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Functional Survey of Industry 4.0, For Smart Factories

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ABSTRACT: Industry 4.0 is a term often used to refer the developmental process in the management of manufacturing and chain production. The fourth industrial revolution takes the automation of manufacturing processes to a new level by introducing customized and flexible mass production technologies. 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. The aim of this paper is to present and facilitate an understanding of Industry 4.0 concepts, its drivers, enablers, goals and limitations. Smart factory concept is presented. The current status of Industry 4.0 readiness of the German companies is presented and commented. Finally it is discussed if Industry 4.0 is really a disruptive concept or simply a natural incremental development of industrial production systems. The world around us has been changing on a daily basis along with development of human civilization. Therefore, technical and technological developments of production are changing as well. Industry 4.0 is a model that shows how industrial production follows the latest developments and changes over time. Thereby, the man, machine and the production itself constitute the force in one intelligent and independent network

KEYWORDS: Industry 4.0, Smart Factory, Internet of Things (Iot), digitization, revolution.

I. INTRODUCTION

The fourth industrial revolution characterized by the increasing digitization and interconnection of products, value chains and business models has arrived in the industrial sector, as well as integration of all actors in the company's chain (suppliers and customers). Technical aspects of these requirements are addressed by the application of the generic concepts of Cyber-Physical Systems (CPS) and industrial Internet of Things (IoT) to the industrial production systems. Furthermore, an extensive software support based on decentralized and adapted versions of Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) is needed for a seamless integration of manufacturing and business processes. The important aspect is handling of a big amount of data collected from the processes, machines and products. Typically the data is stored in cloud storage. The term "Industry 4.0" means the smart factory in which smart digital devices are networked and they communicate with raw materials, semi-finished products, products, machines, tools, robots and men. In a networked factory, robots and men are becoming equal partners, having a higher degree of artificial intelligence in relation to the previous generation of robots. The sense sensors that respond to the slightest signal are embedded into the robots, which enable the cooperation between robots and workers. Computers, automation and robots existed in previous decades, but the opportunities provided by the Internet revolutionize their use, and the opportunities they provide.

The aim of all these activities is to increase productivity (by drastically shortening the time period between the development of a new product and its delivery to customers in the market for 50%), efficiency (automation allows for greater flexibility, better quality of products and more efficient production) and energy savings (e.g. while waiting for materials processing, robots can be switched off, if necessary, which saves up to 15 of electricity) to ensure competitiveness in the global market.

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Following this introduction, the paper is structured as follows. At the beginning of our research, in the literature review we summarize the importance of industrial digitization. Then, we will discuss the appearance of Industry 4.0 in the corporate value chain. We will briefly present the Porter value chain concept, the IoT concept, and their tools and solutions. The third section describes the materials and methods used for the analysis. In the fourth section we will present the results of questionnaire surveys and expert interviews conducted in the summer of 2017 among firms operating in Hungary.

II. LITERATURE REVIEW

Fourth Industrial Revolution, include technical tools and methods. These are automated robots, simulation, horizontal and vertical system integration, industrial IoT, cyber security, cloud-based services, additive production (3D printing), augmented reality, and big data analysis. Today, in an Industry 4.0 factory, machines are connected as a collaborative community. Such evolution requires the use of advance prediction tools, so that data can be systematically processed into information to explain uncertainties and thus make more informed decisions. It can be concluded that the term Industry 4.0 describes different—primarily Information Technology (IT) driven—changes in manufacturing systems. These developments not only have technological but also versatile organizational implications. Industry 4.0 creates a modularly structured smart factory, meaning the Cyber Physical System (CPS) monitors physical processes, maps the physical world in the virtual world, and decentralizes operational decision-making. Accelerated industrial digitization is trying to respond to rapidly changing customer needs. Due to ever new product variants expected by customers, the product lifecycle is considerably shortened, so work on the innovation of the product, and the technology needed to produce it, has to be kept up-to-date. Not only does the product itself need to be renewed from time to time, but a production technology must also be created that can be flexibly altered along with the ever-changing customer product specifications. Due to industrial digitalization, there may be significant effects on manufacturing industries: Substantial reductions in inventory, logistics and material handling costs, shorter lead times and fewer shortages during shipment.

