must be reevaluated and potential benefits quantified.

In recent years, Hansgrohe have recognized that disruptive technological boosts create completely new underlying conditions. **In the future, controllers must** be more than ever ready to **assess the impacts of these technologies** and to supervise the transformation process. These requirements must also be paid commensurate **attention during the controllers' training**.

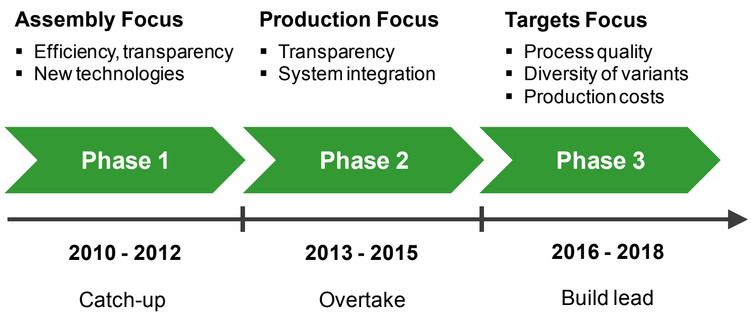


Figure 21: Implementation stages of Industrie 4.0 at Hansgrohe

3.2 Business model innovation at Trumpf

Today, **Trumpf** focuses on machine tools for sheet metal processing. Their activities concentrate on the ongoing development of the machines in order to increase the speed of processing, to improve the quality of the manufactured parts, and to increase the availability of the entire system. Digitization has had a considerable influence on these developments in recent years, and software has become established as an area of expertise alongside hardware (mechatronics, electronics).

TRUMPF GmbH + Co. KG	
Revenue (Group)	EUR 2,343m (2013)
Employees (Group)	9,881 (2013)
Products / Business activity	Machine tools, industrial lasers, high-performance electronics

Software developments in the areas of managing the performance of the machine tools and of the production process for sheet metal processing have led to increases in productivity. Manufacturing processes of customers are typically complex and interlinked can be networked intelligently with one another through digitization. This, for example, enables the optimization of dispatching the production orders to fit the current state of the respective machines (capacity utilization, availability, state of maintenance). This happens in real-time and thus takes current developments in the factory into consideration, from both production and factory perspective.

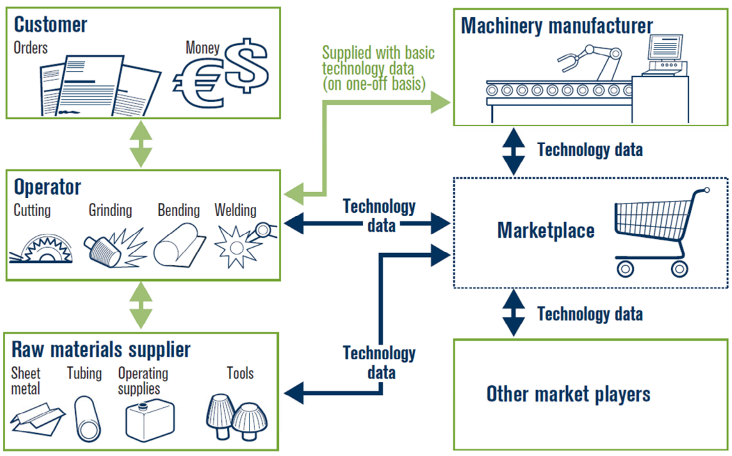


Figure 22: Business model innovation at Trumpf

Web-based technology platforms

Industrie 4.0 goes a step further: **Industrie 4.0 reinvents business models**. In the future, users of machine tools will obtain digital products from web-based technology platforms or internet marketplaces. With the help of these products, they will be able to raise the efficiency both of their machines and of their production to new levels. The sheet metal processors of the future will access the information they need for processing specific sheet metals on the individual machines online for each order. This avoids the need to invest in buying complete and expensive technology databases – usually as part of buying the machinery – as data which is not required does not need to be bought and superfluous investments can be avoided. A further advantage is that the latest technology data is always used. A comparable business model is the permanent online maintenance of the machines (e.g. monitoring the machines with state-based adjustment of the machine parameters).

One thing that all digital business models share is that there are online informations, programs and solutions available for the machine tools of manufacturing companies which facilitate their optimal deployment. Trumpf are working on the development of these business models in order to make the processing of sheet metal even better and even more cost effective.

Contribution of Controlling

Industrie 4.0 is creating new challenges for controlling in mechanical engineering companies. In today's business model, the focus of controlling is on evaluating production in the form of (production) costs and evaluating earnings (the sale of products) in the form of sales quantities, prices and revenues. This will **change fundamentally in digital business models**. On the cost side, it is relevant which expenses are incurred for creating the business models and the corresponding services. Companies will have to devote a lot of upfront outlay similar to the development of products in classical business models. Additionally, high investments are needed to set up the necessary technical digital platforms. Finally, the ongoing operation of the digital systems and their scaling (dissemination of the applications and the increasing number of users) will cause high costs.

As a result, the cost structures of digital business models differ considerably from those of classical business models and require **modifications to the cost accounting systems** in terms of structure, degree of detail and time dimensions. On the **earnings side**, controlling faces new challenges arising from **calculating the prices for digital products and services**. Instead of a cost-based cost estimation, the benefit of the digital product for the customer must be evaluated and then used as the basis for calculating prices. An estimation of the potential sales quantities will also have a significant impact upon prices and economic viability.

The controller must show the cost-effectiveness of the business models

Thus, the economic viability (profitability) of the business model is less dependent on the cost side of the provision of goods and services (production costs) and the price obtainable on the market (margin) but rather much more on the costs incurred for developing the business model (intensity, duration) and the scalability of the business model. The number of users of the digital model determines whether it is profitable. **Industrie 4.0 business models are the same as the business models of the digital world** in the Internet (Google) and, as a result, must also adhere to their approach to controlling. This represents a radical change for a mechanical engineering company.

3.3 Mobile production management at Wittenstein

In line with Industrie 4.0, a mobile assistance system for production workers was introduced at **Wittenstein** which allows them to ask for specific information for production orders during production planning and performance management. The application also supports the recording and documentation of faults in production (known as "escalations"). The main benefits of mobile production management lies in the effective access to information and the acceleration of the escalation process.

WITTENSTEIN AG	
Revenue (Group)	EUR 241m (2013)
Employees (Group)	1,608 (2013)
Products / Business activity	Mechatronic drive technology

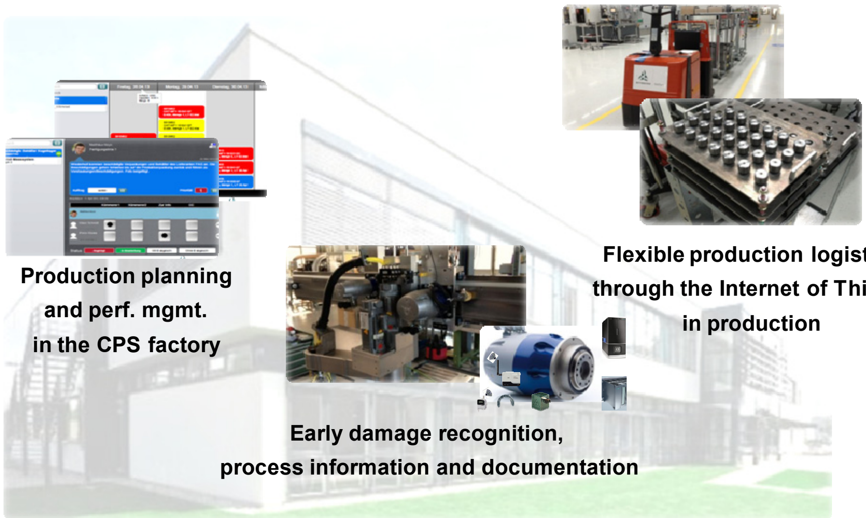


Figure 23: Industrie 4.0 elements at Wittenstein

The first step was to equip all machines and plant workplaces with data matrix codes and to generate these on the production order documents. Parallel to this the core functions of production planning and performance management were ported to a tablet computer with a camera.

