ISSN-L 2664-9969; E-ISSN 2706-5448

UDC 330.342.24
JEL Classification: O31, O33, O38
DOI: 10.15587/2706-5448.2025.331232

Viktoriia Prokhorova,
Svitlana Mushnykova,
Iryna Abernikhina,
Yanyna Yukhman,
Olena Makovoz,
Krystyna Slastianykova

INNOVATION CYCLES AS A STRATEGIC METHODOLOGICAL OBJECTIVITY OF THE NEW TECHNOLOGICAL PARADIGM OF SOCIO-ECONOMIC DEVELOPMENT

The object of research is the processes of socio-economic development in the context of technological transformation, taking into account innovation cycles. The paper examines the role of innovation cycles as a strategic methodological objectivity that determines the dynamics of socio-economic development in the context of the transition to a new technological paradigm. The relevance of the topic is due to the global challenges of our time: digitalization, digitalization of the economy, development of artificial intelligence, transition to a green economy and the need to formulate adaptive development strategies that can respond to the pace of technological change. Innovation cycles are viewed as a multi-stage process that includes emergent ideas, new technologies, mass adoption of innovations and their impact on the structure of production, employment and institutional models.

On the basis of historical and theoretical analysis, the paper traces the evolution of industrial revolutions – from Industry 1.0 to the anticipated Industry 6.0. It is noted that each new phase of industrial development is accompanied by the formation of a new technological paradigm that changes the principles of interaction between technology, capital, labor and knowledge. Industry 6.0, as the expected next stage, is associated with the symbiosis of artificial and biological intelligence, autonomous economies, decentralized management structures and value-oriented innovation development.

The author substantiates the need to understand innovation cycles not only as an empirical phenomenon, but also as a methodological basis for strategic planning. In this context, the paper proposes a conceptual model that provides for the integration of cyclical analysis into the processes of state regulation, forecasting and formation of sustainable growth policies. The conclusions presented are of interdisciplinary importance and can serve as a basis for further research in the fields of economics, sociology, public administration and technological development.

Keywords: *innovation cycles, technological paradigm, industrial revolution, strategic management, socio-economic transformation.*

Received: 03.03.2025
Received in revised form: 27.04.2025
Accepted: 20.05.2025
Published: 02.06.2025

How to cite
Prokhorova, V., Mushnykova, S., Abernikhina, I., Yukhman, Y., Makovoz, O., Slastianykova, K. (2025). Innovation cycles as a strategic methodological objectivity of the new technological paradigm of socio-economic development. Technology Audit and Production Reserves, 3 (4 (83)), 100–105. https://doi.org/10.15587/2706-5448.2025.331232

1. Introduction

In today's context of global transformation of socio-economic systems, innovation processes that shape new technological modes and determine the vectors of society's development are of particular importance. One of the key concepts that allows to understand the dynamics of such processes is innovation cycles – periodic waves of technological renewal that significantly affect the productive forces, economic structure and social institutions. In the context of the formation of a new technological paradigm, innovation cycles are not only an empirical phenomenon, but also a strategic methodological objectivity that opens up opportunities for targeted development management.

The study of the nature, patterns, and methodological foundations of innovation cycles allows to better understand the mechanisms of society's adaptation to radical technological change, which is extremely relevant in light of current challenges, from digital transformation to environmental modernization. In view of this, the analysis of innovation cycles in the context of strategic management is becoming an important scientific and practical issue that requires a comprehensive interdisciplinary approach.

The modern era is characterized by a rapid change in technological modes, where digital transformations, artificial intelligence, biotechnology, and energy innovations radically alter production and socio-economic processes. In this context, innovation cycles act as a key indicator and development mechanism that determines the strategic directions of transformation of the economy, society and public administration. The formation of a new technological paradigm requires not only the introduction of the latest technologies, but also a deep understanding of their methodological status, the logic of the evolution of innovations and their social consequences. That is why the study of innovation cycles as a strategic methodological objectivity is relevant given the need for new approaches to change management, adaptation of economic policy, and sustainable development.

