CHAIN REACTIONS

INNOVATION BRIEF 4

KEY ENABLING TECHNOLOGIES

INDUSTRY 4.0

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ABOUT INNOVATION BRIEFS

CHAIN REACTIONS addresses the challenge for industrial regions to increase regional capacity to absorb new knowledge and turn it into competitiveness edge and business value. There is a strong need to help SMEs to overcome capacity shortages for innovation and integration into transnational value chains.

The project aims at empowering regional ecosystems with the knowledge and tools to help businesses overcome those barriers and generate sustained growth through value chain innovation.

CHAIN REACTIONS focuses thereby on modern approaches considering value chains and their complex developments rather than linear technology transfer approaches. The framework of value chain innovation builds on Porter's 5 forces framework (new entrants, substitutes, customers, suppliers and rivalry) and transversal innovation drivers: key enabling technologies, resource efficiency, digital transformation and service innovation.

During the project lifetime CHAIN REACTIONS will publish about every third month an INNOVATION BRIEF presenting the rationale behind specific innovation drivers and illustrate them with practical examples.

In the context of CHAIN REACTIONS, the most relevant KETs are the ones related to advanced manufacturing systems. We selected the two most relevant ones and describe hereafter their impact on industry in general:

- additive manufacturing
- Industry 4.0

This INNOVATION BRIEF is about the key enabling technology area INDUSTRY 4.0.

INDUSTRY 4.0

The modern global economy is at the threshold of the new industrial revolution, which is proved by a lot of actual tendencies. First, large duration of the global economic crisis of the early twenty-first century and impossibility of overcoming it with the help of the existing possibilities of economic systems shows depletion of the potential of the previous technological model. In the sphere of industrial production, the crisis was first manifested in overproduction of industrial goods and impossibility of selling it in domestic economic systems or in the global markets—which led to massive bankruptcy of industrial companies around the world and increase of protectionist measures from governments of various countries. Second, according to the modern provisions of the economic theory (in particular, the theory of economic cycles, the theory of crises, the theory of innovations, etc.), overcoming the global crisis requires starting a new wave of innovations. This tendency is supported by intensive progress of a lot of countries in formation of the knowledge economy, due to which potential of the global economic system as to its future innovational development is strengthened. Innovations are a generally acknowledged global priority of socio-economic development.

Cyber-physical systems enable the virtual digital world of computers and software to merge through interaction—process management and feedback control—with the physical analogue world, thus leading to an Internet of Things, data, and services. One example of CPS is an

intelligent manufacturing line, where the machine can perform many work processes by communicating with the components and sometimes even the products they are in the process of making. An embedded system is a computational system embedded within a physical system; the emphasis is on the computational component. Therefore, we can think of all CPS as containing embedded systems, but the CPS's emphasis is on the communications and physical as well as the computational domains.

Manufacturing sector

The manufacturing sector is on the cusp of the 4th industrial revolution (I4.0), bringing with it new technologies and techniques that will change the products, processes and supply chains involved in every aspect of the industry.
The Fourth Industrial Revolution, known as "Industry 4.0", emerged in Western countries in 2011 as a project (initiative) aimed at increase of competitiveness of the processing industry (Lu et al. 2016). Specialists offered integrating into industrial processes so-called "cyber-physical systems", or automatized machines and processing centres, connected to the Internet. The purpose is to created such systems that would allow machines to changes production models if the necessity arises.

Key I4.0 Technologies

Industry 4.0 is a coming together of several key technologies in order to produce a system greater than the sum of its parts. The latest advances in sensor technologies, for example, produce not just more data generated by a component but a different type of data, instead of just being precise. Sensors can have self-awareness and can even predict their remaining useful life. Therefore, the sensor can produce data that is not just precise, but predictive. Similarly, machine sensors through their controllers can be self-aware, self-predict and self-compare. For example, they can compare their present configuration and environment settings with preconfigured optimal data and thresholds. This provides for self-diagnostics. Sensor technology has reduced dramatically in recent years in cost and size. This made the instrumentation of machines, processes, and even people financial and technically feasible.