Using this system, workers can access detailed planning information about production orders **regardless of where they are** by navigating on the tablet by means of an app-menu. Scanning a code on the machine or on the production documents of the material enables workers to directly access information on the planned order at their workplace or directly at the point in the planned production sequence.

The system enables workers to create escalations directly on-site and report them to whoever is responsible. They scan the code at the workplace and select the corresponding production order for which the fault has occurred. Alongside describing the problem using the keyboard, they also have additional options (photos, videos and/ or voice messages) and can attach them to the report. After the data is transmitted, the recipient is immediately sent an email as notification of the fault.

This makes the **escalation process more structured and faster**. Further, the **quality of documentation** rises. The increase amount of information makes it easier to identify repetitive faults in the processing of a material and to eliminate them.

Contribution of Controlling

It would appear that the basic requirements for the Internet of Things or Industrie 4.0 have already been fulfilled. The commercial aspects appear to still be in development. In the context of Industrie 4.0, there are direct and indirect influences.

The indirect influence of this development affects controlling processes and employees. The availability of data and transparency in real-time, the flexibility and dynamism of processes and the networking of companies create a huge flood of data. This has considerable impacts upon controlling processes such as strategic planning, forecasting and cost and activity accounting and financial reporting.

Focus on strategic planning, forecasting and cost and activity accounting and financial reporting

Until now, the rule in **strategic planning** was that you had to observe and consider what companies and controllers felt was relevant. Now, this must change radically. The influencing environment of Industrie 4.0 is expanding hugely and must be taken into consideration. If the balanced scorecard sufficed as a planning tool to date, now it is fast hitting its limits due to complex and bi-directional dependencies. An adequate replacement can be found in the Dynamic Scorecard model. Its sensitivity analyses and simulations can identify cause-and-effect relationships and portray the factor of time with its dependencies.

Up to now, **forecasts** were based on a look back into the past which was supplemented with expectations and assumptions about the future. This was sufficient for cyclical developments but rather reaches its limits for disruptive changes (which accompany digitization). A mathematical-physical model must be transformed into a mathematical-socio-economic model whose planning horizons are set dynamically and “ignore” fiscal year structures.

The direct influence of Industrie 4.0 is on corporate business models. If companies engage with the possibilities offered by Industrie 4.0 and accept new business models or change their current ones, this will also affect **cost and activity accounting and financial reporting**. The value added will change, as will possibly the charging and accounting models. In this context we have to expect costs to become more flexible, i.e. a shift in the share of fixed costs, which can be both risk and opportunity for companies.

The impacts of Industrie 4.0 become particularly apparent through the possibilities which arise from changes in the business models. The majority of the important changes caused by digitization occurred in the USA in the areas of “access to products” and “pricing”. This is where the real effect is to be found! Thus, Industrie 4.0 offers companies new opportunities which were previously denied to them. Controlling must come to terms with that and prepare itself accordingly.

3.4 Networked production at Euchner

EUCHNER
More than safety.

Euchner has approximately 10,000 product variants in 57 product families and is a specialist for small series and variant production. It ships 90% of all orders to customers within three weeks. This huge range of variants with short delivery times and global procurement requires than nearly everything is produced in the home country. In order to ensure this is cost-effective and to maintain clarity for materials and production planners, complexity is reduced through the elimination of planning data and data recording. Thus, for Euchner the expected benefits of Industrie 4.0 lie in securing the **competitiveness of production in Germany** and in **mastering small series production down to a batch size of one**.

EUCHNER GmbH + CO. KG

Revenue (Group)	EUR 100m (2013)
Employees (Group)	400 (2013)
Products / Business activity	Safety engineering (incl. safety switches, safety systems)

Managing the variants while at the same time maintaining cost-effective production planning and disposition are clearly conflicting goals in today's environment. The optimal planning of capacities for different types of production orders (Kanban, sales plan, order-based production) requires a large amount of planning data (batch splits, resources, machine times). Purchasing faces a heavy workload of operative tasks due to the large number of procured parts, a workload which could be reduced if these routine activities were supported through a data pool and automation.

Figure 24: Extract from the product portfolio at Euchner

While it is not available today, the networked production propagated in Industrie 4.0, i.e. the amalgamation of IT and production technology, has the potential to generate this information:

Monitor each process step constantly

- **Automated feedback on units produced** and individual process steps and not only the notification of completion of the whole batch at the end of assembly.
- **Precise daily update of production capacities** and not the weekly freezing of production planning.
- **Constant overview of capacity utilization**: Is the order being processed 90% finished or which process steps and quantities are still outstanding?
- **Automated orders** for suppliers after dispatching the production order by using current drawing/ order data.

- **Products can be tracked in production** and report their imminent "availability" or a potential delay to order processing. The production planners could, if necessary, counteract the situation or get the sales department to check whether the customer would accept partial delivery.
- Because serial numbers are not recorded when the products are shipped, today it is only possible to trace a product based on the lot. The **automated reading of serial numbers** using RFID technology when the product is removed from the dispatch warehouse would not make shipping more complicated but would improve the data pool considerably.

Contribution of Controlling

The information required by production planning, purchasing and disposition cannot be fully supplied by controlling today because:

- Providers of the data and users of the information have different organizational structures and systems.
- The sheer amount of information available today already leads to a complexity which cannot be mastered by humans.
- The runtime for some evaluations means they cannot be carried out because they represent an unacceptable burden for the IT systems ("night jobs").

It can be assumed that the greater availability of a wide range of data will lead to even greater expectations from Industrie 4.0:

- More up-to-date information,
- Shorter cycles,
- More timely reports.

Transforming this **data into information and understandable reports** will become a constant challenge for controlling. To master this, the processes must be optimized and standardized in advance and with the active involvement of the employees in controlling in order to ensure inefficient processes are not anchored or junk data is not created. At the same time, the controller must **prevent** the management from being **flooded with data** (just because it's there doesn't mean it's useful!). Alongside this consulting on possible and sensible reports and evaluations, above all the upstream **data analysis** and downstream **data interpretation** will become increasingly important as a service for the management. The technical processing of the data will demand other abilities of the controller, especially concerning **specialized database technologies**:

- Data warehouse with OLAP cube for logical representation of data: Definition of the cube
- In-memory databases: Faster access to data in real-time operations

Big Data turns the controller into a "navigator"!

4 From Industrie 4.0 to Controlling 4.0

4.1 Industrie 4.0 and the main processes of controlling

In order to measure the importance of Industrie 4.0 for the future work of controllers, an analysis of the **seven central controlling main processes** is useful (cf. IGC, 2011; figure 25).

