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Modern Digital Technologies of Industry 4.0

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Abstract:

Purpose: *The paper presents a brief description of the most important technologies creating a new reality.*
Design/Methodology/Approach: *The origin of the concept of Industry 4.0 and its basic recommendations for implementations, which are to lead to the achievement of the so-called smart industry was explained in the paper. The definition of this concept is presented in a descriptive way as a vision, a future state that will be shaped by changes in technique, technology, and organization.*
Findings: *The information and communication technology presented in the article and the applications used in smart industry allowed to create an overall picture of the way all major digital technologies work and interact.*
Practical Implications: *The knowledge can be used as a background for further theoretical research and as a guideline for managers making decisions on Industry 4.0 implementation.*
Originality / Value: *A brief description of all industrial revolutions is the background to present the most important technologies characteristic of the fourth industrial revolution.*

Keywords: *Industry 4.0, industrial revolutions, digital technologies.*

JEL Classification: *M2, D24.*

Paper Type: *Research article.*

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1. Introduction

The innovative technical and technological solutions that have taken place during industrial development turned out to be ground-breaking and initiated revolutionary changes in the industry. They also contributed to the economic and social changes in the world. The new technological solutions have always been associated with increasing the production efficiency and machines efficiency, reducing production costs while maintaining high quality products and with the possibility of producing a diversified assortment and flexible change of the production profile.

The development of new technologies contributed to economic development, market diversification, an increase in the number of producers and the number of offers that became more and more attractive to consumers. The initially dominant manufacturer's market began to transform into the buyer's market (Sławińska, 2016). The needs of customers now dictate the conditions for enterprises. In this way, they determine changes in the way of thinking in the approach to production processes, management systems, logistics and the supply chain. The short product lifetime forces the producers to frequently change the product range, including changes in the production profile and the necessity to quickly adapt to new customer requirements.

2. The Genesis of the Industry 4.0 Concept

The concept of Industry 4.0 comes from the strategic project of the German government, which promoted the computerization of manufacturing processes. The first time was used at the Hannover Fair in 2011 (Schwab, 2018). In the year 2013, a working group was set up in Germany to formulate actions that would allow the definition of the basic principles of factory automation. The result of the work were recommendations for implementations that are to lead to the achievement of the so-called smart industry. Basic guidelines were concerned (Hetmańczyk, 2020):

- creation of cyber-physical systems, i.e., the possibility of connecting machines and production equipment, storage and logistics systems into a global Internet network;
- development of smart industrial objects (machines and devices), production and storage systems, which will be capable of autonomous information exchange, mutual control and self-control, and capable of independent decision making and performing appropriate actions;
- improvement of industrial processes related to design, manufacturing, supply chain control, material flow, control of work-in-progress inventory, product life cycle;
- design, implementation, commissioning and development of smart factories and smart products;
- development of modern methods and tools for diagnostics and communication of industrial facilities, which will be related to the location and identification of the type of failure in real time, with the collection of historical and current data on the condition of machines and devices;

3. Industry 4.0 Definition

The concept of Industry 4.0 is not easy to define due to the fact that the new reality is in the preliminary phase, it is taking shape. The existing definitions are descriptive – they present a vision, a future state that will be shaped by changes in technique, technology, and organization. The Industry 4.0 in a general sense is the integration of machines, devices, industrial facilities, systems and processes, it is the make of modifications in production processes that will increase the efficiency of the production process and allow for a flexible change of the product range. This applies to both technologies as well as new working methods and the new role of worker in industry (Piątek, 2017a).

Literature provides descriptions of the new reality that relate to various aspects of change. A synthesis of these descriptions was presented in the 2015 publication of the Dortmund University of Technology. The authors analysed the publications on the subject Industry 4.0, by identifying the keywords most frequently used to describe the new reality. Based on the results of the study, the authors presented the definition: “Industry 4.0 is the collective term for technical solutions and concepts for the organization of the value chain. In modularly structured smart factories, cyber-physical systems monitor physical processes, create virtual copies of the physical world, and make decentralized decisions.

Due to the Internet of Things, cyber-physical systems communicate with each other and cooperate with each other and with people in real time. Due to the Internet of Services, both internal and inter-organizational services are offered and used by participants in the value chain" (Hermann, Pentek, and Otto, 2016).

