INDUSTRY 4.0 for VET

4. SMART FACTORY

4.1 The topic

The first introduction

"Says one machine to another..." - what sounds like a little joke is the current big dream of the manufacturing industry. Smart factory is THE keyword in the current industrial revolution - also called Industry 4.0.

Because smart is king. The digital revolution enables people to live in a networked world in which everyday objects come to life and constantly communicate with each other. Not only your mobile phone is "smart" - from cars to voice assistants to refrigerators, there is a constant exchange of data and information that makes your life more pleasant.

Now imagine the enormous potential in production: Machines and computers that are in constant data and information exchange, that regulate and coordinate with each other - producing and processing products as autonomously as possible and without the need for human intervention. Not only manufacturing productivity and efficiency could be increased considerably. Accidents, excess production and environmental pollution could also be reduced.

So, you see: smart factory is the future. But it is also already the present: Many producers, for example the automotive industry, are already successfully implementing smart factory concepts.

Of course, Smart Factory is not as simple as you might think - but it's not as complicated as you might think. In this chapter you will learn the basics and application areas of Smart Factory.

The practical relevance - for this you will need the knowledge and skills

Smart Factory is an essential part of Industry 4.0. The basics and areas of application learned here will help you to have a future-proof voice in the field of modern production technology and are able to help shape it.

Learning objectives and competences at a glance

This learning unit gives you an overview of the basics, processes, application areas and problems of the smart factory. You will get to know the most important terms on the topic, learn how smart factory is anchored in Industry 4.0 and which components are available. You will also gain an insight into the areas of application and possible problems and learn why these are so important for the future of industry. The role of humans in an automated environment will also be explained.

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Learning Objectives
Being able to understand the basics, the sense and the decisive factors of smart factory.
Being able to distinguish and understand the operational and technological components of smart factory.
Being able to understand the areas of application and current problems.

4.2 What does smart factory mean?

Not only your everyday and professional life is becoming more and more digital, but also the industry is going through a worldwide process of digitalisation. This process has many names: Industrial Internet, Internet of Things, Internet of Services - but the most important term is "Industry 4.0".

Definition
Industry 4.0 ... is described by the Duden as an "industry based on largely digitalised and interlinked processes". This refers to the constant exchange of information and data between people, production, logistics and products.

The aim is therefore to integrate digitisation in the manufacturing industry and thus to be able to produce more optimally. Industry 4.0 includes many different fields of technology. These include the use of the so-called "cloud", big data management as well as data protection, mobile communications and others.

Smart factory is now also one of the building blocks of Industry 4.0 - in the trade press it is even referred to as the heart of the system. If you take a closer look at the definition, you will see why:

Definition
Smart Factory ... the REFA (the German association for work design, business organisation and corporate development) defines the term smart factory simply as "a production environment that organises itself".

Production environments should therefore function autonomously and, if possible, without human intervention.
A production environment of this kind includes:

- **Production facilities**
  Production and processing machines that manufacture and further process a product or its components (e.g. milling or welding machines but also construction and packaging).

- **Logistics Systems**
  The movement and storage of production goods and parts (e.g. the provision of the correct quantity of adhesive material or the temporary storage of finished products).
- **Product**
  The product itself or its components are also part of the production environment (e.g. car doors or smartphone displays).

The basis for autonomous production is the intelligent networking of these three components. The product should be able to communicate with the production plant and the logistics system and independently provide them with information on production (e.g. what display size the frame requires, how many and which screws are needed).

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On the one hand, this requires a lot of data, on the other hand, it also requires a way to pass on this data at all. The solution? Simple: Chips and sensors!

Every product (or its components) in the factory is equipped with a chip and thus becomes a "smart product". The chip contains information about production and logistical requirements and communicates this to the production environment. The production equipment and logistics systems can process this information correctly and in turn coordinate and perform the necessary next step.

The technological basis for this is called "Cyber-Physical-Systems". This means nothing other than the connection of mechanical or electronic parts with software or information technology components - in very simplified terms, this is exactly what happens when a product is equipped with a chip.

