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Evolutionary Optimization Technologies in Innovation Management: Evidence From the Transport and Logistics Industry under Modern Dynamic Systemic Risks and Uncertainty

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Abstract. The article considers the possibilities of using evolutionary optimization technologies in innovative management of the transport and logistics industry under conditions of uncertainty, turbulence and systemic risks. The advantages of evolutionary computing in solving multi-criteria management problems are substantiated and the prospects for their integration with artificial intelligence and digital transformation technologies are determined.
Keywords: *evolutionary optimization, evolutionary computing, innovation management, transport and logistics industry, logistics systems, multi-criteria optimization, genetic algorithms, supply chains, uncertainty, systemic risks.*

Introduction.

The current stage of the development of the world economy is characterized by a qualitative complication of the environment in which organizations operate [1], in particular: acceleration of innovative technological changes [2], and, in particular, the intensification of global digitalization processes, instability of international markets and increased competition (especially in the service sector [3], [4]), geopolitical and regional tensions (and therefore the complex transformation of supply chains), climate challenges and, in general, an increase in the frequency of crisis phenomena of various modalities = form a new managerial reality [5]. Its special features are high uncertainty, turbulence, nonlinearity and interdependence of economic processes [6]. In these conditions, traditional

INFORMATION AND WEB TECHNOLOGIES

methods of optimizing management decisions, based mainly on deterministic mathematical models, increasingly demonstrate limited effectiveness due to the inability to quickly adapt to rapidly changing parameters of the external environment [7].

These trends are especially clearly manifested in the transport and logistics industry [8], where the efficiency of activity is determined by the need to simultaneously take into account a large number of interdependent factors: demand dynamics, transport availability, resource limitations, fluctuations in transportation costs, time constraints, the risk of supply disruption, infrastructure capacity and a variety of random influences. As a result, optimization tasks acquire a multi-criteria nature and are characterized by extremely high computational complexity [9].

In such conditions, scientific and practical interest in evolutionary optimization technologies (evolutionary computing) is growing, which is a class of intelligent metaheuristic methods for finding solutions based on modeling the mechanisms of natural evolution [10]. Due to the ability to effectively explore large search spaces, adapt to changing system operating conditions and find close to optimal solutions in high-dimensional problems, evolutionary algorithms are becoming an important tool for innovation management [11].

That is why the purpose of this article is to investigate the possibilities of applying evolutionary optimization technologies in innovative management of the transport and logistics industry, analyze their advantages in conditions of high uncertainty and systemic risks, and determine the prospects for the further development of these technologies in the context of the digital transformation of logistics systems.

Main Part.

Considering the above in the introduction, it is clear why metaheuristic optimization methods have received special development in recent decades, among which evolutionary computing technologies occupy one of the leading places [12]. Their fundamental feature is the rejection of a complete enumeration of possible solutions in favor of an intelligent search based on probabilistic mechanisms of self-organization and adaptation [13]. Unlike deterministic algorithms, evolutionary methods allow to work effectively even in the absence of an analytical description of the objective

INFORMATION AND WEB TECHNOLOGIES

function, the presence of a set of local extrema and a high dimensionality of the search space.

Currently, evolutionary computing combines a wide range of algorithmic directions; the most common are: genetic algorithms, evolutionary strategies, evolutionary programming, genetic programming, differential evolution, memetic algorithms and methods of multi-objective evolutionary optimization. Despite the differences in the mechanisms for forming new solutions, all of the above approaches implement the general principle of adaptive search, in which the accumulated information about the quality of previous solutions is used to generate subsequent, potentially more effective alternatives.

For innovative management, the ability of evolutionary algorithms to simultaneously take into account many efficiency criteria is important. In real management tasks, achieving one goal is almost always accompanied by a deterioration in other indicators. For example, minimizing transportation costs can lead to an increase in delivery time, while maximizing the level of customer service often requires an increase in operating costs. Similar contradictions arise between the reliability of the logistics network, the speed of order processing, the level of inventory, the environmental sustainability of transportation, and the efficiency of using transport resources.

