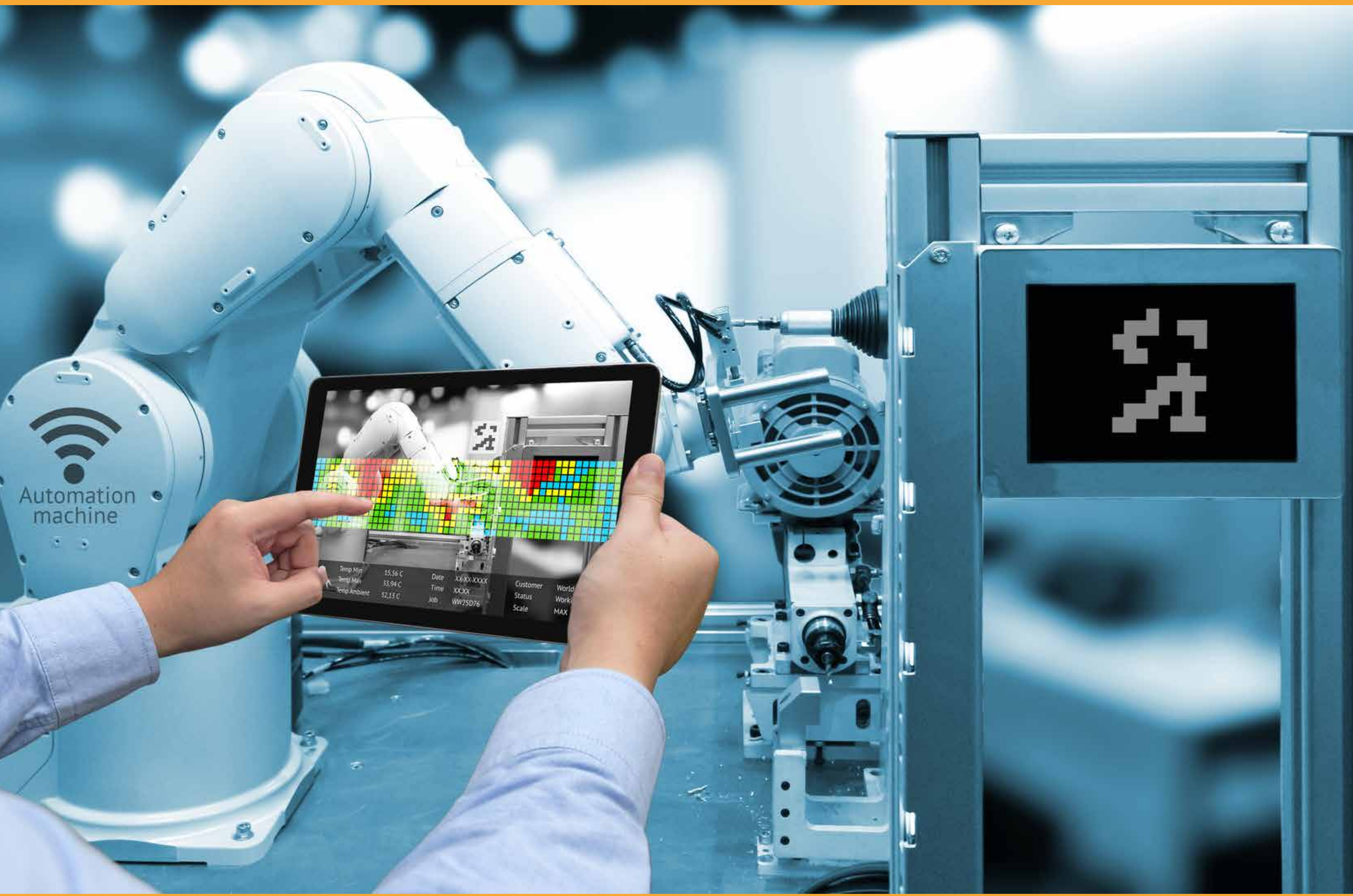
SMeART
Making Europe's SMEs Smart



SMeART University-Business Cooperation Model and Guidelines

Co-funded by the
Erasmus+ Programme
of the European Union

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SMeART University-Business Cooperation Model and Guidelines

SMeART – Knowledge Alliances for Upskilling Europe's SMEs to Meet the Challenges of Smart Engineering

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SMeART University-Business Cooperation Model and Guidelines

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Co-funded by the Erasmus+ Programme of the European Union

CONTENT

1. LIST OF ABBREVIATIONS

A2DP	Advanced Audio Distribution Profile
ACL	Asynchronous Connection-Less
AES	Advanced Encryption Standard
AFH	Adaptive Frequency Hopping
AI	Artificial Intelligence
ASB	Active Slave Broadcast
ATT	ATTribute protocol
AVCTP	Audio/Video Control Transport Protocol
AVDTP	Audio/Video Distribution Transport Protocol
AVRCP	Audio/Video Remote Control Profile
AWS	Amazon Web Services
BLE/LE	Bluetooth Low Energy / Low Engery (Both terms are used to alternately)
Bluetooth SIG	Bluetooth Special Interest Group
BNEP	Bluetooth Network Encapsulation Protocol
BPME	Business Process Management Everywhere
BR/EDR	Basic Rate / Enhanced Data Rate
CDMA	Code Division Multiple Access
CPS	Cyber-Physical System
CSMA	Carrier Sense Multiple Access
DHCP	Dynamic Host Configuration Protocol
DQPSK	Differential Quadrature Phase Shift Keying
DUN	Dial-Up Networking
ECDH	Elliptic curve DiffieñHellman
EIoT	Enterprise Internet of Things
FCC	Federal Communications Commision
FDMA	Frequency Division Multiple Access
GATT	Generic ATTribute profile
GFSK	Gussian Frequency-Shift Keying
HCI	Host Controller Interface
HCRP	Hard Copy Replacement Profile
HEI	Higher Education Institution
HFP	Hands-Free Profile
HID	Human Interface Device
HOGP	HID over GATT Profile
HVAC	Heating Ventilation and Air Conditioning
IoE	Internet of Everything
IoT	Internet of Things
IP	Internet Protocol
IPSP	Internet Protocol Support Profile
IPv6	Internet Protocol version 6
ISM Band	Industrial Scientific, and Medical
L2CAP	Logical Link Control and Adaptation Protocol
LC	Link Control (protocol)
LELL	Low Energy Link Layer
LL	Link Layer
LMP	Link Management Protocol
LMP	Link Manager Protocol
M2M	Machine to Machine
MAC	Media Access Control
MEMS	Micro Electro Mechanical Systems
MitM	Man in the Middle (attack)
MWSN	Mobile Wireless Sensor Network
OBEX	Object exchange
OPP	Object Push Profile
PANU	Personal Area Network User
PHY	PHsical laYer
PPP	Point-to-Point Protocol
PSB	Parked Slave Broadcast
QoS	Quality of Service
QR-Code	Quick Response Code
RFCOMM	Radio frequency communication
RFID	Radio Frequency Identification
RTLS	Real Time Location System
SCO	Synchronous Connection-Oriented
SDP	Service Discovery Protocol
SINR	Signal to Interference plus Noise Ratio (SINR) (this is also known as the Signal to Noise plus Interference Ratio (SNIR))
SNR	Signal to Noise Ratio
SPP	Serial Port Profile
SSID	Service Set IDentifier
TCS	Telephony Control Protocol Specification
UUID	Universally Unique Identifier
WAE	Wireless Application Environment
WAP	Wireless Application Protocol
WLAN	Wireless Local Area Networks
WPAN	Wireless Personal Area Networks
WSN	Wireless Sensor Network

2. INTRODUCTION

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2.1. Preamble

Current digital markets are characterized by a high complexity, which makes it harder for companies to keep hold their competitive position every day for a longer period of time. Potential customers can choose from a wide range of products and services of globally acting providers from around the world, whereby requirements in terms of quality, price and availability are increasing (cf. Becker, Himpel, & Kuß, 2004 p.393; Grundig, 2018, p. 13). Companies of all sizes are challenged by increasing market requirements along the life cycle of their products and services. Industry 4.0, Smart Engineering or Production 4.0 include capabilities of solving the majority of known, existing difficulties in relevant production areas and might add sustainable value to current businesses. Due to the variety of emerging new terminologies, it might be difficult to approach the topic of Industry 4.0. Visions, ideas and technologies are often mentioned jointly and might cause confusion. Since it is so difficult to provide a clear, final definition of I4.0, many companies can not really imagine how I4.0 might contribute to their value creation process. Some visions appear too futuristic and, therefore have the potential of discouraging companies instead of inspiring them. This publication - a guideline for small and medium companies - is intended to support companies in successfully designing and implementing the introduction of processes. This publication draws on the diverse experience of the international editors of an

„ERASMUS+ KNOWLEDGE ALLIANCE FOR UPSKILLING EUROPE'S SMES TO MEET THE CHALLENGES OF SMART ENGINEERING".

This alliance is anchored in a project with the acronym SMeART. In particular, these guidelines are intended to support cooperation between higher education institutions (HEI) and companies for the successful application of the principles of Smart Engineering.

2.2. State-of-the-art

2.2.1. Scientific starting point

Industry 4.0, Smart Engineering or Production 4.0 are current trends of automation and data exchange in manufacturing technologies. These three terms imply an industrial evolution concept with four stages (see Fig. 1). In particular, the term Industry 4.0 is mainly used in Europe, having its roots in Germany (see section 2.2.2.1.).

There are different opinions concerning the actual advent of Industry 4.0 in Small and Medium Sized companies (SME). In terms of selected pilot installations, implementations of the sometimes disruptive Industry 4.0 technologies for SMEs are expected for the period between 2020 and 2025 for broad adaptation of standard solutions. But the realization of a "more true, complete" Industry 4.0 is expected around 2030 (see Fig. 1) (Berger, 2018)). In anticipation of this the initial transformation is happening right now and within the next few years: most research deployments will be done by current researchers, developers and other staff. Nevertheless, there are already highly developed example projects like the "It's OWL"-Industry 4.0- Cluster in Bielefeld/Germany (Siebe, 2018). The large companies have already positioned themselves in terms of staffing and finance to take advantage of the potential of Smart Engineering and digital transformation. Now SMEs are following their example. However, until now not more than 20 percent of European SMEs have digitized their processes.In five years this figure is expected to increase to 80 percent though. For a long time the IoT has no longer been "the music of the future" and the digitization of all production and business processes is an existential must for every company.

Experts consider that SMEs in particular will have good opportunities through digital transformation to increase their competitiveness or rather defend their position against their competitors. Therefore there is no alternative to the digital transformation of the production processes. This is the only way to take a look at the whole process and supply chain in real time and makes the customer structure more transparent. Thus, digital transformation becomes a win-win situation. Customers enjoy a distinctly optimized service and companies gain attractive business models ("Digital Genius," 2017). Industry 4.0 and Smart Engineering have their basic focus on the production process within a smart factory, while another

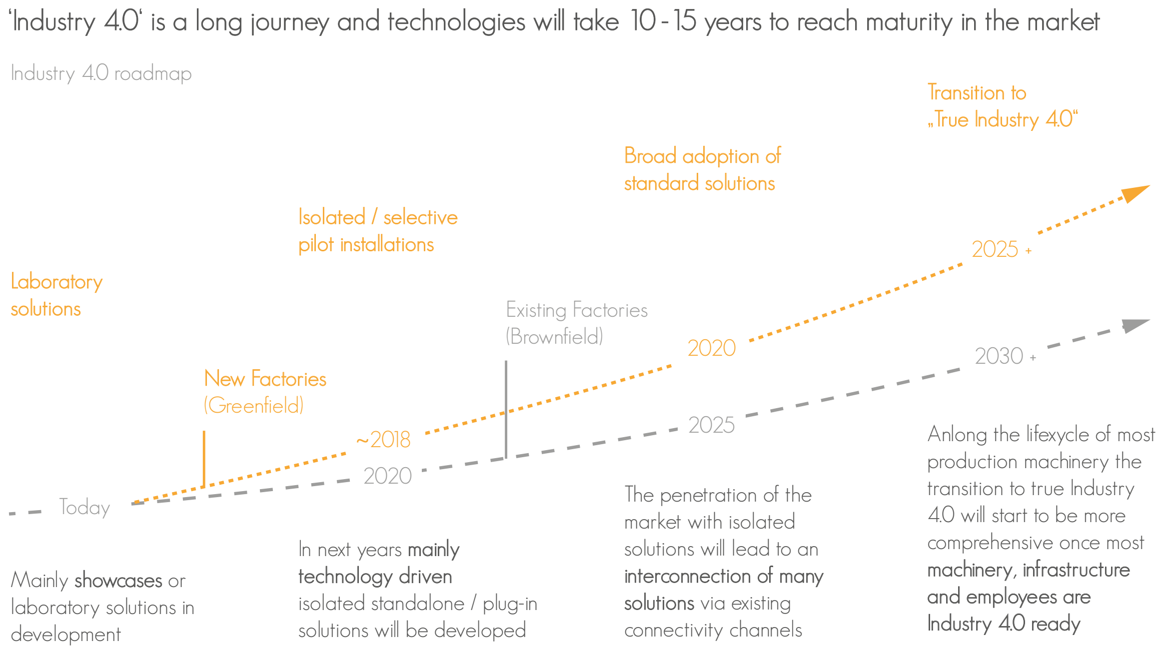

Fig. 1: Most sources predict Industry 4.0 to "arrive" in the years 2025 – 2030. (Berger, 2018)

important term - the Internet of Things (IoT)- focuses on the utilization phase of digitalized and connected devices and products. Industry 4.0 includes cyber-physical systems: The Internet of Things (IoT) and cloud computing (Hermann, Pentek, & Otto, 2016a). Furthermore, the term "Industry 4.0" focuses strongly on smart factories. In order to describe general digital transformation processes, resulting value chain and product life cycle changes (see section 2.4.1.) as well as effects related to non-industrial small and medium enterprises (SME) we consider the term Industry 4.0 as too constricted. The expression "Cyber physical System" however reflects the significance of these new developments in relation to the stages of the industrial evolution better (see Fig. 2).

Industry 4.0 relates to the concept of a smart or intelligent factory, which consists of 3 parts:

- Smart Production: new production technologies that create collaboration between all elements of the production or collaboration between operator, machine and tool
- Smart Services: information and technical facilities that enable to integrate systems; additionally, that allow to integrate a company as a supplier - customer and provide each other with external structures such as roads, hub, waste management, etc.
- Smart Energy: focus on energy consumption, creating higher performance systems and reducing energy waste.

Currently, Smart Engineering is considered as the enabler of the above concept. Examples of related Smart Engineering enabling technologies are:

- Advanced production systems: interconnected and modular systems that allow flexibility and performance. These technologies are covering automatic material handling systems and advanced robotics.
- Additive Production: additive manufacturing systems that increase the efficiency of materials.
- Augmented Reality: vision systems with augmented reality to better judge the operators in carrying out daily activities.
- Simulation: ... of interconnected machines to optimize processes.
- Horizontal and vertical integration: integration and exchange of information both horizontally and vertically between all actors of the production process.
- Industrial Internet: communication between the production units, not only within the company but also externally.
- Cloud: implementation of all cloud technologies such as online storage, the use of cloud computing and external services for data analysis.
- Cyber security: the whole issue of information security and systems.
- Analysis of Big Data: management techniques of large amounts of data based on open systems that allow forecasts or predictions.

Industry 4.0 creates or resembles what is called a 'smart factory'. A smart factory is a smart system that is based on Smart Engineering. Smart systems incorporate functions of sensing, actuation, and control in order to describe and analyse a situation, and make decisions based on the available data in a predictive or adaptive manner, thereby performing smart actions. In most cases the smartness of the system can be attributed to autonomous operation based on closed loop control, energy efficiency and networking capabilities. Smart systems typically consist of diverse components ("Smart Systems", n.d.):

- Sensors for signal and data acquisition;
- Elements transmitting the information to processing unit;
- Processing units that take decisions and give instructions based on the available information;
- Components transmitting decisions and instructions;
- Actuators that perform or trigger the required action.

Smart systems are linked to the development of Industry 4.0 and to the IoT, in that they provide smart functionality to objects, e.g., to industrial goods in the supply chain, or to food products in the food supply chain. With the help of active or passive object identification technology, wireless sensors, real-time sense and response capability, energy efficiency, as well as networking functionality, objects will become smart objects. These smart objects are often seen as special Industry 4.0- and IoT-applications. Smart industrial goods could store information about their origin, destination, components and use. In addition, waste disposal could become a truly efficient individual recycling process ("Smart Systems," n.d.).

2.2.2. Important technical topics and terms

2.2.2.1. Smart Engineering

What is **Smart Engineering**? This term covers the methods, processes and IT tools for the cross-disciplinary, system-oriented development of innovative, intelligent and connected products, manufacturing facilities and infrastructures. These areas are currently also grouped together under the term Industry 4.0. This refers to the networking and comprehensive exchange of information between all the components involved in the manufacturing process, and between all the individual part-processes of product development and manufacture with the aim of achieving significant improvements in performance, cost, quality and customer acceptance of products. An important part of Smart Engineering is securing and testing an interdisciplinary product lifecycle management process (see section 2.2.3.) , as the various knowledge domains and interrelationships are currently not sufficiently connected, with the result that information can be lost and networked relationships have to be recaptured and re-implemented. For product development purposes, Smart Engineering applications come into play as early as the planning stage because within a diverse range of defining criteria, the developer first starts to create the product's structure and associated information models. This digital development process ultimately benefits from the qualifying and networking of production and the modelling of processes and automation technology. This must involve secure and reliable communication between not just the individual sub-processes but also the various components of the manufacturing facilities. A particular challenge here is the communication with mobile elements. Ultimately, Smart Engineering is about the integration of product development, production planning and production management to ensure the rapid market-ready implementation of innovative product ideas and the creation of value via a digital development process (University of Duisburg, 2018).

For these guidelines, smart systems that focus on typical SME value chains will be referred to as SME 4.0. According to Herrmann, Pentek and Otto (Herrmann, Pentek, & Otto, 2016) Smart Engineering constitutes of:

- cyber-physical systems,
- Internet of Things,
- cloud computing.

2.2.2.2. Cyber-physical systems

In **cyber-physical systems** (CPS), physical and software components are deeply intertwined. Each one of the components is operating on different spatial and temporal scales, exhibiting multiple and distinct behavioural modalities, and interacting with each other in a myriad of ways that change with context ("Cyber-Physical Systems (CPS) (nsf10515)," 2010). Examples of CPS include Industry 4.0 or SME 4.0 in general or smart production systems, autonomous automobile systems, medical monitoring, process control systems, robotics systems and automatic pilot avionics in particular. Often CPS are seen as a pre-stage to IoT. They are sharing the same basic architecture, nevertheless, CPS present a higher combination and coordination between physical and computational elements (Rad, Hancu, Takacs, & Olteanu, 2015).

Common applications of CPS typically fall under sensor-based communication-enabled autonomous systems. For example, many wireless sensor networks monitor some aspects of the environment and relay the processed information to a central node (Karnouskos, 2011). A challenge in the development of cyber-physical systems is the large differences in design practice between the various engineering disciplines involved, such as software and mechanical engineering (Fitzgerald, Larsen, & Verhoef, 2014).

2.2.2.3. Industry 4.0

The term „**Industrie 4.0**" is a German word creation describing a bundle of measures to promote a smarter industry. Analogue to that there is, for example, the word „industry 4.0" as an English equivalent. There are various initiatives in many countries promoting this concept. In the US, there is the „Industrial Internet Consortium" (IIC) which was founded in March 2014 by the companies AT & T, Cisco, General Electric, IBM and Intel. New Internet technologies are to be jointly promoted, although the approach is not limited to the industrial sector. Further initiatives in Japan operate under the name „Industrial Value-Chain Initiative" (IVI). Initiators are major Japanese companies. China also took initiatives similar to the German political concept "Industry 4.0" in the five-year plan of 2015. They are intended to play a decisive role in the shift from low-wage countries to global industrial power. South Korea also invests in so-called smart factories. In several European countries there are other activities comparable to the German political initiative "Industry 4.0", such as the French „Industrie du futur". Major European Smart Engineering initiatives have been summarized within the EU Compass for Smart Engineering Initiatives and Policies. The compass is a result of this project (Partners, February 1., 2018).

Other sources say: "Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of Things, cloud computing and cognitive computing. Industry 4.0 is commonly referred to as the fourth industrial revolution (see Fig. 1). Industry 4.0 creates what is sometimes called a „smart factory". Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized

Fig. 2: Devices ("things"), networks, the "Cloud" and the applications represented in a four layer networked structure (Xiaomin et al., 2017).

decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time and via cloud computing, both internal and cross-organizational services are offered and used by participants of the value chain". (Wikipedia, 2016).

The "Plattform Industrie 4.0" identified a lot of potentials and challenges which are all a part of the five fields of action:

- horizontal integration
- digital end-to-end engineering
- vertical integration
- new social infrastructures
- cyber-physical production systems.

General descriptions – more technological or more general – can be found in the literature: besides the documents of the German "Plattform Industrie 4.0" ("Plattform Industrie 4.0," 2018), the report for the "Industry, Research and Energy" Policy Department of the European Parliament is an excellent general guideline (Smit, Kreutzer, Moeller, & Carlberg, 2016). (Rojko, 2017) provides a general overview of Industry 4.0 concepts and technologies, and (Xiaomin, Di, Wan, Athanasios, & Chin-Feng, 2017) discusses the "glue" holding all "parts" of the interconnected industry together: the data communication networks (see Fig. 2).

2.2.2.4. Internet of Things

The Internet of Things (IoT) is the network of interconnected smart objects, which are embedded with sensors, software, network connectivity and necessary electronics that enables them to collect and exchange data making them responsive. The Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as „the infrastructure of the information society" (ITU, 2017). It is an architectural framework which allows integration and data exchange between the physical world and computer systems over the existing network infrastructure. IoT does not have a focus on production, but on the utilization phase of digitalized and connected devices and products which allows the vendors to communicate with their own products while they are used by the customers and to provide new 'digital' customer services such as predictive maintenance (Vogt, Dransfeld, & Landrock, 2016).

In order to provide an architectural classification, it can be said that the devices which constitute the Internet of Things are generally structured in an architecture of three-level network:

1. Interface with the physical world: a large number of nodes at this first level (tags or sensory units) interacts with the environment by providing an identification code, acquiring information or commanding an actuator. These nodes are devoid of power (passive tags) or powered by battery (sensor units and actuators) and generally characterized by a reduced processing capacity and memory. They are also equipped with mechanisms for communication (wired or wireless) to communicate with the units of the second level. The cost depends on the features offered and can vary from a few cents per passive RFID tags up to 30-150 euros for nodes with sensory capabilities and/or implementation; the operational life ranges from a few years with the battery-powered devices (strongly dependent on the type of application) up to exceeding ten years for passive RFID tags.

2. Mediation: the second-level units, which includes the RFID tag readers and gateways, have the task of collecting the information from the first-level nodes to convey them to the control centers. They are characterized by a greater capacity processing and memory, are generally powered from the grid fixed and have a cost which can vary greatly from 50 euros for a gateway node to 2,000 euros for a RFID reader.

3. Processing and control center: the third level units, which includes the acquisition systems, central and operating rooms, have the task of receiving the information from the units of the second level for the subsequent stages of storing, processing and commissioning usability of the data.

Main IoT components are:

- Hardware: making physical objects responsive and giving them the capability to retrieve data and respond to instructions;
- Software: enabling the data collection, storage, processing, manipulating and instructing;
- Communication Infrastructure: consists of protocols and technologies which enable physical objects to exchange data.

Smart physical objects are determined by:

- Object identification,
- Sensors,
- Actuators,
- Communication protocol,
- Identification of location,
- Memory.

Object identification is usually based on auto-id technologies such as:

- RFID, Bluetooth beacons etc.,
- Bar-, QR-Code,
- Image recognition
- Biometrical identification:
- Fingerprint,
- Iris-recognition,
- Face recognition,
- Analysis of surface structures,
- GPS in combination.

Based on various technologies common IoT sensors are able to measure the following parameters:

- Temperature,
- Various light parameters,
- Pressure,
- Vibration,
- Deformations,
- Acceleration,
- Cardinal direction,
- Moisture,
- Acoustical events, speech,
- Visual events, video,
- Personal profiles, e.g. behavioural profiles.

The technological complement to a sensor is an actuator, a device that converts an electrical signal into action, often by converting the signal to non-electrical energy, such as motion. A simple example of an actuator is an electric motor that converts electrical energy into mechanical energy. Actuators may be stand-alone (i.e. just an output device), or may be combined with an IoT input sensor. An example might be an intelligent light bulb designed for night lighting outdoors – where the sensor detects that the ambient light has fallen to a predetermined level (that may be externally programmable), and in addition to reporting this data upstream also directly triggers the actuator (the light bulb itself) to turn on.

In many cases an actuator, in addition to acting on data sent to it over an IoT network, will report back with additional data as well, so some senses may contain both a sensor as well as an actuator. An example, again using a light bulb: the light bulb only turns on when specifically instructed by external data, but if the light element fails, the bulb will inform the network that this device is no longer capable of producing light – even though it is receiving data. A robustly designed network would also require the use of light bulb actuators that issue an occasional 'heartbeat' so if the bulb unit fails completely, the network will detect it and report the failure (Parasam, 2016).

The Industrial Internet of Things

Extension of the general IoT-expression: Today, only some of a manufacturer's sensors and machines are networked and make use of embedded computing. They are typically organized in a vertical automation pyramid in which sensors and field devices with limited intelligence and automation controllers feed into an overarching manufacturing-process control system. But with the Industrial Internet of Things, more devices—sometimes including even unfinished products—will be enriched with embedded computing and connected using standard technologies. This allows field devices to communicate and interact both with one another and with more centralized controllers, if necessary. It also decentralizes analytics and decision making, enabling real-time responses.

2.2.2.5. Other important terms

- Big Data and Analytics
  Analytics based on large data sets have only recently emerged in the manufacturing world, where it optimizes production quality, saves energy and improves equipment service. In an Industry 4.0 context, the collection and comprehensive evaluation of data from many different sources (production equipment and systems as well as enterprise- and customer-management systems) will become standard to support real-time decision making.

- Autonomous Robots
  Manufacturers in many industries have long used robots to tackle complex assignments, but robots are evolving for even greater utility. They are becoming more autonomous, flexible and cooperative. Eventually, they will interact with one another and work safely side by side with humans and learn from them. These robots (see Fig. 3) will cost less and have a greater range of capabilities than those used in manufacturing today.

- Simulation, "co-simulation" and "integrated design"
  In the engineering phase, 3D simulations of products, materials, and production processes are already used, but in the future, simulations will more extensively be used in plant operations as well. These simulations will leverage real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans.
  For example, Siemens and a German machine-tool vendor developed a virtual machine that can simulate the machining of parts using data from the physical machine. This lowers the setup time for the actual machining process by as much as 80 percent.

- Horizontal and Vertical System Integration
  Most of today's IT systems are not fully integrated. Companies, suppliers and customers are rarely closely linked. Nor are departments such as engineering, production and service. Functions from the enterprise to the shop floor level are not fully integrated. Even engineering itself - from products to plants to automation - lacks complete integration. But with Industry 4.0, companies, departments, functions and capabilities will become much more cohesive as cross-companies, universal data-integration networks evolve and enable truly automated value chains.
  As an example: NxTPort (Antwerp harbor) offers (verified) data to harbor based companies, providers of logistics, etc.

- Cybersecurity
  Many companies still rely on management and production systems that are unconnected or closed. With the increased connectivity and use of standard communication protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats

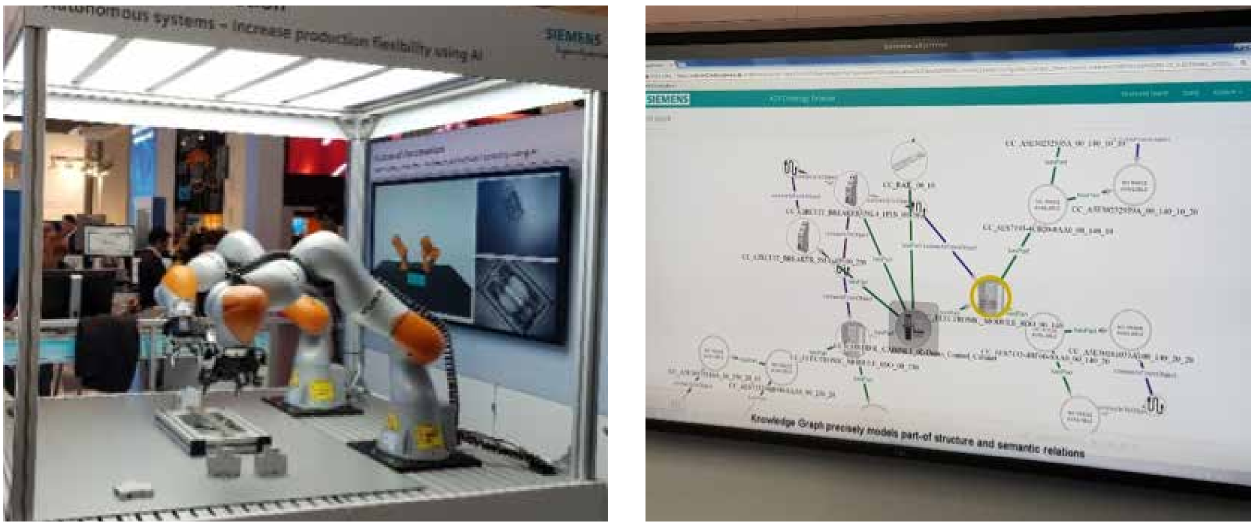

Fig. 3: Artificial Intelligence and Knowledge Based Systems based on semantic technologies and reasoning, shown on the Hannover Trade Fair 2018

increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential. New implementations of software for data exchange, e.g. OPC UA, have embedded security built in.

- The Cloud
  Companies are already using cloud-based software for some enterprises and analytic applications, but with Industry 4.0, more production-related undertakings will require increased data sharing across sites and company boundaries. At the same time, the performance of cloud technologies will improve, achieving reaction times of just several milliseconds. As a result, machine data and functionality will increasingly be deployed to the cloud, enabling more data-driven services for production systems. Even systems that monitor and control processes may become cloud based.

- Additive Manufacturing
  Companies have just begun to adopt additive manufacturing, such as 3D printing, which they use mostly to prototypes and produce individual components. With Industry 4.0, these additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs. High-performance, decentralized additive manufacturing systems will reduce transport distances and stock on hand. For instance, aerospace companies are already using additive manufacturing to apply new designs that reduce aircraft weight, lowering their expenses for raw materials such as titanium.

- Augmented Reality
  Augmented-reality-based systems support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. These systems are currently in their infancy, but in the future, companies will make a much broader use of augmented reality to provide workers with real-time information to improve decision making and work procedures.
  For example, workers may receive repair instructions on how to replace a particular part as they are looking at the actual system needing repair. This information may be displayed directly in a workers' field of sight using devices such as augmented-reality glasses.
  Another application is virtual training. Siemens has developed a virtual plant-operator training module for its Comos software that uses a realistic, data-based 3D environment with augmented-reality glasses to train plant personnel to handle emergencies. In this virtual world, operators can learn to interact with machines by clicking on a cyber representation. They also can change parameters and retrieve operational data and maintenance instructions.

2.2.3. Current situation for not-yet smart SMEs

2.2.3.1. A wake-up call for SMEs

In addition to examining the scientific and technical foundations of Smart Engineering, Industry 4.0 and the Internet of Things, it is important to analyse (Stepponat, 2018). A publication of the German Bundestag emphasizes the potential of the Internet of Things to solve problems of industrial societies. Therefore, there are many approaches in Europe to promote action in the fields of Smart Engineering, Industry 4.0 and the Internet of Things. Since 2009 the European Union has had an action plan to promote the development of Smart Engineering, Industry 4.0 and the Internet of Things in Europe. The Federal Ministry of Education and Research and the Federal Ministry of Economics and Technology are working with representatives of business and industry in Germany on projects on Smart Engineering, Industry 4.0 and the Internet of Things (Horvath, 2012). According to a study by „icom" in 2016, Smart Engineering, Industry 4.0 and the Internet of Things have great potential for SMEs and European private entrepreneurs in the digital economy. The way European companies apply new digital technologies will have a major impact on their future growth. New digital trends include not only Smart Engineering, Industry 4.0 and the Internet of Things, but also cloud computing, mobile web services and smart grids. As a result, the corporate landscape in Europe and the nature of work are undergoing a lasting change. This is due to the innovative power of new technologies, since they not only cause changes at the technological level, but also have an impact on business models and international knowledge transfer (Compagnucci, Della Porta, Marcotullio, & Massaro, 2016) .

The market share of IoT-products is a good measure of the success of Smart Engineering technologies.Therefore, let us have a brief look at the prospected market shares of the Internet of Things in Europe by country: The market share from 2014 is compared, for example, with forecast figures for 2020. The top European countries are the United Kingdom with a share of 21% in 2014 and 23% in 2020 and Germany with a 19% market share in 2014 and 21% in 2020, France with 15% in 2014 and 16% in 2020, followed by Italy, Spain, the Netherlands, Sweden, Poland and Belgium. The high market share of the Internet of Things in the United Kingdom, Germany and France, the top 3 European countries, is due to their high investment in Internet of Things technologies. Together they will account for 50% of all IoT revenues by 2020 and account for 75% of revenues together with Spain, Italy and the Netherlands. In countries with low investments in the Internet of Things it can be assumed that the technology will need longer to become important. Furthermore, the highest growth rate of the IoT is expected in Sweden. Modern communication networks are expected to increase the share from 4% to 24.2% (Compagnucci et al., 2016, p. 36). In 2020, the manufacturing (24%), financial (21%) and government (13%) sectors will have the largest shares in the market of the Internet of Things. In these sectors IoT communication and transaction processes are used in the B2B (business to business), B2C (business to customer), C2C (citizen to citizen) and C2G (citizen to government) areas. Europe has the potential to become the global leader of the Internet of Things, as Europe's information and communication technology can draw on its main strengths. These are B2B software (and services), embedded systems and system solutions in industrial and social environments such as logistic solutions (Compagnucci et al., 2016, p. 38).

In order to fully exploit the potential of Smart Engineering, Industry 4.0 and the Internet of Things in European small and medium sized enterprises(SMEs), the European Commission has set five conditions. In a publication in the context of the „Connect Advisory Forum" in December 2014, these were defined as the cornerstones for the successful use of Smart Engineering and the Internet of Things in Europe. In the course of scalable business models, existing global monopolies will be divided into smaller parts. This means that competition will continue to be global, but not only between large companies. To maintain balance and promote new jobs and economic growth in Europe, all SMEs in particular must participate fairly in the success of Smart Engineering, Industry 4.0 and the Internet of Things. Creating such an environment will be a core task for European SMEs. In addition, so-called smart core industries in Europe must be developed and prepared for the topic of Smart Engineering, Industry 4.0 and the Internet of Things so that only few innovations will have to be imported in the near future. The digital economy must be strengthened by innovations from the European high-tech sector in order to promote technologies of Smart Engineering, Industry 4.0 and the Internet of Things. This goal can only be achieved if new forms of organization, business models, services, development methods and optimizations in the field of digital engineering become part of SMEs' everyday lives (Angoso-Gonzalez et al., 2014, p. 9).

In the future the implementation of Smart Engineering, Industry 4.0 and the Internet of Things applications should be based on reliable standards. For example, it is necessary to define a reference model regarding the architecture of Internet of Things applications in order to promote the compatibility of applications in the industrial sector. Standards in the area of Smart Engineering, Industry 4.0 and the Internet of Things should not only concentrate on one area (e.g. telecommunications), but should be able to be used in different areas. This approach is based on the view that Smart Engineering, Industry 4.0 and Internet of Things applications should always be interdisciplinarily used in order to promote their use in industry (Angoso-Gonzalez et al., 2014, p. 10). These guidelines are intended to contribute to the preparation of appropriate standards for SMEs.

In order to establish a uniform digital market in Europe and to meet the aforementioned conditions, legal and regulatory issues need to be clarified. Smart Engineering, Industry 4.0 and Internet of Things applications have the potential to exert a positive influence on society, for example to make social processes more efficient, environmentally conscious, healthier or safer. In addition, the security of the applications and the data to be processed must be guaranteed and the privacy of persons involved in the process must be respected. This requires clear laws and regulations that promote acceptance of Smart Engineering, Industry 4.0 and the Internet of Things applications and protect consumers. In future, such framework conditions should focus on the requirements for applications and their reliability as well as areas of responsibility without favouring specific solutions in individual cases. In addition, humanistic, ethical and social aspects should always be taken into account. Especially in the field of big data and data analytics, data sets can be made easily accessible by using cloud computing. Especially the data collection of the Internet of Things with sensors does not require any human interaction and can be carried out completely automated. Ethical and social responsibility, which are topics of these guidelines too, must therefore always be examined (Angoso-Gonzalez et al., 2014, p. 10).

Looking at the recommendations of the above mentioned "Connect Advisory Forum" shows that the application of Smart Engineering, Industry 4.0 and the Internet of Things can make a lasting difference for European SMEs. It is possible to use the potential in an economically positive way to strengthen the digital economy in Europe and to establish a strong international market. However, ethical and social aspects must not be neglected. Only through a balanced use of Smart Engineering, Industry 4.0 and Internet of Things applications European SMEs might sustainably benefit from the new digital technologies (Stepponat, 2018).

Nevertheless, for some of Europe's engineering SMEs the implementation of smart principles is still considered a challenge that must be met in the future. The required irreversible leap forward in industrial development is comparable with the introduction of steam power, electricity or basic IT at previous stages and is therefore known as the fourth industrial revolution (see section 2.2.).

Small and medium engineering enterprises must act quickly because they need to:

- build-up IT-controlled communication and interaction processes between various actors during the entire production and value chain,
- develop and implement Cyber-Physical System,
- redefine management and staff skills,
- restructure work organisation and communication flow.

Unfortunately, a number of Europe's SMEs are poorly prepared for these developments and lag behind their competitors in other European regions, the USA and Asia. In particular, a number of SMEs- many of them belong to the backbone of Europe's industry and are still global leaders in many segments of the market- are under enormous pressure in order to not completely lose contact and their share of the market in the medium-term. Recently, many national initiatives have already put smart industry on the agenda. However, a lot of work still has to be done (Stepponat, 2018).

Therefore, the Erasmus+ SMeART project has been started. Not only with these guidelines SMeART intends to support the setup of sustainable cooperation between universities and engineering SMEs in order to ensure the successful transfer to A smart industry. For this purpose we are providing a HEI business cooperation model for upskilling SMEs to meet the challenges of smart engineering.

2.2.3.2. Special challenges for SMEs

The complexity and dynamic of modern markets make it harder than ever for SMEs to hold their competitive position. Due to stricter limitation of their personnel and financial resources, SMEs are challenged by altered market conditions. Major efficiency gains and open world trade have led to a saturation of the markets, enabling customers to choose from a wide variety of products and services and to set higher standards for example in terms of quality, price, sustainability and individuality. Furthermore, easy access to information on the Internet allows potential customers to compare different suppliers from all over the world within just a few clicks.

To stand their ground in an international competition, the capability of developing new products and the continuous improvement of their processes are seen as crucial success factors for SMEs. A glance at reality shows that current technologies and procedures are often not capable of meeting the various new challenges enterprises must face.
The entire development process from the formulation of a first product idea over the manufacturing and testing of different prototypes up to serial production is often much more time-consuming and expensive than originally planned. In addition, the desire for more individual products forces many companies to develop even more product variants (Mollemeier, 1997, p. 23), leading to a further strain on their limited resources. As a consequence, business opportunities are being pursued too late – if they are ever pursued. In terms of production processes, fluctuating demands and an increasing number of product variants pose major challenges

to enterprises. In particular, SMEs involved in larger supply chains need to be able to implement short-term changes in their production program, if they want to remain part of the supply chain permanently, as delivery capability and scheduling are key selection criteria for many customers. But inflexible production processes and slow information exchange often lead to production delays and additional costs (Roth, 2016a, p. 13). For more and more enterprises, the question arises how they can meet the various challenges of modern markets. Many SMEs in countries with higher labor costs relocate parts of their production into low-wage countries to reduce part of their costs and to be able to offer their goods as cheaply as other competitors (Gleich, 2015, p. 22). However, in the long term a simple relocation cannot solve the majority of the problems.Technologies and processes remain too inflexible and slow to cope with international competitors. Numerous economists believe that a fourth industrial revolution, often referred to as Industry 4.0 , is the answer to the challenges of modern markets. I4.0 describes the digital transformation of manufacturing industries with the goal of making enterprises more flexible and efficient, so that even the smallest batch sizes can be produced economically, and enterprises can adjust their production program in minimal time (Roth, 2016a, p. 5). According to numerous authors, I4.0 does not only have the potential of enhancing processes along the entire product life cycle, it also opens up completely new business potentials. SMEs are particularly suitable for developing and implementing ideas in terms of I4.0, since they are often characterized by shorter decision-making paths, a higher participation of employees and higher innovation capability compared to larger companies (Schneider, 2016, p. 254). Although the introduction of I4.0 is seen as a necessity for manufacturing companies to survive in complex and turbulent markets in the future, a survey with more than 500 decision makers in the manufacturing industry reveals that around 71% of companies have no I4.0 strategy yet (Bauer & Horváth, 2015, p. 69).

2.3. Objective of these guidelines

This handbook: **"SMeART University Business Cooperation Model and Guidelines"** (short: guidelines) aims to

- Support European SMEs in the process of the employment of Smart Engineering and Industry 4.0,
- Introduce the general idea and technical details concerning Smart Engineering in connection with Industry 4.0 to universities and SMEs
- Provide explanation and description of quantitative and qualitative standards in the Smart Engineering field
- Include pedagogic, organisational and operative requirements in order to implement successful HEI-business cooperation.
- Support HEIs in order to prepare and implement better cooperation, consulting and learning activities with SMEs for improving their Smart Engineering standards.

The target groups of this handbook are

- European SMEs in general, associated project partners in particular
- Project partners of the SMeART project in order to gain from project results.

These guidelines have been produced within the ERASMUS+ project „SMeART - Knowledge Alliance for Upskilling Europe's SMEs to meet the challenges of Smart Engineering". The project is funded by the European Union. The document is based on contributions of project partners from Austria, Belgium, Germany, Italy, the Netherlands, Spain and Slovenia and was assembled by the University of Applied Science (FHM), Bielefeld, Germany.
In summary, the general objective of these guidelines is the provision of various supporting hints and recommendations in order to promote the Industry 4.0 / Smart Engineering adoption for SMEs.
Above Fig. 4 shows names and acronyms and numbers of the present guideline sections in relation to their general purpose. The sections are following a given regular structure of the well known product life cycle (see Fig. 5). PROD, BUSI, MAN, COOP, TRAIN & COCO are acronyms for the sections. Guideline sections are related to at least one stage of the life cycle. Of course, some sections are related to more than one stage of the life cycle. To make this approach more clear, a number of detailed application examples were explained along the life cycle in section 3.6..
We subdivide the sections into three superconcepts: "The Why","The What" and "The How". **"The Why"** concerns the introduction, explanation of important terms and an explanation of the state-of-the-art and the resulting motivation situation for medium-sized companies. In order to motivate stakeholders we are sending out a "Wakeup Call". **"The What"** concerns the actual guidelines for the support of SMEs. Here, the reader finds the three content chapters that will shed light on the companies' production, management and business opportunities. **"The How"** concerns those chapters of our guidelines that deal with consulting and training. In particular, here we find chapters that analyse the cooperation between universities and companies and give advice in this respect. These chapters are about the important questions about the training and further education of employees for a successful introduction of Smart Engineering. And finally, we find a detailed description of the requirements for the special Industry 4.0 - consulting including hints for its successful implementation in the company.

	Acronym	Section name	Sect. Number	General Purpose
GUIDELINES	INT:	Introduction	2	The WHY
	PROD: BUSI: MAN:	Production process Business opportunities Management challenges	3 4 5	The WHAT
	COOP: TRAIN: COCO:	University-SME cooperation I4.0-trainig & educations I4.0-coaching & consultin	6 8 7	The HOW

Fig. 4: Sections of SMeART- guidelines

2.4. Concepts in order to achieve the objectives

2.4.1. SMeART-product life cycle

PRODUCT LIFE CYCLE – GENERAL	TYPICAL PROCESSES	RELATED GUIDELINE SECTIONS
INTRODUCTION	Product development & Manufacturing Education	PROD, BUSI, COOP, TRAIN
GROWTH	Consulting, distribution, sales	PROD, BUSI, MAN, COCO
MATURITY	Usage, consumption, maintenance	PROD, MAN
DECLINE	Recycling, disposal	MAN

Time — Sales volume

Fig. 5: The SMeART-product life cycle: Relation between a general product life cycle, typical processes and related sections of these guidelines, for acronymes see Fig. 4

The present guideline sections aim to provide a better understanding of Smart Engineering concepts and application examples along the product life cycle. Smart engineering and I4.0 have the capability to improve product features as well as to optimise production processes, and thus contain options in order to increase the profitability and the competitiveness of manufacturing SMEs.The examples provided with these guidelines represent only a small fraction of possible applications - a multitude of technologies enables completely new, individual solutions for the future. Therefore, SMEs are facing the task of identifying decisive factors of their competitiveness. SMEs also have to optimise factors by implementing I4.0-related concepts and technologies.

With these SMeART- guidelines, the Smart Engineering related concepts, processes and technologies that are required for a successful implementation of Industry 4.0 within SMEs, are presented on two linked levels: on one hand on the above life cycle level (see Fig. 5). On the other hand, necessary concepts, processes and technologies are provided by the subsequently introduced SMeART Coaching and Collaboration Model.

2.4.2. SMeART Coaching and Collaboration Model

The SMeART Coaching and Collaboration Model supports the general process of supporting SMEs on their way to become digital. At the same time, the model provides a clear structure of the tools and measures that are provided by the SMeART project. In addition, the model provides links and relations between tools, coaching stages and sections of these guidelines.

The SMeART Coaching and Collaboration Model is based on the SMeART strategic framework. In addition, the instruments of the SMeART toolbox that are provided with the model relate to different stages of various coaching and consulting processes. These tools and their relation to the framework are explained in section 3.6.3. of the present guidelines.

The general structure of the above mentioned model is shown in Fig. 6. The upper half of the figure shows the SMeART strategic framework. In order to structure various Industry 4.0 processes and methods more comprehensible, this specific framework was developed and consequently adopted for consulting and coaching purposes.

In detail, the SMeART strategic framework is introduced and described in section 3.6.3. of these guidelines. For the purpose of an introductory explanation of the SMeART Coaching and Collaboration model, the most important elements of the SMeART strategic framework are shown in Fig. 6. This model will be explained briefly: The framework employs a company's business model as a starting point in order to develop Smart engineering/ Industry 4.0-strategies and deduct subsequent steps and measures. In Fig. 6, below the framework, a row of stages can be seen. These stages are at the same time framework stages and SMeART coaching stages:

- Stage A = Initiation (for tools see section 3.6.3.1.)
- Stage B = Maturity (for tools see section 3.6.3.2.)
- Stage C = Resources (for tools see section 3.6.3.4.)
- Stage D = Potentials
- Stage E = Change Management (for tools see section 3.6.3.5.)
- Stage F = Implementation (for tools see section 3.6.3.6.)

