2. ІННОВАЦІЙНІ ПРОЦЕСИ В ЕКОНОМІЦІ

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INSTRUMENTS FOR ENSURING THE PHASE TRANSITION OF ECONOMIC SYSTEMS TO MANAGEMENT BASED ON INDUSTRIES 3.0, 4.0, 5.0

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The article develops the concept of key categories related to the phase transition to a new socio-economic formation: industrial revolutions Industries 3.0, 4.0, 5.0; the transition implementation mechanism; transformational processes; trialectic mechanisms of system formation. The key features of the economic system, which can be formed through a phase transition, are conditionally characterized. In particular, such an economy can be called a sustainable economy because it ensures the achievement of sustainable development goals. The essence of modern industrial revolutions (Industries 3.0, 4.0, 5.0) is revealed through which the specified phase transition is realized. In particular, Industries 5.0 is a phenomenon of human adaptation to a cybergized environment, during which the personal basis of a person develops, in particular, based on the synergistic integration of human cognitive abilities and artificial intelligence, as well as human biological nature and technical means. Based on a trialectic view of the system-forming factors of the beginning (material, informational and synergistic), the key groups of instruments for ensuring the specified phase transition were characterized, in particular, the group of instruments that provide the material prerequisites for the implementation of the phase transition can include: the introduction of alternative energy; large-scale energy accumulation; implementation of additive technologies (3D printing); formation of cyber-physical systems; implementation of the Internet of Things; miniaturization of economic assets. In the group of information prerequisites, the following instruments can be listed: mass computerization; sensory revolution; dematerialization of economic systems; the formation of the cloud as a global memory system and a global control centre; mass adoption of RFID tags. The group for ensuring synergistic prerequisites consists of globalization of Internet communications; creation of EnerNet (unified information and energy systems); creation of a global GPS; transition to network economic systems; formation of virtual enterprises.

Keywords: *phase transition, economic system, Industry 3.0, Industry 4.0, Industry 5.0, socio-economic formation, digital transformations.*

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Relevance of the research topic. Humanity is in a phase transition (PhT) to a new socio-economic formation. A feature of phase transitions in both physical and social systems is that during them, the properties of the system change in leaps and bounds due to continuous changes in external factors. These can be temperature, pressure, and electromagnetic fields for physical systems. For economic systems – the environment's characteristics, the planet's population, etc.

We are witnessing such transformational changes that are taking place during three industrial revolutions (Industries 3.0, 4.0, 5.0). It is becoming increasingly obvious that individual revolutionary changes in the technical and social spheres are links to a single systemic phenomenon, during which the PhT to a new socio-economic formation is realized.

Analysis of recent research and publications. The works of leading scientists analyze the processes and phenomena of this phase transition (Evans, 2011; Horx, 2020; O'Neill, 2017; Rada, 2018; Rifkin, 2013; Rifkin, 2015; Rossi, 2018; Schwab et al., 2018; Shahan, 2016; Skinner, 2018; Vollmer, 2018; Zennaro, 2017). This makes it possible to formulate the main features of the socioeconomic formation of society is approaching transformational processes (Figure 1).

The purpose of the article is to study directions for the formation of instruments for ensuring the modern phase transition to a new socio-economic formation based on the analysis of the triune system of the essence of system-reproducing factors.

Scientific method. The theoretical and methodological basis of research is based on the systematic approach of the subsequent analysis of the processes and phenomena of the phase transition to a new socio-economic formation and the analysis of statistical data characterizing the course of transformational processes.