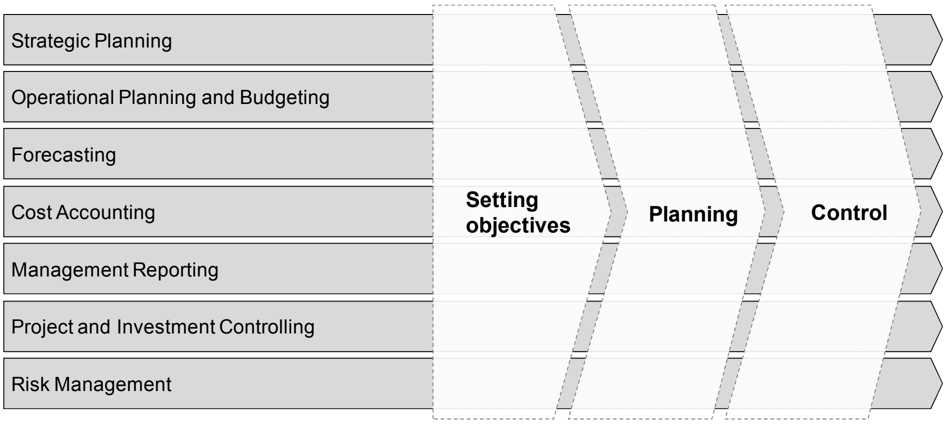


Figure 25: Controlling process model of the International Group of Controlling (IGC) (based on IGC, 2011, p. 21)

The following table shows an overview of the main changes and challenges.

Table 3: Influence of Industrie 4.0 on the main processes of controlling (based on: Seiter et al., 2015)

Main processes of controlling	Changes/ challenges/ influence due to Industrie 4.0
Strategic Planning	▪ Quantification of benefits of digitization and networking in terms of optimization potentials ▪ Identification of new digitization-related business areas
Operative Planning and Budgeting	▪ New KPIs ▪ Flexible budgeting
Forecasting	▪ Continuously up-to-date production and market data ▪ Forecasts in real-time
Cost Accounting	▪ Improved transparency of production costs ▪ Improved basis for calculating production overheads through comprehensive transparency of information
Management Reporting	▪ Use of mobile devices ▪ Forward-looking reports ▪ "What-If" analyses
Project and Investment Controlling	▪ Monitoring of production procedures in real-time ▪ Investment decisions based on scenario-based simulation models
Risk Management	▪ Consideration of new risks arising from comprehensive digitization

Based on the example of the controlling main processes of “Management Reporting” and “Risk Management”, we can demonstrate how the nature of controlling instruments and methods will change. Thus, forward-looking report types will become increasingly important in **management reporting** (cf. figure 26).

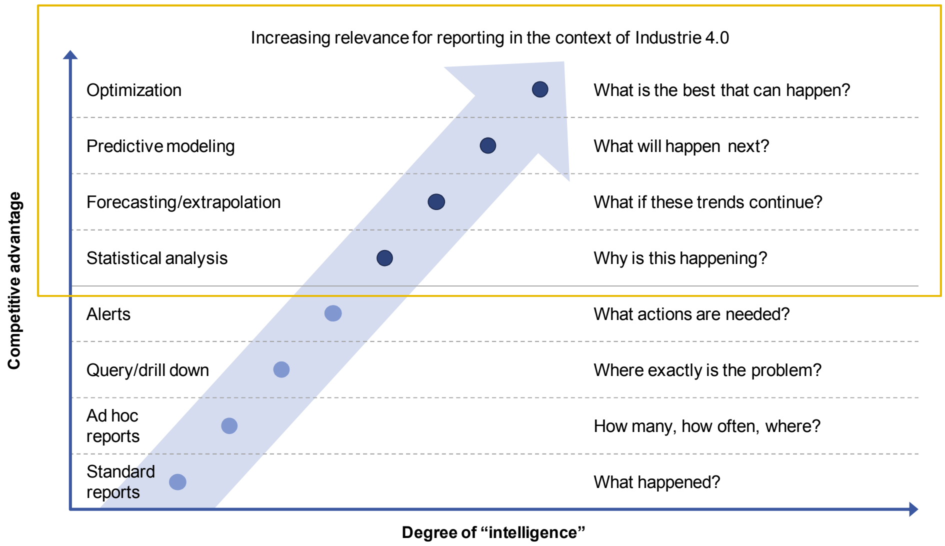


Figure 26: Relevance of report types in the context of Industrie 4.0 (based on: Gronau, 2012, p. 21 and Davenport and Harris 2007, p. 33)

In terms of **risk management,** complexity will rise as new risks and will have to be considered. This becomes particularly apparent in the case of supply chain risk management (cf. figure 27).

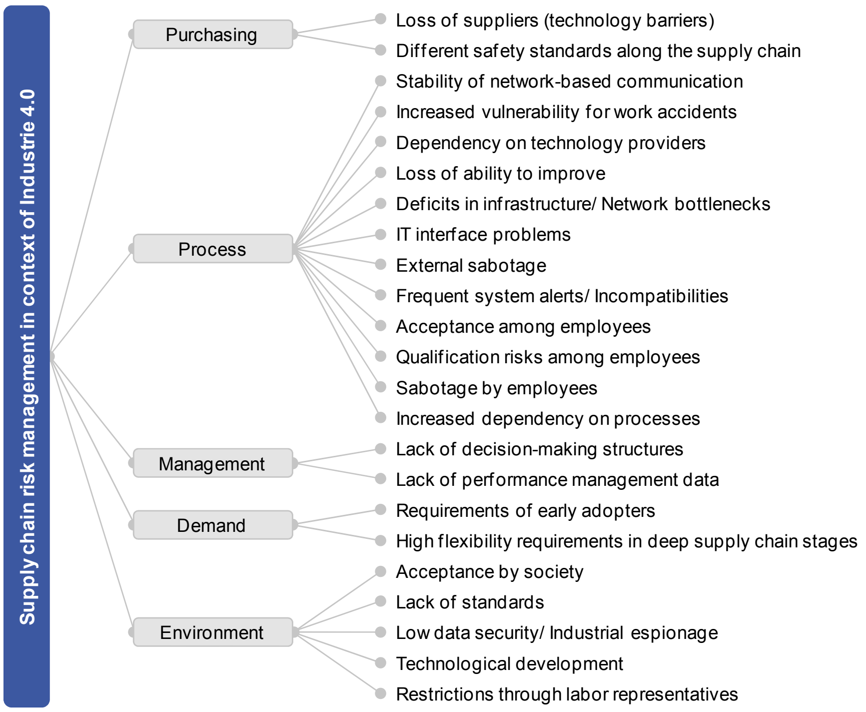


Figure 27: Risk aspects in the context of Industrie 4.0 (based on: Kersten et al., 2014, p. 114)

4.2 Assessment tasks for the introduction and implementation of Industrie 4.0

The controller will have to carry out important assessments as part of the introduction of Industrie 4.0. While they will not require any new instruments, they will need an understanding of the underlying development of Industrie 4.0 and of the specific company business processes. The main assessment categories are shown in Table 4. In each case, the focus lies heavily on **assessing the use of new technologies**. Within the economic evaluation it will be necessary to include non-financial aspects as well.

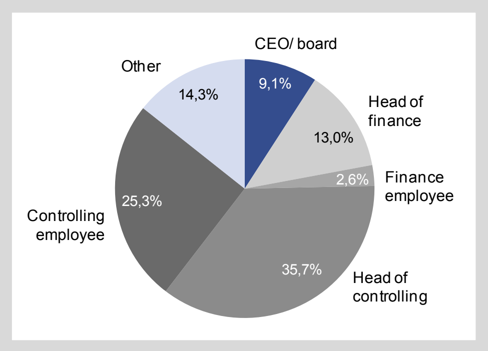
Table 4: Categories for decision-making support (based on: Mertens, 2015)

Categories	Relevant questions
Assessment of system variants	▪ What degree of automation do we need?
Assessment of product variants	▪ Which new product variants are economically viable?
Assessment of process variants	▪ How cost-effective are the production and logistics processes?
Assessment of business models	▪ How good/ suitable are new options in business models?

