1. ІННОВАЦІЙНІ ПРОЦЕСИ В ЕКОНОМІЦІ

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DYNAMICS OF REPRODUCTION OF ECONOMIC SYSTEMS IN THE TRANSITION TO DIGITAL ECONOMY – IN THE LIGHT OF SYNERGETIC THEORY OF DEVELOPMENT*

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The main problems of restructuring social and economic systems as a component of the formation of the digital economy are investigated in the article. The concept of "system", its elements, relationships between them, the functional environment of the system are considered. The main characteristics of the system state parameters are analyzed. It is noted that the systems are combined into larger system formations, called supersystems. The concept of system structure is defined, and its main parameters are given. Categories such as hierarchy and function play an essential role in studying the functioning of systems. The authors determined that to fulfil the tasks of its existence, any system must perform a set of interrelated functions. The more efficiently each of these functions is performed, the more efficient the whole system, and the higher the possibility of accumulation of free energy by the system, and any process of reproduction of the system should be considered as a whole, more than the sum of individual subprocesses of which it consists. Time can be viewed as another horizontal axis of measurement in which the system is formed. This dimension can be called figuratively "timeline" or "lifeline" of the system, and time parameters (sequence, duration, tempo, speed, level of synchronicity of processes, switching time) reflect the quantitative and qualitative aspects of individual processes (subprocesses) of system reproduction. The transition of society to a new formation is associated with changes in the state of socio-economic systems, an integral part of which are restructuring processes (changes in the parameters that shape their structure). The authors proposed a conditional scheme of system formation as a spatial object and process and characterized certain types of restructuring of socio-economic systems in modern digital transformations. As an illustration of such processes, structural changes in the energy sector of Ukraine for the period 2010–2020 are analyzed. This proves that the structure of economic systems is an essential subject of the management of socio-economic development, and the analysis of restructuring processes is an effective tool for justifying management decisions and regulating economic processes to ensure sustainable socio-economic development.

Keywords: *economy, information, process, restructuring, system, transformation, digitalization.*

JEL Classification: *D83, L86, O33*

Introduction. Movement and change are integral attributes of nature's existence. Human society is constantly changing. Some occur smoothly, imperceptibly, slowly transforming the appearance of social structures and production systems within existing formations. Others, commonly called revolutions, are realized through qualitative leaps, bringing the social system to a new level of social progress. This is how changes took place during the First and Second Industrial Revolutions. The first – gave humanity a car and began the emancipation of man from physical labour. The second – formed the systemic basis for implementing industrial production, which harmoniously connects the guiding principle of human intelligence with the power functions of the machine.

Today, humanity is on the verge of another revolutionary leap, which can be called, without exaggeration, unprecedented in its history. These are the industrial revolutions that started almost simultaneously – the Third (Industry 3.0), the Fourth (Industry 4.0) and the Fifth (Industry 5.0). The first is designed to transfer humanity to renewable energy sources and additive technologies based on 3D printers. This should reduce socio-economic systems' energy and resource intensity at times, and sometimes dozens of times. This will lay the foundation

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for solving urgent environmental and economic problems. Industry 4.0 allows you to transfer the implementation of production functions on the "shoulders" of cyber-physical systems, freeing the person for his social (personal) development. And the Fifth must take place in man himself so that he can live and create in a cyber world.

These revolutions are the greatest transformational phenomenon in the history of human civilization. Today, society is on the verge of another phase transition, which can be compared in importance with the qualitative leaps that humanity had to experience during the Neolithic and First Industrial Revolutions. So far, only fragmentary contours of this phenomenon are viewed in scientific publications.

Several publications (Rifkin, 2013; Rifkin, 2015; Schwab & Davis, 2018; Shahan, 2020; Skinner, 2018; Rossi, 2018; Rada, 2018) consider some aspects of transformation processes during those above modern industrial revolutions.

The economy is the key area of society that ensures the implementation of production and consumption processes. Therefore, it depends entirely on the fundamental technologies of material resources and energy production.