Characteristic of the developing socio-economic system. Today, the contours of the economic system with which the mentioned phase transition should end are already clearly visible. Conventionally, it can be called:

– *Sustainable* because it ensures the achievement of the goals of sustainable development;

– "*green*", as it is aimed at greening the production complex, in particular, the use of renewable ("green") natural resources and the transition to circular technologies;

– *informational*, as information becomes a basic factor in the production and consumption of products;

– *network*, since networks are becoming the main organizational form of functioning and communication of production systems;

– *cyber-physical,* since the management of the functioning of production systems is moving to cyber-physical systems, including those based on "smart systems" and cloud technologies;

– *solidary,* as there is a consolidation of social capital and a transition to sharing systems of product consumption;

– *social*, since social (personal) development becomes the primary goal of the existence of civilization.

Characteristics of modern industrial revolutions. The implementation of Industries 3.0, 4.0, and 5.0 revolutions takes place in the conditions of their mutual conditioning and interaction of the processes that caused them.

The third industrial revolution (Industry 3.0) arose as a reaction of the production system to environmental problems that the current socio-economic formation cannot solve. It is probably impossible to give a simple

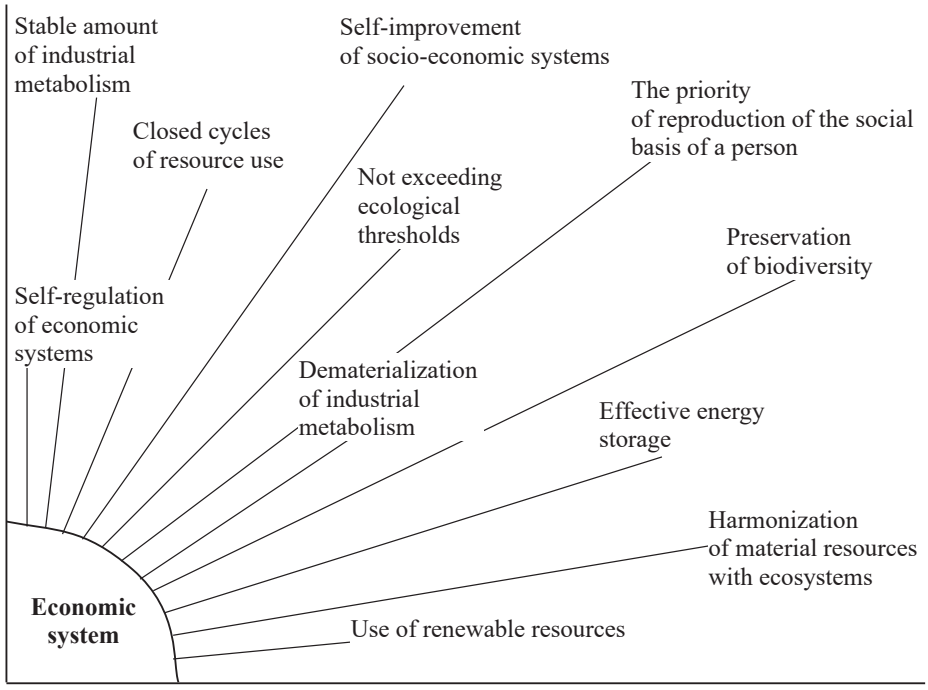

Figure 1 – Key features of the future economic system

definition of Industry 3.0 as any complex, multidimensional phenomenon. With this in mind, Industry 3.0 can be defined by formulating its basic distinguishing features.

Industry 3.0 is a phenomenon of radical qualitative transformation of socio-economic systems, characterized by the following processes: the transition to renewable sources of energy and raw materials, the mass introduction of additive technologies and network production systems, the digital basis of recording and transmission of information, the formation of horizontal production and consumer structures and corresponding them of solidary forms of economic relations.

Industry 4.0 is a phenomenon of the introduction of cyber-physical systems into the processes of production and consumption of products, which gives rise to fully automated networks capable of operating without direct human participation (Industry, 2016; Shahan, 2016).

Industry 5.0 is a phenomenon of human adaptation to a cybergized environment, during which the personal basis of a person develops, in particular, based on the synergistic integration of human cognitive abilities and artificial intelligence, as well as human biological nature and technical means. In Industry 5.0, machines and people work together to achieve optimal results.