These guidelines provide a smart toolbox. These tools are assigned to the above stages. For further information concerning their adaptation see section 3.6.3. of these guidelines.

Stage A, the initiation stage, is to specify a companies business model and to understand how exactly profits are generated. In order to understand how to approach the idea of I4.0, we are recommending the adoption of maturity models. Maturity models are instruments for assessing current levels of development regarding a specific objective (Mettler & Rohner, 2009). In terms of Smart Engineering, maturity models can help to reduce complexity by investigating the initial situation of a company (cf. Schumacher, Erol, & Sihn, 2016). In addition, a maturity assessment can support exact effort estimations. Therefore, assessing the company's maturity level in terms of I4.0 it is the subsequent step (**stage B**) in the proposed framework. Within the SMeART project a specific tool - the SMeART Stress Test Tool - was developed. This tool is based on specific maturity matrix MOSE. The tool is available in order to estimate the maturity of SMEs on their progress in introducing Smart Engineering.

Scenarios and assumptions on the potential business opportunities of Industry 4.0 are assigned to the SMeART strategic framework **stage C** (resources) and **D** (potentials). The initial business model (from **stage A**) serves as an orientation in order to detect currently existing business weaknesses. Such weaknesses might be: insufficient customer service or slow production processes. **Stage A** also helps to determine success factors that have an impact on strengthening the competitive standing in the future. The business model approach supports a holistic view. It does not focus on single technologies or products. Major questions to be answered would be: How will the medium-sized company successfully compete with other companies in the near future? Can a greater variety of products create additional value for current customers while attracting new ones? Is delivery reliability a success factor for a company that wants to improve in the future?

It is the objective of guideline section 3, section 4 and section 5 to to deliver input and inspiration and guidance for SMEs in order to formulate and specify their ambition and potentials in this regard.

Simultaneously, companies need to start to derive tangible resources (see Fig. 6) that are required in order to pursue their ideas. Early on, they need to estimate the required effort to implement innovative ideas. But ideas that turn out to be too risky or costly are required to be customized or discarded. Here the goal is to find a set of new activities, processes or technologies, which are capable of creating sustainable value. The value can be achieved with given means or in other words by formulating a practicable strategy. The phases of strategy definition, planning and implementation merge into each other. Even if not all details of a company's strategy are planned, initial preparation for implementation, such as training for employees, might already start. SMeART strategic framework proposes to integrate change management (see section 3.6.3.5.) in the process of strategy development and implementation. Corporate change fails regularly for different reasons: Intransparent decision processes make it hard for employees to understand the urgency of change or the usefulness of single measures. Considerations and plans are only partly passed between different hierarchy levels of the organisation, consequently uncertainty, frustration or even fear arise. As a result, employees will only engage half-hearted in the change process and diminish success (cf. Nicolai, 2017 p.288). In general, Change Management attempts to control and implement change, particularly with focus on human

beings, that are in some way affected by change processes (cf. Lauer, 2014 p.7 f.). Numerous authors and publications emphasize that successful change can only take place if employees are willing to implement change. Without inner conviction, employees will only work to rule.
Based on this structured approach, the authors are convinced that the smart engineering based decision processes can be designed more transparent and comprehensible for organisations. The usage of business models enables a holistic view on weaknesses and strengths and can help to recognize future potentials in all business divisions. The following section introduces a set of methods, that can be applied in each stage.

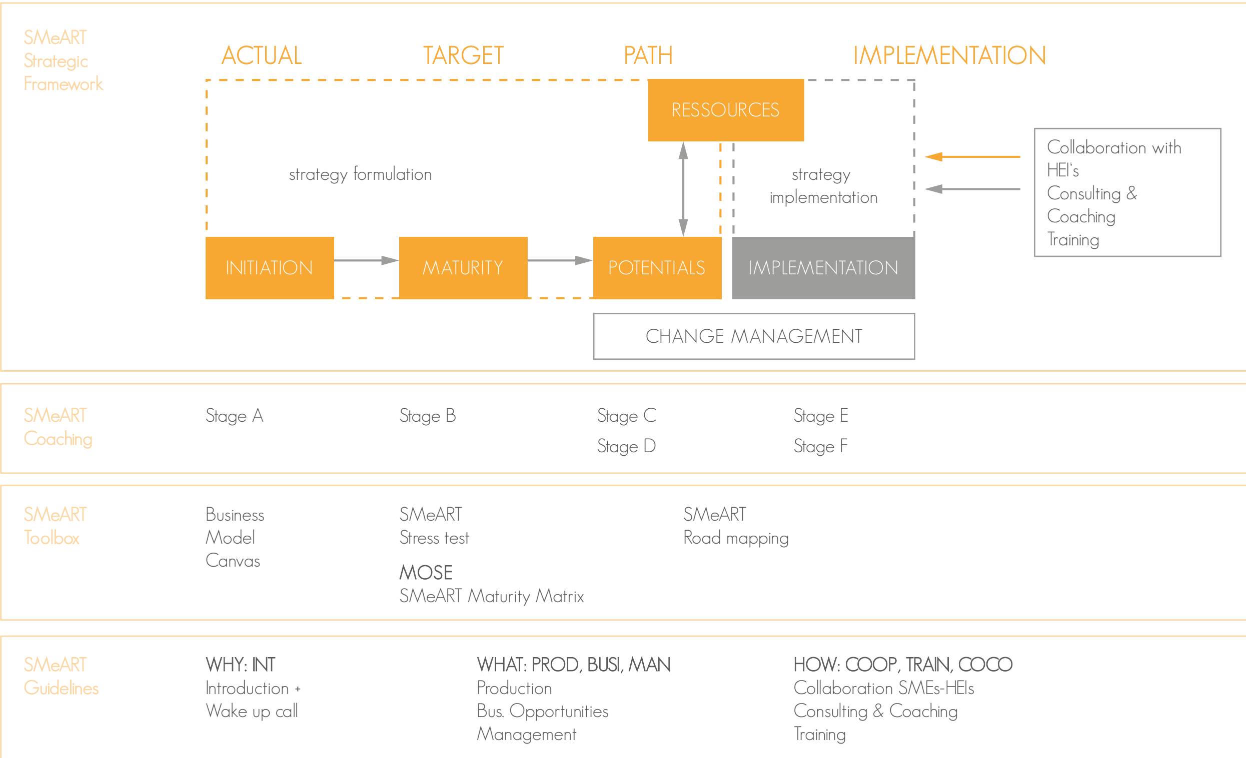

Fig. 6: The SMeART Coaching and collaboration Model

3. PRODUCTION

Author: Martin Westbomke

3.1. Introduction

Modern digital markets are characterized by a high complexity, which makes it harder for companies to keep their competitive position for a longer period of time. Potential customers might choose from a wide range of products and services of globally acting providers, whereby requirements in terms of quality, price and availability are increasing (cf. Becker et al., 2004 p.393) (cf. Grundig, 2018 p.13). Companies of all sizes are challenged by increasing market requirements along the life cycle of their products and services. According to various scientific publications, Industry 4.0 includes the capability of solving the majority of known, existing difficulties in relevant areas and might add sustainable value to current businesses. Due to the variety of emerging, new terminologies, it might be difficult to approach the topic of I4.0. Visions, ideas and technologies are often mentioned jointly and might cause confusion. Since it is so difficult to provide a clear, final definition of I4.0, many companies can not really imagine how I4.0 might contribute to their value creation process. Some visions appear too futuristic and, therefore, have the potential of discouraging companies instead of inspiring them.

The goal of this section is to provide guidance for small and medium sized companies during the process of I4.0 business implementation. Although this section focuses on manufacturing companies including their production processes, the subsequently proposed framework supports the detection and implementation of general potentials along all processes of the product life cycle.

3.2. Current challenges along the product life cycle

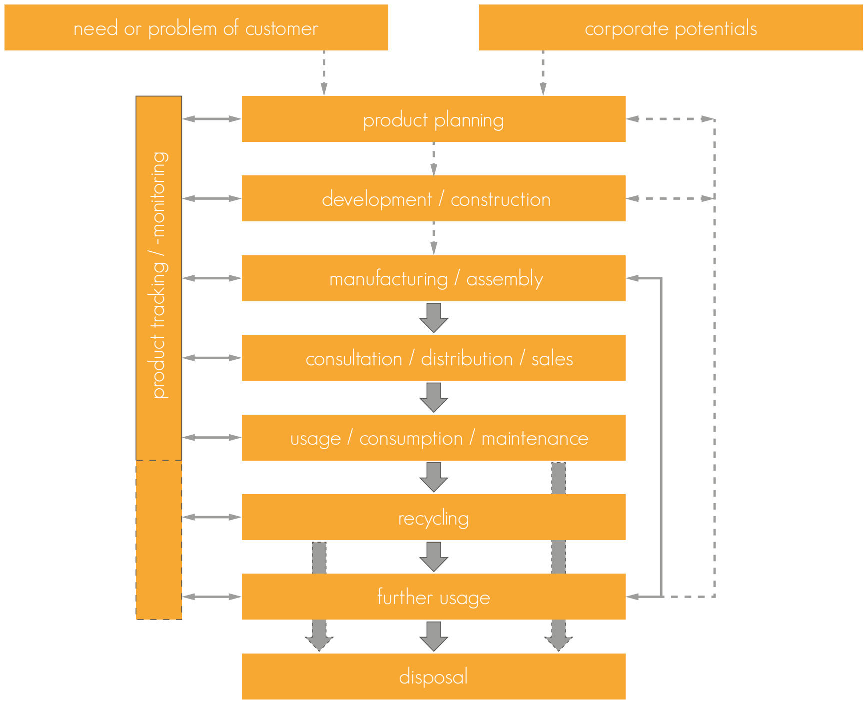

Fig. 7: Lifecycle of products

The starting point of each product novelty is an idea, emerging from the needs, problems or trends and developments in a specific market or customer segment (cf. Grote et al., 2014 p.1). Due to the wide variety of different companies offering similar products, nowadays understanding and meeting customer demands by a flexible adaptation of requirements, products and processes is seen as one of the key elements for economic success (cf. Becker et al., 2004 p.393). Therefore, the first great challenge for manufacturing companies is to recognize or better anticipate the wishes of their customers and react upon these demands in a short period of time (see chapter 3).

On their way from a first idea to a specific product, companies need to perform different activities such as feasibility tests, design studies and the fabrication and testing of different prototypes (cf. Cooper, 1980 p.27 ff.) Although a variety of project planning and estimation techniques has been introduced in the past, many product development processes are still more time-consuming and expensive than expected and originally planned (cf. Meier, 2011 p. 11). Consequently, many companies are not capable of responding to customer demands as quickly as expected and needed.

After the product has been developed and manufacturing preparations have been completed, such as the reprogramming of machines or retraining of production employees (see section 5), the manufacturing process begins. In this stage, a set of input factors such as raw materials or information must be processed and transformed. The difficulty of this stage is to make sure that manufacturing and assembly processes run smoothly. Every unexpected incident, such as a production failure or machine breakdown, causes additional costs. The options of a real time monitoring are limited in today's standard technologies, so that suboptimal processes or products are discovered with delay. Despite the difficulty of controlling and improving the quality of processes and products in real time, increasing variation diversity and fluctuating demands lead to a higher complexity and require flexible production processes, that can be customized with low effort (cf. Vogel-Heuser, Bauernhansl, & ten Hompel, 2016a p.14f.).

Overall, current production systems are often not able to meet requirements of modern markets (see section 4.2.). Although this trend can be observed in almost every field of business, the following stages in particular are characterized by higher demands in terms of service quality. Nowadays high-quality customer service (see chapter 3) is seen as one of the key influences for customer satisfaction and, thus indispensable for sustainable, competitive advantages (Shemwell, Yavas, & Bilgin, 1998). Marketing, sales and distribution characterize the transfer of a product or service to customers (chapter 3). Specifically a high logistic quality can be seen as one of the key service elements for customer satisfaction. The challenge for every company in this stage is to create flexible logistic processes, that are able to ensure a prompt and timely delivery at a moderate cost. During usage or consumption, providing maintenance and repair services can lead to higher durability of products in this stage and, therefore, can also influence customer satisfaction positively (cf. Grote et al., 2014 p.1).

Due to risen legal requirements and a higher environmental consciousness, the recycling of products has become a greater priority for companies and their customers. The recyclability of products provides not only opportunities for further generations (chapter 3), at the same time it can be an influential factor during the purchasing process and improve the corporate image (cf. Nnorom & Osibanjo, 2008 p.844). Products that can be recycled run through the life cycle for a second time, whereas products that cannot be reused are disposed (cf. Grote et al., 2014 p.1).

Overall, smart companies are facing numerous challenges across the life cycle (see Fig. 7) of a product or service: Requirements in terms of time, price, quality, sustainability and service have risen in the last years. In addition, fluctuations in demand and the preference for individualized products necessitate a high flexibility and responsiveness of processes along the entire supply chain that cannot be realized with current production systems. These shortcomings and difficulties of production systems are the point where Industry 4.0 comes into play. In scientific literature, the introduction of I4.0 is not discussed as a possibility to handle all these challenges, it is rather seen as a mandatory requirement for manufacturing companies in order to ensure their economic survival (cf. Roth, 2016a p.13 f.).

3.3. Definition of Industry 4.0

The term "Industry 4.0" was mentioned for the first time at the Hanover fair in 2011 to describe the development of the manufacturing industry towards a fourth industrial revolution (cf. Bousonville, 2016, p. 3 f.). Despite the widespread use of the term in German-speaking countries, to this day no universal definition of the term exists (cf. Hermann, Pentek, & Otto, 2016b, p. 3928). Frequently, I4.0 is described as the digital transformation of manufacturing industries (cf. Roth, 2016b, p. 5), though to this day, the term "digital transformation" itself has no unified definition (cf. Schallmo, 2016, p. 3) and, thus, is not suitable for clarifying the meaning of I4.0. A selection of more comprehensive definitions is shown in Table 1.

Source	**Definition**
(cf. Roth, 2016b, p. 5 f.)	Industry 4.0 comprises the networking of all human and machine actors along the complete value creation chain as well as the digitization and real-time analysis of all information relevant for this purpose, with the goal of making the value creation processes more transparent and efficient in order to optimize customer benefit.
(cf. Bauer & Horváth, 2015, p. 515)	Industry 4.0 refers to the real-time capable, intelligent, vertical and horizontal networking of people, machines and objects for the dynamic management of complex systems.
(cf. Hermann et al., 2016b, p. 3929)	„Enabled through the communication between people, machines, and resources, the fourth industrial revolution is characterized by a paradigm shift from centrally controlled to decentralized production processes. Smart products know their production history, their current and target state, and actively steer themselves through the production process by instructing machines to perform the required manufacturing tasks and ordering conveyors for transportation to the next production stage."

Table 1: selected definitions of the term "Industry 4.0"

According to Roth, the term "Industry 4.0" stands for the networking of all human beings and machines along the entire value chain (cf. Roth, 2016b, p. 5 f.). A value chain can be defined as the sum of all processes, which create value for customers. From the extraction of raw materials and their processing, to the delivery and usage of the final product (cf. Porter, 1985, p. 50 f.). Across such networks, relevant information is gathered, digitized, shared among different actors and processed in real-time. Due to globalization, suppliers and customers of manufacturing companies can be spread all over the globe, making the exchange of relevant information, such as short-term changes in demand, more difficult (cf. Li & Lin, 2006, p. 1641 f.). By building such cross-organizational networks, companies can increase efficiency and transparency of their processes and create a greater customer value (cf. Roth, 2016b, p. 5 f.).

Bauer supplements this definition by adding that I4.0 does not only comprise the networking of human beings and machines vertically and horizontally along the value chain, but also of objects such as materials or workpieces, which also have the capability to gather, digitize, share and process information. Furthermore, he describes it as an intelligent networking between the different actors. The term intelligent in this context suggests that machines and objects receive a certain degree of intelligence which enables them to evaluate information and make decisions autonomously based upon the incoming data. According to this definition, the human being is no longer the only, central instance that must manage dynamic, complex processes. Instead, intelligent objects and machines support human beings by either preparing relevant information in real-time as a decision basis and suggesting optimization potentials or by managing and optimizing processes autonomously. This paradigm shift from centralized to decentralized control and coordination of processes is also addressed in the definition proposed by Hermann et al. This definition illustrates the fourth industrial revolution by the example of an intelligent product, which seeks its own way through production. Particularly in view of the limited resources of SMEs and the current technical possibilities, all definitions inevitably lead to the question, whether the networking of all actors, machines and objects along the entire supply chain is practicable or even useful. From an economic point of view, companies must rather identify vital competitive factors and enhance those factors by the use of I4.0.

Therefore, the following definition of the term "Industry 4.0" is proposed:
Industry 4.0 describes the target-oriented, intelligent networking of human beings, machines and objects through the real-time gathering, digitation, sharing and evaluation of relevant information along the value chain to enable decentralized coordination and control of processes.

The networking of geographically distributed actors along the value chain and the real-time access to relevant information enable an efficient, flexible collaboration that is better capable of meeting the demands of dynamic and complex markets and has the power to change the entire process from the product development to the manufacturing over the use of the product by the customer to its final disposal:

- Smart Engineering describes innovative, interdisciplinary product development processes. Virtual prototypes of products and the real-time sharing of relevant information allow different experts from the company, such as product designers, mechanical engineers and sales representatives, as well as suppliers or customers to develop products together (cf. Anderl, Eigner, Sendler, & Stark, 2012).

- In terms of production, inflexible technologies will be replaced by decentralized, autonomous, so-called smart production systems, that are able to organize and optimize processes along the value chain (see Fig. 7) (cf. Vogel-Heuser, Bauernhansl, & ten Hompel, 2016b p.15 f.).

- Customers profit from smart products that have completely new capabilities and thus offer a greater customer benefit (see Fig 10: capabilities of smart products (cf. Eibl und Gaedke 2017, p.2081)).

Ultimately, Industry 4.0 strives for the vision to reach an amount of flexibility, that allows the production of individual products at the cost of mass production and enables real-time adjustments and optimization of processes and products (cf. Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014a p.239 f.).

In technical literature, Industry 4.0 is often described as the fourth industrial revolution that will lead to a digital transformation of production industries. More precisely, it can be defined as the networking of all human and machine actors across the entire value chain in combination with the digitalization and real-time evaluation of relevant information.

The general goal of Industry 4.0 is to achieve a higher transparency and efficiency of all processes (cf. Roth, 2016a p.5 f.). In terms of production, more less flexible technologies will be replaced by decentralized, autonomous, so-called smart production systems, that are able to organize and optimize processes along the value chain (see Fig. 7) (cf. Vogel-Heuser et al., 2016a p.15 f.). Ultimately, Industry 4.0 strives for the vision to reach an amount of flexibility, that allows the production of individual products at the cost of mass production and enables real-time adjustments and optimization of processes and products (cf. Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014b p.239 f.).

With regard to SMEs, the objective of Industry 4.0 must be a targeted selection of technologies and principles. I 4.0 can be implemented with available resources and has the capability of sustaining and strengthening the competitive position. In order to make the concept of I4.0 more clear, the following section aims to introduce its main visions and key technologies.

3.4. Theory and practise of production in industry 4.0

Due to the vast amount of emerging terminologies, companies can feel overwhelmed when approaching the topic of I4.0. This section will provide an overview of the key concepts of I4.0, the underlying technologies and possible applications.

One of the central visions of Industry 4.0 is the merging of the physical and virtual world, which can be realized by so-called **Cyber-Physical Systems** (CPS). CPS describe the idea of merging cyber and physical objects to form a collaborating and interacting entity. Physical objects refer to any natural or human-made elements such as raw materials, technical devices, buildings, management or logistic processes. Cyber objects describe any software or hardware components (Geisberger & Broy, 2012a). Hermann et al.. distinguish three generations of CPS, depending on their technical features and capabilities as shown in Table 2. The simplest form of CPS is equipped with identification technologies to enable autonomous identification (Auto-ID) and tracking of physical objects (cf. Hermann et al., 2016b, p. 9). Due to their relatively low costs and simple applicability, barcodes are the most common Auto-ID-system. The biggest disadvantage of this system lays in the fact, that barcode labels must be visible, clean and intact for the laser scanner to read the label and therefore are not suitable for all applications and often linked to higher personnel costs, as employees must scan objects manually (cf. Kern, 2006, p. 16 f.). In terms of I4.0, in particular the Radio-Frequency Identification (RFID) is seen as a key Auto-ID technology. An RFID system consists of a chip, also called RFID-tag, and a reader. The RFID-tag is attached to the object to be identified. The reader is usually stationary. As the name implies, the communication between RFID-tags and readers takes place via radio transmission (cf. Kern, 2006, p. 33). Compared to other identification technologies such as barcodes, RFID systems do not need visual contact and can identify several objects simultaneously (bulk recognition). Furthermore, RFID tags are heat, dust and water resistant (Strassner, 2005).

Cyber-Physical System		
1st generation	2nd generation	3rd generation
• equipped with identification technologies • Unable to directly interfere with environment	• Equipped with sensors and actuators • Can directly interfere with environment to a certain extend	• Equipped with various sensors and actuators • Able to store, analyse and share data via networks

Table 2: Three generations of CPS (cf. Hermann et al., 2016b)

One application example is the use of an RFID gate at the goods receipt area to automatically identify goods. Within the digital copy of the physical warehouse, inventory can be updated in real-time within the marginal costs of zero (cf. Reinhart, 2017, p. 508). CPS of the first generation can collect and provide relevant information and thus create a higher transparency, but they cannot affect physical environment directly and have no intelligence to optimize processes. Therefore, second generation CPS are equipped with additional sensors and actuators with a limited range of functions, which enable them to interfere with their environment actively (cf. Bauernhansl et al. 2014, p.16). The basic structure of a second-generation CPS is shown in Fig. 8.

Sensors and actuators enable CPS of the second generation to gather information about their environment and react upon the incoming data by actively interfering in processes. Sensors integrated in physical objects can register chemical or physical statuses such as temperature or humidity and process the information into a digital signal. For example, a workpiece can detect its current position via GPS-sensors and a machine can record its own temperature via temperature sensors. Actuators convert digital signals coming from sensors or commands from human operators into mechanical movements or physical output values, such as the movement of a robotic arm or the adjustment of the temperature of an industrial oven (cf. Geisberger & Broy, 2012a, p. 138).

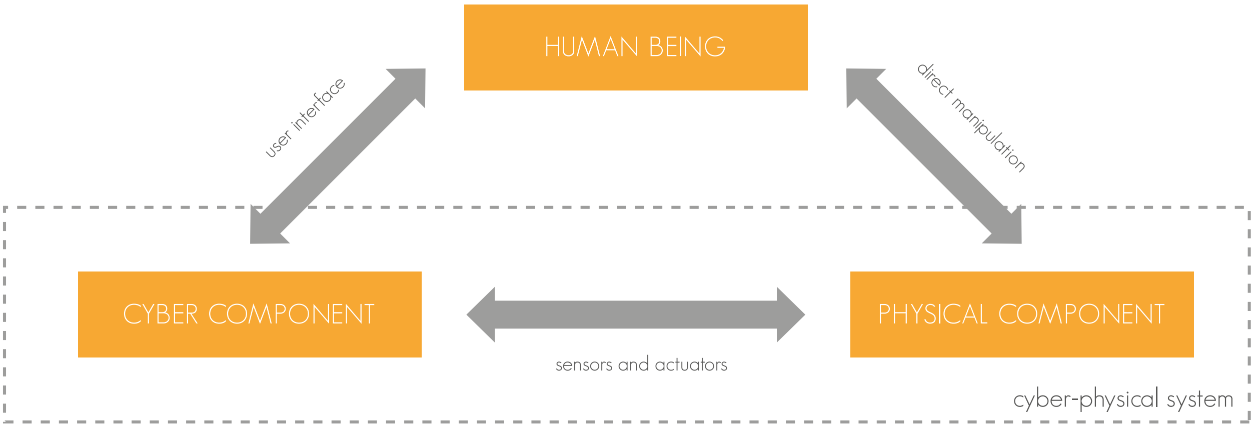

Fig. 8: Own representation of cyber-physical framework, based on (cf. Bauernhansl, ten Hompel, & Vogel-Heuser, 2014, p. p.525; Zamfirescu, Pârvu, Schlick, & Zühlke, 2013)

By connecting the physical and the virtual world via sensors and actuators, endless application possibilities arise, such as warehouses that monitor inventory in real time and reorder goods or processing machines, that can detect and sort out faulty parts autonomously. Human beings can either monitor processes or become part of the CPS by actively interfering with cyber and physical components for example within a human-robot-collaboration. In order to optimize interactions between human beings and machines, instead of keyboards and monitors, humans need the possibility to interact with machines more intuitively for example via gestures or voice. In the last years, numerous applications such as microsoft's control module Kinect have been developed, that enable efficient and intuitive control (cf. Geisberger & Broy, 2012a, p. 134). The highest amount of efficiency and flexibility is achieved by intelligent, network-capable CPS of the third generation that consist of several actuators and sensors. They have the ability to communicate and collaborate with other CPS and thus, they can control and enhance processes autonomously and decentrally (cf. Bauernhansl et al., 2014, p. 17). According to Geisberger and Broy, CPS of the third generation exhibit the following functional requirements and underlying technologies:

Physical Awareness: Whereas CPS of the second generation only register a limited part of their environment, CPS of the third generation need the ability to perceive their entire physical surroundings, including information about all human and technical actors and their condition such as the exact position of a workpiece or the number of employees at an assembly line. This capability can be described as physical awareness and is achieved by various sensors and Auto-ID technologies (cf. Geisberger & Broy, 2012b, p. 138). In order to coordinate processes, sensor equipped objects also need to be able to communicate and interact with each other which can be realized with wireless sensor networks (WSN) (cf. Song, Fink, & Jeschke, 2017a, p. 29,250). The alignment of information from different sensors is necessary to receive a holistic, virtual figure of ongoing processes.

Planned and anticipatory (semi-)autonomous acting: CPS need the ability of acting partially or fully autonomous in order to increase process flexibility. The capacity of autonomous decision-making can be implemented through a multi-criteria situation assessment, which enables CPS to analyze, interpret and evaluate situations in real time on the basis of previously defined criteria. In order to solve this task, information about the physical environment of an object are aligned to domain models, which are able of modelling interrelations and deriving possible actions. Real situation requires the consideration of multiple, interacting variables: All actors, objects as well as human beings, and their behavior as well as their interactions need to be considered. A related concept is Artificial Intelligence (AI) (cf. Geisberger & Broy, 2012a, p. 129 ff.)). AI refers to the ability of objects and machines "to carry out tasks that would require intelligence if carried out by human beings" (Kumar, 2008, p. 6). AI enhanced objects and machines are able to handle new and unknown situations, as they constantly gather knowledge and are able to derive conclusions regarding proper reactions. AI can already be found in various applications: Camera based monitoring systems can detect and report hazardous situations at public places. In the medical sector, high-risk operations can be conducted by high-precision robotic arms (cf. Dengel, 2011a, p. 391). A problematic issue of a multi-criteria situation assessment and AI is the evaluation of contrary goals. A drastic example can be found in autonomous vehicles, that could save the lives of its passengers but endanger pedestrians at the same time. Industry, politics and legislation will face the challenges of finding answers to these kind of moral issues in the future (cf. Geisberger & Broy, 2012a, p. 130).

Cooperation and negotiation: In order to unfold their full potential, a CPS needs the ability to cooperate and negotiate with other CPS. Technical groundwork for collaboration of different CPS are multi-agent systems, whereby the term agent refers to autonomous CPS (cf. Geisberger & Broy, 2012a). Initially each agent pursues its own goals and objectives, has individual preferences and specific prior knowledge, affecting the way an agent interacts with its environment (cf. Monostori, Váncza, & Kumara, 2006a).

The integration of several, initially independent CPS into a collaborating, intelligent system is called **Cyber-Physical Production System** (CPPS). By combining their knowledge and capabilities, "a multi-agent system can occasionally solve problems that are beyond the limits of the competence of the individual agents and/or may exhibit emergent behavior that cannot be derived from the internal mechanisms of the components" (Monostori et al., 2006a).

Traditional, centralized control systems are too slow to react flexibly upon production changes. Multi-agent systems pursue a decentralized approach, that enables CPPS to coordinate processes in real-time such as production planning, resource allocation, production scheduling and control (Monostori et al., 2006a). An exemplary application is the usage of multi-agent systems to design a flexible scheduling strategy: In case of unexpected events such as a machine breakdown multiple CPS share relevant information and collaborate to customize material flow automatically (Kouiss, Pierreval, & Mebarki, 1997a). Multi-agent systems also facilitate collaboration across company boundaries. Processes along the entire supply chain can be independently coordinated and optimized in real time, enabling suppliers to compensate fluctuation in sales at any times or to react upon short term product changes.
The collaboration of different agents across organizational boundaries is shown schematically in Fig. 9.

Human-machine-interaction: Despite the ability of CPS to self-organize and enhance entire process chains, humans play a key role in I4.0. The goal is not suppression of human operators out of plants, much more I4.0 aims to optimize processes and assist employees to achieve superior value creation. CPS can support humans in a number of ways during production: Firstly, they can provide relevant information about production processes, which enables employees to monitor processes in real-time and to intervene if necessary. Eventually, human beings are always the final authority

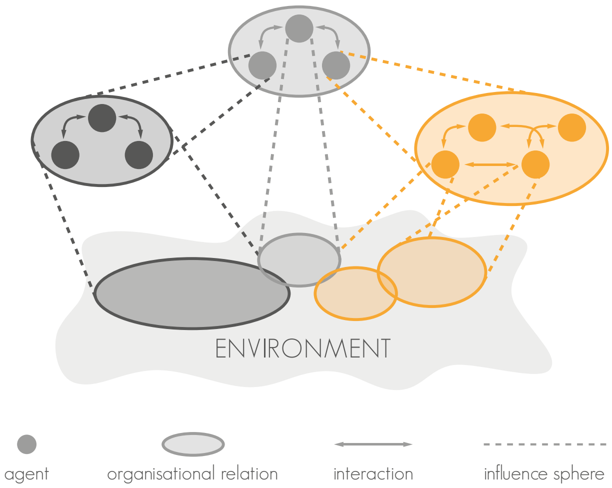

Fig. 9: Generic scheme of multiagent system by (Monostori et al., 2006a; Russell, Russell, & Norvig, 2010)

in I4.0 applications (cf. Bauernhansl et al., 2014, p. 78 ff.). Cyber-physical applications can also be implemented to actively assist employees who perform manual or cognitive tasks for example in data glasses that guide employees on the shortest way to the storage location, where they find the product they are looking for (cf. Borgmeier, Grohmann, & Gross, 2017a, p. 130). Besides innovative interaction modalities such as gesture control, the capabilities of intention and plan recognition facilitate collaboration between CPS and human beings. Intention recognition is the ability to recognize a human being's intention by analyzing past actions or the impact of those actions. Plan recognition enables CPS to anticipate the future intentions and actions based on the past behavior of human beings. A number of reliable probability- and logic-based methods for intention and plan recognition already exists, but the wide application possibilities of CPS require the further development of innovative methods. For example, CPS must be able to recognize alternative courses of action within the achievement of goals or to adapt flexibly to people who have physical limitations. At present, existing methods are not mature enough for tasks of this kind (cf. Geisberger & Broy, 2012a, p. 134 f.).

A concept that closely resembles CPS and is frequently mentioned in association with the fourth industrial revolution is the so-called **Internet-of-Things** (IoT). In scientific literature, mainly two interpretations of the term can be observed. First, some authors define the term as the capability of physical objects to collaborate with each other. By equipping "things" such as sensors, actuators or any other physical object with suitable information and communication technologies, they can communicate and collaborate through unique addressing schemes. In terms of CPS, this interpretation refers to their ability to cooperate and negotiate to reach a common goal (cf. Hermann et al., 2016b, p. 9). Therefore, the focus of these interpretations lays in the capability of "things" to network with other "things".

The other common interpretation refers to IoT as the extension of the internet into everyday objects (cf. Mattern & Flörkemeier, 2010a, p. 107). The first approach of this vision stretches back to 1991, when MARK WEISER described his idea of ubiquitous computing as "integrating computers seamlessly into the world" (Weiser, 1995). Back then as well as today, the interaction between humans and computers usually is carried out via graphical user interfaces. Besides the negative health impacts persistent screen work can have on its operators, the main disadvantage of such user interfaces is that they demand the operator's full attention and therefore result into isolation from the surrounding environment. Instead of computers that adapt to the needs of human beings, humans are forced to adapt to the restriction of computer systems. Therefore, the idea of ubiquitous computing can be understood as abandonment from the dominating concept of graphical user interfaces and the development towards the integration of computers into physical objects (cf. Friedewald, Raabe, Georgieff, Koch, & Neuhäusler, 2010a, p. 29). IoT picks up the vision of ubiquitous computing and combines it with the idea, that computers integrated in everyday objects can access the internet at any time and any place (cf. Carretero und García 2014, p.445). The integration of web services enables a wide range of application possibilities: Everyday objects, whose functionality has been limited before, suddenly receive new, flexible capabilities of digital objects (cf. Mattern & Flörkemeier, 2010b, p. 107). By adding sensors and actuators, web-enabled devices can also perceive and interfere with their environment directly. Thus, the concept of IoT enables everyday objects to become so-called smart products with completely new abilities:

the ability to access web services and data on the internet (smart services)	the ability of remote control (for example via apps)
the ability to interfere with their environment via actuators	the ability of gathering useful information about their environment and their users via sensors

Fig. 10: capabilities of smart products (cf. Eibl und Gaedke 2017, p.2081)

A common example for smart products are smart home devices such as smart heaters, that can be operated from the distance, access the weather forecasts on the internet and measure the room temperature to ensure a pleasant room atmosphere.

Within this interpretation, "things" can also network with other "things", but the focus shifts to the benefits that arise, when embedded computers and internet services support human beings in their everyday life. According to Gartner market research, in 2017 around 8.4 billion web-enabled, networking devices from fitness trackers to smart home solutions existed. By the end of 2020, experts predict more than 20.4 billion smart products and expect huge value creation potential for companies (cf. Jansen 2017).

Besides the products, engineering processes will also change. CPS and any smart product are constantly gathering, sharing and processing vast amounts of data.

Simultaneously, more than 3.2 billion human beings -with rising tendency- are entering the internet via computers, laptops and smartphones, generating even more data (cf. eMarketer. n.d. 2017). Within 60 seconds, around 243,000 pictures are uploaded on Facebook, more than 3,8 million search queries are made on Google and 120 new accounts are created on LinkedIn. At the end of every minute, 400 hours of new video material will be uploaded on YouTube and more than 350,000 Tweets will be sent on Twitter (cf. Go-Globe 2016; statista 2018). When discussing vast amounts of data in the context of I4.0, the term Big Data is frequently mentioned. The question about what Big Data is, can be answered by these three central properties (cf. Gandomi und Haider 2015, p.138):

1. Volume: As the word "big" implies, Big Data refers to data sets of terra-, peta- and eventually even zettabytes that are too big to be handled by traditional information technologies.

2. Variety: Big Data includes structural heterogenous data from various sources such as measurement results from sensors, picture uploads from social networks or audio files from streaming services.

3. Velocity: This characteristic refers to the high rate of data flow and growth of Big Data (cf. Gandomi & Haider, 2015, p. 138) (cf. Katal, Wazid, & Goudar, 2013, p. 404).

According to these properties, Big Data can be interpreted as a vast amount of permanently flowing and growing sets of data coming from all kinds of sources.

Traditional information technologies are unable to handle such data, whereby the "acquisition, storage, searching, sharing, analytics, and visualization of data" form the main problem (Ohlhorst, 2012).
Experts from science, politics and economy believe that in the future, Big Data will be an "important driver of innovation and a significant source of value creation and competitive advantage" (Tan et al. 2015, p.1). The ability to process and analyze Big Data with high-performance technologies and innovative data analysis techniques enables companies to extract relevant information about their products, customers, competitors or suppliers. Vast amounts of data can be handled within short amounts of time, leading to enormous efficiency increases. In addition, patterns and correlations in Big Data can point to future market developments and trends and thus can contribute to the competitiveness of companies and guide them in terms of their strategic decisions (cf. Sagiroglu und Sinanc, Duygu 2013, p.42; Wamba et al. 2015, p.234).
Due to its value creation potentials, data and in particular Big Data is sometimes referred to as the oil of the future (cf. Jodlbauer und Schagerl 2016, p.1475; Jodlbauer 2016). Successful application examples demonstrate the enormous potential of big data:
By implementing Big Data technologies and software, Visa reduced the processing time of two-year credit card data, which included approximately 73 billion transactions, from one month to just 13 minutes.
After the computer science professor Etzioni was annoyed about an excessive ticket price he paid for his flight, he developed the Farecast program, which analyzed 200 billion flight price data to forecast further price developments. Meanwhile, the program is integrated into Google's Bing search engine and helps customers to save 50 dollars on average by predicting future prices (cf. Mayer-Schönberger und Cukier 2013, p.62).

The extraction of relevant information and insights from Big Data requires the processes of Data Management and Data Analytics, which consist of five distinct phases, as shown in Fig. 11.

By applying different analysis techniques and approaches, companies can gain insights about past incidents, such as sinking sale number and identify reasons for the incidents (Descriptive Analytics), but it can also be used to predict future developments such as arising market trends, price developments or machine failures (Predictive Analysis) and identify the reasons for future developments (Prescriptive Analysis) (cf. Bolt 2015, p.674).
Despite the progress in analytical techniques, numerous authors remark that Big Data Analytics still need further research to enhance the quality of processes and results. For example, the detection of irony and sarcasm in unstructured text documents is still a challenge for text analytics techniques: In a test run on the social media platform Twitter only 71% of the posts were correctly classified as sarcastic or not sarcastic (cf. Forslid und Wikén 2015, p.39). In addition, in particular in terms of Predictive Analysis, traditional statistical methods are often unsuitable since they are significant for smaller test areas and therefore might lead to a distortion of Big Data results (cf. Gandomi und Haider 2015, p.144).

To share, communicate and discuss insights of Big Data Analytics, suitable visualization techniques and tools are needed as human beings can perceive information better when they are transmitted in graphics. Visualization Recommendation Systems can support companies during visualization by suggesting suitable visualizations based on the characteristics of the data, the type of problem or individual preferences and thus can provide interesting insights into the results (cf. Kaur und Owonibi 2017 - 2017, p.266; Nikos Bikakis 2018, p.6).

Of course, data security and privacy also play an enormous role in this I4.0 related concept. The previously discussed security and privacy paradigms need to be considered when developing and implementing Big Data applications (see Fig. 9). Data protection laws and gathering and analyzing of Big Data often seem to be incompatible at first sight. Whereas the gathering and analyzing of technical data such as data coming from sensors often is legally harmless, the processing of personal data is strictly regulated in laws. Personal data refers any data, which enables a conclusion about personal or factual circumstances of a particular or identifiable natural person.
For instance, the German data protection law requires that that the collection of personal data should be avoided or at least minimized. Furthermore, the data should only be collected, processed and used for a specific purpose and any change of purpose requires the consent of the person whose data is collected. In Big Data Applications those principles regarding personal data cannot be implemented practically, as Big Data consists of vast amounts of constantly growing, heterogeneous data from all kinds of sources. A solution is the anonymization of any personal data, either by deleting all features that enable identification permanently or by aggregating the data so that the assignment to an individual person is no longer possible (cf. Dorschel und Nauerth 2013). Depending on the country in which companies want to collect data, they must adapt their Big Data Applications to the respective laws.

The concepts of CPS and Big Data show, that data are one of the central elements of I4.0. Data are constantly gathered, processed, shared and analyzed to manage, control and optimize processes and generate knowledge. Therefore, I4.0 applications require powerful computing resources to handle all the data such as storage space, secure networks or intuitive visualization tools, but computing resources often involve high investments and are relatively inflexible. Companies need to pay the entire price, whether they use a software once a month or once a day. In this context, the term Cloud Computing describes a new operation model, that aims to reduce costs and increase flexibility for users (cf. Zhang et al. 2010, p.7 f.). The NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) defines Cloud Computing as follows: „Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell und Grance 2011, p.2). Instead of inflexible resources such as applications, which are stationary installed on computers, cloud users access the resources they need at any place, any time and from any web-enabled device.
In general, three different service models of Cloud Computing exist:

- Software as a Service (SaaS): Users do no install applications on their computer but can access applications on a cloud network at any time and any place and thus can collaborate with other users on projects in the cloud. Applications are managed, installed and upgraded by cloud providers so that businesses do not have to maintain their infrastructure or any other component. Common examples for SaaS are email programs or Enterprise Resource Planning Systems.
- Platform as a Service (PaaS): In this service model, users have access to a cloud environment in which they are provided with the infrastructure that is needed to develop, manage and deploy their own applications. Besides storage space and other IT resources, users have access to predefined tools, programming languages and services that facilitate the development, customizing, testing and hosting of their own applications. Spatially distributed development teams can work on projects simultaneously. The providers are responsible for managing security, operating systems, server software and backups.
- Infrastructure as a Service (IaaS): Users are provided with fundamental computing resources such as servers, storage and network components. They can upload and run software or platforms on the cloud, whereby the provider ensures the availability and reliability of the provided infrastructure (cf. Mell und Grance 2011, p.2 f.; IBM 2018).

- Depending on their needs, companies can choose and switch between the service models. Compared to conventional solutions, Cloud Computing enables companies to reduce costs significantly. First of all, no investments need to be made in advance, since companies only pay for the service and resources they are actually using. Simultaneously, operating costs can be lowered by flexibly reducing resources when they are not needed. The other way around, in times with high data traffic, resources can be easily expanded and thus enable the coverage of workload peaks. Besides cost savings and increased flexibility, companies benefit from the expertise of cloud computing providers in terms of maintenance and cyber security, as ensuring functionality and data security is part of their core businesses (cf. Zhang et al. 2010, p.7 f.). Overall, Cloud Computing can be seen as an enabler for I4.0 applications, as it provides companies and in particular SMEs with the computational resources they need to run their I4.0 applications.

Due to the vast amount of emerging terminologies, many companies feel overwhelmed when approaching the topic of I4.0. This section will provide a brief overview and a comprehensive distinction between visions and technologies of I4.0.

One of the central visions of Industry 4.0 is the merging of the physical and virtual world, which can be realized by so-called Cyber-Physical Systems (CPS) (cf. Vogel-Heuser et al., 2016a p.58 f.). CPS describe the idea of merging cyber and physical objects together in order to form collaborating and interacting entities. Physical objects refer to any natural or human-made elements such as raw materials, technical devices, buildings, management or logistic processes, whereas cyber objects describe any software or hardware components (Geisberger & Broy, 2012c). Whereas CPS refer to individual, separately operating systems, the connection of various systems in terms of production is called Cyber-Physical Production-Systems (CPPS) (cf. Wolf, Dollinger, Hees, & Reinhart, 2017).

The first approach of this vision stretches back to 1991, when Mark Weiser described his idea of ubiquitous computing as "integrating computers seamlessly into the world" (Weiser 1991, S. 94). Back then as well as today, the interaction between humans and computers usually is carried out via graphical and other user interfaces. Besides the negative health impacts persistent screen work can have on its operators, the main disadvantage of such user interfaces is that they demand the operator's full attention and therefore result in isolation from the surrounding environment. Instead of adapting computers to the needs of human beings, humans are forced to adapt to the restriction of computer systems. The idea of ubiquitous computing can be understood as abandonment from the dominating concept of graphical user interfaces and the development towards the integration of computers into everyday objects (cf. Friedewald, Raabe, Georgieff, Koch, & Neuhäusler, 2010b p.29).
After its initial publication back in 1991, the idea of ubiquitous computing has been extended to the so-called Internet of Things (IoT) (cf. Mattern & Flörkemeier, 2010c p.1 f.). The vision of the IoT is to include physical objects into the internet by equipping them with IP-based sensors and identifiers (cf. Weinberger, Bilgeri, & Fleisch, 2016 p.445). The additional integration of web services enables a wide range of application opportunities: Everyday objects, whose functionality has been limited before, suddenly receive new, flexible capabilities of digital objects (cf. Mattern & Flörkemeier, 2010c p.107). A popular example for the usage of the IoT are smart home devices, that can be operated from the distance for example via apps on smartphones or even act autonomously, such as an heater, that either measures temperatures or assesses the weather report in order to maintain a comfortable room temperature. In general, the IoT opens up the possibility of controlling objects from a distance, gather information about their surroundings and enables objects and their users to benefit from internet services (cf. Eibl, Gaedke, & Gesellschaft für Informatik e. V. (GI) Gesellschaft für Informatik e. V. (GI) Bonn, 2017 p.2081).

In literature, the distinction between Cyber-physical systems (CPS), ubiquitous computing and the IoT is often not clear or the terms are even used as synonyms. For these guidelines, despite the different focal points of each concept, since they all have their origin in the same fundamental vision and are based on the same technologies, CPS is understood as the generic term for all concepts.

Although the already mentioned different terms are often used as buzzwords for I4.0, it is still hard to imagine how exactly they can contribute to value creation in companies.

This listing of terms that are important for smart SMEs summarizes the capabilities and underlying technologies of

CPS and highlights how collaborating CPS can add value in a production system (cf. Geisberger & Broy, 2012c p.127).

Physical Awareness:

CPS requires the ability to gather information about the physical environment in order to be able to act appropriately upon the incoming date. These data include information about human and technical actors and their condition such as the exact position of a workpiece or the number of employees at an assembly line. Sensors are used to provide this information. Sensors might determine the chemical or physical status such as temperature or humidity and convert this information into a digitally encoded signal (cf. Geisberger & Broy, 2012c p.127, 138). In terms of object identification and tracking, radio-frequency-identification (RFID) is seen as one of the key technologies. RFID is based on electromagnetic fields. Each object receives a RFID tag with specific, stored information such as its article number. RFID enables an exact tracking of objects at minimal costs (cf. Song, Fink, & Jeschke, 2017b p.197). This principle provides great application potential, particularly in terms of logistic processes such as real-time-tracking (cf. Song et al., 2017b p.29). Instead of time- and cost consuming inventories, which are conducted by employees, sensors might register the available quantities of products at any time at marginal zero costs (Fleisch, Weinberger, & Wortmann, 2014). In order to coordinate production processes, sensor equipped objects need to be able to communicate and interact with each other, which can be realized with wireless sensor networks (WSN) (cf. Song et al., 2017b p.29; 250). The alignment of information from different sensors is necessary to receive a holistic, virtual figure of real processes. A common example for objects with great physical awareness are driverless transportation system that use sensors for orientation.

Planned and anticipatory (semi-)autonomous acting:

CPS require the ability of acting partially or fully autonomous in order to make processes more flexible. Based upon the instructions of human operators or information gathered by sensors, CPS can adapt their behavior and interfere in processes by actuators. Actuators convert digital signals coming from sensors or commands from operators into mechanical movements, such as the movement of a robotic arm, or physical output values, such as a change of pressure or temperature (cf. Geisberger & Broy, 2012c p.138). The capacity of autonomous decision-making can be implemented through multi-criteria situation assessment, which enables CPS to analyze, interpret and evaluate situations in real time on the basis of previously defined criteria. In order to solve such tasks, information concerning the physical environment of an object is aligned to domain models, which are able of modelling interrelations and deriving possible actions. Real situations require the consideration of multiple, interacting variables: All actors, objects as well as human beings, and their behaviour as well a their interactions have to be considered. A problematic issue is the evaluation of contrary goals, for example an autonomous vehicle that could save the lives of its passengers but could endanger pedestrians at the same time. Another promising approach is the usage of artificial intelligence (AI) (cf. Geisberger & Broy, 2012c p.129 ff.). Artificial Intelligence is a science of machines that executes tasks that requires intelligence when they are performed by human beings. What may sound like a future vision is already used by various applications: Advanced consumer electronics such as adaptive earphones, can analyze and fade out ambient noise. Camera based monitoring systems can detect and report hazardous situations at public places. In the medical sector, high-risk operations can be conducted by high-precision robotic arms (cf. Dengel, 2011b p.391).