The synergetic theory of systems development makes it possible to understand the deep essence of this phase transition to a new socio-economic formation.

1. Trialectics of systems development.

The phenomenon of *development* is inextricably linked with the concept of a *system*. If something can evolve, it must be a system. Everything in the world – from the smallest particles to mega cosmic formations – are systems and, in turn, consists of systems.

System – any set of elements (subsystems), integrated into a single whole processes of interaction (material and information exchange) to implement a common function (achieving a common goal). A brief ancient definition of the system is a whole greater than the sum of its parts.

The basis of the formation of any system are three natural principles:

– *material and energy* (or simply – material); it *moves*, enables the system and its individual parts (subsystems) to move, transform and perform work, and therefore change and develop;

– *information – directs*; it provides the direction of movement in space and time; due to this principle, the information algorithm of interaction between individual parts of the system and the program of its development as a whole is formed;

– *synergetic – unites*; it ensures the integration of individual components of the system into a single whole.

Natural principles can manifest themselves only by interacting with each other. For example, a prerequisite for the purposeful action of energy potential is the information principle's directing (managing) influence. Without it, the force can only produce a "Brownian motion" – the unsystematic movement of the object in different directions. On the other hand, you can only direct and unite something material with *energy potential*.

Finally, can the material-energy and information principles be realized without the *synergetic* principle? In order for the system to be able to do at least some work inside or outside, its parts must act in concert, interacting with each other.

Manifesting themselves in this way, natural principles once formed and continue to reproduce different systems – systemic essences of nature: elementary particles, atoms, molecules, cells, organisms, social organizations (families, businesses, countries). They consist of the universe, the nature of our planet and human civilization. Each type of system is represented by many its units. For example, if we are talking about an electron, we need to keep many of these particles in the universe. If we are talking about a species, such as frogs or mosquitoes, we mean billions of individual individuals on the planet.

Each such unit can exist only by reproducing the three mentioned principles: *material-energy, informational and synergetic*.

Based on this, we can conclude that the nature of any of the systems that surround us (including molecules, plants or enterprises) is trialectic. On the one hand, it is a material essence, on the other – an information program, on the third – a product of coordinated interaction of nature's other systems (subsystems).

As a *material object*, the system can accumulate and expend energy while doing work.

As an *information program*, it self-organizes perceives, and processes information from the external environment, reproducing its own; simultaneously, it manages the processes of its formation, functioning, and development.

As a *synergetic phenomenon*, the system is formed in interaction, and hence mutual adjustment and adjustment, first, the parameters of its subsystems to perform system-wide functions, and secondly, the behaviour of this system with other similar systems under their supersystem level.

It is possible to form and destroy the system by influencing each of the mentioned components (principles) and the whole triune mechanism of reproduction of the system as a whole. The example of the economic system can illustrate this.

The enterprise is created by forming its main principles:

– *material* basis (fixed and working capital); this ensures the performance of force functions for the manufacture of products;

– *information*; ensures the operation of algorithms (technologies), according to which the company carries out its production and trade activities, as well as manages them;

– *synergetic*; ensure the implementation of connections inside and outside the enterprise;

integration, which forms the integral potential of reproduction of the three mentioned bases.

The company will degrade if the processes take place in the opposite direction: 1) the operation of fixed capital will be depreciated, will reduce the amount of working capital and the intensity of its movement; 2) information algorithms of operational activity and management at the enterprise will be inadequate to the current situation in time and space; 3) the interaction of links at the internal and external levels will deteriorate; 4) the self-reproducing mechanism of the enterprise will be blocked.

Over millions of years of evolution, nature has achieved in each of its creations a perfect combination of natural principles. Unfortunately, the technological systems created by humanity are still far from perfect. One of the reasons that manifested itself in industrial society's "last stages" is the imperfection of technical and organisational systems' information and synergetic foundations. The enormous energy potential accumulated by mankind is practically excessive and unproductively dissipates due to the extremely low efficiency of technical systems and high losses at the "joints" (in transactions) – between the links of the economic system.