III. INDUSTRY 4.0 DESIGN PRINCIPLES

The term Industry 4.0 was first publicly introduced in 2011 as “Industry 4.0” by a group of representatives from different fields (such as business, politics, and academia) under an initiative to enhance the German competitiveness in the manufacturing industry. The German federal government adopted the idea in its High-Tech Strategy for 2020. Subsequently, a Working Group was formed to further advice on the implementation of Industry 4.0. In 2003, they developed and published their first set of recommendations. Their vision entailed that, **“These Cyber-Physical Systems comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently. This facilitates fundamental improvements to the industrial processes involved in manufacturing, engineering, material usage and supply chain and life cycle management.”**

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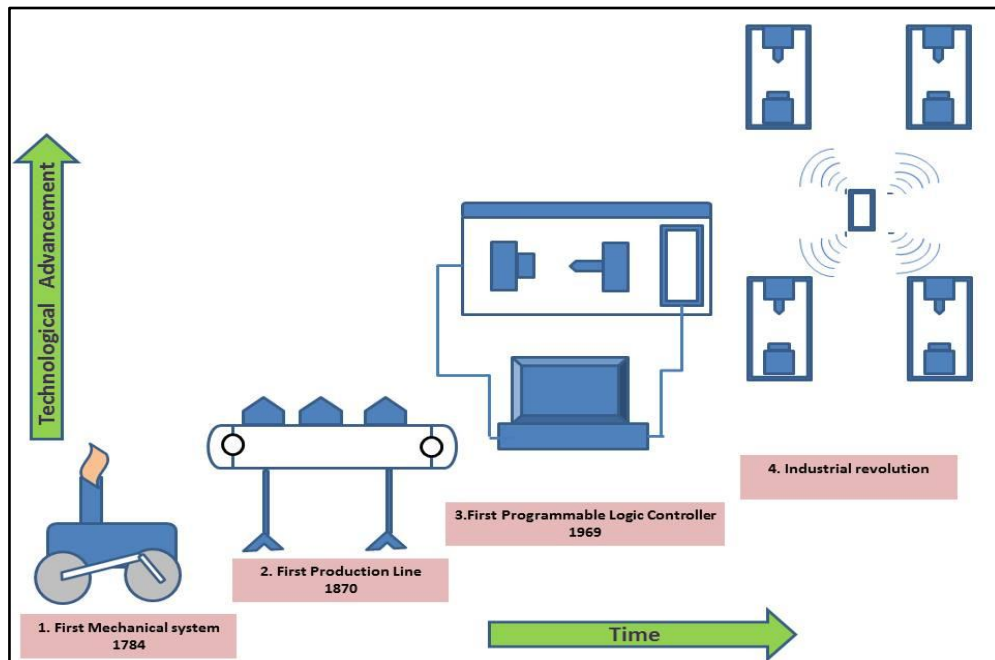


Fig1-The four stages of the Industrial Revolution

Fig1 shows four stages of Industrial Revolution. The fourth industrial revolution takes the automation of manufacturing processes to a new level by introducing customized and flexible mass production technologies. This means that machines will operate independently, or cooperate with humans in creating a customer-oriented production field that constantly works on maintaining itself. The machine rather becomes an independent entity that is able to collect data, analyze it, and advise upon it. This becomes possible by introducing self-optimization, self-cognition, and self-customization into the industry. The manufacturers will be able to communicate with computers rather than operate them.

Communication of machine- The rapid changes in the information and communication technologies (ICT) have broken the boundaries between virtual reality and the real world. The idea behind Industry 4.0 is to create a social network where machines can communicate with each other, called the Internet of Things (IoT) and with people, called the Internet of People (IoP)

IV. HISTORY OF INDUSTRY 4.0

A. the first industrial revolution- The industrial revolution in Britain came in to introduce machines into production by the end of the 18th century (1760-1840). This included going from manual production to the use of steam-powered engines and water as a source of power.