As can be understood from what has been said, the need for the Fifth Industrial Revolution arose as a need for humanity to respond to the course of the Third and Fourth Industrial Revolutions (mainly the Fourth), the pace of which is staggering. The latter can be judged at least from the dynamics of individual indicators (Table 1).

Instruments for ensuring phase transition. The formation of phase transition instruments takes place based on the systemic mechanism of reproduction of socio-economic systems.

Any system has a trialectic nature of its formation. This means it is not only a material and energy object but also an information entity, defining a certain information algorithm for the mutual construction of system parts in space and a program of their development in time. The third natural principle is the synergistic phenomenon, which ensures the realization of the interaction links between individual parts of the system and the links of the system itself with the external environment.

In the system's functioning processes, the mentioned natural principles perform various functions. *The material-energy* principle performs a power function, ensuring the implementation of any types of movement (and, therefore, changes) within the system and during its interaction with the external environment. *The information* principle directs the action of energy impulses and thus ensures the process's purposefulness and efficiency. *The synergistic* principle unites the actions of individual parts of the system into a single whole, ensuring mutual consistency of subsystem actions and functions. It also ensures the integration of this system as a subsystem part in the external environment.

Thus, the PhT of the system to its new level can take place only if all three principles that form the system's content are rebuilt. For example, if there is a desire to increase the car's power, it is enough to install a more powerful engine in it. The entire layout of the technical part of the machine must be changed (in particular, the fuel supply system). In addition, it is necessary to change the system of interaction of individual components of the car that make the transition from one mode of operation to another and much more.

If we are talking about PhT in socio-economic systems, it is appropriate to note that the change of any key components of their functioning to one degree or another leads to a change in all spheres of society's related activity.

In particular, the transition from truck to road transport led to the development of the automobile industry and its research and development divisions. And this gave an impetus to developing the metallurgical and chemical industry to create the necessary materials. Road construction was carried out, traffic rules were created, a specific credit and banking system was created, an oil refining industry was formed, a gas station system was created, a tanker fleet and the corresponding infrastructure were built, and many other transformations were carried out. But the most important thing is that it led to the internal restructuring of the person himself. It was necessary for people to significantly increase the level of their technical literacy, change the rhythm and style of life, and ensure self-discipline during the operation of technical means and driving on the roads.

Table 1 – Dynamics of socio-economic development indicators from 2000 to 2020 (Melnyk, 2020)

Indicator	Value	
	2000	2020
Number of personal computer users, million units	140	5200 (about 70% of the world's population)
Number of unique mobile phone users, million units	109	5170 (67% of the world population)
Number of Internet users, million units	361	4574 (60% of the world population)
Share of renewable energy, %	1	33
World energy storage capacity, GW/GWh	<1/<1	12/21 (1095/2840 – forecast for 2040)
Number of 3D printers, pcs.	1 (prototype)	17 million (70% of companies use it)
Number of devices connected to the Internet of Things, pcs.	6	30 billion
Number of industrial robots, thousand pcs.	742	3000
Share of digital information, %	<50 %	99%
The amount of information produced in the world, zetabyte	<1	44

As we can see, the PhT in this transport sector caused the transformation of all three natural principles in the systems that provided it. The following were changed:

– *material and energy* factors (new technological means and energy carriers for them have been created);

– *an information* system that ensures their functional development (established research and development works, training of special personnel and drivers, etc.);

– *synergistic* factors (a mandatory system of traffic rules, communication arteries, means of mutual notification, etc. was created).

Without all these transformations, humanity could not carry out this PhT and overcome the corresponding phase barrier.

Speaking about the prerequisites for the modern phase transition, it is necessary to highlight a number of key events. In the material and energy factors group, the following are beginning to play a decisive role: first, creating a competitive alternative energy industry with massive energy accumulation; second, forming a fundamentally new production base based on additive technologies and 3D printers.

