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Features of Economic and Mathematical Modeling in Innovative Crisis Management: Specifics of the Transport and Logistics Sector under Uncertainty, Turbulence, and Systemic Risks (SHIVA and WARMI Frameworks)

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Abstract. The article examines the features of economic and mathematical modeling in innovative anti-crisis management of transport and logistics enterprises in conditions of dynamic uncertainty, turbulence and systemic risks (SHIVA and WARMI concepts). The role of modern economic and mathematical models and intelligent digital technologies in increasing the efficiency of management decisions and the stability of logistics systems is substantiated.

Keywords: *economic and mathematical modeling; innovative anti-crisis management; transport and logistics industry; logistics systems; systemic risks; SHIVA concept; WARMI concept.*

Introduction.

The modern service sector (including the transport and logistics industry) operates in conditions of continuous growth of complexity of the external environment [1], which is characterized by high dynamics of changes, global uncertainty [2], geo-economic transformations [3], disruption of international supply chains, intensification of international competition [4] (especially technological competition), digitalization [5], sanctions restrictions, climate challenges and increased systemic risks. Traditional models of strategic and operational management are gradually losing their effectiveness due to the inability to take into account the nonlinear nature of the development of crisis processes and the multidimensionality of external influence factors [6]. If earlier most management decisions were made

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in a relatively stable environment, then modern enterprises of the transport and logistics complex are forced to operate in conditions of constant adaptation to new threats and sources of uncertainty [7].

The specifics of innovative anti-crisis management of enterprises and companies in the transport and logistics industry, based on the use of modern digital technologies, intelligent data analytics, methods of economic and mathematical modeling and technologies for supporting management decision-making [8], are becoming particularly relevant. It is modeling that allows us to study complex economic processes, predict possible scenarios of events, assess the consequences of various management decisions and choose the most effective strategies for the functioning of enterprises and companies in the transport and logistics industry [9].

Additional relevance of this issue is given by the transition of the world economy from classical concepts of uncertainty (VUCA) to more complex models of SHIVA and WARMI, which describe modern reality as a space of continuous structural changes, high turbulence, systemic instability, hyper-connectedness of economic processes, acceleration of innovation cycles and necessity. In such conditions, the importance of complex economic and mathematical modeling [10] increases significantly, which allows integrating various quantitative and qualitative characteristics of the functioning of transport and logistics systems into a single analytical model [11].

Despite a significant amount of research in the field of anti-crisis management, logistics, mathematical modeling and innovation management, many features of the use of economic and mathematical models specifically for innovative anti-crisis management of transport and logistics systems remain insufficiently studied. This especially applies to the issues of integrating forecasting methods, intelligent data analysis, optimization modeling, scenario analysis and digital technologies into a single system for supporting managerial decision-making.

Taking into account all of the above, the purpose of this article is to study the features of economic and mathematical modeling in innovative anti-crisis management of transport and logistics enterprises in conditions of dynamic uncertainty, turbulence and systemic risks of the modern economy.

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Main Part.

1. Theoretical principles of innovative anti-crisis management of transport and logistics systems.

Modern anti-crisis management differs significantly from the classical understanding of crisis management. If the traditional approach was focused mainly on overcoming an already existing crisis, then innovative anti-crisis management is a continuous process of forecasting, warning, adaptation and formation of the organization's resilience to potential external and internal threats.

The transport and logistics industry is one of the most sensitive areas of the economy, as it combines production, trade, financial, information and international processes. Any changes in the external environment are almost instantly reflected in the functioning of logistics chains, transportation costs, infrastructure load levels, product delivery speed and customer service quality.

The SHIVA and WARMI concepts consider the modern economy as a complex nonlinear system in which the crisis becomes not an exceptional event, but a constant state of development of economic processes. Accordingly, the main task of management is not only to minimize the consequences of crises, but also to ensure the ability of the enterprise to constantly adapt to new operating conditions.

That is why innovative anti-crisis management requires the widespread use of mathematical models that allow quantitatively assessing the stability of the enterprise, predicting changes in the state of the system, calculating alternative options for the development of events and determining optimal management solutions.

2. Features of economic modeling in the transport and logistics sector.

Economic modeling is a tool for studying the patterns of functioning of economic systems in the form of building formalized models of economic processes.

For transport and logistics enterprises, the objects of modeling are: transport flows; logistics supply chains; production and warehouse processes; financial flows; information flows; innovative projects; investment programs; risks and uncertainties; indicators of the efficiency of the enterprise.

A feature of transport logistics is the high interdependence of all components of the system. Changing one parameter inevitably affects other elements of the logistics network. For example, an increase in delivery time causes an

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increase in warehouse inventories, changes in financial flows, a decrease in the level of customer service and a deterioration in the competitiveness of the enterprise.