4.3 Status quo within the controller community

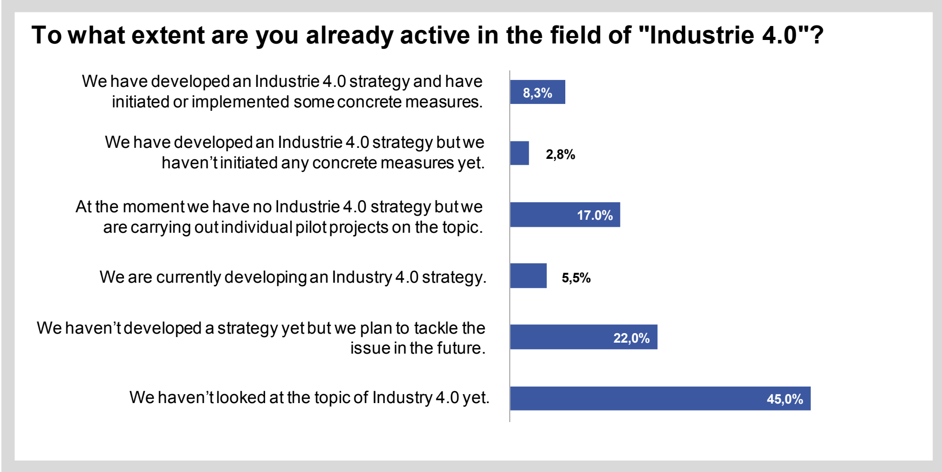
In order to establish the extent to which the controller community is already engaging with the topic of Industrie 4.0 and what changes they expect for controlling, we conducted an online questionnaire-based survey from mid-March to mid-April 2015. In all, **207 people** participated on the survey. The questions were grouped into different themes. The first block dealt with general aspects of Industrie 4.0 (section 1 below). In the second block we wanted to discover what impact Industry 4.0 is expected to have on controlling processes (2). The third block focused on the effects of intelligent networking on the abilities and competences of controllers (3).

The **majority of those surveyed work directly in controlling** (over 60%), most of them as head of department. Additionally, the respondents included heads of finance (13%), CEOs/ board members (9.1%), and employees from finance departments (2.6%). 14.3% stated they had other responsibilities (e.g. production manager).



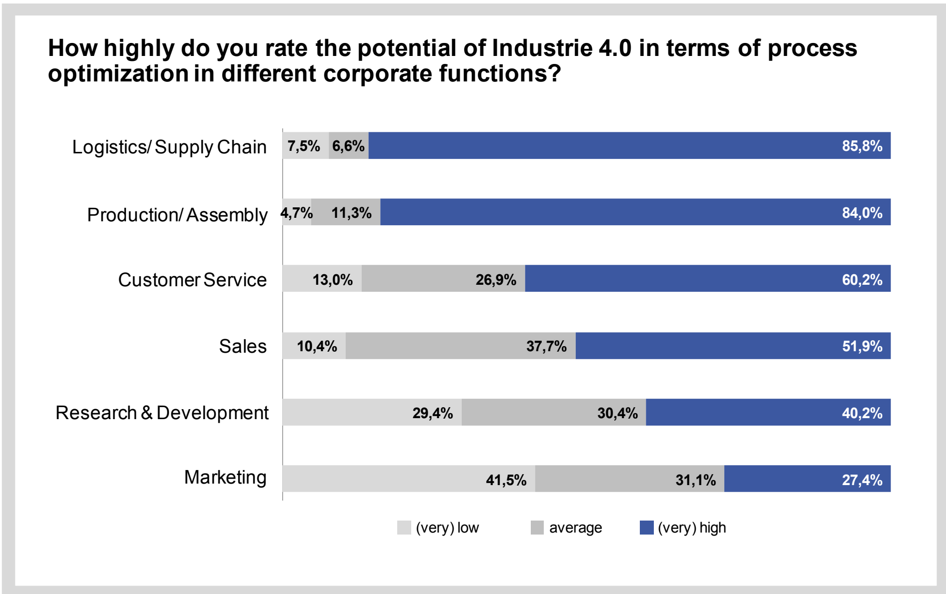
(1) Industrie 4.0 in general

Many companies are not yet tackling the issue of Industrie 4.0



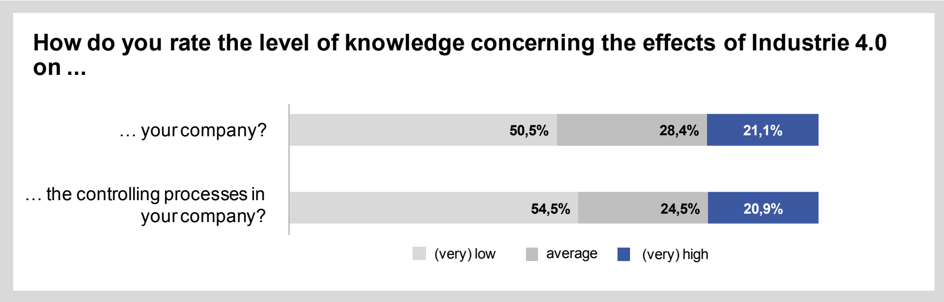
What is striking is that nearly half of the companies (45%) have **not yet specifically tackled Industrie 4.0** at all. For smaller companies (up to 500 employees) this number rises to 58.5%. Only 8.3% have developed a strategy with concrete measures, while 17% of those questioned have carried out individual Industrie 4.0 projects.

Optimization potentials expected, especially in production and logistics



Most respondents see the greatest potential from Industrie 4.0 in the areas of **logistics/ supply chain** (85,8%) and **production/ assembly** (84%). In logistics, networking the individual players in the value chain can contribute to improved communication. More than half (60%) feel there is also (very) great potential in customer service, with intelligently networked smart services, such as downstream services, fostering optimization. Nearly 52% also believe there are opportunities to improve processes in sales. Average to high potentials are also expected in the areas of R&D, and marketing.

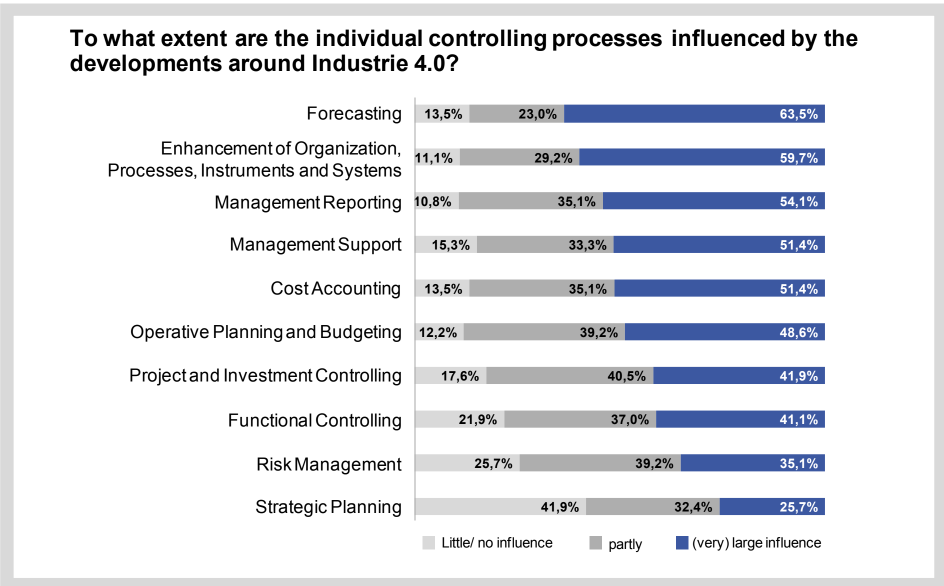
Lack of clarity concerning concrete effects of Industrie 4.0



