I4EU Handbook

Erasmus+ I4EU - Project
Key competences for an
european model of Industry 4.0
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Foreword

The “Industry 4.0” paradigm have generated new opportunities and new challenges for companies. In order to increase their competitiveness and efficiency, companies have to face the digital transformation of the production and logistics chains (smart manufacturing) and of products (smart interconnected objects). The impact of the fourth industrial revolution is huge in terms of involved stakeholders and in potential economic growth. The fourth industrial revolution has also triggered a huge educational challenge, bringing the need to re-train millions of employees to models and technologies unknown even ten years ago.

The I4EU project has been designed in order to share good practices and new business models, raise awareness about new technologies supporting the digital transformations at European level and qualify professionals able to operate inside European companies, enhancing their digital competences and up/re-skill them to Industry 4.0 key competences.

The I4EU partnership involves eight partners coming from six different countries (France, Austria, Germany, Italy, Portugal and Spain).

1. Introduction and methodology

Europe has a strong industrial tradition which is recently offset by an urgent need for modernisation and reindustrialisation. Companies, specifically SMEs, are challenged to adopt innovative advanced manufacturing processes in order to enhance their competitiveness and gain access to transnational value chains. Industry 4.0 is mainly discussed as a technological issue; innovation managers and SME owners face huge organisational and strategic challenges as well. There is an urgent need for a qualification basis across Europe with new transnational approaches towards Industry 4.0.

The “Industry 4.0” paradigm has generated new opportunities and new challenges for companies. In order to increase their competitiveness and efficiency, companies have to face the digital transformation of the production and logistics chains (smart manufacturing). Also their products are changing, becoming more connected and interactive (smart objects). This transformation has been possible due to the simultaneous development of new technologies such as Big Data, Internet of Things, Augmented Reality, Cloud Computing, Artificial Intelligence and Machine Learning. The impact of the fourth industrial revolution is huge. Estimations consider that Industry 4.0 can deliver estimated annual efficiency gains in manufacturing of between 6% and 8%. The Boston Consulting Group predicts that in Germany alone, Industry 4.0 will contribute 1% per year to GDP over ten years, creating up to 390 000 jobs. The fourth industrial revolution has also triggered a huge educational challenge. Even just 10 year ago, none of the 4.0 technologies was mature enough to be included in any training program. Additionally, being relatively young technology, every year updates arise, in a continuous stream of innovation. This implies the need to re-train employees in a sector that involves more than 2 million companies and 33 million jobs at European level. The European Commission has adopted roadmaps in order to ensure an evolutionary perspective: in the last five years we had the “Factories of the Future 2020': Roadmap 2014-2020” (2013), the “European Roadmap for Industrial Process Automation” (2013), the “CyPhERS - Cyber-Physical European Roadmap & Strategy” (2015) and the “Strategic Research Agenda of the European Technology Platform on Smart Systems Integration” (2017). Additionally, the Digital Single Market framework, has launched in 2016 a set of Industry-related supporting initiatives. However, most have been done in this year by means of single national initiatives (e.g. “Industrie du futur” in France, “Piano Nazionale Industria 4.0” in Italy, “Industrie 4.0” in Germany, “Industria Conectada 4.0” in Spain). This approach has produced the creation of different training activities in the different countries, that lacks a unified approach and of a methodology for the transnational recognition of competences.

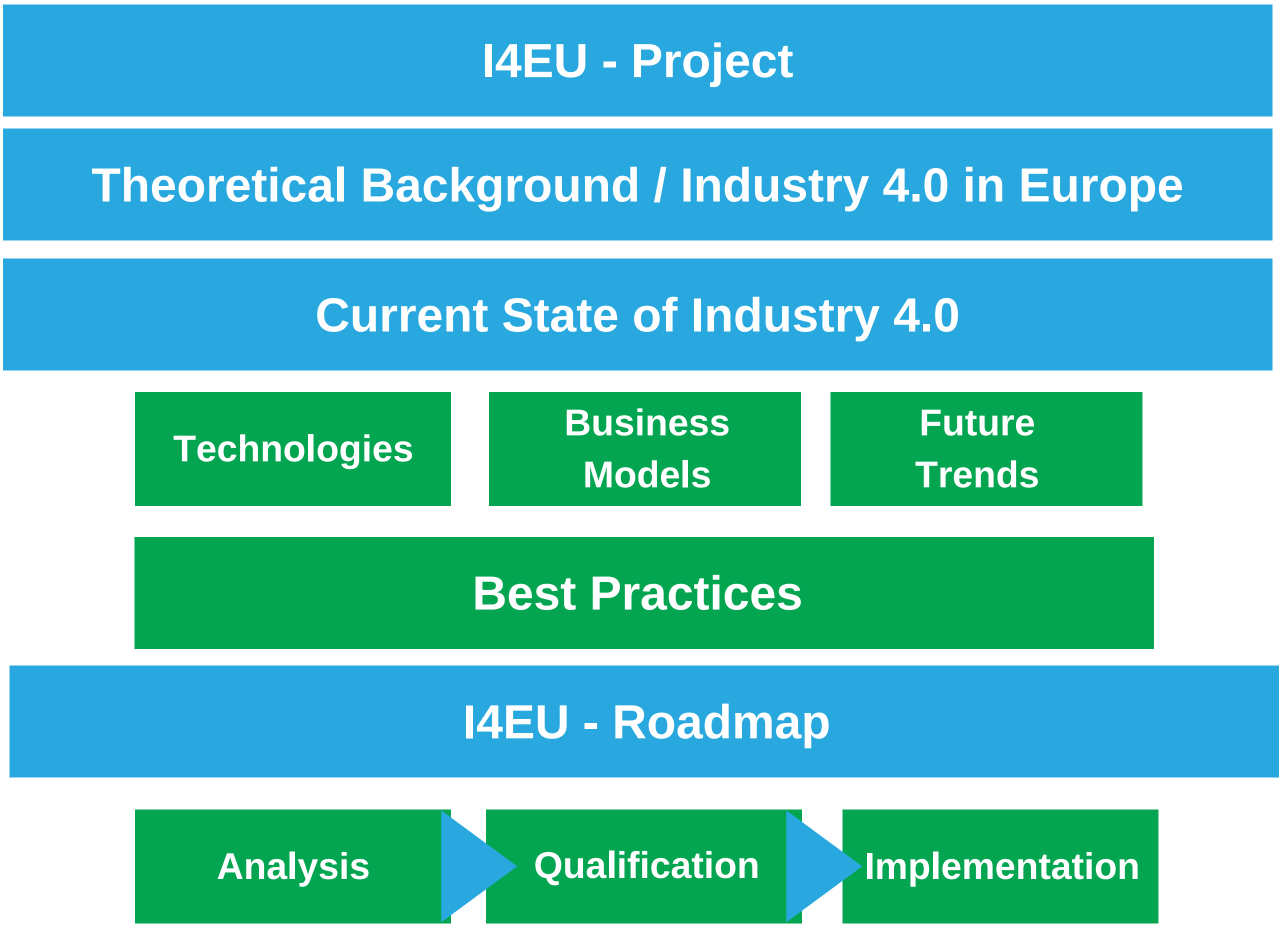
In order to sustain and enhance at European level these initiatives, the Erasmus+ Project team (I4EU) identified that some additional actions are needed:

- the adoption of common European VET frameworks for the transnational recognition of competences
- the definition of common training programs on Industry 4.0 at European level
- the sharing of good practices at European level
- the continuous update of theoretical and practical skills and competences

The need to support the digital transformation of the EU Industrial sector and to support the recognition of competences in this sector are the rationale behind the I4EU project. In line with the national and European policies the main objective is qualifying new professionals able to support the digital transformation of the European companies in the industrial sector, according to the Industry 4.0 paradigm.

Therefore the aim of this Handbook is to provide a useful additional tool for the learners, to simplify the access to Industry 4.0 technologies and solutions through examples, best practices and practical suggestions. The Handbook wants to offer a concise, “hands-on” handbook for all professionals who adopt/manage/implement Industry 4.0 related solutions. Industry 4.0 ecosystem covers an even wider range of applications and business models, and new ones are continuously developed. The professionals that have been trained to deal with Industry 4.0 solutions and want to realize a digital transformation of their productive processes and business models may need practical support including case studies, best practices, possible scenarios and practical suggestions.

Thus, in addition to theoretical background on Industrie 4.0, current technologies and business models, this handbook on the one hand shows a wide variety of realized examples and on the other hand provides a practical roadmap for the implementation of Industrie 4.0 approaches in corporate practice.



The Handbook will be complementary to the other Intellectual Outputs of the I4EU-project.

2. REVOLUTION OR EVOLUTION

In the discussion about Industry 4.0, the question is repeatedly asked whether this is an industrial revolution or rather an evolution. This question will probably never be answered completely and must perhaps be seen from the point of view that Industry 4.0 is the logical further development of companies at both the technological and organizational level. But the fact is that new approaches and technologies in the context of Industry 4.0 and digitization give companies the opportunity to assert themselves in global competition.

2.1. Theoretical Background

When it comes to a uniform definition of Industry 4.0, different terms are often used which actually always mean the same thing - Industry 4.0 is on the one hand the constant technological and organisational development to enable a production of the future, and on the other hand a possibility to remain competitive as a company in the context of the digital transformation.

