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Industry 4.0: Conceptual framework,Scenarios and Application

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Abstract*—With fast advancements in industry, technology and applications, many concepts have emerged in manufacturing. Industry 4.0 is a strategic initiative recently introduced by the German government. The goal of the initiative is transformation of industrial manufacturing through digitalization and exploitation of potentials of new technologies. An Industry 4.0 production system is thus flexible and enables individualized and customized products. . It is closely related with the Internet of Things (IoT), Cyber Physical System (CPS), information and communications technology (ICT), Enterprise Architecture (EA), and Enterprise In- tegration (EI) The aim of this paper is to present and facilitate an understanding of Industry 4.0 concepts, its drivers, enablers, goals and limitations. Finally it is discussed if Industry 4.0 is really a disruptive concept or simply a natural incremental development of industrial production systems.*

Keywords—Cyber Physical System (CPS), Industry 4.0, Internet of Things (IoT), information and communication technology (ICT), Enterprise Architecture (EA)

I. INTRODUCTION

The term "industry 4.0", shortened to I4.0 or simply I4, originated in 2011 from a project of high-tech strategy of the German government, which enhance the computerization of manufacturing.[1] The term "Industry 4.0" was introduced in the same year at the Hannover Fair.[2] In October 2012 the Working Group on Industry 4.0 presented a set of Industry 4.0 implementation recommendations to the German federal government. The Industry 4.0 workgroup persons and partners are recognized as the founding fathers and driving force behind Industry 4.0. On 8 April 2013 at the Hannover Fair, the final report of the Working Group Industry 4.0 was presented.[3]. This working group was headed by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (German Academy of Science and Engineering).As Industry 4.0 principles have been applied by companies they have sometimes been re-branded, for example the aerospace parts manufacturer Meggitt PLC has branded its own Industry 4.0 research project M4. [4]The discussion of how the shift to Industry 4.0, especially digitalization, will affect the labour market is being discussed in Germany under the topic of Work 4.0.

II. THE VISION AND CONCEPT OF INDUSTRY 4.0

There is a basic consensus among many researchers that the industrial revisions require a long-time period of development and cover the following four aspects, considered as the future manufacturing visions:

- **Factory.** The main components of Industry 4.0, the future factory is going to involve a new integrative,where not only all manufacturing resources (sensors, actuators, machines, robots, conveyors, etc.) are connected and transfer information automatically, but also the factory will become conscious and smart enough to predict and maintain the machines; to control the production process, and to manage the factory system. Many manufacturing processes, like, production planning product design, production engineering and production and services, are going to be simulated as compact, and then connectedclosely end-to-end, which means these processes are controlled interdependently. This kind of future factory is known as a Smart Factory [5].
- **Business.** Industry 4.0 implies a complete communication network will exist between various resources, customers,companies, supplier, logistics, factories, etc. Every section optimizes their configuration in real-time depending on the demands and status of associated sections in the network,which makes the maximum profit for all cooperatives with the limited sharing resources. In addition, the costs and pollution, raw materials, CO2 emissions, etc., will be reduced. The future business network isinfluenced by each cooperating section, which couldachieve a self-organizing status and transmit the real-timeresponses [6].

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- **Products.** Advantage from Industry 4.0, will be a new typeof product generated in manufacturing, that of smartproducts. These products are used with sensors,processors, andidentifiable components which carryinformation and knowledge to transfer the functionalguidance the customers and transmits the uses feedback tothe manufacturing system. With these components, manyfunctions can be added to the products, for example, measuring the state of products, carrying this information, tracking the products, and analyzing the resultsdepending on the information. In addition, a full production information can be embedded with product helpingproduct developer in optimizing the design, the prediction, and the maintenance [7].

FIGURE 1: Concept of Industry 4.0

- **Customers.** Customers is also a key elementunder Industry 4.0. A new purchasing method is going to beprovided to customers. It allows customers to orderwhatever function of products, with any number even if onlyone is. In addition, customers could change their ideas andorderat any stage during production even at the last minutewith no charge. On the other hand, the benefit from the smartproducts enables the customer not only to know theproduction information of the product but also to receive theadvice of utilization depending on their own behaviors[8].Besides all of these planned visions of manufacturing, manyresearchers and companies have been working on Industry 4.0in many fields around these concepts [9].

III. COMPONENTS OF INDUSTRY 4.0

- **The Internet of Things**

The IoT refers to an inter-networking world in which various objects are embedded with electronic sensors, actuators, or other digital devices so that they can be connected for the purpose of collecting and exchanging data [10]. In general, IoT is able to offer advanced connectivity of physical objects, systems, and services, enabling object-to-object communication and data sharing. In various industries, control and automation for machining, robotic vacuums, and remote monitoring can be acquired by IoT. One important technology in IoT is automatic identification (auto-ID) technology, which is used to make smart objects. RFID technology provides one such example. It has been reported that nearly 20.8 billion devices will be connected and making full use of RFID by 2020 [11]. Such a shift will influence most of industry, and especially manufacturing sectors. RFID technology has been used for identifying various objects in warehouses, production shop floors, logistics companies, distribution centers, retailers, and disposal/recycle stages [12]. After identification, such objects have smart sensing abilities so that they can connect and interact with each other through specific forms of interconnectivity, which may create a huge amount of data from their movements or sensing behaviors. The interconnectivity between smart objects is predefined; such objects are given specific applications or logics, such as manufacturing procedures, that they follow after being equipped with RFID readers and tags [13]. RFID facilities not only help end-userss to fulfil their daily operations, but also capture data related to these operations so that production management is achieved on a real-time basis.