The concept of Industry 4.0 means reducing to one form and combining all elements into one whole of the real world of production facilities with the virtual world of the Internet and information technology. People, industrial facilities, and IT systems exchange information automatically during production. This exchange takes place both in the area of the enterprise and in the various IT systems operating for the enterprise.

Industry 4.0 covers the complete value chain from placing an order and delivering materials and components for production, to shipping the finished product to customers and after-sales services. It is a concept that represents the complex process of technical, technological and organizational transformation of enterprises. It covers value chain integration, implementation of new business models and digitization of products and services. The implementation of such solutions is possible due to the use of modern digital technologies, the use of data resources, ensuring network communication and cooperation between industrial facilities and people. Industry 4.0 is the transformation of single, separate automated enterprises into comprehensively automated and optimal production environments (Sąsiadek and Basl, 2018).

4. Industrial Revolutions – Technologies that Changed Industry

The industrial revolution is a process of technological, economic, social, and cultural change, initiated in the 18th century in England and Scotland, which was associated with the transition from an economy based on agriculture, workmanship, and manufactory production, to an economy based mainly on mechanized factory production. Handwork has been replaced by machines, and retail production has been replaced by mass production. The main resource in the production process was no longer a man with his knowledge and skills, but a machine. This enabled the production of more the same products in less time.

Figure 1 shows the general stages of technological changes in the evolution of industry along with a brief description of each age. The first industrial revolution began at the end of the 18th century and lasted until the second half of the 19th century. Thanks to the use of technical inventions, there has been a transition from handicraft and manufactory production to mechanized factory production. Most important for that period was the invention of the steam engine, which was used on a large scale in the mining industry.

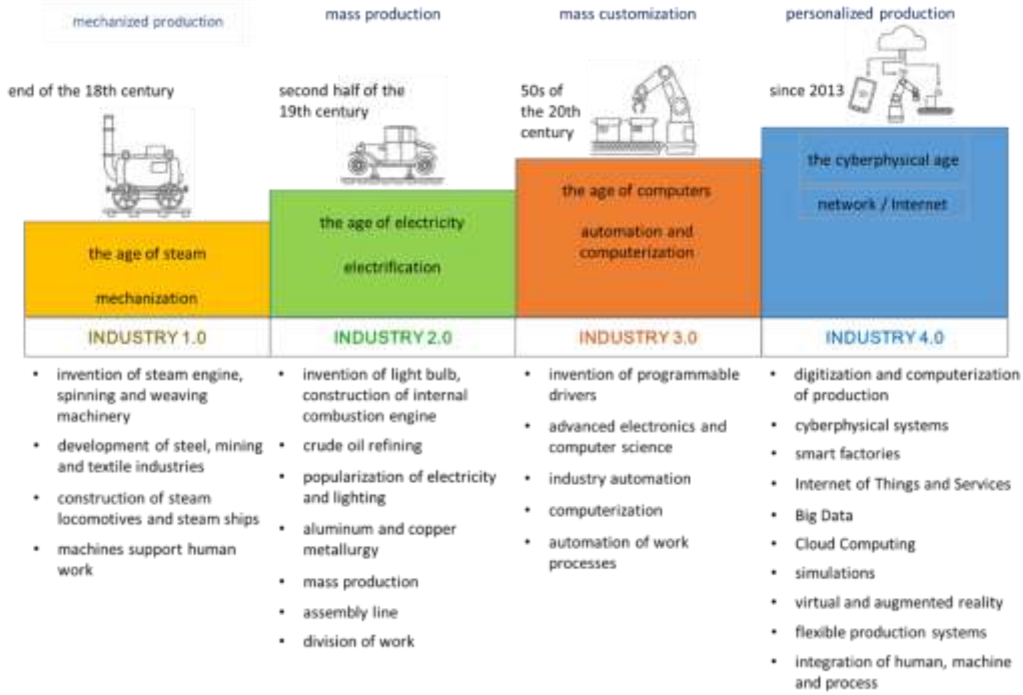
Another significant invention was the spinning and weaving machine, which made it possible to start mass production in the textile industry. The replacement of charcoal with coke in the steel industry turned out to be a breakthrough. The rapid development of the steel, mining and textile industries contributed to the development of machinery. The steam engine was used to build steam locomotives and steamships.

As a result of the first industrial revolution, the energy potential of employees increased - machines supported human work. The organizational revolution in factories, the aim of which was to rationalize the work of workers, not only contributed to an increase in work productivity, but also prepared the industry for the implementation of modern techniques and technologies.