Just over half of the participants rated their own company's understanding of the concrete **effects of Industrie 4.0 on their company and on controlling processes** as (very) low, although approx. every fifth respondent rated it as (very) good. Among larger companies the understanding was seen as worse across the board, which could be a result of greater complexity. In terms of expected optimization potentials, those respondents who stated they had a (very) high understanding of the concrete impacts of Industrie 4.0 felt more positive than those with a (very) low level of understanding.

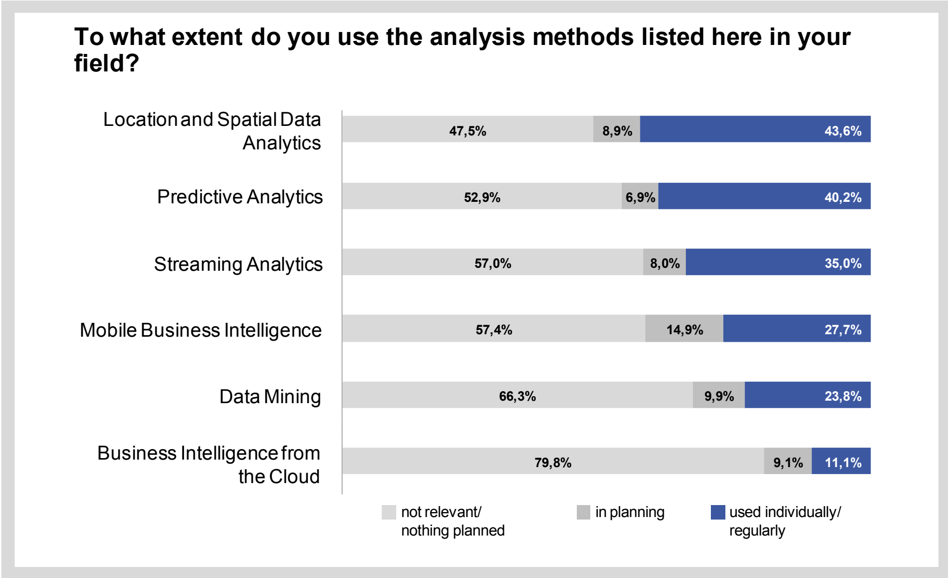
(2) Controlling processes

Forecasts are particularly influenced by Industrie 4.0



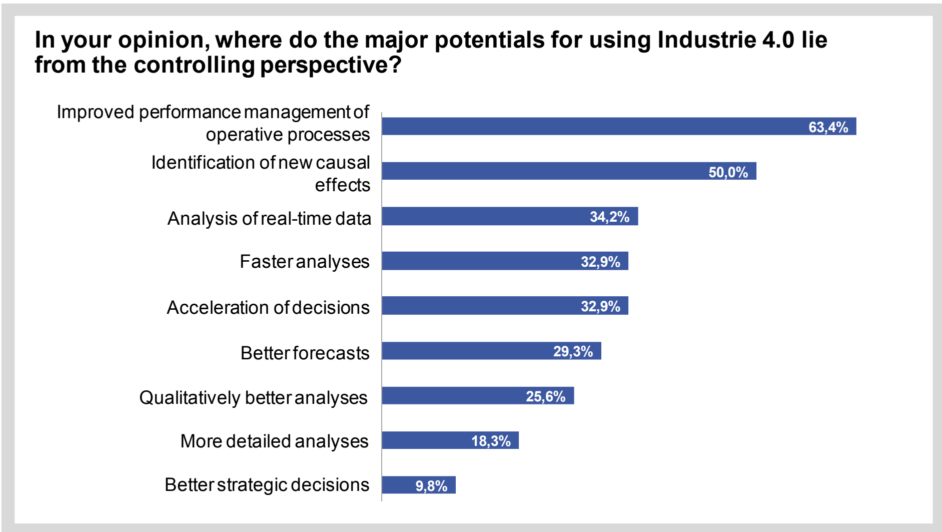
The controller community feels primarily the **forecast** will be (very) heavily influenced (63.5%). **New data evaluation possibilities** like predictive analytics could play a role here. They also believe the process of **further enhancement of organization, processes, instruments and systems** will be heavily influenced, followed by management reporting (54,1%), management support (51.4%) and cost accounting (51.4%).

Innovative analysis methods already in isolated use in practice



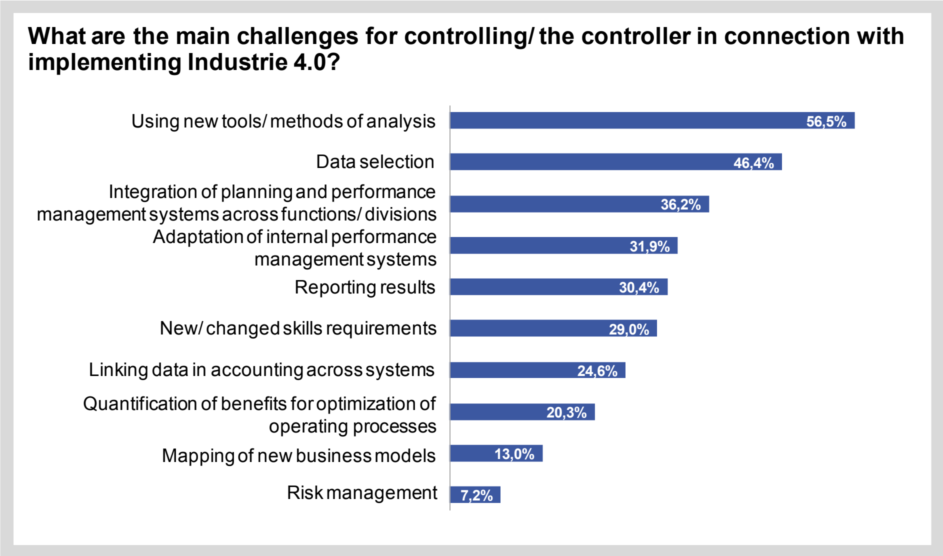
Today, 43.6% of the controllers surveyed already use **location and spatial data analyses**, while just over 40% also already use **predictive analytics**. Streaming analytics (analysis of real-time data) is used by approximately one in three controllers; there is still little use in business practice of data mining for pattern recognition (23.8%) and business intelligence from the cloud (11.1%).

Improved performance management of operative processes and discovery of new causal effects as main potentials for use



63.4% of the respondents expect **improved performance management** of operative processes. Integrated systems could enable last-minute changes to the production program and even during manufacturing or operations. Half of those surveyed hope to **discover new causal effects**. Here, it is possible that new analysis methods, such as pattern recognition within large data quantities through **data mining**, could find application. The analysis of **real-time data** (34.2%), **faster analyses** (32.9%) and **accelerated decisions** (32.9%) all focus on time-critical potentials.