Each product "knows" itself in which production stage it is at the moment, how and where it is to be processed and what it needs for this. It communicates this knowledge with the entire production environment so that it knows how to handle it.

An example shows the process in an understandable way:

Example
Example automotive industry Imagine you are a car door and you are lucky enough to be manufactured in a smart factory. Your production environment contains many components of the finished product - a car. This is where tires are stored, chassis are manufactured, the on-board electronics are assembled, individual parts are painted, etc. For this purpose, the factory has the proper production machines and also the appropriate logistical means of transport (e.g. conveyor belt from machine A to machine B). Today is your big day, because today the doors are being assembled. You know this because the product (car) has told the production environment via a chip that everything else in the car is already installed. So, you will be taken out of temporary storage via a logistics system and painted green - the car has communicated the colour in advance. Yet, you also have something to say with the help of your chip: "I am a car door in the front left-hand corner. I need 8 screws. ...but I still have to dry the varnish first."

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So, the production environment knows what to do, stores them for drying, provides 8 screws and mounts you on the front left.

Of course, the actual production process is only the beginning. Take the example of the refrigerator, which orders the milk itself when it notices that it is running out. Or the car dealership, where spare parts or even entire cars are automatically ordered from the car manufacturer depending on the current stock level.

As you can see, the possibilities of smart factory are not limited to a factory itself. In the future, it should be possible to automatically produce (also called "just-in-time production"), deliver and consume in real time according to supply and demand. In this way, resources can be consumed more accurately, and bottlenecks can be avoided.

Important

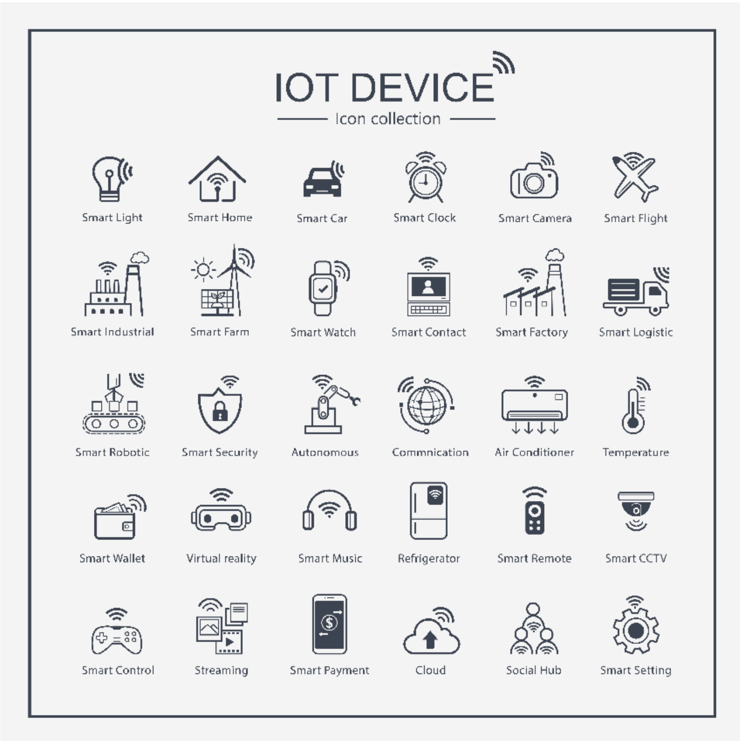
Economic factors

The development and implementation of such technologies is of course not cheap. Industrial companies also anticipate economic benefits.

Smart factory, for example, enables mass production and individual production in the same factory. This allows savings to be made on the purchase of machines. In addition, resources and industrial goods can be ordered more promptly and expensive surplus or wear and tear can be reduced.

Smart factory is thus one of the most important components of digitisation and plays a major role, not only in industry but also in the networked, "smart" everyday life of people.