Cooperation and negotiation:

In order to unfold its full potential, CPS require the capability to cooperate and negotiate. The goal is to coordinate different CPS in real-time to ensure smooth processes and a collective, target-oriented behaviour. Technical basis for collaboration of different CPS are multiagent systems (MAS). The term agent refers to a software module that can act autonomously. Interactions with the surrounding environment take place via sensors and actuators. By the use of AI methods, agents receive task driven problem-solving-competences. In MAS numerous agents interact with other agents to find an optimal solution (cf. Geisberger & Broy, 2012c p.132). Whereas traditional, centralized control systems are too slow to react flexibly upon production changes, MAS and CPS in general, pursuit a decentralized approach, that enables to coordinate processes in real-time such as production planning, resource allocation, production scheduling and control (cf. Monostori, Váncza, & Kumara, 2006b). An exemplary application is the usage of MAS to design a flexible scheduling strategy: MAS can react upon unexpected events such as a machine breakdown and will automatically customize material flow (Kouiss, Pierreval, & Mebarki, 1997b).

Human-machine-interaction:

Despite autonomous robots and self organizing processes, humans play a key role in I4.0. The goal is not the substitution of human operators, I4.0 aims to optimize processes and assist employees to achieve superior value creation. CPS can support humans in various ways during production: Firstly, they can provide relevant information about production processes, which enables employees to monitor processes in real-time and to intervene if necessary. Eventually, human beings are always the final authority in I4.0 applications (cf. Vogel-Heuser et al., 2016a p.78 ff.). Cyber-physical applications can also be implemented to actively assist employees who perform manual or cognitive tasks. For instance exoskeletons can lead to a higher efficiency and ergonomic motion sequences of their carrier (cf. Cernavin, Schröter, & Stowasser, 2017 p.38). Another possible application are data glasses in logistic processes: They can guide employees on the shortest way to the storage location, where they find the product they are looking for. Simultaneously, data glasses can function as barcode scanners and update the inventory list immediately. As a result, search times and mistakes will be minimized and additionally, the employee has both hands free (cf. Borgmeier, Grohmann, & Gross, 2017b p.130). In order to optimize interactions between human beings and machines, instead of keyboards and monitors, humans need the possibility to interact with machines more intuitive for example via gestures or voice. In the last years numerous applications such as microsoft's control module Kinect have been developed (cf. Geisberger & Broy, 2012c p.134), that can be used to support employees during production processes.

Cloud computing:

In order to process mass of data that are gathered, utilised and stored in CPPS, high-performance information technologies are needed. The terms Big Data and Cloud Computing are often mentioned in this context (cf. Vogel-Heuser et al., 2016a p.572 f.). Big Data refers to "datasets that are too large for traditional data-processing systems and that therefore require new technologies" (Provost & Fawcett, 2013 p.54). One goal is to be able to process the high amount of data and then extract relevant information and knowledge by the use of algorithms. This procedure is called data mining. Extracted information can be used by companies to gain competitive advantage, for example by predicting marketing trends (cf. Provost & Fawcett, 2013 p.51-59). Data mining can also be used to enhance production processes: During the project EIDOdata for example, scientists were able to develop a software, that has the capability to analyze process data and derive optimization potentials in terms of energy and raw material consumption (Eidodata, n.d.-a; Schebek, Kannengießer, & Campitelli, 2017a p.45). On the other hand side, cloud computing refers to the provision of IT-infrastructures such as software or storage space as web services via the internet. Major advantages can be found in terms of accessibility and scalability: Users can access web-services from any mobile device. Additional resources such as a greater storage space can be activated immediately (cf. Baun, Kunze, Nimis, & Tai, 2011 p.1 f.).

The overarching objective of I4.0 can be found in the concept of the smart factory. The term "Smart factory" describes a factory, that uses the above mentioned technologies and ideas in order to optimize processes along the entire value chain. Although technologies are not mature enough yet, experts hypothesize that within a Smart factory, objects, machines and human beings will be able to cooperate in the most efficient way and enable high flexible production processes up to individualized products at the cost of mass production (cf. Radziwon, Bilberg, Bogers, & Madsen, 2014 p.1184-1189; cf. Vogel-Heuser et al., 2016a p.633).

3.5. How Industry 4.0 and Smart Engineering are changing the product life cycle

Based upon its various features, Industry 4.0 opens up completely new opportunities for companies of all sizes and all industries. Looking back at the life cycle of products, the first challenge for companies was the fast, efficient development of products, that can satisfy the wants and needs of targeted customers. Firstly, I4.0 enables product innovations, that can offer greater value to customers. In this context, the buzzword Internet-of-things is often used to describe web-enabled objects with identification and sensors. Besides product innovations, companies can profit from time and cost savings during development processes. For example, augmented reality technologies can be seen as a great opportunity to increase efficiency during this stage. It enables the virtual design of prototypes and also the virtual change of product features, such as colours or materials and virtual introduction of functionalities without additional material- and manufacturing costs. In addition, all provided changes can be documented automatically and transparent (cf. Borgmeier, Grohmann, & Gross, 2017c p.127 f.).

In terms of **logistics**, great potentials arise along the entire life cycle of a product (see Fig. 11). Real-time monitoring of the inventory in the warehouse, product tracking and monitoring by sensor technologies such as RFID are just a few of promising applications, that can increase efficiency.

Manufacturing and assembly processes can be optimized in terms of quality, flexibility and efficiency and consequently also contribute to sustainability. CPS can be used as assistant systems, such as exoskeletons or head-mounted displays in data glasses. Whereas relevant information is often unavailable or insufficient in companies nowadays, assistant systems enable to display relevant information in real-time. Moreover, they can support employees for example by displaying working instructions. CPS such as autonomous robots can execute tasks, that are physically demanding or inefficient if performed by employees. Different CPS working together have the ability to adjust and optimize complete production processes in real-time. Decentralized decision-processes represent a new level of speed and flexibility.

The next steps in the product life cycle (see Fig. 11) are marketing, sales and distribution (chapter 5). Especially in case of E-commerce, a high number of retours strains companies and the environment. Online images differ from customer expectations about the real product and therefore are send back (cf. Deges, 2017 p.1 ff). Customers can be supported during decision processes for example by the use of augmented reality and virtual reality technologies. These technologies allow customers to test products and their different features before ordering a product online and thus can contribute to lower retour ratios. In addition, Big Data can be used to assess the preferences of a specific customer group and customize product recommendations (Deloitte, 2017).

During product **usage**, customers can benefit additional functionalities of smart products and a higher product diversity. Simultaneously, companies can benefit from additional data such as energy consumption of their products, that can be used to detect shortcomings and optimize products. In terms of maintenance, technologies such as 3D printers can be a cost-effective alternative to manufacture spare parts or data glasses, which can support technicians during reparation by displaying the next steps or possible causes of failure (Deloitte, 2017).

Also, in the area of **recycling**, I4.0 technologies can enhance processes. For instance, sensors are already used to sort materials automatically and thus can contribute to higher recycling rates (Eidodata, n.d.-b; Schebek, Kannengießer, & Campitelli, 2017b p.45).

Summary: I4.0 can enhance processes along the entire value chain in terms of quality, time, efficiency, sustainability and flexibility. The applications introduced above, aim to demonstrate the capabilities of I4.0 technologies and provide orientation. Due to the amount of emerging technologies and visions, it would go beyond the scope of these guidelines to list more applications. But this is just where the strength of I4.0 unfolds: Combining different technologies to design innovative solutions. The following sections aim to guide companies in the process of the detection of I4.0-potentials within their own business. These guidelines might also inspire them in terms of formulating a consistent I4.0 strategy as well as deriving and implementing tangible measures in order to achieve their business goals.

3.6. Applications of Industry 4.0 along the product life cycle

Although various authors emphasize the potential of I4.0 to enhance processes along the entire product life cycle, many publications only focus on specific sub-sectors such as logistics (cf. Bousonville 2017) or manufacturing processes (cf. Spath et al. 2013). Therefore, this section aims to compile possible applications of I4.0 along the entire product life cycle from various publications. Due to the variety of arising technologies and their wide-ranging capabilities, the following compilation does not attempt to cover all possible applications. Much more, it aims to provide a concise overview to interested readers and encourage further research. The typical product life cycle is shown in Fig. 11.

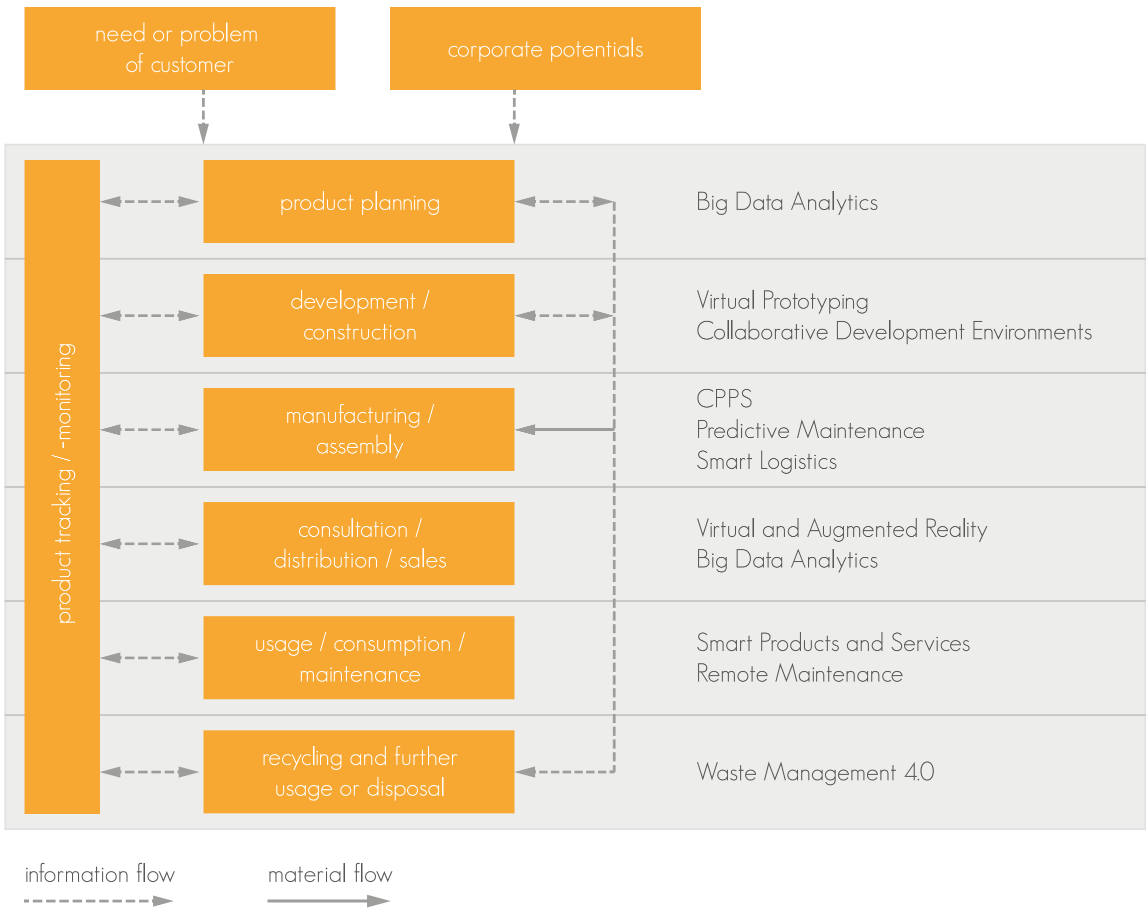

Fig. 11: Product life cycle with flows

The starting point of each successful product innovation is an idea. The idea might emerge from the requirements or problems of a specific market or customer segment (cf. Grote et al. 2014, p.1). Researchers and managers report, that Big Data currently is "a strong driver of innovation and a significant source of value creation" (Tan et al. 2015, p.223). Big Data can be used to derive insights concerning current and future trends and can help companies to gain a better "understanding of their products, customers, and markets which is crucial to innovation" (Tan et al. 2015, p.224). Various Big data solutions already exist on the market, which can automatically analyze data such as transactions and interactions of customers, user-generated content or social media data and thus support companies in generating ideas for innovations (cf. Markl et al. 2013, p.11). So far, transforming those ideas to a working product requires various time-consuming and cost-intensive activities, such as feasibility tests, design studies, the fabrication and testing of different prototypes (cf. Cooper und Centre 1980, p.27 ff.).

Augmented and Virtual Reality technologies can be employed in order to increase efficiency during this stage by enabling the virtual design of prototypes. Characteristics such as color, material and functionalities can be changed quickly without additional material- and manufacturing costs, even tests of proper function and certifications can be performed with digital prototypes, whereas the automatic documentation of all conducted changes leads to a higher transparency of the entire process (cf. Choi und Cheung 2008, p.477 f.; Borgmeier et al. 2017, p.127 f.; Christoph Runde, p.13). In addition, different departments of a company might work jointly and simultaneously on virtual prototypes in so-called Collaborative Development Environments. A Collaborative Development Environment is a „virtual space wherein all the stakeholders of a project – even if distributed by time or distance – may negotiate, brainstorm, discuss, share knowledge, and generally labor together" (Booch and Brown 2003, p.2). The benefits are obvious: By integrating experts from different areas such as manufacturing, logistics or marketing and enabling them access to relevant information in real-time, potential weaknesses of a product can be detected at an early stage and the risks for failure are minimized. As a result, efficiency and quality of development processes and the ability of companies to meet the demands of dynamic and complex markets strongly increase. Virtual and Augmented Reality solutions are already successfully used in SMEs, for example to prototype complex technical systems or to discuss product designs with customers (cf. Baltes und Freyth 2017, p.36 f.). A detailed overview concerning future technologies that can enhance product development processes is provided by Rauch et al.

Besides the capability to enhance development processes (see Fig. 8), I4.0 also enables companies to develop products with completely new functionalities. The classical product in a physical world might be supplemented by tailored, smart services that provide significant added value (cf. Borgmeier et al. 2017, p.113 f.). A common example are Smart Home solutions. The thermostat manufacturer Nest offers internet-enabled thermostats, which can collect data about the user behavior and derive individual energy saving potentials for customers (cf. Kaufmann 2015, p.3). A leading example for smart, connected products in the public sector can be found in the city of Barcelona. The city "has implemented Internet of Everything solutions to improve water management, waste management, parking and public transportation – all of which are helping the city save money. For instance, through connected water management alone, the city is saving US$ 58 million a year. Connected street lighting solutions have reduced costs by a third, saving Barcelona US$ 37 million annually. And what its leaders view as an even more important benefit, Barcelona estimates that the Internet of Everything has created 47,000 jobs over the past seven years" (Chambers 2014). These two examples demonstrate that I4.0 does not only offer opportunities in order to increase profit, but also supports companies inr lining up to their social responsibility. Prior to the actual production of a new product, materials, components and assembly units have to be procured. Material costs make up around 43% of the overall costs of manufacturing companies, wherefore cost reductions in this area have an immense influence (cf. VDI 2016). Big Data enables the autonomous gathering, processing and forwarding of relevant data such as material prices of different suppliers in real time and thus enables companies to minimize their material costs. Simultaneously, Big Data might support companies in order to solve important strategic questions, such as make-or-buy-decisions to find a cost-optimal solution (cf. Kleemann und Glas 2017, p.9).

In terms of the manufacturing and assembly processes, I4.0 offers major quality, flexibility and efficiency enhancements. A relatively simple and cost-effective way to improve production processes is the introduction of I4.0 assistance systems for production staff:

Data glasses can display relevant information such as current process data, technical documentations, maintenance rules or repair instructions and thus improve the efficiency and quality of processes through the targeted support of employees. In case of a system failure, the visual field of the user of the data glasses can be transmitted directly to the helpdesk of the manufacturer of the affected equipment, who then can offer optimal support and increase the rapidity of the maintenance process (cf. Bauernhansl et al. 2014, p.488).

Smart exoskeletons such as Robo-Mates can be worn by employees when performing physically strenuous activities. Integrated sensors register physical stress and the exoskeleton redistributes heavy loads from the shoulder area to the entire body. As a result, even demanding tasks can be executed more efficiently, the physical stress decreases and the health of employees will be promoted in long term (cf. Fraunhofer IAO 2015).

The combination of various I4.0-technologies enables innovative solutions with the capability of enhancing the entire production. Table 3 shows a compilation of a few successful I4.0-applications, which resulted in higher revenues and higher quality of products.

Company	I4.0 application
3D-Schilling GmbH	Each processing machine is equipped with sensors to measure tools and pieces. Further processing only takes place if all dimensions are within tolerance. The automatic documentation of the measurements leads to a higher transparency and enables the detection of systematic errors. As a result, revenue has increased by 60% in the first year (cf. Plattform Industrie 4.0).
Habermaass GmbH	An in-house developed CPS has the capability of accessing, enriching and forwarding relevant data such as customer information or master data. At all workstations, a networking takes place between CPS, workpieces and processing machines. Relevant information and specifications are forwarded to the employees in real-time. In addition, all subsequent employees will receive feedback on the current processing progress and the whereabouts of the semi-finished parts. Lead times, storage costs and punctuality could be significantly improved (cf. Plattform Industrie 4.0).
FlammSyscomp GmbH & Co. KG	Punching processes are characterized by a very high scrap portion of 40-60%, wherefore the Flamm Group is committed to develop a material-optimized punching process. Sensors and software determine the optimum punching position to save material and reduce scrap. Due to various cameras, queries and sensors, only 100% tested components are produced (cf. Plattform Industrie 4.0).

Table 3: Examples of successful Industry 4.0 applications in production

The examples shown in Table 3 represent companies of different sizes and thus prove, that I4.0 is not only limited to a specific company size or a product. Whereas the Habermaass GmbH is a large company in the furniture industry, the 3D-Schilling GmbH with 36 employees, manufactures forms and molded parts for the production of plastic parts. I4.0-applications enabled those companies to enhance their processes significantly, leading to a higher competitiveness and profitability.

Another promising concept of I4.0 with the capability of increasing efficiency of production processes is promoted under the buzzword predictive maintenance. As the term implies, the idea of predictive maintenance is to use data, recorded by sensors and Big Data Analytics to forecast and minimize machine breakdowns. For example, Linde Material Handling, one of the leading producers of forklifts, equips its products with sensors, which register vehicle parameters such as speed, acceleration or thermal load. Together with relevant information from the Enterprise Resource Planning System (ERP) such as previous maintenance or damage reports, possible machine breakdowns can be predicted and components can be replaced before damage occurs (cf. Lemke et al. 2017, p.179 f.).

The entire logistic from the receipt of the goods to the production and dispatch can be partly or fully automated. Time-consuming inventories can be completely replaced by intelligent storage boxes, which are equipped with cameras to detect their content and determine the exact quantity via a cloud in real-time. Orders can be placed automatically (cf. Vogel-Heuser et al. 2016, p.19). RFID-tagged materials and products can help to monitor the goods flow and are leading to a higher transparency. Automatically guided vehicles are able find the optimal route through production independently and bring the goods to their destination within a short period of time. The Fraunhofer Institute has developed a so-called cellular transport system: The individual automated guided vehicles are able to communicate with each other and thus are able to adapt capacities in real time (cf. Fraunhofer IML 2010).

After the completion of the production process consultation, distribution and sales form the next step in the product life cycle (see Fig. 9). Augmented Reality and Virtual Reality technologies can be used to assist customers in finding the right product. Especially for online trade, a number of retours strains companies and the environment. Online images often differ from customer expectations about the real product and therefore, are send back (cf. Deges 2017, p.1 ff.). These technologies allow customers to try out products and various features before ordering a product and thus can contribute to lower retour ratios. Big Data can be used in this stage to assess the preferences of a specific customer type and offer individual services. Furthermore, predicting sales volumes can improve availability and delivery time of products (cf. Hood et al.).

For the customer, the usage or consumption of products will change as more products will be complemented by Smart Services. Such services offer customers added value (cf. Bullinger 2015). Benefits are not generated solely by products anymore, but only by the combination of products and services (cf. Borgmeier et al. 2017).

This example was already discussed in the context of product development: The smart NEST thermostat. Compared to conventional thermostats, it provides the advantage of actively helping customers to reduce the energy consumption based on data analysis. But smart products do not only offer premium services, they also enable innovative business models, which can help companies to increase customer satisfaction. The engine manufacturer Rolls Royce changed the game in the markets, when it introduced smart airplane engines that can be monitored in real-time. Rolls Royce provides its customers with the engines, but instead of paying the entire loan period, customers only pay the actual operating time. Furthermore, Rolls Royce uses the gathered data to offer optimal maintenance and repair services (cf. Smith 2013, p.999 f.). Putzmeister, a leading german manufacturer of concrete and mortar pumps introduced the same business model. Instead of selling their pumps, they offer a combined product-service solution and customers only pay the time they are actually using the pumps (cf. Borgmeier et al. 2017). In both cases, customers as well as manufacturers benefit from the new business model. Currently, high-quality customer service is seen as one of the key factors of customer satisfaction, and, thus, indispensable for sustainable, competitive advantage (cf. Shemwell et al. 1998, p.156 f.). Providing maintenance and repair services can lead to a higher durability of products in this stage and therefore can also influence customer satisfaction positively (cf. Grote et al. 2014, p.1). Besides the opportunity to predict maintenance or repair services, remote access to Smart Products can speed up the entire process as technicians do not necessarily need to be on-site to diagnose the source of a problem or instruct customers during installation or maintenance (cf. Sciocchetti 2015). In addition, monitoring and remote access to their products enables manufacturers to learn more about the usage behavior of its customers. Those insights can be used to optimize their products or generate product innovations.

Due to current legal requirements and a higher environmental consciousness, the recycling of products has become a high priority for companies and their customers too. The reusability of products not only provides opportunities for further profit generation, at the same time it can be an influential factor during the purchasing process and improve the corporate image (cf. Nnorom und Osibanjo 2008, p.844). On the one hand, collaborative development environments during product development can help to design recyclable products by integrating experts in the field of recycling. On the other hand, I4.0 enhanced sensor-based sorting systems can be used to increase the recycling rate. Valuable raw materials such as metal can be detected by sensors and computers calculating their exact location on the conveyor belt. By using compressed air, the valuable materials can be separated from the rest of the scrap, leading to a cleaner material separation and thus enabling higher recycling rates (cf. Dückert et al. 2015, p.155; VDI ZRE 2017, p.45 f.). According to a survey of more than 1000 players of the waste management sector, I4.0 will enable a circular economy in the future – innovative technologies and the urgency to save natural resources will further increase the recycling of materials with the goal of reaching a recycling rate of 100% (cf. ISWA 2017).

The previously discussed concepts and application examples related to the product life cycle (see Fig. 8) demonstrate the capability of I4.0 concerning the enhancing of product features and processes, and thus options in order to increase the profitability and the competitiveness of manufacturing companies. The examples show a small part of the possible applications - the multitude of technologies enables completely new, individual solutions. Companies are therefore faced with the task of identifying which factors are decisive for their competitiveness and optimizing these factors by implementing I4.0-related concepts and technologies.

3.6.1. Examples for Smart Products

"Smart Industry digitizes and integrates processes across the entire organization, from product development and purchasing, through manufacturing, logistics and service. All data about sales, operations processes, process efficiency and quality management, as well as operations planning are available real-time, supported by ICT-systems and software (f.i. augmented reality) and optimized in an integrated network. By integrating new methods of data collection and analysis, companies are able to generate data on product use and refine products to meet the increasing needs of end-customers" (PWC, 2016a).

Within the above mentioned SMeART project, a survey concerning SME i4.0-requirements was conducted (reference on WP2 report t). In our survey, the 'development of new products' has a high score when it comes to opportunities to implement smart solutions [link Q13]. Internet technology primarily affects the products themselves. After delivery, they can notify the supplier on how they are used, which is useful for instance if you want to apply a pay per use business model (3.3.3). They can also report whether maintenance is required and they can receive software updates. In a sense, products come to life in this way (van Ede, 2017a). Smart products are user-friendly, attractive (human touch) and digitally connected. They are designed at minimum total lifetime costs (in energy, materials, transport). Smart products have built-in intelligence, are usable with flexible electronics so that they can communicate with their environment (users, but also any remote administrators). Smart products will be customer-specific (capital goods) or even ultra personalized (consumer products). Also, these products are designed for reuse of components and flexible (n = 1) productions ("Smart Industry heeft als ambitie dat Nederland in 2021 het meest flexibele en het beste digitaal verbonden productienetwerk van Europa heeft. - Smart Industry," 2018a).

Making products smart(er) can be achieved by:

- Adding digital features to existing products (such as cameras and sensors and communication devices to make them connected)
- Combining digital products and (databases) services, offering customers total solutions
- Using data analytics to create products-as-a-service and creating an online platform for customer access to content as well as data-based services
- Integrating external data and products and services from other companies in own portfolio and platform in order to unburden customers. This will mean cooperation with other suppliers and/or value chain integration, building a customer-centric ecosystem.

Factories and also supply chains have to demonstrate the capability of changing product variants in varying quantities. Custom order smaller quantities in the context of JIT (Just in Time) and they demand customization. Moreover, life cycles of products are becoming shorter. It is therefore no longer sufficient to work in a lean way, you also need to be flexible and agile.

In the industry, many improvement methods that provide flow and change are applied (Lean Production, Six Sigma, TOC, QRM, TPM, Agile, First time Right, Value Stream mapping etc.). QRM and Lean, for example, are methods for reducing faults in office and production processes. At QRM, the main goal is to deliver quality with high delivery reliability, despite a large variation in orders. While with Lean, the emphasis is more on reducing or eliminating waste on the production floor. Due to both, there will be fewer faults and lower costs through efficiency.

An important step is to learn to think differently in a streamwise manner instead of per product, to see where value is lost in the entire process. The deployment of line managers instead of production managers, who plan and work on the basis of collecting and analyzing production data, is a visible trend in industry.

In order to design, produce and deliver tailor-made products in a faster way, it is essential to switch from an ETO (Engineering-to-Order) to a CTO (Configure-to-Order) process. While

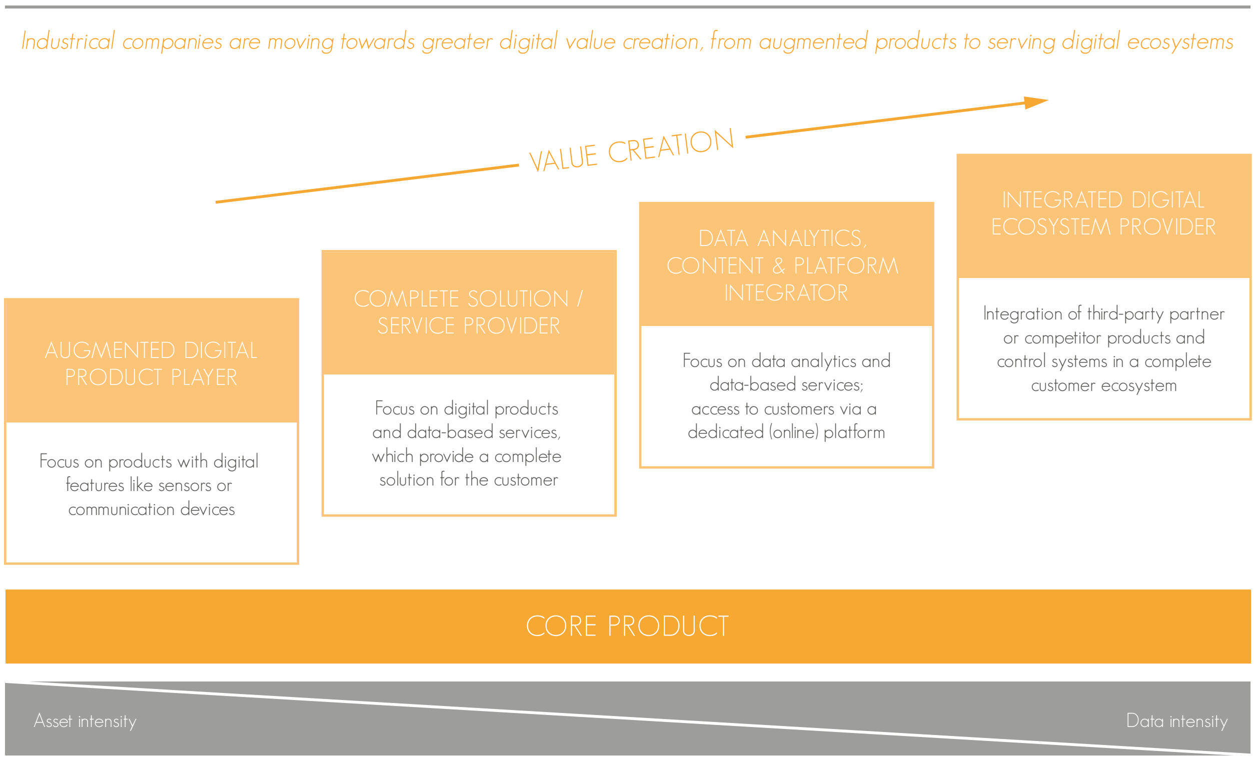

Fig. 12: Digital Value Propositions ("[No title]," n.d.-a)

ETO forces you to engineer every single order 'from scratch', CTO compiles each order from existing building blocks. By varying in standardized building blocks such as hardware, software, electronics, but also operational building blocks such as production systems and resources, customers will get tailored solutions through a standardized route. The advantages are better products, fewer errors, shorter time to market, more time for innovation and less costs (Cadac Group-Create, manage & Information, 2017).

According to our survey, the use of Computer Aided Design (CAD) is quite common. Automated product configurators are far less used [link Q43&Q65]. Automated quality checks of products are hardly implemented by SMEs (link Q49&Q71].

In addition to the mentioned CAD, smart companies use a whole range of Computer-aided technologies (CAx) for design, analysis and manufacturing of products like Computer-aided manufacturing (CAM) and Computer-aided engineering (CAE).

3.6.2. The strategic framework

Companies that seek for guidance in scientific literature in terms of strategy will quickly be confronted with the problem of finding a clear definition of the term "strategy". Dozens of interpretations make it hard to capture the essence of "strategy".

A common issue seems to be the differentiation between operational effectiveness and strategy. A variety of tools has been developed that aim to increase operational effectiveness. Whereas these tools can reach impressive improvements in terms of production quality and speed, they do not lead automatically to sustainable profitability. Despite operational effectiveness, companies struggle to acquire and retain customers and hold their ground in international competition. Consequently, operational effectiveness can be seen as a requirement for an outstanding performance, but strategy is the key element, that enables the survival and success of companies in the long run (cf. Porter, 1996). In general, a successful strategy must consider three key players on the market: the company itself, customers and competitors, also called "the strategic three Cs" (cf. Ohmae, 1982).

The interaction of these three market participants is crucial for a company's economical performance. Only if a sufficient number of customers will buy the products and services of a company, it can survive and gain profit. Therefore, understanding the needs and aspirations of customers are the core element of every successful business. Simultaneously, a company needs to fulfill customer needs better than its competitors, otherwise it will constantly lose parts of the market share (cf. Ohmae, 1982 p. 48)

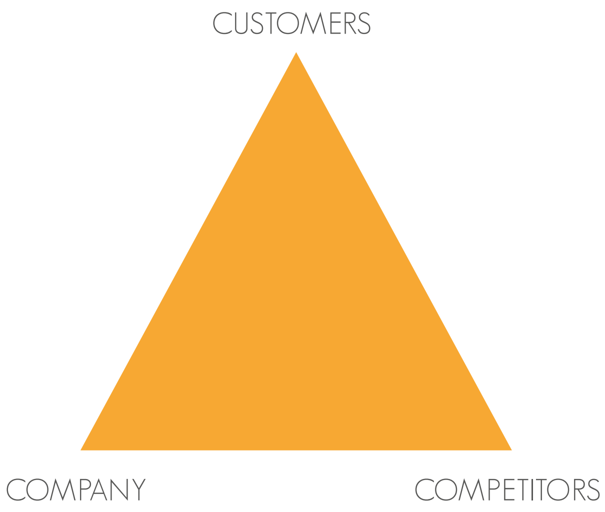

Fig. 13: the strategic three Cs (cf. Ohmae, 1982)

According to Porter (cf. Porter, 1996), sustainable differences between a company and its competitors do not emerge from single activities. For example, the introduction of a new production technology might create competitive advantages for a while by decreasing production costs, but single measures can be benchmarked and copied easily by other companies, which cause them to look more similar in the long run instead of securing an outstanding performance. Much more the combination of "hundreds of activities required to create, produce, sell, and deliver […] products and services" (cf. Porter, 1996) distinguishes one company from another and defines whether a company can create more value for its target customers than other competitors in the long run. Hence, business strategy is about finding a mixture of different activities, whose power unfolds through the unique linkage of its single elements and therefore cannot be copied easily (cf. Porter, 1996).

Scientific publications are proposing a wide range of strategic tools and frameworks, but the majority of them exhibits the same shortcoming: They aim at supporting companies in order to define a strategy, but they rarely offer support in the deduction of concrete activities and measures for implementation and execution. Whereas the definition of a strategy requires the abstraction of the complex, dynamic interactions between the three strategic C´s, so that companies can outline and understand the key elements of competition. Strategy execution requires a detailed understanding of the company's resources and processes to derive concrete measures und assess the feasibility of a strategy early on (cf. Richardson, 2005 p.134 f.). In addition, the importance of strategy implementation is often neglected in scientific literature, many approaches focus on strategy formulation and classify implementation rather as an attachment of formulation instead of an equally important element (cf. Raps, 2017 p.24 ff.). Theoretically, the best strategy might not be able to enhance any business if it is not implemented successfully. Especially in terms of I4.0, the complexity requires a strategic framework, that can guide and support companies all the way from defining a strategy to its execution. Moreover, a successful tool should support communication and enable transparent decision processes. The aim of this section is to introduce a holistic framework and describe its single stages and elements. Subsequently, a selection of tools and methods will be introduced for each stage, that offers practicable guidance for companies. The suggested framework is shown below:

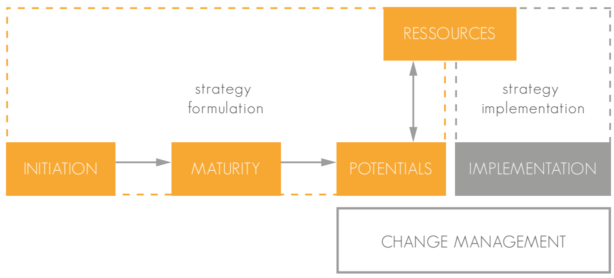

Fig. 14: Stages of the strategic framework

The basic idea of the strategic framework is to use the company's business model as a basis to develop an I4.0 strategy and deduce concrete measures.

In general, a business model can be defined as "a statement of how a firm will make money and sustain its profit stream over time" (Stewart & Zhao, 2000) and thus describes the interactions between a company, its competitors and customers. In terms of strategy, business models can be seen as the connecting element between a company's strategy in theory or its idea about how to compete and the concrete processes, activities and resources a company employs in order to execute this strategy (cf. Richardson, 2005 p.135). Whereas strategists are still in disagreement, whether economic success is based on the resources a company has or rather depends on choosing the right market and competitive positioning, a holistic business model is able to capture elements from both views and analyze internal and external success factors as well as their interdependencies (cf. Chesbrough, 2002 p.529 f.). Capturing the present business model in written form will not only help companies to highlight how exactly they generate profit, in addition, documenting the actual state will lead to a shared understanding of the initial situation, which will prevent misunderstandings and can speed up the process of detecting present weaknesses and opportunities for the future (cf. Nicolai, 2017 p.288). Consequently, the goal of stage 1, the initiation stage, is to specify a companies business model and to understand how exactly profits are generated.

Due to the high amount of new opportunities and the resulting complexity, especially SMEs struggle with specifying tangible I4.0 technologies and processes. They plan to implement these I4.0 technologies and processes later. Sooner or later, dissatisfaction and frustration evolves because entrepreneurs do not know how to approach the idea of I4.0. In order to prevent this difficulty, a structured proceeding is needed that can support entrepreneurs in the elaboration of concrete measures and actions. A series of scientific publications and studies recommends the usage of I4.0 maturity models. In general, a maturity model is an instrument to assess the current level of development regarding a specific subject (Mettler & Rohner, 2009). In terms of I4.0, maturity models can help to reduce complexity by further defining the initial situation of a company (cf. Schumacher et al., 2016). In addition, a maturity assessment can serve as a reference point during effort estimation.

Consequently, assessing the company's maturity in terms of I4.0 is the next step (stage 2) during the Maturity stage (see Fig. 14) of the proposed framework.

In framework stage 3, realistic scenarios should be formulated about future potentials or – in other words – how the profit generation can be enhanced by the use of I4.0. The initial business model (stage 1) serves as orientation to detect current weaknesses such as insufficient customer service or slow production processes. It also helps to determine crucial success factors, that can be build up further to strengthen competitive standing in the future. The business model approach helps to create a holistic view, instead of thinking about single technologies or products. How does the company want to compete in the future? Can a higher product variety provide value to existing customers or attract new customers? Is delivery reliability a crucial success factor for the company, that should be improved in the future? Chapter 2, 3 and 4 serve input and inspiration and are a guide for companies to formulate and specify their ambition and potentials.
Simultaneously, companies need to start to derive tangible resources (see section X) that are required in order to pursue their ideas. Early on, they need to estimate the effort that is required to realize each idea. Ideas that turn out to be too risky or costly, need to be customized or discarded. The goal is to find a set of new activities, processes or technologies, which are able to create sustainable value and can be achieved with given means or in other words, to formulate a practicable strategy. The phases of strategy definition, planning and implementation merge into each other. Even if not all details of a company's strategy are planned, initial preparation for implementation, such as training for employees, might already start. The framework (see Fig. 14) suggests to integrate change management in the process of strategy development and implementation. Corporate change fails regularly for different reasons: Intransparent decision processes make it hard for employees to understand the urgency of change or the usefulness of single measures. Considerations and plans are only partly passed between different hierarchy levels of the organization, consequently uncertainty, frustration or even fear arise. As a result, employees will only engage half-hearted in the change process and diminish success (cf. Nicolai, 2017 p.288). In general, Change Management attempts to control and implement change, particularly with focus on human beings, that are in some way affected by change processes (cf. Lauer, 2014 p.7 f.). Numerous authors and publications emphasize that successful change can only take place if employees are willing to implement change. Without inner conviction, employees will only work to rule.

Based on this structured approach, the authors are convinced that the decision processes can be designed more transparent and comprehensible for organizations. The usage of business models enables a holistic view on weaknesses and strengths and can help to recognize future potentials in all business divisions. The following section introduces a set of methods that can be applied in each stage.

3.6.3. The SMeART Toolbox

3.6.3.1. Initiation

A number of business model approaches have been developed in order to support companies when examining their initial situation. Osterwalder suggests a viable approach, the so-called Business Model Canvas, that consists of nine key elements (cf. Osterwalder & Pigneur, 2011). By analyzing each of these elements, companies might capture the essence of their business.

Customer Segments	For whom are we creating value? Who are our most important customers?
Customer Relationships	What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Which ones have we established? How are they integrated with the rest of our business model? How costly are they?
Channels	Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient? How are we integrating them with customer routines?
Value Propositions	What value do we deliver to the customer? Which one of our customer's problems are we helping to solve? What bundles of products and services are we offering to each Customer Segment? Which customer needs are we satisfying?
Key Activities	What Key Activities do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue streams?
Key Resources	What Key Resources do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue Streams?
Cost Structure	What are the most important costs inherent in our business model? Which Key Resources are most expensive? Which Key Activities are most expensive?
Revenue Streams	For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues?

Table 4: Eigene Darstellung in Anlehnung an (cf. Osterwalder & Pigneur, 2011)

At the beginning of every single purchasing process is a customer with a specific requirement (cf. Sandhusen, 2000). Consequently, the goal of this stage is to support the activities, resources and technologies that create value for all customer segments along the whole product life cycle.
In addition, a structured presentation of a companies business model can be used as guidance to explain the urgency and potentials of I4.0 to all members of the organization.

3.6.3.2. Maturity

In terms of I4.0, Maturity Models can help companies to reduce complexity and help to evaluate, whether a company has the abilities and personal and financial resources to engage specific technologies and activities (cf. Schumacher et al., 2016). Within SMeART, a maturity model has been developed, that is not only able to determine the current state of development in terms of I4.0, but can also derive measures, that can be implemented by SMEs to reach a higher maturity level.

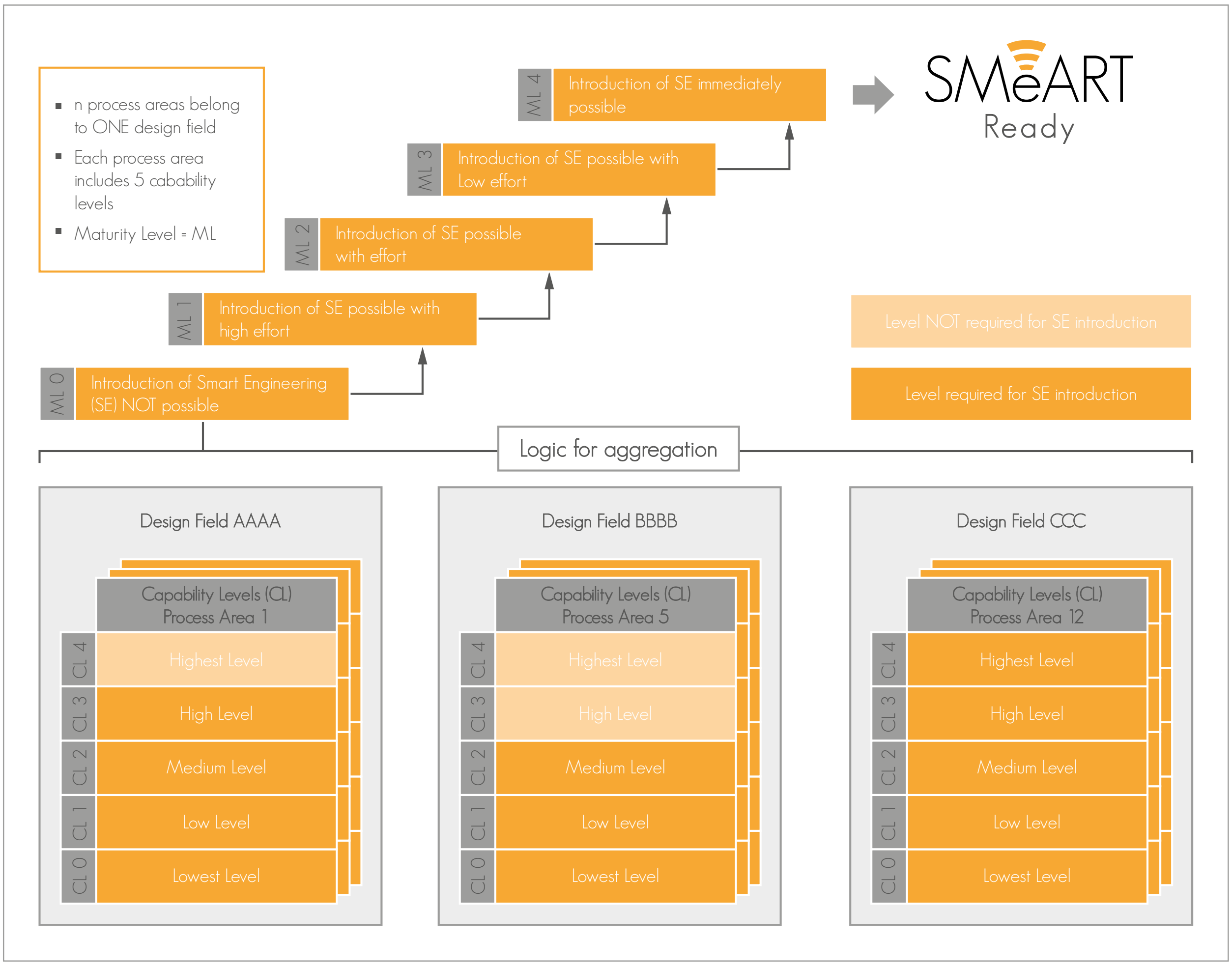

Fig. 15: The SMeART MOSE

In Fig. 15, the Model for Smart Engineering (MOSE) is limited to 3 design fields. These fields are defined individually for SMeART ("people, technology, organisation"). Within each design field we have various individual SMeART-process areas, like "education" for the field "people". The capability levels (CL) are criteria to judge the maturity of the individual process areas. Actually, the CL are input from the SMeART Stress Test Tool users. After user input, the CL from various design fields are logically combined and aggregated by the logic for aggregation. The capability levels (CL) of the individual process areas are summarized by the aggregation logic to a superordinate degree of maturity (ML).

Finally, the result of the aggregation is an overall maturity level ML. The ML is a number or code which can be used to automatically produce further recommendations for the user. The definition of general measures or recommendations also supports SMART users (companies) to achieve the next higher level of capability CL in the considered process area.These recommendations might be presented to the user via website or email document.

The maturity model MOSE attempts a linear classification of the different levels of maturity ML (see aggregation logic). As ML increases, by definition it is easier for companies to introduce Smart Engineering or to make it easier for them to do so.

With this approach, a SME is able to quickly identify whether and to what extent it is capable of introducing Smart Engineering. Immediate Smart Engineering implementation is possible when the required capability levels are achieved in all process areas of the respective design fields. This results in specific maturity models for specific implementation scenarios of Smart Engineering. When the next CL is reached, companies are supported by the inclusion of suitable general measures in the considered process area.

Generally, we will adapt this approach by the following steps:

1. Determining/ defining of the minimum required level to be able to introduce Smart Engineering in the SME (What is a Smart SME marked for?).
2. Determination of the actual state of the individual maturity levels (for example by online survey).
3. Determination of the (average) target achievement (ML), there are 3 options.
4. Interpretation of the results, e.g. by spider charts.
5. Automatic generation of advice to generate the next higher ML.

3.6.3.3. Combining stage 1, 2 and 3: Potentials

In this stage (see Fig. 14), enterprises have already completed two important tasks: They analyzed the interactions with their customers and competitors and therefore captured how profit is generated. Also, they assessed their maturity level in terms of I4.0. Based on these results, realistic scenarios can be proposed concerning the profit generation or – in other words – how the company can be enhanced by the use of I4.0. During preparation, it is important to keep in mind that the goal of this stage is not to reach the highest, possible maturity level in terms of I4.0, but to reach the level that is required to pursuit corporate goals and is reachable with available resources.

Since customers can be described as the heart of a business, a deeper and more detailed analysis of their requirements and wishes is useful in order to discover potentials and customize processes.