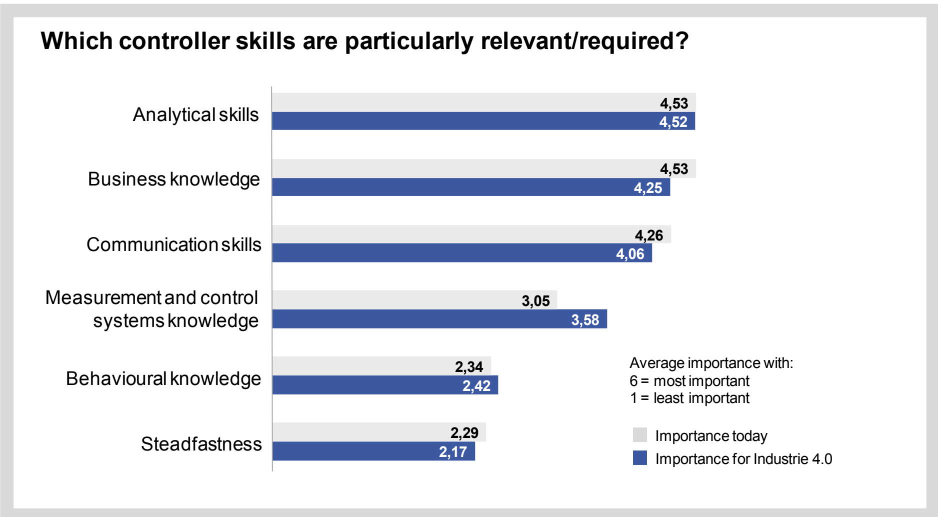
Dealing with new analysis methods and data selection are the main challenges



Alongside potentials, there are also **challenges** for controlling associated with Industrie 4.0. The majority of the survey respondents see the greatest challenge as the **use of new analysis methods** (56.5%). Such topics must be integrated to a greater extent in the training of future controllers. Additionally, **data selection** (46.4%), i.e. the decision which data from a large flood of data is actually relevant, is also seen as a challenge.

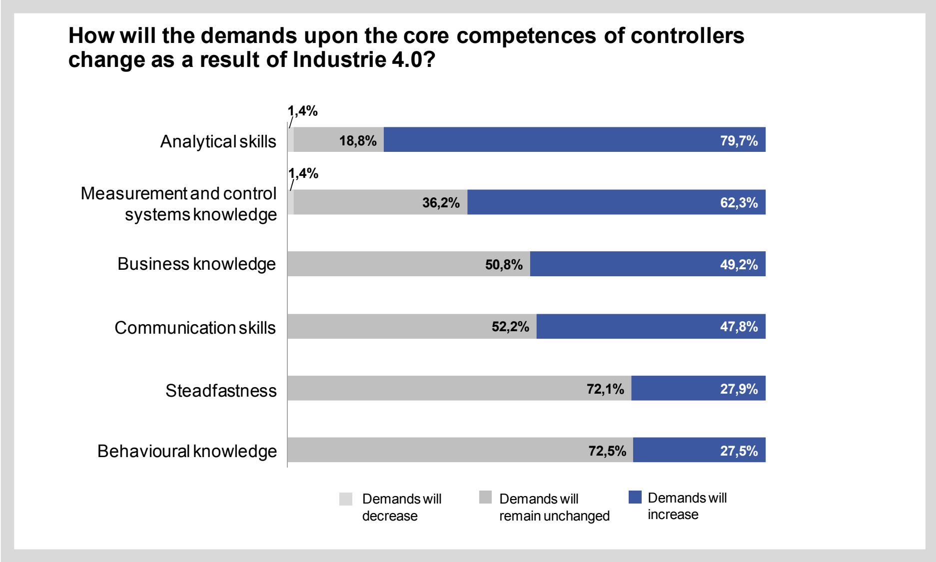
(3) Abilities of the controller

Ranking of core competences remains the same for Industrie 4.0



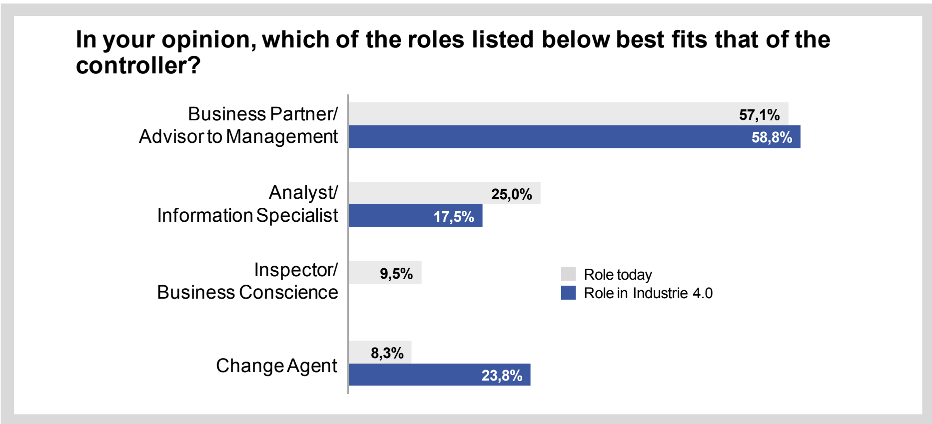
In the opinion of the controller community very little will change in the **ranking of their core competences**. Both today and under Industrie 4.0, analytical skills and business knowledge are the most important skills of controllers, with communications skills coming in a close third. The importance of knowing measurement and control systems will increase slightly. The other abilities are behavioural knowledge and steadfastness.

Increased demands especially on controllers' ability to analyze and knowledge of measurement and control systems



When asked about the demands upon the controller's core competences, the participants were very clear: They expect the **demands** upon the **ability to analyze** (79.7%) and the **knowledge of measurement and control systems** (62.3%) to **increase**. They also expect the demands upon understanding the company's business to increase. Almost half of the controllers expect that greater demands will also be put upon the controller in the future concerning their communications skills.

The controller will need to be a driver of change



For both today and the time of Industry 4.0, nearly 60% of the controllers see themselves in the role of **business partner** or advisor to the management. Their main task lies in supporting the decision-making of management. In the opinion of the controlling community, the role of **analyst/ information specialist** will become slightly less prevalent under Industrie 4.0 than before: While one in four of the controllers see themselves in this role today, that number falls to only 17.5% for Industrie 4.0. Currently, nearly one in ten of the respondents regards the controller as the business conscience of the company. In Industrie 4.0, however, this role seems to disappear almost entirely. In contrast, what is remarkable is that the role of the controller as **change agent** is expected to grow sharply. As such, the controller will have to initiate change processes in the company independently and proactively. This development also confirms the increasing demands upon the controller in the age of intelligent networks.

4.4 Readjustment of controller competences

Industrie 4.0 represents a great challenge for controllers. They will have to act as knowledgeable business partner for the management during its introduction and implementation. For this, it is necessary for the all controllers to proactively develop and actively live a specific Industrie 4.0 skills profile (cf. Figure 28). In doing so, they must ensure there is a close correlation to the knowledge, business and controlling processes of the company.