The second industrial revolution dates to the second half of the 19th century and the beginning of the 20th century. The greatest innovations that revolutionized and dynamized the industry at the time were two new energy sources: electricity and the internal combustion engine. The era of mass production with the division of labour has begun. The development of the first method of refining crude oil meant that it began to be used as a fuel, and the invention of the light bulb contributed to the spread of electricity and lighting. Another breakthrough was the construction of the internal combustion engine. Crude oil displaced the less useful and less calorific coal, aluminium and copper metallurgy developed. The world's first assembly line was launched at the Ford car factory.

The third industrial revolution is known as the scientific and technical revolution. Great changes in technology, science and industry have been taking place since the 50s of the 20th centuries. The most important aspects of the third revolution can be included computerization, the use of alternative energy sources, the development of the production of synthetic materials, the improvement of telecommunications and transport, the development of industrial applications of programmable controllers, opening the era of industrial automation based on advanced electronics and information technology, and automation of work processes. Inventions that have shaped the industry in its current form increase production efficiency and speed and reduce costs. As a result, mass production is possible.

Figure 1. *The stages of technological changes in the evolution of industry*



Source: *Own study.*

Strong competition and growing customer expectations make it necessary to constantly increase production efficiency. The problem is to manufacture short series of products designed to meet the needs of a specific customer, and their price should not be higher than the price of mass-produced products. The flexibility of production systems is one of the main assumed effects of the fourth industrial revolution.

The development of the Industry 4.0 will intensify activities aimed at digitization and computerization of production. Cyber-physical systems (CPS) will then be created, from which smart factories will be developed. Machines and devices, due to the connection in the network, will communicate and make autonomous decisions. Human participation in the process will be kept to the minimum necessary. Industry 4.0 is not intended to create factories, where workers are replaced by robots.

The workers will be still the most important in the process and due to new solutions, they will receive more support. It will be an integration of man, machine, and process. Interaction in such a system will be possible between machines, machines, and people, as well as between entire stages of production, which will become interdependent. Then the supply chain will become more flexible and the manufacturing process more efficient and faster.

It is predicted that the fourth industrial revolution will start with the development and use of new technologies. One of the most important ones will be the Internet of Things (IoT), through which huge amounts of data will be sent on the condition of machines, devices, work in progress, inventory, etc. Therefore, advanced methods of data processing will be required, which is why techniques of Big Data analysis and Cloud Computing are being developed. The security of transmitted and processed data in the network will also be related to the development of cybersecurity.

The technologies that complement the main system architecture should be included advanced simulations, virtual and augmented reality, additive (3D) printing and full integration of enterprise IT systems. Key technical innovations, considered as factors enabling the fourth industrial revolution, are (Soldaty, 2016):

- a new quality of communication in which both the digital and real worlds are connected with each other, due to which machines, products in various stages of processing, systems and people exchange digital information via the Internet protocol;
- intelligent sensors with built-in systems of individual identification, data processing and communication;
- cloud computing with high response dynamics;
- big data analysis on all aspects of product development and production;
- techniques for simulating the functioning of real objects in their virtual representations, based on data provided and processed in real time, allowing for testing and optimization of the configuration of production processes before implementing physical changes;
- direct communication between devices;
- advanced human-machine interfaces;
- cyber-security solutions, ensuring secure communication and identification as well as managerial access to systems and devices;
- a new generation of robots, characterized by active interaction with the environment and with other robots as well as adaptation to changing conditions and requirements;
- augmented reality systems supporting the design and servicing of devices;
- additive manufacturing technologies, e.g., 3-D printing – both for prototyping and individual orders.

Breakthrough changes in the industry will be caused by the scale of their application, synergy, integration, as well as the dynamics of development.

The fourth industrial revolution is a generalizing concept referring to the term of the industrial revolution in connection with the contemporary mutual use of automation, data processing and exchange, and manufacturing techniques (Schwab, 2018). The fourth industrial revolution is driven, among others, by the increase in the amount of available data and the analysis of this data, the use of mobile connectivity to transfer data from devices and the automation of production processes, i.e., robotization (Kuźniar, 2019).

5. Components and Technologies of the Industrial 4.0

The key components of Industry 4.0 identified by scientists at Dortmund University of Technology are: cyber-physical systems, Internet of Things, Internet of Services and smart factories.