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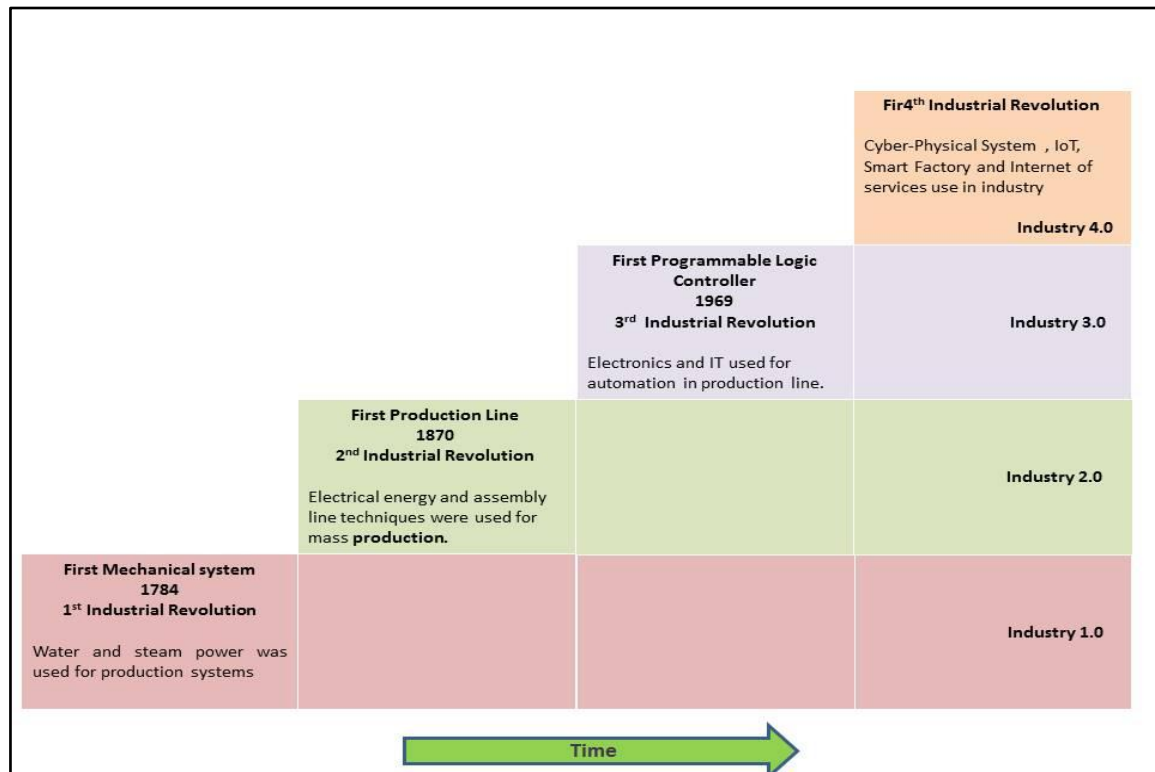


Fig 2- Evolution of Industries

Fig 2 Shows stepwise evaluation of industries from 1760 first industrial revolution to current industry 4.0. The fourth industrial revolution has an impact on the entire company, so it is very important to understand how the various elements of it are able to exploit the opportunities offered by digitization

B. The Second Industrial Revolution-The second one dates between 1870 and 1914 (although some of its characteristics date back to the 1850) and introduced pre-existing systems such as telegraphs and railroads into industries. Perhaps the defining characteristic of that period was the introduction of mass production as a primary means to production in general.

C. The Third Industrial Revolution-The third industrial revolution is dated between 1950 and 1970. It is often referred to as the Digital Revolution, and came about the change from analog and mechanical systems to digital ones.

