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Optimization of global supply chains through models of friendly and regional localization of production

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Abstract. *The study's relevance stems from the increase in geoeconomic instability, the disruption of established global supply chains, and growing geopolitical risks, which require greater economic security and the sustainability of national and corporate production and logistics systems.*

The purpose of the article is to substantiate approaches to optimizing global supply chains by applying friendly, regional production localization models in the context of increasing geoeconomic instability and structural transformations of the world economy.

Research methods include system-structural and logical-analytical analysis, generalization of theoretical provisions of contemporary studies on global value chains, comparative analysis of production organization models, and interpretation of scientific and practical approaches to risk management and supply chain optimization.

The evolution of global supply chains has been examined, and the key drivers of the transition from profoundly globalized models to configurations based on friendly and regional localization have been identified. The economic characteristics of these models within global value chains have been revealed, and the feasibility of applying multi-criteria approaches to supply chain optimization considering resilience, reliability, cost efficiency, and strategic autonomy has been substantiated. The main scientific and practical challenges of implementing localization models have been identified, including institutional constraints, rising transaction costs, and risks of market fragmentation.

It has been substantiated that friendly and regional production localization models should be regarded as adaptive instruments for optimizing global supply chains, capable of balancing economic efficiency with long-term resilience requirements. The necessity of aligning corporate strategies with state economic policy in implementing these models has been demonstrated.

Prospects for further research include the development of quantitative methods to assess the efficiency of localized supply chains, the analysis of hybrid configurations combining global and regional models, and the study of the role of digital technologies in ensuring their long-term resilience.

Keywords: *geoeconomic instability, value creation chains, economic resilience, strategic autonomy, production regionalization, supply risk management, institutional compatibility.*

Оптимізація глобальних ланцюгів постачання через моделі дружньої та регіональної локалізації виробництва

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Анотація. *Актуальність дослідження зумовлено посиленням геоекономічної нестабільності, порушенням усталених глобальних ланцюгів постачання та зростанням геополітичних ризиків, що вимагає підвищення економічної безпеки та стійкості національних і корпоративних виробничо-логістичних систем.*

Метою статті є наукове обґрунтування підходів до оптимізації глобальних ланцюгів постачання шляхом використання моделей дружньої та регіональної локалізації виробництва в умовах зростаючої геоекономічної нестабільності та структурної трансформації світової економіки.

Методи дослідження включають системно-структурний та логіко-аналітичний аналіз, узагальнення теоретичних положень сучасних досліджень у сфері глобальних ланцюгів створення доданої вартості, компаративний аналіз моделей організації виробництва та інтерпретацію науково-практичних підходів до управління ризиками й оптимізації ланцюгів постачання.

Вивчено еволюцію глобальних ланцюгів постачання та встановлено чинники переходу від глибоко глобалізованих моделей до конфігурацій, орієнтованих на дружню та регіональну локалізацію. Виявлено економічні особливості зазначених моделей у системі створення доданої вартості та доведено доцільність використання багатокритеріальних підходів до оптимізації ланцюгів постачання з урахуванням стійкості, надійності, витратної ефективності й стратегічної автономії. Встановлено основні науково-практичні проблеми впровадження локалізаційних моделей, пов'язані з інституційними обмеженнями, зростанням трансакційних витрат і ризиками фрагментації ринків.

Обґрунтовано, що моделі дружньої та регіональної локалізації виробництва слід розглядати як адаптивний інструмент оптимізації глобальних ланцюгів постачання, здатний забезпечити баланс між

економічною ефективністю та вимогами довгострокової стійкості. Доведено необхідність узгодження корпоративних стратегій і державної економічної політики у процесі реалізації таких моделей.

Перспективи подальших досліджень пов'язані з розробленням кількісних методів оцінювання ефективності локалізованих ланцюгів постачання, аналізом гібридних моделей поєднання глобальних і регіональних конфігурацій та вивченням ролі цифрових технологій у забезпеченні їхньої довгострокової стійкості.

Ключові слова: *геоекономічна нестабільність, ланцюги створення доданої вартості, економічна стійкість, стратегічна автономія, регіоналізація виробництва, управління ризиками постачання, інституційна сумісність.*

Problem statement. Global supply chains, formed under the dominance of cost minimization principles and deep geographical fragmentation of production, have proven vulnerable to systemic shocks caused by geopolitical instability, trade restrictions, pandemic crises, and the Russian Federation's armed aggression against Ukraine. Disruption of logistics routes, concentration of critical production capacities in certain regions, and asymmetry of access to resources have highlighted the need to revise traditional models of organizing international production and supply from the standpoint of economic security, sustainability, and adaptability. In this context, approaches focused on friendly and regional localization of production are particularly important, involving reducing excessive dependence on geopolitically risky jurisdictions, diversifying supply chains, and forming regionally balanced production and logistics ecosystems.

The issue of optimizing global supply chains through the above models is directly related to the key scientific tasks of modern economic science, in particular, with the development of the theory of the international division of labor in the

context of fragmentation and regionalization of the world economy, the improvement of risk management models in transnational value creation networks and the formation of new approaches to assessing the effectiveness of supply chains taking into account the criteria of sustainability, reliability and strategic autonomy. At the same time, this issue has a distinct applied dimension, since the results of its research are the methodological basis for developing practical solutions in the field of corporate strategic management, state industrial and trade policy, post-war economic recovery programs in Ukraine and the integration of national production systems into regional and European value chains.