Cyber-physical systems (CPS) due to sensors and executive modules mounted on objects, the physical world connects with the virtual world, where information is processed based on the mathematical mapping of real objects (Furmanek, 2018).

The Internet of Things (IoT) is a dynamic global network of physical objects, systems, platforms, and applications, capable of communicating and transferring data and sharing intelligence with each other, the external environment, and people (Furmanek, 2018).

Internet of Services (IoS) is used to flexibly build a network of values by dynamically configuring services selected from various resources shared on the network (Furmanek, 2018). Smart factories are treated as the target solution of the concept. These are factories in which cyber-physical systems communicate with each other via the Internet of Things and, using the Internet of Services, assist workers and machines in carrying out their tasks. They monitor physical processes and create virtual copies of the real world and are also capable of making decentralized decisions (Furmanek, 2018).

The main technologies currently associated with Industry 4.0 and influencing its development are (Kaliczyńska, 2018; Astor, Rodak, and Gracel 2017):

- autonomous robots – which learn to realize processes, use the data provided to them from the systems; they are autonomous, flexible, cooperative; they increase the efficiency and effectiveness of processes, and reduce production costs;
- simulations – three-dimensional simulations in the design phase of products and processes that can use real-time data; reflect the physical world in a virtual model; this way it can optimize machine settings and parameters in the virtual world, shorten machine setup times and improve process quality; simulation and modelling allow for digital mapping of the production process, creating the so-called digital twin; the simulation process consists of: a 3d model, a mathematical model and connection with a real object; they save time and costs in the preparation of prototypes, shorten the implementation time, minimize risks, present failure scenarios;
- system integration – the flow of data and information between production devices, IT systems, people and business processes; it is vertical and horizontal integration, data exchange of companies, suppliers of raw materials and equipment and customers; IT platforms and data integration networks enable the management of the exchange of product and production data between organizations; shorter delivery times for individual orders, faster decision-making process between organizational units;
- Internet of Things (IoT) – the Industrial Internet of Things (IIoT) provides real-time data through the combination of devices and factories; industrial facilities can communicate and interact with each other; IoT decentralizes data analysis and decision making, enabling real-time responsiveness; a prerequisite for building the Industrial Internet of Things (IIoT) is a highly developed system integration;
- cybersecurity – system integration, building IoT applications, data processing in the cloud and Big Data require appropriate data protection against unauthorized access; secure, reliable communication and advanced identity management are essential;
- cloud computing – systems for monitoring and controlling production processes are based on database and analytical systems in the cloud; cloud computing is a technology

that allows the use of external hardware resources and applications to process data from the production area;
- additive manufacturing – it is manufacturing (3D printing) used mainly for prototyping and manufacturing of single components; it lowers the costs of prototyping and spare parts storage;
- augmented reality – systems based on augmented reality provide various services, provide employees with real-time information in order to improve the decision-making process, work and tasks accomplishment by production and service personnel;
- Big Data – large data sets used to collect, store and analyse large amounts of data from various sources, the analysis of which can be used to optimize the production and diagnostics of devices; sending data to external servers allows to use their large computing power;

5.1 RFID Technology

New technologies combine and support processes, creating new modern solutions that can be used in the environment of the new industrial reality. Such technologies include RFID (Radio-Frequency Identification), i.e., smart products which, due to the use of identification technology, they communicate directly with machines and production management systems.

RFID stands for identification by means of radio waves. It is a technology that allows to read and transmit data and to electronically power the chips that store the data. Depending on the type of tag (RFID tag) and chip, the operation of this object is possible at several dozen centimetres to a dozen or so meters. The construction of the radio frequency identification system allows reading many tags within the reader's range. RFID technology is used in industrial, production, logistics and warehouse processes.

Currently, due to the development of digitization and robotization technologies, it is becoming a standard for wireless object identification and communication between them. RFID helps to automate processes, identify products, machines, and devices, improves control, increases the efficiency of tasks and synchronizes production processes carried out in various locations. It often supports production traceability. The common use of this technology is the NFC (near-field communication) standard used in mobile telephony (smartphones and mobile devices) for wireless payments or data transfer between devices (RFID Polska, 2019).

5.2 Autonomous and Cooperating Robots

A lot of hope is placed on the possibility of using data from the IoT (Internet of Things) or Industrial Internet of Things (IIoT) networks on industrial facilities, for independence in making decisions about the performance of production tasks. We are talking about autonomous robots, i.e., smart machines that perform tasks without direct worker intervention. It is possible when the machine or device will independently monitor the condition of its own works, condition, and parameters of the process.