V. CURRENT STATE OF INDUSTRY 4.0

When considering the current state of the Industry 4.0, it is important to understand the preconditions that have to be fulfilled so that a new concept can be introduced in industrial manufacturing system. At least the following has to be fulfilled:

1. Stability of the production has to be guaranteed also during the transition phase.
2. Stepwise investment should be possible as most of the industrial processes cannot bear big one-time investments.
3. A good know-how protection is necessary. Closely connected is the cyber security issue.

German organization has conducted a study on the readiness of Germany companies for Industry 4.0. The following six dimensions were evaluated:

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- 1.Strategy and organization (investments, innovations management),
2. Smart factory (equipment and IT systems, data capturing and usage, digital modeling),
3. Smart operation (integration of value chain, cloud storage),
- 4.Smart products (physical components, virtual identity),
- 5.Data-driven services (ICT functionalities, prediction and optimization of business outcomes).
- 6.Human resources (skills of employees, continuous education).

A survey was conducted of 268 companies from Germany with more than 20 employees. The results showed that 56.5% of all participating companies are not fulfilling any requirements concerning Industry 4.0 readiness. Further, 20.1% of the companies are assessed to be on the Level 1 (beginner), which means that the company is involved in Industry 4.0 through pilot initiatives in various departments and investments. This is however limited to a single area and only few processes are already supported by IT systems. Only 0.3% of companies (8 companies from 268 that were participating) are ranked on the Level 5 (top performer). This means that they have already implemented the Industry 4.0 strategy and have sufficiently addressed all six evaluated dimensions.

Industry 4.0 is a strategic initiative of the German government that traditionally heavily supports development of the industrial sector. The main idea is to exploit the potentials of new technologies and concepts such as:

1. Availability and use of the internet and IoT,
2. Integration of technical processes and business processes in the companies,
3. Digital mapping and virtualization of the real world,
4. 'Smart' factory including 'smart' means of industrial production and 'smart' products.

Besides being the natural consequence of digitalization and new technologies, the introduction of Industry 4.0 is also connected with the fact that many up to now exploited possibilities for increasing the profit in the industrial manufacturing are almost exhausted and new possibilities have to be found. According to some sources, Industry 4.0 factory could result in decrease of:

1. Production costs by 10-30%,
2. Logistic costs by 10-30%, •quality management costs by 10-20%.
3. A shorter time-to-market for the new products,
4. An improved customer responsiveness,
5. Enabling a custom mass production without significantly increasing overall production costs,
6. More flexible and friendlier working environment,
7. More efficient use of natural resources and energy.

VI. INDUSTRY 4.0 COMPONENTS

Although "Industry 4.0" is the common term referring to the fourth industrial revolution, academics still struggle to properly define the approach. Cyber-Physical Systems, Internet of Things, Smart Factory, and Internet of Services are the most common four terms cited in academic research publications related to the industry. Consequently, and given its initial stage, these are the four main components of the industry.

1. Cyber-Physical Systems

As mentioned above, a cyber-physical system aims at the integration of computation and physical processes. The development of such a system consists of three phases:

1. Identification

2. The Integration of Sensors and Actuator

3. The Development of Sensors and Actuators

2. The Internet of Things (IoT)

The Internet of Things is what enables objects and machines such as mobile phones and sensors to "communicate" with each other as well as human beings to work out solutions. The integration of such technology allows objects to work and solve problems independently. Of course, this is not entirely true as human beings are also allowed to intervene.

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3. The Internet of Services (IoS)

The Internet of Services aims at creating a wrapper that simplifies all connected devices to make the most out of them by simplifying the process. It is the customer's gateway to the manufacturer.