The following diagram shows how many different factors this can be:



Smart factory is therefore only one area in a large pool of smart concepts. For the (manufacturing) industry, however, it is at the heart of it all.

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Remember
Smart factory is an essential part of digitisation in the industry. In this process... • production plants, logistics systems and products exchange information with each other independently... • ...so that the production environment is as self-organising as possible. The machines and products involved require... • a connection of the mechanical and electronic components with a software or information unit (chip)... • ...to participate in a network of data exchange. This will ensure that... • production and logistics can be controlled in real time according to demand, • resources are managed more efficiently, • and production costs are reduced.

4.3 What does a smart factory need?

A smart factory is a pretty modern thing. To make it work, it needs a few basic operational and technical requirements. In this section you will learn what a smart factory absolutely needs. You will see that this is quite a lot!

Important
The data exchange The requirements start with the data exchange itself. A smart factory exchanges a large amount of information. This data exchange must be able to run according to the following basic rules: • **Bidirectional data transfer** Information exchange works in both directions (both sending and receiving information). • **Horizontal and vertical data transfer** Information is exchanged both vertically across different departments (e.g.: customer order management, factory floor, product) and horizontally (machine A to machine B on the factory floor).

Since the goal is to record important process data in production in real time, operational control systems must be integrated in the data exchange. These operational control systems are concepts that help to manage, monitor and control companies in the production sector. The following must be included:

- **Enterprise Resource Planning**
  This is where resources, such as material and operating equipment, but also personnel, capital and general information technology, are planned, controlled and managed.

- **Manufacturing Execution**
  This refers to the control and monitoring of real-time production (also referred to in German as production control system).

- **Product Lifecycle Management**
  A concept that deals with the lifecycle (from design, construction and production to sale, use and disposal) and the management of the information generated in the process.

- **Supply chain management**

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The management and improvement of the supply chain, i.e. the delivery and receipt of production and service goods.

Of course, technological building blocks and prerequisites are also needed for a smart factory to function in real time. Some of the most important are already developed and in use. These are very general components such as sensors ("sensing elements" that can detect physical or chemical properties of their environment) and actuators (components that perform mechanical movements when electrically controlled). Modern, automatable production techniques such as robotics and 3D printing are important here, but also various operational IT applications, e.g. for production management and controlling. Networking via broadband Internet and control via cloud systems (external servers that provide computing power) are already technically possible.
However, other systems and components are still in their infancy, such as augmented reality - here the perceived reality is "extended" with the information from a computer (e.g. Google Glass). The following table gives a brief overview of the required technological building blocks:

	SENSOR TECHNOLOGY	INNOVATIVE PRODUCTS	ICT
TECHNOLOGY	Actuators Sensors Cyber-physical Systems Logistics Systems	Digital upgraded production lines Cyber-physical Systems MES M2M-Solustions HMI Human Machine Interface (secured terminal devices) Additive Production (3D-Druck) Robotics	IP v6 Cyber-Physikal Systems IKT-Infrastructure Broadband Network communication ERP PLM SCM Databases, In-Memory Cloud Computing Big Data Analytics Augmented Reality Cyber Security
PROCESS PERFORMANCE	Real-time-capability Traceability Reliability Completeness	Complete networking Self-configuration	Wireless & Mobile networking Real-time-capability Data protection

Excursus

Industry and factories in transition

If you define smart factory as a part of Industry 4.0 it is obvious that there must have been an Industry 1.0, 2.0 and 3.0.

While the first and second stages of industrialisation led to the introduction of mechanical production facilities and mass production, Industry 3.0 was already about automation, the use of IT and electronics - but without these components communicating with each other in real time and influencing each other.

As just mentioned, some of the necessary technologies are already in use as further developments of these industrial precursors, but others have yet to be developed from scratch. There are also influences from non-industrial areas. The "Internet of Things" plays a major role here and is already more widely known in the private sector than the networking of household appliances (example: mobile phone recognises that you are coming home and automatically switches on the lights in the apartment, at the same time the coffee machine makes an espresso and the TV turns on the news).
Industry 4.0 must take Internet of Things technologies to an industrial level and put them into an economically profitable framework. This is the only way a truly new and fourth "industrial revolution" can succeed.