Unlike traditional methods focused on finding a single optimal solution, modern technologies of multi-objective evolutionary optimization allow you to form many Pareto-efficient alternatives, each of which is a certain compromise between conflicting criteria. This approach significantly expands the possibilities of innovative management, as it provides managers with the opportunity to choose a development strategy taking into account the current priorities of the organization, external constraints and predicted scenarios of changes in the market environment.

In addition, evolutionary algorithms have a pronounced adaptability. When external conditions change, the search process does not start anew, but continues using already accumulated information about the structure of the solution space. This ensures a significantly higher stability of the management system to unexpected changes in the environment compared to most classical optimization methods.

The modern transport and logistics industry is one of the most complex areas of application of intelligent optimization

INFORMATION AND WEB TECHNOLOGIES

methods. Its functioning is determined by the constant interaction of a large number of participants in the logistics network, including manufacturers, suppliers, transport operators, warehouse complexes, distribution centers, terminals, information platforms and end users [14]. Each element of this system is characterized by its own development dynamics, resource limitations and significant dependence on external factors, as a result of which the process of making management decisions acquires a multidimensional character [15]. Evolutionary optimization technologies acquire particular relevance under the conditions of transformation of global supply chains [16]. In recent years, the world economy has faced a whole range of systemic challenges, including pandemic restrictions, geopolitical instability, armed conflicts, energy crises, inflationary processes, disruption of the functioning of transport corridors, changes in the structure of international trade and increased requirements for the environmental sustainability of logistics [17]. As a result, traditional planning models, focused mainly on environmental stability, are increasingly proving to be insufficiently effective.

That is why modern innovative management is gradually moving from the concept of static optimization to the concept of continuous adaptation of management decisions. If earlier the main task was to find a single optimal option for the functioning of the logistics system, today the ability of the system to quickly rebuild itself when new restrictions arise, a change in the structure of demand or the occurrence of emergency situations is becoming much more important.

One of the most common areas of application of evolutionary computing is the optimization of transport routes. Classical vehicle routing problems belong to the category of NP-hard problems, for which a complete search of options is practically impossible even for a relatively small number of service objects. Genetic algorithms allow for the effective formation of delivery routes taking into account numerous constraints, including vehicle carrying capacity, customer service time windows, traffic conditions, order priority, fuel cost, transport infrastructure utilization level and the possibility of delays. The use of population search provides the ability to study a large number of alternative solutions simultaneously, significantly increasing the possibility of finding options close to the global optimum.

INFORMATION AND WEB TECHNOLOGIES

An equally important area is supply chain management. Modern logistics networks operate in conditions of constant change in demand volumes, instability of raw material supplies, fluctuations in transport tariffs and a high probability of disruption of individual links in the supply chain. Evolutionary algorithms allow to simultaneously optimize the levels of safety stocks, distribution center locations, purchase volumes, delivery schedules and distribution of transport flows, minimizing the total logistics costs while maintaining the required level of service reliability.

The use of multi-objective evolutionary optimization is of particular importance, since the efficiency of modern logistics is determined not by one, but by a set of interdependent criteria. In addition to minimizing costs, it is necessary to take into account the speed of delivery, the stability of supply chains, the level of customer service, the level of transport capacity utilization, environmental indicators, energy consumption and the carbon footprint of transportation. The formation of a set of Pareto-efficient solutions allows managers to choose the most rational strategy for developing the logistics system depending on the current priorities of the enterprise and environmental changes.

An important advantage of evolutionary computing is its ability to integrate with other digital technologies. As the concept of digital transformation of enterprises develops, evolutionary algorithms are increasingly used together with technologies of artificial intelligence, machine learning, big data analysis, digital twins and Internet of Things. Such integration significantly expands the possibilities of intelligent management of logistics processes.

It should be noted that the modern external environment is increasingly described by the concepts of VUCA, BANI, SHIVA and WARMI, which reflect the growing instability, nonlinearity, fragility and unpredictability of socio-economic processes. In such conditions, the importance of not so much the search for an absolutely optimal solution as ensuring the stability of the system's functioning in the implementation of various scenarios of events increases. That is why innovation management is gradually moving from classical optimization to adaptive management, which is based on the constant revision of management decisions and the continuous search for new alternatives.