Big Data and advanced analytics are another key driver and enabler for the IIoT as they provide for historical, predictive, and prescriptive analysis, which can provide insight into what is actually happening inside a machine or a process. Combined with these new breed of self-aware and self-predicting components analytics can provide accurate predictive maintenance schedules for machinery and assets, keeping them in productive service longer and reducing the inefficiencies and costs of unnecessary maintenance. This has been accelerated by the advent of cloud computing over the last decade whereby service providers like AWS provide the vast compute, storage, and networking capabilities required for effective Big Data at low cost and on a pay-what-you-use basis.

This technology ushers in even greater connectivity that will allow manufacturers to maintain their competitive edge in a rapidly changing world, and respond flexibly and quickly to customers' requirements. Not all manufacturers are at the same stage of knowledge about what this will mean for their business. Indeed, we are at the start of this I4.0 journey and understandably, many manufacturers are still getting to grips with the subject.

The benefits of I4.0 technology adoption for manufacturing will be widespread, with smarter supply chains, smarter production and smarter products. Manufacturers will need to keep pace with the change, they themselves say it will be happening more quickly than ever before and it will fundamentally change their customers' expectations. This is isn't just a regional phenomenon, it is a global shift, which offers opportunities for European manufacturers as global supply chains are joined up more effectively. But this global shift also presents a risk if

European manufacturers fail to keep pace. Manufacturers currently feel Europe's industry isn't geared up for the change, but that their business is – demonstrating a need for greater communication across supply chains and industrial sectors about the benefits. The I4.0 journey starts with optimising existing business processes and many are doing this – we outline some practical use cases in this report. Manufacturers will be prioritising smarter supply chains and embedding smarter production processes within their business.

The experts also distinguish the basic characteristics of Industry 4.0:

- transition from manual labour to robototronics, which ensures automatization of all production processes;
- modernization of transport and logistical systems, caused by mass distribution of unmanned vehicles;
- increase of complexity and precision of manufactured technical products, manufacture of new construction materials due to improvement of production technologies;
- development of inter-machine communications and self-management of physical systems, conducted with the help of "Internet of things";
- application of self-teaching programs for provision of constant development of production systems.

But beyond technology there are also steps manufacturers must take to prepare their business to ensure any move towards I4.0 is a success. These include applying visionary thinking as there will be less certainty on return on investment, changing the internal innovation culture of their business and boosting the role of IT and technology in decision making across all parts of the business.

The manufacturing sector is on the cusp of the 4th industrial revolution, ushering in new technologies and techniques that will change the products, processes and supply chains involved in every aspect of industry. This technology will enable manufacturers to maintain their competitive edge in a rapidly changing world, and respond flexibly and quickly to customers' requirements.

Manufacturers view the core to all of this as being about connectivity. Physical networks link with cyber networks together as one system to allow a real-time flow of information. Data is collected, turned into information and insights, and can be acted upon quickly.

There are three core components to this transformation

1. The Industrial Internet of Things (IIoT) – machines and technologies collecting, sharing and acting on data between themselves
2. Big data – the capture of data on everything and real-time analysis of that data by machines and systems
3. Secure and reliable digital infrastructure – a resilient network to link everything up

Data collected can help firms to understand what really is going on, whether that's how a product is being used or how production processes are performing. Data collection can happen in real-time and more importantly can be analysed immediately. Issues or problems can be acted upon quickly, maximising equipment efficiencies, minimising downtime and gaining new data-driven insights to help drive growth strategies and respond to customer demands.

These increased insights will also enable and drive possible new business models, giving the opportunity for higher value activity to derive competitive advantage such as mass customisation, service-enhanced business models, service-oriented business models, factory-

less goods producers and the circular economy.