One possible approach is to analyze customers jobs, pains and gains. To highlight the meaning of each of these elements, they are explained with a customer A who wants to buy a new sound system. [(Fig. 16 following cf. Osterwalder, Pigneur, Bernarda, & Smith, 2015)]

- Customer Jobs describe the tasks customers want to complete. These tasks can be of functional, emotional or social kind. Exemplary, the functional job of customer A is to listen to music. At the same time, he or she might want to relax while listening (emotional job) or invite friends over to impress them with the new sound system (social job).
- Customer Pains describe the obstacles and problems customers must face while trying to getting their jobs done. Customer A might have troubles in turning on the sound system. Also, it might be difficult to connect different devices with the system.
- Customer Gains describe functions that add extra value for the customer. In the example, customer A might profit from a sound system, which has a voice control and connects to his or her devices automatically via Bluetooth (cf. Osterwalder et al., 2015).

Another option is the adoption of creativity methods such as the Delphi Method or Six Thinking Hats Method in order to support innovative thinking and therefore encourage innovative solutions (Phillips und Gully 2013, S. 309; Goldenberg und Mazursky 2002, S. 54).

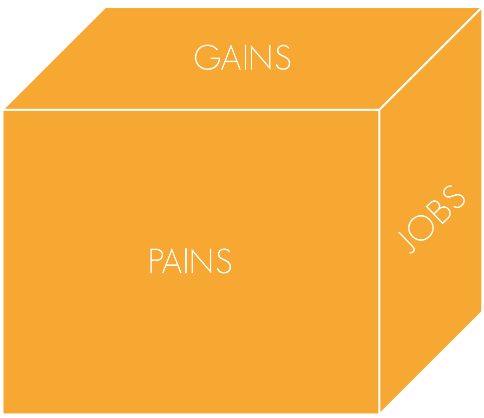

Fig.: 16

3.6.3.4. Resources

Ideas that make it into the shortlist, need to be evaluated in terms of their practicability, potential and implementation costs. The goal of this stage (see Fig. 14) is to assess the resources that are required in order to implement each idea and upon this assessment, estimate project costs. Resources can be of material kind, such as financial means or technologies, or immaterial kind, such as technological know-how or time. Depending on which resources are available within a company and which ones need to be acquired, companies can assess practicability of each idea:

1. What material and immaterial resources are needed to realize a specific idea? Which of these resources are already available within the company?

2. Depending on required resources, what are the estimated costs in total?

In general, three different classes of cost estimation techniques exist:

- Algorithmic methods
    - parametric methods
    - factor- or weighting methods
- Comparative methods
    - analogy methods
    - relational methods
- key figure methods
    - multiplier methods
    - productivity methods
    - percentage based method (Burghardt, 2018)

Mostly, project estimation techniques that rely on experiences of earlier projects are applied. Companies can fall back on their own projects of comparable size and complexity. If no comparable projects have been implemented before, calculation software can be used that assesses data from projects in the past in combination with mathematical calculation procedures. The main advantage of cost estimation via software is, that it also considers uncertainty during calculation and therefore can deliver more precise results (cf. Dumitrascu & Nedelcu, 2012).

3.6.3.5. Change Management

In general, successful change processes in organizations run through three distinctive phases named unfreezing, moving and refreezing (Lewin, 1947).

During unfreezing, employees need to understand why the organization needs to change. Since change is always connected with insecurities and efforts, employees who cannot see any necessity for change, most likely will neither invest their time and nor their personal skills to engage in change processes. In the worst case, resistance will arise because employees rather want to maintain things as they are.

The reasoning can be based on the business model that was written for stage 1 of the strategy framework:

1. What are today's main shortcomings?
2. If business is continued as it is, what will be the results?

Only if all team members of the organization understand the necessity of change, they will be willing to participate.

During moving the actual change takes place. In terms of strategy, the implementation starts at this phase. New processes and behaviors need to be learned and trained. It is important to keep in mind, that change does not happen overnight and some employees might need more time than others or training courses.

Freezing takes place when new processes and behaviors consolidate and become the new normal. Reward or feedback systems might be useful to support consolidation.

3.6.3.6. Implementation

In general, the strategy implementation refers to two different elements: adaptation, for example in terms of employees skills, corporate culture or organisational structure and application of strategy at the operational level (cf. Huber, 1985 p.106).

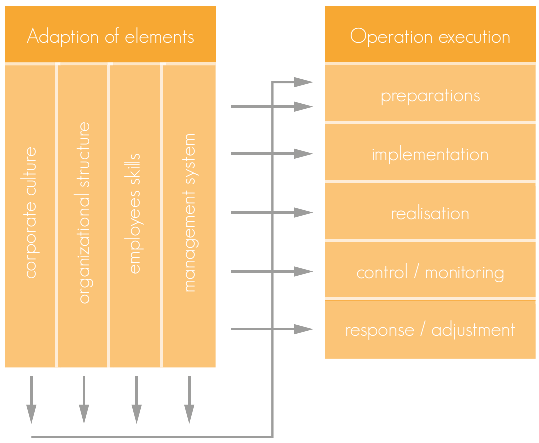

Fig. 17: Implementation process (cf. Huber, 1985 p.106); (cf. Raps, 2017 p.62)]

Both elements are crucial for successful implementation processes: The introduction of an assistant system for instance will not be able to enhance value creation if employees do not know how to use it or are unmotivated to even try. Whereas change management focuses on adaptation processes, in terms of operational execution, a variety of project management tools and techniques can be applied to enhance strategy implementation.

In general, a project structure plan, that lists all work packages, sub tasks and responsibilities, helps to maintain a general overview. A survey among over 200 project managers revealed that one of the most crucial issues for projects success are clear goals and objectives (cf. White & Fortune, 2002). A widespread common understanding is to define goals based on the S.M.A.R.T. approach:

Specific, **M**easurable, **A**ttractive, **R**easonable, **T**ime-bound (Locke & Latham, 1990).

The following example demonstrates a goal 1.) without S.M.A.R.T approach and 2.) with S.M.A.R.T.:

1. "In our online store, we want to represent our products as realistic as possible in order to create a better shopping experience for our customers."

2. "By the use of Virtual Reality technologies in our online store, we want to reduce return ratios by 40% until the end of the year."

4. BUSINESS OPPORTUNITIES

Authors: Sandra Verweij and José Laan (Parbleu)

4.1. Introduction and objectives of this section

"A good hockey player plays where the puck is. A great hockey player plays where the puck is going to be."
Wayne Gretzky, Canadian hockey icon 1978–1999

As we saw in chapter 3 and 4, Smart Industry affects all aspects of a manufacturing companies; from research, development, (re)design and production, to marketing, service and recycling of products. It changes products, services, processes and what is even more important, business models of individual companies and it reshuffles entire supply chains. Smart Industry creates opportunities for existing and new companies in – once – traditional markets, and it opens up new markets. Nevertheless, recent research shows that manufacturing companies tend to focus mainly on the technological aspects and (potential) efficiency gains of Smart Industry, rather than on the paradigm change of business value propositions and business models (Ibarra, Igartua, & Ganzarain, 2017). "Industrial companies that combine the digital and the physical world, open up entirely new dimensions in the way they operate and in the value they can provide to customers and shareholders. They can drastically reduce the time to introduce new products to their market, and respond faster to customer needs. Translating real-time customer data, factory data and supply chain data into insights will make those factories and supply chains able to respond much faster to shifts in customer needs and external shocks" (Annunziata, 2014a). In fierce market competitions, with constantly changing variables, an increasing fight for (digital) attention of customers and their demand for personalised solutions within a short time to market, business models and market strategies must be reconsidered, and market positions need to be defined in new ways.

The content of this subchapter serves as input, inspiration and as a guide to involve business opportunities in your SMeART Roadmap. After reading this chapter, you will be able to understand and apply to your own business:

- What business opportunities smart industry can offer.
- How to modify products or develop new, ***valuable*** smart industry based customer solutions.
- How to build a future proof product- and service portfolio.
- How to introduce or improve ***smart*** marketing in your company.
- What effects smart industry will have on your supply chain and how to react and profit from that.

4.2. Market needs

The main ingredients for a company to create new, smart business opportunities are a profound understanding of:

- Its own ambitions and (potential) resources,
- Technical and social developments and market trends,
- Customer needs, issues and customer value.

Our survey shows that 51% of the respondents need more market knowledge and understanding of customer needs (Knowledge Alliance for Upskilling Europe's SMEs to Meet the Challenges of Smart Engineering, 2018).

International market trends that relate to Smart Industry, will have increasing effects on individual manufacturing SMEs and on their value chains:

1. Individualization

- Demand for customer specific total concepts, including maintenance and other services
- Shorter product life cycles, caused by rapidly changing customer requirements and acceleration in technology
- Flexible modular machine concepts facilitate customization and increase the speed of response to changes in the market
- Final customers demand more development capacity and flexibility.

2. **Servitization**
   Adding (data based) services to products, offering total solutions, from ownership to access (chapter 5.3.3)

3. **Business Models based on performance**
   E.g. pay-per-use revenue models (chapter 5.3.5)4.

4. **Sustainability**
   Increasing focus on circular economy and reuse of (parts of) machines, more attention to and demand for ‚clean tech' applications (chapter 5.3.4)

5. **E-commerce**
   Online and social marketing, also applied in B2B markets (chapter 5.5)

6. **Changing market conditions**
   Increasing automation/ robotization requires cooperation with specialized partners and causes supply chain integration (development, production and service, chapter 5.6).

A company can choose different strategies or postures to react to changing market circumstances, specific trends and (technical) developments, depending on the expected relevance and potential of those trends and developments. They can try to *shape the future* (play a leadership role in establishing how the industry operates, by setting standards and/or creating demand), *adapt to the future* (win through speed, agility and flexibility in recognizing and capturing opportunities in existing markets) or just *reserve the right to play* (invest sufficiently to stay in the game but avoid premature commitments) (Courtney, Kirkland, & Viguerie, 1997).

4.2.1. Customer needs

We are living in a world where the supply is much bigger than the demand. Therefore mainly the products or services that are based on identified users' problems and needs, have the potential to become successful market products.

Smart Industry is aimed at transforming mass production into mass customization: tailor made products will be manufactured at mass production costs. In depth knowledge of customers' behaviour, perceptions, values and needs as well as being able to fastly translate these insights into modified or new products and services (customer intimacy), will increasingly become a crucial competence for all manufacturing companies.

Our survey shows that there there is room for improvement when it comes to feedback from end-users to the production department (Knowledge Alliance for Upskilling Europe's SMEs to Meet the Challenges of Smart Engineering, 2018).

In this digital and technological era, ways to meet customer needs and opportunities to exceed customer expectations are drastically and constantly changing. Markets are transparent, customers are well informed and critical and in the driving seat when it comes to how, when and where they want their (custom made) orders to be delivered. Creating customer value and developing new ways to do so, demand a keen eye on (changing) market situations and profound insights in customers' behaviour, wants and needs.

4.2.2. Customer insights

"If I had asked people what they wanted, they would have said: faster horses."

("Talk: Henry Ford - Wikiquote," n.d.)

Asking customers what they want, hardly ever leads to breakthrough innovations in the long run. Why? Customers usually only request solutions that are based on known problems, needs and options. Collecting customer insights in order to create (more) customer value, is not about asking customers what products or services they would like, but about investigating the context in which they will be using the products and services. It is about figuring out what the purpose behind buying products or services really is: what is he or she trying to accomplish or fulfill? Customers are experts on their own daily (work) routines, issues and ambitions. A smart supplier supports and facilitates those, as an expert in state-of-the-art and smart(er) ways to do so.

4.2.3. Collecting customer insights

Disruptive smart digital business models are often focused on generating additional digital revenues and optimizing customer interaction and access. Real breakthroughs in performance happen when you actively understand consumer behavior and can orchestrate your company's role within the future ecosystem of partners, suppliers and customers. Smart companies use digital technologies to create and deliver value to the customer in an integrated, innovative solution. (WC, 2016)

There is a range of analog and digital techniques to collect customer insights that can be executed by an SME itself: customer panels, customer interviews, customer expert meetings, client observations, etc. An interesting way to start is to shift oneself in an existing or potential customer, and to describe his or her job to be done (tasks, processes and interactions or touchpoints) in a *customer journey*. The customer journey map is a useful tool to take the perspective of a customer, as a guideline to identify opportunities and develop or adjust products and services (Kwakman, Rudolph Johannes Antonius, Smeulders, & Moerman, 2017). By designing a customer journey, a product or service is placed in its context, as just one part of a customer's solution and overall experience. A customer journey can be used to generate insights how to unburden customers and then create smart new propositions and to (re)design customer processes. Within the value chain, this can lead to in depth specialization (unbundling products and services) or integration (bundling products and services to create total solutions).

An effective and achievable way for SMEs to collect customer insights, is by arranging dialogues with customers, users and possibly suppliers, to discuss:

- What are our customers' aspirations and how can we help him to meet them?
- What tasks does our customer have to get done and how can we help?
- What do the best customers of our best customer need? How can we help our customer to add value?
- What kind of relationship does our customer expect us to build with him?
- For which value(s) is the customer willing to pay?
- How is our customer preferably addressed and achieved?
- How do we, as a company, fit in his routines in the best possible way?

(Osterwalder, 2013)

Together they can even co-create the 'ideal' customer journey, (re)designing value proposition(s), products and services, off- and online processes, customer relations and customer experiences.

Like the company's world, its customer's frame of reference is constantly changing too. By having future-oriented dialogues with customers on a regular basis, an entrepreneur (and his R&D team or product manager) will get a constant flow of input for innovation.

Digital technologies to make increasingly better predictions of customer behavior improve every day. Data analytics will be used more and more to predict customer and machine behaviour as well as product or service demand. Customers participating in product and service development will become commonplace. They become an integral part of smart business models by providing information on their individual needs and their use of products and services. The design and implementation of new, smart business models will have to allow the active integration of co-creation with customers.

Even though the business paradigm often claims that a customer is at the center, it makes sense to look at this paradigm from other perspectives. Developments and solutions found in other industries and work fields may serve a company as inspiration or a key to (breakthrough) innovations. History shows that many radical and epochal innovations were developed on completely new technologies. Some decades ago, there was no need for mobile phones. It was a technology, which enabled development and consequently a completely new market was established. Another, much older but still very relevant example is related with Michael Faraday, who in the 19th century, discovered an induction. Without it we can not imagine today's life: It is used for radio, television, machines, electric cars, mobile phones and computers. When asked by the finance minister about the benefit of the discovery, the inventor replied, „I do not know why it is useful, but I'm sure your successor will collect taxes from that."

Richard Branson (Raymundo, 2014) succeeded to build Virgin into a global powerhouse. To him, most important are the employees, not the customers. It seems to be a radical approach, but the logic behind can explain this important business concept. The satisfied and creative employees are most important for development of new business models and products. If we have such people, they will be able to do their job perfectly, identify the market needs and prepare creative solutions. Such products will consequently create customer value and economic results.

4.3. SMART Business Opportunities

A connected device or machine becomes something entirely new, blurring the lines between products and services. In a similar way, a company producing interconnected industrial devices can become a fundamentally different company (Annunziata, 2014b).
Our survey shows that most respondents encounter challenges when it comes to (new) business models, based on Smart Industry (Knowledge Alliance for Upskilling Europe's SMEs to Meet the Challenges of Smart Engineering, 2018).

It's all about creating value

'Value is not determined by those who set the price. Value is determined by those who choose to pay it.' (Simon Sinek)

Customer value is the core of a business model. To be able to deliver the right customer value and to develop a corresponding revenue model, a few important questions have to be answered: Who exactly is your customer, what are his aspirations and job(s)-to-be-done, what keeps him from achieving them (better, faster, easier, more pleasantly), what are his current options and for what value does he want to pay (more)?
In general, customers are not really interested in buying products or services. They are interested in solutions and in ways to get things done in a faster, cheaper, more pleasant or more convenient way compared to perceived alternatives. Value is not in the product or service itself, but in the use of it. The value of a company's offer is determined by its tangible and intangible benefits, seen from a customer's point of view. The extent to which a company manages to continuously create customer value, determines its competitiveness and success. One can distinguish economic value (an offer provides cost reduction, increases revenues), functional value (saves time and effort, easy in use, unburdens customers) emotional value (offers appreciation, attention, design, surprise, fun), symbolic value (sense of belonging, status) and social value (safety, health, environment). Successful business models generally combine these different kinds of value.

Perceived value is determined by:

- The size and importance of a problem, need, annoyance or challenge; the ‚pain' or ‚desire' a customer encounters,
- The extent to which an offer resolves a problem or serves as add-on value (the 'gain'),
- The number of providers that, from the customer's perspective, offer something similar (options),
- The distinctiveness (uniqueness) of an offer or it's provider,
- The time between identified needs and adequate market products (time to market).

Industry changes and increases the opportunities for companies to create (more) value. Combining profound customer insights with smart technologies will create new business opportunities which can lead to valuable, integrated new product and service concepts and interesting or even disruptive business models.

Gartner (2014) predicts that as early as 2020, one in five cars will be connected in one way or another. What does this mean for the auto industry? Will they provide services in addition to cars? Developing entirely new business models, such as design marketplaces on the internet? And which companies that are not in this market yet, will join the connected automotive market? And who earns money with what kind of added value? Companies with a business model based on customer value and customer solutions, will have excellent opportunities to create profit in any market ("[No title]," n.d.-b).

Smart Industry offers manufacturing companies new business opportunities in ways of:

- Creating smart (digitized and customized) products;
- Creating value with (big) data;
- Developing smart services and total solutions (servitization);
- Contributing to social issues, applying smart technical solutions.

Digitalization of products and Smart Engineering can realize the production of client specific (modular) products at the speed and price of mass products. It will generate a lot of information and data, that can be used to improve existing products and services and to develop new, customer tailored offers. Offering added services, total solutions or even products as a service, will unburden customers and can be become a substantial part of a manufacturing company's revenues. Enriching and analysing data can provide new revenue models. State-of-the-art technologies and new ways to collect and interpret data, can provide new knowledge and even solutions for 'sticky' social and environmental issues.

4.3.1. Smart products

"Smart Industry digitizes and integrates processes across the entire organization, from product development and purchasing, through manufacturing, logistics and service. All data about sales, operations processes, process efficiency and quality management, as well as operations planning are available real-time, supported by ICT-systems and software (f.i. augmented reality) and optimized in an integrated network. By integrating new methods of data collection and analysis, companies are able to generate data on product use and refine products to meet the increasing needs of end-customers" (PWC, 2016b).

As our survey shows, 'development of new products' has a high score when it comes to opportunities to implement smart solutions (Knowledge Alliance for Upskilling Europe's SMEs to Meet the Challenges of Smart Engineering, 2018). Internet technology primarily affects the products themselves. After delivery, they can inform the supplier on how they are used, which is useful for instance if you want to apply a pay per use business model. They can also report whether maintenance is required and they can receive software updates. In a sense, products come to life in this way (van Ede, 2017b). Smart products are user friendly, attractive (human touch) and digitally connected. They are designed at minimum total lifetime costs (in energy, materials, transport). Smart products have built-in intelligence, so they can communicate with their environment (users, but also any remote administrators). Smart products will be customer-specific (capital goods) or even ultra personalized (consumer products). Also, these products are designed for reuse of components and flexible (n = 1) production ("Smart Industry heeft als ambitie dat Nederland in 2021 het meest flexibele en het beste digitaal verbonden productienetwerk van Europa heeft. - Smart Industry," 2018b).

Making products smart(er) can be done by:

- Adding digital features to existing products (such as cameras and sensors and communication devices to make them connected),
- Combining digital products and (data-based) services, offering customers total solutions,
- Using data analytics to create products-as-a-service, and creating an online platform for customer access to content as well as date-based services,
- Integrating external data and products and services from other companies in one's offerings and platform, in order to unburden customers. This will mean cooperation with other suppliers and/or value chain integration, building a customer-centric ecosystem (PWC, 2016a)

The availability of data and new production technologies enhance the knowledge and control of the production process, making giant quality improvements possible (for instance zero defect).

4.3.2. Creating value based on Big Data

Organizations of the future are data-driven organizations, making money through collecting, aggregating, analyzing and (re)selling data.

Our survey shows that at this time, data is mostly used for optimisation and efficiency (Knowledge Alliance for Upskilling Europe's SMEs to Meet the Challenges of Smart Engineering, 2018).

The data landscape is a work field of its own with many aspects such as infrastructure, analysis, (smart data) applications, data sources, data management, clouds and platforms. Many companies already use data analytics to analyze and report on processes, focusing mostly on using data analytics to control and improve their overall business planning and manufacturing operations. But these approaches are just the beginning. There are other uses for data analytics that far fewer companies have on their radar screen. These include better R&D opportunities, better service and maintenance of companies' products owned by customers, and better cooperation and decision-making with customers and partner companies. These open up possibilities for new service offerings and ways of working. To succeed, companies will need to use data in predictive, forward-looking ways that make sense of market developments and customer behavior to improve products and develop new products and services (PWC, 2016c).

The purpose of collecting and analysing data can be:

- **Descriptive**: to find out what happened in the past
- **Diagnostic**: to understand why something has happened
- **Predictive**: to find out what might happen
- **Prescriptive**: to determine how a desired result could possibly be realized.

(Yaqin, 2016)

Usage data of products/machines is harvested to improve research and development, quality and operations, to create customized/personalized offerings based on user profiling and to create new products and services.
When starting to collect data, many companies face a dilemma. Should you start from the idea of collecting as much data as possible, analyzing and combining it later and ‚hoping' that you collected the right data to distil trends and predictions? Or should you start by devising what you strategically need to know and apply in 3-5 years time to decide what essential and specific data you should collect and analyze in the coming period? Formulating one specific question at a time, making an inventory of your internal and external data resources, making a list of variables and parameters that relate to your question and listing the datasets you need, might be good first steps. The next phase would be to 'clean' or filter your data before analysing, combining, validating and translating it into knowledge that can be converted into (new) valuable specifications, technological functions, products and services.

Monitoring regards both products and processes, and through remote controlling it is possible to optimize products and processes in real-time.

4.3.3. Smart services (servitization)

"Servitization starts with putting your customer in the center. Try to look beyond your product and to think carefully about what additional services are needed to offer your customer an optimal customer journey. The next step is to connect your products and use the resulting data to further improve the customer experience." ("Wat kan servitization jouw bedrijf opleveren? - MT.nl," 2017)

Service innovation is on the rise within larger industrial companies and multinationals. They expand their offerings by providing (disruptive) digital solutions such as data-driven services and integrated platform solutions ("Industry 4.0: Building the digital enterprise," 2016). Manufacturing companies turn into service providers or even integrated solutions providers (manufacturing as a service), turning service departments into profit centers instead of cost centers. More consciousness of manufacturing SME's in dealing with services, whether or not in addition to their current product portfolio, can mean higher sales, a better return on investments and a better bond with customers.

Service innovation, even more than product innovation, requires customer insights and co-creation. Defining a value proposition in another way e.g. supplying productivity instead of selling production systems-, opens up new ways of delivering value. It is up to the company to come up with optimal combinations of product(s) and service(s) or entirely new services in line with its core qualities, ambitions and visions.

Service innovation requires new organizational principles, new structures and processes, and are distinguished to product innovations particularly in the area of social development (organization and company culture) and business development. Services innovation offers plenty of innovation opportunities, but often means a conversion in the strategy and the organization of a company, especially in case of a product-oriented organization. Servitization is the process by which services play an increasingly important role in the business models of product oriented companies. Becoming a supplier of services, will affect a company's strategic position and customer relationships. In its most basic form, a manufacturer carries out only elementary installation and maintenance services, arising from warranty obligations (after sales services). A next step is to move to more proactive services, shifting from a product focus to a focus on the use of a product and providing all sorts of business services complementing it. In a smart way: Combining digital products and data-based services as a solution partner. In case of maintenance, a company can start by mapping out where its installed machines and appliances are located and work from there to a situation where it proactively can offer service. In addition to maintenance, a company can offer services as leasing (including finance of hardware products). Through the Internet of Things (IoT), 5G and blockchain technology, services as condition-based maintenance by means of remote monitoring of installations are made possible.

In the most far-reaching role, a company does not transfer products to customers, but offers value (e.g. guaranteed uptime / increase of productivity) through data-based products-as-a-service, including predictive maintenance to unburden its customers all the way as a value partner. An online platform for customer access to content and date-based services can be accomplished by partnerships or alignments with existing platforms. The development of (digital) platform solutions that merge multiple applications and components, can reinforce this role and position.

Fig. 18: A typology of service strategies. Adapted from 'Service addition as business market strategy: identification of transition trajectories', International Journal of Service Industry Management , 21, p. 698. (Matthyssens & Vandenbempt, 2010)

The above mentioned customer-access platform forms an important interface between the company and its customers. This user interface is an interactive link between a human being and a machine. A user interface aims to proactively help the customer, for instance visually or remotely. This is precisely where a manufacturing company can add a lot of customer value. For example, to inform a customer that there is a defect to his machine, even before the customer notices (Geertsma, n.d.). Due to even faster developments in technology and data networks, more smart customer-oriented interfaces can be developed, e.g. digital assistant applications.

Service Strategy and Service Management

Adding smart service(s) to tangible goods, machines or products, gives manufacturing SMEs the opportunity to add customer value and to develop new business- and revenue models.

Total added value = product added value + service added value + a combination of machine and service added value (van Looy, Gemmel, & Dierdonck, 2003).

A service and growth strategy is needed to decide what service value to develop. A sound service strategy should answer questions like:

- What are our customers' needs and expectations?
- What do we want our customer value to be? E.g. growing from delivering after sales to a genuine value partner
- What does it take us to get there? What needs to be changed in our company? How will we transfer our culture from product oriented into service oriented?
- What kind of services can we deliver (f.i. consultancy, training, maintenance etc.)?

- Related to maintenance:
  - What is the technical lifetime of our (machine) parts and assets?
  - What kind of maintenance strategies are useful and valuable for our customers?
  - TCO (Total-Cost-of-Ownership) models rises in popularity. But what does TCO mean for our business processes, financing, and service provision?
- What will be our revenue model on service(s)?

Different types of maintenance concepts can be distinguished:

- **RCM** (Reliability Centered Maintenance), based on reliability
- **TBM** (Time Based Maintenance), based on time intervals
- **TPM** (Total Productive Maintenance), optimizing machine availability.
- **CBM** (Condition Based Maintenance), status conditioned maintenance
- **Run-To-Failure**
- Combinations of the above.

At the moment we can see a shift from time-based maintenance (periodic preventive maintenance) to predictive maintenance (preventive maintenance as soon as a machine indicates that this is necessary).

Services can be delivered to customers at different levels, in different forms and within different customer relationships. The service market can be classified from generic to highly specific: from generic parts service and process / application service to full customer-centric services (Fig. 18). Each type of service demands a specific organization and specific competences.

ICT can not be ignored in a good service management policy, using specific software and systems. PDs, e.g. for receipt registration, can be linked to this system, feeding interactive reporting, financial administration and contract (e.g. SLAs with uptime agreements).

Keeping information up to date on installed machines, including delivered maintenance components, is not very well tuned in yet by many (SME) machine builders. Document management gives many SMEs a headache. Delivered factory parts are often not corresponding with the original drawings. For recall actions it is essential to know what strategic parts went into which machine (track and trace of parts). In addition, software updates (often partly client specific) are not well registered, which causes faults and even machines coming to a halt.

Development of a spare part strategy and spare part management can result in decent business profits. Classification of spare parts can be a first step: A-parts (generic items) can be bought everywhere, B-parts (more specialist articles) and C = parts (can only be ordered from the machine manufacturer itself). It can also ensure a sustainable relationship with customers and a high margin (new) revenue model, due to the locked-in system of C-parts delivery. By making machines and spare parts smart through connectivity, predictive maintenance can be made possible. In some years, connected machines will order their own spare parts just in time, all by themselves.

Within many machine building SMEs, a heavy cost item is keeping in stock parts of machines that have been built long ago. An obsolete parts list with accompanying phasing out strategy, can be an opportunity to provoke sales of a new machines.

4.3.4. Contributing to social and environmental issues with smart technical solutions

As we saw in the previous chapters, Smart Industry opens up new ways to use resources more efficiently, like reducing the need for raw materials (e.g. through additive manufacturing) and the consumption of energy (e.g. through remote maintenance).

Smart Industry in relation to social and environmental issues, also offers business opportunities to manufacturing companies. For instance, by improving or providing new (technical) solutions for sustainable energy, affordable medical devices, safety and sustainable and reliable mobility. "Within the Smart Industry domain, ICT, Mechatronics, Robotics and Manufacturing are enabling technologies essential to tackle the big challenges our society is facing. Novel robot technologies, precision motion systems, and energy-efficient drive techniques can, for example, constructively help to address problems we are facing in Climate Change (environmental monitoring, but also more efficient production), Energy (efficient design of machines), Health (novel diagnostic or robotic intervention), Mobility (coordinated intelligent transportations) and Security (Monitoring and Intelligent prevention or Screening)". In addition, Smart Industry ensures that these products and services can be delivered efficiently and local-to-local, keeping innovation and realization close to each other. ("[No title]," n.d.-c)

Upcoming revenue models related to servitization, like „products-as-a-service" (see chapter 5.3.5), in which a sold product remains owned by the producer, will require and contribute to advanced and integrated life cycle management, including (design to) reuse, refurbish and recycle.

4.3.5. Smart revenue models

A revenue model shows how the value created by a company, is converted into one or multiple income streams. A revenue model is not the capstone of a business model, it is an integral part of it. It describes who will pay for which value and how it is charged to customers. And, of course, the costs incurred to develop and deliver this value. The revenue model determines the price of products and services.

A company can support one revenue model (e.g. price per product) but it can also adopt multiple revenue models (e.g. fixed prices for machines and hourly rates for maintenance).

> A supplier of software can charge per software package, per customer transaction or offer the software cheap or even for free, charging for upgrades or services such as advice and training. So the same product offers multiple possibilities for merits.

One can approach the innovation of a revenue model in four different ways:

1. Offering more, different or new value and adjusting the revenue model accordingly.
   For example a subscriptions fee for preventive maintenance on machines.

2. Making the revenue model *a reason* for customers to buy and stay:

- Taking away financial thresholds by avoiding high investments for customers, for example by offering lease constructions. Or to offer a low(er) product price in combination with a service contract. Another possibility is to make fixed costs variable, for instance a machine builder can charge rental per hour, payment for uptime or payment per product produced on his machine. The trend 'from ownership to access' will shift financial risks from customers to suppliers. A drawback for SMEs is that they are not as well provided with enough capital to offer this kind of revenue models.

- Offering subscriptions (maintenance contracts, financial services, consultancy, engineering/refit services, data services, service support (digital help), special spare parts delivery and stock etc.). In this way, a company can bind customers. This kind of revenue models offer customers clarity and certainty of delivery and ensure suppliers a regular income during the term of the agreement.

- Differentiated or modular offers; different prices for different types of services or a basic package to which a customer can add products or services. Customers have the opportunity to choose something that suits their needs and budget. In this way, a supplier can appeal to multiple customer groups.

3. Make the value of goods and services *visible* that are now provided for free, and ask for value (in any form) in return. This could be engineering hours for quotations, after sales services or data that is provided to customers.

4. Use and value a company's resources in a better way, including data. For instance, your customer might be very interested in the data you are generating for condition monitoring of your products or installed machines (5.3.2, Creating value with data).

Another way of charging a customer, often means that new target groups are being addressed or that a companies' offer is changing. Conversely, a new offer or a new target group can mean reasons and opportunities for a new revenue model.

Relevant revenue models for manufacturing companies are:

- The traditional model of product sales and hourly invoices for (added) services (exchange models);
- Rental, licensing, hosting (utility models);
- Revenue models based on measured consumption (supplying models):
  Customers pay for use or consumption of products or services (*pay per use*). Often a basic price is offered with a usage surcharge, in subscription form. *Prepaid, Pay As You Go or Pay As You Use* are forms in which you pay in advance for a credit. The credit will be debited when the service is actually used.
- Customers pay for value that is actually delivered (performance models), e.g. *uptime agreements* on machines;
- *'Waste' as a commodity*, e.g. designer furniture of reclaimed wood (reuse or circular models);
- Delivering products and services that are free of charge or inexpensive, while customers pay for (spare)parts, services or upgrades. Like relatively cheap printers with expensive ink cartridges or paid extra services of Skype and Spotify (entry-level or freemium models).

Smart revenue models combine these existing principles and models with new technical possibilities. By defining your products in another way, (new) services can be added or created. Think of leasing, insurance or logistic services. Due to connectivity of products and machines and the data provided by them, (composed) revenue models like dynamic pricing, pay per use, pay for uptime or pay per approved product/part, will be applied more and more in industry. Leaving it up to a company's creativity to fulfill its value proposition with (a mix of) products, services and applications (e.g. users pay for use of light instead of buying lamps).

4.4. SMART Innovation of products, processes and services

Author: Prof. dr. Borut Likar, MBA

Limited time, unlimited options

Future proof market strategies and shockproof product portfolios are created by blending two interacting major forces: technology-push and market-pull. Continuous customer centric research, development and innovation based on state of the art technologies, is the guideline for effective and smart product management. With constantly changing customer needs and almost infinite technical options to fulfill them, product management as well a R&D will more and more get the characteristics of innovation management.

Managing Innovation in SMeART Industries

Innovation is vital for European competitiveness in the global economy. The EU is implementing policies and programs that support the development of innovation to increase investment in research and development, and to better convert research into improved goods, services or processes for the market. As highlighted by EU Industrial Policy, industry is crucial for EU competitiveness and innovation is a key factor in this regard. It is especially important for Industry 4.0.

4.4.1. Developing a smart innovation portfolio

Firstly, it should be stressed that companies which are innovating and also addressing various types of innovations, are more shockproof and survive economic recessions easier. Therefore, it is important not to be limited only to new product developments. Innovation activities bring highest value if balanced and addressing different types of innovations as follows:

- Product (which results in new products or services or enhancements to old products or services)
- Process (which results in improved processes within the organisation – for example business process re-engineering)
- Marketing innovation (including the functions of product promotion, pricing and distribution)
- Organisation (which improves the way the organisation is managed)
- Process innovations (improvement of all processes, also R&D and production processes in smart industry)

Additional typology of innovations:

- Technological and non-technological innovations
- For smart industry technological innovations are important, e.g. technological breakthroughs based on API- Application programming interface. At the same time, non technological innovations are related to company performances and also to market(s).
- Incremental and radical innovations
- Even though incremental innovations often represent smaller improvements related with minor financial results, we can expect many of them in companies. On the other side, radical innovations can bring huge financial results, but are rare and often risky – e.g. the inventor of the turbo reactive motor/airplane was De Havilland (Comet), but the final winner was Boeing, which was actually an innovation follower.
- Technology-push and market-pull concept
- Some innovations are strictly technology-push driven (e.g. electric airplanes, where the bottleneck are high capacity batteries), others are following the market-pull concept (e.g. development of the digital camera and photo editing software).

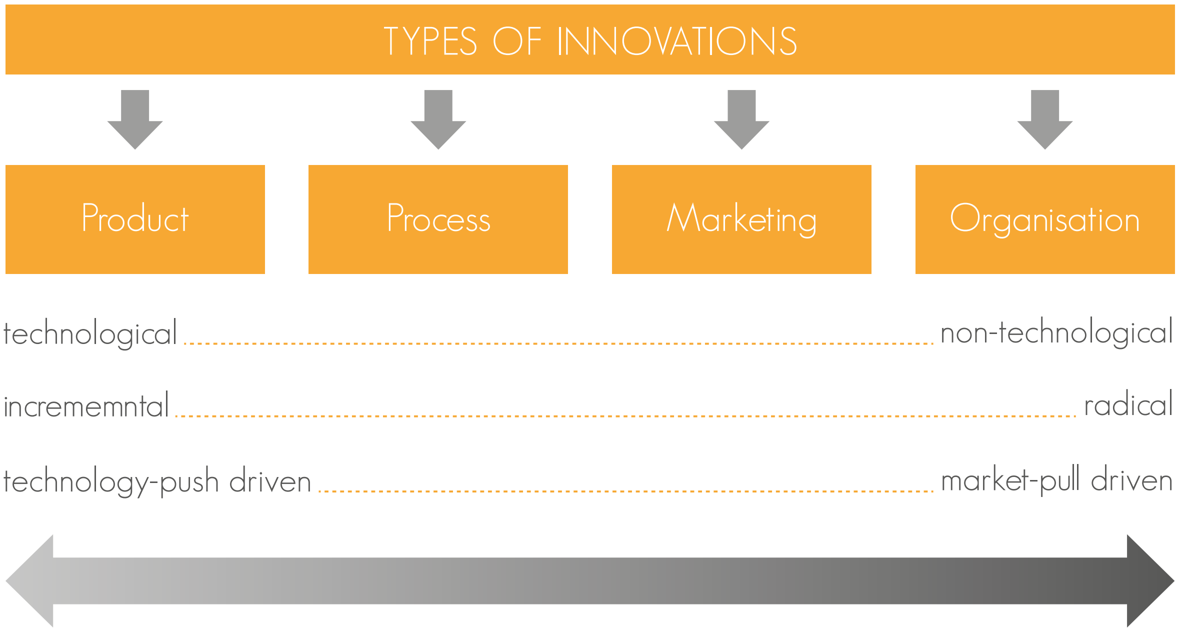

Fig. 19: Typology of innovation. Companies which are innovating and also addressing various types of innovations, are more shock proof.

There are some other types, which are becoming more and more important in the last years:

- Eco-innovation
  It is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risks, pollution and other negative impacts on resources used (including energy use) compared to relevant alternatives.

- Social innovations
  These are new strategies, concepts, ideas and organizations that aim to meet social needs resulting from working conditions, education, community development, and health. These ideas are created with the goal of extending and strengthening civil society.

For a smart company it is important to have all types of innovations in mind because each of them can bring benefits. But of course it should focus on those which are related with the smart company's core business.

4.4.2. Innovation management

According to the words of management guru Peter Drucker each organisation needs one key competence: innovation. This is the process by which businesses improve their competitiveness and profitability. Innovations result in the development of new products and services, new features in existing products and services, and new ways to produce or sell them or a different approach to any other process within the company. Completely new ways of doing business are often called new business models, which bring highest added value. We can say that innovation is not only a process, it is a way of life.

If we want to establish or improve innovation within the organisation, there is not a uniform procedure how to do it. But there are many elements and concepts, which can help companies to achieve the innovative performance. Innovation management begins with defining the strategy and setting innovation objectives. An innovation strategy is a strategy of efficient answers to competition. Developing successful innovation strategies is often difficult, which explains why many firms choose not to do so, even though the benefits of innovating are widely understood.

The scope of innovation

The most common innovation goals are the following (Likar & Fatur, 2007):

- Increase added value for customers
- Reduce product/ service costs
- Increase innovation hit rate
- Improve product/ service quality
- Increase development efficiency
- Increase rate of product/ service introductions
- Shorten time to market
- Develop new product/ service categories
- Create new business models
- Improve working conditions for employees.

Building the innovative culture

If the company wants to achieve mentioned and similar goals, building the innovative culture is essential and encompasses:

- Leadership by visionary, enthusiastic champions of change
- Top management support and encouragement of creativity, both financial and psychological
- An effective communication system. Leaders share the business vision with their staff and empower them to optimise their potential in achieving the business goals
- Flexibility towards new thinking and new behaviour patterns. The creative organisation readily adapts to change and proactively searches for new opportunities
- Customer focus
- A creative culture is outwardly focused, looking for ideas among customers, competitors, academe, suppliers, and even industries with a different focus.

The culture of innovation can be developed by:

- Selecting innovative employees
- Training for creativity and innovation
- Developing a learning culture
- Empowering the employees
- Setting up idea capture schemes
- Developing managers to support the innovation of others
- Making creativity a requirement of the job
- Improving employee participation in decision-making
- Having appropriate reward systems for innovations
- Allowing risk-taking as an acceptable mode of practice
- Encouraging investments in research and development
- Benchmarking (actively undertaking systematic approaches to locate and assess good practice elsewhere in attempts to improve your own performance).

Some other important measures affecting the organisational environment:

Responsibility of innovation placed on all staff:
While some roles will be more directly involved in innovation (e.g. research and development, product development) all staff should have a mandate to act innovatively within their roles.

Human resource system that develops and encourages staff to be innovative. This requires a dedication to training, education, mentoring and the rewarding of staff for innovative behaviours. Staff also needs time and resource allocations to stop and think about new ideas, which will not happen while they are giving 100% of their time to the daily routine. Especially for smart industries, permanent training focused on new technologies and fast developing sectors is essential.

Performance measurement system that measures the innovative pulse of a company. Simple measures that are often used include spending on innovation (often labelled R&D expenditure), a new product percentage (number of new/ changed products introduced this period as a proportion of total product numbers) and a number of patents held.

Linkages with the marketing function:
Understanding the customers, their needs, and the competition is critical for targeting resources to the innovation systems. The most successful innovators understand the customer's needs better than the customers themselves. They are often able to identify and solve problems before the customer has realised that perhaps there is a problem, let alone thought about buying a solution.

Knowledge acquisition and management processes that constantly bring new ideas, information, concepts and knowledge into the organisation. This can range from simple things such as receiving trade, scientific, engineering and professional magazines, attendance at conferences and participation in industry networking forums right through to having a comprehensive research capability. Where knowledge is not readily available, polytechnics, universities and research institutes have the capabilities for developing it for you.

Intellectual property management systems that identify, protect, value, manage and audit the organisation's intellectual property (IP). This intellectual property is the new knowledge that arises out of the innovation process e.g. it may be a unique understanding of a production process that facilitates superior efficiency or design in a new product. Some organisations have difficulties in identifying their IP. One way of doing so is to answer the question: What do we know and our competitors don't and what do we not want them to know? Once identified, it needs to be protected or the competitors will find out! Protecting your IP can range from simply keeping it confidential, not only physically but also electronically up to more formal means such as trademark protection, patents and plant variety protection. These are especially important for smart technologies. Last but not least, one of the most important instruments is being faster than the competitors: Responding to the market needs, developing the novelty, selling the product and when competitors succeed to copy it, you will already have a new one. This is also a concept of Akrapovič, Slovenian manufacturer of exhaust systems: one of the best in the world.

Fig. 20: Casy Stoner with Akrapovič's exhaust system, which is permanently innovated. Some elements are patented, the other protected following the fast "time to market" concept. (Google free pictures)

Open innovation is a concept where boundaries between a company itself and its environment have become more permeable; innovations can easily transfer inward and outward between firms and other firms and between firms and creative consumers, academic institutions and researchers resulting in impacts at the level of the consumer, the firm, the industry and the society (Wikipedia contributors, 2018a). At the same time it enables companies to search for new ways of commercialising their ideas and know-how by selling intellectual property rights, spin-offs and other forms. Clustering of similar organisations and their supportive industries is a proven tool for ensuring collective growth by sharing those parts of the innovation and business process where their interests overlap (e.g. European Automotive Cluster Network - an initiative that reunites nine of the most important cluster initiatives in the automotive sector from seven European countries).

OPEN INNOVATION

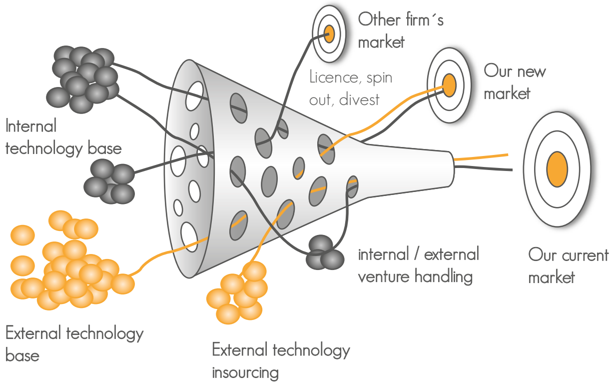

Fig. 21: Open innovation concept (Lubiewa-Wielezynsk, n.d.)

Flexible, organic structure, which encourages teamwork and also acts as a stimulant to people to be more creative. Having an elastic business definition helps to ward against protectionist instincts and the organisation thus avoids subconscious defence against necessary changes. The management of the organisation should be directed to spend a significant amount of its time looking for opportunities outside the boundaries of the business they are managing.

Employees' motivation:
Motivating an employee means that he should feel his personal success at work, his positive contribution to the company's goal, his responsibility corresponding to abilities, acknowledgement for his performance, the acquirement of new experiences and development of abilities.

Participative leadership style:
Managers focus both on the task and the subordinates and enable them to participate in the planning and decision-making process.

Flexible organisational boundaries:
It is not necessary to create all innovations internally. Partnerships can be a useful strategy to promote innovation. Also, in addition to development, acquisition can be an effective innovation strategy.

Manage the risk:
A strategy should not be monolithic; it should be sufficiently varied to allow organisational agility and flexibility. You need to remember that most innovation ideas will not pan out, so don't think big in terms of funding every single innovative idea. The strategy should be to fund a number of ideas. A low-risk experimentation is of key importance – invest in many ventures but start out small. Although most new ventures will fail, a learning effect can be acquired from each. Project risks must be distinguished from portfolio risks – the risk of any new project will be high but if there are enough innovation projects, the portfolio risk will be manageable.

Transform organisational strategy:
A typical strategic planning is often antithetical to promoting radically innovative business models and strategies. Innovation cannot be held to a scheduled strategic planning timeline; it should be on-going. Also, strategy should not be restricted to the same set of top level decision-makers. An innovative strategy does not necessarily come from the top but too often not a word about contributing strategically appears in the performance criteria for anyone below the level of senior executive.

Other factors, as a systematic collection of all impulses that could lead to innovation, good team work, continued education of employees, the ability to finance the innovation activities (Likar & Fatur, 2007).

4.4.3. Developing an innovative product or service

Regarding the innovative process, it is possible to define key stages, as a route to achieve progresses for innovation. However, it should be taken into consideration that innovation is a multicausal and not-linear phenomenon, which is defined as a result of a wide range of links, interactions, cycles and feed-backs (Likar et al., 2013).

Attending to these considerations, we can draw main stages:

A. Problem/ opportunity identification
B. Problem redefinition
C. Ideation
D. Pretotyping/Prototyping
E. Idea testing and selection.

4.4.3.1. Problem/ opportunity identification concepts

Finding new opportunities may involve:

- periodic review of external and internal opportunities of the organisation
- establish the proper communication channels (in order to "hear" the opportunities)
- develop methodologies to identify trends and insights (e.g. trend in Cryptocurrency)
- perception of market opportunities (e.g. big ship cruises)
- detection of competition's weaknesses (e.g. long response time for pizzas' delivery)
- detection of technology opportunities (e.g. blockchain technology)
- knowledge form academic institutions (related to Spin-off, e.g. plasma cleaning concepts)
- building on our own hobbies (e.g. Pipistrel – Slovenian producer of ultralight airplanes)
- legislation requirements (e.g. environmental standards for car engines).

Problem understanding tools

In addition to the mentioned concepts, concrete tools are available, e.g.:

Ishikawa Diagram (fishbone diagram) is usually implemented in the context of a group, which is considering the possible causes of a problem which is broken down into several levels of sub-causes. Thus, we gradually extract and identify the underlying or root causes of the basic problem. We can also expect ideas for solutions.