The logic of human evolution in its advancement in the digital economy reveals a tendency to improve these "bottlenecks", ie *information algorithms* for managing production and consumption (including decision-making systems, goal setting, technology, motivation, etc.), as well as the synergistic basis (including the implementation of connections, communications, relations, etc.) the functioning of economic systems.

2. Dynamics of system-forming factors during the industrial revolutions.

To implement qualitative transformations of the economic system, the prerequisites for this must be ripe, namely, the desired state of the components of the triad of system-forming groups of factors is formed. This means that each of these groups (material-energy, information and synergetic) must meet the goals and objectives of the transformation leap and be consistent with the other two groups. Thus, in the new state, all three groups of factors must correspond to each other. At different stages of socio-economic development, the leading role of a kind of "locomotive" of change is usually played by one of the three groups of factors.

During the First Industrial Revolution (also called the Great Industrial Revolution), which usually dates back to approximately 1770–1860, the leading role in the transformation process was played by the material and energy group of factors. The main thing is that the transition from manual to machine labor was initiated.

It can be stated that both *the prerequisites of necessity* and *the preconditions of sufficiency* were of a material and energy nature. The first was related to the shortage of labour and energy resources (wood), and the second–wasduetotechnologicalandeconomicopportunities (the ability of humanity to invent the car and sufficient funds to implement it). Material factors created the impulses to transform (align) two other groups of factors – informational and synergistic.

In particular, the components that form the composition of *information factors* have begun to move. The science and technical inventions of individual craftsmen, who the unpreparedness of society had previously hampered, became significant.

The development of *synergetic factors* was also given an impetus. The production potential of factories increased and required the development of transport communications (railways, canals), on the one hand, for the supply of raw materials, on the other – for trade in finished products. It also stimulated the development of faster means of communication (including the telegraph).

The second industrial revolution was the formation of an industrial system around machines. In the course of it, it became clear that the further development of the industry requires not only a sufficient amount of energy, but also "fuel" of another kind. The industrial-factory monster, which increased in size, gained energy power, but was clumsy in its coordination, began to "suffocate" without new information ideas. They have become vital for improving production equipment, improving the accuracy of its work, improving the quality of products, and uniting into a single production facility system that has spread over long distances from sources of raw materials and consumer networks. Material and energy factors began to give way to the leadership of *the information group*.

Development of information base of influence on material-energy and synergetic group of factors. New ways of obtaining and using energy, new materials, engines, vehicles were created. Communications were improved (networks of highways, communication lines, etc. were created).

Initiating the development of the other two groups of factors (material and synergistic), *the information factors* themselves received a powerful impetus. Fundamental and applied sciences have risen. The state and individual corporations began to invest heavily in this. New means of recording, processing, transmitting and reproducing information (printing, telephone, radio, photography, cinema, video, television, computer/computer, fax, copier, printer) have emerged.

But most importantly, the new production conditions began to require new knowledge, worldview, intellectual skills and for most performers. The profession under the conditional name "white collar" (and this – engineers, employees, secretaries, managers, etc.) has become popular. There was a need to ensure general literacy, the use of new management methods, and specific methods of influencing workers, their organization and motivation.

Thus, it can be argued that the Second Industrial Revolution created more than just metal cutting machines, streaming, electricity, telephone, radio, computer, automobiles and aviation. Her creation was also a new "man-labour" – a participant in the production process, a mass worker whose activities the mental labour skills were a priority.

At the same time, there were qualitative structural changes in society. In industrialized countries, the critical majority of the population began to belong to intellectualized performers, most of whom remained employees. But it is they with their needs and financial capabilities have become mass consumers (and hence customers) of products, determining their demand.

Under the influence of the process of intellectualization of consumers, the appearance of these products is constantly changing. The component of information factors is growing, science intensity and information capacity are growing. Modern appliances, communications, housing, and personal transportation are becoming smarter, incorporating electronic controls and computer hardware. The same can be said about another part of the goods entering the market – *the means of production*. *The sphere of services* is no less information. This applies both to the services themselves (education, literature, art, shows, tourism) and the means of their production.