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, which ensures communication: the man with man, man with machine, and machine with machine; secondly, the formation of a "cloud", that is, a global memory system, which is increasingly beginning to perform the functions of a kind of control centre; thirdly, the use of artificial intelligence and "smart" cyber-physical systems ("Internet of Things").

In the group of *synergistic* 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.

Numerous facts convincingly evidence the fact that the phase transition has already begun. We will mention only some of them (Table 2).

Toolkit for ensuring phase transition at the level of companies and enterprises. The phase transition also affected the work of enterprises. Their economic system has been transformed. Thanks to Industries 3.0, 4.0 and 5.0, we are seeing significant changes in how businesses operate, and the instruments enabling businesses to move from one industry to another have also changed. Companies are forced to comply with phase transitions to remain competitive, and putting the right instruments in place can help ensure a smooth transition. Let's present the main instruments that can contribute to the breakthrough stage of the transition to Industries 3.0, 4.0 and 5.0.

Data Analytics. Industry 3.0 focuses on process automation and using computers for manufacturing processes in manufacturing. In Industry 4.0, data analytics is key. Companies that can collect and analyze data about their operations can optimize processes and make better decisions. They can use data analytics to identify trends, improve equipment performance and improve sales. In addition, companies can use artificial intelligence and machine learning to analyze huge amounts of data, automate tasks, and make predictions.

Internet of Things (IoT). The Internet of Things is an essential component of Industry 4.0. It refers to the interconnection of devices and sensors, allowing them to communicate and exchange data. Companies can use the Internet of Things to streamline operations and improve efficiency. For example, manufacturers can use IoT to monitor the health of machines, detect problems early, and plan maintenance before a breakdown occurs. In addition, IoT can be used in logistics to track deliveries, control inventory levels, and optimize delivery routes.

Cloud computing. Cloud computing is an important instrument for companies moving towards Industry 4.0. This allows businesses to store and access data and software over the Internet rather than on local servers. This makes it easier for companies to access information from anywhere, collaborate remotely with partners, and scale operations as needed. In addition, cloud computing providers offer artificial intelligence and machine learning

Table 2 – Instruments for ensuring a phased socio-economic transition

A group of factors	Security instruments
Synergistic factors	– globalization of Internet communications; – creation of EnerNet (unified information and energy systems); – creation of a global GPS system; – transition to network economic systems; – formation of virtual enterprises
Information factors	– mass computerization; – sensory revolution; – dematerialization of economic systems; – formation of the cloud as a global memory system and a global control center; – mass introduction of RFID tags
Material factors	– introduction of alternative energy; – large-scale energy accumulation; – introduction of additive technologies (3D printing); – formation of cyber-physical systems; – implementation of the Internet of Things; – miniaturization of economic assets

services that can help companies analyze and understand their data.

Robotics and Automation. Robotics and automation have been actively introduced since Industry 3.0, but they have evolved significantly in Industry 4.0. Companies may use robots to perform tasks that are too dangerous, difficult, or repetitive for humans. They can also use automation to streamline processes and reduce errors. For example, robots can be used in manufacturing to assembling products, while automation can be used in logistics to sort and pack goods.

Virtual and augmented reality. Virtual and augmented reality technologies are becoming increasingly popular in Industry 4.0. These instruments allow companies to create immersive experiences for their employees and customers. For example, a manufacturer can use virtual reality to train workers on complex equipment or simulate dangerous scenarios. In addition, retailers can use augmented reality to let shoppers try on clothes or see how furniture would look in their home.

The instruments required for companies to break through phase transitions to Industries 3.0, 4.0, and 5.0 iffer due to different technological advances and shifts in emphasis between each industry. The classification of the main instruments for each Industry is presented in Table 3.

