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Conference Paper · November 2017

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How to Define Industry 4.0: The Main Pillars Of Industry 4.0

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Abstract
Evolving customer trends have given rise to a myriad of technological improvements. The evolution of Industry 4.0 has emerged as a German project that describes the strategic approach to digitalization in manufacturing. One of the key features of Industry 4.0 is the creation of highly automated industries through human-machine interaction. In this context, Industry 4.0 will inform future business models driven by the advanced technologies. In this paper, the definition of Industry 4.0 is described based on reviewed literature. In addition, the main drivers of technological advances through Industry 4.0 are analyzed, leading to greater integration, optimal business solutions, organizational communication and other efficiencies. In light of reviewed literature, the best description of the future vision of Industry 4.0 is that put forth by Boston Consulting Group (BCG). This research strives to inform future insights concerning the basic concepts of Industry 4.0 and the path of technology, as well as a basic understanding of Cyber-Physical Systems (CPS) and Internet of Things (IoT).

Key Words: *CPS, Industry 4.0, IoT, Nine Pillars*
JEL Classification: *O14*

1. Introduction

Manufacturing value chains are complex. Technological progress has created several advantages for business world; new concepts such as digitalization, Internet of Things (IoT) and Cyber Physical Systems (CPS) have gained importance across industries including manufacturing. These terms are used in defining the Fourth Industrial Revolution (Industry 4.0), also known collectively as a German high-tech strategy for future manufacturing industries (Hofmann and Rüsch, 2017). Industry 4.0 triggers a staggering effect by transforming the manufacturing and production processes in industries. In other words, Industry 4.0 will play significant role in transforming traditional companies into Smart Factories with the help of Internet of Things (IoT) and Cyber Physical Systems (CPS).

A decentralized approach takes great importance in Industry 4.0, which emphasizes independent management of processes and smart objects throughout the network; by doing so, real and virtual worlds collaborate on the processes (Ungurean and Gaitan, 2014). The development of integrated processes and human machine interaction stimulate complexity and agility but also data transmission between value chains. With the help of Industry 4.0, industries will gain operational efficiency both in time, cost and also productivity. Building the infrastructure of IoT offers shared platforms via cloud systems between partners in Supply Chains; therefore business processes can be optimized (Lu, 2017).

The concept of Industry 4.0 has gained great importance in recent years. The increase in usage of computerized systems after the 3rd Revolution, Industry 4.0 deals with creating more digitized systems and network integration via smart systems. Through Industry 4.0, smart systems would enable the replacement of the human-being in certain tasks and ease the working environment. The main goal of the paper is to give the literature review of the definition of

Industry 4.0. Therefore, in this paper, the future vision of Industry 4.0 is examined and what sort of concepts would appear in business environment through Industry 4.0. The vision of Industry 4.0 is described through nine concepts, previously defined by Boston Consulting Group (Rüßmann et al., 2015). Therefore, in this paper, those nine main concepts of Industry 4.0 are further analyzed by giving current examples in the business world.

2. Literature review

Brettel et al (2014) describes how industries have adjusted their production strategy by concentrating on customized products and fast time to market. Therefore, the strategies made possible by Agile Manufacturing and Mass Customization will transform manufacturing industries into more integrated networks with better access to real time data. Hermann et al (2016) defines Industry 4.0 as a collective term for technologies of value chain organizations and the components of Industry 4.0 are categorized as Internet of the Things, Cyber Physical Systems, Internet of Services and Smart Factory. Posada et al. (2015) shows the comprehensive overview on the new technologies and describes that visual computing could be seen as the key component of Industry 4.0. Sommer (2015) notes that the important thing is to increase the awareness of Industry 4.0 and its dimensions in order to increase the competitiveness of the companies. Yin and Kaynak (2015) analyze that the intelligent systems and the data generated by them have an important role on the companies' performance levels, cost efficiency and quality and fault free processes. Also, it is necessary to develop the data capacity and statistics of the countries to get ready for technological developments and Industry 4.0. Keijzer and Klingebiel (2017) offer that the strategy required for Industry 4.0 in order to solve the capacity problem of data generated by smart systems and that countries need to be proactive for the technological improvements. Rüßmannet al. (2015) shapes the vision of Industry 4.0 on defining nine aspects related to the concept; these are big data, autonomous robots, simulation, horizontal and vertical integration, Internet of Things, the cloud, additive manufacturing, augmented reality, and cyber security. Therefore, companies should be aware of the dimensions and new business models generated by Industry 4.0 in order to create new strategies through Industry 4.0.

