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Management Model Transformation in the Digital Economy

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Abstract – **In recent years there has been a rapid increase in the use of digital technologies, the role of which is steadily increasing compared to other types of technologies. The growing role of information is changing economic structures in such a way that we can talk about the formation of a new economy – the digital economy. The digital economy, according to the policy documents of the European Union "is the result of the widespread use of new information technologies, which affected all sectors of the economy." However, if we apply the methodology of economic theory, the digital economy can be understood as a set of social relations arising from the use of electronic technologies, electronic infrastructure and services, technologies for analyzing large amounts of data and forecasting in order to optimize production, distribution, exchange, consumption and increase the level of socio-economic development of states.**

Most of the papers on the sixth technological order formation and the development of Industry 4.0 focus on the study of the impact of the digital economy on the business transformation. The article shows that each technological structure of the economy corresponds to its own management conceptual model of the production and economic system. And, consequently, the formation of the digital economy foundations immanently leads to the evolutionary development of management models in socio-economic systems, which are insufficiently studied in the available works.

The article substantiates the conclusion that in the conditions of the digital economy there will be a transformation of the cost management model to the technology efficiency management model. This means that the main source of economic growth will be not just innovative development, but the search for more effective innovative technologies. In the digital economy, technology will become almost universally available, so the key to success will be new models of digital technology management, allowing for both operational regulation and modeling of future opportunities and threats of the state, business, and every member of society.

Keywords – technological order, industrial revolution, digital economy, the dominant model of management.

I. INTRODUCTION

In recent years the leading countries of the world economy actively discuss the oncoming fourth industrial revolution, which is often called Industry 4.0 [1]. The term was first coined at the 2011 Hannover Messe and was used to describe the process of fundamentally transforming global value chains through innovative, fully automated production technologies. PricewaterhouseCoopers (PwC) defines the concept of Industry 4.0 as follows: digitalization of products and services; digitalization and integration of vertical and horizontal value chains; digital business models and customer access. In fact, we are talking about the mass introduction of cyberphysical systems (Cyber-Physical Systems – CPS) based on the Internet of things (Internet of Things – IoT), self-regulating factories of printed electronics in three-dimensional printing (3D), large amounts of data (Big Data) and the widespread introduction of artificial intelligence technologies (Artificial Intelligence – IA), not only in the production of material goods, but also in almost all spheres of society and the individual's life, including his work, life, and leisure[2].

All these closely related digital technologies are prerequisites for the digital revolution that is ripening before our eyes, and to be more precise, digital technologies determine its essential characteristics, so we can conclude that the world is entering the digital era. Klaus Schwab, the president of the World Economic Forum in Davos, is the first in the world who gives general characteristics of the Industry 4.0 in his book "the Fourth industrial revolution". K. Schwab considers three major characteristics of the fourth industrial revolution to be qualitatively new: non-linear rates of development; the breadth and depth of the new stage of the digital revolution, the systemic impact of the digital world [3].

Thus, it is the use of digital technologies in their system interaction that forms a qualitatively new type of the new sixth technological order, since the system application of digital technologies is not only an unlimited expansion of production capabilities, but, according to K. Schwab, "wide and deep,

external and internal transformations of the global world, countries, industries, companies, society as a whole" [3].

In numerous works devoted to the study of the production technologies evolution, the authors' attention is mainly focused on the main characteristics and substantive aspects of the development of production and marketing systems in the digital economy, on identifying the features of the innovation cycle that is being formed in front of our eyes, and on the structural dynamics of the leading sectors of the economy and their resource support under the influence of digitalization. At the same time, insufficient attention is paid to the problems of the management system evolution, while the authors believe that each evolutionary type of economy has its own management concept of the production and economic system. And, therefore, the formation of the digital economy foundations immanently leads to the evolutionary development of management models in socio-economic systems.

The content of the management model is largely determined by the behavior of the management subjects. Systematic descriptions of production management models in the framework of a technologically evolving economy are absent in principle, and the number of models and their variations mentioned so far in the scientific literature is immense, which actualizes the problem of creating their evidence-based classification and factors of evolutionary transformation.

II. METHODS

The study is based on the comparative analysis of the dominant concepts of social production management within different technological structures, understood as an uneven process of consistent replacement of integral complexes of technologically related industries [4]. In addition, the study is based on an evolutionary methodology, according to which each technological structure corresponds to a reduction in the degree of the production system information materialization, as well as a reduction in the size of the formation processes (Table 1). Finally, the authors use a systematic approach, in which each industrial revolution corresponds to one or another technological pattern. Thus, the first industrial revolution (Industry 1.0) lasted in the developed countries in the period from the 1760s to the 1840s between the 1st and 2nd technological orders. The Industry 1.0 trigger was a massive transition from manual to machine labor, from the manufactory to the factory. Industry1.0 is associated with the advent of the steam engine and railway. During the first industrial revolution, there was a global transformation of the agrarian society into an industrial one.