Summing up the results, it can be stated that *the preconditions of necessity* during the transformation processes of the Second Industrial Revolution began to be determined by the needs of intellectualized "man-labour", which at the same time became a mass buyer in the market. The rapidly growing income of the latter began to perform the functions of capital (a kind of quasi-energy of the economic system), which financially secured the demand for mass-produced products. This created *the preconditions for sufficiency* in the development of industrial society.

By the second half of the twentieth century, the possibilities of industrial society began to be exhausted, facing severe restrictions on the impact on the environment. The enormous material and energy intensity of economic systems, and the global scale of the industrial complex against the background of progressive population growth of the planet were incompatible with the real possibilities of reproduction of local ecosystems and the biosphere as a whole.

Unlike the First Industrial Revolution, the main problem is not the shortage of natural resources – the industrial technological base has learned to cope with this, particularly by replacing some source material resources with others. It has become much more difficult to solve the problem of degradation of local ecosystems and the biosphere as a whole, i.e. natural systems that ensure the assimilation potential of the planet and keep the Earth's energy system from destruction due to the overproduction of human energy.

3. Organizational and economic mechanism of functioning of economic systems in the transition to digital economy.

The main tasks to be solved by the Third Industrial Revolution (Industry 3.0) are fundamentally different from the tasks of its two predecessors – the First and Second Industrial Revolutions. During the First and especially the Second Industrial Revolutions, humanity tried to increase its material and energy capacity, competing with the elements.

The Third Industrial Revolution has historically had a different goal: to return to harmony with nature in the new wave of socio-energy development through the transformation of production systems, greening of social order, lifestyle and environmentally oriented transformation of man himself. Under such conditions, it is necessary to strive not to increase the scale, capacity and forms of social production but rather to miniaturize them, usually accompanied by increased productivity, increased functionality, and increased efficiency of economic systems.

As in the two previous industrial revolutions, in the Third – all three groups of system-forming factors of economic systems are subject to transformational shifts: material-energy, information and synergetic. However, the leadership relay passes to synergetic factors at the present stage. They are designed to integrate individual components of local economic systems into a single systemic whole – the global economy of the "spacecraft" Earth. Such integration processes occur in nature, where individual local ecosystems combine to form a single planet's biosphere.

The fact that synergetic (communication) factors became the basis of its transformation processes during the Third Industrial Revolution is explained by objective reasons.

First, in the manufacturing sector, the "centre of gravity" is transferred from large economic forms (powerful regional power plants, industrial giants, huge processing and enriching complexes, complexes) to a network of thousands and even millions of small production units – power plants, IT companies using 3D printers). They can become a productive force only if integrated into integral systems.

Secondly, the reality today is cross-border virtual production, which can only function based on perfect synergies.

Third, the operation of computer (information) control systems on principle: "smart" plant, "smart" house, "smart" city, "smart" highway, "smart" highway, "smart" country – is also impossible without analytical and integrative influence of information networks (especially the Internet).

Fourth, the Internet itself, as a basic factor in the universal memory of mankind, has become a product of the synergistic integration of local information systems based on "cloud" technologies and the Internet of Things.

In fact, the turn of the XX and XXI centuries should be considered the time of the beginning of the Third Industrial Revolution. During this period, the three significant inventions of humanity, which form the key tools of global memory: the personal computer, the Internet, and digital technology, were fully integrated into the World Wide Web. They have provided a tremendous speed (speed) of implementation at the global level of three key memory functions, namely: recording, storage and reproduction of information in all its forms (print, audio, video). This ultimately led to the explosive avalanche of social relations and technology, in particular through the transfer of the latter, as the speed of development of any system (including socio-economic) is due to the characteristics of the speed of their memory.