Noting the multifaceted and multidisciplinary nature of the topic, it is possible to focus on several aspects, namely: studies aimed at defining the innovation cycle; changes in technological paradigms and individual components of the innovation cycle.

Studies [1, 2] consider innovation cycles as periodic phases of renewal that reflect the dynamics of the innovation environment in the economy. In [2], attention is focused on the relationship between the stages of the innovation life cycle and management strategies, emphasizing the importance of adaptive models in the context of technological change. Paper [1] develops the idea of cyclical innovation renewal at the macro level, analyzing the impact of global challenges on innovation policy. Both authors emphasize the need to strategically anticipate the next phases of innovation development.

The issue of technological paradigmaticity is discussed in [3, 4]. The authors of [3] study the evolution of scientific discourse in the educational and technological context, defining paradigms as knowledge systems that influence management and research practices. Paper [4], in turn, emphasizes the importance of reflection within the framework of changing technological modes, pointing to a shift in focus from technocentrism to humanities-oriented models. These works demonstrate that the paradigm shift encompasses not only technical but also cultural and social dimensions.

Some elements of the innovation cycle are the innovation lag and certain types of innovations. In [5, 6], the innovation lag is interpreted as a key barrier to the introduction of new technologies. Both authors identify external and internal factors that affect the duration of the lag, including institutional unreadiness, infrastructure constraints, and investor caution. They propose the development of tools to reduce the lag as a means of increasing the innovation efficiency of the economy.

Works [7, 8] provide a detailed classification of innovations by novelty, functional purpose, scope, etc. The authors emphasize the importance of a differentiated approach to managing different types of innovations, including products, processes, organizational and social. The authors also emphasize the need to take into account the specifics of industries and the level of innovation culture.

However, the impact of the stages of industrial evolution on the duration of innovation cycles, combined with the challenges to the new technological paradigm within the framework of strategic management, has not been sufficiently considered by either domestic or foreign researchers and scholars.

The aim of research is to substantiate the role of innovation cycles as a strategic methodological objectivity in the formation of a new technological paradigm of socio-economic development. This will make it possible to identify effective tools and mechanisms for influencing the long-term transformation of socio-economic systems in the strategic management of innovation development.

2. Materials and Methods

The object of research is the processes of socio-economic development in the context of technological transformation, taking into account innovation cycles.

The subject of research is innovation cycles as a methodological basis and strategic tool for the formation of a new technological paradigm of socio-economic development.

To analyze scientific concepts, views of various authors on the development of technological modes, transformation of production paradigms and identification of key characteristics of Industries 4.0, 5.0 and 6.0, the method of theoretical generalization was used. This method allowed to form a holistic view of the stages of industrial evolution and its relationship with innovation processes.

The method of comparison helped to identify differences in technological modes, made it possible to identify signs of continuity and gaps between stages, and to assess the impact of each industry on the duration and nature of the innovation cycle.

The logic-structural analysis was used to model the relationship between the innovation lag, types of innovations, financial support, and the innovation cycle. On the basis of this method, a generalized structural scheme of the dynamics of innovation processes in the context of modern technological changes was built.

Mathematical methods of analysis were used to formalize the relationships between quantitative indicators of innovation development, in particular, when building models for prioritizing industries and enterprises by the level of innovation activity, investment attractiveness and efficiency of financing.

By applying an interpretive approach, the content of key concepts related to the innovation index, industrial structures and methods of measuring innovation activity is substantiated.

3. Results and Discussion

Since the Industry 4.0 stage, the global economy has entered a phase of deep digital transformation, which involves the massive introduction of cyber-physical systems, the Internet of Things, big data, and artificial intelligence. These technologies have fundamentally changed approaches to managing production, logistics, communications, and employment. In the context of this revolution, it is possible to observe a significant reduction in the duration of the innovation cycle – from idea to commercialization. Previously, this cycle could last for decades, but nowadays innovations are realized within 2–5 years, and sometimes in real time [9–11].