TABLE I. THE EVOLUTION OF MANAGEMENT CONCEPTS WITHIN TECHNOLOGICAL STRUCTURES [4]

Time period	The dominant technological order	The dominant concept of social production management	The degree of the production system information materialization, in %	The size of the formation processes
1830	1	Management of the simplest production	15–14	1–0,2 mm
1880	2	Production Systems Management	14–13	100–50 μm
1930	3	Enterprise Management	13–11	50–10 μm
1980	4	Company management	11–9	
2000	5	Business management	9–7	10–0,5 μm
		Value management	7–5	500 – 10 nm
2020	6	Technology Performance Management	5–3	10–0,1 nm

The second industrial revolution (Industry 2.0) took place in developed countries between the end of the 1880s to the mid-1950s within the 3rd and 4th technological orders. Industry 2.0 has led to the emergence of mass production era through the spread of electricity, the development of the fuel and energy complex, the chemical industry and universal engineering. Mass production with a wide use of synthetic materials solved the problem of limited nature-technological production resources and brought the world economy to a qualitatively new development level.

The third industrial revolution (Industry 3.0) began in the developed countries since the 1960s, when semiconductors and large computers appeared –prototypes of modern personal computers – it laid the foundations of the 5th technological order. Industry 3.0 is often called the computer revolution, which is associated with the production and widespread adoption of personal computers, the widespread use of information and communication technologies and the rapid development of the Internet. Industry 3.0 is also associated with the active development of nuclear and unconventional energy, microelectronics, computer science, nano and biotechnology, and the aerospace industry.

Analysis of the world management thought history, as well as the results of our own research allowed the authors to identify the technological factors of the production management and economic systems conceptual models evolution and develop their appropriate classification.

The proposed evolutionary typology of management models is based on the ideas of I. Wallerstein on the stages of production systems development based on the analysis of the processes of technological input of information into the labor product [5]. Based on the assumptions of I. Wallerstein, it can be argued that a quantitative assessment of the economic development level is possible on the basis of the information evaluation contained in the dominant production system and its entropy.

The law of the required diversity of William Ross Ashby postulates that management consists in such a transformation of a set of states, as a result of which the probabilities of some (unwanted) controlled states decrease, and the probabilities of

others (desirable) increase, which ensures a decrease in entropy [6].

III. RESULTS

The study allows us to conclude that from the beginning of the XIX century to the present, there is a consistent change of concepts (models) of social production management, which the authors see as follows: in the early stages of development of production systems corresponding to the first and second technological orders, the main objects of management were the simplest technological processes and machines. At this stage there was a high degree of materialization of information in the production systems - about 15% and large size of the formation processes. The main criterion for evaluating the activity of an enterprise at this stage was profit. This stage, which lasted until the 1880s, was the time of the domination of the production management concept (Table 1).

It is characterized by a Management by Exception model, a linear hierarchical organizational structure of management, well implementing direct administrative, formally-directive management methods and clear management algorithms consisting of finite sets of prescriptions for obtaining a specific result or solving a problem through a finite number of operations.

From the 1880s until the 1920s, industrialization became the main source of social and economic development, and the first technological complexes appeared in the world. The achievement of higher productivity of enterprises was provided mainly by mechanization and scaling of production. During this period, the concept of management of production systems dominates. It is characterized by a slight decrease in the degree of information materialization to 13-11% and more than 10 – fold reduction in the size of the formation used and obtained in the production process: from 1 mm to 100-50 μm.

Since about the beginning of the 1930s, complex technological complexes have appeared in developed countries, knowledge of the functioning of which is dispersed among engineering, production and management personnel. There is a problem not only in coordinating technological complexes, but also in increasing the efficiency of their activities. The birth of management theory, and then its use in advanced industrial enterprises in the United States by the end of the 1920s convincingly showed that using only production factors for increasing the companies' profitability was insufficient, that enterprises are complex socio-technical systems where professional management, on the one hand, was a necessity, and, on the other hand, itself led to market success and financial and economic well-being. At this time, the methodology of bureaucratic management is formed on the basis of functional management and the corresponding organizational management structures with a multi-level management hierarchy, including planning, organization, motivation, coordination and control systems. Also, a variety of methods, directions and schools of the administrative management paradigm are formed, and with them the first mathematical algorithms for making management decisions. Management by results can be considered the dominant management model in this period of time.