Therefore, economic models of transport logistics should take into account not individual indicators, but a system of interconnected parameters that form a single economic space of the enterprise.

Modern models are gradually moving from static schemes to dynamic digital models that allow modeling the functioning of the enterprise in real time using Big Data technologies, artificial intelligence, digital twins, cloud computing and intelligent analytics.

3. Specifics of mathematical modeling in innovative anti-crisis management of enterprises/companies in the transport and logistics industry.

Mathematical modeling is the foundation of quantitative analysis of management processes.

In modern conditions, different classes of models are used.

The first group consists of deterministic models, which are used when there is sufficient certainty of the initial information.

The second group consists of probabilistic models that allow taking into account the random nature of the development of economic processes.

The third group consists of simulation models designed to study complex transport and logistics systems that operate under conditions of numerous interrelated factors.

A special place is occupied by optimization models that allow determining the most effective management decisions regarding resource allocation, transportation routing, placement of warehouse complexes, inventory management, formation of transport schedules and distribution of investment resources.

In the conditions of SHIVA and WARMI environments, adaptive models are widely used, which are able to automatically change their own parameters when the characteristics of the external environment change.

Such models are much more stable than classical mathematical models, as they take into account the nonlinearity of economic processes, the effect of accumulation of crisis impacts and the possibility of unexpected events.

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4. Integration of innovative modeling technologies for enterprises/companies of the transport and logistics industry.

Modern innovative anti-crisis management is impossible without the use of intelligent digital technologies. The most promising areas are machine learning, artificial intelligence, methods of intelligent data analysis, Big Data technologies, digital twins of transport systems, agent modeling, multi-agent systems, evolutionary computing, genetic algorithms, swarm intelligence methods and hybrid optimization technologies.

The use of such tools allows you to significantly increase the accuracy of forecasting crisis situations, identify hidden patterns in the functioning of transport and logistics systems, automatically assess the level of risks and generate recommendations for making management decisions.

Particularly promising is the creation of digital twins of logistics systems, which allow modeling a large number of alternative scenarios of events without interfering with real production processes.

Integration of artificial intelligence with economic and mathematical models ensures the transition from reactive management to proactive management based on forecasting future changes.

5. Specificity and features of modeling for enterprises/companies of the transport and logistics complex = in the conditions of SHIVA and WARMI concepts.

The SHIVA and WARMI concepts significantly change the requirements for modern economic and mathematical models. If previously most models were based on the assumption of the stability of the economic environment, then the modern model must take into account the constant variability of system parameters.

Under these conditions, the importance of scenario modeling increases significantly, which allows simultaneously analyzing many possible options for the development of the external environment.

In addition, a modern model must have the following properties: adaptability; self-learning; multi-criteria; resistance to incomplete information; the ability to work with large data sets; the ability to take into account nonlinear relationships between variables; integration of expert knowledge with quantitative analysis methods.

In fact, we are talking about a transition from

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traditional mathematical modeling to intelligent economic and mathematical modeling, which hybridly combines [12] classical methods of operations research, econometrics, artificial intelligence, machine learning and digital technologies for decision support.

It is this approach that most fully corresponds to the modern transport and logistics industry, which operates in conditions of continuous transformation of the world economy.

Conclusions.

The conducted research shows that the modern conditions of the functioning of the transport and logistics industry require a new approach to the organization of innovative anti-crisis management. The SHIVA and WARMI concepts reflect a qualitatively new level of complexity of the external environment, in which crisis phenomena become a constant factor in the functioning of socio-economic systems, and uncertainty acquires a systemic character.

It has been established that economic modeling provides a comprehensive study of economic processes, identification of patterns in the functioning of transport and logistics systems and the formation of sound management decisions. In turn, mathematical modeling allows quantitatively assessing the effectiveness of alternative strategies, predicting the development of crisis situations, optimizing the use of resources and increasing the resilience of enterprises to external influences.

It is shown that the most promising direction of development is the integration of traditional economic and mathematical methods with intelligent digital technologies, including artificial intelligence, machine learning, Big Data, digital twins, simulation and agent modeling, evolutionary algorithms and methods of intelligent optimization. Such a comprehensive approach ensures the transition to adaptive decision support systems capable of functioning in conditions of high turbulence, dynamic uncertainty and systemic risks. It is advisable to link the prospects of further research with the development of intelligent hybrid economic and mathematical models of innovative anti-crisis management of transport and logistics enterprises, integrating methods of multi-criteria optimization, predictive analytics, digital twins and artificial intelligence technologies for the formation of sustainable intelligence.

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