In general, instruments specific to each Industry build on previous ones, incorporate new technological advances, and shift the focus to new areas of development. Industry 3.0 has focused on automating manufacturing processes, while Industry 4.0 has emphasized integrating digital technology with manufacturing. Industry 5.0 focuses on collaboration between humans and machines to achieve new levels of productivity and efficiency.

Companies need to transform instruments to adapt to the phase transition to Industry 5.0., which focuses on collaboration between humans and machines. Therefore, companies must implement instruments that allow them to work together seamlessly. For example, companies can use brain-computer interfaces to allow employees to control devices with their thoughts or use haptic feedback to communicate with machines through touch. Already, companies are actively implementing exoskeletons that help increase productivity and keep their human capital healthy.

In general, combining the right instruments can help companies make a breakthrough in the transition phase to Industries 3.0, 4.0 and 5.0 and control it.

Measuring the effectiveness of instruments to ensure a phase transition. Managers can measure the effectiveness of the instruments that help them transform from one industry to another. To do this, you can use qualitative and quantitative methods, most of which the leading companies have already implemented in their business activities. The following metrics may be useful to consider:

Performance Metrics. Managers can measure the effectiveness of instruments by tracking performance metrics such as throughput, efficiency, quality, and profitability. For example, if a company has implemented an IoT system to monitor the condition of machines, it can measure the number of breakdowns, repair time, and downtime to evaluate the system's effectiveness.

User Reviews. Managers can collect employee feedback using the instruments to identify issues and areas for improvement. For example, if a company has implemented a virtual reality system to train employees on complex technology, it may collect employee feedback to determine the effectiveness of the training. If a company has implemented an augmented reality system that allows customers to try on clothes virtually, it can measure the impact on customer satisfaction and sales.

Cost Savings. Managers can measure the effectiveness of instruments by evaluating the cost savings they provide. For example, a company implementing a robotic automation system to perform repetitive tasks can measure labour and time savings.

Return on investment (ROI). Managers can measure the effectiveness of instruments by calculating the return on investment. For example, if a company has invested in a data analytics system, it can calculate the ROI by comparing the cost of the system to the financial benefits generated by the system, such as increased revenue or cost savings.

In general, managers should use a combination of these approaches to measure the effectiveness of instruments used in Industries 3.0, 4.0 and 5.0. They should also regularly evaluate and adjust their methods to maximize the benefits of these instruments.

Prospects for further research. Phase transitions, through which society moves from one industry to the next, are based on the development of technology and the transformation of society's needs. Deeply analyzing modern development trends, with a certain degree of probability, we can assume that the next industrial revolution will be associated with the following areas:

Table 3 – Instruments for ensuring phase transition of companies to Industries 3.0, 4.0 and 5.0

Indusry 3.0	Indusry 4.0	Indusry 5.0
– automation of production processes; – intensification of the use of computers and electronics; – computer-aided design and manufacturing (CAD/CAM); – programmable logic controllers (PLCs); – machine tools with numerical control (CNC)	– big data analytics; – machine learning; – artificial intelligence; – augmented and virtual reality; – robotics and automation; – cloud computing; – internet of things; – implementation of blockchain technologies	– brain-computer interfaces; – tactile feedback; – advanced robotics; – process management based on artificial intelligence

1) *Additive economy.* Formation of an additive economy based on the wider adoption of 3D printing and additive manufacturing. Although 3D printing and additive manufacturing have been around for a while, they are still in the early stages of adoption in many industries. The next industrial revolution may lead to a wider adoption of these technologies and their integration into mainstream manufacturing processes (Melnyk, et al., 2022).

2) *Sustain production*. With growing concerns about climate change and environmental sustainability, the next industrial revolution could focus on developing sustainable manufacturing processes and products based on the recycling economy 2.0 with deeper recycling levels.

3) *Digital production*. With the increasing sophistication of robotics and artificial intelligence, the next industrial revolution may focus on developing fully autonomous manufacturing processes that can be controlled and controlled remotely from digital devices.