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- **Cyber-physical system**

A CPS is a mechanism through which physical objects and softwareare closely interconnected, enabling different components to interact with each other in a myriad of ways to exchange information. A CPS involves a large number of trans disciplinary methodologies such as cybernetics theory, mechanical engineering and mechatronics, design and process science, manufacturing systems, and computer science. One of the key technical methods is embedded systems, which enable a highly coordinated and combined relationshipbetween physical objects and their computational elements orservices [14]. A CPS-enabled system, unlike a traditional embedded system, contains networked interactions that are designed and developed with physical input and output, along with their cyber twinedservices such as control algorithms and computational capacities. Thus, a large number of sensors play important roles in a CPS. For example, multiple sensory devices are widely used in CPS to achieve different purposes, such as touch screens, light sensors, and force sensors. Nevertheless, integrating several different subsystems is time-consuming and costly, and the whole system must be kept operational and functional. The heterogeneity and complexity of CPS applications result in several challenges in developing and designing high-confidence, secure, and certifiable systems and control methodologies[15].

FIGURE 2: Components of Industry 4.0

- **Cloud computing**

Cloud computing is a term that used to delivering computational services through visualized and scalable resources over the Internet . The scalability of resources makes cloud computing interesting for business owners, as it allows organizations to start small and invest in more resources .The ideal cloud should have five characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. This cloud model is composed of four deployment model such as public, private, community, and hybrid and three delivery model like "software as a service," "platform as a service," and "infrastructure as a service" Organizations of all kinds and sizes are using cloud computing to increase their capacity with a minimum budget and without investing in licensing new software,

Despite the significant benefits of cloud computing, critical challenges affect the reliability of this ongoing concept. Researchers and service providers have conducted numerous studies to identify and classify problems related to cloud computing. Based on the study, the most important concern about cloud computing is related to privacy subjects and security. Other challenges such as data management and resource allocation, scalability and availability,load balancing [16], migration to clouds and compatibility, and interoperability and communication between clouds reduce the reliability and efficiency of cloudbased systems.

- **Information and communications technology**

ICT refers to an extended IT that highlights allied communications and the combination of telecommunications and other

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technologies that are capable to store, transmit, and changinginformation easy to understand . ICT covers a wide range of computer science and signal-processing techniques such as wireless systems, enterprise middleware, and audio-visual systems. It focuses on information transferring through various electronic media such as wired or wireless communication standards, and is crucial in intelligent manufacturing, where production operations and decision-making heavily rely on the data. ICT has been found to have a distinct impact on firm organization, such that better ICT for plant managers and workers is associated with more autonomy and a wider span of control. The use of ICT facilitates the handling of information resources and results in cost reduction and the increase of client compliance [17]. In the modern manufacturing sector, large amount of digital devices have access to Internet-based networks. This rapid growth has caused ICT to become a keyelements of manufacturing systems, where the rapid and adaptive design, production, and delivery of highly customized

IV. INDUSTRY 4.0 ADVANTAGES

- **Customizations:** Creating a customer-oriented market that is flexible and will meet the population's needs and growing demands fast and efficiently. Manufacturers will not have to communicate within factories and companies and externally to the customers, which in turn fastens the production and delivery processes.It will destroy the gap between the manufacturer and the customer and communication will take place directly between them.
- **Optimization:** Production optimization is a significant advantage of Industry 4.0. A 'Smart Factory' containing thousands of smart devices that can self-optimize will lead to almost zero production downtime. This is extremely critical for industries which use expensive and high manufacturing equipment . Being able to utilize production consistently and continuously, the company will profit; cost-efficient and increased productivity. According to a Price Waterhouse Coopers report "Digitized products and services generate approximately Euro 110 billion of additional revenue per year for the European Industries."
- **Pushing Research:** The adoption of industry 4.0 technologies will influence research in different fields like IT security and will have an impact in particular of the education industry. A new industry will require new skill-sets. Consequently, 'Education and Training' will take a new-shape which caters to such industries which require skilled-labor.

IV. INDUSTRY 4.0 DISADVANTAGES

- The IoT security is a major concern. The companies are working to address the security-related loopholes
- Workers working on industry 4.0 based processes need to improve their technical skills and education.
- It requires maintaining integrity of production processes
- It requires educating staff to adopt this 4th industrial revolution. This requires considerable time as well as efforts across the industries.
- There is general reluctance to change to industry 4.0 by company stakeholders

V. CONCLUSION

As increasing attention is given to Industry 4.0, intelligent manufacturing is becoming more and more important in the advancement of modern industry and economy. Intelligent manufacturing is considered to be a key future perspective in both research and application, as it provides added value to various products and systems by applying cutting-edge technologies to traditional products in manufacturing and services. Product service systems will continue to replace traditional product types. Key concepts, major components are covered in this paper. Ihope that the concepts discussed in this paper will spark new ideas in the effort to realize the much-anticipated Fourth Industrial Revolution.

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