One of the most essential tasks of transforming the material and energy basis of the economy during Industry 3.0 is its harmonization with the natural environment. This involves primarily dematerialization of production and consumption systems, in other words, their significant "relief", ie reduction of material and energy consumption per unit of output (work performed) and per capita of the Earth, whose livelihood must be provided by all. In addition, the task of ecological harmonization of the material and energy basis necessitates the transition to organically acceptable for ecosystem metabolism substances and closed cycles of resource use. It is no coincidence that the English language uses the terms "environment friendly" and "natural sound", which means environmentally *friendly*, or *in harmony* with nature.

We must not forget about another task that is designed to solve Industry 3.0. It must change the imperative of forming the essential principles of man. In particular, the economy must move from serving mainly the material needs of the physiological and economic nature of man (i.e. "man-bio" and labour essence "man-labour") to ensuring the systematic personal development of human social essence ("man-socio").

The indicators of the transformation of the energy and transport spheres in Ukraine testify to the extremely rapid course of the Third Industrial Revolution (Table 1).

The course of the Third Industrial Revolution objectively determines the beginning of the Fourth Industrial Revolution (Industry 4.0), which, in turn, necessitates the Fifth Industrial Revolution (Industry 5.0).

The need for the Fourth Industrial Revolution is explained by the enormous information complexity of the technological systems based on which Industry 3.0 can be implemented, in particular network systems of alternative energy and additive production. Industry 4.0 started with significant revolutionary changes in production systems.

First, machines began to evolve into cyber-physical systems. They "see" and "hear" around themselves with sensory organs and "think" with a computer "brain".

The second event was that all these cyber physical systems merged into a single technical civilization. Called this phenomenon *the Internet of Things*. By communicating with each other through the Internet, things were able to make their own decisions, produce goods, move them and serve people, adapting to their desires and preferences.

The new implementation of Industry 4.0 poses another challenge for the Fifth Industrial Revolution. The fact is that cyber-physical systems that do not require the participation of the human factor displace man from the production space. This poses significant threats to the personal development of humanity. After all, without the need to solve serious economic development problems, humanity is doomed to consumer degradation. The Fifth Industrial Revolution is aimed at finding the place of man in the economic system of the cyber-physical era

According to the authors of the concept of the Fifth Industrial Revolution, a man really must leave the production processes, from which he is already displaced by cyber-physical systems and the Internet of Things. They will perform all routine, standard, monotonous and uninteresting work. But the person who will leave production will be a man of labour. She is accustomed to performing standard operations that produce standardized products for consumers with standard needs and requests.

In place of the man-labour in the production must come a completely different person – a man-personality. Instead of making products, it will create information images that will easily materialize additive technological systems with the help of 3D printers. That's how 2D printers now print everything we have invented on their displays. Moreover, the final product will materialize at the place of its destination, i.e. at the consumer's address. And what is essential – this product will be personalized, i.e. made according to consumers' wishes and preferences.

This is extremely important. After all, the main consumer will also be *a person*. And the personal development of humanity is possible only where people differ from each other, and this difference will increase.

Schematically, the changes that are made in the social landscape of these industrial revolutions in the transition to a digital economy are shown in Table 2.

During the Third Industrial Revolution, the preconditions for forming a "green" economy were laid through a threefold system of interaction of material and energy, information and synergetic factors.

Speaking about the preconditions for the modern phase transition, it is necessary to identify several key events (Figure 1). In the group of *material and energy* factors, the decisive role is beginning to play: first, the creation of competitive alternative energy with mass-energy accumulation; secondly, the formation of a fundamentally new production base based on additive technologies and 3D printers.