4. Smart Factory

Smart factories are a key feature of Industry 4.0. A smart factory adopts a so called Calm-system. A calm system is a system that is able to deal with both the physical world as well as the virtual. Such systems are called "background systems" and in a way operate behind the scene. **"The Smart Factory can be defined as a factory where CPS communicate over the IoT and assist people and machines in the execution of their tasks."**

VII. INDUSTRY 4.0 DESIGN PRINCIPLES

The design principles allow manufacturers to investigate a potential transformation to Industry 4.0 technologies. Based on the components above, the following are the design principles:

1. Interoperability: Objects, machines and people need to be able to communicate through the Internet of Things and the Internet of People. This is the most essential principle that truly makes a factory a smart one.

2. Virtualization: CPSs must be able to simulate and create a virtual copy of the real world. CPSs must also be able to monitor objects existing in the surrounding environment. Simply put, there must be a virtual copy of everything.

3. Decentralization: The ability of CPSs to work independently. This gives room for customized products and problem solving. This also creates a more flexible environment for production. In cases of failure or having conflicting goals, the issue is delegated to a higher level. However, even with such technologies implemented, the need for quality assurance remains a necessity on the entire process

4. Real-Time Capability: A smart factory needs to be able to collect real time data, store or analyze it, and make decisions according to new findings. This is not only limited to market research but also to internal processes such as the failure of a machine in production line. Smart objects must be able to identify the defect and re-delegate tasks to other operating machines

5. Service-Orientation: Production must be customer-oriented. People and smart objects/devices must be able to connect efficiently through the Internet of Services to create products based on the customer's specifications. This is where the Internet of Services becomes essential.

6. Modularity: In a dynamic market, a Smart Factory's ability to adapt to a new market is essential. In a typical case, it would probably take a week for an average company to study the market and change its production accordingly. On the other hand, smart factories must be able to adapt fast and smoothly to seasonal changes and market trends.

Industry 4.0 includes:

1. Factory 4.0:
 - a. Robots,
 - b. Autonomous Vehicle (unmanned vehicles),
 - c. 3D Printing / Additive Manufacturing,
 - d. Advanced Manufacturing System,
 - e. Sensors (sensors - data collections),
 - f. Industrial mobile devices (platform), Nanotechnology / advanced materials,
2. Cyber Security (Information Security),
3. Software for data processing - Big Data,
4. Logistics 4.0,
5. Mass Customization (a large number of custom),
6. Internet of Things (IOT),

High-quality team of employees and experienced team of associates.

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VIII. IMPORTANCE OF INDUSTRY 4.0

By Industry 4.0, we mean the intelligent networking of industrial products and processes. Its main impact comes from five technology areas: Embedded systems, smart factories, strong networks, cloud computing and IT (Information Technology) security.