When these technologies reach some threshold number and receive necessary development, which prepares them for implementation (practical application) into industrial production, the process of transition from quantity to quality is started. In synergy, these transitions take place in the bifurcation points (critical states of the system). This transition marks the start of the industrial revolution, which is systemic transformations in industry. This causes the need for new infrastructure and presents serious challenges for the state (growth of expenditures for modernization of the real sector economy) and society (mastering of new industrial products, increase of qualification of industrial specialists, etc.). A new technological mode is established in the course of the industrial revolution—i.e., transition to completely new technologies of industrial production. Reorganization of production and mass modernization of technologies and equipment leads to growth of efficiency of industrial production. As a result, in the real sector of economy, which is treated as an economic system in this research, synergetic effect appears—which is caused by reduction of the volume of consumed resources and energy (economy of resources and energy) with simultaneous growth of the volumes of industrial production, reduction of cost by means of achievement of the "scale effect", improvement of logistics (increase of the speed of transportation of intermediary and final industrial products, reduction of probability of products' defects, possibility of transportation of large items, etc.) and growth of complexity (increase of quality: precision, reliability, sustainability to temperature changes and improvement of technical characteristics) of issued industrial products. The final result of industrial revolution is transition to a new level of development (new quality of growth) of the real sector of economy.

The most important difference of transition to Industry 4.0 from previous industrial revolutions is elimination of human from the production process. While previous industrial revolutions allowed for certain reduction of human's participation (industrial specialist) in the production process, with preservation of his important role in the work of the production system, the new industrial revolution will lead to human's elimination from the production system. This will require reconsideration of the essence of this system's work, as it will turn from socio-technical into fully technical system. Artificial intelligence allows for full elimination of mistakes caused by "human factor", thus ensuring rationalization and optimization of all business processes. Another difference is revolutionary change of not only separate but all business processes of an industrial company. The capabilities of artificial intelligence allow for deep change, modernization, and optimization of all components of the production and distribution system, including logistics, management, marketing, etc. For example, it is possible to simplify and accelerate deals due to full automatization of the process of development of products and its manufacture. With receipt of order from a customer, it is possible to develop a technical solution (project, draft, etc.) and create an initial model with 3D printer by the order from the computer, and then the project is passed to production and the necessary volume of products is created automatically. Thus, human does not participate in any of the above operations. Another difference is caused by the possibility for simultaneous usage of the possibilities of globalization and minimization of negative social consequences. Industry 4.0 envisages global interaction of companies. Computers, which are controlled by AI, can exchange the incoming information in real-time via the Internet, this passing orders into production. During the previous industrial revolutions, optimization of production was accompanied by negative social externalities that were connected to reduction of the population's living standards of the territories on which the industrial companies were located and to negative influence of production on these companies' employees.

There will be ways that I4.0 technologies and techniques can create value across the

manufacturing ecosystem. Ultimately ambitions will be rooted in winning new business – increasing sales and growing market share and will be tailored towards the needs of each individual business. New technology as part of I4.0 will be the enabler of these ambitions. In very broad terms, there are three areas where I4.0 technologies will support in delivering this:

- Smarter supply chains – greater coordination and real-time flow of information across supply chains and relationships allows better tracking of assets and inventory and integrated business planning and production. This unlocks new ownership and collaboration models across supply chains.
- Smarter production – the use of data analytics and new production techniques and technologies (such as autonomous robots, multi-purpose production lines and augmented reality) helps to improve yield and speed up production. This allows new business models to be pursued such as mass customisation.
- Smarter products – Rapid innovation and a faster time to market is enabled by data collected from products along with user feedback, whether direct or collected via social sentiment on the internet. This data also allows remote diagnostics and remote/predictive maintenance.

The I4.0 Journey

The journey starts with conceptualising the realm of possibility from their unique business context, to optimising or evolving existing processes before a revolution is ushered in and with it fundamental changes in current business models. All of these steps will be driven by business ambition and strategy, which will not be the same for everyone.

There are many different benefits to this transformation. In the short term, the focus will be on improved operational efficiency through better use of capital, workers and resources. Over the medium term the transformation will unlock new products, services and business models that will allow value to be added and captured in different ways.

- The first phase – Conception – where companies figure out what I4.0 is all about, what it can offer and how it could apply to their business.
- The second phase – Evolution – a period where there can be some advancement on current practice; concepts and some off the shelf solutions can be implemented and tested, further optimising current processes and putting in place new solutions.
- The third phase – Revolution – this will be the huge step change in terms of how value is derived and how interaction with customers and suppliers happens.