The term Industry 4.0 was defined in Germany a few years ago and has since been described in ever greater detail. The German Plattform I4.0 uses the following definition for the term Industry 4.0 (www.plattform-i40.de):

“Industry 4.0 combines production methods with state-of-the-art information and communication technology. The driving force behind this development is the rapidly increasing digitisation of the economy and society. It is changing the future of manufacturing and work in Germany: In the tradition of the steam engine, the production line, electronics and IT, smart factories are now determining the fourth industrial revolution.

The technological foundation is provided by intelligent, digitally networked systems that will make large self-managing production processes possible: In the world of Industry 4.0, people, machines, equipment, logistics systems and products communicate and cooperate with each other directly. Production and logistics processes are integrated intelligently across company boundaries to make manufacturing more efficient and flexible.

This facilitates smart value-creation chains which include all of the lifecycle phases of the product – from the initial product idea and development, production, use and maintenance through to recycling. In this way, customer wishes for everything from the product idea through to recycling can be taken into account, as well as the related services. This enables companies to produce products that are customised according to individual customer requirements more easily than before. The individual production and maintenance of products could become the new norm.

At the same time, manufacturing costs can be reduced despite the individualised manufacturing. Networking the companies in the supply chain makes it possible to optimise not only individual production steps, but the entire value chain. Comprehensive realtime information enables companies to react to the availability of certain raw materials early on, for example. Production processes can be controlled across company boundaries to save resources and energy.
All in all, production efficiency can be improved, the competitiveness of German industry strengthened and the flexibility of production increased”

While the Plattform I4.0 continues with the definition by addressing the social and political tasks, this introduction shall focus primarily on the technical aspects. As said in the definition, the name of Industry 4.0 describes the 4th industrial revolution, which comes after the 1st revolution through mechanisation, the 2nd revolution through mass production and the 3rd through computer and automation.

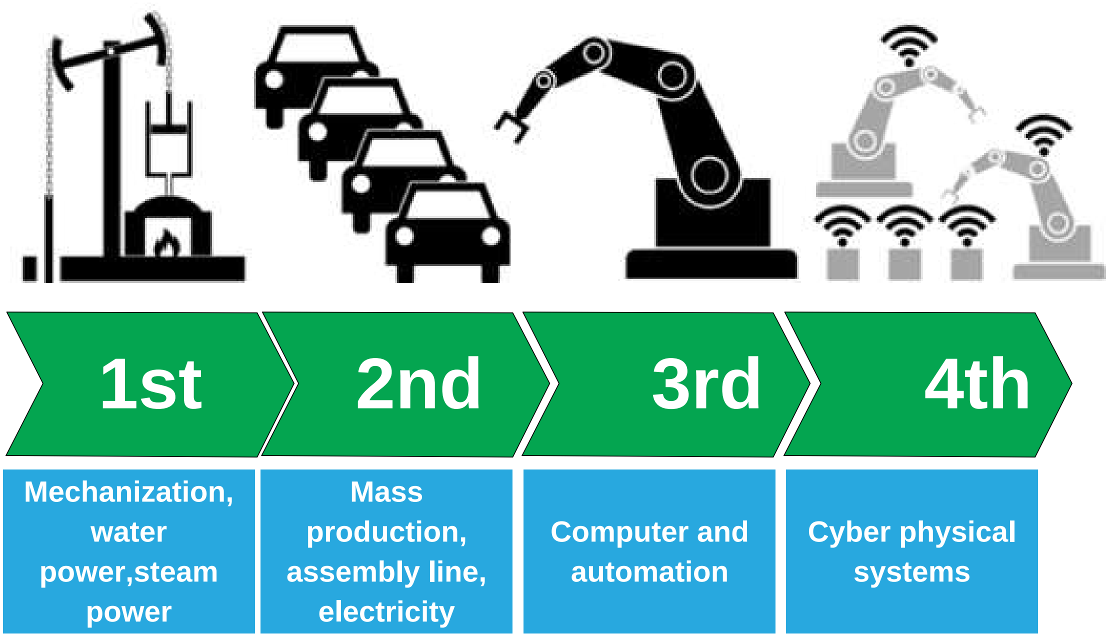


Figure 2: Steps of Industrial Revolutions from 1st to 4th
(Source: Christoph Rose at AllAboutLean.com)

One of the main aspects in the definition above are the digitally networked systems needed to realize a world where everything from machines to people are connected to each other. These intelligent connected devices can also be called cyber-physical Systems or CPS, since it consists of information technology / software and physical mechanical and electrical parts, which are able to communicate with each other for example over the internet.

While the definition of Industry 4.0 also states that the driving force behind I4.0 is the rapidly increasing digitalisation of the economy and society, there are some other basic developments in the market, which are promoting this development. Two of the main factors are:

● Generally shorter product lifecycles, especially in electronic products
● Growing demand for individual products (mass customisation)

The trend towards individual products leads to an increasing number of product variants, which counteract a high productivity. The development of productivity and variant diversity can also be mapped to the four stages of industrial revolution as shown in Figure 3. While manual work could produce many variants, the productivity was very low due to missing mechanization.

The first industrial revolution was able to increase productivity by using (steam-)machines in the production. On the other hand, the number of variants was lowered due to the fixed purpose of machines. While the second revolution could increase productivity even further due to electricity and assembly lines, the product variants were lowered even further. This development can be summarised best with a famous quote by Henry Ford: “Any customer can have a car painted any colour that he wants so long as it is black”.

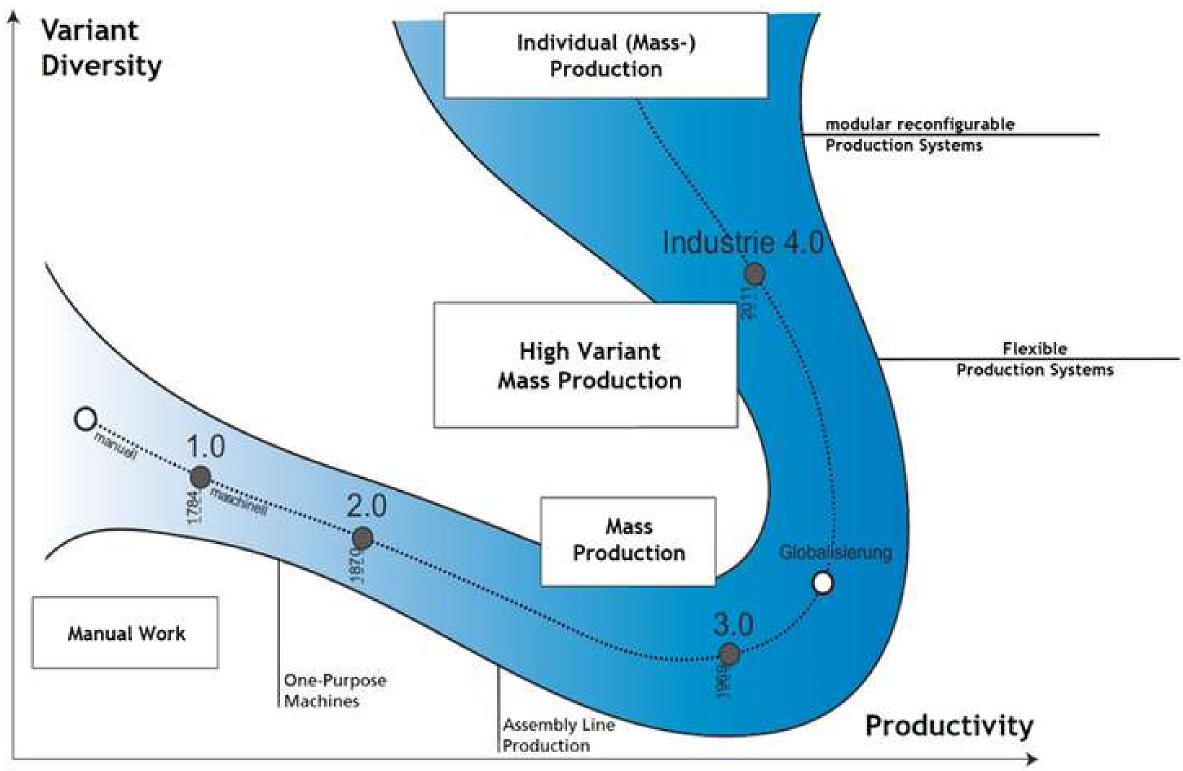


Figure 3: Dependency of Variant Diversity and Productivity in Relation to Different Industrial Revolutions (based on: Handbuch Industrie 4.0)

The third industrial revolution, which came with computerized automation, was then a turning point. While this development caused a peak in productivity due to more intelligent control systems, it also enabled a intelligent and flexible automation system. As shown in Figure 3, the goal of Industrie 4.0 is an increase in variant diversity while keeping the productivity level of mass production and thus resolving in mass customization. The concepts of higher connectivity in combination with more intelligence within the components are main concepts of Industrie 4.0 to achieve these goals.

Since these are only general trends in the context of Industrie 4.0, an example should be presented as storyline in which a possible implementation in SMEs is shown. The following lead-questions can be used for this guiding example:

● How can data be extracted out of a machine in general?

