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GENESIS DEFINITION CONCEPT OF "INDUSTRY 4.0" IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

ГЕНЕЗИС ДЕФІНІЦІЇ КОНЦЕПЦІЇ «ІНДУСТРІЯ 4.0» В КОНТЕКСТІ СТАЛОГО РОЗВИТКУ

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Гончаренко О. С., Барабаш О. О., Цзяньмін М. У. Генезис дефініції концепції «Індустрія 4.0» в контексті сталого розвитку. Оглядова стаття.

У статті представлено авторське визначення концепції Індустрія 4.0 (Industrie 4.0) в контексті сталого розвитку на основі огляду та аналізу основних її складових. Також сформовано принципи та перспектив її впровадження в Україні. Аналіз наукової літератури дозволив виділити чотири ключові компоненти Industrie 4.0: кіберфізичні системи, Інтернет речей, Інтернет послуг, Смарт фабрики. В статті визначено, що функціонування Індустрії 4.0 засновується на основі таких техніко-технологічних принципах: операційної сумісності, віртуалізації, децентралізації, управління в реальному часі, сервісної орієнтації, модульності. Для більшої комплексності та системності їх доповнено такими: системність, гнучкість, комплексність, самовідтворюваність, екологічна та соціальна відповідальність, економічна ефективність.

Ключові слова: Індустрія 4.0 (Industrie 4.0), Кіберфізичні системи, Інтернет речей, Інтернет послуг, Смарт фабрики, сталий розвиток

Goncharenko O. S., Barabash O. O., Jianming M. U. Genesis definition concept of "Industry 4.0" in the context of sustainable development. Review article.

The article presents the author's definition of the concept "Industry 4.0" ("Industrie 4.0") in the context of sustainable development on the basis of review and analysis of its main components. The principles and perspectives of its implementation in Ukraine are also formed. The analysis of scientific literature has allowed distinguishing four key components of Industrie 4.0: cyber-physical systems, Internet of things, Internet services, Smart factories. The article states that the functioning of Industry 4.0 is based on the following technical and technological principles: interoperability, virtualization, decentralization, real-time management, service orientation, modularity. For greater complexity and systemicity, they are complemented with the following: systemic, flexibility, complexity, self-reproduction, environmental and social responsibility, economic efficiency.

Keywords: "Industry 4.0" ("Industrie 4.0"), Cyber-physical systems, Internet things, Internet services, Smart factories, Sustainable development

Due to the aggravation of global environmental, social and economic problems, humanity is in a state of unceasing search for solutions. In this context, the hopes of developed countries rely on the Fourth Industrial Revolution, which in the course of the last decade, is one of the most frequently discussed topics among world community scientists ("Industry 4.0") [6, 8, 26]. Increased interest in this topic is characterized by several reasons. First, "Industry 4.0" is a priori predictable, not defined by post factum [7]. It provides enterprises and research institutions with a wide range of opportunities for active work and the formation of a "future". Secondly, a number of researchers [1] predict a huge economic effect from the introduction of a new industrial revolution. Thus, by 2025 Germany is expected to increase its GDP by 78 billion euros due to the development of "Industry 4.0".

Analysis of recent research and publications

The fourth industrial revolution, which began several years ago, was preceded by three others, which drastically changed the development of mankind. The First industrial revolution took place with the introduction of mechanization into production, starting in the second half of the 18th century, and intensifying throughout the 19th century. In the 1870s, electrification and division of labor (i. e. Taylorism) led to the Second industrial revolution [22]. The Third industrial revolution, also called "digital", originates approximately in the 1970s, when advanced electronics and information became the basis of technology and automation of production processes. The term "Industrie 4.0" became well-known in 2011, with the support of the federal government for the initiative of business

representatives, politicians and academics to strengthen the competitiveness of the German manufacturing industry [12, 23] by means of information technology, new technological and organizational innovations. The government announced that "Industrie 4.0" is an integral part of "Germany's High Technology strategy 2020". It was identified as an initiative aimed at leadership in technology innovation. In a publication [13], "Industrie 4.0" describes as follows: "In the future, enterprises will create global networks that combine their equipment and machines, storage systems and production facilities in the form of cyber-physical systems (CPS). In the production environment, these CPS include intelligent machines, storage systems, and production capacity for the autonomous exchange of information, initiation of actions and control of each other. What facilitates fundamental improvements in industrial production processes associated with production, engineering, materials and supplies management of chains and life cycle. Intelligent factories that are beginning to appear using a completely new approach to production. Smart products are uniquely identified, can be located at all times and know their own history, current status and alternative ways to achieve the target state. Embedded production systems are vertically connected with business processes within the factories and enterprises and are horizontally related to scattered networks of value which can be managed in real time - from the time the order is placed to the outgoing logistics. In addition, they simultaneously allow and require the full work of engineering throughout the chain of value creation.