3. Research methodology

This paper reviews available literature on the basis of the defitinion and future vision of Industry 4.0; therefore several papers are analyzed in accordance with Industry 4.0 and its aspects. The databases includes Emerald Insight, Science Direct, IEEE Xplore and Google Scholar; which suggest the most cited articles related to the field. A total of 53 papers were collected by searching for keywords such as 'Industry 4.0, CPS, IoT, smart systems, dimensions of Industry 4.0' in search engines; and the journals selected refer to the period between 2011-2017 since the term of Industry 4.0 is mostly used after 2011. After the analysis of several research papers, nine aspects are selected for describing the future vision of Industry 4.0 as the same description of BCG over Industry 4.0 (Rüßmannet al., 2015). Therefore, in this paper, the concepts that shape the future vision of Industry 4.0 are described and how these concepts would be strategically important to the development of new industrial revolution.

4. The vision on industry 4.0: The main pillars

4.1. Big Data and Analytics

The concept of big data applies to large, diverse and complex datasets that affect the organizational decision making of a company concerning their strategy. Therefore, the increase in level of data and improvements on technological capabilities accelerates firms' competitive advantage by increasing productivity, innovation and competition. The decision makers launch

big data projects to solve challenges at the organizational level by monitoring, measuring and managing in a better way. The framework of Big Data could be described as data as a tool(solve traditional value chain problems by existing capabilities), data as an industry (new ventures and develop software systems for handling big data)and data as a strategy(building data resources by developing new innovative business models). The process of big data analytics is to analyze the large datasets, which gives the information about customers' preferences, algorithms in case of correlations, trends and other information. Big data analytics could be used in various areas such as fault prediction to reduce error probability, (Ji & Wang, 2017) and also big data driven predictive algorithms reduce the harm before many damages happen (Seele, 2017). The capability of managing big data gives competitive advantages to the firms, which could benefit their operations, marketing, customer experience and more. The wider technological shifts will encourage companies to manage mainstream business practices by increasing their talent and infrastructure development. Therefore, big data pushes companies into vast, complex and comprehensive aspects of their business.In the modern world, data generated by machines, cloud solutions and business management has increased more than 1000 Exabytes annually; for example, in consumer packaged goods company, just a single machine produces 5000 data samples in every 33 ms, resulting in 4 trillion samples in per year. From this point of view, the big data concept takes the important role on Fourth Industrial Revolution (Yin and Kaynak, 2015).

4.2. Autonomous Robots

Robots are used in manufacturing industries in order to solve complex tasks which can not be solved easily by a human. By the traditional automation strategy, companies could not fully implement JIT strategies and continuous improvements if they do not opt for autonomous robots. The current improvements in industries would make use of robots less complicated and easily utilized them. Various human-robot interfaces create close cooperation of utilising robots and human brain. However, the operator usage is also significant since it enables in connection with the station on performed tasks. Therefore, the needed information would be provided by the operator and controls the system, giving instructions to the industrial robots (Hedelind and Jackson, 2011).

The usage of more industrial robots in factories accelerates with Industry 4.0. Robots could be used in several areas such as production, logistics, distribution activities and could be controlled remotely by humans thanks to the human robot cooperation. Several new technologies are introduced by the companies in terms of robotics technology such as Kuka LBR IIWA is achieving sensitive tasks in working places and collaborate with human. This robot has the ability of learning from human colleagues and check, optimize and document the tasks by the help of cloud systems (Aiman et al., 2016).

4.3. Simulation

Simulation tools play a supportive role in production related activities by promoting sustainable manufacturing environment. The digital tools, which achieve the design of the production system, have the ability of self-configuration; therefore, they enable effective shop-floor management. In increasingly competitive business environments, simulation offers the adjustments into complex systems by planning the operations, having the knowledge and information and accurate estimations about the system by using the engineering capacity (Weyer et al., 2016). The strategic planning could be done by simulation models which allows dynamic investigation for production systems by the help of real time data acquired. Therefore, the system creates real time optimization on operations (Uhlemann, 2017).

4.4.Horizontal and Vertical System Integration

Vertical integration refers to the flexible and reconfigurable systems inside of the factory and the extent to which they are fully integrated with each other for achieving agility; horizontal integration deals with the integration of partners within the SCs. The industrial network collects Big Data in order to optimize the system performance and send them into the cloud. This coordination mechanism creates the framework of the smart factory. Therefore, the manufacturing systems are designed as self-organized structure that integrates the every physical objects into each other through smart networks. Besides, cloud based systems enable vertical partners to integrate into each other through shared platforms. The product and process flows would be visualized and tracked by SC members (Wang et al., 2016).

4.5. The Industrial Internet of Things (IoT)

IoT refers to the next technological revolution by giving solutions for computations, analytics etc, by relying on cloud based systems. The main task of IoT is to connect the Internet by collecting data from physical objects. By collecting data, computers or higher level devices make the decision about operations (Rahman and Rahmani, 2017). By the usage of IoT, the business operations become more agile and integrated as well as achieving competitive advantage on the basis of SC. Therefore, IoT capabilities of the firms, would be crucial in the future, which mostly associated with operational agility and effective decision making (Akhtar et al., 2017).