● How can sensors be used to generate data and how are they connected?

● Which data is really needed to realise certain use cases?

● How can this data be transferred into a cloud?

● How can this data be analysed? What are the concrete benefits of this analysis in SMEs?

A concept which should also be mentioned in the context of Industrie 4.0 is the Reference Architecture Model Industrie 4.0 (RAMI 4.0), which is shown in Figure 4. The RAMI 4.0 is a framework that allows standards to be identified in order to determine whether there is a need for additions and amendments. It is a three-dimensional layer model that compares the hierarchy levels of Industrie 4.0 with the life cycle and value streams of products, factories or machinery based on different layers, from the (physical) asset to a business layer. The objective of the model is providing a clear structure for the interdisciplinary topic of Industrie 4.0 by dividing existing standards into manageable parts.

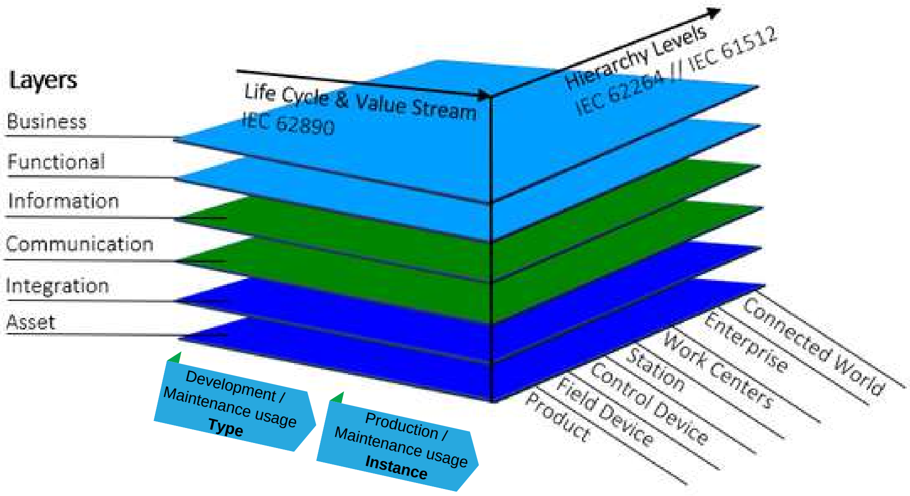


Figure 4: The Reference Architecture Model Industrie 4.0 - RAMI 4.0
(Source: ZVEI / Plattform Industrie 4.0)

The term "Industrie 4.0" is a German word creation but there is, for example, the expression "Smart Industry" as an English equivalent. There are, however, similar initiatives in many countries. In the US, it is called "Industrial Internet Consortium" (IIC). The IIC 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. There are further initiatives in Japan called "Industrial Value-Chain Initiative" (IVI). Initiators are major Japanese companies. China also established initiatives similar to the German political initiative “Smart Industry” 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.

So Industry 4.0, Smart Industry or Smart Engineering have their basic focus on the production process within a "Smart Factory", while the Internet of Things (IoT) focuses on the utilization phase of digitalized and connected devices and products. Smart Industry includes Cyber-Physical Systems, the Internet of Things and cloud computing. The term “Smart Industry” strongly focuses on Smart Factories. To describe general digital transformation processes, resulting value chain changes and effects related to non-industrial small and medium enterprises (SMEs), we consider the term Smart Industry as too constricted.

In the context of Smart Engineering the world of production will become more and more networked until everything is interlinked. This means that the complexity of production and supplier networks will grow enormously. So far, networks and processes have been limited to one factory. However, in a Smart Industry scenario, these boundaries of individual factories will no longer exist. Instead, they will be lifted in order to interconnect multiple factories or even geographical regions. The main point of future industrial products and machines are integrated intelligence, connectivity, user-friendliness and a high degree of customizability.

Today, mechatronic high-tech products have reached a very high level of quality so that the customers cannot perceive any differences between them. The only way to make a product better than other high-end products is to improve the functionality by advancing the software or making it more customizable. One part of Smart Industry is the use of cyber-physical-systems (CPS), which are characterized by reconfiguration and self optimized adaptation to changing production orders and operating systems. The basic technology of CPS comprises embedded systems, which are basically mini-computers. These mini-computers are able to measure physical stats by sensors and to process those data. The embedded systems are equipped with an IP address and modern communication interfaces. The CPS technology is now able to detect where and in what state of completion a product is and by what machine it will be processed next — as long as the machine is able to communicate, too. As a result, production can be decentralized in real time and not be organized centrally.

2.2. Industry 4.0 in Europe

Various studies and papers show that advanced technologies are currently fueling the so-called "fourth industrial revolution", with the potential of transforming EU industries and creating enormous growth in the European economy. Rather than creating new industries, the greatest digital opportunity for Europe lies in the transformation of existing industry and enterprises (see Digital Transformation Monitor 2017). The low adoption rate of digital technologies in enterprises – over 41% of EU companies have yet to adopt any of the new advanced digital technologies – is just one example that enterprises are facing challenges in the wake of this transition. However, a recent survey of EU businesses gives reason for hope: It shows that 75% of respondents regard digital technologies as an opportunity, while 64% of companies investing in digital technologies have generated positive results. National I4.0 policies in Europe in response to the challenges, most of the EU governments have made I4.0 a priority adopting large-scale I4.0 policies to increase productivity and competitiveness and improve the hightech skills of their workforce.

While often united in their goals, the I4.0 policies differ in their policy design, funding approaches and implementation strategies. Although national authorities are aware of the I4.0 policies of their peers, a more systematic cooperation and exchange of good practices is missing.

Policy recommendations, which can have a positive impact on the European economic development in the field of Industry 4.0 are (see Interreg Europe Policy Learning Platform 2019):

● Policy recommendation 1. To Devise Regional Industry 4.0 Strategies.

The first policy recommendation is for regions that have a significant industrial base to shape regional industry 4.0 strategies. The policy complexity of Industry 4.0 requires policymakers to closely work with the private sector to devise a coherent Industry 4.0 strategy to embark in industrial modernisation. This policy recommendation is especially relevant for regions with a significant industrial base (>18% of the regional GDP). In the European Union, some regions such as Flanders and Wallonia in Belgium, the Basque Country in Spain, or Baden-Württemberg in Germany, have drafted Industry 4.0 strategies (see Map 3). In 2013, the Vanguard Initiative (for New Growth through Smart Specialisation) was launched. The Vanguard Initiative is a network of some 30 European regions with high-level political commitment that seek to use their smart specialisation strategies to boost their regional economies through bottom-up entrepreneurial innovation and industrial renewal in European priority areas.

● Policy recommendation 2. To Support the Creation of Makerspaces in Higher Education Institutions.

The second policy recommendation is for regions to promote the use of makerspaces in higher education institutions. The skill sets need to considerably evolve to match the needs of industry 4.0. A makerspace is defined as "a community centre that provides technology, manufacturing equipment and educational opportunities to the public". As a result, makerspaces can prepare students for the skills needed in industry 4.0.

● Policy recommendation 3. To Adopt Responsible Criteria in Public Procurement Tenders.

The third policy recommendation is for regions to adopt responsible criteria in public tenders. The new technologies such as big data and analytics, autonomous robots, simulation, synthetic biology, artificial intelligence (AI), cybersecurity, augmented reality that are being used in Industry 4.0 have some important ethical implications.

● Policy recommendation 4. To Promote Public-Private Partnerships to Diffuse Industry 4.0 Technological Innovations.

The fourth policy recommendation is for regions to promote public-private partnerships (PPP) to diffuse industry 4.0 technological innovations, namely to SMEs. Diffusion, and more importantly the speed of diffusion of technologies and their effective take up is essential for economic development. International technology diffusion determines productivity and growth differences, partly because only a handful of rich countries account for most of the world's creation of new technology.

● Policy recommendation 5. To Promote Diffusion of Industry 4.0 Technological Innovations in Lagging Regions.

The fifth policy recommendation is for lagging regions to promote the diffusion of Industry 4.0 technological innovations. In these regions, regional policymakers often overestimate their regional innovation systems' capacity to develop new ideas and to produce technological innovations. In lagging regions, regional innovation policies must promote the diffusion of Industry 4.0 technologies and adapt the technologies to the regional context through increasing the absorptive capacity of local stakeholders, namely SMEs, to adopt new technologies.

● Policy recommendation 6. To Promote Disruptive Industry 4.0 Technological Innovations in Leading Innovative Regions.

The sixth policy recommendation is for leading innovative regions to promote disruptive Industry 4.0 technological innovations. Regions that are ranked as innovation leaders in the Regional Innovation Scoreboard should promote the next wave of radical and disruptive technological innovations to remain at the technological frontier and innovation leaders.