The transition to Industry 5.0, which emphasizes a human-centered approach, ethical use of technology, sustainable development, and human-machine collaboration, requires a rethinking of not only innovations themselves but also the paradigmatic foundations on which modern technology policy is based. Technology is no longer an end in itself; it must work for the benefit of people, society, and the environment. In the context of an accelerating innovation process, this means the need to integrate an interdisciplinary approach and new forms of strategic foresight.

The concept of Industry 6.0, which is emerging at the intersection of biotechnology, neuroscience, nanotechnology, and artificial intelligence, envisages an even deeper transformation of socioeconomic systems. It contains the potential for autonomous, decentralized, ethically governed eco-economies that require a complete revision of not only the technological order, but also the value system, institutional architecture, and interaction models. All of this indicates the inevitability of revising the technological paradigm from the dominance of efficiency to the priority of viability, sustainability, and humanity. A generalized view of the evolution of industrial stages, the innovation cycle and the technological paradigm is presented in Table 1.

Table 1

Evolution of industrial stages, innovation cycle and technological paradigm

Stage	Key characteristics	Implications for the innovation cycle	Need for a paradigm shift
Industry 4.0	Cyber-physical systems, IoT, AI, automation	Significant reduction of the innovation cycle: from idea to implementation – 2–5 years	Transition from mechanistic to digitally adaptive logic
Industry 5.0	Human-centeredness, sustainable development, ethical AI	Innovations should take into account social, environmental and ethical factors	The need to humanize technologies and change value orientations
Industry 6.0 (future)	Integration of bio-, neuro-, nanotechnologies, autonomous systems	Cycles become nonlinear, partially autonomous, permanent	Rethinking the interaction "human-technology-ecosystem", formation of a new civilization model

ISSN-L 2664-9969; E-ISSN 2706-5448

Thus, industrial revolutions from 4.0 to 6.0 not only demonstrate the stages of technological development, but also impose qualitatively new requirements for: the way of thinking; strategic planning; and management of innovation cycles. Therefore, they become not linear but adaptive, fast and systematically linked to ethical, social and environmental imperatives.

In the context of strategic management of innovation activities, it is of particular importance to build a logically interconnected model that explains the formation and effectiveness of the innovation cycle (Fig. 1).

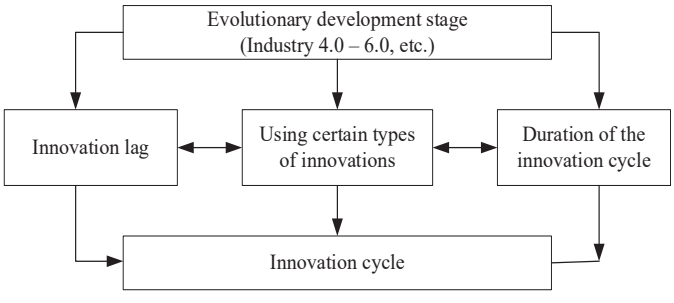

Fig. 1. Model of the innovation cycle in the strategic management of socio-economic development

The proposed model includes three main structural elements:

1. *Innovation lag* – depending on the stage of industrial evolution, it plays an increasingly important role. It is defined as the period of time between the creation of an innovation and its actual implementation. The implementation and aging stages of an innovation are rapidly decreasing. There may be various reasons for this, from lack of investment to resistance to change. In this case, the longer the lag, the greater the loss of innovation potential in the market.

2. *The length of the innovation cycle.* The lag directly affects the overall duration of the cycle. The current environment requires shortening cycles to a minimum through flexible management, digital tools, and proactive implementation policies.

3. *Use of certain types of innovations.* Effective cycle time management is possible with the right choice and combination of types of innovations: product, process, organizational, or marketing. A successful combination of different types can not only speed up the cycle but also increase the efficiency of market entry.

The end result is a full-fledged innovation cycle that covers all stages – from the idea to its scalable implementation. Well-proven models of such cycles are the basis for strategic planning and the formation of the next waves of innovation.

Thus, this analytical model allows to integrate the multi-level elements of the innovation process into a single management logic, in which reducing the lag and competent use of types of innovations become key levers for accelerating innovation development.