For this purpose, the robot must be equipped with sensors, and the results of current measurements draw conclusions and adjust. This will require the implementation of learning algorithms and other elements from the area of artificial intelligence in its control system. Thanks to self-control, the robots will not require inspection.

Properly created mathematical models allow to effectively predict potential failures of machines and devices. Due to this, it is possible to take preventive actions before the first symptoms of incorrect operation of machines are noticeable to operators of machines or control systems. Mathematical modelling enables complex analyses of machines, trends, behaviour patterns of individual elements of the production process and the identification of anomalies that are likely to lead to failure in the long term. Such analyses can be the basis for taking preventive actions aimed at foreclosing the failure of machines or minimizing its effects (PwC Polska, 2017).

Thanks to automation and advanced information technologies, it becomes possible to network robots, machines, devices, and other industrial objects. In this way, the physical world is connected to the virtual world, where information is processed. Cyber-physical systems will then be created, creating smart factories, which in turn will create smart industry. Thanks to the network connection, smart industrial facilities will communicate and make autonomous decisions.

5.3 Big Data and Cloud Computing

Using Industry 4.0 technologies, including the Internet of Things (IoT), and more specifically the Industrial Internet of Things (IIoT), involves the transfer of huge amounts of data from industrial facilities to database units, where they are stored, analysed, grouped, and processed in such a way that they can be used for ongoing process control. Such data belongs to the group of Big Data, the collection and analysis of which is beyond the company's capabilities. It is related to their number, counted in petabytes (1PB = 10^{15} bytes), data transmission speed in both directions (transmission and reception) and diversity (numerical, text, graphic, video data).

For Big Data processing, cloud computing is used. It is a data processing model based on the use of the services provided by the service provider. Cloud is a service offered by given software. The cloud model assumes storing data, files, and applications in the cloud, i.e., on servers located around the world, outside the local corporate network. It allows to choose the right amount of space for data, speed of their processing, computing power.

It reduces the costs associated with the need to install servers in the enterprise and guarantees a high level of data security thanks to the encryption technology. Accidental data deletion is no problem due to the backup technology used for real-time backup and data recovery. Access to data is possible from any predefined device, including mobile devices. This has a significant impact on the efficiency of communication, cooperation and raising the work culture in the organization (IT. INTEGRO).

On one side of cloud computing there are data sources - controllers, robots, sensors, computers. The ability to connect to the cloud and transfer data is provided by network gateways based on industrial computers. On the other side of the cloud, there are IT systems that enable the visualization of processed data (Piątek, 2017b).

The variety of services in the field of cloud computing allows to choose the best solution in the area of Internet delivery: infrastructure (Infrastructure as a Service – IaaS), software (Software as a Service – SaaS), platform (Platform as a Service – PaaS). Infrastructure as a Service is a cloud model that provides the customer with IT infrastructure, i.e., hardware, software, and servicing (number of servers, disk space, memory resources, computing power) (Trojnar, 2010).

Platform as a Service is a cloud model related to the service of providing a virtual work environment by the provider. It is the sale of a ready-made set of applications tailored to the user's needs. The necessary programs are on the provider's servers, and the customer has access to the interface through a program, e.g., a web browser, i.e., from any computer connected to the Internet (Trojnar, 2010).

Software as a Service is a cloud model in which the customer gets access to applications and functions located on the service provider's servers and is made available to users over the Internet. This eliminates the need to install and run the program on the client computer. He uses whatever software he needs. Has access to specific, functional tools (Trojnar, 2010).

5.4 Virtual and Augmented Reality

Virtual reality (VR) and augmented reality (AR) are new technologies that are constantly developed and are increasingly used in various fields, including industry. VR is an image of artificial reality created with the use of information technology. This concept is defined by the following phenomena, interaction, immersion, imagination (Burdea and Coiffet, 2003). The three-dimensional computer-generated image shows objects and events. It can be based on elements of the real world as well as completely fictional.

AR is a system that connects the real world with the computer-generated world – the real image is combined with graphics, so it expands the image by adding new elements, objects, information, without creating a full three-dimensional image. The areas in which VR and AR technology are increasingly used are, product design and development, skills training in the manufacturing process, maintenance, repair and machine operation, remote cooperation, and design of improvement processes. Thanks to these technologies, it becomes possible to create a virtual image of a complete product, even a very complex one.