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Of course, at first glance, many of these technologies are somewhat opaque in terms of meaning and function. Therefore, the most important ones will be explained in more detail in the following:

Cyber physical systems (CPS)

First things first: CPS are the technical cornerstone of every smart factory. Also known as embedded systems, this refers to any electronic and information technology equipment of objects in the production environment. These can be:

- **Sensors,** for the direct environment of the object
- **Actuators** that actively move objects (for example levers)
- **Identifiers** to uniquely identify and assign objects (e.g. barcode)
- **Microcontrollers** (chips mentioned above), which analyse data, determine the status and determine the next steps
- **Communication systems** that allow access to the network via cable or radio

This is what makes an object "smart" – in other words, intelligent. Examples of such smart objects in the production environment are tools or intelligent containers. Such a container can be identified via its barcode and provides information about its position and contents via sensors and microcontrollers.

IPv6 - many, many Internet addresses

Another basis for Smart Factory development is a new Internet protocol. Such a protocol can ensure a sufficiently large so-called "address space". The more intelligent objects are connected to each other, the more Internet addresses are needed to address them unmistakably.

Broadband networks

Smart factories generate, send, receive and process a vast amount of data. This must happen quickly - otherwise it is not possible to work in real time. This requires broadband networks to ensure sufficiently high data transfer rates, keep delay times low and provide fail-safe operation.

Important
WLAN and mobile communications To put it simply, of course, a strong WLAN is required internally - but outside the company, mobile phone networks must also be considered (example: a truck that automatically informs the receiving factory of a traffic jam and thus delayed resources via mobile phone).

Machine-to-machine communication (M2M) - intelligent machines

Other technological building blocks are interacting machines that can automatically exchange information with other machines and the products. Material data, order information, the current status and maintenance measures are communicated. They also collect data about their system status - in principle, "how they are doing". Thus, ongoing processes can be analysed and (re-)controlled in real time.

Human-Machine-Interfaces (HMI)

The interaction of man, machine and product (note: in real smart factories all three must be intelligent) is particularly exciting. While highly mobile devices such as tablets and smartphones already offer direct human

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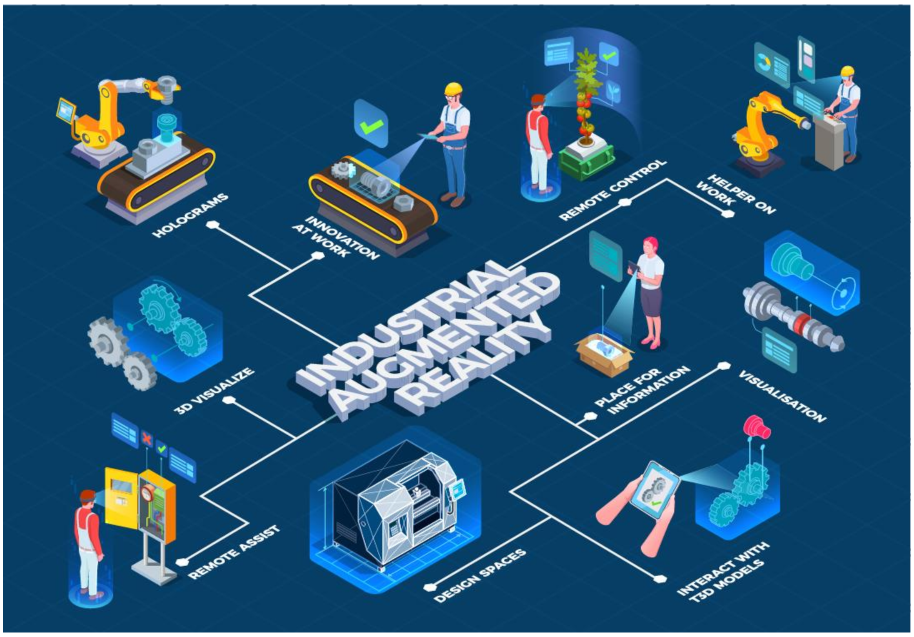
integration into the network and communication of a smart factory, there is still a lot of scope for research in this area.