4) *Quantum computing.* Quantum computing has the potential to revolutionize many industries, including manufacturing. The next industrial revolution could lead to integrating quantum computing into manufacturing processes, making manufacturing processes more efficient and effective.

5) *Nanotechnology*. Nanotechnology involves the manipulation of matter at the nanoscale and has many potential applications in manufacturing, including the development of stronger and lighter materials, new manufacturing technologies, and more efficient energy storage systems.

The presented directions are connected with modern scientific developments and breakthrough innovations. It is important to note that the result will depend on many factors, including technological progress, societal needs and economic conditions.

Conclusions. Thus, we can conclude that the phase transition of the economic system describes qualitative changes in the structure and functioning of the economic system in response to changes in external and internal factors. This concept can be used to describe the transition of an economy from one phase of development to another when there are global changes in the economic structure, technological capabilities, social relations, political conditions, or other key factors.

The phase transition of economic systems takes place based on changes in material and energy, informational and synergistic factors that occur simultaneously or influence each other. The three latest industrial revolutions, Industry 3.0, 4.0, and 5.0, determine the need to form a theory of the phase transition of economic systems at both the macro and micro levels. As a result of phase transitions, we can already observe the emergence of such economies as sharing, sustain, creative, knowledge economy, artificial intelligence economy, etc.

Therefore, the toolkit for ensuring the phase transition of economic systems to management based on industries 3.0, 4.0, and 5.0 requires a more detailed classification and development of methods for its implementation and performance control.

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ІНСТРУМЕНТАРІЙ ЗАБЕЗПЕЧЕННЯ ФАЗОВОГО ПЕРЕХОДУ ЕКОНОМІЧНИХ СИСТЕМ ДО ГОСПОДАРЮВАННЯ НА ЗАСАДАХ ІНДУСТРІЙ 3.0; 4.0; 5.0

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У статті формується поняття про ключові категорії, пов'язані з фазовим переходом до нової соціально-економічної формації: промислові революції Industries 3.0, 4.0, 5.0; механізм реалізації переходу; трансформаційні процеси; триалектичні механізми системоутворення. Умовно характеризуються ключові риси економічної системи, яка може бути сформована через фазовий перехід. Зокрема, така економіка може бути названа сестейновою, адже вона забезпечує досягнення цілей сестейнового (sustainable) розвитку. Розкривається сутність сучасних промислових революцій (Industries 3.0, 4.0, 5.0), через які реалізується зазначений фазовий перехід. Зокрема, Industries 5.0 – це явище адаптації людини до кібергізованого середовища, за якого отримує розвиток особистісна основа людини, зокрема і на основі синергетичної інтеграції когнітивних здібностей людини і штучного інтелекту, а також біологічної природи людини і технічних засобів. На основі триалектичного погляду на системоутворювальні фактори начала (матеріальні, інформаційні й синергетичні) були охарактеризовані ключові групи інструментів для забезпечення зазначеного фазового переходу, зокрема, в групу інструментів, що забезпечують матеріальні передумови реалізації фазового переходу можна занести: впровадження альтернативної енергетики; масштабне акумулювання енергії; впровадження адитивних технологій (3D принтингу); формування кіберфізичних систем; впровадження Інтернету речей; мініатюризація економічних активів. В групі інформаційних передумов можуть бути перелічені інструменти: масова комп'ютерізація; сенсорна революція; дематеріалізація економічних систем; формування хмари як глобальної системи пам'яті та всепланетного управлінського центру; масове впровадження міток RFID. Групу забезпечення синергетичних передумов складають: глобалізація Інтернет-комунікацій; створення ЕнерНету (єдиних інформаційно-енергетичних систем); створення глобальної системи GPS; перехід на мережеві економічні системи; формування віртуальних підприємств.

Ключові слова: *фазовий перехід, економічна система, Industry 3.0, Industry 4.0, Industry 5.0, соціально-економічна формація, цифрові трансформації.*

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