Economy and business are the two key areas of society that ensure the implementation of production and consumption processes. Therefore, they are fully dependent

Table 1 – Some indicators of the transformation of the energy sector in Ukraine over ten years (compiled by the authors according to Internet publications)

Indicator	Year	
	2010	2020
Renewable energy share (including hydro), %	6	16
Renewable energy share (without hydro), %	1	9
Number of private solar power plants	1	40 000
The capacity of private solar power plants, MW	0,02	1 000
Number of electric cars	1	30 000

Table 2 – The contours of the components of socio-economic systems due to modern industrial revolutions in the transition to a digital economy

Industrial revolution		
Industry 3.0	**Industry 4.0**	**Industry 5.0**
Renewable energy. Large-scale energy storage. Additive technologies (3D printers). Internet. Digitization. Horizontal structures of the organization. Solidarity economy. Digitization of social space. Electrification and hydrogenation of transport. Biotechnology (genetic modification, hydroponics, 3D printing). Virtualization of the production process. GPS. New materials	Artificial Intelligence. Internet of Things. Circular economy. "Smart" network systems (enterprise, city, territory). Unmanned vehicles. Blockchain implementation. Digitization of management. Self-organized work. Cybergization of the physical world	Harmony of physical, informational and biological spheres. Dialogue between man and artificial intelligence. Individualization of needs. Individual human biomonitoring. Individualization of human communications. Sociologization of man. Human cyberization. Personalization of production and consumption

Source: (compiled by the authors based on publications: Rifkin, 2013; Rifkin, 2015; Schwab & Davis, 2018; Schwab, 2017; Shahan, 2016; Skinner, 2018; Rada, 2018; Rossi, 2018)

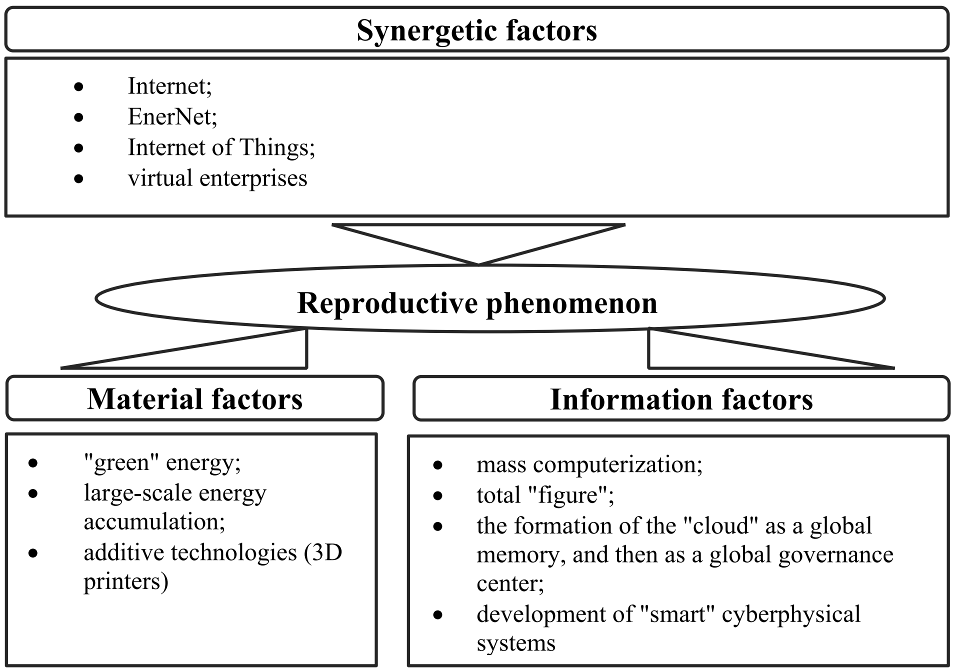

Figure 1 – Formation of prerequisites and relevant breakthrough technologies for the implementation of modern phase transition

Source: compiled by the authors

on the fundamental technologies of material resources and energy production.

In the group of *information* factors, along with mass computerization, the most important role is played by: first, the creation of a single ("digital") basis for recording and transmitting information that provides communication: human to human, human to machine and machine to machine; secondly, the formation of the "cloud", ie the global memory system, which is increasingly beginning to perform the functions of a kind of control centre; third, the use of artificial intelligence and "smart" cyber-physical systems ("Internet of Things"). In the group of *synergetic* factors, the decisive influence is exerted by: the total networking of economic systems and social life based on the Internet; the formation of horizontal production and consumer structures; emergence of intercontinental virtual enterprises.