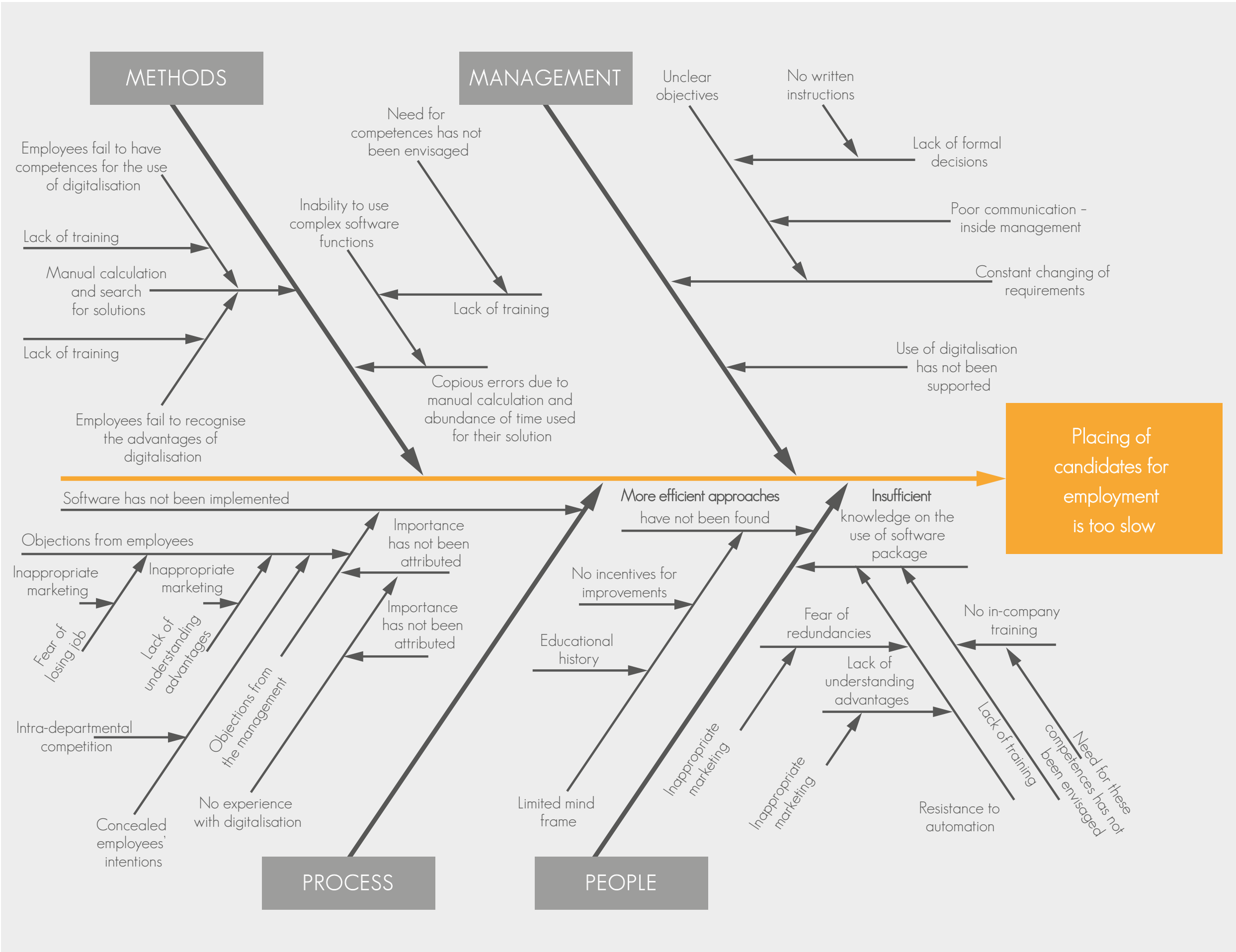

Fig. 22: Ishikawa Diagram in praxis (source; Košmrlj, K., Širok, K., & Likar, B. 2015)

QaDIM (Quick and Dirty Method) is primarily intended for the identification of opportunities for incremental innovations on the already existing product, but in the process of discovering problems and opportunities, an idea for a breakthrough innovation may also arise.

SWOT Analysis:
A problem or a challenge is addressed from the point of view of its strengths, weaknesses, opportunities and threats.

TRIZ entails a systematic approach to review patent databases. We approach the solving of a problem by redefining it with regard to previous related problems, the solutions which we can find in the patent database. The slogan of this tool is that „someone somewhere has already solved such a (or very similar) problem".

Delphi is a lengthy and complex method, which attempts to predict future developments in the field under consideration (e.g. the future of photovoltaics). It is based on the individual work of more individuals who are experts or connoisseurs in the field.

eMIP:
Methodology for mass identification of problems which are present in the company and its environment, yet not sufficiently clearly detected. It is very appropriate for applying the open innovation concept, where also external partners form the value chain are participating.

Innovation Cube directs participants systematically towards a broader way of considering and addressing problems and needs, opportunities and ideas for novelties as well as towards finding new markets, also future trends.

Understanding the customer
Many innovations are a response to customers' needs. Therefore, it is crucial to understand the need of the market or a concrete customer. Empathy helps to understand them

better and to define the problem properly. Empathy helps to be human/customer oriented rather than technology focused which can result in product failure. An example is Google Glass: While being technologically impressive, it failed to perform well, and a lot of that comes down to a lack of empathy towards the users. On the other hand, the innovation called the Embrace Warmer (new type of incubator for developing countries http://embraceglobal.org/about-us/) has been developed by postgraduate students at Stanford following the empathy concept and became very successful.

Empathy based methods

Conduct interviews with empathy. Empathy interviews are the cornerstone of Design Thinking. By entering and understanding another person's thoughts, feelings, and motivations, we can understand the choices the person makes, we can understand his behavioural traits, and we are able to identify his needs. This helps us to innovate and create products or services for that person (Empathy methods, 2018 – pls. see link within paragraph Literature for more info).

Use photo and video user-based studies. Photographing or recording target users, like other empathizing methods, can help you uncover needs that people have which they may or may not be aware of.

Other useful methods: Assume a beginner's mindset. Ask What-How-Why. Engage with extreme users. (Design thinking, 2018).

4.4.3.2. Problem redefinition

Rather than accepting the problem, it is important to explore, describe and analyse the problem and its context and re-interpret or restructure the given problem in order to reach a particular framing of the problem that suggests a route to a solution. You can also use the presented Ishikawa Diagram.

For more info see: The art of managing innovation problems and opportunities (Košmrlj, Širok, & Likar, 2015)Košmrlj, K., Širok, K., & Likar, B.(Košmrlj et al., 2015).

4.4.3.3. Ideation

Ideas come from people we know, stories we hear, the work we do, our interests, our opinions and our experiences. Business ideas are all around you. Some business ideas come from a careful analysis of market trends and consumer needs; others come from luck. But how can you find a source of ideas and knowledge? A very important base is a clear definition of problems and opportunities, which has already been presented (Likar & Fatur, 2007).

In order to maximize the creative potential of the problem solving group, the idea generation activity should be of a collaborative nature. This can be accomplished in many ways. Idea management and innovation process management often provide collaboration tools, while facilitators of brainstorming and other ideation events should promote collaborative idea development (Schober et all, 2015)

Some techniques for creation of ideas:

- Brainstorming
- Philips buzz 66
- Bionics
- Six thinking hats.

Brainstorming can be viewed as a 'storm of ideas'. It is a team problem solving method. The basic rule is that all team members are equal and the session should have the character of a friendly meeting. The team is mostly led by a moderator. Criticism or evaluation of suggestions are strictly forbidden. That will be done within the next phases.

Philips buzz 66 is very similar to Brainstorming, but very short and appropriate for solving of daily challenges with only few participants. It can be efficiently used over the course of a daily coffee.

‚Six Thinking Hats' is a powerful technique. It is used to look at decisions from a number of important perspectives, e.g. emotional, intuitive, creative or negative viewpoint. If you look at a problem with the ‚Six Thinking Hats' technique, then you will solve it using all approaches. Your decisions and plans will mix ambition, skills in execution, public sensitivity, creativity and good contingency planning.

Bionics or biologically inspired engineering is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. Examples of bionics in engineering include the hulls of boats imitating the thick skin of dolphins; sonar, radar, and medical ultrasound imaging (picture showing a human embryo) imitating animal echolocation. In the field of computer science, the study of bionics has produced artificial neurons, and artificial neural networks. Due to its specificity, this method represents a strong tool for smart industries.

4.4.3.4. Pretotyping/Prototyping

Pretotyping is a simple way of materialisation of ideas (often made in some hours or a day) before attempting to actually prototype it. Therefore, we get an idea and insight into future challenges – conceptual, development, technology, costs.

Rapid prototyping tools
A prototype is an early sample, model, or release of a product built to test a novelty concept or process. It should be prepared in a way so that the entire functioning of innovations can be tested or their final version can perform its function. The aim is to be presented to final users or potential buyers. It can be done using rapid prototyping tools, e.g. CAD/CAM, 3D printing, laser cutting, selective laser sintering etc. Often it is possible to use standard electro-mechanical devices and components, „kit" versions, finished completed modules. For technical inventions we can use universal programmable electronic circuit, development„open source" platforms, like Arduino etc. At the same time, work should be done professionally - in terms of functionality and design. The aim of prototyping is to be flexible and fast and have the possibility to redesign it after testing.

Idea testing and selection
The phase of idea assessment and selection is one of the most critical phases of the innovation process. The praxis demonstrates that inventors or companies' managements frequently fail to consider its value precisely enough. They thus continue with development and the phases which follow while the costs increase dramatically. There are some main filters helping us to choose ideas with highest potential:

- test your novelty by your customers/final users
- verify various aspects of the new concept.

Test your novelty by your customers/final users
Testing means to get feedback from potential users/customers. Instead of describing the idea, a more efficient way is to present a prototype and get a deeper understanding of the users. The most important questions, which should be answered, are: Do the users like the novelty/prototype? Do they understand how to use it? Is the use intuitive enough? Is it user friendly? Does it fulfil the users' requirements? Are there too many functions available etc.?
When undertaken correctly, the testing stage allows you to empathise and gain a better understanding of your users. Even better results can be achieved if testing is done in a real life environment (e.g. testing of alpinist equipment in the mountains). It is also important that we track reactions during the usage (emotions, use, understanding, practicality…).

Beside non-verbal feedback, it is also useful to talk about the experience. You may ask them what they're thinking about the novelty. It also makes sense to encourage them to talk about (un)related topics.

When you get all the feedback, analyse the responses and use them for the concept/prototype improvement. After that, testing should be repeated.

Verify various aspects of the new concept
Before starting with pre(o)totyping, ideas should be evaluated and selected as well.

- Key success factors (we define and evaluate most important aspects, e.g. market potential, feasibility study & technological aspects, financial aspects, production price etc.)
- SWOT analysis (see previous text)
- Input/Result method (ration between inputs needed and expected results)
- Numerical sensitive analysis (make calculation and simulations related financial and other aspects)?

It is important to select one or more most relevant methods, analyse the results and use them as input in a decision face. Often it is useful to also take into account the results of the previous phase related to problem/opportunity analysis.

Design thinking

One of the modern approaches dealing with the idea-innovation process is Design Thinking (also known as D Schools).

Design thinking refers to the cognitive, strategic and practical processes by which design concepts (proposals for new products, buildings, machines, etc.) are developed by designers and/or design teams. Compared to the innovation process presented, a strong emphasis is given to the first phase - understanding the problem/need of the final user. It is also very human-focused and prototype-oriented.

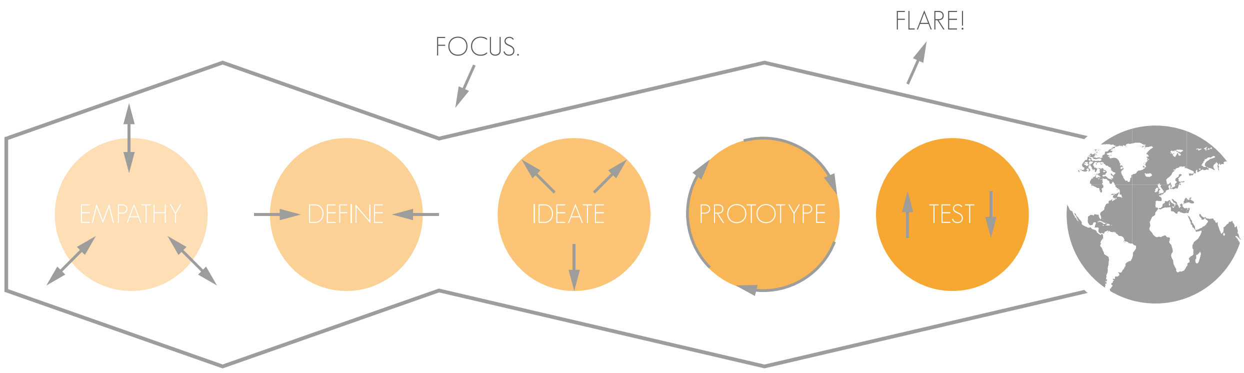

Fig. 23: Design thinking concept. (Design, 2018)

One of the properties of modern innovation development concepts is that all phases are strongly interrelated - e.g. when prototype is done, we often need to redefine our problem, create new ideas, etc. and prepare a new prototype. Similar situation occurs in other phases (Design thinking-wiki, 2018, Design thinking, 2018).

Roadmap to the final product and/or service

Within the section 4.3., we focused on the innovation process. Therefore, we would just like to briefly present a wider picture – basic steps and processes which should be done to transform ideas into the final market product as follows:

- Innovation strategy and goals (see: Innovation management)
- Development of innovative organisation and culture (see: Innovation management)
- The process of innovation (see: Developing an innovative product/service)
- Research and development (especially smart industries are closely related to R&D – see also: Innovation management, Cooperation between Higher Education Institutions and Businesses)
- Intellectual property protection (see: Innovation management)
- How to finance innovation (e.g. subsidies - EU, national and regional and local programmes, credits, venture capital, tax incentives etc.)
- Production
- Marketing.

More can be found in other parts of these guidelines and in literature.

Instead of a conclusion, we prepared a simple recipe for innovation:

Basic Ingredients: a large spoon of creativity, a bit of criticism, a healthy measure of research spirit, a positive thought that others will love our novelty too, a pinch of teamwork, a spice of an appropriate speed so that the dish does not dry out, a couple of drops of managerial courage. Stir well together, make it hot, and success is guaranteed. Bon Appetite.

4.5. SMART Marketing

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Digital transformation has far-reaching implications for all activities that create added value across entire companies and value chains. Due to new technologies, for example Smart Engineering, previously distinctly separate areas such as procurement, production and sales have become interconnected units which need to be effectively coordinated, not only within the confines of one single company. Consumers too are integrated into the value creation processes of every company through digitisation (Biesel & Hame, 2018, p. 9). Likewise, the discipline of Marketing is a subject to far-reaching changes. Consumers are no longer just looking for a product simply to consume. Instead they want to contribute to its development, want it to be tailored to their own needs and wish to interact with the product. In addition, they are looking for ways to evaluate the product and to share their experiences of using the product. Through the use of social media and new technologies, products as well as the development and production processes are becoming more transparent. Companies and customers are becoming a single interconnected entity. Consumers are taking over tasks from producers, which is reflected in the word prosumer (Vikram, 2016). The company, however, acquires knowledge about customers and markets, which can in turn be used to optimise their offer and to adapt it to different target groups. In summary, transformation means for companies, deriving processes from customers and using appropriate technologies to achieve the successful positioning of the company and its products on a globally transparent market (Biesel & Hame, 2018, p. 1). The following section highlights the impact that digital transformation is having on marketing.

4.5.1. The development of Marketing 4.0

Marketing has changed dramatically since the beginning of industrialisation. In the early stages of industrialisation and mass production, marketing was implemented through the producer's perspective. Based on a seller's market with a limited range of products, the needs and wishes of customers played a subordinate role to those of the companies. Rather, technological progress was the driving force behind product development. Thus, there existed a product-centric marketing approach. Marketing was solely focused on the mere sale of products without any regard for the needs of customers or markets.

With increasing ranges of products on offer, a greater choice for customers was created, which in turn greatly altered the challenges faced by marketing. Customers compared products and became more informed about them. Producers were therefore forced to highlight the value of their products to customers. The focus of Marketing 2.0 shifted from a product to a consumer-oriented approach.

Changing social values, in particular due to generation Y, meant that consumers were becoming more interested in the sustainability of products and companies. This became particularly evident through the newly identified group LOHAS (lifestyle of health and sustainability). Consequently, companies were required to communicate clearly to the consumer how products are manufactured and how companies safeguard their social responsibility (Stehr & Struve, 2017, pp. 3–10).

With Marketing 3.0 it became important to understand the buyer not only as a customer, but also as a person whose values influence the purchase of a product. The corporate social responsibility (CSR) of a company became integrated into the communication processes to support positive purchase decisions by customers. Not only the product, but also the economic, social and environmental responsibility of the company became part of Marketing 3.0.

Through the increasing use of social media, brand and product communication became a two-way process. No longer do companies just communicate their products, but consumers evaluate and communicate their own experiences, as well as influence other potential customers. At the same time technological development has also enabled customers to participate in the development or design of the product. Likewise, there is an increasing desire to connect products and interact with products. The role of the customers in Marketing 4.0 has changed even more. They are now fellow developers, creators of ideas and evaluators of products. Thus, Marketing 4.0 means the integration of the customer into the marketing process through collaboration (Jara, Parra, & Skarmeta, 2012, p. 854).

4.5.2. Definition of Marketing 4.0

Currently there is very little literature available offering comprehensive definitions concerning the topic of Marketing 4.0 or digital marketing.

Lies describes Marketing 4.0 as follows:
„Marketing 4.0 is (...) essentially understood as the current phase of marketing, which no longer regards the market first but rather the customer as its human focus, and at the same time shapes digitisation as an applied digital transformation of the middle class." (Lies, 2017, p. 59).

The more general definition is emphasised further by the term „concretisation", coined by the Financial Times. Digital Marketing is defined as follows:
„The marketing of products or services using digital channels to reach consumers. The key objective is to promote brands through various forms of digital media. Digital marketing extends beyond internet marketing to include channels that do not require the use of the internet. It includes mobile phones (both SMS and MMS), social media marketing, display advertising, search engine marketing, and any other form of digital media." ("Digital Marketing Definition," 2018).

Kotler approaches this topic with a comprehensive description. Under Marketing 4.0, Kotler's approach is followed, and Marketing 4.0 is defined as follows:
„Marketing 4.0 is a marketing approach that combines online and offline interaction between companies and customers. In the digital economy, digital interaction alone is not sufficient. In fact, in an increasingly online world, the offline touch represents a strong differentiation. Marketing 4.0 blends style with substance. While it is imperative for brands to be more flexible and adaptive due to rapid technological trends, their authentic character is more important than ever. Its authenticity, in an increasingly transparent world, is its most valuable asset." (Kotler, 2016).

Therefore, overall, the term „Smart Marketing" can be understood as follows:
Smart Marketing means the expansion of consumer-centric online and offline marketing through the integration of technologies for interaction with consumers, as well as through integrated digitalisation of processes and use of data, to achieve the optimisation, flexibilisation and personalisation of customer contact.

4.5.3. Consequences of Marketing 4.0

The ever-increasing interconnection between companies and customers is leading to more and more power moving into the hands of the customer. For one, through social networks and other social media applications, in general, transparency with regard to similar products and prices is becoming increasingly significant. Through trading platforms, which enable worldwide sourcing of products and access to international brands, pressure is steadily increasing on producers. In addition, the customer, with the ability to rate and comment upon products, can now actively influence the reputation of the product, brand or company. The credibility of marketing and the creation of added value for the customer, who makes change more difficult, is thus becoming a decisive success factor within Marketing 4.0.

As a consequence, Marketing 4.0 consequently influences the primary components of the classic brand management concept (see Fig. 20).
Basically, according to the model, a brand first requires the right identity. Burman et. al. (2012) describe these as „the self-image of the brand from the perspective of the internal target groups within the institution that bears the brand" (Burmann et al., 2012). Concretely, identity thus transports the consistent and elementally essential characteristics of a brand (see Esch et al., 2005) in the direction of external target groups. In particular, it is crucial to create an identity that allows the brand to differentiate itself from other products, services or businesses because of its specifics (regarding a unique selling proposition).

Building on this self-image of the brand, companies issue concrete targets that go hand in hand with the corresponding positioning of the brand (e.g. as a premium brand for the solvent lady over 50). This presupposes a correspondingly designed target-group-specific communication policy and, if successful, leads to a consistent brand image. The term brand image, therefore, represents the external image of the brand and is the result of a meaningfully designed brand management. „Image" here describes the image that „[..] is

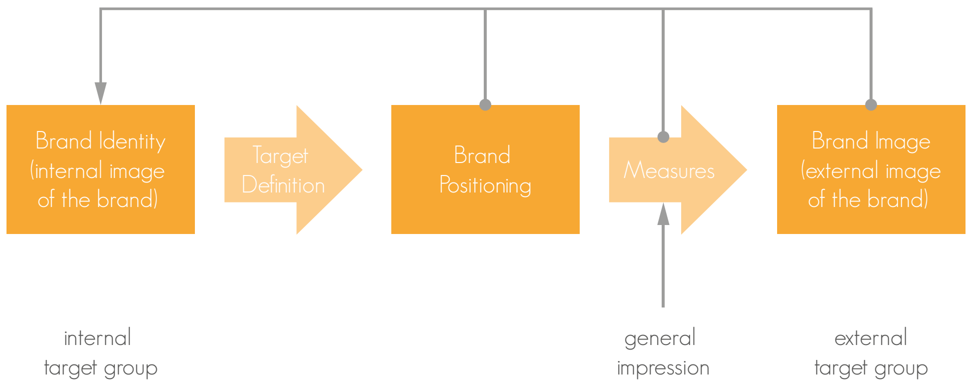


Fig. 24: Brand identity, brand positioning and brand image. In reference to: Esch 2012, 9

composed of subjective impressions of the consumers to a holistic image of the brand image" (Burmann / Blinda 2006, 8).

Marketing 3.0 addresses the mind, heart and soul of the consumer. Kotler (Kotler et al., 2010, p. 54 ff.) describes the latter as „Central DNA" (Kotler, Kartajaya, & Setiawan, 2010, p. 55). A product receives its brand identity through the brand itself and its positioning. The differentiation of the product supports the brand integrity, and thus its credibility. Through differentiation the needs of each customer can be met. When commitments to the customer are upheld and the brand meets the customer needs then the result is a positive brand image. The identity ensures that there exists a clear brand image in the mind of the consumer, that there is integrity for consumer confidence in the brand and that the image provides the consumer with an emotional connection to the brand. Marketing 4.0 extends this triangle to a fourth dimension, the experience and the resulting associated interaction with the brand. Above all the customer experience is the focus of this interaction. This interaction takes place at different levels (Jara et al., 2012):

- Interaction between product and consumer (e.g. displaying application examples or processing examples via a QR code)
- Interaction between different products of a brand or different brands (e.g. interaction of various Apple devices with each other)
- Interaction via online platforms and social media channels to analyse whether a product complies with the requirements and needs of the user (e.g. search engine results, rating platforms, social media posts)
- Checking brand integrity and reputation by reviewing the brand with the values and experiences of other customers (e.g. social media posts, test reports, CSR reports).

By means of typical interactions, multiple stakeholders can therefore influence the company within Marketing 4.0. These are highlighted by different characteristics (Lies, 2017, p. 11):

1. Online-Offline-Orientation (OOO): In particular, generation Y and the current generation Z, which have grown up with digital media, switch between online and offline options. Thus, Online-Offline Orientation has led to the ROPO purchase behaviour. ROPO stands for Research Online and Purchase Offline (Richter, 2017). Accordingly, it remains essential in Marketing 4.0 to serve different online and offline channels.
2. Active approach: Stakeholders interact with companies by expressing their opinions through sharing, liking or posting, recommending a company or product, or collaboratively participating in the product development process. Therefore, Marketing 4.0 needs to be structured in such a way that customers are able to interact.
3. Late purchase decision-making: Due to the vast array of possibilities available, the online- offline customer journey offers customers a wide variety of options for comparisons. Purchase decisions are made frequently quite late or even not at all. Smart Marketing can aim to motivate the customer to make a positive purchase decision.
4. Experience orientation: In today's world shopping should be a positive experience for many customers. In the over the counter retail sector this means that marketing needs to create unique worlds that encourage customers to enter a shop. Within online retailing this can also mean offering platforms with good levels of usability and which facilitate the easy acquisition of goods.

4.5.4. The Challenges of Modern Marketing

Digitalisation of customer management

The challenges posed by the fourth dimension of „Interaction" mean that customer management is also required to undergo fundamental changes. The following consequences are particularly relevant in the case of medium-sized companies.

Defining the brand, product and performance strategy
Even if a company continues to decide itself which products and services it wishes to offer and under which brand, it is no longer independent within today's digitised world. A variety of stakeholders will affect decisions taken by companies, for example by the fact that opinions about a company, product or needs can be expressed through social media forums. In order to be successful in the market, it is important to incorporate these findings into the development of a product and service strategy.

Defining products and services
The precise definition of products and services offered by a company is ultimately based on the evaluation and use of data obtained via the various stakeholders. In addition, products undergo agile processes through scrutiny by various stakeholders, so that the success of a product is not only measured after the launch of the product, but rather in advance of its launch by means of analysis through various iterative processes. „Always in Beta" describes the fact that products or services are not brought to the market in a perfect form, but rather in an advanced prototype stage (Bruce & Jeromin, 2016, p. 63).

Smart Production
Automated and modularised production processes allow that, in a so-called smart factory, customers can configure products themselves, and which can then be manufactured as individualised products despite the use of mass production methods. Customers now become prosumers. This value creation, which goes back to ideas of Alvin Toffler, describes the combining of producer and consumer into a single person in the form of co-designers or co-producers (Toffler, 1983).

Digitalised processes
The digitisation of processes within companies reduces the number of interfaces involved in terms of customer management. Companies can also pass on subtasks to customers through self-service portals, which leads to advantages in relation to efficiency (see chapter 2). Processing times as well as errors can thus be reduced.

Defining Smarter Data
In order to optimise processes from the business and customer perspectives, it is essential to use data smartly. It is therefore necessary to specify which data should be evaluated and stored in order to optimise processes and thus satisfy customers.

4.5.5. Consumer dialogue in a digitised world of brands

In an environment, in which each enterprise, each brand and each product can be compared on a world-wide basis with competitors, it is essential that marketing is target-group-specific and speaks to customers. The following instruments support optimised and smart online marketing (see Fig. 25).

Online marketing takes place at different levels. Some of the instruments employed are visible to the end-user, whilst others remain hidden.

Visible online marketing is undertaken, on the one hand, through traditional advertising banners or product or company images, which can be displayed on company-own websites, websites of third parties as well as on various online platforms and in search engines. To increase their visibility companies can make use of paid adverts in search engines (so-called keyword adverts or also sponsor links). In addition, promotional emails and electronic newsletters have offered opportunities to companies since Marketing 3.0 for informing consumers about a company or product. Online marketing is also closely associated with the area of E-commerce. Via online platforms customers have the opportunity to purchase goods or services. As soon as the user registers with a platform, the company acquires immediate access to the customer and can therefore match its customer care and retention concepts to the individual user and to his or her specific needs and consumer behaviour.

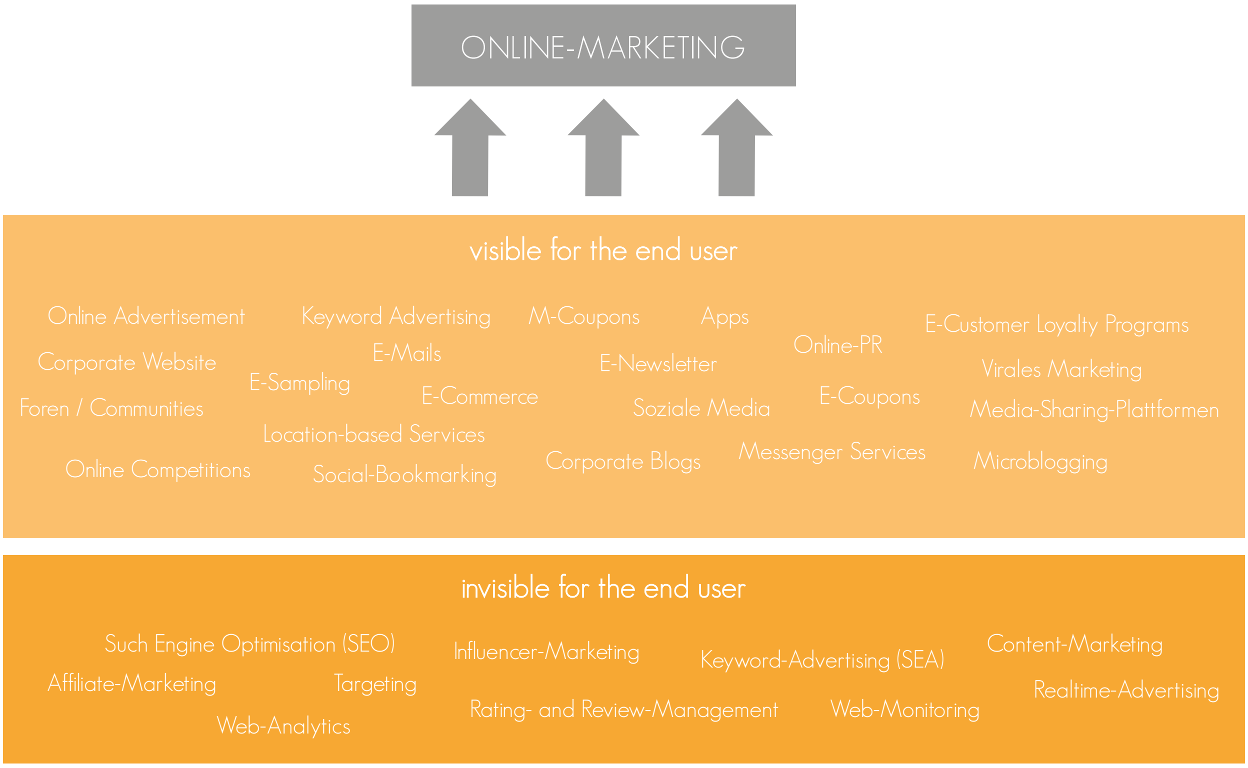


Fig. 25: Instruments for smart Online-Marketing (Kreutzer, 2013, p. 2)

When a customer registers on a platform and when customer loyalty cards are issued, a company receives access to key customer data. The information, extracted from the customer data, is a critical tool in terms of how a company distinguishes itself from its competitors. In addition to the consumer behaviour of customer in relation to a company's own products, the use of customer loyalty cards such as Payback etc. also provide an insight into the purchasing behaviour of customers in connection with other products. This allows the development of a clear picture concerning the types of customers and their habits. Thus, by means of incentives, such as E-coupons, purchases can be actively encouraged.

As already mentioned above, interaction with customers is a particularly crucial further development within the context of Marketing 3.0 and 4.0. This is made possible through the use of various social media channels. On the one hand, companies and products can be presented via social media networks, such as Facebook or LinkedIn, and can benefit from user networks. On the other hand, forums and communities can be used, for example, with respect to communicating effective PR statements on various topics or for information exchange with different target groups. Social media sharing platforms, e.g. YouTube, Instagram and SlideShare, enable companies to present themselves online in a more comprehensive manner, making use of different media tools, such as images, audio, video or story-telling. The content plays a vital role in terms of the appropriate presentation of a company or product. Blogs are a further area of social media marketing. Within the context of corporate blogs, specific events within a company can be communicated and generate benefits through exchange. Microblogging services such as Twitter, which only allow a certain number of characters, enable rapid interaction with users, e.g. drawing attention to different services or information about current events such as new products or a company's specific activities.

Instant Messaging services, such as Facebook Messenger, WhatsApp or Snapchat, also enable direct contact with users to convey texts, images, videos and audio files.

The development of a 24/7 online society has increased the importance of mobile marketing during recent years. The number of different apps worldwide that can be used on a Smartphone, has increased significantly during recent years. Apps allow SMEs to present themselves in a variety of ways, or to draw attention to themselves. In addition to traditional pull communication, which is based on the fact that the user is actively concerned about information on the internet, the trend is currently moving towards so-called push methods, such as personalised advertising banners or push messages. Without actually doing anything the user receives, based on his or her profile, advertising passively.

Through online marketing and especially via interaction on social media platforms businesses and customers come into close contact with each other. Companies and their activities, products or advertising messages can be commented upon by the company itself but also by the customer or by other interested parties. This enables companies to explore the possibility of communicating directly with an individual or with an entire community. Moreover, online marketing can connect and link different platforms and websites together to achieve a wider distribution of messages to different users. Furthermore, the networking of individuals within various communities supports what is known as viral marketing. This can also be actively promoted by companies. Through the sharing of information about a company or product, customers can, for example, be offered various services, which they can then use, or which enable them to participate in competitions. At the same time, by analysing the behaviour of different customers, work can be undertaken in the areas of optimising customer communication or customer retention initiatives. Advertising can be employed in a more targeted way to avoid wastage from scattered advertising. Mobile marketing is especially suited to directing customers to offers in their locality when their location function is activated. Thus, customers can, for example, be made aware of a traditional offline shop.

Apart from activities that are visible to the end user, companies can run additional measures in the background to optimise their marketing activities. Keywords can be stored within search engine advertising. If a user enters certain words into a search engine these are stored as keywords, then relevant websites will be displayed to the user. Companies should consider carefully which search words and phrases users could potentially use and thus which words and phrases they should store as keywords. Therefore, to the user it is not clear why he or she is shown a particular advert or search result. Within the context of search engine optimisation companies can try using an „organic listing" in order to appear within the first few search results on the most common search engines, such as Google, Yahoo! or Bing. In addition, the search engine providers' bots work with various factors that are usually not completely transparent. In addition to keywords, other factors also play a role. These include content (content, quality, relevance, etc.), the user experience, activities on websites (clicks, length of stay, bounce rate), the responsive design of a website, links, social media connections plus other factors (Melnik, 2017). By means of affiliate marketing companies have the opportunity to advertise on the websites of third parties. If the advertising leads to success (clicks, sales, etc.) then the online advertising space providers (affiliates) receive commission. Ultimately data can be gained from all visible and invisible online marketing activities, which can then be continuously evaluated. Within the context of Web Analytics, the behaviour of users on individual websites is evaluated, whilst web monitoring examines at the meta level how the company is perceived in relation to its web presence. In addition, analysis factors such as comments about products or the company or also prognoses related to possible trends are important, which can provide expressions of complaint, suggestions for product developments or opinions from users. As described above an immense amount of data in different formats (text, images, audio, video) is produced through the various online opportunities which can be evaluated by employing the appropriate systems. Thus, for example, within the context of BIG data analysis, posts on social media networks with YouTube videos or images can be evaluated to highlight market trends and developments about the needs of users, which in turn inform about forecasting and developments in relation to future products and services. This is also referred to as targeting.
In addition, based on the profiles of users, companies can optimise their advertising by means of so-called real time advertising or real time bidding. This means that advertising is personalised to suit certain users (Kreutzer, 2013).

4.6. Smart supply chains and value networks

Smart supply chains have a focus on value maximization for (end) customers, with as little waste of time and materials as possible (Lean), as well as the ability of responding quickly to changes in customer demand and customer requirements (Agile) ("The Triple-A Supply Chain," 2004).

Manufacturing companies are digitizing essential functions within their internal vertical operation processes, as well as with their horizontal partners along the supply chain. Smart Industry implies much more integrated value chains by using new, connecting technologies that allow co-design and co-creation, involving customers and keeping the end user in mind. Horizontal integration includes technologies from track and trace devices, to real-time integrated planning and execution. Innovative business models will be based on a dynamic network of companies, continuously moving and changing in order to afford more and more complex compositions of services ("[No title]," n.d.-d).

Through digitization, cooperation with key partners can be facilitated and strengthened. Greater integration of data between manufacturers and customers can open up new collaboration opportunities. A clever use of pooled data, for example, can allow efficiencies throughout the value chain, as well as customer value creation: joint innovations of processes, products and services ("[No title]," n.d.-e). On the other hand, data-based integration of development, production and maintenance can also lead to shifts and even dropouts of functions and companies throughout existing supply chains.

"Industry 4.0 is expected to bring several conversions for industrial value creation, encompassing entire value-added networks. Small and medium-sized enterprises (SMEs), which play an important role for both the German as well as the European economy, struggle to integrate the concept of Industry 4.0 within their value creation. However, due to the high importance of SMEs for industrial value creation networks, their integration is essential to successfully establish Industry 4.0 across value chains. Several SMEs struggle to obtain the resources required for equipment and machinery or do not possess the required market shares or market access to establish new business models. Large enterprises are often seen as too powerful to be a partner for a SME. Nevertheless, cooperation strategies among SMEs may present a viable alternative to successfully implement Industry 4.0 across the value chain". (Müller, Maier, Veile, & Voigt, 2017) , https://tubdok.tub.tuhh.de/handle/11420/1465

4.6.1. From supply chains to VALUE chains

Manufacturing companies often are focused on cost reduction when it comes to procurement and distribution management. According to prof. Jack van der Veen ("Operational Excellence is uit – CEX is in - Logistiek," n.d.), this is useful, but it lacks the real goal: "A supply chain is ultimately intended to optimally service end users. Therefore, a value chain should be designed and function to create and capture customer value (flow) and to pursuit Customer Excellence (CEX)". Instead of a constant strive for a bigger piece of the existing cake, supply chain partners should strive to co-create 'the best' customer value, in order to enlarge the cake.

4.6.2. Customer-centric value networks

Smart, networked factories work together with customers and suppliers in (worldwide) industrial digital ecosystems; dynamic (temporary) value chains, data networks and platforms, collaborating with customers, suppliers, technology partners and even competitors, without limiting their vision based on current constraints. They move their focus beyond technical details and consider what impact new applications could have on their value chain and their relationships with, and access to, their customers (PWC, 2016a).

Smart industry requires cooperation between customers and suppliers in a network of organisations, but also technical collaboration between equipment from different manufacturers (*interoperability*). Production will increasingly take place in loosely-based partnerships. In these networks, close collaboration and knowledge exchange take place via platforms. The (digital) collaboration must lead to production processes being organized more efficiently and innovations getting off the ground faster and with reduced time to the market (Wilhelmus Adrianus Franciscus & Timmer, 2016). Security of data exchange and the protection of intellectual property is vital here (see chapter 6.5). A big challenge is to set the right incentives and find suitable benefits in sharing models that compensate everyone fairly for their contribution. The most basic business model in an ecosystem is a marketplace, which brings together multiple sellers and buyers, capturing value from commissions on the transaction value (PWC, 2016a). For SMEs, developing new business by utilizing existing platforms, can be a smart path to (rapid) growth.

The establishment of a network-centric production system that spreads throughout the entire asset life cycle, may lead to the emergence of new forms of collaboration that are characterized by a co-creation approach to value creation. In the coming decade, a network-centric approach to production will replace linear production processes with intelligent and flexible (regional) ecosystem approaches. These networks will interconnect parts, products and machines across production plants, companies and value chains at a highly granular level. The network-centric approach will radically optimize production in existing value chains and, more importantly, the notion of network-centric production finally spells the end of the 'value chain' and the birth of the 'value network' ("SI Implementatieagenda 2018, NL," n.d.).

Smart Industry, by definition, demands a collaborative approach. Smart Industry is all about connecting, including services and matters that a company does not provide itself. Intelligent software and IoT facilitate data exchange between machines, departments and companies. Via a cloud-based platform, (end) users have access to the data of all collaborating parties.

4.7. Main findings and recommendations

Manufacturing companies tend to focus mainly on the technological aspects and (potential) efficiency gains of Smart Industry, rather than on (new) business opportunities, value propositions and business models.

In this digital and technological era, ways to meet *customer needs* and opportunities to exceed customer expectations are changing drastically and constantly. Markets are transparent, customers are well informed and critical and in the driving seat when it comes to how, when and where they want their (custom made) orders to be delivered.

The extent to which a company manages to continuously *create customer value*, determines its competitiveness and success. Creating customer value and developing new ways to do so, demand a keen eye on (changing) market situations and profound *insights* in customers' behaviour, wants and needs. Customers are experts on their own daily (work)routines, issues and ambitions. A smart supplier supports and facilitates those, as an expert in state-of-the-art and smart(er) ways to do so. An effective and achievable way for SMEs to collect customer insights, is by arranging dialogues with customers, users and suppliers on a regular basis. By doing this, a company will get a constant flow of input for innovation. Data analytics will be used more and more to predict customer- and machine behaviour as well as product- or service demand.

Smart Industry offers manufacturing companies *new business opportunities* in ways of:

- Creating smart (digitized and customized) products;
- Creating value with (big) data;
- Developing smart services and total solutions (servitization);
- Contributing to social issues, applying smart technical solutions.

Digitalization of products and Smart Engineering can realize the production of client specific (modular) products at the speed and price of mass products. It will generate lots of information and data, that can be used to improve existing products and services and to develop new, customer tailored offers. Offering added services, total solutions or even products as a service, will unburden customers and can become a substantial part of a manufacturing company's revenues.

Smart revenue models combine existing principles of revenue models with new technical possibilities. By defining products in another way, (new) services can be added or created. Think of leasing, insurance or logistic services. Due to connectivity of products and machines and the data provided by them, (composed) revenue models like dynamic pricing, pay per use, pay for uptime or pay per approved product/part, will be applied more and more in industry. Leaving it up to a company's creativity to fulfill its value proposition with (a mix of) products, services and applications (e.g. users pay for use of light instead of buying lamps).

Future proof market strategies and shockproof *product portfolios* are created by blending two interacting major forces: technology-push and market-pull. Continuous customer centric research and innovation based on state of the art technologies, is the guideline for effective and smart product management. With constantly changing customer needs and almost infinite technical options to fulfill them, product management as well a R&D will more and more get the characteristics of *innovation management*.

Innovation entails the development of new products and services, new features in existing products and services, and new ways to produce or sell them or a different approach to any other process within the company. Completely new ways of doing business are often called new business models. Innovation activities bring highest value if balanced and address different types of innovations: Products and Services, Processes, Marketing and Organisation.

If you want to establish or improve innovation within the organisation, there is not a uniform procedure on how to do this. But there are many elements and concepts, which can help companies to achieve the innovative performance. In 5.4, we focused on the innovation process, tools and the basic steps and processes which should be done to transform ideas into the final market product:

- Innovation strategy and goals
- Development of an innovative organisation and culture
- The process of innovation (problem/ opportunity identification, problem redefinition, ideation, pretotyping/prototyping, idea testing and selection)

- Research and development
- Intellectual property protection
- How to finance innovation
- Production (see chapter 4)
- Marketing.

The discipline of *Marketing* is a subject to far-reaching changes due to the digital transformation and the use of social media. Consumers are no longer just looking for a product simply to consume. Instead they want to contribute to its development, want it to be tailored to their own needs and wish to interact with the product. In addition, they are looking for ways to evaluate the product and to share their experiences of using the product. Through the use of social media and new technologies, products as well as the development and production processes are becoming more transparent. Companies acquire knowledge about customers and markets, which can be used to optimise their offer and to adapt it to different target groups. Marketing 4.0 thus means the integration of the customer into the marketing process through collaboration. *Smart Marketing* means the expansion of consumer-centric online and offline marketing through the integration of technologies for interaction with consumers, as well as through integrated digitalisation of processes and the use of data, to achieve the optimisation, flexibilisation and personalisation of customer contact.

Traditional marketing is a triangle involving brand, positioning and differentiation. Marketing 4.0 extends this triangle to a fourth dimension: the experience and the interaction with the brand. Above all the customer experience is the focus of this interaction.

In an environment, in which each enterprise, each brand and each product can be compared on a world-wide basis with competitors, it is essential that marketing is target-group-specific and speaks to customers. This is made possible through the use of various social media channels, as described in chapter 5.5.

Smart Industry implies much more *integrated value chains* by using new, connecting technologies that allow co-design and co-creation, involving customers and suppliers. Intelligent software and IoT facilitate data exchange between machines, departments and companies. Via a cloud-based platform, (end) users have access to the data of all collaborating parties. The (digital) collaboration must lead to production processes being organized more efficiently and innovations getting off the ground faster and with reduced time to markets. Innovative business models will be based on a dynamic network of companies, continuously moving and changing in order to create customer value and allow more and more complex compositions of products and services.

Cooperation strategies among SMEs are vital to successfully implement Industry 4.0 across the value chain. Instead of a constant strive for a bigger piece of the existing cake, supply chain partners better strive to constantly co-create 'the best' customer value, in order to enlarge the cake. A challenge is to set the right incentives and find suitable benefit sharing models that compensate everyone fairly for their contribution.

5. FUTURE MANAGEMENT CHALLENGES

Authors: Joseba Sainz de Baranda, Eva Arrilucea

5.1. Introduction and objectives of this section

This section analyses the main management challenges that companies must face in the context of the 4th Industrial Revolution characterised by the outbreak of new industrial technologies and communication technologies, that increase dramatically the level of connectivity between the components involved in the production process.

Thus, the 4th Industrial Revolution has the potential to improve the flexibility and productivity of businesses and companies, but also brings risks for competitiveness, job markets and society. Since top management support is essential to foster Industry 4.0, and management is the core process of a company, changes in management affects all the main processes of the company and all the business model components: value proposal, main activities, relationship with stakeholders, technology and innovation absorption capacity, organisational structure, corporate culture and even risk management.

This section focuses on the employment challenges in respect of demographic of employment, job losses and job creation because of the technological changes, but also on the human resources management perspective that aims to develop a highly committed and qualified workforce to achieve the company's objectives.

Since the answer to the new productive challenges needs a close multi-dimensional collaboration, this report includes a chapter to explore the different dimensions of collaboration: between companies and customers, between companies and other stakeholders, and between workers and robots. Furthermore, the effects of the 4th Industrial Revolution on companies has not only technology and organisational implications but also regulatory and legal ones. This section reflects the importance of regulation in certain aspects such as data access and ownership, product liability, IP, occupational risks, workers rights and standardization. There is also a specific mention of the monitoring process management.

Finally, the section summarizes the main recommendations related to management challenges for companies in the 4th Industrial Revolution context.

5.2. The business model management

The 4th industrial Revolution has the potential to improve the flexibility and productivity of businesses and companies, but also brings risks for competitiveness, job markets and the society.

Since top management support is essential to foster industry 4.0 (PWC, 2014) and management is the core process of a company, changes in management affects all the main processes of a company, such as customer relationship, collaborative model, product and service creation and development, distribution and sales, finance, quality, administrative and other supporting processes. For example, the executive level will need a more direct relationship at the operational level. Also, the **executive level** will need to maintain connected to the customer base. And the conventional management system will change from controlling workers to active engagement, understood as a mutual transfer of knowledge between the manager and operational levels. Furthermore, while it is possible that a management hierarchy will exist, the decision process will be through the collective understanding of the shared knowledge. In general, workers will not be passive agents, but "knowledge workers" with a more active role in the organisations (Davies R, 2017).

In other words, Industry 4.0 needs a transformation of the current business models (see Fig. 28) and a re-definition of the value proposal for companies. Switching from a traditional company to a digital one implies big technology changes (scalable IT-systems, use of big data), process changes (end-to-end processes) and interaction changes (with customers, clients, suppliers and so).