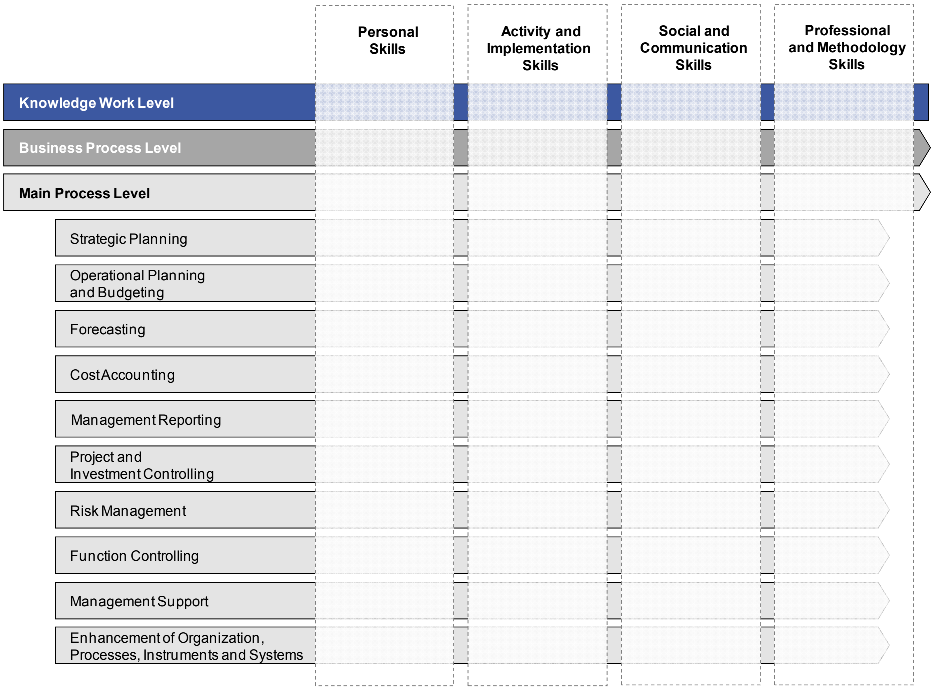


Figure 28: Matrix for the Controller Competence Model (cf. IGC, 2015)

In our opinion, a readjustment and fine-tuning is absolutely vital in the field of professional and methodology skills. We wish to emphasize three topic areas here:

- IT-supported business analytics
- Technical state-of-the-art production and logistics processes
- Business model developments

By adjusting their skillsets, controllers will be able to remain the „single source of truth“ in the age of Industry 4.0. This applies for both strategic and operative issues. In the context of comprehensive transparency of information and variety of data, the controller will have to filter the relevant data on the one hand and ensure the quality of data remains commensurate on the other.

5 The Formative Role of the Controller

In the coming years the controller will be required to tackle the topic of Industrie 4.0 to a much greater extent. In the production sector, in particular, the potentials of digitization which goes hand-in-hand with Industrie 4.0 are not yet sufficiently transparent.

In order to proceed systematically with Industrie 4.0, this chapter formulates recommendations and in doing so identifies the aspects which the controller will need to deal with. Based on this, an example Industrie 4.0 controlling roadmap is used to present which steps are necessary over time.

5.1 Actively shaping the development of Industrie 4.0

Recommendation 1

Create interdisciplinary Industrie 4.0 project teams

Industrie 4.0 is a topic which is heavily driven by technology, with the focus lying in particular on connecting information and communication technologies with production technology. When dealing with Industrie 4.0, however, it is important not to neglect the economic aspects. At the latest when positioning Industrie 4.0 projects and strategies on the top tier of corporate management will economic aspects have to be prepared, communicated and presented using examples and proof.

Accordingly, the **creation of interdisciplinary project teams** should be seen as a basic requirement for the internal treatment of Industrie 4.0 by companies to ensure all relevant aspects are considered. Ideally, such project teams should consist of experts from production, from the IT department, and from controlling. Depending on the orientation of a specific company's Industrie 4.0 strategy, further experts from other functions such as marketing or sales should be brought in.

Recommendation 2

Sensitize controllers even more for operative processes

In order to be able to properly judge the relevance of comprehensive digitization and intelligent networking for a specific company and to formulate suitable actions and measures, an extremely good understanding of business is required. In this context, **controllers must be even more sensitized about the operating processes** than before so they can support the management in decision-making.

Hence, for example, controllers will be required to be able to fully assess the relevance of new data sources and, if necessary, use those sources to achieve objectives. In order to be able to judge whether new data sources are important, they will require a far-reaching understanding of the cause-and-effect relationships of the company's business activities and operations.

Recommendation 3

Initiate and carry out benefit quantification

The implementation of Industrie 4.0 projects is not an end in itself. From a corporate perspective, Industrie 4.0 projects must have a beneficial effect in terms of cost-effectiveness or profitability. This applies to both the creation of goods and services (objective: optimized processes) and the provision of goods and services (objective: increased customer benefit). The controller should **initiate and carry out the benefit quantification** necessary for Industrie 4.0 projects.

In terms of the creation of goods and services, first concrete application examples and pilot projects must be defined and then the impact of digitization and intelligent networking must be proved. For the provision of goods and services, the controller as business partner must strive to answer the following questions (cf. Porter and Heppelmann 2014, p. 50):

- Which intelligent, networked product functions should the company strive to create?
- Which functions should be integrated into the product and which should be outsourced to the cloud?
- Should the company aspire to an open or a closed system?
- Should the company develop all the functions and the infrastructure itself or commission others to do so?
- Which data does the company need to maximize the value of its products?
- How does the company administrate the ownership and access rights for the product data?
- Would the company be better served by eliminating sales partners or service networks?
- Should the company change its business model?
- Should the company sell the acquired product data to third parties?
- Should the company expand its field of activities?

Recommendation 4

Identify and tackle potentials and challenges for controlling processes, instruments and systems

Alongside the company-wide perspective which focuses on the creation and provision of goods and services, controllers should also **identify and tackle the potentials and challenges of Industrie 4.0 for controlling processes, instruments and systems**.

Regarding the potentials, the comprehensive availability of real-time data gives rise to new possibilities. From the perspective of controllers, it is important to investigate the extent to which these can be used in forecasts or management reports. Additionally, the new analysis instruments and methods from predictive analytics or data mining need to be investigated to see which specific controlling tasks they can be applied to. Regarding the challenges, there is the question of how digital business models can be depicted in cost and activity accounting and financial reporting, as ultimately they have very different payment streams compared with purely physical products.

Based on the different examples in this Dream Car report, we make the case that the following theses should be considered in the further development of controlling processes, instruments and systems:

- **Agile not deterministic**: Improved availability of real-time data enables more detailed and faster performance management of operative functions. Capacities and requirements are managed decentrally. Processes and systems are increasingly prepared for future volatility.

- **Predictive not retrospective**: The basis for information for strategic and operative decisions consists increasingly of statistical prognoses which complement the traditionally retrospective reporting.

- **New KPIs**: Real-time data from the networked value chain facilitates new and more refined operative performance indicators which can be used in operative performance management. The retrospective (plant) profitability analysis has lost its importance for performance management. KPI information trumps due to the advantage of being more up-to-date.

- **Ad-hoc reporting**: Alongside the changing performance management approach there is also great demand for reports which are available in the short-term and are modular by nature. They make great demands upon BI systems and the design of reporting.

- **Decisions are made very quickly**: The available timeframe for decision-making is considerably shorter. This is necessary because the competition has become increasingly reactive and the networked value-added is more complex.

- **Complexity management is a success factor**: The complexity in performance management has increased exponentially due to the increased networking and its associated interdependencies. Mastering this complexity is an active discipline within controlling.