Virtual technologies make it easier for enterprises to focus on individual, tailored production by streamlining the process of designing and improving products. Simulation capabilities of VR technology and AR technology functions in combination with digital twins and IIoT technologies, given the opportunity to design, research and test virtual prototypes (Control Engineering Polska, 2019a).

In addition to training in assembling complex products, engineers can improve product design and manufacturing processes in smart factories using worker guidance systems based on augmented reality technology. Such a system uses the technological possibilities of artificial intelligence, which ensures the production of products without defects and errors. The use of appropriate tools, devices, and applications in the field of virtual technologies allows for quality control of elements and the correctness of their placement in the assembly process. The method of projection of operation sheet or assembly instructions can successfully replace traditional methods (Control Engineering Polska, 2019a).

Maintenance units in enterprises use virtual technology to monitor the technical condition of machines and devices, thus making it easier to detect potential problems before acting. Currently, virtual technologies are combined with the technology of the Internet of Things, creating new possibilities and technological experiences in reality of the Industry 4.0.

5.5 Edge Computing

The quality of data transmission and handling services has a significant impact on the speed of execution of key operations. Data transfer from industrial facilities to the cloud is supported by edge computing technology. This means that a lot of computing power is at the edge of the enterprise network, closer to the data source. This means that the data is prepared according to a specific cloud computing model at the enterprise level and then sent to cloud analysis. Data processing at the edge of the network is becoming one of the more important information technologies with benefits for smart manufacturing (Control Engineering Polska, 2019b):

- responsiveness – lack of data circulation between the enterprise network and the cloud reduces data transfer delays and allows for faster response;
- reliability of operations – there are situations when monitoring of facilities may be difficult due to unreliable Internet connection; in this case, edge devices store and process data without data loss;
- cybersecurity – it is possible to avoid the need to transfer large amounts of data between objects and the cloud, thanks to the option of filtering valuable data locally; only the necessary information is sent to the cloud; this allows you to build security platforms and comply with standards;
- profitability – in edge computing technology it is possible to process data locally, perform calculations and analyses, which gives the possibility of making decisions about which services can be run locally and which in the computing cloud; it allows to optimize the costs of implementing IoT technology solutions;
- compatibility – edge devices are a communication link between older and modern facilities, technologies, IoT solutions.

Edge computing has valuable advantages, but cloud tools offer disproportionately better computing capabilities for processing large amounts of data, predictive algorithms, and interoperability with artificial intelligence. The combination of edge computing and cloud computing technologies allows to create new possibilities of using IoT for smart production.

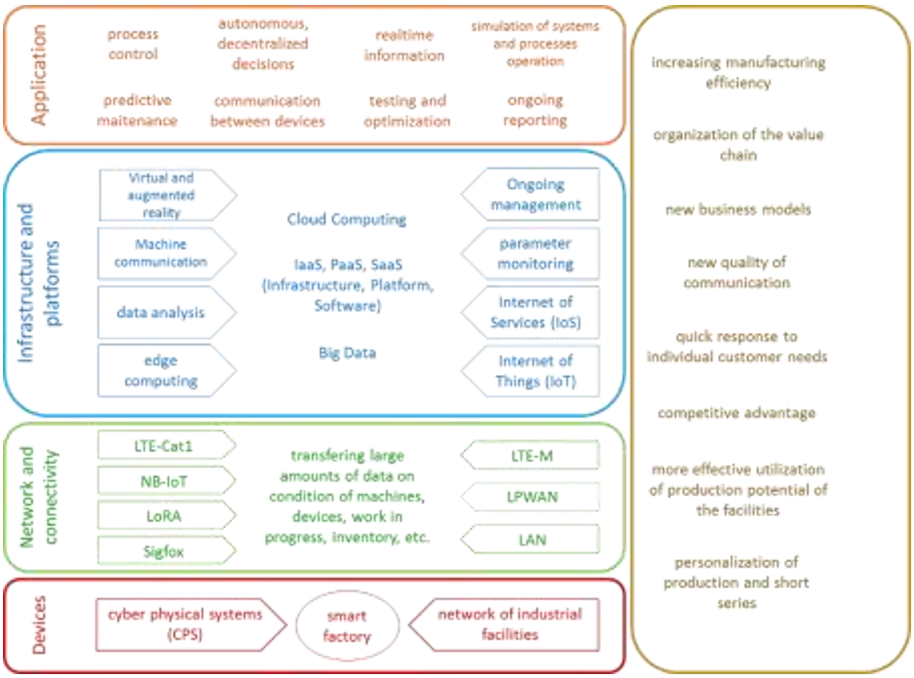
6. Industrial Internet of Things Technologies and their Application for Smart Manufacturing