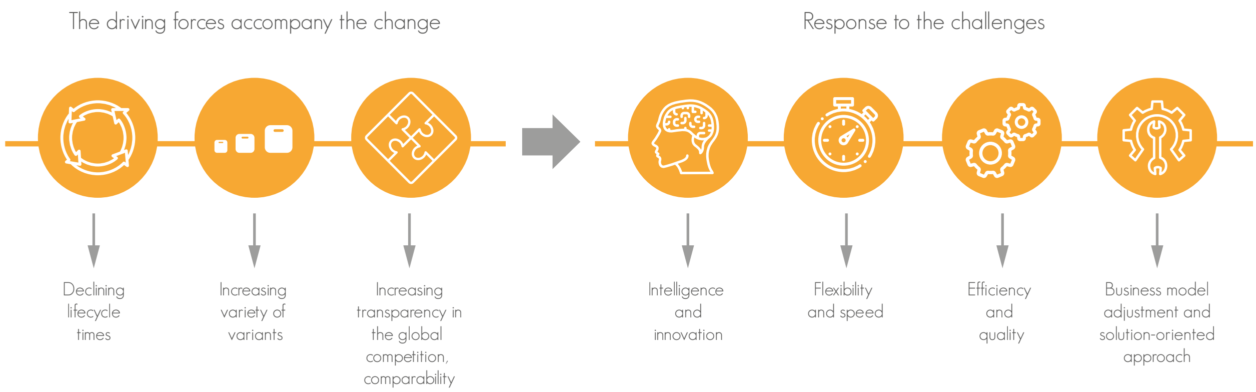


Fig. 26: Driving forces of the change. Source: (KPMG, 2016)

For this to happen three kinds of integration movements are necessary (see figure 2):

- Vertical integration and networked manufacturing systems, that refer to the creation of a flexible system by the integration of hierarchical systems,
- Horizontal integration through value networks that aims to create collaborations between different companies in the value chain,
- End-to-end digital integration of engineering across the entire value chain.

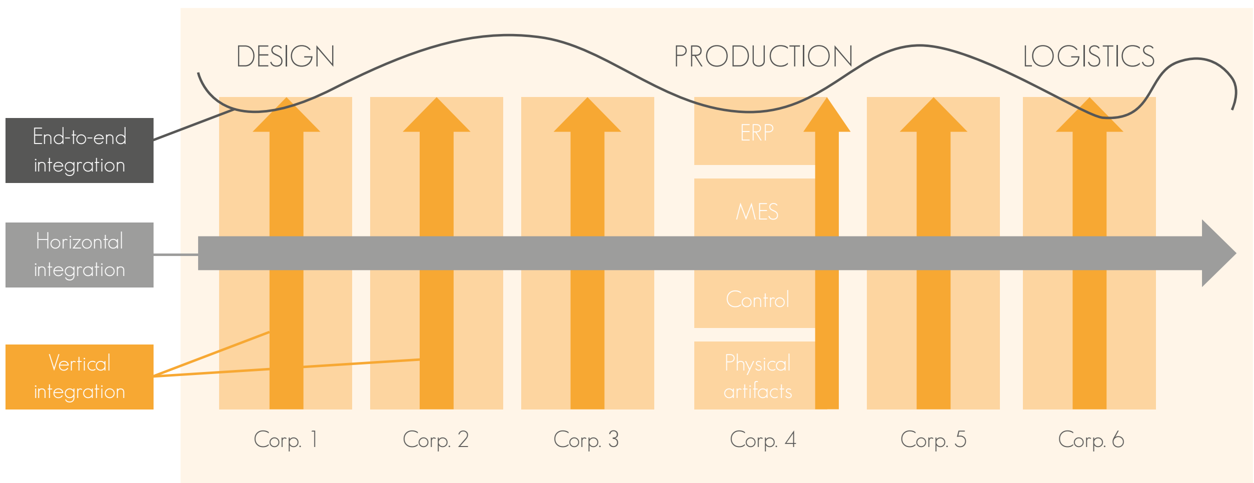


Fig. 27: Industry 4.0 integration aspects. Source: (Foidl & Felderer, 2016)

The great amount of available data allows real-time decision making and more operational agility. Lifecycle times decline and transparency becomes more and more important in the global competition.

To face the changes, companies must develop a toolbox that allows them to make the most of their capacities. The factory of the future is flexible to give a customised answer to each client on time, optimising the production and resources. In this sense, a big amount of data becomes knowledge and information that can be used to monitor and speed up decisi-on-making processes related to the management but also to the production. The impact of data analysis in a company is enormous: Data can provide information for financial planning, restructure the value chain, choose new partners, redefine targets and goals, develop new products and services and more. The big challenge for managers is to develop an adaptive leading to balance automatization with demand for variation and, at the same time, maintaining a high-quality product.

In any case, to act upon driving change forces using these tools implies to **change the current business models** having into account that a) companies must have a clear and differential value proposal and b) changes affect all the areas and processes in a company (strategic, operational and support processes) (see Fig. 28).

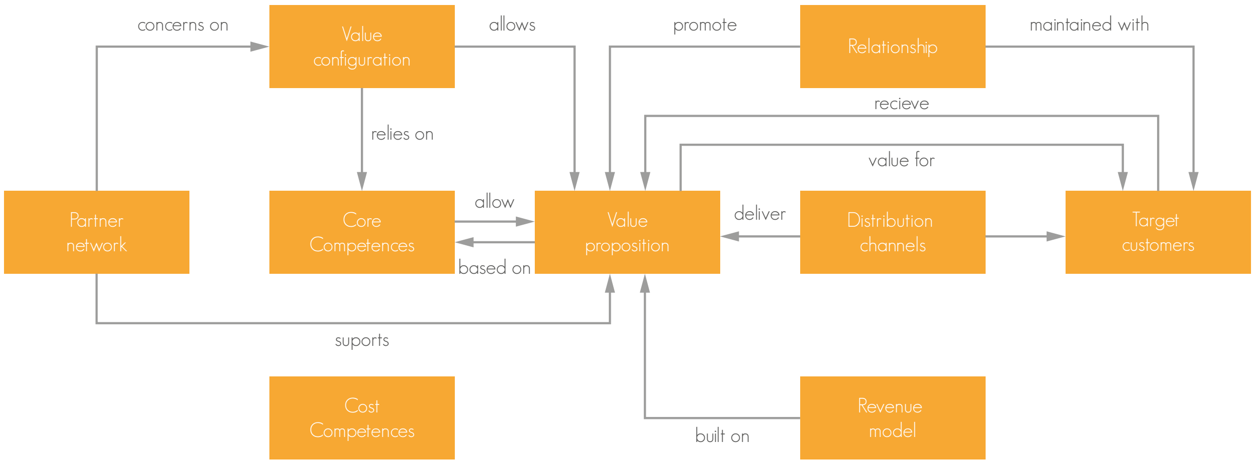


Fig. 28: Elements constituting the business model. Source: (Christian Arnold, n.d.)

In the context of Industry 4.0, **value proposition** is the most influenced component of business models, due mostly to the introduction of the Internet of Things and big data analysis (Christian Arnold, n.d.). The second most affected components are the core competencies, and the third one, the cross-sectorial relationships.

Furthermore, Industry 4.0 enables business models that take advantage of mass customization (for example, assembly product lines for multiple product models, or mixed-model assembly lines with different products that can be assembled on the same line), and to do this, include **new forms of data management, new organisational structures and new digitally oriented culture**. The transition from mass production to mass customisation implied much more integrated value chains and uptake of new technologies that allow co-design and co-creation. At the same time, reduced costs of launching new products could mean new business opportunities and higher productivity levels. And, finally, there is an enormous pressure to include **social and environmental factors** (Stubbs & Cocklin, 2008) in the new generation of business models, having into account new factors such as product obsolescence design practices, input of energy and water, sustainable innovation, impact of activity on natural resources and climate, waste management and others (see Fig. 30).

Other factors to take into account during the development of new business models is the **servitization or manufacturing-as-a-service model** that is a competitive approach to increase added value and be more resource efficient. Technology allows the optimization of production systems regarding costs, reliability, time, quality and efficiency. In fact, distributed manufacturing, virtual factors and embedding services in new product-service combinations offer new opportunities with lower market access barriers for small companies (European Commission, 2018). Virtual factories and mini-factories are just two examples of new business models that can emerge from the integration of all these new factors.

Another key aspect is the **risk management** in an Industry 4.0 context. Risk management is the process that helps companies to understand the risks inherent to the current situation and the correct answer for them. In the manufacturing sector, operational risks are associated with the manufacturing process management, maintenance, operation methods and tools, material, human resources, machines and manufacturing technologies and machine environments. The concept of Industry 4.0 generates new risks associated with the connection of cyberspace and outsourcing of services among others. Although Industry 4.0 can have impact on all the processes of the company, most of the risks are related to information security (Tupa, Simota, & Steiner, 2017).

Finally, new business models imply the use of novel revenue models (dynamic pricing, pay-by-usage, performance-based billing) and cost/investment models.

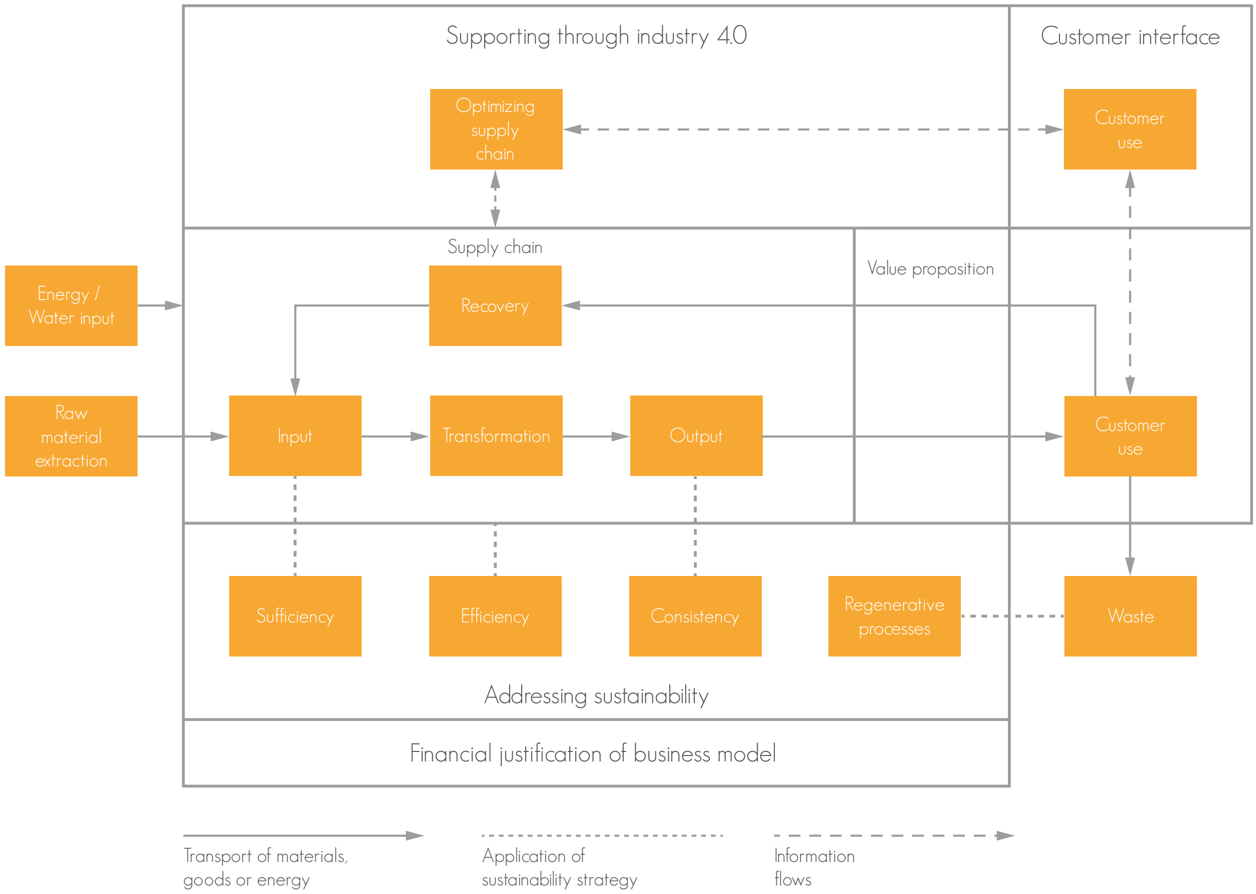


Fig. 29: Connecting sustainability and Industry 4.0 to the business model. Source: (Man, de Man, & Strandhagen, 2017)

Although these new business models might seem to be more complex, complexity of coordination could be reduced by increasing flexibility, dividing the production process into smaller units aligned with high-level goals (Brettel, Friederichsen, Keller, & Rosenberg, 2014). In general, the change in business models is justified by one of the following goals: increase of flexibility, improve of productivity, costs reduction, reduction of delivery time and/or improvement of process quality.

To face the challenges related to changes in business models, SMEs need to fully understand technology so they can be able to absorb it. There are some new tools to help SMEs to test technology and to know in advance how technology can affect them, for instance, Digital Innovation Hubs (one-stop-shops to help SMEs to become more competitive using digital technologies) or testbed labs (experimentation platforms to test and use new technologies). Also, SMEs need managers with a double technological and management profile, able to understand the potential of new technologies in an uncertain environment.

5.3. Employment Challenges

Although the relation between technology and employment is quite complex and difficult to predict, both work with the organisation and design, and training and continuing professional development are going to be two of the key areas for a successful implementation of Industry 4.0. Employees have a changing role from operators to problem-solvers and companies need to establish the mechanism to facilitate and accelerate this process.

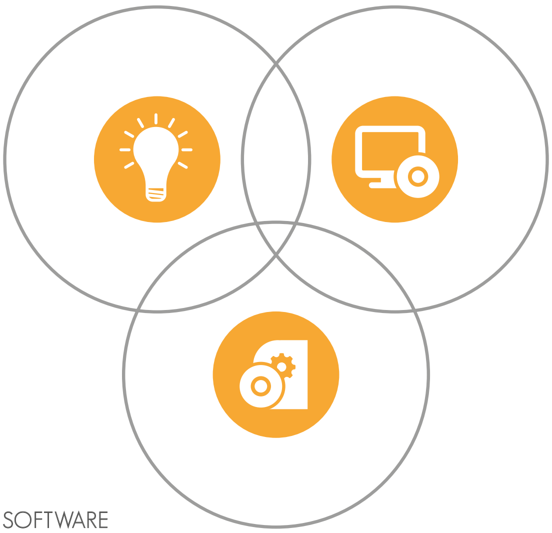
5.3.1. Impact of technological change in jobs

On one hand, smart factories are characterised by a real-time control that transforms the entire productive process and offers workers the opportunity to have more responsibilities and improve their professional careers. On the other hand, as Fig. 30 shows, since production processes are more and more complex, Industry 4.0 radically changes job and competence profiles, so training and long-life learning are becoming more and more important.

Fig. 30: Industry 4.0 skills profile. Source: (KPMG, 2016)

THEORY AND EXPERTISE

- Masterial and production skills
- Process skills (from the customer to the customer)
- Electrical engineering
- Software
- Information and communication technology



HARDWARE

- Mechanical and plant engineering.
- Automation technology
- Mechatronics
- Microsystems technology
- Electronics
- IT infrastructure
- IT security

SOFTWARE

- Documentation Integration
- Customising (process mapping)
- Maintenance, servicing and further development of the Systems
- Training and continuous professional development

According to (KPMG, 2016), Industry 4.0 needs specialised, methodological and system skills, as well as technology and market related expertise and knowledge, hardware, software and algorithms skills. It is important to have profiles with knowledge of processes, organisation, production, technology and also, social and emotional capabilities. The availability of these complex profiles is probably the greater challenge that industry 4.0 must face now and require educational and training systems to adapt their programs to the new reality.

The effects of technological change on employment are one of the main debates in the past century. Historically, a technological challenge has not reduced the number of industrial jobs but it has changed the employment structure ("Project RockEU," 2016). However, some authors point out, that, since the speed of technological progress is quickly increasing, the capacity of workers to respond to the changes can be exceeded, inducing job losses (Brynjolfsson & McAfee, 2014), (Frey & Osborne, 2017). Although most of these studies predict high rates of job losses for different economies (US, German, European Union), a recent study by Bonin (Bonin H, 2015) specifies that only a part of these jobs could be automated because even in the jobs highly susceptible to be automatized, there are specific tasks hard to automate. In this study, the authors found that only 9% of US workers and 12% of German workers were involved in tasks that could be automated. There are subsequent reports that confirm similar results for OECD countries (see Fig. 31).

Fig. 31: Share of employees with high risk by OECD countries. Source: (Arntz, 2016)

Another important finding of these studies is that automatability strongly decreases in the level of education and in the income of the workers: low-skilled and low-income individuals face the highest risksof being automatable.

The main changes that will affect the demography of employment could be: (Martin, 2017)

- Quality control processes based on big-data will provoke a decrease of the need for quality control workers and an increase of big data scientists demand.
- Smart devices equipped with cameras and sensors will be able to assist the production process replacing human workers by "robot coordinators".
- Self-driven vehicles will optimise logistics and transportations and will replace human drivers.
- Since the need for industrial engineers to simulate production lines will increase, it will raise the demand for mechanical engineers specialized in the industrial field.
- Maintenance technicians could disappear and be replaced by smart devices that allow manufactures to predict failures.
- Machines and technology will be sold as a service since manufacturer will set up and maintain the machines and clients will take advantage of the service it provides.

However, the replacement of jobs is not as immediate as it could be since in some cases, such as health care, there is a strong preference for human labour, and there are other conditioning factors that could delay technological change, such as legal or cultural barriers. Accordingly, several recent studies confirm that technological change will not have a negative aggregate employment effect. (Nordhaus, 2015), (Graetz G, 2015). Although there are tasks in high risk of being automated in transport, logistic, administrative work and the manufacturing sector, in general, it seems that the main challenge for the future employment will lie in the structure of jobs rather than in the number of jobs, so flexibility of labour markets to react to technological changes will be crucial to profit gains. The greatest threat of employment is not the automatization but the inability of stay competitive in the future. In this sense, an educative system has a very important role to train skills and competences which are difficult for machines to acquire: problem-solving, creativity, social intelligent, communicating abilities, openness to new experiences and so on. It is important to consider diversity and avoid the one-size-fits-all approach in the human resources strategy (see Box 1: Foxconn).

Box 1. Foxconn

Foxconn, China's largest exporter of high-tech consumer electronics, started in 2017 a 3-phase plan to fully automate its Chinese factory using robotic units known as Foxbots.

The first phase wants to replace the dangerous, repetitive or unpleasant works. The second one improves efficiency reducing the number of excess robots in ten production lines, and the last phase will automate the entire factory with a minimal number of human workers assigned for production, logistics, testing and inspection processes. Foxconn's strategy is keeping up with the Chinese policy "Made in China 2025" to replace humans with robots in manufacturing industries and increase productivity.

In 2016, 60.000 factory workers were replaced, not only in the production lines but in the entire factories. In Feb 2018, the company has announced 10,000 job cuts in Taiwan.

5.3.2. Impact of technological change in human resources management

Human resources management is defined as a strategic approach towards the effective employment and development of a highly committed and qualified workforce to achieve the company's objectives. Human resource managers have the following goals:

- Improving individual effectiveness and performance
- Improving organizational effectiveness and performance
- Developing knowledge, skills and competences
- Enhancing human potential and personal growth.

The three main areas of human resources development are personal development, team development and organisational development (Hecklau F, Galeitzke M, Flachs S, Kohl H., 2016).

We have seen that the irruption of technological changes in companies affects the automation of tasks but also the physical presence of workers in workplaces. The information and communication technologies facilitate working and open the door for a new relationship between workers and employers. In this sense, managers are changing from being "people managers" to "people and machine managers". Since CEOs operate in a technology-driven world, the leading business schools are focused on the intersection of businesses, technology and also design to anticipate digital disruption in companies. (Symonds, 2018)

CEOs and Human Resources Managers must be the main driving forces of change, being an example of adoption of technology in its own working activity, and preparing the ground for the whole company to smoothly embrace the changes. To do this, it is necessary to develop a credible script about the positive added values provided by technological changes of the industry. And even more important, it is necessary to develop the measures to ensure the updating and recycling of worker profiles and improve their employability in the organisation.

In an Industry 4.0 context, employers want to improve productivity, reduce the employee's rotation, keep down the costs and innovate. **Transparency, control and communication** are key factors in this process, so workers can face the changes in a trusted and, at the same time, tecno-diverse work environment. Human Resources Managers must be responsible of managing the cultural change of working in technological environments where machines are our new co-workers.

Furthermore, **different forms of work organisations** are emerging, affecting worker-employer relationships. In these new forms, human dimension is more important – human centred manufacturing – specially when human work cannot be replaced. These worker centred models affect the design of workplaces and the allocation of workload, and are expected to increase the worker satisfaction and make the workplace healthier and safer (European Commission, 2018). Also new work organisations take into consideration constraints of the workforce such as the ageing of workers.

One of the main conclusions related to Human Resources Management is that companies must take care of the **workers employability** rather than jobs. On the other hand, training, new learning methods, and long-life learning and developed are key factors to aim this goal and to improve the acceptance by workers of technological changes in the company.

To face the challenges related to the employment, SMEs have some possible actions such as carrying out a study of current internal expertise and future needs, to reveal the gaps between the two situations. Also, SMEs should fill the key posts with T-shaped persons: people with expert knowledge that, at the same time, have personal skills to connect with other fields of knowledge. In any case, SMEs are going to need close connections with other agents in the innovation system to analyse the gaps, to develop the suitable profiles and to include them in the internal work organisation. In this sense, universities, research and technology organisations, vocational training centers, innovation hubs and testbeds could be good partners where training aspects would be developed and offered.

5.4. Collaboration Challenges

The answer to the new productive challenges needs a close collaboration between different technologies and different sectors, and also between different stakeholders across the entire productive value chain integrated in an active and collaborative way.

Regarding to technology, collaboration is one of the main components of the 4th Industrial Revolution. **Cyber-physical systems** such as smart grids, autonomous automobile systems or process control systems have changed the ways of collaboration in current production systems. The connection between the **real and virtual world** affects processes, embedded systems, software components and even robots.

Since technologies such as QR (Quick Response Code), NFC (Near Field Communication), RFID (Radio Frequency Identification), Bluetooth and others allow the stakeholders to be constantly informed about the status of production, the involvement of customers and business partners becomes one of the main features of the future industrial production system.

Change in **customer relationships** affects the company's market and product strategy, so it is important to understand their needs and priorities to establish a collaborative model that allows the company to define a correct value proposal and associated business model. In the context of industry 4.0 clients are involved since the very first part of the product delivery process - the forecast phase and development of product ideas - to the last one, the delivery and after-sales phase, and it is important to take into account both its preferences and the available data related to its needs and personal profile. Also, the opportunities of Industry 4.0 enable more flexible value propositions resulting in the provision of individualized products and the possibility to attract new customers beyond industry borders (Emmrich V, Döbele M, Bauernhansl T, Paulus-Rohmer D, Schatz A, Weskamp M., 2015). All these factors result in an improved, long-term, intensified and more direct customer relationship.

Also, **collaboration between workers and robots** now take place in a shared environment, within the same physical place and, in some cases, with verbal interaction (see Box 2: The Baxter Difference).

Box 2. The Baxter Difference

Rethink Robotics is a company founded in 2008 and located in Boston, specialised in the production of the collaborative robots Sawyer and Baxter, trained to work with human workers.

Baxter was created in 2012, to break the idea of robots working separated from human workers. Baxter is equipped with the software Itera so to use the robot in a manufacturing environment. Among other things, the robot can be "trained" just moving its arm to demonstrate to it the correct movements.

Also, the robot works with critical production metrics (part counts, cycle times, speed, signals), has cameras to perform complex vision tasks and, through titanium flexures, the robot can set the amount of force required while running a task.

In any case, collaboration poses some challenges to shift from a centralised to decentralised factory control system and others linked to production security that still are no solved. To face all the challenges related to collaboration issues, SMEs should integrate business intelligence processes in their activity, so they could incorporate ideas and new knowledge to the company's strategy. Also, SMEs should consider the stakeholders in their value chains (suppliers, clients, competitors, etc) as part of their own business, and not only as isolated agents delinked from the internal decision-making process.

The concept Open Innovation, defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively (Henry Chesbrough, 2003), plays a key role as well in cooperation. Furthermore, since innovation cycles are increasingly smaller, collaboration with other stakeholders through specific platforms becomes a strategic value to incorporate new ideas and knowledge to the company, and to increase the number of opportunities. The collaboration with third parties is essential to foster technology transference to the companies and to develop interdisciplinary and integrated solutions to the market. The benefits of Open Innovation are clear:

- Reduction in the time and cost of innovation projects.
- Incorporation of solutions and innovations in the form of ideas, patents, products and technologies.
- Commercialization of inventions.

For industrial SMEs is important going forward and deeper from the process of collaboration to the act of co-creation. **Co-creation** as the joint creation of value by a company and other stakeholders, and in particular consumers who work with the company to co-construct the service experience to suit his or her preferences (Prahalad & Ramaswamy, 2004a). As first steps, here you can find a general approach:

- Establish your vision —who are you going to help, and what will you help them do?
- Create a blueprint—this is how you will help, broken into smaller pieces or features.
- Capture each piece on a separate piece of paper—describe that piece's value to your customer.
- Present your vision to your customer—confirm that this is something they need help with and if not, ask why or what task they do need help with.
- Give your customer the scrambled pieces and some blank pieces of paper and a pen—ask them to arrange the pieces to form a complete picture that helps them with their task. Ask them to discard pieces they don't need and add ones they do need.
- Ask them to start to fill in the details—what would be included in this piece? Capture the words they use to describe it.
- Refine and repeat (Medium,2017).

https://medium.com/@Inceodia/7-steps-to-co-creating-innovative-solutions-with-your-customers-3489e38120ab

Box 3. Co-creation in the manufacturing industry

Dewalt is a leading manufacturer of high-quality power tools. Millions of professionals rely on the company to produce the latest durable products that solve new challenges on the worksite. To understand the direction technology and innovation need to go, DEWALT has an award-winning insight community of more than 10,000 end users.

The company uses its community to get to know customers and their needs while gathering product, packaging and marketing feedback. Dewalt also has an invention submission where professional tradesmen and loyal customers submit ideas for entirely new product lines.
(VISION CRITICAL, 2018).

One of the latest developments in that sense, applied to industrial SMEs, is the rise of **smart value chain** processes, which are defined as new processes or new solutions which save at least one step in the value chain, thereby achieving cost savings, time reduction and provide a better quality of output. Smart value chain manufacturing processes therefore have a direct impact on the competitiveness of manufacturing companies.

One of the key drivers of the trend is a clear market demand for more flexible, agile and efficient manufacturing processes.

By integrating various aspects of the value chain in the smart manufacturing processes, or by providing innovative solutions that increase flexibility, agility and efficiency, substantial gains can be made across the value chain. Various markets that are touched by this trend showcase a high growth potential.

Several success factors were also identified. Companies typically provided highly innovative solutions that have a clear competitive edge over their competitors. Moreover, a combination of private funding, bank funding, venture capital funding and public funding provided a good mix of available resources. While some continue to struggle with finding highly skilled and specialised workers, others were able to attract talent by taking on PhD positions in the company or by establishing a name in the field. http://ec.europa.eu/growth/content/smart-value-chains_en

In the process of implementing the smart value chain concept, Iot plays a principal role, acquiring devices data and leveraging its value for the benefit of the company. The key point for most of the SMEs would be how to start, and which considerations SMEs have to have in mind before starting. Find below some interesting issues:

- Where do you see opportunities to automate business operations?
- What is the specific business problem your organisation wants to solve?
- How many clients are going to be involved?
- Do you need any other actors/companies/HEIs/Tech. centers/Consultants for a proper implementation?
- What IoT component addresses this project best? Options could include connected operations, remote operations, predictive analytics, preventative maintenance, metering and measurement, IoT as a service, remotely controlled machines and equipment, industrial control zones, smart environments and many others.
- Have you identified cross-functional team leaders and partners to co-implement the IoT solution?
- What specific project and location do you have in mind for your use case?
- Can you describe in plain terms the project scope, IoT solution and business problem it solves?
- Can this starter project eventually be scaled and optimized across the enterprise?

https://www.networkworld.com/article/3293878/internet-of-things/the-first-step-to-starting-an-enterprise-iot-project.html
In most of the cases SMEs need assistance, not only to respond all the questions described and to establish a trustful and solid relationship between the units of the smart value chain, but also to implement all the technology behind Iot. In that sense, apart from the technology devices used to capture and manage data, there are other managing technologies that will influence the managing procedures of the supply chains.

Major challenges faced by supply chains related to information sharing and trust. With its intrinsic properties, **blockchain** and IoT offer bright opportunities to tackle these challenges related to the continuity of information, accessibility to information, link between physical and information flows and code of conduct violations and fraud detection.

https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf

5.5. Legal and regulatory challenges

The implementation of Industry 4.0 has not only technology and organisational implications but also regulatory and legal ones. The regulatory framework at European level is defined by following **rules and recommendations**:

- European Parliament's report with recommendations to the Commission on Civil Law Rules on Robotics (2015/2013(INL)). It contains recommendations related to "smart robots", civil law liability, interoperability: access to code and intellectual property, a code of ethical conduct for robotics engineers and a code for research ethics committee and "electronic entity" among others.
- ISO /TS 15066:2016- Robots and robotic devices, that specifies safety requirements for collaborative industrial robot systems and the work environment, and supplement the requirements and guidance on collaborative industrial robot operation given in ISO 10218-1 and ISO 10218-2. The rule applies to industrial robot systems as described in ISO 20218-1 and ISO 10218-2 but it does not apply to non-industrial robots, although the safety principles presented can be useful to other areas of robotics.
- EC Communication on strengthening Europe's cyber resilience system and fostering a competitive and innovative cybersecurity industry, to ensure trust in advanced digital systems.
- General Data Protection Regulation (GDPR) by which the European Parliament, the Council of the European Union and the EC intend to strengthen and unify data protection for all individuals within the European Union ("Regulation (EU) 2016/679 - European University Institute," n.d.).

The development of legislation is not homogeneous in all countries. US, Japan and South Korea are some examples of countries with higher degree of regulation on robots and robotics. In Europe, debate is focused on two main questions: the right time to regulate, and the intensity of regulation. About the first one, an early regulation may hinder the technological development but a late regulation may not control the social, political and economic consequences. About the intensity, there is no consensus on the degree of detail of regulatory definitions. Neither if regulation should be hard (bonding rules) or soft (general guidelines).

Some of the most important legal issues for companies in the digital era are **data access, liability, data ownership and the cloud** (Guido Lobrano, Patrick Grant, Dr Heiko Willems, Dr Peter Bräutigam, Christiane Hinerasky, 2017).

Regarding to **data ownership and access**, currently there is no legal concept of data ownership for non-personal data and the general practice is to establish agreements on the rights on data. In order to encourage the free flow of data, the EU Commission is evaluated the creation of a new "Data Producer's Right" for non-personal and anonymised data (European Commission, 2017). Although the General Data Protection Regulation has been an important step towards harmonisation, it is important to establish dependable rules for international data transfer. Also, the data protection law can go further in a few special areas: employee data protection, law of digitalisation of the energy transition and adoption of the e-health law.

Since **intangible assets** are key drivers of success, the added value of the company can be in the place of production (including home offices), place of R&D activity or in the place of market activity (including virtual environments). Although the protection of intangible assets (such as intellectual property) is a key to the survival of companies in the Industry 4.0 context, it is not easy, and it is still an issue under discussion, (KPMG, 2016) how to tax the company in the place in which the added value is being created. Best practices in IP exploitation should be identified and promoted to stimulate a further development of new approaches in manufacturing.[Citation error]

Furthermore, the company must operate in a given legal context that regulates intellectual property and knowledge, data issues, employment, corporate responsibility and foreign trade and exports among others. For all these reasons, companies must develop the capacity to offer simple solutions to increasingly complex legal problems.

A situation that could affect companies is the increase of **tax costs for the use of robots**. One of the main supporter of this idea is Bill Gates (Delaney, 2017) who proposes that robots should pay taxes equivalent to those paid by workers. In fact, in 2017, EU legislators considered a proposal to charge robot owners to pay training for workers who have lost their jobs. The proposal was rejected and, in return, European Parliament proposed a regulation about creation and distribution of robots in working places (Delvaux, 2017). Although this issue is still under consideration, there is a real risk of increase in social inequalities and it could be a solution if robots assume tasks with no opportunity to replace job losses.

Moving on to other issues, collaborative work with robots implies changes in **measures for the prevention of occupational risks**, while introducing new technology in a manufacturing environment may involve new business obligations and new risks (worker-robot accidents, electrocutions, burns, technostress and others). In this sense, regarding to labour legislation, it is necessary to have into account some important issues that affect directly to collective and individual workers rights:

- the implementation of a **quota system** to force companies to have a certain number of human workers
- a change in the tax allowances and deductions in **social contributions** incurred by employers so to increase the attractiveness of hiring human workers
- new **employment measures and public plans** in a robotic economic context
- new regulation of concepts as **working time**, **working shifts** and **job classification**
- legislation to guarantee fundamental rights such as **career advancement, long-life learning, non-discrimination, privacy and data protection** (the use of audiovisual devices may raise concerns about workers privacy), **technological conscientious objection** (negative worker reaction to work in a robotic environment), trade-union freedom, right to strike.

Some of the main recommendations of Project RockEU (2016) (Arntz, 2016) point that regulation should be focused on encouraging the market.

Moving on to other issues, **standardising data streams** is urgent to develop the innovative potential of Industry 4.0. Characterised by interconnected devices and systems, smart factories need to maximize the efficiency in resource allocation and the agility in production processes. To meet this objective, it is necessary to have an ecosystem of customers, suppliers and partners communicated in real-time with safe and integrate information, and for this to happen, circulation of data calls for standardisation. Some sectors, such as European aerospace industry, have already reached this conclusion, creating a sector-based platform to share information across the entire value chain (Rizk, 2016).
In this sense, in order to get an effective standardisation environment for digital technologies, European Commission has identified five priority areas for standardisation efforts: 5G, cloud computing, the Internet of Things, data technologies and cybersecurity. This focus would be supported by a delivery mechanism, building on regular monitoring by the Commission, a dialogue of the Commission with all stakeholders, cooperation with standardisation organisations and strengthened international engagement (European Commission, 2016).

From the point of view of SMEs there is little they can do to influence the fiscal, legal and regulatory system but they can anticipate changes and future trends by using an efficient market and technology surveillance system. If SMEs know what is going to happen in the near future in the regulatory/fiscal/legal environment, they will be prepared with the adequate resources to face the new situation. On the other hand, SMEs have the option to group under bigger corporate structures (sector or industry or professional associations) to make their voices heard in front of other stakeholders.

5.6. Monitoring and Control Challenges

Continuous monitoring is one of the core competencies of a factory of the future because companies will be in a continuous process of strategic repositioning with structural changes and continuous improvement.

Product and service offerings are strongly data driven and based on the collection, monitoring and analysis of processes, and open the door to new and innovative concepts such as **predictive maintenance** to prevent problems in production. Thus, a monitoring system equipped with sensors that generate a huge amount of data about the processes, can compare these data with historical ones, revealing patterns and being able to predict fails or vulnerabilities in a production environment (vibration analysis to detect misalignments, unbalances and other failures, infrared techniques to detect problems in electrical mechanisms, etc.). Prompt actions can be taken and such actions will increase the reliability of the production process.

Machines can even provide remote diagnosis and offer maintenance services from their locations, and such data can also be useful to know in which conditions the machines are operating and what to learn from such data (Khan A, 2016).

At an operational level, data can be transmitted in real time and can include production orders, production surveillance (key production metrics), maintenance necessities, data analysis or virtual value stream mapping among others (Davies R, 2017).

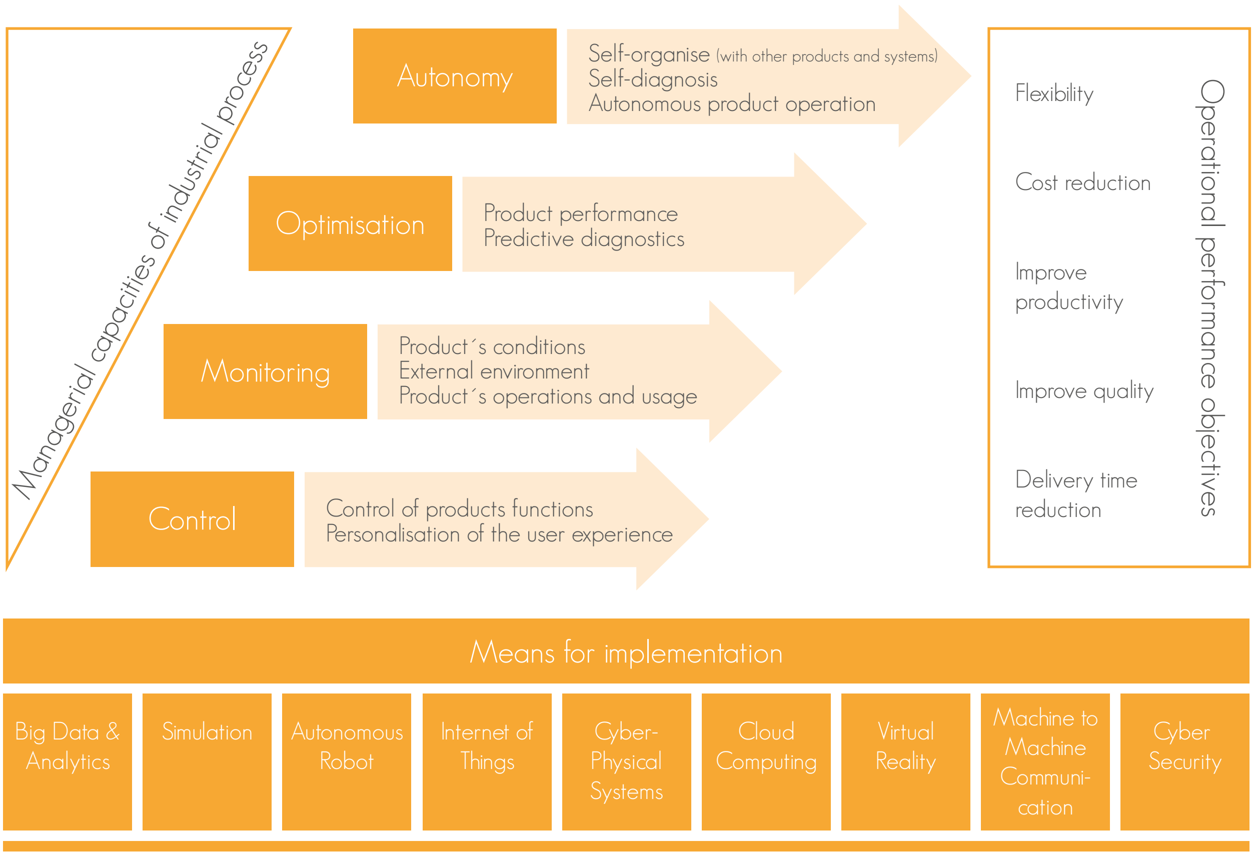


Fig. 32: Managerial capacities of industrial process. Source: (Moeuf, Pellerin, Lamouri, Tamayo-Giraldo, & Barbaray, 2018)

Following the analytical framework provided by Moeuf, 2017 (see Fig. 32), four levels of managerial capacities can be established for monitoring and control purposes:

- Global monitoring for the production system by connected devices. The monitoring function can also take the form of a historical analysis used for decision-making purposes. This is the easiest level of managerial capacity that can be achieved in Industry 4.0.

- Control based on historical data to detect situations requiring a decision via an alert. Control favours the interaction of employees with the system by using historical data and predetermined thresholds.
- Optimisation in real time using monitoring data, system models and simulation systems. This level aims at improving systems and processes and can be achieved through numerous approaches.
- Monitoring capacities, control and real-time optimisation combined to get higher levels of optimization, for example, using systems capable of learning autonomously from their own behaviour, and adapting themselves as a function of the results obtained.

All of these levels can be materialised through the implementation of different technologies such as big data, simulation, autonomous robots, Internet of Things, CPS, cloud computing, virtual reality, machine-to-machine communication and cybersecurity.

To face this challenge, SMEs should have a formal monitoring process with key performance indicators linked to the company more strategic activities, and perfectly woven with the rest of the company processes. This way, SMEs will be able to make informed decisions about the current and future activity, and they will count on precise information to make strategic decisions in the medium and long term.

5.7. Main findings and recommendations

- The **4th Industrial Revolution** supposes the merge between the physical and the virtual world. Networking and transparency are the basis of the Industry 4.0 paradigm that shifts production from "centralised" to "local" in a transition from central production management systems to local intelligence with an improved decision-making basis.

- In this context, **factories became "smart"** with improved processes involved in manufacturing, engineering, supply chain and life cycle management, in a complete new approach to production. The smart factories have embedded manufacturing systems vertically networked with non-producing systems, and horizontally integrated to value networks across the entire value chain. This allows product customization and a more agile production, which implies innovative business models around new value proposals and more efficient business practices.

- Industry 4.0 needs a **transformation of the current business models** and a re-definition of the value proposal for companies. Switching from a traditional company to a digital one implies big technology changes, process changes and interaction changes. This implies three kind of integration movements: vertical integration and networked manufacturing systems, horizontal integration through value networks and end-to-end digital integration of engineering across the entire value chain.

- The change in business models is justified by one of the following goals: **increase of flexibility, improve of productivity, costs reduction, reduction of delivery time and/or improve of process quality**.

- Since top management support is essential to foster industry 4.0 and **management is the core process of a company**, changes in management affects all the main processes of the company. The big challenge for managers is to develop an adaptive leading to balance automatization with demand for variation and, at the same time, maintaining a high-quality product.

- Risk management is the process that helps companies to understand the risks inherent to the current situation and the correct answer for them. In the manufacturing sector, operational risks are associated with manufacturing process management, maintenance, operation methods and tools, material, human resources, machines and manufacturing technologies and machine environments. The concept of Industry 4.0 generates new risks associated with the connection of cyberspace and outsourcing of services among others. Although Industry 4.0 can have impact on all the processes of the company, the **higher share of the risks is related to information security**.

- To face the challenges related to changes in business models, SMEs need to fully understand technology so they can be able to absorb it. There are some new **tools to help SMEs to test technology** and to know in advance how technology can affect them, for instance, Digital Innovation Hubs (one-stop-shops to help SMEs to become more competitive using digital technologies) or testbed labs (experimentation platforms to test and use new technologies). Also, SMEs need managers with a double technological and management profile, able to understand the potential of new technologies in an uncertain environment.

- Industry 4.0 radically changes job and competence profiles. Workers have a **changing role from operators to problem-solvers**.

- Automatability strongly decreases in the level of education and in the income of the workers: **low-skilled and low-income individuals face the highest risk of being automatable**.

- Managers are changing from being "people managers" to "people and machine managers". Since CEOs operate in a technology-driven world, the leading business schools are focused on the intersection of **businesses, technology and design** to anticipate digital disruption in companies. In this sense, the greatest threat to the employment is not the automatization but the **inability of stay competitive in the future**.

- Companies must take care of **workers employability rather than jobs**, and training, new learning methods, and long-life learning and development are key factors to aim this goal and to improve the acceptance by workers of technological change in the company.

- **Different forms of work organisation** are emerging, affecting worker-employer relationships. In these new forms, human dimension is more important – human centred manufacturing – specially for works in which human work cannot be replaced. These worker centred models affect the design of workplaces and the allocation of workload, and are expected to increase the workers' satisfaction and make the workplace healthier and safer.

- To face the challenges related to the employment, SMEs have some possible actions such as carrying out a **study of current internal expertise and future needs**, to reveal the gaps between the two situations. Also, SMEs should fill the key posts with T-shaped persons: People with expert knowledge that, at the same time, have personal skills to connect with other fields of knowledge. In any case, SMEs are going to need close connections to other agents in the innovation system to analyse the gaps, to develop the suitable profiles and to include them in the internal work organisation. In this sense, universities, research and technology organisations, vocational training centers, innovation hubs and testbeds could be good partners where training aspects would be developed and offered.

- The answer to the new productive challenges needs a **close collaboration and open innovation** between different technologies and different sectors, and between different stakeholders across the entire productive value chain integrated in an active and collaborative way.

- To face all the challenges related to collaboration issues, SMEs should integrate **business intelligence processes** in their activity, so they could incorporate ideas and new knowledge to the company's strategy. Also, SMEs should consider the stakeholders in their value chains (suppliers, clients, competitors, etc) as part of their own business, and not only as isolated agents delinked from the internal decision-making process.

- Some of the most important legal issues for the companies in the digital era are **data access, liability, data ownership and the cloud**.

- SMEs can anticipate changes and future trends by using an efficient **market and technology surveillance system**. If SMEs know what is going to happen in the near future in the regulatory/fiscal/legal environment, they will be prepared with the adequate resources to face the new situation. On the other hand, SMEs have the option to group under bigger corporate structures (sector or industry or professional associations) to make their voices heard in front of other stakeholders.

- Continuous monitoring is one of the core competencies of a factory of the future because companies will be in a continuous process of strategic repositioning with structural changes and continuous improvement. Product and service offerings are strongly data driven and based on the collection, **monitoring and analysis of processes**, and open the door to new and innovative concepts such as predictive maintenance to prevent problems in production. In this sense, SMEs should have a formal monitoring process with key performance indicators linked to the company's more strategic activities, and perfectly woven with the rest of the company processes.

6. COOPERATION BETWEEN HIGHER EDUCATION INSTITUTIONS AND BUSINESSES

Author: Gianluca Ross

6.1. Introduction

The greatest challenge for Europe's SMEs in the engineering sector is the so called 'smart industry', understood as the intelligent IT-based components and systems within all areas of supply, production and distribution chains. In order to be well-prepared for these developments, the contribution of HEIs, through their knowledge and research, represents an important support. On the other hand, SMEs need to develop in the knowledge, skills and competences of its staff, but also need special pedagogic approaches tailor-made to their production processes and business life. In this context, the HEI-business cooperation model is one of the most important tool SMEs could use in order to become "smart", increasing their competitiveness and improving their position on the market.

The aims of this section are:

- to provide a definition of the HEI-Business cooperation model
- to explain how the European Commission encourages and supports the HEI-business cooperation model
- to demonstrate the reason why HEI and SME should cooperate: In this subsection the roles of univer-sities and businesses will be presented and also the advantages and disadvantages of this cooperation
- to present a HEI-Business cooperation model proposal tailor-made on the SMeART project
- to present the best practices of HEI-Business cooperation models on the Smart Industry field at European level.

6.2. Definition of The HEI-Business Cooperation Model

The University-Business Cooperation is all types of direct and indirect, personal and non-personal interactions between HEIs and business for reciprocal and mutual benefit, aiming at exchanging knowledge within innovation processes, as well as technology transfer of intellectual properties, publications, joint research, mobility and training (The State of University-Business cooperation, August 2011).

The key to a successful cooperation between HEIs and business is a mutual understanding and appreciation of one and another's goals and objectives, and they can cooperate with each other as follows:

- Companies put the know-how developed by the academic researcher to good use through innovations development;
- Universities use the know-how transferred by the businesses for purposes of education and continue the research.

The close cooperation of HEI's and SMEs can help universities to increase the capacity for regeneration and renewal in research, help businesses to gain and maintain their competitiveness of the national economy, contribute to the economic development at various levels (regional, national and European) and meet the demands of the labour market to provide more relevant knowledge and skills.