These policy recommendations are important and are the basis for concrete initiatives and platforms to foster the implantation. The European Platform of national initiatives, launched in March 2017, is at the core of the coordination effort of the European Commission. The Platform plays an essential role in the roll-out of digitalisation of industry across Europe by supporting experience exchange, collaboration, triggering joint investments, common approaches to regulatory frameworks, measures for staff up- and re-skilling. As of October 2017, 15 Member States have already launched national initiatives for the digitisation of industry. They are:

• Austria (Industrie 4.0 Österreich: https://plattformindustrie40.at/?lang=en, Digital Roadmap Austria https://www.digitalroadmap.gv.at/);

• Belgium (MADE DIFFERENT – Factories of the future http://www.madedifferent.be/, Flemish initiative on Industrie 4.0 https://www.vlaanderen.be/nl/publicaties/detail/vision-2050, Digital Wallonia https://www.digitalwallonia.be/madedifferent-digital-wallonia/);

• Czech Republic (Průmysl 4.0: https://www.mpo.cz/en/industry/industry-four/);

• Denmark (MADE - Manufacturing Academy of Denmark http://made.dk/);

• France (Alliance Industrie du Futur http://www.industrie-dufutur.org, Programme des Investissements d'Avenir http://www.gouvernement.fr/investissements-d-avenir-cgi, Transition Numerique www.transition-numerique.fr);

• Germany (Plattform Industrie 4.0 www.plattform-i40.de, Mittelstand 4.0 http://www.mittelstanddigital.de/DE/Foerderinitiativen/mittelstand-4-0.html;

• Hungary (IPAR4.0 Technology Platform https://www.i40platform.hu);

• Italy (Piano Nazionale Industria 4.0 http://www.mise.gov.it/index.php/it/industria40);

• Lithuania (Pramonė 4.0 http://www.industrie40.lt/platform/);

• Luxemburg (Digital4Industry - D4I http://digital4industry.lu/);

• Netherlands (Smart Industry - Dutch Industry fit for the Future http://www.smartindustry.nl);

• Portugal (Indústria 4.0 www.i40.pt);

• Spain (Industria Conectada 4.0 http://www.industriaconectada40.gob.es);

• United Kingdom (Digital Strategy https://www.gov.uk/government/news/uk-digital-strategy-the-next-frontier-in-ourdigital-revolution).

Seven more initiatives in the countries Bulgaria, Croatia (Digitising impulse 2020), Cyprus (National Integrated Industrial Strategy 2017 – 2030), Finland (Digitising Finnish Industry program), Poland (Platforma Przemysłu Przyszłosci – PPP), Romania, and Slovakia (Conception of Smart Industry for Slovakia) are under preparation.

In general, 18 months after the launch of the initiative, clear alignment of national and European initiatives is evident. This is a good foundation for defining together the longer-term visions and actions for the digital transformation of Europe. However, more efforts and investments are required to close the gap between top- and lower-performing countries and to leverage the digital opportunities. A more detailed glance at Europe's digital industry landscape shows that more than 30 European, national, and regional initiatives on digitizing industry can be identified.

3. Current state of Industry 4.0

This chapter includes on the one hand an analysis of the different technologies, applications and business models, as well as future trends and should provide a clear picture of the actual (and foreseen, where possible) Industry 4.0 ecosystem, in terms of technologies and models.

3.1. Technologies

Additive Manufacturing / 3D Printing

Due to the demand for individualized products, new manufacturing processes are needed, which are able to produce a high variant diversity up to batch size one. Since classical primary shaping processes like casting or plastic moulding have very high tool costs, their usage is only profitable with very high batch sizes. While some reshaping processes like punching or pressing are also dependent on very high batch sizes, machining processes like milling or turning can be used to produce very individual products. The problem with machining can be the broad variety of processes needed to shape a specific product as well as tools and machine programming.

As a result of this development, the technologies summarised with the term 3D printing or additive manufacturing have developed to the most promising manufacturing processes to produce batch size one. 3D printing or additive manufacturing are any processes in which material (such as liquid molecules or powder grains) is joined or solidified by the use of computer control to create a three dimensional object of any shape.

Generally, there are three processes that can be distinguished:

● Manufacturing out of a liquid state (e.g. stereolithography)
● Manufacturing out of a plastic state (e.g. Fused Deposition Modeling)
● Manufacturing out of a powdered state (e.g. SLM, SLS, EBM)

Simulation, Digital Twins and Virtual Commissioning

To achieve shorter set up times in production lines, simulation can be used for creating or testing the configuration virtually before setting it up in reality. In this context, the terms “Digital Twin” and virtual commissioning are used very often. Another term that has to be mentioned in direct correlation to virtual commissioning is hardware in the loop (HiL).

With the Industrie 4.0 Initiative, the term “Digital Twin” emerged, while it was originally used in 2011 by NASA to describe a very detailed simulation model for their spacecraft. Since it is a better marketing term than “simulation” it was then adapted broadly in the I4.0-community for marketing purposes.

Virtual commissioning is an important component for shorter set up times. It enables the testing of a complete configuration (hardware as well as software) before setting it up in reality and thus minimizing errors upfront. This saves costs and time in contrast to testing it with real hardware since errors can’t be corrected as easily as in a simulation model. Changes to the system are also very expensive in late stages of a project.

Besides a full simulation of the whole production system, there are also mixed systems between hardware and software. As an example, the program on a programmable logic controller (PLC) can be tested by connecting it to a simulation model of actors and sensors, which can process the control signals and simulate their effect. This is called hardware in the loop (HiL), since physical hardware (in this case the controller) interacts with a virtual system that simulates its planned environment over it’s in- and outputs.

Human Machine Collaboration / COBOT

Human machine collaboration describes generally a coordinated, synchronous activity between a human and a machine that is the result of a continued attempt to achieve a common goal. This means that the machine and the human are directly working together on one task. The term “COBOT” is short for collaborative robots and a specialization of human machine collaboration. It refers to (industrial) robots working together with humans and supporting them in their tasks.

The terms collaboration and cooperation are often confused in this context: While a collaboration describes the two partners working on the same task together, a cooperation only means that the two partners share a common working space but work on their individual tasks independently. It should also be mentioned that current research shows that a cooperation is a more realistic scenario in the near future than a collaboration.

Connectivity Technologies

Connectivity between all machines to form a digitally networked system can be considered as one of the main goals of Industrie 4.0. However, in today's automation systems, there are many different interfaces and protocols for connectivity present, which are often also preferred or developed by certain manufacturers. To connect every machine to each other, full interoperability and thus a unified communication needs to be established. Since components are also more intelligent and therefore have to exchange more information with each other, the interface has to be able to transfer complex data in an intelligent way. While Industrial Ethernet already offers a more sophisticated data transfer in comparison to classical Field Buses, they don't provide all the necessary functionalities required by I4.0 (e.g. service orientation, integrated data models, etc.). Therefore, a number of "I4.0-Interface Technologies" have evolved to fulfil these requirements.

The following technologies are considered especially relevant in this regards:

- OPC UA
- MQTT
- MTConenct
- OneM2M
- TSN
- 5G

It should be noted, if these technologies are able to replace current Industrial Ethernet standards or not. A substitution could for example not be possible due to a lack of deterministic real time capability. Detailed examples on the application of these standards will be given in the Advanced Trainings.

Data Models

While unified interface standards are important to connect all machines with each other, this does not necessarily mean that a full interoperability is provided. It is still possible to transfer proprietary data by using bits and bytes without any common understanding about their semantic meaning. Therefore, it is necessary to create common data semantics, which are known by all participants in an I4.0-network. These data models can be based on existing standards in a domain, but have now to be adapted to the new communication technologies.

While there can be very generic information, which is common for any machine (e.g. Identification), other part models are very domain specific. Examples would be the physical description, and therefore need to be specified within these domains or the processing of big data from different types of machines for condition monitoring, predictive maintenance or online process optimisation.

Security

While more and more machines will be connected over the Industrial Internet of Things (IIoT), the aspect of security becomes especially important. For security reasons, most production systems are currently heavily protected by firewalls or completely isolated from outside networks and therefore not able to transmit any data to the outside world. This completely contradicts the concept of the IIoT.

To open the path for IIoT without lowering the current security level, new connectivity concepts and standards must have very high security standards that can withstand any attack from the outside world. The aftermath of a hacking attack on production systems with industrial robots and similar automation systems could directly and physically damage the production system or even endanger human lives.

Data Collection via Cloud and Big Data

While interfaces and data models are the basis for data collection, architectures and technologies have to be found to collect and store this data efficiently. Since most of the IIoT-Standards portrayed before are not capable of deterministic real time communication, they are currently used to collect data for use cases like condition monitoring or online process optimization. These use cases are elaborated in the following chapters.

The volume of data necessary to utilise such use cases is very high and the algorithms are very complex. The sources of the data are in most cases sensors and actuators, which are connected to a PLC. Storage space and computing power is a valuable and expensive resource in these kinds of controllers and algorithms mostly need the data of different machines to be feasible. Therefore, it is very useful to redirect the data directly to higher systems with a lot of storage and computing power. This is where cloud services are very useful. Some popular clouds are Amazon Web Services (AWS), Microsoft Azure IoT, SAP HANA and clouds from typical vendors of automation equipment like Siemens Mindsphere or the Bosch IoT Cloud.

Within the collection of data from a PLC to different cloud services different technologies like MQTT, OPC UA and AMQP can be used to transfer data into an ERP or MES from where the data is transmitted to the cloud providers. The figure also shows that data from different machines and even different factories can be bundled here to apply comprehensive algorithms. There are also approaches to transfer the data directly from PLCs, bus-couplers or field devices into the cloud. An example for this would be Microsoft Azure IoT, which can access OPC UA capable devices directly and collect their data.