One of the indicators that characterizes the level of innovation in a country is the innovation index. The Global Innovation Index (GII) is an international indicator that annually determines the level of innovative development of countries around the world. It is developed and published by the World Intellectual Property Organization (WIPO), INSEAD and Cornell University in cooperation with other partners. The index is a recognized global tool for comparative analysis of the innovation potential of countries and identification of strengths and weaknesses of national innovation systems [12].

The Innovation Index consists of two main sub-indices:

1. *Innovation Input Sub-Index* – characterizes the conditions for creating innovations:
– institutions (political environment, regulation, business environment);
– human capital and research (education, research);
– infrastructure (ICT, energy, logistics);
– market development (access to finance, investment, competition);
– business development (knowledge work, cooperation, clustering).

2. *Innovation Output Sub-Index* – demonstrates actual results:
– knowledge and technology creation (patents, scientific publications, technological output);
– creative activity (brands, cultural products, digital content).

Each of the variables in the sub-indices is scored (from 0 to 100) and then weighted.

The overall index is the arithmetic mean of the sub-indices of inputs and outputs. Data sources include international databases (WHO, World Bank, UNESCO), as well as GII's own analytical data.

The GII is used by governments, think tanks, academics, and businesses to:
– assessing the effectiveness of national innovation systems;
– identifying barriers and drivers of innovation;
– developing development strategies and attracting investment;
– monitoring progress in the global innovation environment.

Fig. 2 shows a generalized description of the twenty countries with the highest level of innovation development and Ukraine's place in this ranking in 2024.

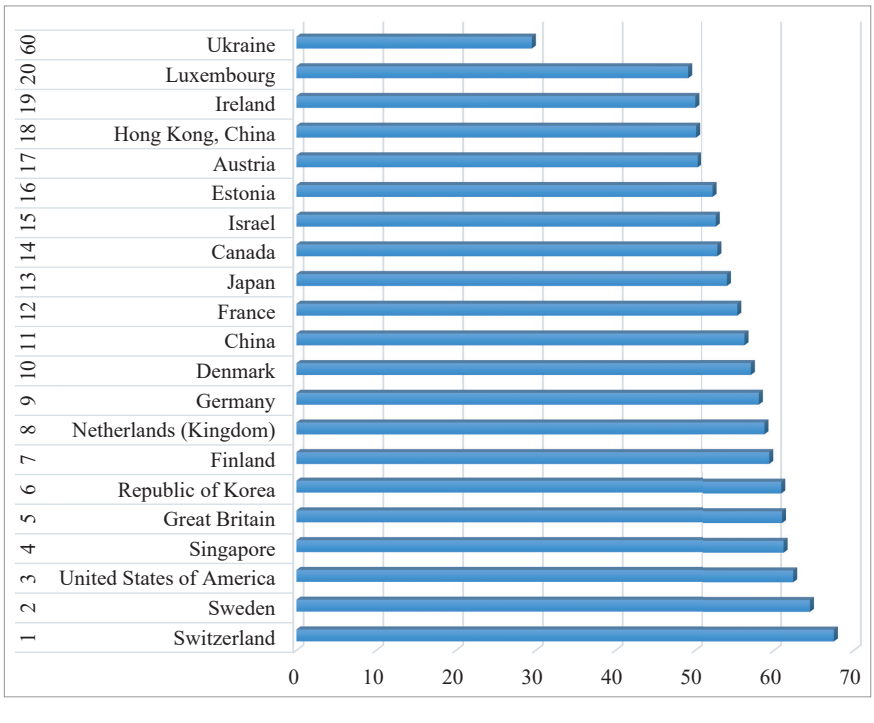

Fig. 2. Ranking of countries by the Innovation Development Index in 2024 [12]

The leaders of innovation are countries with a high level of digitalization, investment in R&D, and effective cooperation between business, science, and the state. These countries use a systematic approach to innovative development, which ensures their competitiveness at the global level.

Ukraine ranks only 60th in this ranking (Table 2).

Table 2

Ukraine's position in the GII (2020–2024) [4]

Year	Position	Index (points)
2020	45	36.32
2021	49	35.60
2022	57	31.00
2023	55	32.80
2024	60	29.50

In recent years, Ukraine has become one of the top 3 countries with lower average incomes, behind only India and Vietnam [12]. This is a consequence of full-scale military operations on the territory of Ukraine.