4.6. The Cloud

Cloud computing (CC) brings various advantages to the ICT paradigm such as helping SCs to automize and integrate but also facilitate management and administration. It is the way of virtualizing the resources and services and combining client/server based system. CC includes pools of IT resources that offer storage and processing capabilities in virtual system by serving multiple users. There are three models of cloud computing; Software as a Service (SaaS) where the access depends on the customer purchase such as ERP, Platform as a Service (PaaS) where customers are allowed to access their applications on the cloud such as software developers and Infrastructure as a Service (IaaS) offers the basic activities such as storing capabilities. The best known examples of Cloud systems Google Drive offered by Google, Windows Azur by Microsoft and BlueCloud by IBM (Candel-Haug et al., 2016).

4.7. Additive Manufacturing

Additive Manufacturing, also defined as 3D Printing, refers in producing customized goods for the requirements of customers. The most common way is the prototype and 3D printing methods in order to produce small batches by gaining advantage of having less stock on their hand and overproduction. Rüßmann et al (2015) gives the example of aerospace companies use these techniques to reduce their aircraft weight and raw materials usage such as titanium.Various leading companies in the world invest in 3D printing activities such as Google, Motorola and Apple in order to accelerate continuous smart phones activities. The perceived advantage is a reduction in lead times, production volume as well as increasing mass customization and staying agile (Conner et al., 2014). Additive manufacturing is regarded as the process of making parts from 3D model data. The process activities such as machining, milling are completed by layer upon layer(powder bed, wire fed systems, powder fed) that means small lots products could be produced by less raw materials. In this technology, the tasks enable JIT production system because of succeeding versatility, speed and adaptability (Frazier, 2014).

4.8. Augmented Reality (AR)

Augmented reality is defined as the interactive technology that enables harmony between the virtual world and its users while the virtual world is being used as the part of the real surroundings. The world's first augmented reality glasses were launched by Google known as Google Glass; also, Magic Leap was founded in 2011, which adjust to the human eye by converting the light field Angle and depth (He et al., 2017). This technology enhances human- machine interaction, remoting control on maintenance tasks and visual inspection of the human provided by virtually. It could be used in many applications by combining computer generated graphics and physical objects. AR gives the motion control of its users by using sensor technology in order to control the certain tasks.

4.9. Cyber Security

Cyber Security is another important issue, which could have a destructive impact on business environment due to the harmful intents of terror attacks; therefore, preventable solutions and defense systems are necessary against the negative effects of terror incidents. There are some solutions that destroy cyber terror attacks by analyzing previous terror attacks via radiation control before future attacks occur. Besides, it is significant to construct national defense systems and train employees against cyber attacks. Although solutions against cyber war would cost the companies, the expected total cost would not be high considering the potential negative effects of cyber attacks (Cho and Woo, 2017).

Table 1 indicates the summary of the concepts that define the future vision of Industry 4.0.

Table 1: The summary of the concepts that define the future vision of Industry 4.0

THE CONCEPTS	THE DEFINITIONS OF THE CONCEPTS	THE EXAMPLES OF THE CONCEPTS
BIG DATA	Large,complex datasets that affect the decision making of companies	Big data analytics, algorithms, software programs
AUTONOMOUS ROBOTS	Solve complex tasks which cannot be solved by human	Kuka Iwaa has the learning ability to achieve some certain tasks
SIMULATION	Mathematical modelling, algorithms that optimize the process	Software programs
HORIZONTAL&VERTICAL SYSTEM INTEGRATION	Integration of inside of the factory and SCs	Smart factories, cloud systems
INTERNET OF THINGS	Connection of the physical objects and systems	Smart network
CLOUD COMPUTING	Shared platforms that serve to the multiple users	Google Drive, BlueCloud, Windows Azur
ADDITIVE MANUFACTURING	3D printing technology, producing in mass customization	3D printers to produce smart phones

AUGMENTED REALITY	Human-machine interaction on maintanence tasks	Google Glass
CYBER SECURITY	Cyber attacks to business environment	National defense systems in order to prevent attacks

Source: Author's own findings

5. Conclusıons

Industry 4.0 is the current vision shaping the future of many industries by creating new business models through CPS. Therefore, it is crucial to investigate its dimensions in order to realize efficiencies in the business environment. In this paper, the concepts of Industry 4.0 are shortly described as well as how they would help companies achieve their objectives concerning Industry 4.0. After the reviewed literature, nine pillars (big data, autonomous robots, simulation, additive manufacturing, IoT, cloud computing, augmented reality, horizontal and vertical integration and cyber security) of Industry 4.0 are defined as referring the findings of BCG over Industry 4.0 (Rüßmann et al., 2015). The paper also gives some examples of how they are used in the real life. Therefore, this paper gives the insights for future works conducted on Industry 4.0 and future business models of the companies.

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