6.1 Information and Communication Technology

Connecting machines, devices, and other industrial objects in the network (IIoT) allows, using communication standards, to transfer large amounts of data on the condition of machines, devices, production in progress, inventory to servers located inside the company, and then to the cloud computing, which provides highly efficient data analysis, and thanks to the use of additional technologies, it also enables management, monitoring and safe storage (archiving) of data.

The IoT platform provides real-time information, which allows to control industrial facilities and ensures connectivity between systems. It also allows to simulate changes, test, and optimize processes and systems.

Figure 2. *Information and communication technology for Industry 4.0 and their application for smart manufacturing (based on (Industrial IoT Center)*



Source: *Own study.*

Thanks to the control of industrial facilities, systems and processes and the provision of detailed reports in real time, tools and techniques used in maintenance and failure prevention are developing. All this implies benefits considered at the level of enterprise management: increased production efficiency, more efficient organization of the supply chain, a new level of communication not only between machines and between machines and employees, which favours more effective use of production potential, but also between employees, which allows for a quick reaction of the company to individual customer needs, personalization of production and manufacture of short production series (production run), and new business models give a competitive advantage (Figure 2).

6.2. Techniques of Communication on the Internet of Things

Industrial facilities, sensory systems, control systems can function automatically, without interference, if they communicate in a common language. The facilities can operate with different standards (protocols) of data exchange depending on the type of product and manufacturer, so it is important to develop and implement an open data exchange standard that will mediate between the manufacturer's communication protocol and the computer. The Internet of Things, operating based on an open data exchange protocol, contributes to the technical and IT structure responsible for uninterrupted communication between the production system objects (Domińska, 2017).

Today, there are many communication standards used to connect IoT objects. There are four main groups of communication standards for IoT (Automatyka.pl, 2018):

- PAN (Personal Area Network) and HAN (Home Area Network), i.e., short-range networks that enable communication between personal and household devices. Devices operating in these networks are characterized by the lowest energy consumption (battery), and their operating range, depending on the communication protocol used, ranges from a few centimetres (NFC) to several dozen meters (Wi-Fi, ZigBee, Bluetooth).
- LAN (Local Area Network) is a network with a greater range (building, enterprise). The Internet of Things devices that work in this network are primarily wireless sensors that communicate with gateways that enable data transmission to the Internet. The range of this network is several dozen to several hundred meters. The most commonly used communication protocols are Wi-Fi and Bluetooth (version 4.1 and higher).
- WAN (Wide Area Network) – a network covering a large geographic area. Wireless communication takes place using the GSM network (2G, 3G, 4G). Then the devices require constant power supply.
- The new LPWAN (Low Power Wide Area Network) communication technology, dedicated to IoT, allows devices to send small amounts of data over long distances with low energy consumption (battery). The most popular wireless communication techniques in this group include: LoRA, Sigfox, NB-IoT, LTE-Cat1, LTE-M. LPWAN technology is new and rarely used due to the high cost of communication modules.

6.3 Fifth Generation Network

In the age of the Internet of Things, when a huge number of devices will be connected to the network and will constantly communicate, a technology that meets the requirements will be needed. The Industry 4.0, which is based generally on robots and artificial intelligence, requires connectivity for all autonomous objects connected in the network. They will communicate with each other and with the cloud computing, which is the central unit managing the current situation.

This requires reliable network operating in real time with delays counted in milliseconds. The emerging 5G network is designed to meet these needs. It is based on a new radio access standard that provides for various uses. The first option is to use it for the needs of virtual and augmented reality, where high data transmission speed is required. The second one is related to the high reliability of the network, as it will be used in autonomous transport and control of automation systems of industrial facilities. The third one concerns the operation of the Internet of Things, so it must have properties that allow simultaneous handling of a very large number of devices in a specific time unit.