Unsolved aspects of the problem

Such positive economic results contribute to increasing the relevance of theoretical and practical developments in the fields of not only developed countries, but also developing countries. Industry 4.0 is becoming a top priority for many research centers, universities and companies. However, despite this growing number of studies, there is no clarity in the definition of the concept itself and the practical mechanisms for its implementation and management [2]. Usually, authors describe the vision, the main components and possible scenarios of the concept development [13, 16], without paying certain attention to the key tenets and goals of sustainable development, which is chosen mainstream of human development. As a result of the generally accepted

definition, Industrie 4.0 has not been published so far. It is well-known that scientific researches are complicated if there are no clear definitions of an object, since any theoretical or practical study requires a reasonable terminology. Nevertheless, the situation is changing, especially in developed countries. Thus, in 2014 it was revealed that "most of the companies in Germany do not have a clear understanding of what Industrie 4.0 is and what place they will occupy in the context of its development" [16], however, in 2019, hundreds of practical cases and examples of implementation of artificial intelligence, running date, Internet of things, a new generation of robots, blockchain, 5G, etc. were represented at the "Hannover Messe" exhibition. As for Ukraine, such a tendency for it is not typical, although there are certain positive trends mainly in the development of the IT sector. As for fundamental research, the Google Academy search engine on the topic "Industry 4.0" provides results about 10.000 scientific works, including Russian-language sources and citations. Also, several powerful Internet portals were created that brought together active representatives of various institutions (enterprises, educational organizations, public organizations, active citizens, scientists, etc.) with the aim of developing and implementing the concept Industry 4.0 in the economic and social space of Ukraine. However, despite the above mentioned, discussions in the context of the Industry 4.0 concept raise more questions than answers.

The aim of the article is to present, on the basis of the review of both foreign and national literature, the author's definition of the "Industry 4.0" concept in the context of sustainable development and the definition of the principles and prospects for its implementation in Ukraine.

The main part

In the paper of the V. I. Skitsko [26] is considered in detail the interpretation of the concept "Industry 4.0" by various scientists and specialists. We use this analysis for a critical evaluation to match the key words with the goals and principles of sustainable development, the distinction of key characteristics and the components of the future definition of the concept of Industry 4.0. The evaluation results are presented in tab. 1.

As shown by the characteristics of Industry 4.0 in tab. 1, there is a large number of multi-directional definitions of this category.

Table 1. Assessment of interpretation of "Industry 4.0" in the context of sustainable development

Authors	Definition and interpretation of the concept	Keywords	Compliance with the postulates of sustainable development
1	2	3	4
H. Kagermann, V-D. Lukas [13]	"Industry 4.0" is a mean of increasing the competitiveness of the German manufacturing industry through the intensified introduction of "cyber-physics systems" in the factory processes	A tool for improving competitiveness	Does not correspond: limited by the development of industry or a separate industry