After analyzing the state of innovation activity of enterprises, the results of which are presented in Fig. 3, it is possible to say that, despite the rather low level of the country's Innovation Index, some sectors of the national economy are developing.

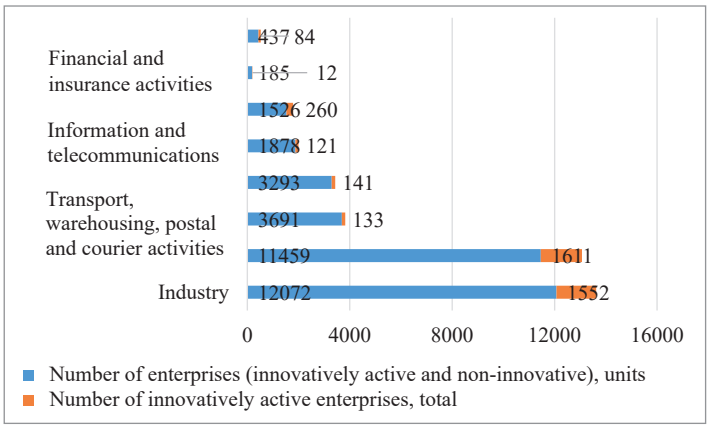

Fig. 3. Innovative activity of Ukrainian enterprises by economic sectors, 2018–2022 [13]

The following results of the analysis can be observed for individual sectors of the economy over four years (2018–2022).

Industry – the total number of enterprises decreased from 12072 to 11459. The number of innovatively active enterprises increased from 1552 to 1611. The level of innovation activity increased from 12.9% to 14.1%.

Transport and logistics – there were a decrease in the total number of enterprises: from 3691 to 3293, but an increase in innovation-active enterprises: from 133 to 141. The share of active enterprises increased from 3.6% to 4.3%.

In information technology and telecommunications, the situation is similar to the previous industry, namely: against the background of a decrease in the total number of enterprises from 1878 to 1526, the number of innovatively active enterprises is growing: from 121 to 260, and, accordingly, the share of activity increased from 6.4% to 17%.

A rapid increase in the total number of enterprises from 185 to 437 is observed in the financial and insurance sectors of the economy. And the number of innovatively active companies increased from 12 to 84, which was reflected in the share of innovation activity, which rose from 6.5% to 19.2%.

In other words, the most dynamic growth is observed in the IT and finance sectors, which indicates the intensification of digital transformations and the introduction of high technologies in key industries.

Despite the difficult period of the state's existence, the government has identified strategic priority areas of innovation activity, which are as follows [14, 15]:

1) technological renewal and development of the national security and defense sectors;

2) development of new energy transportation technologies, introduction of energy-efficient, resource-saving technologies, development of alternative energy sources;

3) development of new technologies for the high-tech development of the transport system, rocket and space industry, aircraft and shipbuilding, armaments and military equipment;

4) development of new technologies for the production of materials, their processing and connection, creation of the nanomaterials and nanotechnology industry;

5) technological renewal and development of the agro-industrial complex;

6) introduction of new technologies and equipment for quality medical care, treatment, and pharmaceuticals;

7) widespread use of cleaner production and environmental protection technologies;

8) development of modern information and communication technologies, robotics.

Strategic directions of socio-economic development through increased innovation activity of both individual enterprises and sectors of the national economy require a revision of the research methodology. One of the tasks is to identify the key factors influencing innovation development and formalize the dependence between sectoral priorities. That is, which sector of the economy has a priority position in relation to others in terms of financial support with the possibility of using significant amounts of combined sources of financing, and the innovative activity of enterprises.

As part of the research, the authors propose models of innovative development, which have become a relevant tool for analyzing, planning and optimizing technological renewal processes both at the level of an individual enterprise and at the industry level. Their use is based on a systematic approach to determining the structure of the innovation cycle, taking into account the innovation lag, typology of innovations, financial parity and reduction of the duration of the innovation cycle.