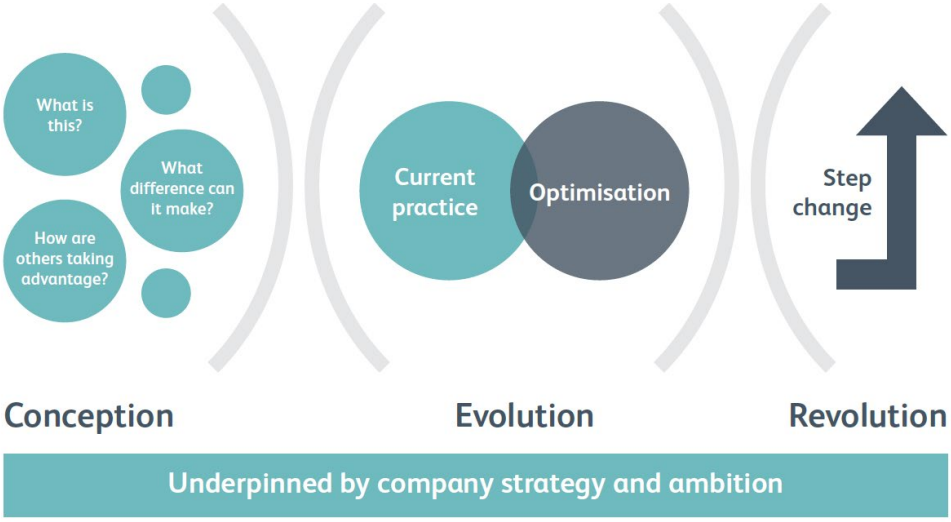

Figure 1: I4.0 journey
Source EEF: THE 4TH INDUSTRIAL REVOLUTION: A PRIMER FOR MANUFACTURERS

It will be happening in different phases: a research and conception phase, an evolution of business processes followed by a revolution in business models and ways of creating value. For some the concepts will not be new – different companies will be at different stages of awareness and adoption and will be approaching this from different angles. All of this will be overseen with the ambitions and strategy of a successful and growing business in mind.

Industry 4.0 Architecture

Industry 4.0 is reliant on the structure of M2M technology. Sometimes, it is older established technologies and practices that have been around for decades, that can spark innovation, and as a result, IIoT's architecture is often seen as a natural evolution of M2M. This is particularly true within manufacturing, which is the biggest user of IIoT technology, primarily due to its long history with machine automation, robotics, and M2M communication and cooperation.

There are many industrial systems deployed today that are interconnected (M2M)and they combine a mixture of sensors, actuators, logic components, and networks to allow them to interconnect and to function. The difference with the Industrial Internet approach is that these industrial systems (ISs)will become Industrial Internet systems (IISs)as they become connected to the Internet and integrate with enterprise systems, for the purpose of enhanced business process flow and analysis. The IISs will provide operational data via its sensors to enterprise back-end systems for advanced data processing and cloud-based advanced historical and predictive analytics. The advanced cloud services will drive optimized decision-making and operational efficiencies and facilitate the collaboration between autonomous industrial control systems. To realize these goals, IISs require a standard-based, open and widely applicable architectural framework. By providing reference architecture, the IIC (Industrial Internet Consortium) have provided the means to accelerate the widespread deployment of IISs, using a framework that can be implemented with interoperable and interchangeable building blocks. The interchangeable nature of the Industrial Internet reference architecture is notable, as it is designed to be flexible and cover a wide range of deployment scenarios across many industries, such as energy, health care, and transportation, for example. Therefore, the reference architecture is a common framework that works at a high level of abstraction, which enables designs to follow and adhere with the reference architecture without burdening the design with unnecessary and arbitrary

restrictions.

Furthermore, by de-coupling, the architecture from the technical specifics and complexities the Industrial Internet reference architecture transcends today's available technologies. This approach will drive new technology development through the identification of technology gaps based on the architectural framework.

Industry 4.0 in CHAIN REACTIONS

Uses of industry 4.0 technologies in different value chains will be explored within CHAIN REACTIONS in the framework of our transnational pilots.

Different I4.0 technologies will be further explored in our thematic briefs.