By the beginning of the Second World War, there is a sharp reduction in the size of the formation processes (up to 10 μm), as well as the degree of information materialization (less than 11%), and this leads to the study of the labor psychology of all stuff categories using the achievements of behavioral sciences, since management staff lost the ability to comprehensively administer the business. In 1942–1945 for the first time there were used technologies allowing producing equipment with less than 10% of information about the technology and production systems of its creation, which virtually excluded the possibility of its direct copying without preliminary R&D and pilot production.

In 1940–1950 in developed countries the concept of company management ultimately dominates, the results of which are highly probabilistic and depend on clearly determined production processes and a variety of factors of controlled and uncontrolled variables. Therefore, when making management decisions objectively, it becomes necessary to apply mathematical logic and quantitative models for measuring and evaluating the performance of companies. During this period of time administrative, organizational, economic, as well as mathematical methods of management, based on informal and indirect indicators of the company's activities, have been developed. The increased role of professionals and intellectuals leads to the fact that the management model is institutionalized by delegating authority (Management by delegation).

In the mid-1950s, the concept of business management was formed. Under the influence of the unprecedented high post-war global demand in the USA, the USSR, the countries of Eastern and Western Europe, production volumes are booming, new industries and markets are emerging, and the product range is being updated and expanded regularly. The degree of information materialization in production systems at the same time is reduced to 9–7%, and the size of the formation processes = is reduced to 10 microns. In the structure of business costs, the volume of R&D and basic research is increasing, engineering, industrial and technological education are actively developing all over the world, and qualification requirements for personnel who carry scientific and technological knowledge are sharply increasing. The growing role of the human factor in business management leads to the rapid development of economic and socio-psychological methods of management; formation of new models and decision-making algorithms based on the wide involvement of personnel in decision-making processes in order to use its heuristic potential. All types of divisional organizational management structures are widely used. A business is viewed as a complex systemic combination of economic, technological, market, managerial, social, and production factors and its results are considered probabilistic. Thus, system concepts of control, previously used in military science, technical systems and natural sciences, "enter the economy". In the same period, cybernetics was actively developing – the science of the general laws of obtaining, storing, transforming and transmitting information in complex control systems, whether it be machines, living organisms or society. At the same time, an understanding of control algorithms is developed on the basis of set-theoretic representations: these are also precisely defined rules for solving a specific problem, but developed on a finite and ordered set of parameters that influence the management

decision making. Peter Drucker creates Management by Objective model; collaborative management (the Habsburg model of management) and models of a systems approach to management (St. Gallic model of management, models of PEST and SWOT analysis, 4P, 7S and other models) appear as new management models [7]. Within the framework of the economic bureaucracy, new adaptive (called organic) organizational management structures – design and mathematical – are widely used, flexible decision-making algorithms are developed using computer programs. In industrialized countries, domination of the business management concept lasted until the mid-1980s.

From the mid-1980s, the third industrial revolution took place first in the United States and the developed countries of Europe, and later in Asia, and the foundations of the fifth technological order were formed. The degree of information materialization in business is reduced to a critical 5–7%, the size of the production processes reduced to 0.5 μm. In the core countries of the 5th technological order, nanotechnologies are actively developing, new products and brands are being created that are focused on creating more value while further rapidly reducing the size of the end products. Electronics penetrates into all sectors of the world economy without exception and becomes itself the leading sector of the fifth technological order. If before 1990 it was possible to clearly distinguish between the production of electronic components and electronic systems, then with the achievement of the production size less than 350 nm the production of super-large integrated circuits, combining both components and complete circuits, began. Intellectual property, embodied in implicit knowledge of key technologies, in conjunction with Internet capabilities, leads to the emergence of the first virtual organizations based on the network business model, and network management structures of Internet business completely displace mechanistic (bureaucratic) management structures in high-tech sectors of the economy, which in the new conditions not only stopped working, but in principle lost their financial efficiency and economic value [8]. Management methods based on economic incentives are gradually being supplanted by the methods of self-management, which correspond to new control models (controlling, soft & self-control). The concepts of leadership, trust and emotional intelligence are actively used in business.