Factors which influence the University-Business Cooperation model are the following:

- The **relationship** between university and business: HEIs and businesses work in a cooperative and mutually beneficial relationship. In general the existence of mutual trust for the University-Business Cooperation is higher in large companies, (followed by medium and small companies) which are more willing to cooperate with Higher Education Institutions. Their cooperation often is already long-lasting which builds trust and commitment between the two stakeholders. Mutual trust and commitment are the factors which promote the cooperation with universities to a high extent among those companies which already have high extent of a University-Business Cooperation.
- The **pillars** of the University-Business Cooperation: strategies, structures and approaches, activities, framework conditions.
- The **barriers, drivers and situational factors** which affect the ability of HEIs to undertake the cooperation:

1. **Drivers** that facilitate the cooperation between businesses and higher education institutions are the following:
   - Existence of mutual trust and commitment
   - Existence of shared motives
   - Prior relationships with HEI
   - Interest of HEI in accessing practical knowledge
   - Close geographical distance of HEI
   - Access to HEI's Research & Development facilities
   - Financial resources for working with HEI
   - Flexibility of HEI.

2. The main **barriers** that companies are facing in cooperation with higher education institutions are the following:
   - Bureaucracy within or external to the HEI: The bureaucracy of the university is important and sometimes too much time is needed to comply with the formalities required which in some cases can slow or even stop the collaboration. The bureaucracy is time demanding what the rapidly changing labour market cannot afford.
   - Different time perspective between HEI and business
   - Difficulty in finding appropriate persons within HEISs
   - Different motivations and values between HEIs and businesses: divergent methods of communication and language barrier between the two sectors.
   - Limited ability of knowledge transfer
   - Current financial crisis

3. The **situational factors** which influence the extent of University-Business Cooperation. Undertaken are ages, genders, years at the HEI, years in business, type of HEI, sectors of companies and countries.

There are 8 different ways in which HEIs and businesses can cooperate:

1. collaboration in research and development (R&D),
2. mobility of academics,
3. mobility of students,
4. commercialization of R&D results,
5. curriculum development and delivery,
6. lifelong learning,
7. entrepreneurship,
8. governance.

Successful cooperation of HEIs in synergetic relationships with governments and businesses is considered the ideal driver of knowledge-based economies and societies. The University-Business cooperation produces benefits for all actors involved in the model:

- For Students: improving the learning experience, increasing skills and graduating development, improving the employability of future graduates.
- For HEIs: achieving the mission of the HEI; increasing the academic reputation in the fields; improving research.
- For Businesses: improving the performance of the business.
- For Society: improving local employment, benefiting the local industries, improving regional productivity; creating a various range of social and recreational benefits.

Some of the results attributed to a successful University-Business Cooperation include improving the education and future job prospects of students, the research conducted within the HEI and the transfer of knowledge and research to the community. Additionally, there are indirect results including support in the creation of a knowledge economy, support for local business, creation of jobs, stimulation of economic growth and increased living standards.

6.3. How the European Commission Supports HEI Business Cooperation

During the last 10 years there has been a growing acceptance across member states of new relevance of universities to social and economic development. This is recognized by the Europe 2020 Growth Strategy and especially the developing "smart specializations" strategies across the European Union in preparation of the next round of structural funds, which gives increasing prominence to the role of universities not only in terms of the supply side (research and skills) but also in supporting the demand side through capacity building and supporting the governance in regional innovation.

Based on DG Education and Culture study, there has been an increasing trend over the past decade to include universities more explicitly in regional strategies, and for universities to adopt a more formal role in the region as expressed in their mission statements. With some exceptions, the cooperation between HEIs and business in Europe is still in the early stages of development. In fact, the European University-Business Cooperation is influenced by several factors including the perception of benefits coming from the cooperation as well as barriers to and drivers of the cooperation (Measuring the Impact of University-Business cooperation, 2014).

As highlighted by the Agenda for the modernization of higher education, obstacles to the University-Business Cooperation could be the following:

- Higher education in Europe is not equipping enough people with the right skills for modern society. Too few graduates are leaving higher education with skills in fields where there is high demand (like Science, Technology and Engineering professionals, ICT professionals, etc) and too many are leaving with poor basic skills and limited soft skills relevant for work (like critical thinking, problem solving, communication, etc..).
- Higher Education Institutions are not contributing enough to innovation in the places they are located. Europe's universities lag behind competitors in the US in pioneering international research. But they are also too often disconnected from the companies and public services, meaning their teaching and research activities are not being used to bring benefits surrounding areas.
- Higher education systems are not organised and funded in a way that allows them to give the best results. Funding and quality systems give little incentive to staff and institutional managers to deliver good teaching, to cooperate with firms on innovation projects and to build links with the society (An Agenda for the modernisation of Higher Education, 2017).

Following the Europe 2020 strategic plan, the Lisbon agenda and the modernisation agenda of European universities, the European Union has recognised the importance of the role of HEIs (through education, research and innovation) in the transfer of knowledge to society and their vital contribution to Europe's economic competitiveness. The need for closer cooperation between universities and the business world is underscored as UBC has proven that it provides a range of advantages and benefits for HEIs, students, business and society alike.

The European Commission supports links between higher education and business at the European level through a series of initiatives. Closer links between business and academia can:

- encourage the transfer and sharing of knowledge
- create long-term partnerships and opportunities.

6.4. Drive innovation, entrepreneurship and creativity

(7th European University-Business Forum, 2017)

The European Commission encourages the cooperation between university and business through two major initiatives:

1. *KA2 Cooperation for Innovation and Exchange of Good Practices* – **Knowledge Alliances** under the Erasmus + Programme. Through the funding reserved to this programme, HEIs and SMEs have the opportunity to cooperate together in order to:

    - **Promote innovation** in HEIs and SMEs developing and implementing new learning and teaching methods (such as new multidisciplinary curricula, learner-centred and real problem-based teaching and learning); organising continuing educational programmes and activities with and within companies; developing solutions for challenging issues, product and process innovation which involve all the stakeholders.

    - **Stimulate entrepreneurship and entrepreneurial skills** of HEI teaching staff and company staff: creating schemes of transversal skills learning and application throughout higher education programmes developed in cooperation with enterprises aiming at strengthening employability, creativity and new professional paths; introducing entrepreneurship education in any discipline to provide students, researchers, staff and educators with the knowledge, skills and motivation to engage in entrepreneurial activities; creating opportunities through the practical application of entrepreneurial skills, which can involve and/or lead to the commercialisation of new services, products and prototypes,

    - **Stimulate and facilitate the exchange and flow of knowledge** between university and business through: study field related activities in enterprises which are fully embedded in the curriculum, recognised and accredited; set-ups to trial and test innovative measures; exchanges of students, researchers, teaching staff and company staff; involvement of company staff into teaching and research.
    Source: www.ec.europa.eu/programme/erasmus-plus

2. **HEInnovate** is a free self-assessment tool for all types of higher education institutions, pursued and supported by the European Commission, DG Education and Culture and the OECD LEED Forum, and composed by a panel of six independent experts. The HEInnovative tool allows higher education institutions to assess their institution using a number of statements related to its entrepreneurial activities, including leadership, staffing and links with business. Extensive training and support materials, including practical case studies, are available to support workshops and further development within the institution.
    Source: https://heinnovate.eu/en

A more comprehensive understanding of what contributes to a successful University-Business Cooperation is also required and needs to be recognised in other funded projects. A review of the funding programmes would highlight the need for projects to build upon existing University-Business relationships that have already achieved proven results.

6.5. Why should university and business cooperate?

During the last decade universities were playing a new role in the economy and society, due to the relations with businesses and various stakeholder at local, regional and national level. Universities evolved from the basic functions of teaching and research to a third one, the commercialization where the partnership with the industry is the most important element.

Mainly, universities are interested in applying the fundamental research in practice, and the business find interest in applicative research, searching for new products and services based on scientific discoveries.

The University-Business Cooperation is considered to be the engine towards knowledge-based societies and economies. It is specially needed in the European context, threaten by increased global competition, with ongoing economic issues and high levels of unemployment.

Outcomes attributed to a successful University-Business Cooperation include:

- Ø improving the competitiveness of business,
- Ø increasing the relevance and innovativeness of research in HEIs,
- Ø creating jobs,
- Ø stimulating economic growth,
- Ø increasing living standards,
- Ø reducing of hindrances to good living.

The research cooperation (including cooperation in R&D, consulting to business, mobility of staff) is the main University-Business Cooperation activity in most HEI faculties as well as industry sectors. However, HEIs and business could also cooperate in the following areas:

- **education**: curriculum co-design, curriculum co-delivery, mobility of students, dual education programmes, lifelong learning
- **valorisation**: commercialisation of R&D, academic entrepreneurship, student entrepreneurship
- **management**: governance, shared resources, university support (Why should University and Business Cooperate?, 2013).

Nevertheless, there is a lack of awareness of all the ways in which university and business cooperate and how they interrelate especially in respect to professional mobility and education activities (curriculum design and delivery, lifelong learning and study programmes) as well as valorisation and management cooperation.

The lack of awareness of the ways in which HEIs could cooperate with the businesses is found also in the Smart Engineering field. The Report on Learning and Business Consultant Needs of Europe's SMEs realised under the SMeART project, shows that about half of the companies interviewed are not in contact with any HEIs, especially micro and small companies, and if they were in contact with HEIs, they could use mainly the knowledge provided by the university, but also innovation and consultant. One of the main reasons for which companies are reluctant to cooperate with higher education institutions is the strong theoretical approach by the research sector and their lack of practical orientation. The enterprises' representatives interviewed within the SMeART project reported that the possible practical areas of support HEI and the research sector can provide are the following:

- Testing of material and product and participation in study groups; analysis of the production; measurement.
- Innovation such as development of new technologies, products and services; Research & Development, internationally-funded projects.
- Knowledge: competences in production planning, IT competence, management, accounting, optimisation process, technological know-how, statistical approaches, mathematics, etc…
- Consulting: advice about the existing offer and practical support, conducting analysis concerning concrete solutions to become "smart"; supporting the implementation of smart industry.
- Network: collaboration in Research & Development, projects development supported with grant requests, transfer of know-how between the academic and professional world.
- Future employees: Higher education institutions can train new IT engineers who are interested to work in their company in order to become "smart".

These data prove that there is the necessity to promote the awareness and importance of close cooperation with the universities in order to encourage the transfer of knowledge, drive innovation and improve the business competitiveness becoming a smart industry.

In order to define the cooperation model which meet the SMEs requirements, it could be interesting to describe the specific role of HEI and business in the cooperation model and also the advantages and disadvantages resulting from this cooperation.

The **academic collaborators** typically initiated their own cooperation with business at regional or national level. Their biggest motivations for a cooperation is to cooperate with business for research outcomes more so than promotion and reputation in the university and their cooperation is best facilitated through trust and mutually beneficial relationships with business. The academic collaborators could have worked in business for a period of time increasing their cooperation with each year of experience they have with it. They work at larger universities, which are most likely applied sciences universities or technical universities although older HEIs tend to have a research focus and younger HEIs, a focus on cooperation in education. These HEI also tend to have more localized partnerships with business in order to stimulate economic growth and regional development.

The main advantages HEIs can benefit from the cooperation are as follows:

- Focused research: Professors have the opportunity to realise new researches in different fields, testing the results, new methods and technologies.
- Access to knowledge from the industry: Professors have the opportunity to learn about new market realities.
- Development of new textbooks and updating of training materials based on the research results.
- Facing the challenge of the "third mission of universities", the commercializing which includes, in particular, the innovative mission through consulting contracts and solution developments for the industry.

The cooperation model between university and business presents also some threats for the academic partners: the lack of specialized staff in marketing departments or technological transfer offices, the bureaucracy structure and high administrative costs.

On the other hand, the business collaborators tend to cooperate primarily in research, however cooperate with their academic partners in more than one way indicating that it tends to be a relationship with the academic partner rather than a one-off transaction. Their biggest motivations for a cooperation is to support their innovation efforts, particularly with a longer-term perspective, which is supported by external funding. The business collaborator perceives cultural differences to be the largest barriers to a University-Business Cooperation, particularly differing motivations and lack of business experience in HEIs as well as different time horizons. As the business gets older, they are more likely to cooperate with HEIs at higher levels especially in education and as they get larger, more likely to increase cooperation in more long-term cooperation areas such as education and management.

From the point of view of the business, research and development receive a major attention and demonstrate to be a profitable investment on long-term and an important contribution in productivity increase.

In general, the cooperation with the university could be formal or informal. The last one is suitable for the cooperation model designed under SMeART Project, because it is specific to small and medium enterprises, which are interested in a rapid and flexible access to economic and relevant information and are open to a university partnership. This partnership is recommended for the industry that searches solutions for problems that cannot be solved internally with own skills and competencies. The cooperation with the HEIs offers the following advantages:

- innovation process
- reduction of stages in order to become a 'smart industry' in less time
- economies of scale: There is not the need for infrastructure investments or personnel with special competencies and skills, because the companies can take advantages from those of the university;
- impulse for changing the perspective on the market and development
- obtaining public funded research projects.

On the other hand side, the cooperation between University and business presents some risks:

- problems related to the internal bureaucracy both of university and business which could negatively influence the management of the common project;
- problems related to the risk that one part uses the project results for its own purpose;
- protection of know-how, the team members belong to the university and to the business and there could be the risk of piracy.

It is important to prepare a contract in order to regulate the cooperation between university and business clarifying the conditions of the collaboration, the contribution and the responsibilities of each part.

The University-Business Cooperation model is composed by the following activities which could be implemented in parallel:

- Research
- Learning / Training
- Consulting.

The SMeART- HEI Business cooperation model is essential to help SMEs to tackle the challenges of
Smart Engineering, not only through formal learning activities but also through cooperation and consulting models with HEIs focussing on workplace-based learning, transnational learning mobility, exchange and networking with other SMEs (Why should University and Business Cooperate?, 2013).

The cooperation could be formalized through the following tools:

- Contract research: unilateral knowledge transferred by the university to companies in relation to the know-how to be developed.
- Cooperation research: oriented to the exchange of experience, information, know-how in general between the university and companies.
- Contract for work and services: If the agreement is linked to success, it is a contract of work; if the agreement is linked to activities, it is a contract of service.

6.6. The SMeART HEI Business cooperation model

The cooperation model proposed within the SMeART Project is suitable for SMEs in the engineering sector. It could be composed by different activities:

6.6.1. Consultancy and Engineering Services

The HEI experts could offer their specialist services in order to support the SMEs to tackle the challenges to become a smart industry through skills and human resources, knowledge about new technology and implementation, business and innovation strategies.

This cooperation is an important instrument by which the academic experts can share their expertise and knowledge with the engineering SMEs. The consultancy services could be: direct consultancy where the academic expert transfer their specialized knowledge to the SME.
Sharing of experience: The academic expert can apply previous experiences carried out in similar companies in the context of the SME where he gives the consultancy.

Tailor-made consultancy on the SME's needs: the HEI expert helps the company at identifying the gaps or problems in order to become a "smart industry" and, consequently, suggest the best way to solve the problem.

6.6.2. Exchanges between University and SMEs

Through exchanges and mobility programmes of university experts in the companies, the SMEs managers could transfer to them additional skills and specific knowledge from companies, such as managerial, entrepreneurial and communicative competencies.

The mobility promotes knowledge transfer and unlocks some of the intellectual assets of university for the benefit of the host company. In addition, the boundary spanning skills of researchers could create opportunities for future collaborations by breaking down barriers between the university and businesses.

The companies can benefit from the experience of researchers with a number of businesses in the same industry and operating in a much larger geographic sphere than SMEs to bring them a global experience and expertise to help address local issues.

6.6.3. Training 'On the Job'

The Training model "on the job" seems to be especially suitable to the needs of companies which want to invest continuously in innovation processes. It means training activity to be carried out directly in the workplace, focussed on improving the technical, transversal competencies of managers and employees. In addition to align the technical competencies to the available technology, this activity helps employees to develop an overall idea of all company production processes, so that they will be able to anticipate problems and/or know to refer to anyone who can help them when the problems arise. The training will allow them to acquire this awareness in practical manner rather than a theoretical transfer of knowledge.

The training could be composed by the following activities:

- TUTORING: transfer of knowledge through laboratory activities carried out by university researchers in support to managers of different processes.
- MENTORING: training activity carried out by the process' managers, already trained by the university experts, in order to transfer the information learnt to "young" workers through support in workplace.

The universities' researchers will cooperate closely with the SME manager/owner in order to understand the business processes and, consequently, propose the instruments aiming and obtaining the same products with innovative methods of automation, optimization, control and measurement.

At firm level, customised corporate trainings are being integrated or enriched to ensure that each employee can acquire the specific skills necessary to increase his or her productivity. As regards recruitment processes, new digital platforms allow companies to improve applicants' skills assessment in order to better screen, attract and hire the talents needed at every step of their value chain.

An interesting tool the companies could use is the platform, creating a Best Practice Network: In order to benefit from the upcoming changes, manufacturing companies will need to re-think historic business paradigms. **Smart Industry Forum's network** is a powerful community for sharing experiences and for learning from best practice examples. Across this network, the Smart Industry Forum has the passion to promote the emerging open standards and to share experiences from their practical deployment throughout the manufacturing industry.

6.7. Best Practices of HEI-Business Cooperation Models at European Level

Many universities as well as public and private research centers are already active on the Smart Industry field and increase the amount of collaborative projects with companies. Across Europe, there is an increasing appetite and enthusiasm for collaborations as the projects have proved to generate valuable intellectual property which supports innovation by all industrial partners.

All across Europe, academics/universities and industries (especially Smart Industries), are beginning to set up a sort of "positive interaction", supporting improvements in manufacturing through innovations in digitalization and automation. It results in product development, increased flexibility, improved quality, reduced costs, environmental and energy gains all of which are relevant for being competitive in the market.

Following are reported some projects of industry-university cooperations experienced in the sector of Smart Industry at European level:

1. At Chalmers University Technology (Sweden), the Stena Industry Innovation Laboratory (SII-Lab), a test-lab for digitalisation and future jobs in industry, has been recently opened. The university works closely with the Swedish industry to open up great opportunities for research, innovation and education. An important piece of the puzzle is for Chalmers to remain an internationally leading environment in the area of production. Now we can contribute even more strongly to increase the speed of Swedish industry's digitalization. With the help of funds from the Stena Foundation, an old library at Chalmers University of Technology, Sweden, has been transformed into a multifaceted laboratory – the Stena Industry Innovation Laboratory. Inside there is much of what is required for new industrial practices, or what is commonly called 'Industry 4.0'. In smart industrial production, technologies and tools are adapted to the employee. Builders, operators and production developers can utilize their creativity and perform their work better with the use of digital tools. For industry, the test-lab is long-awaited.

2. University of Nottingham (UK): It encourages the students to undertake a year in industry as a part of their undergraduate course to help them gain vital employability skills and to create partnerships with businesses for year-long placements as well as summer internships. The placement team works with a range of companies from large corporations to SMEs to help employers find the right student for their business needs. It has strong links with a variety of businesses from large corporations to small and medium enterprises (SMEs). In the new industrial age, smart factories will deliver highly personalized goods and services. This demands profoundly new approaches to how products are created, manufactured and used, while redefining the relationships with technologies and each other. The university's vision is to establish a programme of far-reaching fundamental and transformative discovery and to deliver responses with a speed and agility that matches the unprecedented pace of change in the digital world. By bringing together expertise from informatics, creative design and industrial technologies, as well as the social sciences, the academic discoveries will enrich personal experiences, build better-connected societies and provide exciting opportunities for business in a skills-rich UK economy. The university is committed to fundamental discovery and its application in key UK sectors including aerospace, automotive, consumer and the creative industries. The University of Nottingham represents a best practice in the field of Smart Industry as it delivers:

- Smart, interactive products: New approaches to interactivity and design customize, mass production and deliver unique user experience
- Smart production processes: Data, humans and systems seamlessly interact – instead of programmed, passive machines, manufacturing will be truly dynamic
- A connected industrial infrastructure: By delivering models for the digital marketplace, taking in the whole system lifecycle, the university would make UK's industry a world leader in this new industrial and consumer landscape
- An ethical framework: Complex questions arise from heightened interactivity and richer user experiences.

More information is available at https://www.nottingham.ac.uk/engineering/industrial-placements/for-business/index.aspx

3. National initiatives on digitizing European industry in THE NETHERLANDS: Public-Private Partnerships are co-operations where large/SME industries, local schools/academia and research & technological institutes as well as representatives from local/regional/national government work together to achieve jointly defined ambitions. They exist in all kind of different forms. The Smart Industry action program at national level, and field labs at regional/local/city level are examples. Many are bottom-up established when multiple parties encounter a joint challenge. By organising a triple helix structure one expects to accelerate the development of (regional) eco-systems. Field labs (practical environments where companies and knowledge institutions develop, test and implement Smart Industry solutions in a targeted manner) were established when the EU in the KET discussion (Key Enabling Technologies) identified the lack of means to cross the valley of death in bringing research to innovations into markets. As a result pilot-lines were defined as environments where activities were conducted at TRL (Technology Readiness Level) 4-7/8. Previous co-operation with subsidy funding was limited to pre-competitive research (TRL 1-3/4). In the Netherlands two pilot lines were renamed fieldlab as innovation activities in industrial, but not yet commercial producing environments. The field labs were initially focused on innovation research projects, they now also tend to include (vocational and technology) training for students and employees using the newest technologies too. Digital Innovation Hubs: In general a fieldlab has a focus on a single technology, but currently we see regional clustering such as companies and their employees, but also schools and students have access to them close by. As a result of this evolution the creation of a limited number of Digital Innovation Hubs in the Netherlands is foreseeable, as a set of field labs in a certain region where together they form a digital innovation hub around several technology topics (3D/AM, robotics, supply chain coupling, composite production, preventive maintenance).

4. University of Groningen (HOLLAND): The engineering programmes at the University of Groningen train future experts who are capable of contributing with scientific knowledge and skills in the design of products, processes and technologies. The University provides expertise in several areas:

   - Energy
   - Electronics of materials
   - Mechanical engineering
   - Diamond-like coatings
   - Biobased materials
   - Complex Systems
   - Advanced Instrumentation and Big data
   - Chemical, cellular and pharmaceutical engineering

   There are several examples of successful projects developed in the area of Smart Industry by engineering researchers at the University of Groningen and public and private partners. In this particular case, the Smart Industry Roadmap, 25 companies (large and small) and knowledge institutes conduct joint research.

   More information is available at https://www.holland-hightech.nl/nationaal/innovatie/roadmaps/smart-industry

5. **The University of Twente** (NETHERLANDS/Enschede) will receive half a million euros from the EFRO (European Regional Development Fund) to co-finance 18 PDEng programmes in the field of Smart Industry. This will enable SMEs to collaborate with the university at greatly reduced cost. The STW Technology Foundation has recently also made €1 million available for four Smart Industry projects that the University of Twente is involved in. A PDEng (Professional Doctorate in Engineering) programme involves a two-year post-Master's at the University of Twente, with a strong focus on collaborating with industry. The programmes yield considerable added value for industry because there is a strong demand for professionals who can work on designs for multidisciplinary issues independently. This grant from EFRO will enable closer links between SMEs in the east of the Netherlands and the University of Twente. The PDEng Cluster for Smart Industry in

the east of the Netherlands links the manufacturing sector with the university in order to foster talent and develop targeted solutions for Smart Industry themes (January 2017).

More information is available at https://www.utwente.nl/en/news/!/2017/1/153390/ut-successful-in-smart-industry-research

6. **Universidad Pontificia Comillas** (SPAIN/Madrid): the Master in Smart Industry is a university-specific degree of ICAI School of Engineering. It is conceived as the response of Comillas Pontifical University to the Fourth Industrial Revolution. The digital transformation of the industry represents both challenges and opportunities for engineers. Companies require professionals with a global perspective of the Smart and Connected Industry, combining the command of enabling technologies and deep understanding of the keys for their application to business. In addition, it is very important to take care of the social impact associated with this industrial change. This Master program has been designed with the aim of educating the professionals who will lead this industrial revolution we are already living today.

   The program has been conceived in a close cooperation with 10 Sponsor Companies of the Smart Industry Chair, which guarantees the practical approach that companies need, as well as the academic rigor of a MA program. One of the highlights of the program is the offer of internships in Industrial or Technological companies in Spain or abroad, which will allow students to work in real projects.

   More information is available at http://www.icai.comillas.edu/en/master/mic-en

7. **Tartu City Government (ESTONIA)**, together with **Tartu County Development Agency** and **ADAPTER**, a network of Estonian universities, research and development organisations, organised a learning workshop in the example of packaging industry within the INNO INFRA SHARE project in Tartu on 3rd of May for nearly 80 people. One of the most relevant outcomes was the need to turn the „researcher" mindset into an entrepreneurial one and work together with the companies: Sustainable research is about designing products/services to meet companies' needs, respect their go-to-market time, and create trustful and heterogeneous networking environments. The first part of the workshop was more focused on the university and research institutes' side and how they could help the industry needs today and tomorrow. Representatives from the Association of Estonian Printing Industry, University of Tartu (biggest infrastructure holder in Tartu), Estonian University of Life Sciences, Food And Fermentation Technology Development Center and Tallinn University of Applied Sciences presented their potential and cooperation possibilities. The second part of the workshop was more focused on the industry and discussed the industry needs and experiences in cooperating with universities and research institutes and other stakeholders. Industry representatives from the packaging industry (Estiko Plastar) and companies using packaging (Lumi, Dragonfly Desk Lamps) presented their cases. Several questions have been raised - from the idea to the first contact with the universities and their interactions with SMEs/ corporates with an „entrepreneurial" and agile mindset. Trust, cooperation and reliability are the key pillars for these interactions, and need time and effort to be gained. As the workshop gained so much interest, a follow-up workshop is planned to be held in October this year.

   More information isavailable at https://www.interreg-europe.eu/innoinfrashare/good-practices/

8. **Tallinn University of Technology – TTÜ (ESTONIA)**, the only technological university in Estonia, is the flagship of Estonian engineering and technology education. Here the synergy between different fields (technological, natural, exact, social and health sciences) is created and new ideas are born. TTÜ signs almost every day different cooperation agreements with Estonian and foreign companies and government agencies. For developing innovative solutions, financing prototyping and to support commercializing, TTÜ established NBO Prototron with SA Tallinna Teaduspark Tehnopol and Swedbank AS. An interesting cooperation model between

businesses and universities is represented by MEKTORI (Modern Estonian Knowledge Transfer Organisation foR You), a networking environment where businesses, students, professors, school-children and investors from all over the world meet to generate new ideas and innovation together as one team. The aims of MEKTORY are:

Technology transfer: to bring together scientists, students and entrepreneurs; solve practical product development problems and generate new intelligent ideas.

- Labs, practical side of the studies: to maximize theoretical studies at the university through practice, to prepare better-trained engineers with experience in cooperating with companies.
- To encourage students start-up companies to move forward.
- School of Technology : to address upcoming generations and show that engineering is exciting, feasible and down to earth.

More information is available at: https://www.ttu.ee/mektory-eng

The following HEI-Business cooperation models are implemented between Faculty of Engineering - University of Perugia and several Italian companies in the field of Smart Industry:

- **University of Perugia – Rosati Fratelli**
  Rosati Fratelli is a small company of Leini, near Turin, in Italy who manufactures plastic fan for automotive and other application. A cooperation with the University of Perugia starts from a meeting of Ing. Guido Rosati with some Professors of the Faculty of Engineering at a stand of the University of Perugia at a Fair of the automotive sector in Modena, in 2005, and still goes on.
  Guido Rosati found in that first meeting with Perugia researchers useful competences in terms of new measurement techniques he believes useful to improve their products. Many research projects, mainly partially founded by Italian Research Ministry, has been carried out since 2005 to realize new fan blade design, prototype, components to improve performances, vibrations and fatigue life of the fan blades.

- **University of Perugia – Martech**
  Martech is a small company in Jesi (Ancona) manufacturing test bench for mechanical components testing and quality control based on image analysis. The meeting of Martech engineers and CEOs was stimulated by Meccano Spa, a consortium of companies and universities, also participated by the University of Perugia, that won a research project submitted to Marche Region for founding the development of new automatic quality control machines. The research team of the University of Perugia was invited thanks to their image analysis skills that Meccano well know from previous cooperations. Research performed in the 2016-2017 period consists in development of image recording, lighting and data processing software for the new automatic quality control machine developed by Martech.

- **University of Perugia – Schnell**
  Schnell is a medium sized company (240 employees) manufacturing build construction machines.
  It is located in Calcinelli di Saltara, Pesaro, Italy.
  The cooperation with the University of Perugia's measurement techniques research group arose in 2014 based on a from a long-standing acquaintance of the research chief engineer of Schnell with a professor of the University of Perugia. They were students together at mechanical engineering courses. Needs of the company in 2014 were new sensors for measure and control the strictness of the steel bar that their machine produce for concrete reinforcement.
  All the actually kind of sensors commercially available show problems to be used in these machines because of the very hostile environment, a lot of powder make impossible to use optical measurement techniques and mechanical constraints and positioning requirements make impossible to use conventional other proximity sensors. After a couple of years of research activity a new sensor was invented and patented for this application, based on magnetoresistive measurement principles, previously used by Perugia research group for aircraft engine blades monitoring, but on purpose developed to be a bi-dimensional proximity non contact probe, actually in production inside the company and in integration of the new series of machines.

- **University of Perugia – Korg Italy**
  Korg Italy is a small company of Castelfidardo (Ancona) producing keyboards worldwide sold and known from musicians. The cooperation with the research group of the University of Perugia started from 2013. Technicians of Korg contacted University' researchers for vibration testing of keyboards, necessary to certify their capacity to well survive in their packaging system to transport in trucks, aircraft, containers, etc.

  A specific standard has to be applied for testing in a test facility at Perugia laboratories but the vibration analysis and problem solving experience of the researchers was very important and appreciated by Korg technicians, in order to not only testing the packaging system, but in advance solving problems that could carry to a failure of the test, done accordingly the typical standards.

7. CONSULTING & COACHING

Author: Simona Rataj

»The goal of coaching is the goal of good management: to make the most of an organisation›s valuable resources«

(Harvard Business Review)

A SME manager, overtasked by his many responsibilities and obligations, will ask himself: »Why do I need consulting or coaching«? Or »Why should I use consulting or coaching«?

The answer lies in the accelerated globalization and the reality of digitalisation of the economy; it brings challenges that require faster business model changes and flexible adaptation to the business environment. Often business decisions have to be made very quickly; time plays an important factor in the success. Therefore, it's crucial that a manager, as a leader, sees the whole picture, is able to think quickly and make the right choices.

It is thus necessary to introduce changes in t education and behaviour of entrepreneurs, enabling them to answer the new business requirements and expectations on more effective and professional manner. The adoption of new managerial knowledge, skills and competences is an important precondition and among key factors for success of entrepreneurial ventures, as well as for development and sustainable growth of SMEs.

One of the ways how entrepreneurs, simultaneously with performing ongoing business activities, improve their operations and acquire the necessary additional knowledge and skills is the use of management consulting and /or coaching services.

The main goal of coaching and consulting activities, which will be performed during the SMeART project lifespan, is to prepare and support interested companies in their transformation towards smart companies (in terms of Industry 4.0).

7.1. Introduction

Innovation thrives in a variety of political, economic and social developments. These changes require effective and timely management of the company which will enable the changing environment and achieving the main long-term goals - to increase profits and the value of the business system.

The growth of the consulting and coaching industry shows positive effects in all areas of business activities, although there still lingers some scepticism towards them, especially in small and medium-sized enterprises.

Entrepreneurs generally lack sufficient knowledge about management coaching / consulting, they are not aware about standards and processes in providing coaching / consulting services, which is one of many causes of reluctance in purchasing and using of consulting services. In this chapter we will present the process of coaching / consulting and introduce the manager on how to prepare himself to achieve the most efficient outcome.

SMEs are in most cases formed by experts in a particular industry, which possesses a perfect knowledge of their profession in the context of technical competence, but they have a lack of knowledge and experience in management. In this way, they run their company into trouble because all the attention is focused on strictly professional technical knowledge and skills, and managerial skills are neglected.

The lack of expertise in planning, the lack of time of business owners to devote more seriously to long-term planning, are two of the main reasons for the stagnation and decline of small businesses.

In a number of studies, assistance of consultants or coaches is highlighted as essential to the success of small and medium enterprises (Deakins, 2000).

One of the ways how entrepreneurs, simultaneously with performing ongoing business activities, improve their operations and acquire the necessary additional knowledge and skills is the use of management coaching / consulting services. In modern economies, the coaching / consulting has proven to be a good form of assistance to entrepreneurs and owners of small businesses when solving business problems for which they lack expertise, knowledge and experience.

Working with coaches / consultants, entrepreneurs / managers educate themselves and build or improve their managerial skills. In practice, coaching / consulting helps emerging and maturing professional and dynamic managers who successfully manage change and who know the specific management activities and processes. Characteristics of coaching / consulting for small and medium enterprises is arising from the individual nature of these enterprises; individual problems are encountered in the process of growth and development, and as well as in the transformation process, for which routine solutions cannot be applied (Dukić, Milivojević, 2011).

The primary objective of this chapter is to describe the approach toward consulting versus coaching, present the Does and Dont's of the consulting process, and a checklist for executing consultancy / coaching. The reader, will be able to:

- understand the goals and the benefits of coaching and consulting (C&C), what to expect from C&C, what are the differences
- understand the coaching and consulting process in the SMeART project
- understand how to set up a coaching and consulting plan for a company
- identify and understand the reasons for monitoring and evaluation process of the coaching and consulting
- understand, how to prepare the company for a coaching and consulting implementation during the pilot phase for the maximum benefit.

7.2. The main benefits of SMeART Coaching and Consulting

An external expert can offer to SMEs information on new business opportunities, emerging from the smart industry. He will be able to conduct an accurate in-house analysis of a company's level of preparation for a smart industry and propose concrete consulting, training and/or coaching actions which will allow the company to respond individually to its smart market challenges. The SMEs will have the opportunity to strengthen their position in the global markets.

7.2.1. The main benefits of coaching and consulting for an SME

The beneficiary SMEs, through collaboration with coaches and consultants, will be able to better prepare for the requirements of the Smart Engineering industry. In the long-term, this will contribute to the strengthening of their position in the global markets. Main focus will be given to the following topics, important for SMEs:

- accurate in-house analysis of a company's level of preparation for a smart industry;
- interaction of SMEs with higher-education institutions (HEIs) in an open process in order to gain new knowledge for the company;
- free usage of the SMeART stress test tool for engineering SMEs will allow them to respond to smart industry challenges according to real demands and resources available;
- identification of new business opportunities, developing from the smart industry;
- concrete consulting, training and/or coaching actions which will allow the company to respond to its smart market challenges;
- strengthening the company's position in their main markets.

7.2.2. The potential benefits for higher-education institutions

The higher-education institutions, providing coaches and consultants, will be able to transfer some of the needed knowledge and experience to the beneficiary SMEs. They will be also able to

- perform the "Smeart industry stress test tool" together with the beneficiary SMEs;
- prepare a tailor-made coaching / consulting plan (including an innovative open learning programme)
- co-develop and test a one year lasting pilot. The HEI-business collaboration model, the stress test tool and training programme will available to HEI for better support to the regional, national and European economy; results, knowledge and experiences achieved in connection with the project will be available for the transfer to own curricula and training programmes and thus assure the transfer to the next generation of academic and SME staff.
- confirm and update the results of the SMeART survey: what is the state of the art in all EU member states concerning smart industry initiatives and policy; what are the needs, frameworks and demands expressed by SMEs when considering HEI business cooperation services dealing with Smart Engineering.

7.3. Which to choose – a coach or a consultant? Is there a difference?

A consultant's primary attention is on helping an individual achieve personal or organisational results through the application of their specific expertise where they advise the client on the best course of action for achieving desired goals. Consultants may or may not also be charged with transferring knowledge or a skill set to their client. The consultant works with clients on strategy, planning and problem solving, and helps clients develop business skills and knowledge. These topics range from designing a business model or marketing plan, to determining which marketing techniques to use and how to use them. A business consultant gives advice, teaches skills, and brainstorms with the client to produce practical results and enhance strategic thinking.

A business coach helps clients to create success by focusing on personal development: time management, self-sabotaging behaviour (like procrastination and distraction), finding clarity, decision making, and getting into action. When somebody puts on him a coaching hat, he does not give advice. Instead, he helps the client find the answers from within themselves. Coaching involves working with people who usually, but not always, already have some degree of success but are „stuck" and want to move forward and don't know how. There is, in coach-speak, a „gap" between where they are right now and where they want to be, and this may involve their professional career or their personal life, or both. This may also be on a larger corporate scale or on a small individual level.

The Coach's primary attention is on strengthen the client's wisdom, thought processes, and directed action toward the future, based on the client's self-identified agenda. A supportive and non-judgmental environment is created in which to inquire, challenge, and stimulate critical thinking and new ways of being, thinking, and acting, often resulting in new behaviors applicable to the client's whole life (US Dpt. of Agriculture University, 2016).

Coaching is a co-creative process. Coaches assist clients to accomplish their life goals and dreams and discover and fulfil their purpose in life in a process that involves the client 100%. So, regardless of whether the issue is career related or personal, a coach will help you find out what it is you really want out of life and „coach" you to achieve it. Coaches are non-judgmental and do not provide therapy or tell person what they should do next. A person hires a coach to assist them to design the life they want. If a person wants more of the same, then they hire a consultant. Coaches also assist career professionals who have forgotten how to „have a life" and no longer have work/life balance. With the increase in company downsizing and added pressures applied to many career executives, more and more of these stressed out individuals hire coaches to help them ease into a new career or start their own business, or just cope with what they are currently doing with more ease and joy.

	Consultant	Coach
The goal	A Consultant's primary attention is on helping an individual achieve personal or organizational results through the application of their specific expertise where they advise the client on the best course of action for achieving desired goals. Consultants may or may not also be charged with transferring knowledge or a skill set to their client.	The Coach's primary attention is on strengthen the client's wisdom, thought processes, and directed action toward the future, based on the client's self-identified agenda. A supportive and non-judgmental environment is created in which to inquire, challenge, and stimulate critical thinking and new ways of being, thinking, and acting, often resulting in new behaviors applicable to the client's whole life.
Focus	Usually problem-focused, i.e., identifies and tries to correct problems or weaknesses. Goals generally related to programs and funding.	Builds on the client's strengths. Values-based goal setting.
Client commitment	Requires limited commitment from client to implement.	Maximizes client's commitment to implement solutions.
The role of the expert	Regarded as the „expert" who will solve problems (the magic bullet). If behavior change is needed, consultant generally does not get involved in it. Provides information. Gathers data and reports on what needs to be done.	Enabler of the client - solving problems or change things for the better. A focus on individual and interpersonal dynamics supports behavior change. Promotes self-discovery. Facilitates growth.
Benefits for the company	Consultant brings technical expertise to advise on solutions.	Coach brings relationship expertise to support the client's solutions.
Which employees to include	Usually works with more than one person, often in a team, group, board, or department. Structures projects for specific deliverable or result, which the consultant is primarily responsible for.	Works on a one-to-one basis; may coach more than one person in an organisation, individually. Supports the client to achieve her or his own result or outcome.

Table 5: Overview of the differences between Coaching and Consulting, Source: https://www.501commons.org/resources/tools-and-best-practices/management-leadership/whats-the-difference-between-coaching-and-consulting

7.4. The SMeART Coaching and Consulting process

Step 1: Identification of the specific challenges, goals and strategic plans of the company will be performed by the SMeART staff. The challenges will be identified via meeting with the company and using SMeART guidelines for an interview (already used in the WP1). Add the link to the interview guidelines.

Step 2: Identification of the needed expertise of coach / consultant. A coach / consultant with the appropriate competences and references will be appointed to the company. Add the link to the list of coaches.

Step 3: An in-depth diagnostics of the company's challenges and needs will be performed by the coach / consultant. The coaches / consultants will use the following tools to add link to the tools, the coaches / consultants are planning to use. The SMEs will undergo an in-depth cooperation and a training programme led by HEIs, research centres and other experts from the partnership. During this phase individual business development plans will be developed by the coach / consultant including steps to be taken and goals to be achieved.

Step 4: Implementation of the action plan for transforming the SME into a smart SME (Smart SME PLAN); included in these activities will be the company, the coach / consultant and the SMeART staff - responsible person for the company. Any deviations from the action plan will be notified and considered, also additional requirements from the company will be identified and discussed. The Smart SME plan will be implemented by the company to improve its competitiveness in the Smart Engineering market.

Step 5: The coach / consultant, together with the SMeART staff will prepare the coaching / consulting report. Also follow up - the success of the pilot activity will be performed by SMeART staff.

7.4.1. Coaching and Consulting Plan Setup (templates)

The process of coaching / consulting is the following:

- Diagnostics of the challenges, company's goals and plans, expectations (diagnostic tools)
- Identification of mayor challenges of the company
    - Identification of needed expertise of the consultant / coach; required references of the consultant / coach
- Search for an appropriate consultant / coach
    - Preparation of the consultancy / coaching plan, including achievable goals. Identification of possibilities/next steps to take.
- Identifying the employees, involved in consultancy / coaching.
- Defining the roles of all involved and their responsibilities. Defining the required results, deadlines to be achieved and required resources to be invested.

Coaching /Consulting **plan - Template**	
Name of the **SME**	
SME legal representative	
Name of the contact person	
E-mail	
Phone	
Coach / Consultant Name	

Coaching / Consulting **objectives**

Description of the tasks and which resources are required	N No. of hours
Total hours	

Signature: SME ________________________

Signature: Coach / Consultant: ________________________

SMEeRT partner: ________________________

Table 6: Form to be used

7.4.2. Monitoring / evaluation process for the coaching / consultancy activity

The process of monitoring / evaluation process for the coaching / consultancy activity is the following:

- The SMeART staff will be, together with the coach / consultant and the beneficiary SME responsible for the time management of the tasks;
- The SMeART staff will be in charge for the evaluation of the expertise of the coach / consultant with the requirements of the beneficiary SME during the first half of the coaching / consulting process;
- The SMeART staff will be, together with the coach / consultant and the beneficiary SME responsible for the evaluation of the achievement of the set goals;
- The SMeART staff will be, together with the coach / consultant and the beneficiary SME responsible for the evaluation of the added value of the coaching / consulting activity (new knowledge in the company, new processes, new products/services, new business model ... etc.

Coaching /Consulting **report - Template**	
Name of the **SME**	
SME legal representative	
Name of the contact person	
E-mail	
Phone	
Coach / Consultant Name	

Achieved results	
What has been achieved regarding the set tasks and objectives?	
What has not been achieved?	
What difficulties have you faced?	
What is your impression of how the client takes it up?	
Have any successful partnerships been established?	
What do you think still needs to be done for this company?	

Table 7: Evaluation report template

7.5. Do's and don'ts for efficient coaching and consulting

The SMeART teams Do's and Don'ts for an efficient and successful coaching / consulting and your invested time:

DO	DON'T
Check the references of the coach / consultant. Check his success stories.	Hire a coach / consultant, interested only in money. The coach / consultant should show also his own motivation for your success.
Invite the coach / consultant to the initial meeting - you are compatible in terms of energy, expertise and experience? Work with a coach / consultant you feel connected to.	Work with a coach / consultant you do not trust.
Check for the possibility of conflict of interest between your company and the coach / consultant.	Bring to the coaching / consulting process co-workers who are not open to changes. Listen to their doubts, find solution or response and reply to the objections through general communication activities.
Be personally committed to the growth and change of the company. Work with your co-workers, also willing to change.	Expect changes over night; lasting and efficient changes are a process.
Be an inspiration, a role model for your employees. Be better every day!	Expect the coach / consultant to make decisions for you. He will support you to take decisions on your own.

8. TRAINING

Authors: Philippe Saey, Mathieu Troch, Frederic Depuydt

This section provides insight in how to train for the Smart Industry (r)evolution:

- who to train and for what, in which time frame
- how to use new training technologies, and how to merge with old concepts
- how to avoid some pitfalls and find keys to a successful training implementation in factories.

"Changing how we think, train and work using data" …

"The concept of digitizing everything is becoming a reality. Automation, artificial intelligence, IoT, machine learning and other advanced technologies can quickly capture and analyze a wealth of data that gives us previously unimaginable amounts and types of information to work from. Our challenge becomes moving to the next phase – changing how we think, train and work using data – to create value from the findings obtained through advanced technologies."
Brian Householder, President and Chief Operating Officer, Hitachi Vantara

Cited from "Talent and the workforce: evolution vs. revolution – The future of work" in [Deloitte2018] "The Fourth Industrial Revolution is here – are you ready?"; report Deloitte Insights, 2018.

8.1. What is Smart Industry (in a nutshell)?

"Smart Industry is a name for the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing. Smart Industry is commonly referred to as the fourth industrial revolution. Smart Industry creates what is sometimes called a „smart factory". Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time, and via cloud computing, both internal and cross-organizational services are offered and used by participants of the value chain." [Industry4.0_2018]

The "Plattform Industrie 4.0" identified a lot of potentials and challenges which are all a part of the five fields of action:

- horizontal integration
- digital end-to-end engineering
- vertical integration
- new social infrastructures
- cyber-physical production systems.

A lot of general descriptions – both more technological or more general – are found in the literature: Besides the documents of the German "Plattform Industrie 4.0", the report for the "Industry, Research and Energy" Policy Department of the European Parliament is an excellent general guideline(Smit et al., 2016). (Rojko, 2017) provides a general overview of Smart Industry concepts and technologies, and (Xiaomin et al., 2017) discusses the "glue" holding all "parts" of the interconnected industry together: the data communication networks (Fig. 33).

Fig. 33: Devices ("things"), networks, the "Cloud" and the applications represented in a four layer networked structure (Xiaomin et al., 2017).

8.2. Who to train, and for when?

How to estimate the time frame of the (training for) the Smart Industry evolution.

The timing for the implementation of the sometimes disruptive Smart Industry technologies is in the period of 2020 (selective pilot installations) over 2025 for broad adaptation of standard solutions to the realization of a "more true" Smart Industry around 2030 (Fig. 34) (Berger, 2018). Consequently, the transformation is happening right now and in the next few years: Most researches, developments and deployments will be done by current staff.