Evolutionary computing fully corresponds to this

INFORMATION AND WEB TECHNOLOGIES

management paradigm. Due to the probabilistic nature of the search, high adaptability, the ability to work with incomplete information and take into account a large number of criteria at the same time, they provide significantly higher resistance of logistics systems to the influence of external risks. At the same time, the effectiveness of their application increases as they are integrated with modern technologies of artificial intelligence, cognitive analytics, digital platforms and intelligent decision support systems.

At the same time, the use of evolutionary optimization is not without certain limitations. The quality of the obtained solutions significantly depends on the correctness of the choice of the structure of the solution representation, the setting of population parameters, selection, mutation and crossover operators, as well as the criteria for assessing fitness. In addition, the computational complexity of individual tasks may require the use of high-performance computing platforms and parallel computing. However, the development of cloud technologies, distributed computing architectures and specialized hardware accelerators is gradually removing these limitations, expanding the possibilities of practical application of evolutionary computing in the intelligent management of complex transport and logistics systems.

Conclusions.

The conducted research allows us to conclude that evolutionary optimization technologies (evolutionary computing) are becoming one of the promising areas of development of modern innovative management under conditions of qualitative complication of the environment of functioning of socio-economic systems. Unlike traditional methods of mathematical optimization, focused mainly on solving static problems in the presence of rigidly specified parameters, evolutionary algorithms provide adaptive search for rational solutions in conditions of multi-criteria, incomplete information, high dimensionality of the search space, dynamic change of constraints and influence of numerous uncertainty factors.

Using the example of the transport and logistics industry, it is shown that the use of evolutionary computing allows to significantly increase the efficiency of management of complex logistics systems by optimizing transportation routes, changing supply chains, distributing transport and warehouse resources, managing inventories, forming

INFORMATION AND WEB TECHNOLOGIES

sustainable logistics networks and supporting the adoption of strategic ones. These technologies are of particular importance in the context of continuous market changes, disruption of global supply chains, increased geopolitical instability, increased systemic risks and the need for operational adaptation of organizations to new business conditions.

It has been established that one of the key advantages of evolutionary optimization is the ability to simultaneously take into account many conflicting efficiency criteria. The formation of a set of "Pareto-efficient" solutions provides innovative management with a significantly higher level of flexibility compared to the use of single-criteria optimization methods, as it allows choosing management solutions taking into account the strategic goals of the enterprise, resource constraints, the level of acceptable risk and predicted scenarios for the development of the external environment.

The prospects for further development of evolutionary computing are directly related to their integration with technologies of artificial intelligence, machine learning, big data analysis, digital twins, the Internet of Things, multi-agent systems and cloud computing. The formation of intelligent hybrid decision support systems opens up opportunities for the creation of self-adaptive management mechanisms capable of continuous optimization of logistics processes in real time.

Thus, in the current conditions of the formation of a new management paradigm, caused by high uncertainty, turbulence, nonlinearity and systemic risks, evolutionary optimization technologies are transformed from a specialized computational tool into one of the basic elements of digital innovation management. Their further development and practical implementation can provide a significant increase in the stability, adaptability, efficiency and competitiveness of transport and logistics systems, as well as create a methodological basis for the formation of new generation intelligent management models focused on functioning in conditions of continuous environmental changes.

References:

[1] Maksym Naumenko (2024). Modern concepts of innovation management at enterprises. *Scientific innovations and advanced technologies* No. 6(34) (2024). DOI: https://doi.org/10.52058/2786-5274-2024-

INFORMATION AND WEB TECHNOLOGIES

6(34)-435-449

[2] Ostapenko T., Onopriienko D., Hrashchenko I., Palyvoda O., Krasniuk S., Danilova E. (2022) Research of impact of nanoeconomics on the national economic system development. *Innovative development of national economies*: collective monograph. – Kharkiv: PC TECHNOLOGY CENTER, 2022. – pp. 46-70. URL: https://er.knutd.edu.ua/handle/123456789/23169

[3] Hrashchenko, I. S. (2011). Problemy ta osoblyvosti prohnozuvannia na pidpryiemstvakh sfery posluh [Problems and features of forecasting at service enterprises]. *Ekonomichnyi visnyk Donbasu - Economic Bulletin of Donbass*, (3(25)), 175-179. https://www.evd-journal.org/download/2011/2011-3/Ek_visnyk_3_2011.pdf [In Ukrainian].