The fifth technological order is immanent in the concept of cost management, due to the phenomenon of globalization and its characteristic tendency to move competition from commodity markets to capital markets. The key criteria for evaluating management efficiency are maximizing the welfare of shareholders, i.e. the market value of the company and long-term discounted cash flows, the inextricably related indicators of the market value of the company and its businesses (including the valuation of intangible assets). Participatory management models and group decision-making methods are widely used. Due to the wide penetration of the Internet and information technologies into all areas of the socio-economic systems functioning, virtual organizations that produce virtual goods and services, as well as virtual means of payment appear. Decision-making algorithms within an increasingly virtual business are based on computer programming. New decision-making algorithms are a sequence of commands executed by a computer, and a set of commands is a computer program. Ubiquitous computer processing of information in various areas of life develops technologies for storing huge data arrays (Big Data), which leads to further machine learning and the emergence of the first samples of artificial intelligence (AI), whose applications are estimated by world experts limitless [9]. The role of the human factor in the management of socio-economic systems is sharply reduced and qualitatively changes: the requirements of a humanistic and ethical nature come to the fore. And the former organizational forms of doing business are being replaced by high-tech digital platforms that coordinate the work of many participants within their ecosystem. Today a wide variety of economic actors exchange data and use machine learning technology to identify and satisfy needs through the digital platforms. All business processes of the digital platform are implemented via the Internet in a software environment, which is aimed at optimizing the adoption of any decisions online. Using machine learning to interpret data in real time, individual digital platforms have achieved unattainable performance, approaching a virtual market monopoly and global competitiveness [10].

The information component on the necessary technologies and production systems reduces to the critical 5%, which leads to the fact that in the structure of the product up to 80% value is information about innovative ways of its production. The basic model of mass production becomes outsourcing, allowing owners of information (embodied in the form of a patent, license or know-how) to assign a large part of the proceeds from the production, placed on the side. Thus, economic activity in innovatively developed countries shifted from the production of goods to the provision of high-tech services, including patent-license, innovation-design, scientific-technical, research, industrial-production services, to developing countries. The source of productivity and economic growth in the core countries became knowledge spread through information processing. Global technological control models have become actively used in the world. Thus, in recent years, in all leading countries of the fifth technological order, national digital development strategies have been actively implemented, the basis of the digital economy has been formed [1,9].

IV. Discussion

Since in the sixth technological order economy "the key factors of economic activity are electronic technologies and services, as well as digitized, voluminous, diversified data, the processing and analysis of which allows, in comparison with traditional forms of economic management, to significantly increase production efficiency and quality and the consumption of goods, works and services, as well as in management procedures, those countries whose economies are based on the most advanced electronic technologies and services, including "big data" analysis technologies and forecasting technologies, have a competitive advantage"[1,2,3].

With the development of high-tech industries in the global economy, the beginnings of a new concept of technology efficiency management are emerging [1]. This means that companies, regions and national governments are looking for

sources of growth in innovative development, and scientific knowledge is increasingly generating innovation, aimed at finding more efficient technologies [11,12].

According to our estimates, the corresponding digital management model will be formed in the countries of the digital economy by 2025. Big data and digital technologies for their processing will become a new form of capital [3]. The formation, accumulation and use of this kind of capital require network interaction and active cooperation of the state, business and civil society.

The conceptual model of social and economic systems management at all levels of their functioning (from enterprise to state) will be based on the following principles:

- Receiving data in real time;
- Economic management based on automated big data analysis;
- High decision-making speed, real-time rule change – instant response to changes and interactivity of the environment;
- Orientation to a specific user, the life situations of customers as a business process (the user is getting closer thanks to mobile devices and the Internet of things);
- One-touch solutions;
- The digital ecosystem is understood as a center of synergy between the state, business, and citizens.

The formation of the digital economy and the potential for the wide dissemination of information methods of managing the behavior of an individual and a social group, and even society as a whole, create objective opportunities for the development of a model of a manipulative management (management of freedom of the person – MFP).

Thus, the digital form of providing information and the virtual nature of economic activity, the qualitative transformation of producer-consumer relationships by incorporating the latter into the production process of tangible virtual goods and services, the dynamic development of digital platforms uncontrolled by human consciousness and global scales of cyberspace indicate the presence of deep contradictions of future development and serious threats of global digital interaction.

V. CONCLUSION

In conclusion, we note once again that the key to success in the cross-border digital economy will not be the digital technologies themselves, which will become practically publicly available, but new models of technology and data management, allowing for rapid response and dynamic simulation of future challenges and problems of business, states, and each member of society. Therefore, the problems of developing new cost-effective humanistic models, methods and algorithms of socio-economic systems management in the digital age are relevant and socially significant.

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