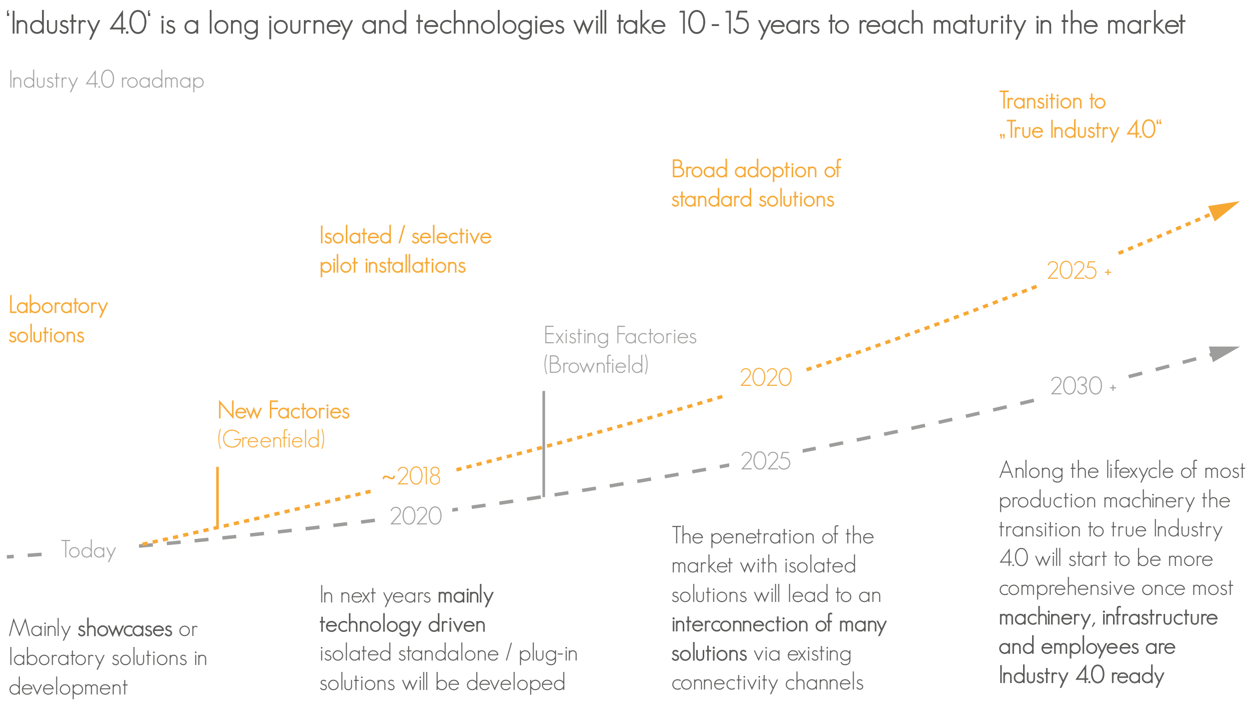


Fig. 34: Most sources predict Smart Industry to "arrive" in the years 2025 – 2030.

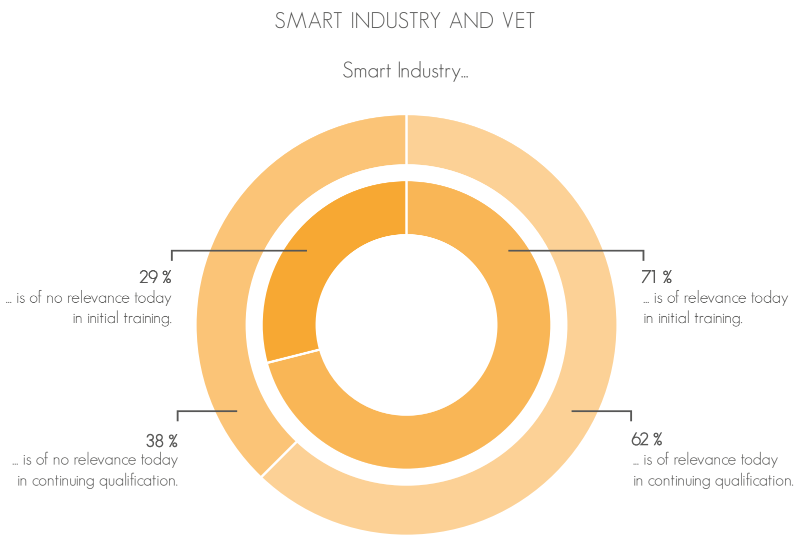


Fig. 35: VETtoday: Not all companies think that Smart Industry training is relevant today in continuing education.

This means that we need to focus mainly on training of existing staff: Lifelong learning & adult learning and training are of primary importance in this phase of realizing Smart Industry. In parallel, the "millennials" need to be integrated in the workforce.

Strangely enough, not all companies think that Smart Industry training is relevant today in continuing education (Fig. 35). Fig. 36 shows that mostly large enterprises take a proactive/ innovative position with regard to organising VET in the workplace, meaning that SMEs need to be made more sensible of the need for preparing for Smart Industry (Pfeiffer, Lee, Zirnig, & Suphan, 2016).

DIFFERENT WAYS OF ORGANISING VET IN THE WORKPLACE

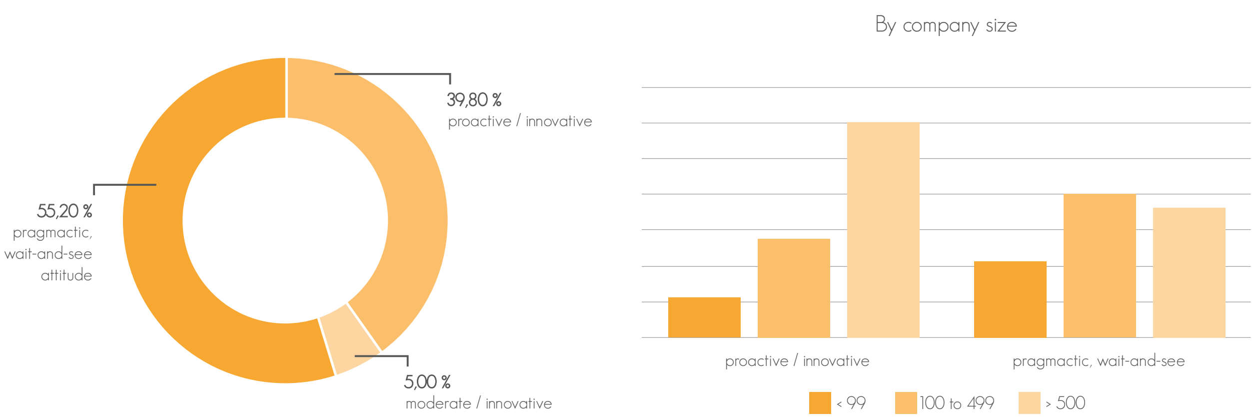


Fig. 36: proactive: Mostly large enterprises take a proactive/innovative position with regard to organising VET in the workplace.

8.3. What we need to train for

These paragraphs provide information on how to estimate the different dimensions of the technology changes, and their impact on qualifications relevant for VET (Vocational Education and Training) and for the higher level STEM (Science, Technology, Engineering and Mathematics) profiles.

8.3.1. Dimensions of Smart Industry relevant to VET

8.3.1.1. Qualifications for Smart Industry relevant for VET

There is no single, definitive version of Smart Industry, and therefore no single answer to the question of the appropriate qualifications for VET (Vocational Education and Training). Qualification requirements are most easily and accurately identified by participatory involvement of employees in the implementation of Smart Industry.
And qualification is ultimately also a question of will: Do companies want a broad qualification base in the future, or do they aim to design technology in such a way that automation will supposedly make them independent of such qualifications in the future?
Table 8 (Pfeiffer, 2015) shows an overview of the dimensions of Smart Industry that – reasoning from the current state of art – will be relevant for the VET qualification.

Dimensions of Smart Industry relevant to qualification

social media @PRODUCTION	Web 2.0. Shift doodle. Tablets.	Approaches in which Web 2.0 usage scenarios become part of manufacturing, i.e. web-based applications for interpersonal communication which are available on any platform and on the corresponding mobile devices; for example an app such as "Doodle" to coordinate shift work, or maintenance staff who communicate via web through the use of tablets.
data @PRODUCTION	CPS. Internet of Things. Big Data.	Qualitatively new data links between physical objects that previously had no data connections give rise to new potentials for self-organised production management, maintenance and logistics integration (cyber-physical systems). Internet of Things and Big Data applications on machine wear, logistics etc.
nextGEN PRODUCTION	2-armed robots. Lightweight robots. Adaptive robotics. 3D printing.	New automation approaches in production and/or handling technology include lightweight and dual-arm robots, robots with more sensors (with higher sensitivity or adaptability) or additive technologies such as 3D printing.
AUTOMATION @body & mind	Wearables. Quantify-me. Big Data access to vital functions	Wearables and self-quantifying apps, combined with Big Data and intelligent algorithms, enable access and monitoring of bodily and vital functions of employees.

Table 8: overview of dimensions of Smart Industry relevant to VET.

- Social media@production: mobile web communication in production.
  Approaches in which Web 2.0 usage scenarios become part of manufacturing, i.e. applications for interpersonal communication which are web-based, and therefore available on any platform and on the corresponding mobile devices. For example, an app such as "Doodle" might be used to coordinate shift work. These approaches are more in the nature of a catch-up, as social media use penetrates into areas of enterprise in which it has not previously been used. Strictly speaking, this is not about Smart Industry, but simply a change in communication media. This is more likely to have effects on corporate culture than on employment and qualification: The Millennials introduce it while entering the work floor.

Some typical scenarios are:

- "Shift Doodle" and Web 2.0: Employees use an app to confer in a group, or across different shifts, for example to decide who will come to work on Saturday if an extra shift is necessary. Web-based tools are also used for idea management and continuous improvement processes.

- Mobile devices for monitoring production (in-house or on the customer's premises): Thanks to new, largely self-controlling networks, production sequences no longer require as much intensive support as before. The staff no longer has to be on hand at all times. Less staff is needed, but these must be more highly qualified. The many sensors throughout the manufacturing sequence show the status of the system on mobile devices, and indicate when there is a need for (future) intervention.

- Data@production: the integration of material production.
  Qualitatively new data links between physical objects that previously had no data connection give rise to new potential for self-organised production management, maintenance and logistics integration (cyber-physical systems). They augment and expand previous steps towards computerization (such as ERP[1] systems), and integrate these more closely with real world value creation (within the company) and real-world logistics processes (via global value chains to the end customer). This potential for a new kind of permeation of the physical world by data paves the way for scenarios based on big data and intelligent algorithms. Major changes can emerge on this level, leading to changed production sequences, new business models, and more "fluid" value chains. This development is most likely in areas that already have a high degree of computerization and automation, and will primarily lead to a huge increase in the complexity of the overall systems. It is not possible to estimate effects on employment and qualification in general terms, but these will occur – in a very specific form – when the contents of jobs and the intersections between them change.

Typical scenarios are, for example:

- Cyber-physical systems/Internet of Things: In a medium-sized enterprise, technically sophisticated gear wheels are manufactured in small batches. The status of different work steps (milling, grinding, hardening etc.) of different batches and the location of the different parts is recorded with the help of QR codes, which transmit data to an external service provider. The service provider uses this data to suggest optimized routes for the so-called "milk runner" (i.e. the person responsible for intralogistics, delivering parts to the relevant machines at the appropriate time); the qualified logistician can then access these on his/her tablet.

- Real-time parts/services tracking by customers: All sequences are digitized in such a way that it is always possible to see how far the assembly of a machine has progressed, or what stage in the engineering design process a customer project has reached. Not only can all staff check the status of processes in the corresponding app – the customer can also be offered the option of tracking the processes related to his project in real-time.

[1] ERP: Enterprise Resource Planning

- Big data analytics in maintenance/remote servicing: The countless sensors in the machines and systems – whether in a company's own production line or when the machines/ systems are used on the customer's premises – constantly generate huge amounts of data. Technology that has already been used successfully in the past, for predictive maintenance or remote maintenance on the customer's premises, has now been developed further. Big data applications and algorithms based on artificial intelligence (AI) allow data to be analyzed constantly. This means that plant downtimes in-house and on customer premises can be considerably reduced, and spare parts can be produced and supplied in good time, before any signs of wear and tear.

- Personalization of products down to batch size 1: Increasing integration and more intelligent production sequences have made it possible to produce articles in an even more customer-specific way. In the near future, many products can be offered/produced in batch size 1, with a cost structure that was once only imaginable for large batch sizes and relatively standardized products. In some cases customers can already configure products themselves on-line, to meet their own very specific requirements.

- Production control by the product: Significant improvements have been made in the fine control of production, which is now decentralized. The product being manufactured virtually controls itself through the whole process. Every processing step, every quality test – everything is done largely automatically, as parts and machines exchange their data directly.

- nextGEN production: new production techniques. New approaches in production and/or handling technology include lightweight and dual-arm robots, robots with more (and more sensitive or adaptive) sensors, additive processes such as 3D printing, the use of drones, rapid prototyping, virtual commissioning, digital twin technology, etc.
Inexpensive robots and drones are probably the innovations most likely to bring about decisive changes in areas that have so far, for economic reasons, had comparatively high proportions of human labor – e.g. transport and logistics, packing, delivery and shipping services, and manual or hybrid assembly.
3D printing (or other additive processes), virtual commissioning and digital twin technology will, within the foreseeable future, accelerate innovation cycles in the manufacturing sector.
Typical scenarios for the area of industrial production could be:

    - Additive processes/3D printing: In just a few years, 3D printing has gone from a gimmick to a serious proposition. Today this technology can produce any materials needed with sufficient dimensional accuracy. This has considerably altered the processes in toolmaking, where rapid tooling is increasingly being used.

    - Dual-arm and lightweight robots: Large industrial robots were typically not financially viable in our SMEs in the past. But as robots – not to mention cobots – have become lighter and cheaper, it has become profitable to use them in more and more areas. For example, a dual-arm robot can be used for individual supply and insertion operations, and even for the packaging of spare parts.

    - Rapid prototyping and virtual commissioning speed up the design and development process, and the actual commissioning of new mechatronic production machines.

- Automation@ body & mind: data-supported access to bodies and knowledge.
Wearables, augmented and virtual reality tools, combined with big data and intelligent algorithms, expand access and monitoring into the bodies and vital functions of workers. This allows work processes to be designed more ergonomically, and ergonomics to be optimized for the individual. This could also pave the way for work that takes into account the ageing process. At the same time, the recording of large, regularly gathered quantities of data presents unknown dangers – it offers unimpeded access to the subject and even the private sphere, which is very much related to the body.

Typical scenarios in the near future could be:

- Wearables, augmented and virtual reality tools: Technologies which employees wear on their body are new. In assembly, for example, a smart glove helps workers to use the right techniques. Since products are becoming more and more diverse, assembly jobs have become more demanding: Routine and constantly recurring sequences are virtually a thing of the past. The smart glove helps by indicating on a display if the wrong part is fitted or the wrong screw picked up. Smart glasses for augmented/virtual reality also help with e.g. the maintenance of machines on the customer's premises.

- **Recording of vital data:** The data gathered by wearables during usage are analyzed by means of algorithms based on AI. Employees can voluntarily connect their private fitness gadget (such as a smart watch) to the health module of the company's software. The company's health management can use the non-personalized, aggregated data to see what the employees' state of health is like, and whether particular peak loads occur in certain departments.

8.3.1.2. Impact on qualification needs

These 4 technological dimensions lead to a series of qualification needs, of which a number of them is mentioned in the Table 9.
The data@production contains the real changes in what is usually referred to as the core of Smart Industry (see next section), and the area with the largest potential for disruptive changes. Automation@body & mind will not only play a role in Smart Industry, but more general also in Smart Health.

	Smart Industry and influencing factors – demands for qualification				
	Participation	**Increase**	**Extent of change**		
	Design process	**Complexity**	**Means of work**	**Object of work**	**Work organisation**
social media @PRODUCTION	Only effective if shaped by employees according to their needs.	Comparatively unproblematic, often familiar from everyday use. Learning by doing is possible. Knowledge of control, transparency, performance increase in importance.			
data @PRODUCTION	Only shapeable with input of technical and practical knowledge of employees.	Labouring capacity increases in importance, but more difficult to realise.	Disruptive change. Increasing demand for formal qualification in data handling and ability to relate off- and on-line. Upgrading of qualification in industrial and logistic core skills, risk of downgrading at margins. Contents of demanded qualification can hardly be determined ex ante.		
nextGEN PRODUCTION	Only shapeable with input of technical and practical knowledge of employees.	New labouring capacity emerges.	Machine operation skills can be acquired incrementally if starting from skilled worker qualification.		Partially new procedures, new proximity to customers, increased complexity.
AUTOMATION @body & mind	Develop with employees to avoid misuse and strengthen benefits on their behalf.	Danger of underestimating practical knowledge. Acquisition of new practical knowledge more difficult.	Depending on principal design decisions: Little qualification demands in case of mere support of humans. Otherwise risk of systematic downgrading of qualifications.		

Table 9: Smart Industry and influencing factors – demands for qualification.

The impact of the 4 dimensions mentioned are shown in Table 10.

	Smart Industry and influencing factors – demands for qualification				
	Participation	Increase	Extent of change		
	Design process	Complexity	Means of work	Object of work	Work organisation
social media @PRODUCTION	●	◐	◔	◔	◐
data @PRODUCTION	●	●	●	◕	◕
nextGEN PRODUCTION	●	●	●	◕	◐
AUTOMATION @body & mind	●	◐	◐	◐	●

Table 10: qualimpact: impact and required changes for the employees.

8.3.2. Higher level STEM challenges for automation and production in Smart Industry

8.3.2.1. Introduction

The challenges in STEM (Science, Technology, Engineering and Mathematics) with regard to Smart Industry at a higher (academic) level are diverse and sometimes disruptive. This section gives a broader overview of the technology areas that were indicated as data@- and automation@- . It should not only be seen as aimed at education and lifelong learning, but also for research & development and for (open) innovation. Pfeiffer states in (Pfeiffer et al., 2016, p. 7) that – in Germany – a large proportion of the companies are in the traditional and/or catch-up later atmosphere with regard to collaboration between training departments and R&D. Although beyond the scope of the work, it is important to note this point.

8.3.2.2. Smart Industry technology trends to educate and train for

In the last 30 years, there are three paradigm shifts in industrial production, having an impact on education topics and training: first CIM, and via lean manufacturing now to Smart Industry (Schallock, Rybski, Jochem, & Kohl, 2018).
The first paradigm shift, CIM (Computer Integrated Manufacturing) emphases automation and information flow. These are in fact again the core fields of technologies that may change a lot in Smart Industry, as indicated earlier. The focus was on the introduction of computers on shop floor level connected with CAD and ERP systems.
The second paradigm, the "Lean wave", brought organisational design and segmentation of factory structures into the focus.
For the upcoming paradigm shift, Smart Industry, the focus lies on the digitization in the industry.

COLLABORATION BETWEEN TRAINING DEPARTMENTS AND R&D

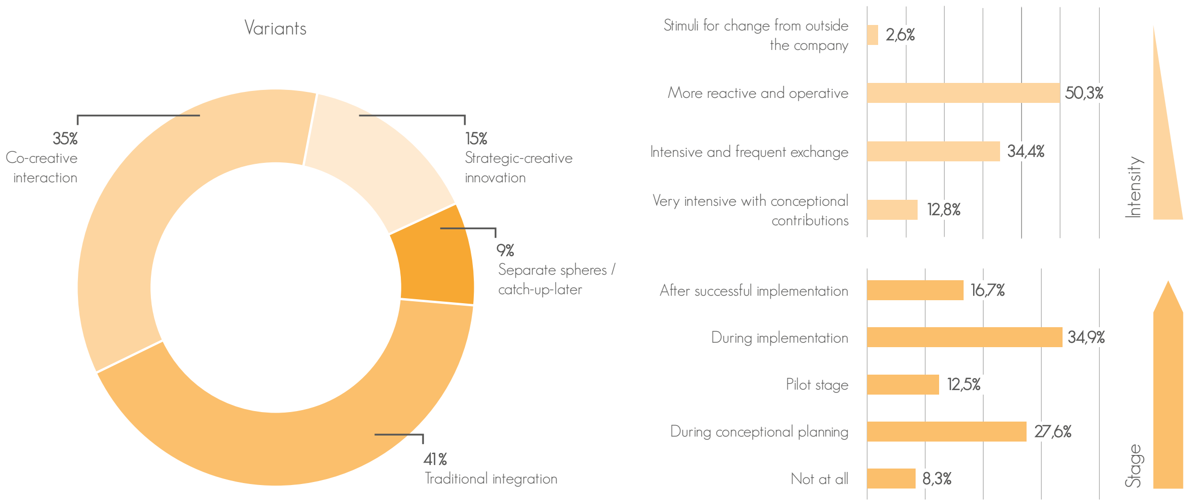


Fig. 37: collaboration: Collaboration between Training and R&D Departments.

A wide survey for VDMA (Pfeiffer et al., 2016, p. 14) indicates the relevance of nine technology trends in Smart Industry now and in (as expected in) 2025. These form a good indication of the training needs.

The "Plattform Industrie 4.0" pointed out the following demands as the scope for qualification:

- Digital learning techniques (see Section "How to train for")
- Job-related qualification (e.g. training on-the-job, lifelong learning)
- Lead and operate production systems
- Interdisciplinary product and process development (rapid prototyping, virtual commissioning, digital twin technology)
- Specific Smart Industry competencies (see the next paragraphs)
- Competency evaluation.

These demands and challenges show the importance of qualification and human resource development in the near future. It makes clear that Smart Industry is more than just technology. The human resources will be probably even more important in times of Smart Industry.
These demands can for example be met by companies planning adequate training and lifelong learning programs, or e.g. in training schemes of "learning factories" (Schallock et al., 2018). A learning factory could (or should) cover the following three categories of skills:

- Technical skills
- Transformation skills (e.g. propose and realize changes in all stages of the production system; learn to adapt transformation principles in their home plants)
- Social skills (e.g. knowledge transfer, knowledge acquiring, collaboration for synchronization of processes and delivery dates and analyzing defects, communication, collaboration with others in groups and teams, management of conflicts, assertiveness, physical and mental resilience, conceptual work and systematic solution of problems).

It is – with regard to technical skills – a challenge to overcome labour shortage in IT skilled personnel and Smart Industry competences. It is important to have workers who know the right technology, but - surprisingly – success or failure depends not only on mastering the right technology (programming skills, software, sensor technology) but on a broader range of people focused factors. As is stated in Price Waterhouse Coopers 's 2016 Global Industry 4.0 Survey: "Industrial companies need to develop a robust digital culture and to make sure change is driven by clear leadership from the C-suite. They'll also need to attract, retain, and train digital natives and other employees who are comfortable working in a dynamic ecosystem environment."

A(nother) set of 9 technology trends – suggested by (Rüßmann et al., 2015) – is discussed briefly in this paragraph 8.1. These form the basis for selecting the topics of lifelong learning programs, and for future changes in initial education:

- Big Data and Analytics
- Autonomous Robots
- Simulation, "co-simulation" and "integrated design"
- Horizontal and Vertical System Integration
- The Industrial Internet of Things
- Cybersecurity
- The Cloud
- Additive Manufacturing
- Augmented Reality.

Many of the nine advances in technology that form the foundation for Smart Industry are already used in manufacturing, but with Smart Industry, they will transform production: Isolated, optimized cells will come together as a fully integrated, automated, and optimized production flow, leading to larger efficiencies and changing traditional production relationships among suppliers, producers, and customers—as well as between human and machine.

8.3.3. Impact of industrial innovation on the role of labour

The effect of computerization on the labour market has been intensively studied. The composition of (routine) tasks where human interaction is needed has changed and the demand for skills to handle these tasks is substituted by the demand for non-routine work as productivity rises due to digitization. Table 11 provides an overview of the impact of computerization at work (Ellermann, Kreutter, & Messner, 2016, p. 119).

Task category/impact	**Routine tasks**	**Non-routine tasks**
Analytic and interactive cognitive tasks	Examples: Record-keeping Calculation Repetitive customer service (e.g., bank teller)	Examples: Medical diagnosis Legal writing Persuading/selling Managing others
Computerization impact	Substantial substitution	Strong complementarities
Manual tasks	Examples: Picking or sorting Repetitive assembly	Examples: Truck driving Janitorial services
Computerization impact	Substantial substitution	Limited opportunities for substitution or complementarity

Tab. 11: Impact

The digitization of factories will change the jobs in manufacturing SME's. The Future of Jobs Report from the World Economic Forum mentions the top ten skills required from employees. These important skills are: (1) complex problem solving, (2) coordinating with others, (3) people management, (4) critical thinking, (5) negotiation, (6) quality control, (7) service orientation, (8) judgment and decision making, (9) active listening and (10) creativity.
(World Economic Forum. Industrial Internet of Things.Unleashing the potential of connected products and services, 2015)

Technological change requires/enables changes in work organisation that translates in different jobs & qualification requirements, that requires different employee competences. In theory this could (should?) be planned in this logical order. In real life, firms are changing in all three areas (and not necessarily synchronous directions). The entrepreneur (person) and his competences, the firm (collective actor) and its work organisation, job definition, and (current) workers (persons) and their competences are all relevant targets to address.

The Association of German Engineers (VDI) and the American Society of Mechanical Engineers studied the impact of industrial innovation on the role of labour in the future of manufacturing. They analysed different tasks and set up a list of qualifications and skills which will be important in the factory of the future. They used the MuShCo (Must, Should, Could) technique to prioritize the qualification and skills. Two main outcomes of the research are: The set of qualifications and skills needed in the factory will fundamentally change and in order to be successful in the manufacturing sector, a skilled workforce is needed. The results are in (Table 12) (Gehrke et al., 2015).

	Must…	**Should…**	**Could…**
	…be included in the skillset of the skilled labor of the future		
Technical Q&S	IT knowledge and abilities	Knowledge Management	Computer programming/ coding abilities
	Data and information processing and analytics	Interdisciplinary / generic knowledge about technologies and organisations	Specialized knowledge about technologies
	Statistical knowledge	Specialized knowledge of manufacturing activities and processes	Awareness for ergonomics
	Organisational and processual understanding	Awareness for IT security and data protection	Understanding of legal affairs
	Ability to interact with modern interfaces (human-machine / human-robot)		
Personal Q&S	Self- and time management	Trust in new technologies	
	Adaptability and ability to change	Mindset for continuous improvement and lifelong learning	
	Team working abilities		
	Social skills		
	Communication skills		

Table 12: Qualifications and Skills of Workers in a Factory of the Future

Important for the sustainable implementation of new education and training solutions is the integration of relevant stakeholders such as trade unions, business academies, private education provider or industrial and chambers of commerce and craft chambers. In addition, the imparting of relevant digitization knowledge is also a task for (vocational) schools, colleges and universities (Source: Allianz für die Region). "Allianz für die Region" identified the main barriers for developing skills and knowledge:

- Rash and ill-considered changes as lack of use and integration of existing approaches and resources
- Fear of the introduction of Smart Industry technologies as an investment in the future
- Refusal of new developments, technologies and business models
- Lack of understanding of the needs of customers or the requirements of the competition
- Replacement of employees instead of further qualification
- Lack of use of the chances of digital offers for targeted training and further education for digitization and Smart Industry
- Adhering to traditional corporate structures and hierarchies
- Decisions without involvement of employees
- Lack of development of a digitization strategy for the enterprise.

8.4. How to train for … Learning methods for the transformation

The following paragraphs indicate how and why to select a learning method is suitable for your company's training and education needs. With respect to e-learning and especially MOOCs, it is also indicated where to find these, which MOOCs are targeted at STEM and even Smart Industry specifically, and which are the determining success factors for implementation in companies.

8.4.1. Main concepts

8.4.1.1. Traditional learning versus e-learning

These days online courses and training have become extremely popular, as more and more institutes and companies are offering courses on-line. However, despite the popularity of on-line education, vast groups of people consciously stay away from such methods, mostly due to misconception. At the same time, despite the rising popularity of on-line courses, traditional (classroom) training is trying to adopt newer means of retaining the learners' interest.
For some individuals, on-line training is more appropriate, while for others classroom training is the preferred delivery method. Furthermore, some training courses requiring (industrial) experience and hands-on training might be less suited for on-line learning.

Before going deeper into e-learning, a brief description of traditional learning and a short comparison with on-line learning – anno 2018 de facto reduced to e-learning – is given. Refer to (De, 2018) for further reading.

Traditional classes are seen as more suitable for young children, teenagers, and young adolescents who are yet to join the workforce. Regular attendance in classes helps them interact with other individuals of their own age, be better disciplined, follow a regular schedule, and improve their mental alertness. Classroom learning helps students and teachers to know each other in a better manner, allowing teachers to know the students and evaluate their strengths and weaknesses better, act as mentors, and guide students in their career possibilities. In a traditional classroom, students can directly interact with the teacher; continuous interaction between students and teachers helps students to get rid of their fears regarding exams, which can rarely happen with on-line guidance. Furthermore, interactions with good teachers help to motivate students to achieve higher marks.
Acquired diplomas and certificates are for future employers a guarantee of minimal competences.
Given busy day schedules and long working days, on-line learning looks more convenient for lifelong learning. Individuals can take a course from the comfort of their office or home. On the other hand, for more difficult or totally new topics, a minimum amount of time and focus is required. In general, communication with an on-line instructor is often very impersonal or sometimes even impossible. Alternatives to live contact like on-line forums, emails, chatrooms, MOOC meetups, etc. improve communication between instructor and student. Some of these solutions lead to two-way synchronous e-learning.

"Do-it-yourself" learning by acquiring knowledge using resources found using e.g. Google often results in information overload, and make the selection of relevant and correct information difficult. This seems more suited for people having master degrees and able to spend a lot of time to study.

8.4.1.2. E-learning

Introduction

"E-learning" is basically a set of on-line educational services, teaching and helping to improve students and trainees [elearningtheory2018]. It can nowadays be seen as the most important form of "distance learning".
Different concepts using computers in the learning context, among which Computer Assisted Instruction (CAI), Computer Assisted Learning (CAL), Computer-Based Education (CBE), e-learning, Learning Management Systems (LMS), self-directed learning[2] (SDL), and Massive Open On-line Courses (MOOC) are discussed in [elearningtheory2018]. All these concepts have two aspects in common: learning and computers; only SDL does not necessarily apply to computer usage.
Computer literacy will prove to be a decisive factor in the success of taking on-line courses (see paragraph "Keys to success - Pitfalls).

On-line platforms can also offer more diverse representations of student populations as learners prepare for working in Smart Industry. The diversity comes from interacting with students outside of one's geographical location, possibly offering a variety of perspectives on course content and this way decreasing cultural differences.

Learner experience is typically asynchronous, but may also incorporate synchronous elements (Wikipedia contributors, 2018b). The vast majority of institutions utilize a Learning Management System (LMS) for the administration of on-line courses (Quizworks B.V., 2018). In the next section, methods of delivery (synchronous and asynchronous learning) and Learning Management Systems are discussed.

Methods of delivery: synchronous and asynchronous learning

Basically, synchronous learning involves on-line studies through "chat". This kind of learning can only happen on-line. By being on-line, you can stay in touch with your teacher and other students. It's called synchronous learning, because the system allows students to ask their teacher or fellow students questions instantly through instant messaging.
Asynchronous learning on the other hand, can be carried out on-line and off-line. Asynchronous learning involves coursework delivered via web, email and message boards that are then posted on on-line forums.

Asynchronous learning environments are on-line spaces where work is supported through the use of digital platforms in such a way that participants are not required to be on-line at the same time. Threaded discussions, (individual) Skype meetings, e-mail, and telephone calls are options of an asynchronous delivery. Although this "anytime-anywhere" might be appealing, regularity in studying might be compromised.
A benefit of asynchronous learning is the learner having more time to generate content-related responses to the instructor and peer postings; they have time to find facts to back their written statements, do tests, relate to colleagues in the factory, etc. . The additional time provides an opportunity to increase the learner's ability to process information. The spelling and grammar within postings of an asynchronous environment should be like the one found in formal academic writing.
On the other hand, one of the main limitations of this delivery method is the greater potential for a learner to feel removed from the learning environment. Asynchronous learning is viewed as less social in nature and can cause the learner to feel isolated. Providing the student a feeling of belonging to the university or institution will counter feelings of isolation: Links to university support systems, to the library, to laboratories can be very useful for this aspect.

Synchronous learning environments most closely resemble face-to-face learning. Synchronous learning takes place through digital platforms where the learners are utilizing the on-line media at the same time. When compared to asynchronous learning, synchronous on-line environments provide a greater sense of feeling supported, as the exchange of text or voice is immediate and feels more like a conver-

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[2] Self-directed learning is a process in which students take the initiative to diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies, and evaluate learning outcomes. The role of the instructor shifts from being the ‚sage on the stage' to the ‚guide on the side' in a self-directed learning environment. (http://edutechwiki.unige.ch/en/Self-directed_learning)

sation. If platforms such as web conferencing or video chat are used, learners are able to hear the tone of voice used by others which may allow for a better understanding of the content. As in a traditional classroom environment, on-line learners may feel a need to keep the conversation going, so there is a potential for focusing on the quantity of responses over the quality of content within the response. However, the synchronous environment – with real-time responses – can allow students or instructors to provide clarity to what was said, or alleviate any possible misconceptions.

Learning Management Systems

Most on-line learning occurs through a college's, university's or company's Learning Management System (LMS): It is important to have a uniform system in place that allows the follow-up of the person taking a course.
A LMS is a software application for maintaining, delivering and tracking educational resources. According to the Educause Center for Analysis and Research (ECAR) the use of a LMS is nearly omnipresent as 99% of North-American colleges and universities report having one in place (Wikipedia contributors, 2018b). Among faculty, 87% report using a LMS and find them useful for „enhancing teaching (74%) and student learning (71%)". Similarly, 83% of students use an LMS in their courses, with the majority (56%) using them in most or all courses. Most institutions – figures are for USA and Canada – utilize LMSs by external vendors (77%): Blackboard currently dominates the LMS environment with an adoption rate of 31.9%, followed by Moodle at 19.1%, and Canvas at 15.3% (Wikipedia contributors, 2018b). However, in the last year Canvas, by Instructure, has gained an increasing amount of the market share.

8.4.1.3. Massive Open Online Courses (MOOCs)

Introduction

"A massive open on-line course (MOOC) is an on-line course aimed at unlimited participation and open access via the web. In addition to traditional course materials such as filmed lectures, readings, and problem sets, many MOOCs provide interactive user forums to support community interactions among students, professors and teaching assistants (TAs)" (Wikipedia contributors, 2019).

An overview of MOOCs from multiple platforms can be found on "Class Central" [MOOCoverview2018]. A more extended list can be found on [MOOCplatforms2018].
Originally, MOOCs started as completely free on-line courses, but this has changed quickly. The original MOOCs – mostly developed at American universities, Fig. 38 – were free and of high level. The offer has now widened, is for different levels of education, and often (partially) paying (Shah, 2017).

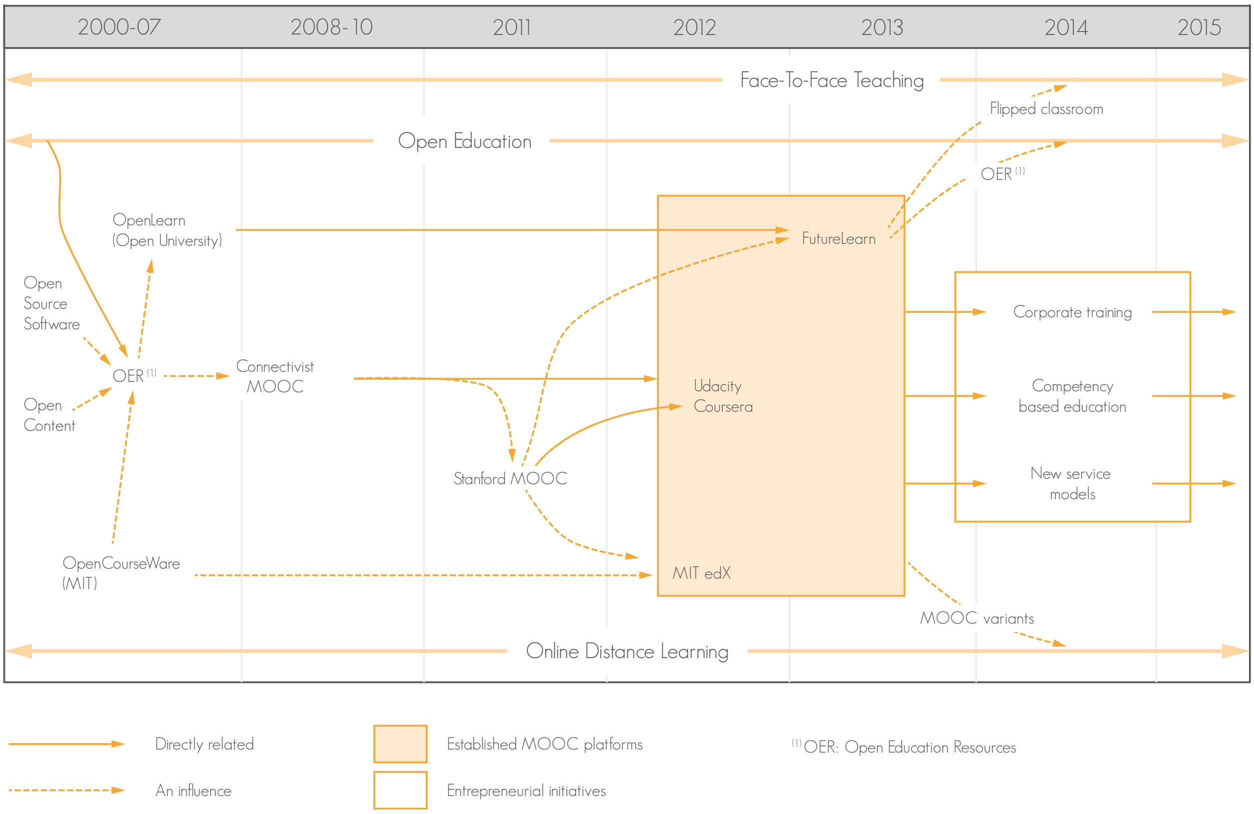

Fig. 38: MOOChistory: Overview of the development of MOOCs, starting from the OCW at MIT.

Basic features of MOOCS

Massive:
Thousands of students can take the same course "at the same time". The course "Introduction to Artificial Intelligence" – often seen as the first true MOOC – was signed up for by more than 150.000 students in 2012.

On-line:
Students can take courses from everywhere, and interact with other students; the latter is – just like any distance learning tool accessed with a LMS – a large advantage and often leads to insights from a multicultural viewpoint.

Open:
Anyone can use the courses – regardless of prior academic achievement – and they are free or at very low cost, and sometimes available in 4 or 5 languages.

Course:
The courseware is more than merely listening to pre-recorded lectures; MOOCs are designed to be effective and interactive for on-line distance learning. Pre-recorded lectures are however an important part of the course.

The meaning of the Acronym MOOCs (Source: [MOOCplatforms2018])

MOOCs are a recent development in distance education which were first introduced in 2006 and emerged as a popular mode of learning in 2012[3].

OpenCourseWare (OCW) emerged at MIT back in 2006, and in fact simply put high level "written courses" available for the rest of the world. The main goal was to make quality education accessible to everyone. At the other end of the distance learning spectrum are on-line colleges: The student is enrolled at the university, pays a tuition fee, and follows the course on-line on the scheduled moment (synchronous learning).

Table MOOC indicates some properties of OCW, MOOCs and on-line colleges.

	OpenCourseWare	**MOOC**	**On-line colleges**
Cost	Free	Usually free to small tuition fee	Expensive
Structure	Requires nothing from the learner	Some structure and timing, typically asynchronous learning	Strict deadlines, homework; synchronous learning
Grading	None, or sometimes by externals	Automated computer grading, peer grading, human grading method	Done by the professor
Availability	Open, freely accessible, sometimes even editable if source is mentioned	Property of the institution, company or platform	Only accessible by students that were accepted and enrolled
Remarks		Sometimes used to "test" students and afterwards enroll them in normal colleges	Sometimes used as a solution for multi-campus faculties

Table 13: MOOC

Because of massive enrollments, MOOCs require instructional design that facilitates large-scale feedback and interaction. The two basic approaches are:

- Peer-review and group collaboration
- Automated feedback through objective, on-line assessments, e.g. quizzes and exams. Machine grading of written assignments is also underway, using AI techniques (AI: Artificial Intelligence).

To counter the fact that studying a MOOC is basically a solitary task, and mostly asynchronous so tempting to lose study rhythm, MOOC Meetups have been set up in many large cities worldwide (Hagel, Wooll, Brown, Mathew, & Tsu, 2014, p. 14). Companies are – in the ongoing evolution of MOOCs and other digital learning – experimenting with Meetups to fill the role of the social learning environment that is a characteristic of the traditional college experience. Meetup, founded in 2002, is an on-line social networking portal that facilitates offline group meetings in various locations around the world. On-line education provider edX has over 40 Meetup communities around the world, while Udacity has 18. Nearly 220 other Meetups exist for categories like "MOOCs" and "online learning". MOOC Meetups span the globe with concentrations in places like New York, London, Bangalore, and San Francisco and newer groups in Beijing and Hyderabad.

These Meetups create a physical environment for learners to gather and engage with the content together. City and university libraries may have a future role in this context; in fact nothing else than their historic role in "human sciences", now typically applied more to exact and engineering sciences. SMEs and larger companies should consider organising this in their training or R&D departments.

[3] "Introduction to Artificial Intelligence" by Sebastian Thrun is often seen as the first true MOOC; it was signed up for by more than 150.000 students in 2012.

Where to find your MOOC

Some of the largest MOOC platforms anno 2018 are:

- Coursera (https://www.coursera.org/)
- edX (https://www.edx.org/)
- Udacity (https://eu.udacity.com/)
- FutureLearn (https://www.futurelearn.com/).

Table MOOCproviders discusses a number of business model, price range, offerings, number of enrolments, etc. of some MOOC platforms (Hagel et al., 2014, p. 20).

There are MOOCs carrying "Industry 4.0" (almost) directly in their title, e.g.

- Industry 4.0: How to Revolutionize your Business (https://www.edx.org/course/industry-4-0-how-revolutionize-business-hkpolyux-i4-0x)
- Digital Manufacturing & Design Technology Specialization (https://www.coursera.org/specializations/digital-manufacturing-design-technology)

The topics discussed under "What to train for" are all among the top ranking new topics of MOOCs. So for more theoretical foundations of future technologies, there are a wide choice and a lot of opportunities.

As most steps towards Smart Industry rely heavily on engineering courses and technologies, the hands-on exercises and design, and the contact with the actual industrial equipment is still missing. This is briefly discussed in the next section.

8.4.2. Formats for hands-on education and training

The choice of the format of the hands-on education and training – and also the previously discussed traditional learning, OCW, MOOCs, e-learning in general, etc. – largely depends on the target public. Pfeiffer (Pfeiffer, 2015) presents a detailed study of effects, requirements, perspectives on the initial and continuing VET (Vocational Education and Training) including lifelong learning for vocational functions in Austria. On-the-job training – as part of lifelong learning – and long-term traineeship – during the initial education – are standard practices for VET in e.g. Germany and Austria.

For more theoretical courses and training, traditional face-to-face classroom teaching with a lot of learner-teacher interaction is the preferred method for the vocational level. The same applies for the master level, with a tendency to also use OCW or MOOCs.

As the typical topics for Smart Industry are STEM (Science, Technology, Engineering, Mathematics), thus requiring a lot of exercises, hands-on sessions and project work, we list some options:

- Long-term traineeships during initial vocational education.
- On-the-job training – once at work – is suitable for short trainings, familiarization with new equipment and webtools, etc. It is suitable for all levels.
- Hands-on trainings and lab experiments on new technologies are provided in many ways:
    - In-house training departments – typically in larger companies – or company "universities" (e.g. ArcelorMittal University) offer hands-on trainings and courses, sometimes on-site and sometimes in close operation with local education partners or universities.
    - Private companies (e.g. ATS (NL, BE) and professional organisations (e.g. VDMA, ie-net, etc.) offer – often vendor-dependent – training sessions.
    - As dissemination or as actual output, EU and national research projects sometimes offer free hands-on courses on results of research or on demonstrators designed during the project. E.g. the i-MOCCA Interreg 2 Seas project reached in 3 years in Flanders more than 250 companies: More than 750 engineers attended hands-on courses between a half day and 4 days (Knockaert, De Lepeleer, Stevens, & Saey, 2014).

	Location	Started	Business model	Course price range	Course offerings	Number of students
Khan Academy	Mountain View, CA	2006	• Not-for-profit • Large amount of funding from foundations and donations • Mission is to provide "a free world-class education for anyone, anywhere"	Free	• Personalized learning dashboard, 100000+ exercise problems, and 4500+ microlectures/video tutorials covering a wide range of topics	10 million students per month
Udemy	San Francisco, CA	2010	• "iTunes® of instruction" – allows anyone to author and post courses • Author owns IP and sets price of course • Corporations can purchase Udemy as a learning system to use available content or add own content	$0-$399 (price determined by course author)	• 9000 courses, primarily skill-based programs for professional purposes • 5-18 lessons long	1 million
Coursera	Mountain View, CA	2012	• Most courses are free • Signature program ($100/course) verifies student identification • Partners with universities and takes a percentage of any revenue generated from the course	Free for most courses $49+ for ID verification option	• 600+ academic courses offered: subjects range from computer science to music, film, and audio • 5-15 weeks long	5,9 million
Udacity	Mountain View, CA	2012	• Develops content for a fee • Shares revenue with partners (recently partnered with AT&T and Georgia Tech to offer a complete master's degree in computer science) • Offers access to courseware for free, or to a full course for a subscription	$0 or $150 for college credit with ID verification	• ~30 courses total • Subjects are all STEM-based • Technical courses • 5-16 lessons long	1,6 million
edX	Cambridge, MA	2012	• Founded as a non-profit • Partners with universities to offer courses on open-source platform • Universities pay an upfront fee and share future revenues • Formal partnership program for corporate training	$0 for most courses Additional fee for ID verification option	• Currently ~150 courses offered in a wide range of academic subjects, from city planning to finance to the science of cooking • 6-12 weeks long	1,6 million
NovoEd	San Francisco, CA	2013	• For-profit venture capital • Partners with institutions and allows them to create their own on-line community brand, with NovoEd running in the background	$0-999, depending on course	• Wide range of academic subjects • Focuses on entrepreneurial content • Differing course lengths	170000+

Table 14: MOOC-providers

- Use of augmented reality & virtual reality. E.g.: Practeria – a UK based company – offers a blend of virtual experience, multimedia content and expert coaching to train CNC operators (Practeria: http://practeria-web.azurewebsites.net/).

- Use of "gamification" as "on-the-job" training. E.g. Accenture uses virtual reality as a "gamification" of on the job training, rendering it more realistic and challenging than "serious games".

- Learning factories cannot only be used for multidisciplinary research and open innovation, but also for training. This training can be technical skills, transformation skills (e.g. propose and realize changes in all stages of the production system; learn to adapt transformation principles in their home plants) or even social skills (e.g. team work, knowledge transfer, acquiring knowledge, collaboration for synchronization of processes and delivery dates and for analyzing defects).

8.4.3. Keys to success / pitfalls

How to find the keys for success in "learner satisfaction" and "transfer of learning": Prepare learners for e-learning by strengthening computer and technology self-efficacy, and actually do implement new things learned.

In an excellent study Charlotte Gunawardena et. al.[Gunawardena2010] describe the main points of attention for corporate on-line education programs, in order to achieve success in both "learner satisfaction" and "transfer of learning". This well documented study points out that for learner satisfaction, the "on-line self-efficacy[4]" is by far the most determining factor. Of secondary importance – some with almost no influence on a learner' satisfaction – are the course design (refer to the paragraphs on MOOCs) and to e.g. the VR course on CNC (previous paragraph), learner-learner interaction and learner-instructor interaction. Of the latter, the learner-learner interaction is evaluated as the least important.

For efficient transfer of learning/knowledge, collegial support (accepting to implement new things learned) and organisational support (resources and adequate workload) are the most important. Manager support and organisational incentives are found to be less (varying to not) influential.

[4] The learner's confidence and prior knowledge – mainly in computer and software tools – in using technology to engage in training.

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