Continuation of the table 1

1	2	3	4
A team of authors led by M. Rübmann [18]	"Industry 4.0" is a vision of industrial production in the future, based on nine developments (results) of technical progress: large data and their analysis, autonomous work, simulation, horizontal and vertical system integration, industrial Internet of things, cybersecurity, cloud technologies, additive production, virtual reality.	Certain form of industrial production, characterized by technical and technological innovations based on digitalization	Does not correspond: there are no key principles of sustainable development – the social sphere, ecology
R. Schlaepfer, M. Koch, P. Merkofer [17]	The term "Industry 4.0" refers to the future stage of development of the organization and management of all processes of the value added chain involved in the manufacturing industry. The basis of this concept is the cyber-physics production systems, the merger of real and virtual worlds	Chain Management of value added	Does not correspond: there are no key principles of sustainable development, namely the principle of interdependence and the principle of diversity
W. Walster, G. Hamchyshkin [21]	"Solutions that are corresponding to "Industry 4.0" represent a single integrated process in which production equipment and products are active system components that control their production and logistics processes"	Special management process, in which the control subsystem acts including a managed subsystem	Does not correspond: there are no key goals and principles of sustainable development, namely the promotion of a careful approach to the welfare of the planet as a whole
A. Korzhebin [3]	"Industry 4.0" is the application of Internet of things in production	Technology in production	Limited by consideration of the use of "global web"
I. Hel [19]	"Industry 4.0" is the production party, which is oriented of the consumer of "Internet of Things" in which household items (from cars to toasters) will be connected to the Internet"	System that integrates people and machines	Does not correspond: there are no key goals and principles of sustainable development, uncertainty and precautions to ensure that some actions can lead to unforeseen consequences
M. Hermann [11]	"Industrie 4.0" is a generic term for technology and cost chain concepts in modular, structured, intelligent factories 4.0, in which cyber-physics systems control physical processes, create a virtual copy of the physical world, and take decent decisions. Within the cyber-physics systems, communication and collaboration takes place between the subjects (human machine, machine-machine) in real time. Internet of things are supposed to be used by participants as a tool for creating a value chain for goods and technologies	A set of technological solutions	Does not correspond: missing key goals and principles of sustainable development did not take into account that the resources of the planet are exhausted, and the consequences of uncontrolled and unstable growth is increasing the scale of poverty
A. Bespalov [3]	"Industry 4.0" involves the exchange of data among all the members of the production chain: enterprise specialists, ERP-systems, robots, products, and other systems. Products manufactured by the company within the "Industry 4.0" will "tell" to the equipment as, where, who and what it can be made. Automatic machines and production lines will independently change the configuration depending on the "inquiries" of products on the conveyor wire", and components, systems management, ERP-systems and personnel will be exchanged data on technological processes"	Characteristics of the features of technical and technological systems	The rights and obligations that include understanding the importance of universal rights and recognizing that our actions can have unpredictable consequences for present and future generations are not taken into account.
N. A. Iastreba [27]	"The onset of the fourth industrial revolution is connected with the development of global industrial networks, the creation of intellectual production (SmartFactory), the introduction of cyber-physics systems, the proliferation of automatic identification services, data collection, machine-machine interaction, etc. "	The direction of technical and technological development	Does not correspond: there are no key goals and principles of sustainable development
Jay Lee [14]	"Industry 4.0" involves the creation of intelligent installations that will have their own consciousness, themselves will carry out forecasting and interaction, as well as independently perform optimization and change of configuration. It's not just about helping people to minimize and eliminate problems, but also about implementing innovation, boosting productivity, and achieving a higher level of customer focus"	Characteristics of machines and equipment	Does not correspond: there are no fundamentals related to the social sphere and the preservation of the mineral resource base

Source: completed of the authors on the materials [26]

However, they do not all meet the main goals of sustainable development. Therefore, to formulate the author's definition of "Industry 4.0", we will consider some methodological bases. Therefore, in order to formulate a general definition, we turn to the essence of definitions creation. Thus, the definition refers to a logical operation, which: 1) reveals the meaning (sense) of the phenomenon by describing the essential and characteristic of its features, which are denoted by the given name (denote of the name); 2) explains the meaning of the term [24].

In the process of defining the term should be directly written as its value or extension (object), and / or intension (sign). If the term is clearly not connected with objects or signs, it remains a symbol that has no semantic meaning. Given the foregoing, we can describe the object of the "Industry 4.0" prevailing in the economy system of processes of production and consumption of products. Based on the definitions presented in tab. 1, as an intensional (feature), we propose to understand the high-tech system, which is based on the creation of: the means of cyber-physics systems that control physical processes, create a virtual copy of the physical world and take decentralized solutions, and communication and collaboration takes place between the subjects of these systems (man-machine, machine-machine) in real time; Internet of things, Internet of services, Smart factories. We agree with the authors [11], which determine the importance of the functioning of "Industry 4.0" based on the following technical and technological principles: interoperability, virtualization, decentralization, real-time management, service orientation, modularity. We consider it necessary for them to be more integrated and systematic to be complemented by the following: systemic, flexibility, complexity, self-reproduction, environmental and social responsibility, economic efficiency. Any system has the purpose and means of its achievement. As the goal of the "Industry 4.0", we believe that the goals set forth in the resolution of the United Nations General Assembly (UN) of September 25, 2015, "The Transformation of our World: An Agenda for Sustainable Development for the Period up to 2030", which has demonstrated the decisive intentions of the world community to move towards sustainable development, reflected in 17 goals and 169 tasks. The main tasks are as follows:

- to ensure the participation of developed countries in the transformation processes, taking into account the development of developing countries;
- to achieve rational consumption and efficient use of natural resources;
- reduce the amount of household waste by half and reduce food losses in production and distribution chains;
- by 2020, achieve rational use of chemicals throughout their life cycle and reduce emissions from NPPs;
- 2030 to reduce the volume of waste by preventing their occurrence, introduction of re-processing and

- re-use;
- maintain an up-to-date and informative statistical base on the determined indicators of production and consumption processes;
- inform people around the world about the need for SD;
- to provide assistance to developing countries in increasing their scientific and technological potential for the achievement of the SD, etc. [20]. Recall that sustainable development means development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs [4]. That is, the economy should be aimed at obtaining positive socio-ecological and economic effects. Therefore, summarizing all the above, we can formulate a general definition of the "Industry 4.0" concept as follows: it is prevailing in the economy system of processes of production and consumption of products, defined by such characteristic high-tech elements as cyber-physics systems, Internet of things, Internet of services, Smart factories based on principles of interoperability, virtualization, decentralization, real-time management, service orientation, modularity, systemicity, flexibility, complexity, self-reproducibility, environmental friendliness and social responsibility, economic efficiency, the existence of which is aimed at achieving positive environmental and socio-economic effects for society as a whole and each individual in general.

As already noted, the analysis of scientific literature has allowed to highlight four key components of "Industry 4.0": cyber-physics systems, Internet of things, Internet of services, Smart factories. Let's consider them in more detail for a deeper understanding of the concept.

Cyber-physics systems (CPS)

An important component of "Industry 4.0" is the "merger" of the physical and virtual worlds [13]. This synthesis was made possible by the creation of a CPS, the essence of which we can formulate on the basis of [14], as the integration of computing and physical processes, as a result, embedded computer systems and networks control the physical production and sales processes, usually with feedback loops, where physical processes affect the calculation and vice versa. The development of the CPS is characterized by three phases or stages. The first generation of CPS includes the following identification technologies: RFID tags, which enable the introduction of a unique identification of objects, entities of the system. The storage of information and analytical actions occurs through the central service. The second generation of CPS is characterized by the equipment of all process sensors and drives with a limited set of functions. CPS third generation is characterized by storage and analysis capabilities, equipment with multiple sensors, drives and connecting to a single network [2]. One example is the intelligent container (iBin) from Würth Company. It has a built-in infrared camera module for

controlling C-parts, which determines the number of C-parts inside the iBin. If their number falls below the safety margin, iBin automatically orders new parts through RFID. This allows to manage real-time consumption of C-parts [10].

Internet of things

According to Kagermann, the integration of the Internet of Things (IoT) and Internet of Services (IoS) into production processes and initiated the Fourth Industrial Revolution [13]. In part, we can agree with this judgment, since the IoT allows "things" and "objects" such as RFID, sensors, drives, mobile phones to interact with each other through unique address circuits and collaborate with "neighboring" "Intelligent" components to achieve common goals" [11]. Therefore, IoT can be defined as the network of which CPSs cooperate with each other through unique addressing schemes. Examples of IoT applications are smart factories, smart homes and smart grids [2].

The practical application of IoT is that, for example, SWIFT will soon make GPI-payments available on the basis of blockchain technology. As stated in the report, this solution will resolve some payment problems, as well as automate the connection to the banking system. The future system of cross-border payments by definition is global. Thus, the problem of creating and maintaining the utility and effectiveness of the "system" of cross-border payments is much greater than it could be on a single internal market.

As it is known, GPI is used to speed up money transferring, as well as to increase their transparency. According to SWIFT specialists, 55% of all international transactions are carried out using GPI technology (about \$ 40 trillion a year). Most of these transfers are done in a matter of minutes, but it happens that they hang all day. With the help of blockchain technology, all these transactions can be implemented faster, more reliable and easier.

It should be noted that the overall project of the consortium R3 and SWIFT, based on which the above report was written, originally meant the connection of the GPI Link gateway with the Corda blockchain platform for tracking transaction flows, API support for developers, and SWIFT / ISO standards [15].

Internet of services (IoS)

Internet of services enable service providers to provide their services through the Internet. IoS consists of participants, infrastructure for services, business model and the service itself. Services are created and combined by different suppliers as a result of communication with users through various communication channels [5].

Such development gives a new path to the dynamics of change and cost-sharing along a particular chain [16]. Perhaps this concept will be transferred from individual plants to entire value added networks in the future. Plants can go a step ahead and offer special production technologies, rather than simple production methods. These production technologies will be offered through IoS

and can be used to produce products or compensate for production capacities [11].