A highly contemporary, alternative method is the isolated use of Augmented Reality glasses, which provide the employees in the production environment with additional virtual information.



Production control systems - Manufacturing Execution Systems (MES)

These have already been mentioned above in the operational control systems and are used for the management of resources (operating resources, personnel and delivery parts) and for the comprehensive recording of production data (operating, machine and personnel data).

Such production control systems have existed for a very long time, but they are not yet fully networked. Once they are able to exchange information in real time with production plants, logistics systems and products, the full potential of a smart factory is released.

Big Data Analytics

If everything and everyone generates, processes and sends data in real time, then of course enormous amounts of data result - these want and need to be handled properly by appropriate IT infrastructure and IT equipment. Further analysis also requires a high computing capacity.

Big Data Management and Big Data Analytics are already offered on the market with standard solutions or are carried out as an integrated cloud solution - but the requirements are constantly increasing.

Cloud computing and storage space

Cloud computing refers to the external use of computing power and storage space made available via an Internet or Intranet. Given the high demands on data performance, integrating a "cloud" in a production environment is not a bad idea. This allows all applications and data to be managed and coordinated centrally. Previously used in-house server solutions can no longer meet the demands of big data processing and the requirements of a smart factory for analysis, planning, controlling and optimisation in real time.

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Important

And the human?

In this chapter you have learned that production should largely operate without humans, but now again that humans are integrated via augmented reality - well, now what?

Well, even if the smart factory is supposed to be fundamentally self-organising and automate the manufacturing process, the human being is still a part of it - just not in the role of production, but of further optimisation and control of the manufacturing systems. In doing so, they coordinate interfaces to other systems or production environments, for example. Augmented reality as a concept is also important here - it enables virtual intervention without any physical contact.

A smart factory also needs generalised standards and norms. A common semantic basis (i.e. compatible programming languages and a universal production language) is absolutely necessary. A standardisation of smart factory operations can prevent systems that should communicate with each other from not understanding each other in the end due to technological differences.

Example

Legal challenges in the smart factory

Rapid technological developments also raise legal issues, some of which have not yet been fully resolved. An example illustrates the problem:

A vendor receives a purchase order from a company. The company processes Plasticine into funny animals and then sells them to toy shops. The company uses a smart factory, which means it is automatically networked with both, the supplier (raw modelling clay) and the customers (toy store). However, a purchase order was sent because the system incorrectly processed customer demand and is much higher than the company can process or store. Of course, the company does not want to pay the surplus, the toy retailers do not need such a huge amount of Plasticine anyway and the supplier is angry because he produced Plasticine for free.

Who is to blame now? Who must pay if the mistake has caused a system that involves all three parties? Here the law is not yet interpreted clearly enough.

In addition, the question of data protection, compliance and secrecy within partnerships arises. When all data is exchanged, everything is disclosed at the same time. For example, which of the data made available may be used by the supplier? For what purpose? Here, too, concepts still need to be developed.

Remember

Smart factory requires some operational and technical prerequisites to enable the desired networking and real-time data exchange.

The main technological building blocks are:

- Cyber-Physical-Systems
- Big Data and Cloud Computing
- Broadband and sufficient address space
- Human Machine Interfaces
- Integration of operational production control systems

Man is no longer a part of production, but controls and optimises the production processes.

Smart factories must also be considered within a legal framework - standards and norms can help here.

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4.4 What are the current application and problem areas of smart factories?

Smart factories are the most important part of the digitalised Industry 4.0 and thus the future of the manufacturing and production industry. But how far have factories and industry progressed in practice? What areas of application are there and what problems still need to be solved?