The collection of such data volumes is commonly known as “Big Data”. This term refers to the three dimensions of big (data-)volume, velocity and variety (bandwidth and data types). Sometimes these dimensions are also extended by value and validity to emphasise the added business value and the quality of the provided data. This data can then be analysed to generate a concrete benefit, which is elaborated in the following chapters.

Condition Monitoring and Predictive Maintenance

As stated in previous chapters, there is a lack of real time capability in modern IIoT-Standards which makes them prominent for use cases that are based solely on data collection. Very popular examples are condition monitoring and predictive maintenance. These terms do also have a relation to each other, since condition monitoring is the basis for predictive maintenance.

While condition monitoring considers the current state of specific devices with their measured parameters and tries to determine if the parameters are in a normal or critical operational state, the algorithms behind predictive maintenance use the chronological development of these states to find out when a device will be in a fault. In short, condition monitoring concentrates on giving feedback on the current health state of a device and sends corresponding alarms if the state is critical while predictive maintenance concentrates on the prediction of the future state.

In general, the following different types of maintenance can be distinguished:

● Preventive Maintenance: The date of maintenance is being determined by time or condition

● Time-Based / Planned Maintenance: Maintenance is performed in fixed intervals, without considering the actual state of the machine (e.g. a regular oil change)

● Condition-Based Maintenance: The condition of a machine is checked in fixed intervals and maintenance is only performed if really necessary

● Predictive Maintenance: The point in time when maintenance will be necessary is predicted by considering the current condition and it is possible wear based on the development so far.

● Corrective / Breakdown Maintenance: Maintenance is performed if a machine has already broken down

Intelligent Sensors / Retrofit of existing machines

Often very old machines can be found in production systems, which have no connectivity options or even computer control. In these cases, sensors have to be added to utilise the use cases of condition monitoring and predictive maintenance. An example for these kinds of sensors is the ABB Ability Smart Sensor. This sensor is able to detect vibration, noise and high temperature and can be placed on practically every motor. The data is transmitted over Bluetooth and can be transferred to the cloud with an ABB-Gateway or smartphone. The main use cases of this kind of sensor are predictive maintenance as well as performance optimisation.

If a machine already has sensors but is missing connectivity, it is possible to fit adapters or gateways to adapt proprietary data formats and connectivity options to standardized Industrie 4.0 protocols and data models. This process can also be called “retrofitting”.

Advanced Manufacturing Control Systems

The concepts presented so far are key elements to realise the vision of I4.0. However, connectivity and standardisation is not enough for a truly intelligent production. The components themselves have to get more intelligent and less dependent from centralized control systems as well as the hierarchical structure of the automation pyramid. Intelligent components where physical and software components that are deeply intertwined and connected to the industrial-IoT can be called cyber-physical systems or CPS. The use of these components lead to a completely networked and CPS-based automation.

The CPS would also have to organise themselves for a highly autonomous production, since there are no hierarchical commands from the automation pyramid anymore. To do this, agent based systems in which all participants negotiate with each other over a given order, are one of the most promising concepts. Since todays automation system are only flexible but not able to perform a complete reconfiguration by themselves (especially regarding hardware) these agent based systems are mostly tested in logistics with driverless transportation systems

3.2. New business models

The fourth industrial revolution brings with it a wealth of possibilities, things can be done now that were never before possible. This gives organisations in the manufacturing industry the freedom to make the leap from supplying a product to delivering a service. An interesting example of this is the German company Kaeser Compressors. It transformed from being a supplier of compressors and being quite active both inside and outside manufacturing into being a supplier of compressed air. This transformation was realised after Kaeser started up a large-scale project to integrate business processes. To do this, the Internet of Things (IoT) – the motor that runs Industry 4.0 – was put into place to connect processes and devices via sensors. As a consequence, Kaeser got great insight into the entire production chain, a starting point from where service levels could be raised. Service is therefore central in the revamped business model.

As a result of smaller batch sizes and product life cycles, production systems have to be adopted to new products in a very short time to be cost efficient. In this context, the two terms “flexibility” and “changeability” are used very often to describe this kind of adaptability.

While flexibility describes the ability of a production system to adapt quickly to new products, which were already considered in the planning phase, the term changeability refers to the efficient adaptability to new products, which were unknown at the planning phase. There are many flexible machines that can produce a variety of product variants. However, the changeability of production systems is still a huge challenge, since production systems have to be able to integrate new modules and devices to produce new variants. This means that the mechanical, electrical and IT interfaces have to be integrated in a very short time. Industry 4.0 especially promotes an easier integration due to new concepts in information technology like unified control interfaces and data semantics within devices.

So a company has to be flexible and changeable as well to the development a business strategy for, which defines the path that the business will take to achieve its goals. These goals include the elements of the business model, along with any additional mission or goals. It explains the steps, processes and changes that the business will follow and it identifies the strategies the business will use to counteract potential upsets and hurdles. Achieving the business strategy requires the efforts of every employee. The business strategy should be contemporary, if not advanced, to meet the current industry demands, as well as the forecasted demands.

Benefits of Business Models

The best business idea is usually not sufficient if it is not based on a well thought-out and functioning business model, which covers the key pillars of future success.
Making a business model serves several purposes, firstly the people involved in authoring the model engage very intensively with all the important aspects of the business, which can help to better understand it. On the other hand, the unique selling point can be worked out even more clearly and thus a better positioning in the market can be made possible. In addition, a mature business model provides a better estimate of the scalability of a business idea.

New I4.0-Business Models / existing Models that can be developed in direction of I4.0

● Principal of E-Business in B2B market

The term eBusiness has become a generic term used in a variety of brands. It is interpreted differently and often misunderstood. IBM defines the term as "reshaping strategic business processes and meeting the challenges of a new market increasingly characterised by globalisation and based on knowledge." Strategic business processes include the entire value chain and the relationship of a business with its partners. This description of the e-business term leaves a concretisation of the "redesign" open and also, by which means e-business should be realised, although the term itself implies an implementation by electronic, i.e. information and communication technology.

● Extreme Integration of Suppliers and Customers (value chain gets more connected)

For every industrial company, the promise of Industry 4.0 is enormous. And perhaps nowhere is it more important than in its potential to transform the supply chain. By combining a variety of digital tools—integrated planning and execution systems, logistics visibility, autonomous logistics, smart procurement and warehousing, spare parts management, and advanced analytics—fast-moving companies have the very real potential to win the battle for efficiency and speed to market.

● Mass Customisation is getting easier with I4.0

Industry 4.0 is all about connecting everything centrally, including services and matters that are outsourced or that a company might not provide itself. I4.0 enables sharing of e.g. simple information with third parties. Via a cloud-based portal, end users have access to the data of all collaborating parties.
All this requires an IT system with the capacity to compute an enormous amount of data. All mutations must be recorded and accessible, day and night. That necessitates a powerful database. But then, all the information you need is available in real time, and you can respond even better to your customers' requests.

● Service-based business models

The digitalisation of plants and mechanical engineering enables many new business areas. Most of these Industry 4.0 business models affect service providers in the IT industry (such as software developers, software providers, data processors, service providers, web and app designers), and there are many new value-added opportunities for plant and machine builders, as providing Infrastructure as a Service with pay-per-use / pay-per-hour models. These new business models shift the classic services of the plant and machine manufacturer to IT-based services.

As part of the pay-per-use business model, the manufacturer waives the sale of a component or a machine. Instead, it provides the plant infrastructure or the machine as a service for a service charge. Thus, for example, the manufacturer of a power plant turbine could receive a fee only per completed operating hours of the turbine. This life-cycle-based approach shifts the maintenance and operational risk within the agreed availability to the plant and machine builders.

However, a pay-per-use model could offer some advantages, especially for plant and machine builders. On the one hand, he could incorporate his entire production know-how into the operation of the plant and make efficient use of synergies. On the other hand, he could gain information from the operation of a larger number of systems. By analysing the data (big data) from the fleet control, so-called predictive maintenance, that is the optimal timing of the maintenance based on pathological machine data, could be established. Especially the unplanned maintenance could be reduced in this way. As a result, the plant manufacturer could achieve more operating hours than would be possible, for example, with an "analog" plant operator.

Thanks to its comprehensive understanding of the product, the plant and machine builder can also develop a company-oriented remuneration model. The cost transparency achieved in this way could in particular also be used by the customer for the use of such a model. The customer pays only for the operating hours incurred, so that he can use his capital very efficiently.The plant and machine builders also benefit from the associated customer satisfaction. Linking the pay-per-use business model with other digitalisation options (such as smart contracts or distributed ledger technology, such as Ethereum or Blockchain) also allows for transparent and tamper-proof documentation of the operation, which could be used to pay in real time.