The IoS idea was implemented in the SMARTFACE project within the "Autonomics for "Industrie 4.0" program initiated by the Federal Ministry of Economics and Energy. It develops a new distributed control of production for the automotive industry. The project is based on a service-oriented architecture. This allows the use of modular assembly stations, which can be flexibly modified or expanded. Transportation between the assembly stations is provided by automated controlled vehicles. Both assembly stations and automated controlled vehicles offer their services through the IoS. The project of an uncreated vehicle "knows" the request, wishes and configurations that a specific client makes and can independently decide on the work to be done, which components need to be added to meet all the needs and interests of the client. Therefore, they can individually compile the necessary processes through the IoS and autonomously move on production [9].

Smart factory.

"Smart factories are a key feature of Industrie 4.0" [13]. "An intelligent factory is defined as a factory that helps people and machines interact in the performance of their tasks. This is achieved by the technology that allows the system to run in the background, the so-called Calm-systems technology, that is, at which the system can take into account and define context information such as geo-position and object status.

These systems perform their tasks on the basis of information coming from the physical and virtual world. Information about the physical world is for example the position or state of the instrument, as opposed to virtual world information, such as electronic documents, drawings and simulation models, etc. On the basis of the preliminary definitions of the components of the Industry 4.0, the Smart Factory can be defined as the physical space where the CPS communicates through the IoT and help people and machines perform their tasks. An example of an intellectual factory is the WITTENSTEIN factory. This is a production complex in Fellbach (Germany), whose subject matter is the production of a wide range of items, mainly for the machine-building industry. The work of the whole factory is organized according to the principles of economical production. This complex produces parts that are the carrier of the intellectual part of the work. Namely, they report when the workpiece is ready for machining or assembling, and it allows to initiate work only if there is demand for it. This helps to reduce the amount of work and free workers from unnecessary [19].

Conclusions

Summing up, we can talk about the specificity of the administration system, which combines the features of management, at the same time is a separate management unit in the enterprise, is included in the system of enterprise management and itself is a

system. The listed and examined components of the system under study reveal its essence, and further presentation of the necessary elements of the administration system in the form of indicators of the management process will enable to develop the idea of improving administrative management as one of

the important processes in the enterprise, to form a series of criteria that are determinant in the management process. On the basis of the obtained results it will be possible to compile a quantitative description of the administration system.

Abstract

Due to the aggravation of global environmental, social and economic problems, humanity is in a state of unceasing search for solutions. In this context, the hopes of developed countries rely on the Fourth Industrial Revolution, which, in the course of the last decade, is one of the most frequently discussed topics among the world community scientists. Positive economic results contribute to increasing the relevance of theoretical and practical developments in the fields of not only developed countries, but also developing countries. "Industry 4.0" is becoming a top priority for many research centers, universities and companies. However, in spite of this, a growing number of studies do not clarify the definition of the concept itself and the practical mechanisms for its implementation and management. The purpose of this article is to present, on the basis of the review of both foreign and domestic literature, the author's definition of "Industry 4.0" in the context of sustainable development and the definition of the principles and prospects for its implementation in Ukraine. The object of "Industry 4.0" can determine the prevailing in the economy system of processes of production and consumption of products. The functioning of "Industry 4.0" is based on the following technical and technological principles: interoperability, virtualization, decentralization, real-time management, service orientation, modularity. For greater complexity and systemicity, they are complemented with the following: systemic, flexibility, complexity, self-reproduction, environmental and social responsibility, economic efficiency. Any system has the purpose and means of its achievement. As the aim of the "Industry 4.0", we believe that the goals set forth in the resolution of the United Nations General Assembly (UN) of September 25, 2015, "The Transformation of our World: An Agenda for Sustainable Development for the Period up to 2030", which has demonstrated the decisive intentions of the world community to move towards sustainable development, reflected in 17 goals and 169 tasks.

Therefore, summarizing all above mentioned, we can formulate a general definition of the concept "Industry 4.0" so that it is prevailing in the economy system of processes of production and consumption of products, defined by such characteristic high-tech elements as cyber-physics systems, Internet of things, Internet of services, Smart factories based on principles of interoperability, virtualization, decentralization, real-time management, service orientation, modularity, systemicity, flexibility, complexity, self-reproducibility, environmental friendliness and social responsibility, economic efficiency, the existence of which is aimed at achieving positive environmental and socio-economic effects for society as a whole and each individual in general.

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