The 5G system will use frequencies in the several hundred MHz band with a large range, as well as in the several and several dozen GHz bands, which have a large capacity but a small range. This means that not only large base relay stations will be created, but also a dense network of small-range facilities, located in various places and objects of everyday use, like home Wi-Fi routers. The network architecture, dynamic management of the radio frequency band and flexible adaptation to different needs and requirements, allow to serve many users at the same time in different modes, which provides new, versatile application possibilities (Grzeszak, 2019).

7. Artificial Intelligence

Artificial Intelligence (AI) technology is a significant factor in the development of new Industry 4.0 solutions, as it enables machines to learn and solve complex problems. It creates models of intelligent behaviour as well as programs and systems simulating intelligent behaviour. Of particular interest to AI are problems that are not efficiently algorithmized. The concept of artificial intelligence is defined as the ability of a system to correctly interpret external data, learn from them, and use this knowledge to perform specific tasks and achieve goals through flexible adaptation (Kaplan and Haenlein, 2019).

Cloud technology allows you to transfer complex calculations and data analysis outside the company's servers. It also allows the use of algorithms based on artificial intelligence (AI), which is mainly related to the robotization of industry. Until now, robotic devices have been programmed by engineers in such a way that they can perform specific tasks. It is anticipated that the robots will soon learn by themselves how to perform production tasks as well as how to interact with other robots, industrial facilities, and people. Communication between robots requires technologies that collect, transmit, process, and analyse data, and provide valuable information.

The possibility of using AI in machine technology is related to the technology of machine learning and deep learning. It can be said that artificial intelligence is the ability of an object to simulate human intelligence, so it allows the object to function without the need for human programming. Deep learning enables objects to learn from their own experience (Hardin, 2017).

The extensive use of artificial intelligence tools may contribute to the creation of better tools to fight cybercrime. The most important aspects of using AI in this area include the ability to recognize activity in the network deviating from the norm, detecting, and patching system and security gaps, and predicting a cyberattack (Piątek, 2018).

8. Benefits of Company's Technological Transformation

The Internet of Things (IoT) technology is one of the most important technologies in the fourth industrial revolution. Digital transformation has become necessary for organizations that want to increase production efficiency, efficient flow of data and information, and better management of processes. Modern enterprises use the technology of systems for supervising, monitoring, or acquiring data from the production system, systems for resource management and maintenance. The use of IoT solutions can bring many additional benefits to companies. The IoT standard provides built-in advanced data analysis tools. Thanks to personalized software and services, there is easy access to data, and feedback is sent in real time, on an ongoing basis.

The development of digitization of enterprises, advanced computerization and robotization of production systems, connecting industrial facilities into a network of cyber-physical systems, creating intelligent factories, will contribute to creating new opportunities for enterprises: algorithmic and programmable products and services related to data processing in the cloud and the use of artificial intelligence. It will be possible to collect customer feedback that will influence the design of products that achieve new value for customers. For the company, this opens the possibility of creating new businesses and strategies.

The greatest advantage of the Internet of Things is participation in the Big Data analysis process. New solutions, tools, services, and applications will improve the efficiency of collecting and combining data from separate IT systems.

In addition to participating in analytical processes, IoT allows to monitor and detect upcoming problems in maintenance and repair planning. In this way, it supports the concept of predictive maintenance, and thus increases the reliability of machines and devices, their availability and reduces the costs of unplanned downtime (Dyess, 2019).

The main factor influencing the development of the Internet of Things (IoT), especially the Industrial Internet of Things (IIoT), is a necessity to control production infrastructure by monitoring performance and maintenance costs. A big challenge for the organization, in the context of the fourth industrial revolution, is to change the way of thinking and notice the benefits of using IoT solutions in industrial processes: business analytics, faster and better decision-making processes, higher efficiency and lower production costs, predictive maintenance, diagnostics and analysis of the condition of machines, increased safety (Control Engineering Polska, 2018).

9. Summary

Technological changes in the aspect of Industry 4.0 are primarily smart production processes. The new level of industrial communication, advanced computing, intelligent machines, better access to data and the possibility of storing them increase the scope, quantity, quality and distribution of available data, information, and knowledge. The goal of the smart manufacturing is to create applications that allow cooperation between industrial facilities, employees, and resources in the value chain.

Production becomes more efficient and flexible if production and logistics processes are integrated and smart. The smart value chain covers all stages of a product lifecycle: from design, simulation, and development to manufacturing, use, service, and recycling. This gives companies the opportunity to more easily and flexibly produce products tailored to individual customer needs.

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