3.3. Future Trends

Besides technologies and new business models there can be pointed out some new trends in the wide field of Industry 4.0, Smart Factory and Digitisation. Especially focused on new skills, the The following four key technological developments can be distinguished within Industry 4.0. (see “Skills for Industry - Curriculum Guidelines 4.0 - Future-proof education and training for manufacturing in Europe, 2020)

1. Digitisation and integration of vertical and horizontal value chains:
Industry 4.0 implies vertical digitisation and integration of processes across the entire organisation, from product development and purchasing, through manufacturing, logistics and service. All data about operations processes, process efficiency and quality management, as well as operations planning become available real-time, supported by augmented reality and optimised in an integrated network. Horizontal integration goes beyond the internal operations from suppliers to customers and all key value chain partners. It includes technologies from track and trace devices to real-time integrated planning with execution.

2. Digitisation of product and service offerings:

It includes the expansion of existing products, e.g. by adding smart sensors or communication devices that can be used with data analytics tools, as well as the creation of new digitised products which focus on completely integrated solutions. By integrating new methods of data collection and analysis, companies become able to generate data on product use and refine products to meet the increasing needs of end customers.

3. Digitisation of business processes and way of working:

part of the industry pressure to move towards Industry 4.0 also comes from the fact that new technologies are changing the way products are designed, manufactured and subsequently distributed to end-users. From customer service to factory floor, new technologies like robotic process automation, smart assistants, collaborative robots (cobots) and exoskeletons are not so much replacing humans as enhancing what a human can do in a limited amount of time. These productivity benefits should not be underestimated.

4. Digitisation of business models and customer access:

Industry 4.0 also implies expanding company offering by providing disruptive digital solutions such as complete, data-driven services and integrated platform solutions. Disruptive digital business models typically focus on optimising customer interaction and access and generating additional revenue. Digital products and services often aim to serve customers with complete solutions in a distinct digital ecosystem.

Industry 5.0 – the next paradigm?

Respectively new is the Industry 5.0 paradigm - Industry 5.0 complements the existing Industry 4.0 paradigm by highlighting research and innovation as drivers for a transition to a sustainable, human-centric and resilient European industry. It moves focus from shareholder to stakeholder value, with benefits for all concerned. Industry 5.0 attempts to capture the value of new technologies, providing prosperity beyond jobs and growth, while respecting planetary boundaries, and placing the wellbeing of the industry worker at the centre of the production process.

The concept of Industry 5.0 was discussed by participants from research and technology organizations and funding agencies across Europe in two virtual workshops organized by the Prosperity Directorate of DG Research and Innovation on July 2 and 9, 2020. The focus was primarily on enabling technologies to support Industry 5.0, and there was consensus on the need to better integrate European social and environmental priorities into technological innovation and shift the focus from individual technologies to a systemic approach.

Six categories were identified, each of which should develop its potential in combination with others as part of a technological framework:

1) Individualized Human-Machine Interaction;
2) Bio-Inspired Technologies and Smart Materials;
3) Digital Twins and Simulation;
4) Data Transmission, Storage and Analytics Technologies;
5) Artificial Intelligence;
6) Energy Efficiency, Renewable Energy, Storage and Autonomy Technologies.

The new paradigm has three major approaches – Human-centric, sustainable and resilient: Rather than taking emergent technology as a starting point and examining its potential for increasing efficiency, a human-centric approach in industry puts core human needs and interests at the heart of the production process. Rather than asking what we can do with new technology, we ask what the technology can do for us. Rather than asking the industry worker to adapt his or her skills to the needs of rapidly evolving technology, we want to use technology to adapt the production process to the needs of the worker, e.g. to guide and train him/her. It also means making sure the use of new technologies does not impinge on workers' fundamental rights, such as the right to privacy, autonomy and human dignity.

For industry to respect planetary boundaries, it needs to be sustainable. It needs to develop circular processes that re-use, repurpose and recycle natural resources, reduce waste and environmental impact. Sustainability means reducing energy consumption and greenhouse emissions, to avoid depletion and degradation of natural resources, to ensure the needs of today’s generations without jeopardising the needs of future generations. Technologies like AI and additive manufacturing can play a large role here, by optimising resource-efficiency and minimising waste.

Resilience refers to the need to develop a higher degree of robustness in industrial production, arming it better against disruptions and making sure it can provide and support critical infrastructure in times of crisis. Geopolitical shifts and natural crises, such as the Covid-19 pandemic, highlight the fragility of our current approach to globalised production. It should be balanced by developing sufficiently resilient strategic value chains, adaptable production capacity and flexible business processes, especially where value chains serve basic human needs, such as healthcare or security.
(see Industry 5.0 – Towards a sustainable, human-centric and resilient European Industry – European Commission 2021 // Industry 5.0 - Publications Office of the EU (europa.eu))

This approach and the associated priorities are still relatively new and will play a major role in the future at a wide variety of levels and will be reflected in economic and research policy strategies and programs as well as in funding programs and many, many projects. Of course, these developments must also be taken into account and included in the direction of training and qualification.

3.4. Realised Examples / Best Practices

To gain a deeper insight into the diverse possibilities and areas of application of Industry 4.0 technologies, you will find examples from the partner regions of the I4EU project in the following section. Details on these and other projects are also available at www.i4eu-pro.eu!

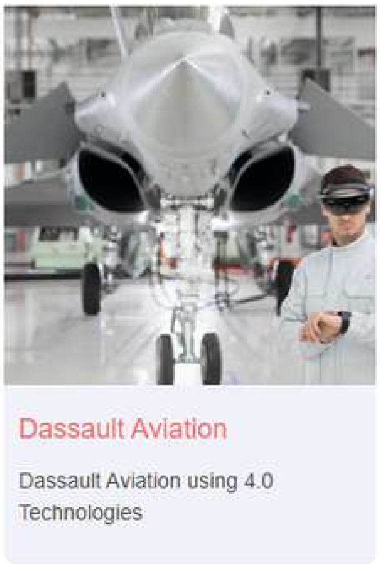
Alarming via Smartwatch-App – STWIA Advanced Products GmbH, Austria

In order to improve the interaction between man and machine (HMI), the STIWA Group business unit "Manufacturing Software" has developed its own Smartwatch-App in close cooperation with the production site in Gampern, which actively notifies the machine operator in case of malfunctions. The Smartwatch is connected to the company network via WLAN. The app can be used on various mobile devices (e.g. Huawei-, Casio-Smartwatch etc.).

STIWA Advanced Products

Alarming via Smartwatch-App

Dassault Aviation using 4.0 Technologies – Dassault Aviation Merignac, France



Founder of the digital enterprise industrial revolution, Dassault Aviation is one of the most innovative companies in France that has made a breakthrough in Industry 4.0. Several areas of transformation have been undertaken to support the current challenges and maintain a competitive positioning. The opportunities offered by 4.0 technologies will be evoked with supporting examples revealing the overall strategy of Industry 4.0.

Efficient and safe connectivity of power and gas metering - Stadtwerke Bielefeld GmbH, Germany

The public utility company of the city of Bielefeld has tasked the company MarcanT with finding a way to connect their gas and power meters in a secure and future proof way so that customers were able to access their data. The company came up with an idea involving roaming SIM-Cards.

Nordmeccanica adopting 4.0 technologies – nordmeccanica group, Italy

Nordmeccanica is one of the most innovative companies in Italy. Innovation is deemed important to face current challenges, maintain a competitive positioning and lead the new industrial revolution. Nordmeccanica sees in 4.0 technologies an opportunity to evolve and develop its business. Partnerships with other companies proved to be essential in this regard and led to the creation of innovative tools to support industrial IoT.

Protecting the technological infrastructure of the Spanish health sector against advanced cyber threats – Grupo Oesìa, Spain

Headquartered in Madrid, the company has a factory in Valdepeñas (Ciudad Real) and offices in Spain, Colombia and Perú. The health sector is a preferred target of attack by cybercriminals, mainly because of the valuable data that is managed in hospitals. A Spanish hospital has taken an interest in securing all its technological infrastructure in order to guarantee the privacy and protection of its patients' data against advanced threats and the new vectors of attacks that arise as a result of the Digital Transformation and the deployment of new technologies, to allow the operational continuity of health services to the Spanish society.

Blockchain Possibilities – Unidemi, Portugal

Blockchain technology is a new paradigm and part of Industry 4.0 possibilities that can influence many sectors and provide new solid solutions involving digital solutions and having higher trust in the process and outcomes. This technology is a driving force behind the next generation of Internet that can reshape many sectors. Researchers and practitioners of blockchain technology are discovering many interdisciplinary ways to practically connect to science, technology and industry ultimately possibly resulting in new business and societal models of not just doing business but other ways of trustworthy societal behaviors.

Videos:
There are also several Interview videos on the I4EU website in which different experts talk about the following topics:

- Artificial Intelligence
- Consultancy
- Cyber Physical Systems
- Data Science
- Education
- Entrepreneurship
- Innovation
- Internationalization
- Manufacturing
- Mobility

Link to the videos: Interviews – I4EU Project (i4eu-pro.eu)

4. How to implement – a ROADMAP

The roadmap represents a bottom-up approach in which the departments both analyze the current state and independently define the target state - naturally within the framework of the corporate strategy. The implementation of Industrie 4.0 solutions in a company or in products basically requires a very individual consideration of the respective situation in a company and must subsequently be implemented adapted to the specific needs and challenges.