Tables 3 and 4 show the key factors of prioritizing the innovative development of industries and individual enterprises.

Table 3

Key factors of prioritization of innovative development of industries

No.	Factor	Designation	Characteristics	Approximate weight (W)
1	Industry multiplier effect	F1	Impact on related industries, ability to create chain effects	0.30
2	The level of technological readiness of enterprises	F2	Availability of infrastructure, personnel, digital solutions	0.25
3	The volume of innovation activity of enterprises	F3	Share of innovatively active enterprises in the industry	0.20
4	Value-added potential	F4	Economic feasibility of innovations, ROI	0.15
5	Export potential of the industry	F5	External demand for products and technologies	0.10

ISSN-L 2664-9969; E-ISSN 2706-5448

Table 4

Key factors of prioritizing innovative development of an enterprise

No.	Factor	Description	Approximate weight (W)
1	The company's innovation strategy	Availability of a clearly defined innovation policy and development plan	0.25
2	Investment capacity	Level of financial readiness to implement innovations	0.20
3	Human resources and R&D competencies	Qualified staff, research and development departments, cooperation with universities	0.20
4	Technological base	Level of equipment modernization, digital infrastructure	0.15
5	Flexibility and ability to change	Speed of adaptation to new conditions, corporate culture of innovation	0.10
6	Market position and competitiveness	Market potential for new products, market share	0.10

1. *Basic model of industry priority*: The sector priority index (P) is calculated as a weighted sum of the key factors

$$P = W_1F_1 + W_2F_2 + W_3F_3 + W_4F_4 + W_5F_5, \quad (1)$$

where F_1 – the multiplier effect ($W_1 = 0.30$); F_2 – the level of technological readiness ($W_2 = 0.25$); F_3 – the innovation activity of enterprises ($W_3 = 0.20$); F_4 – the value-added potential ($W_4 = 0.15$); F_5 – the export potential ($W_5 = 0.10$).

Sectoral priority indicators (F_i) are determined on the basis of an expert study of individual sectors of the economy and are normalized within the range [0; 1]. Moreover, the scale of values of priority indicators should differ depending on the selected sector of the economy.

2. *Basic model of financial support*

$$FZ = \alpha P + \beta A + \gamma R, \quad (2)$$

where FZ – the amount of financing of innovations in the industry; P – the priority of the industry; A – the innovative activity of enterprises; R – the parity of financing sources; α, β, γ – the weighting factors (for example, 0.5, 0.3, 0.2, respectively).

3. *The model takes into account the duration of the innovation cycle:* The efficiency of the cycle is taken into account through the reduction factor C

$$C = T_{Benchmark} / T, \quad (3)$$

where T – the actual duration of the innovation cycle in the industry; $T_{Benchmark}$ – the desired (reference) duration, for example, 3 years.

If the cycle is shorter than the benchmark – $C > 1C > 1C > 1$, the innovation process is effective.

If it is longer – $C < 1C < 1C < 1$, the process is slow.

Updated formula

$$FZ = (\alpha P + \beta A + \gamma R) \cdot C. \quad (4)$$

Thus, shortening the cycle ($C > 1$) increases funding, while lengthening it reduces the effectiveness of support.

– High priority industries with short cycles receive an advantage in funding.

– If the cycle is too long, even the priority industry loses a share of funding, as the risks of implementing innovations increase.

The key factors that determine the priority of innovation development at the level of an individual enterprise differ from the sectoral ones in that they focus on the company's internal potential, strategy and resources

$$IPE = W_1F_1 + W_2F_2 + W_3F_3 + W_4F_4 + W_5F_5 + W_6F_6, \quad (5)$$

where F_i – the normalized value of each factor (in the range from 0 to 1).

Similar to the sectoral priority indicators, the key factors of priority for the innovative development of an enterprise are determined on the basis of expert assessment. The value of the indicators should differ depending on the type of enterprise and its belonging to a particular sector of the economy.