- **Information architects and interpreters**: A core competency of controlling is to prepare the information with major performance management relevancy from the increasing flood of data. IT-specific skills concerning system and data architectures are required for this, as are controlling-specific skills and the ability to interpret data.

- **Performance management cycles throughout the year**: The conventional annual tranche view of companies has become less important. Decisions are evaluated, taken and implemented throughout the year. The systems for planning and profitability analyses, including forecasting, reporting and the incentive systems, have been adapted accordingly.

5.2 Industrie 4.0 roadmap for controlling

An Industrie 4.0 roadmap for controlling should incorporate two main perspectives: The company-wide perspective **"Supervise the Industrie 4.0 transformation process"** and the internal controlling perspective **"Further develop controlling"** (cf. figure 29).

As the influence of Industrie 4.0 can vary hugely depending on the business model of a company, the substantive focuses of the roadmap must be elaborated individually for each company.

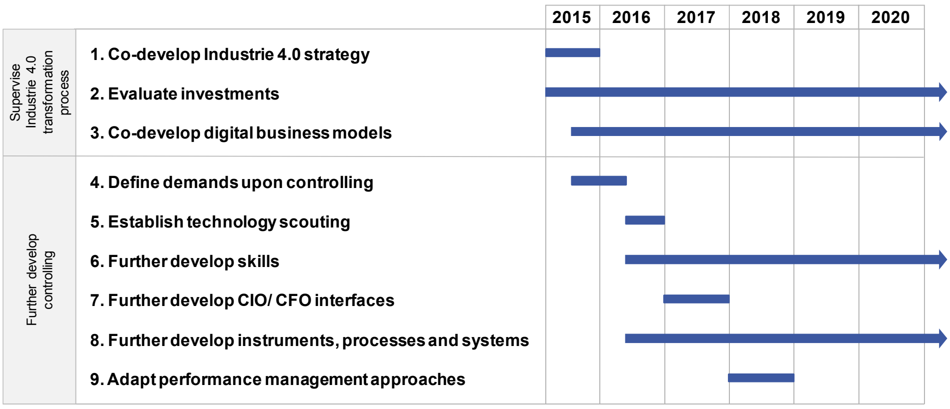


Figure 29: Example of an Industrie 4.0 controlling roadmap

Supervise Industrie 4.0 transformation process

As the advisor to management, it is the job of controlling to evaluate the challenges of Industrie 4.0 and to take decisions.

1. **Co-develop Industrie 4.0 strategy**: The possible implications of Industrie 4.0 for the company's business model are evaluated. Relevant future fields of application are identified and evaluated with the help of controlling. The result is the Industrie 4.0 strategy of the company.

2. **Evaluate investments**: Industrie 4.0 requires high levels of investment in innovation, research & development, IT infrastructure, and new technologies. Controlling acts in a support function for information preparation, risk assessment and decision-making, as well as playing the role of gatekeeper in the investment process.

3. **Co-develop digital business models**: New digital models require a comprehensive and unbiased business case analysis. Additionally, business models themselves require new forms of performance management.

Further develop controlling

Additionally, controlling must continually develop itself in order to be able to cope with future demands.

4. **Define demands upon controlling**: Based on the application fields developed in Point 1 above, the necessary changes in controlling instruments, processes and systems are derived. These changed requirements developed to create a target controlling image for Industrie 4.0.

5. **Establish technology scouting**: The rapidly changing technologies and requirements are observed continuously and evaluated for the company by a technology scout in controlling.

6. **Further develop skills**: The abilities and skills in controlling are continuously further developed in parallel to the technical, methodological and process-related changes which take place. To this end, the competence model in controlling is overhauled in line with the target image developed in Point 4 above.

7. **Further develop CIO/ CFO interfaces**: The interfaces with the IT function are remodeled to reflect the even closer cooperation.

8. **Further develop instruments, processes and systems**: The elements which require change (e.g. in data management, reporting, planning, forecasting, cost accounting) are developed in interdisciplinary teams. For this, multi-stage roadmaps are developed and agile implementation projects initiated.

9. **Adapt performance management approaches**: The performance management approach of the value creation functions and the digital business models are modified to fit the new circumstances.

The following milestones can be reached over time when implementing such a roadmap:

- **2015**: More and more isolated technical application possibilities are being developed and marketed under the umbrella of Industrie 4.0. The frontrunners are implementing the first cohesive concepts in their own value creation. All other companies in the manufacturing industry are first developing their own understanding of Industrie 4.0 and deriving implications for their business model.

- **2016**: Standards and platforms are increasingly forming the basis for cohesive Industrie 4.0 applications in your value creation. The transfer of concepts to the real-world is running into many hurdles. New information technologies and analytical methods are in the trial phase in many major companies and have been implemented in some parts of those companies.

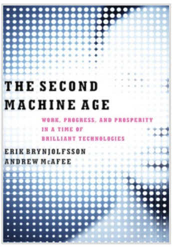
- **2017-2019**: More and more value creation is digitized or networked. Inter-company applications based on Industrie 4.0 are also becoming reality. New digital business models are creating new markets or transforming old ones. Real-time data from the value creation processes is changing the performance management concepts of manufacturing companies permanently. Complex data models are enabling increasingly accurate forecasts and sensitivity analyses. Deterministic performance management principles are being replaced step-by-step with agile ones. The need for real-time reports is increasing.

- **2020+**: The frontrunners of Industrie 4.0 are realizing significant efficiency advantages, and the use of specific digital interfaces is a critical competitive factor for their suppliers. The performance management of value creation is increasingly agile. Forecasting models and sensitivity analyses form the basis for important strategic and operative decisions.

Recommended Reading

The final report **"Recommendations for Implementing the Strategic Initiative Industrie 4.0"** from the working group Industrie 4.0 provides a comprehensive overview of this topic. Headed up by Dr. Siegfried Dais (Robert Bosch GmbH) and Prof. Dr. Henning Kagermann (National Academy of Science and Engineering - acatech), this working group defined the areas of application and the research needs for Industrie 4.0 and presented its recommendations for implementation to German Chancellor Angela Merkel at the Hannover Fair 2013.

The book **"Industrie 4.0 in Production, Automation and Logistics"** by Prof. Dr.-Ing. Thomas Bauernhansl, Prof. Dr. Michael ten Hompel and Prof. Dr.-Ing. Birgit Vogel-Heuser discusses initial applications and important questions from the perspective of industry. It deals with relevant elements from Industrie 4.0: from basic technologies through vertical and horizontal integration to cyber-physical systems.



In their book, **"The Second Machine Age"**, Erik Brynjolfsson and Andrew McAfee describe the ramifications of the so-called digital revolution, while analyzing the profound changes through the use of information and communication technologies. With the aid of diverse examples, they not only explain the effects of intelligent interconnectedness in industry, they also illustrate how communicating devices or voice recognition systems enrich the lives of people outside of their daily work life.

Together with Ingenics AG, the Fraunhofer IAO has carried out the representative market survey **"Production Work of the Future - Industrie 4.0"**. 518 decision-makers from mainly mid-sized companies participated. The respondents all saw a clear value-added from using Industrie 4.0. It was not the technical requirements which they identified as the main barriers to implementing IT innovations but "the lack of ability to change within the organization".

The study **"Industrie 4.0 – Economic Potential for Germany"** by the Fraunhofer IAO and commissioned by BITKOM investigates possible productivity increases and growth impulses arising from the use of Industrie 4.0 technologies in six selected industries. Additionally, it shows the future shift in value creation along the value chain and what is needed for the successful use of Industrie 4.0 technologies.

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