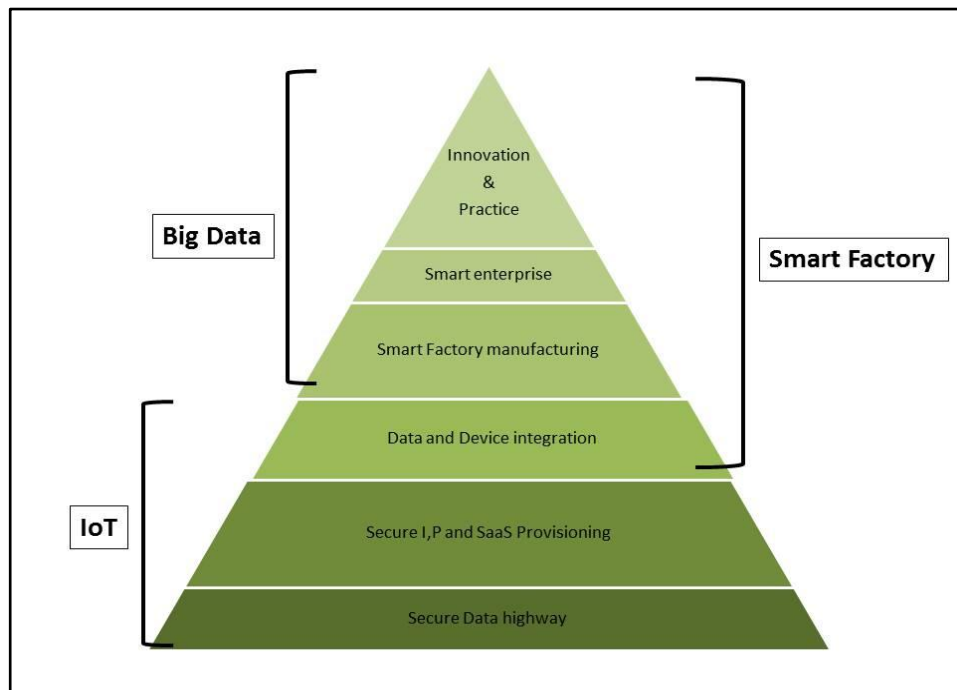


Fig 3-Industry 4.0 Smart Manufacturing's element

Fig 3 Shows smart manufacturing element about industry 4.0. Software tools are crucial for operating of the Industry 4.0. Today, in an Industry 4.0 factory, machines are connected as a collaborative community. It can be concluded that the term Industry 4.0 describes different primarily Information Technology (IT) driven changes in manufacturing systems. These developments not only have technological but also versatile organizational implications. The perception of the productivity of new technologies is influenced by company-level calculations it is worth considering the possibility that the timing of the studies may distort the conclusions drawn from the results. At the same time, calculations have also been made at the national economy level, including reference, which, by examining 17 countries, clearly demonstrates the effects of industrial robots on economic growth and productivity gains. In their analysis, Industry 4.0 investments in each industry and found that the largest investments are now being carried out by the electronics industry, and it is expected that this will continue to be so in the future. By 2020, the value of investments will reach 243 billion US dollars a year. According to Geissbauer, Vedso and Schrauf, the cost of value-creating processes can lead to a 3.6% annual decrease in costs in the future (reduction in lead times, improved asset utilization and improved product quality), in return for spending 5% on digital skills and tools in the next few years. They believe that these requirements are supported by emerging technologies, including IoT, wireless sensor networks, big data, cloud-based services, embedded systems, and mobile Internet. Overall, we can conclude that Industry 4.0 penetrates the entire value chain of the corporation although most of the value chains are interpreted as production-based, possibly supplemented with the logistics operations. It builds on new network-linked technology and requires new procedures (e.g., data analysis software, cloud, programming) that require new capabilities from the company (e.g.,

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continuous innovation, life-long learning, trust, data sharing) and possibilities of digitization and integrates the corporate value chain and the supply chain into a new level of customer value creation.

IX. INDUSTRY 4.0 PRODUCTION SYSTEM

The core process is digital to physical conversion in a reconfigurable manufacturing system. Reconfigurable manufacturing systems are the latest advance in the development of a manufacturing system. As the results of the latest development are reconfigurable manufacturing systems able to adapt their hardware and software components to follow ever-changing market requirements of type and quantity of the products. Machines in Industry 4.0 factory are Cyber-Physical Systems, physical systems integrated with ICT components. They are autonomous systems that can make their own decisions based on machine learning algorithms and real-time data capture, analytics results, and recorded successful past behaviors. Products in such factory are also ‘smart’, with embedded sensor that is used via wireless network for real-time data collection for localization, for measuring product state and environment conditions. Smart products also have control and processing capabilities. Thus they can control their logistical path through the production and even control/optimize the production workflow that concerns them. Furthermore, smart products are capable of monitoring their own state, During the whole life cycle, including during their lifetime application.