Capabilities of the models:

– high analytical flexibility: the models allow to adapt to different types of enterprises and industries;

– quantitative assessment of innovation attractiveness and efficiency not only of an individual enterprise, but also of the economy sector;

– support for strategic decision-making in the field of innovation investment;

– possibility to formalize the relationship between the technological paradigm and the financing structure;

– consideration of the multifactorial nature of innovation.

Limitations of the models:

– the need for high quality and completeness of input data (expert opinions, market statistics, etc.);

– the possibility of subjectivity in determining the weights of factors;

– limited consideration of socio-cultural and political factors of innovation activity;

– not all models fully cover the synergy effects when combining different types of innovations.

In a further study, it would be interesting to obtain practical confirmation of the proposed judgments regarding the use of models of innovative development of sectors of the national economy and individual enterprises with the identification of key priority factors. The proposed models provide an effective basis for making informed management decisions regarding the innovative development potential of not only an individual enterprise, but also the economy sector. Given their multidisciplinary nature, practical implementation is possible when integrated with modern digital analytical platforms, which allows to improve the accuracy of forecasting and strategic planning of socio-economic development in the context of rapid technological change.

4. Conclusions

The study found that innovation cycles are a crucial element in the formation of a new technological paradigm of socio-economic development. The analysis has shown that accelerating the pace of technological change, reducing the innovation lag and shortening the duration of innovation cycles are key characteristics of the current stage of economic evolution. This necessitates a systematic review of strategies for managing innovation development at both the macro and micro levels.

The proposed approach to the interpretation of the innovation cycle as a strategic methodological objectivity allows to form more flexible and effective management decisions in the context of the transition to a new technological paradigm. The role and place of the innovation lag, types of innovations and financing mechanisms in shaping the innovation dynamics of enterprises and industries are determined. It is

confirmed that optimization of the structure of the innovation process in accordance with the latest challenges ensures an increase in the competitiveness and sustainability of the economy in the long term.

Particular attention in the study is paid to the construction and substantiation of models that reflect the relationship between the duration of the innovation cycle, innovation lag, types of innovations and their combination. The significance of such models lies in their ability to:

– provide a systemic vision of innovation dynamics at the enterprise and industry levels;

– formalize decision-making processes regarding the priority of innovations, areas of investment and optimization of technological development;

– adapt management strategies to reduce the duration of innovation cycles and reduce the innovation lag;

– serve as a tool for quantifying the level of innovation capacity and attractiveness.

Thus, the models presented in the article are not only of theoretical value, but also play an important role in applied analysis and strategic management of innovative development of socio-economic systems in the context of rapid technological change.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship or other, that could affect the research and its results presented in this article.

Funding

The research was conducted without financial support.

Data availability

Data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in the creation of the presented work.

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Viktoriia Prokhorova, *Doctor of Economic Sciences, Professor, Department of Economics and Management, Educational and Research Institute Ukrainian Engineering Pedagogics Academy, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0003-2552-2131*

✉***Svitlana Mushnykova,*** *Doctor of Economic Sciences, Professor, Department of Financial Management, Accounting Analytics and Business Monitoring, Educational and Research Institute Dnipro Metallurgical Institute of the Ukrainian State University of Science and Technology, Dnipro, Ukraine, e-mail: svetamush@gmail.com, ORCID: https://orcid.org/0000-0002-3860-522X*

Iryna Abernikhina, *PhD, Associate Professor, Department of Financial Management, Accounting Analytics and Business Monitoring, Educational and Research Institute Dnipro Metallurgical Institute of the Ukrainian State University of Science and Technology, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0003-0692-1276*

Yaryna Yukhman, *PhD, Associate Professor, Department of Enterprise and Investment Economics, Institute of Economics and Management, Lviv Polytechnic National University, Lviv, Ukraine, ORCID: https://orcid.org/0000-0003-3535-731X*

Olena Makovoz, *PhD, Associate Professor, Department of Economics and Management, Educational and Research Institute Ukrainian Engineering Pedagogics Academy, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0003-0187-719X*

Krystyna Slastianykova, *Assistant, Department of Economics and Management, Educational and Research Institute Ukrainian Engineering Pedagogics Academy, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0002-7114-5165*

✉*Corresponding author*