The starting point is usually a thorough analysis of the current situation, in which opportunities and ideas for I4.0 projects are openly discussed based on a hopefully existing digitization strategy. As a first step, it is important to create awareness of Industrie 4.0 within the company and among the employees directly involved. A startup workshop is intended to provide an impetus by presenting the key contents, concepts and technologies of Industrie 4.0. It is also important to define and communicate the scope of the planned project in the startup workshop so that employees are involved in the change process at an early stage and the transformation process to Industrie 4.0 is sustainably secured. Using an appropriate assessment such as the Competence Meter, these ideas can be identified and further defined.

The next step is to check whether the company or its employees have the appropriate qualifications and competencies, since only with an understanding of new I4.0 technologies can they be implemented in a company in a way that is beneficial. Therefore you find various qualification programmes, which can be used by companies as well as by students.

The implementation itself should only be carried out for a selected area, process or product at the beginning, since a holistic implementation of a comprehensive digitization strategy is very difficult to carry out, especially for small and medium-sized companies.

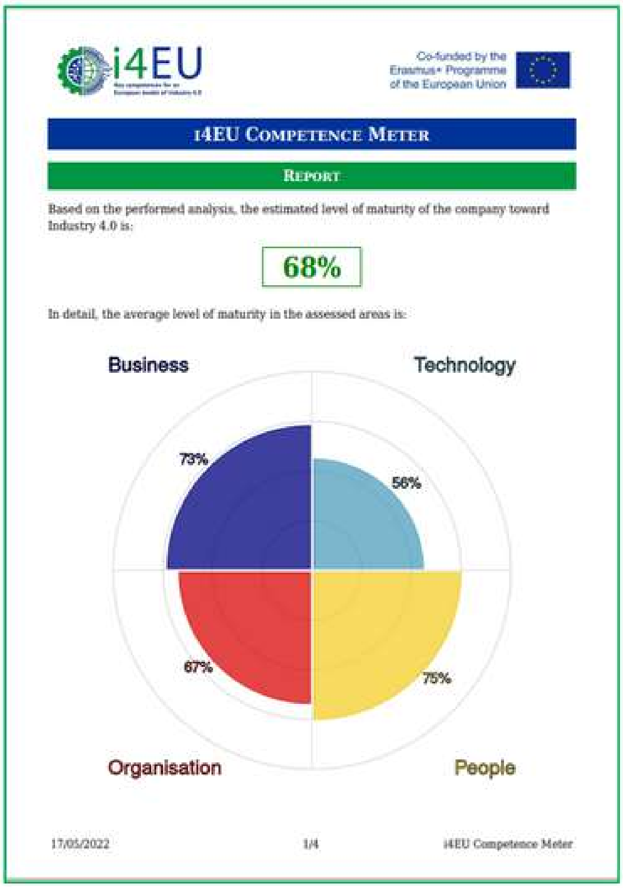
These three steps - analysis / qualification / implementation - are referred to and described in more detail in the following as the I4EU - ROADMAP.

4.1. Analysis – the Industry 4.0 Competence meter

Are you really ready to move into Industry 4.0? Do you want to evaluate your level of maturity to adopt the Industry 4.0 technologies and methodologies? This is the right place!

In order to change their processes, companies need to be aware of the digital competences and their level of maturity towards the Industry 4.0 technologies and models. Often they are not able to self-assess their skill and ask for a support to external experts, such as consultants, incubators, chambers of commerce, etc.

The I4EU project provides a self-assessment tool, open access and designed according to the trans-national competences of the project partnership. The Competence Meter performs a multidimensional analysis of the users' digital skills according to four different dimensions: Technology, People, Organization, Business. The tool assesses the level of maturity with respect to each of the assessed dimensions and estimates the distance with respect to the "ideal" level of maturity needed to successfully implement Industry 4.0 models. Then, the tool provides Recommendations useful to fill the eventual gap of competences.



i4EU Competence Meter

Report

Based on the performed analysis, the estimated level of maturity of the company toward Industry 4.0 is:

68%

In detail, the average level of maturity in the assessed areas is:

17/05/2022 1/4 i4EU Competence Meter

Recommendations

Based on the performed analysis, in order to further increase your digital competences and to move towards industry 4.0, we recommend:

1. Smart activities have already started in the company. We recommend the procurement of a new system by the IT department that meets all requirements or adaptation of the existing system by the internal IT department or external experts.
2. You already use innovative technologies in your production process, however make sure, that your employees, customers and suppliers can keep up with your digitalisation process.
   Please also have a look at the following Chapters of the related SMeART-Guidelines: 4.4, 4.6
3. Informing people about new technology without involving them in strategic choices certainly does not facilitate the implementation of innovation and the active collaboration of employees. It is important to involve employees in the planning of a new technology, both to facilitate the introduction and because sometimes good suggestions can arise from the operational people.
4. Digital transformation has entered the industry, often becoming the key measure of the competitive advantage of companies, particularly in markets characterized by strong and rapid changes, both in demand and supply. It is important to immediately embrace this challenge and begin to train your staff, before the competitive delay becomes unresolvable.
5. Industry 4.0-innovation activities have already started in the company. However please be aware that more efforts are needed to reach your full innovation potential and take into consideration to travel to other comanies abroad. Consider the possibilities of national/international cooperation and funding. At the moment there are many programmes/initiatives and funds available. For detailed information please have a look into the related initiatives and policies of the European Union.
   You can also find useful information in the SMeART University-Business Cooperation Model and Guidelines.

17/05/2022 2/4 i4EU Competence Meter

Note: the Competence Meter is a self-assessment tool, designed to support the companies in a process of self-awareness of its digital skills and competences. It is not intended to replace the work of a consultant who, working in the field, can provide tailored solutions to the specific needs of each company.

>> LINK to DEMO Competence Meter https://i4eu.demo.innosans.dev

4.2. Qualification

The “Industry 4.0” paradigm has generated new opportunities and new challenges for companies. In order to increase their competitiveness and efficiency, companies have to face the digital transformation of the production and logistics chains (smart manufacturing) and of products (smart interconnected objects). The impact of the fourth industrial revolution is huge in terms of involved stakeholders and in potential economic growth. The fourth industrial revolution have also triggered a huge educational challenge, bringing the need to re-train millions of employees to models and technologies unknown even ten years ago. Within the I4EU-project employees. In order to enable a higher qualification, possibilities for further training and building up expertise were developed within the framework of this project.

Certifications

In conjunction with the analysis of needs skills and experiences within the Competence Meter, certifications and training programmes have been developed to build knowledge in the four areas of technology applied in Industry 4.0, soft skills of people, organisation and management applied to Industry 4.0 and business opportunities and collaborations.

Within the project four different certifications have been developed to improve knowledge in each set of competences:

● Certification for Junior Tech Profesional in Industry 4.0:
It provides knowledge about the existing tools and technology in Industry 4.0 and its main applications for business. The certified professionals are able to use the most common Industry 4.0 technologies and services and are able to evaluate their utility for the company and their cost-effectiveness.

● Certification in Junior Talent Manager:
It is a basic qualification for all professionals, students, teachers and researchers. It provides the basic knowledge in soft skills, important transversal skills in the field of Industry 4.0. The participants will improve their soft skills abilities in order to further apply it to the domain of Industry 4.0 and to implement these abilities in their working contexts or to enter in the labour market.

● Certification in Junior Operation Manager applied to Industry 4.0:
It is a basic qualification that provides the basics of management linked to Industry 4.0 and an outline of the main applications for managing and organising.

● Certification in Junior Business Strategist:
It is a basic qualification for all the target groups. It provides the basics of cooperation, research, innovation and customers related to Industry 4.0 and an outline of the main applications. The certified operator is able to adopt (or suggest the adoption) of strategies applied to Industry 4.0.

These certifications are adresse to following target groups:

(i) Staff from companies, especially SMEs, interested to Industry 4.0 technologies at any level (managers, designers, production assistants, technicians, ICT managers, ICT operators, process managers, etc)

(ii) Professionals that intend to train or re-train in order to acquire specific skills on Industry 4.0, in order to use the related technologies in their working contexts or to enter in the labour market as expert users/managers of Industry 4.0

(iii) Professionals that intend to train or re-train in order to acquire specific skills on Industry 4.0, in order to develop new technologies, services and applications
(iv) University staff and students (professors, researchers, technicians, students, alumni, etc.)

(v) Other stakeholders, whose interaction is fundamental to strength competences and abilities, namely local and national governments, policy-makers, standardization authorities.

Main target sectors,which are adressed, are:

● the business sector, being the main target of the project. Due to the high number of professionals potentially interested to the qualifications, it is reasonable to propose several qualifications with different degrees of complexities and different levels of deepening of the Industry 4.0 concepts

● the professionals (users and developers), due to the high impact that the Industry 4.0 services and technologies can have both in the upskilling and reskilling of the citizenship, and due to the widespread need for continuous update of theoretical and practical skills and competences.

● the education sector, due to the potentiality of the Industry 4.0 to enhance the common teaching and learning methodologies and the need for teachers at all levels to improve their skills.

● Public administration bodies due to the importance of involving policy makers and reaching the expected impact of the project.