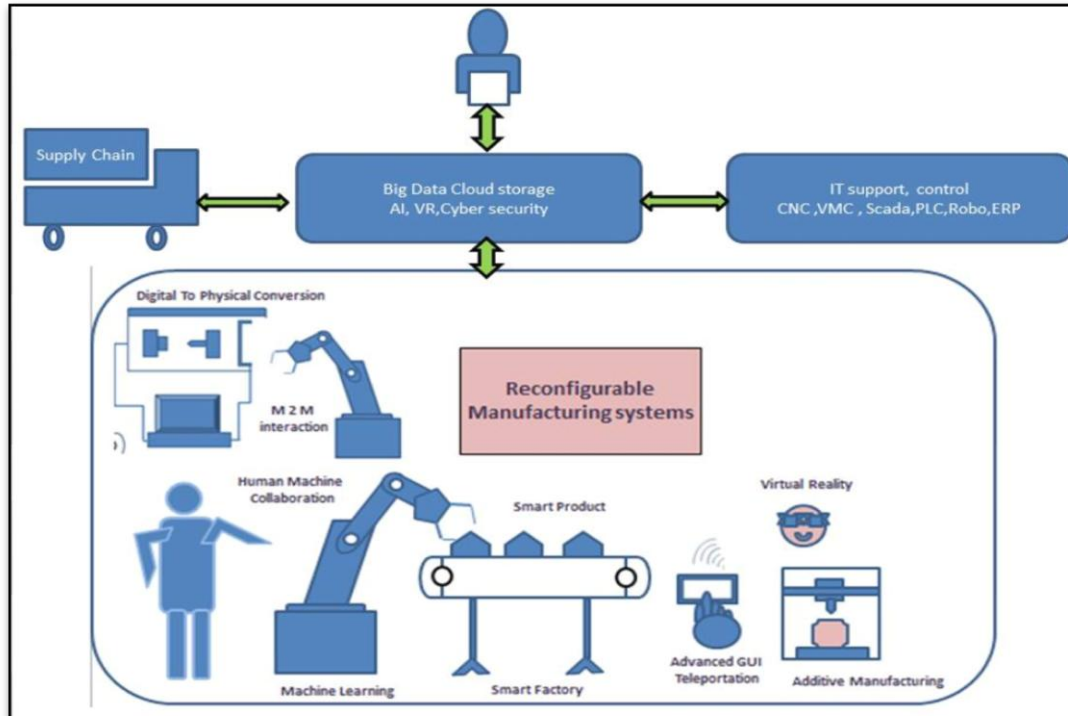


Fig 4- Smart digitization Manufacturing cycle

Fig 4 shows smart digitization manufacturing cycle in Industry 4.0. Important elements of the Industry 4.0 concept are also interoperability and connectivity. A continuous flow of information between the devices and components, Machine-To-Machine interaction (M2M), manufacturing systems and actors should be established. Hereby the machines, products and factories can connect and communicate via the Industrial IoT (mostly based on wireless network). Another important topic is Human-To-Machine (H2M) collaboration that is necessary as some production

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tasks are too unstructured to be fully automatized. A lot of research effort is currently also invested in so called collaborative robotics.

X.CONCLUSION

Industry 4.0 is new industrial revolution of the 21st century, which enables companies to create “smarter” products and services by reducing costs and increasing efficiency, where the human factor is crucial for the application and the work is based on the existing literature in the area.

Smart Factory makes a solution which, due to the system’s automated procedures, uncomplicated setup including simple, need-based installation, and, ultimately, high degree of scalability can help companies in the manufacturing sector further optimize their processes and significantly boost their internal efficiency.

Five million workplaces could be lost due to digitalization in major industrialized nations by 2020. Also, it will quickly stop the market demand for the products made with outdated technologies due to lack of quality and such production would have to be shut down due to high costs and inefficiency.

In this paper, the background and development of the Industry 4.0 concept are presented. Although the concept is very comprehensive and complex, three main points can be identified:

1. The Industry 4.0 concept is not limited to direct manufacturing in the company but it includes also a complete chain from providers to customers and all manufacturing company and services.
2. The main purpose of Industry 4.0 is to achieve improvements in terms of automation and operational efficiency, as well as effectiveness. And fundamental improvements to the industrial processes involved in manufacturing, engineering, material usage and supply chain and life cycle management
3. The main aim of Industry 4.0 transformation of industrial manufacturing through digitalization and exploitation of potentials of new technologies

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