Conclusions. It should be noted that in the phase transition to the digital economy, the leading role belongs to man. The development of the personal principle of man is designed to take a leading place in the system of goals and values of future society. At the same time, all human life needs will have to be met by automated cyber-physical systems (including the Internet of Things). In this way, a person can be exempted from participating in routine production operations in the name of developing the personal (social) principle and creative abilities of a person.

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This, however, characterizes only one of the possible evolutionary trajectories of mankind. To implement such a scenario, one of the most important conditions must be met: the phase barrier must be overcome. The main part of its components is contained within the person.

And the fact that, along with the Third and Fourth Industrial Revolutions, humanity has contemplated the Fifth Industrial Revolution, which focuses on the development of *the individual*, leaves hope for a favourable verdict on history itself.

Whatever the case, the first results of the rapid process of the Third and Fourth Industrial Revolutions (avalanche-like process of development of "green" energy, electrification of transport, rapid development of additive technologies, transition to "digital", the emergence of "cloud" as a single global memory system, implementation artificial intelligence and "smart" machines, human cyborgization, the launch of the Internet of Things and more) create the impression of "non-random" events. This, in turn, leaves some hope that man himself will take a worthy place in the world to come.

However, there is very little time left for a person to solve the most challenging problems of phase transition. After all, the phase transition has already begun, and the issues that arise will have to be solved "on the fly".

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ДИНАМІКА ВІДТВОРЕННЯ ЕКОНОМІЧНИХ СИСТЕМ ПРИ ПЕРЕХОДІ ДО ЦИФРОВОЇ ЕКОНОМІКИ – В СВІТЛІ СИНЕРГЕТИЧНОЇ ТЕОРІЇ РОЗВИТКУ

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У статті досліджено основні проблеми реструктуризації соціально-економічних систем як складової формування цифрової економіки. Розглянуто поняття «система», її елементи, взаємозв'язки між ними, функціональне середовище системи. Проаналізовано основні характеристики параметрів стану системи. Зазначено, що системи об'єднуються у більші системні утворення, які називаються надсистемами. Визначено поняття структури системи та подано її основні параметри. У дослідженні процесів функціонування систем дуже важливу роль відіграють такі категорії, як ієрархія та функція. Авторами визначено, що для виконання завдань свого існування будь-яка система має здійснювати комплекс взаємопов'язаних функцій. Чим ефективніше виконується кожна з зазначених функцій, тим ефективніша діяльність усієї системи, і тим вища можливість накопичення системою вільної енергії, а будь-який процес відтворення стану системи слід розглядати як ціле, що більше суми окремих підпроцесів, з яких воно складається. У свою чергу, час умовно можна вважати ще однією, горизонтальною віссю вимірів, у яких формується система. Цей вимір може бути названий образно «лінією часу» або «лінією життя» системи, а параметри часу (послідовність, тривалість, темп, швидкість, рівень синхронності процесів, час перемикання) відображають кількісні та якісні сторони реалізації окремих процесів (підпроцесів) відтворення системи.

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Перехід суспільства до нової формації пов'язаний із зміною стану соціально-економічних систем, невід'ємною складовою чого є процеси реструктуризації (зміни параметрів, які формують їх структуру). Автори запропонували умовну схему формування системи як просторового об'єкта та процесу та охарактеризовано окремі види реструктуризації соціально-економічних систем в ході сучасних цифрових трансформацій. Як ілюстрація таких процесів проаналізовано структурні зрушення в енергетичному секторі України за період 2010–2020 років. Це доводить той факт, що характеристики структури економічних систем є важливим предметом управління соціально-економічним розвитком, а аналіз процесів реструктуризації є дієвим інструментом обґрунтування управлінських рішень та регулювання економічних процесів з метою забезпечення сестейнового соціально-економічного розвитку.

Ключові слова: *економіка, інформація, процес, реструктуризація, система, трансформація, цифровізація.*

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