Important
Innovation vs. standard solution As explained above, standards and norms at the (software) technical level would certainly benefit the development of smart factories. However, there is a major problem. In order to be successful as a company, you have to be ahead of the competition - those who wait for standard solutions may then have a clear competitive disadvantage. That's why we are working at full speed on individual, proprietary solutions. This, in turn, contradicts a universal overall solution.

Especially car manufacturers such as BMW and Audi are already using at least parts of a smart factory in the production and construction of vehicles. Especially in robotics, the industry has already come quite far.

Audi currently uses the ***PART4you* system**, for example. This is a robot that uses integrated cameras and vacuum cups to pick up individual components and move them independently to the correct position in the factory. Sensors and chips are also used to ensure that safety standards are maintained in the production environment.

At BMW, **smartwatches** are increasingly used as a virtual interface between man and factory. The people involved in production are thus informed about the requirements (e.g. equipment line, number of screws, etc.) - in real time about the smart product parts themselves. Barcode scanners worn on the wrist, for example, are also used for this purpose. Audi is already testing augmented reality glasses in this field, which particularly ensures shorter training times.

Drones are also already used. Some manufacturers use them, for example, to take stock of their inventories. In principle, such an **"inventory drone"** is a flying barcode scanner that can identify and allocate each storage location and each product based on barcodes. The information is then forwarded to the operational systems - quite brilliant, isn't it?

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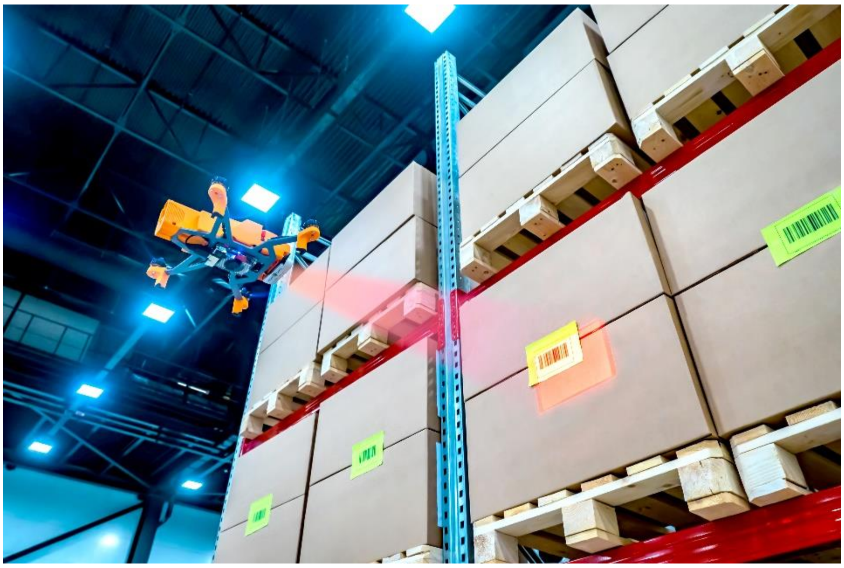

The **agricultural industry** is also already enjoying the benefits of some parts of smart factory. Drones also play a major role here. These are mainly used for risk identification (e.g. finding animal nests). The drones communicate with the harvesting vehicles and ensure improved navigation.

As you can see, smart factory is already being used and tested extensively in some areas - but there is still a long way to go before it is actually implemented. In addition, there are still **some open questions and problems to be clarified**:

- **Standards and norms**
  As already mentioned: In a networked (industrial) world, all computers should speak the same language if possible. This is difficult in the case of individual innovation research by individual companies.

- **Law and data protection**
  Whose fault is it if the machine makes a mistake? The company using it? The manufacturer? The person responsible for the shift? That has not really been clarified yet. The question of data secrecy remains also unanswered - after all, no company wants its own patents or research results to be disclosed. However, this is also difficult with a complete network.