[4] Hrashchenko, I. S., & Pryshchepa, N. P. (2016). Formuvannia konkurentnoho potentsialu pidpryiemstv za umov zrostannia mizhnarodnoi konkurentsii [Formation of the competitive potential of enterprises in conditions of growing international competition]. *Skhidna Yevropa: ekonomika, biznes ta upravlinnia - Eastern Europe: economics, business and management*, (4), 118–122.

[5] Naumenko, M. (2024). Methodology of determining factors of activity efficiency and competitive position of the enterprise on the market in crisis conditions. *Scientific innovations and advanced technologies*, № 7(35) (2024). DOI: https://doi.org/10.52058/2786-5274-2024-7(35)-648-665 [in Ukrainian].

[6] Nevmerzhytska S. M. (2018). Formation of a strategy for the innovative development of enterprises in conditions of uncertainty. *Scientific Bulletin of the Kherson State University. Series: Economic Sciences*. 2018. Vol. 32. pp. 99-103. URL: https://ej.journal.kspu.edu/index.php/ej/article/view/422/418.

[7] Krasnyuk M.T., Naumenko M.A. (2024) Efektyvne zastosuvannia henetychnykh alhorytmiv u vyrishenni bahatoekstremumnykh optymizatsiinykh zadach v menedzhmenti konkurentnoho pidpryiemstva [Effective application of genetic algorithms in solving multi-extremum optimization problems in the management of a competitive enterprise]. *Grail of Science*, № 41, June 2024, 65-73. URL: https://archive.journal-grail.science/index.php/2710-3056/issue/view/05.07.2024/29 [in Ukrainian].

[8] Krasnyuk, M., & Kustarovskiy, O. (2017). The development of the concept and set of practical measures of anticrisis logistics management in the current Ukraine conditions. *Zarządzanie. Teoria i Praktyka*, Wyższa Szkoła Menedżerska w Warszawie, (1 (19)), pp. 31–37.

[9] Oksana Karpenko , Olena Palyvoda, & Olena Bondarenko (2018). Simulation modelling of strategic development of transport and logistics clusters in Ukraine. *Baltic Journal of Economic Studies*, 4 (2), 93-98. doi: 10.30525/2256-0742/2018-4-2-93-98

[10] Kulynych Y., Krasnyuk M., Krasniuk S. (2022). Efficiency of evolutionary algorithms in solving optimization problems on the example of the fintech industry. *Grail of Science*, № 14-15, May 2022, (pp. 63-70). DOI: https://doi.org/10.36074/grail-of-science.27.05.2022

[11] Deb, K. (2001). *Multi-objective optimization using evolutionary algorithms*. John Wiley & Sons.

INFORMATION AND WEB TECHNOLOGIES

[12] Michalewicz, Z., & Fogel, D. B. (2004). *How to solve it: Modern heuristics* (2nd ed.). Springer.

[13] Storn, R., & Price, K. (1997). Differential evolution-A simple and efficient heuristic for global optimization over continuous spaces. *Journal of Global Optimization, 11*(4), 341-359. https://doi.org/10.1023/A:1008202821328

[14] Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2021). *Designing and managing the supply chain: Concepts, strategies, and case studies* (4th ed.). McGraw-Hill Education.

[15] Pourhejazy, P., & Kwon, O. K. (2016). The new generation of operations research methods in supply chain optimization: A review. *Sustainability, 8*(10), Article 1033. https://doi.org/10.3390/su8101033

[16] Potvin, J.-Y. (2009). State-of-the-art survey-Evolutionary algorithms for vehicle routing. *INFORMS Journal on Computing, 21*(4), 518-548. https://doi.org/10.1287/ijoc.1080.0312

[17] Skitsko, V. I., & Voinikov, M. Y. (2024). Supply chain management using evolutionary algorithms. *Problemy Ekonomiky, 3*, 240-248. https://doi.org/10.32983/2222-0712-2024-3-240-248