Short Learning Programs

In order to achieve this certification, corresponding qualification programmes were developed with the following main topics:

1- I4.0 Junior Tech Profesional

Specific computer science skills for Industry 4.0 /1
Specific computer science skills for Industry 4.0 /2
Lean Manufacturing and industry 4.0 Technologies for supply chain efficiency
Enterprise Interoperability
Cyber Security and Protection of Critical Infrastructures
Digital Twin

2 - I4.0 Junior Talent Manager

Digital Transformation
General Soft Skills
E-leadership and negotiation
Cyber Security and Protection of Critical Infrastructures

3 - I4.0 Junior Operation Manager
Digital Transformation
Open innovation for Industry 4.0
Smart industry and circular economy
Production Management in Digital Factory
Cyber Security and Protection of Critical Infrastructures
Supply Chain and Networked Enterprises

4 - I4.0 Junior Business Strategist
Digital Transformation
Business plan and data analysis
Business analysis and low code platforms
International funding and partner search

More details see www.i4eu-pro.eu!

Smart Industry Labs

Learning scientific disciplines require a significant practical component in their training since, in general, professional ecosystem will be far from the theoretical framework. The experience of working with real equipment and components provides complements to learning widely known by professionals and necessary for anyone seeking learning beyond the theoretical models. Likewise, laboratory experiences also allow students to contact with research and innovation, developing skills and competencies that could not be acquired otherwise.

The experience acquired through laboratories provides complementary and unique capabilities and abilities. The development of the Internet has made feasible the provision of remote tools. Hands-on laboratories, remote laboratories, virtual laboratories and simulators are the efforts mainly developed by educational institutions in order to provide the required experimental environments in fields in which experimentation plays a core role.

The I4EU project has implemented a set of virtual and remote laboratories, to enable the learners to integrate the theoretical competences gained in the training courses with hands-on activities. The laboratories intend to be didactic demonstrators where the learners can make practical experiences in controlled situation but using real or virtual equipment. This learning-by-doing methodology is fundamental when dealing with a topic such as Industry 4.0 technologies, where practical skills are essential.

The demonstrators are fully controllable online, allowing the learners to access them without constraints of time and space. Through the bottom menu it is possible to browse the demonstrators. For each of them the functionalities, objectives and the use modes are described.

1) 3D Virtual Smart Factory

Author: MAG-Uninettuno ⓘ
Use: the software comes with a 30-days trial licence, ask to project coordinators for an additional extension.
Tags: Smart factory, PLC programming, industrial automation
Requirements: Software installation
Description: Programmable Logic Controllers are the basis of industrial automation, as they are robust and efficient devices. Also, they can easily programmed with a visual language.
In this laboratory, based on the software Factory I/O®, the student is able to design a custom factory with a wide range of elements including working stations, robots, conveyors, sorters and warehouses. All these elements are equipped with sensors and actuators, controlled by PLCs. The student can program the PLCs through the visual programming language and run the 3D simulation to observe the factory in action. A set of guided exercises help the student to learn the visual programming language, from easier to more complex scenarios.
It is worth noting that the activity is not just an exercise: if you had a real PLC, you could make it work with the same code produced in the laboratory.

3D Virtual Smart Factory – I4EU Project (3D Virtual Smart Factory vish – I4EU Project (i4eu-pro.eu))

2) Use of electric power emulator
Author: UNED ⓘ
Use: Free use
Tags: Arduino, IoT, Data acquisition
Requirements: Web browser
Description: This lab will take you through a first simple working example of the collection technology using an Arduino-based electric power emulation station The data obtained come from a real system where the light power and the motor power can be regulated The measured power can be acquired during the experimentation.

Electric power emulator – I4EU Project (electric power vish – I4EU Project (i4eu-pro.eu))

3) Image anonymizer for car accidents
Author: CEDEL ⓘ
Use: Free use
Tags: Image analytics, Image processing, Deep learning
Requirements: Web browser
Description: This lab is an application of deep learning in image processing. The online tool is able to remove from a picture all the elements that concern the costumer's identity, by developing an automated anonymization procedure. This finds application in the insurance industry, to make image analytics compliant with European regulation on data protection.

Image anonymizer – I4EU Project (image anonymizer vish – I4EU Project (i4eu-pro.eu))

4) Industrial Cybersecurity Breakout
Author: UNED ⓘ
Use: Free use
Tags: Cybersecurity, Gamification
Requirements: Web browser
Description: Cybersecurity is a crucial aspect in Industry 4.0. This online application implements the scenario of an industrial environment, where cybersecutiry problems occous. You have to take the proper decisions to solve the critical situation.

Industrial Cybersecurity Breakout – I4EU Project (industrial cybersecurity breakout vish – I4EU Project (i4eu-pro.eu))

5) Analysis of rain, temperature, barometric pressure data

Author: FHM ⓘ
Use: Free use with ThingSpeak account
Tags: Raspberry Pi, ThingSpeak, Data collection
Requirements: Web browser
Description: For Industry 4.0 purposes data analysis is often based on the online-aggregator ThingSpeak & MATLAB. This lab will take you through a first simple data analysis example using data from an Arduino-based Weather Station Data are collected and analysed by an MATLAB-based app running on a ThingSpeak online-aggregator.

Weather station – I4EU Project (weather station vish – I4EU Project (i4eu-pro.eu))

6**) Analysis of wind data**
Author: FHM ⓘ
Use: Free use with ThingSpeak account
Tags: Raspberry Pi, ThingSpeak, Data collection
Requirements: Web browser
Description: For Industry 4.0 purposes data analysis is often based on the online-aggregator ThingSpeak & MATLAB. This lab will take you through a first simple data analysis example using data from an Arduino-based Weather Station Data are collected and analysed by an MATLAB-based app running on a ThingSpeak online-aggregator.

Wind station – I4EU Project (Wind station – I4EU Project (i4eu-pro.eu))

7) Supply Chain Digital Twin
Author: UBx ⓘ
Use: the software comes with a 30-days trial licence, ask to project coordinators for a possible additional extension
Tags: Supply chain, Smart factory, Digital twin, Anylogic
Requirements: Software installation
Description: Play with this demonstrator, the digital twin of a supply chain. You are the main coordinator of a linear supply chain and you have to decide the production quantities at the factory.

Supply chain – I4EU Project (supply chain digital twin vish – I4EU Project (i4eu-pro.eu))

4.3. Implementation

Based on the analysis of the current situation using the I4EU Competence Meter and the corresponding competence development in the company and among and with employees, the implementation is primarily about the definition of a desired target state, the associated definition of corresponding goals in very specific fields of action and company areas. These must then be selected and prioritized in terms of their relevance and contribution to the corporate strategy, and translated into concrete measures and sub-projects. In conjunction with budget planning, these measures and subprojects are made binding.

At the beginning, it is advisable to launch only individual pilot projects from the defined measures and to take the experience gained from these into account in the next implementation steps. In this way, problems in implementation can be identified and avoided at an early stage. Based on the development of software, this is referred to as solution design.

After the pilot implementation, the measures and projects should be evaluated after a period to be defined with regard to sustainable anchoring in the company and thus successful implementation. If necessary, adaptations should be carried out.

The most important steps are thus:

- Determination of the target state

- Definition of concrete goals

- Definition of measures and subprojects

- Budgeting of these measures and subprojects

- partial implementation of these, starting with pilot projects to avoid mistakes

- evaluation and adaption of implemented measures and projects

5. Conclusions

Digital transformation is very diverse and represents a cross-sectional topic. Relevant technologies include IoT, AI/machine learning, analytics, cyber physical systems, virtual reality, simulation, digital twin and many more. The use of these technologies, methods and approaches requires investments in companies just as much as changes in workflows and processes across the entire value chain (from development/production, sales or service of machines and systems to new business models).

The reality often shows that an increase in performance through new technologies and methods still takes too long to be justified by a cost-benefit calculation. The extensive possibilities of these technologies, methods and approaches are also a challenge for companies and their employees due to the increasing complexity and diverse interactions internally between departments or externally with suppliers and customers.

This requires a corresponding understanding and a high level of competence in companies and among their employees. The human factor is given far too little consideration in the digital transformation. The best technological solutions are useless if employees or customers do not use them or do not recognise their benefits. The big picture, i.e. a holistic and consistent digitisation strategy, is often missing, which is why small and medium-sized enterprises in particular are losing ground more and more in contrast to large companies. Accordingly, in addition to technological solutions, the know-how and methodological competence of the acting persons are also important.

It is now necessary to take these challenges into account and to use existing technologies in a beneficial way, thereby constantly developing them further and supporting sustainable innovation. In any case, the digital transformation offers more opportunities than dangers - and it is important to take advantage of them.

Pursuing individual Industry 4.0 projects in a company does not necessarily lead to a high Industry 4.0 status. When it comes to the concrete implementation and operationalization of defined Industry 4.0/digitization projects, companies often fail due to the challenge of defining the right mix of measurable, manageable projects from the broadly formulated topics.

In any case, it is extremely important to engage in intensive strategic discussions involving all areas of the company, to conduct a comprehensive analysis of the initial situation, and to build up the relevant competencies within the company. Combined with a precise target picture in the form of a defined target state, concrete measures and conscientious implementation in small steps, the implementation of this I4EU roadmap will lead to the desired success.

Project Partner