- **Security and hacking**
  Computers and systems networked with the Internet are vulnerable to cyber attacks from outside. Cyber warfare or espionage is becoming an increasingly serious issue. What happens when a smart factory is hacked?

- **Dependence**
  A totally networked system must also function when individual parts fail. If individual units in the system do not function correctly, it must be ensured that the factory continues to operate without them if possible - otherwise production losses could have serious economic consequences for the company.

- **Is man becoming more stupid?**
  And as always, when it comes to modern, intelligent technologies, the question arises - will humans become more stupid if the machine becomes more intelligent? Not likely. However, the following thought is quite justified: if humans only act as a controlling organ in the production process, will

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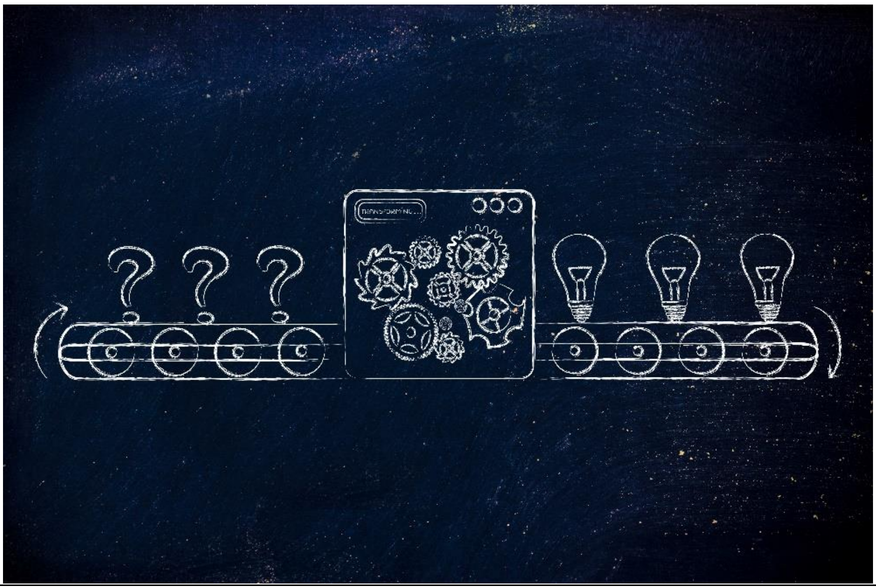
they be able to "step in" in case of failures? Is it possible that know-how is lost here if the plant itself always indicates what needs to be done?



Remember

Smart factory is already being used in sub-sectors in various industries - the most advanced of which is the automotive industry.

The following techniques, among others, are already in use:

- Smart Robotics
- UAVs
- Smartwatches as human-factory interface

However, there are still some open questions and problems:

- Standards vs. innovation
- Law and data protection
- Security and hacking
- Dependence on a system
- Loss of human know-how

There is still a long way to go before smart factories can be fully implemented. Although companies are already researching, testing and developing at high pressure, several **technical, security-related** and **legal problems** still need to be solved before all sub-areas can be combined.

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4.5 Summary

The smart factory is an **essential part of digitisation in the industry**. Production plants, logistics systems and products should independently exchange information with each other so that the **production environment is as self-organizing as possible**.

For this purpose, the machines and products involved require a connection of the mechanical and electronic components with a software or information unit in order to participate in a **network of data exchange**.
Man is no longer a part of production, but controls and optimises the production processes.

This ensures that production and logistics are **controlled in real time as required**, resources are managed more efficiently, and production costs are reduced.

A smart factory requires **some operational and technical prerequisites** to enable the desired networking and real-time data exchange.

The main technological building blocks are fast broadband Internet, big-data applications and cloud computing, human-machine interfaces and cyber-physical systems.

Smart factory is already being **used in sub-sectors in various industries** - the most advanced of which is the automotive industry. Especially smart robotics, drones and smart watches (as human-factory interface) are already successfully used.

However, there are still some **open questions and problems**. These include legal issues as well as data protection, the use of standardised technologies, security concerns and system vulnerability.

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