Analysis of recent research and publications. A review of modern scientific research indicates a gradual shift in emphasis from classical, globally configured supply organizations to more adaptive, digitally managed, and sustainable forms of supply organization. A significant part of the research focuses on the use of digital tools to support flexible management of regionalized logistics networks. Thus, in the work of K. Skliarenko, the potential of Big Data in logistics marketing for predicting customer churn and implementing dynamic pricing is substantiated, enabling rapid restructuring of commodity flows within regional markets and reducing dependence on global sales channels [1]. O. M. Korobkova, analyzing customs brokerage activities in the USA, demonstrates that digitalization and institutional consistency of customs procedures are critically important for the stability of supply chains between economically and politically «friendly» countries [2].

The technological aspects of digital integration of logistics systems are explored in the works of L. Kaptosv, who considers the design of RESTful APIs for geospatial logistics platforms as a tool for synchronizing information flows in regionalized supply networks [3]. In a related study by L. Kaptosv, it is shown that caching optimization using Redis increases the reliability of high-load digital services, which are essential to the functioning of modern supply chains in conditions of territorial decentralization [4]. The operational aspects of digital

management are complemented by the research of Y. Hasenko, who proves that the implementation of a Material Requirements Planning system in the Fast-Moving Consumer Goods sector contributes to the reduction of inventories, increased transparency of material flows, and reduced dependence on global suppliers [5]. In the following work, the author focuses on the role of optimal supply planning in enhancing the environmental safety of logistics processes, a characteristic feature of regionalized and «short» value chains [6].

Along with technological aspects, the research also pays significant attention to the transformational factors driving the development of global supply chains. M. Sandul analyzes the impact of crisis phenomena, the growth of logistics risks and geoeconomic instability, justifying the inevitability of the transition to more localized and regionally oriented models of production and supply [7]. The spatial dimension of these transformations is revealed in the work of N. M. Popadynets and co-authors, who prove that the regionalization of logistics services markets stimulates the development of national industry and strengthens internal production ties [8]. Similar conclusions can be drawn from the study by N. Maievska, who substantiates the effectiveness of alternative models of value chain management for micro- and small-scale agricultural producers based on the localization of production and sales [9].

The international dimension of regional localization is examined in works that analyze global-local configurations of supply chains. L. Macchion and R. Fornasiero demonstrate that for customized and highly variable production, regional configurations provide higher flexibility and reduced order fulfillment times compared to traditional global models [10]. M. A. Cohen and H. L. Lee justify the need to design the «right» global supply network, taking into account the trade-off between cost efficiency, sustainability and strategic autonomy, which directly correlates with the concepts of friend-shoring and near-shoring [11]. A separate layer of research focuses on the sustainability and crisis-resilience of supply chains.

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S. Nandi et al. analyze the redesign of supply chains using blockchain technologies and circular economy principles, emphasizing that regionalization increases transparency and reduces systemic risks identified during the COVID-19 pandemic [12]. V. Yakavenka et al. propose a multi-criteria model for designing sustainable supply chains for perishable products, in which regional localization is a key factor in minimizing losses and logistical instability [13]. M. S. Sodhi et al. focus on preparing supply chains for essential goods in anticipation of future pandemics, emphasizing the feasibility of forming regional reserves and reducing critical global dependencies [14]. Summarizing the lessons of the pandemic, G. Zhu et al. highlight the structural shortcomings of overly globalized supply chains and argue for their long-term transformation towards regional, sustainable models [15].

Highlighting previously unresolved parts of the general problem. Despite active research into the transformation of global supply chains, significant gaps remain in scientific works. The factors of the transition from globalized models to friendly and regional localization are not sufficiently systematized, the economic features of these models in the structure of added value creation are only partially revealed, and approaches to optimizing supply chains based on a set of criteria for sustainability, reliability, cost-effectiveness, and strategic autonomy are fragmentarily generalized. The institutional and transactional limitations of implementing localization models, as well as the risks of market fragmentation, remain insufficiently studied, thereby reducing the practical applicability of existing approaches. Solving these problems will allow the formation of scientifically sound recommendations for corporate and public management and deepen understanding of the mechanisms for ensuring sustainability and strategic autonomy of supply chains.

Formulation of the article's objectives (task statement). The purpose of the article is to substantiate approaches to optimizing global supply chains based on

models of friendly and regional localization of production in the context of increasing geoeconomic instability and structural changes in the world economy.

To achieve the goal, the article provides a solution for the following tasks:

1. To substantiate the evolution of global supply chains and the factors of the transition to models of friendly and regional localization of production.

2. To summarize the economic features of models of friendly and regional localization and approaches to optimizing supply chains according to the criteria of sustainability, reliability, cost efficiency and strategic autonomy.

3. To identify key problems in the implementation of localization models and formulate recommendations for their practical application at the corporate and state levels.

Presentation of the study's main material. The evolution of global supply chains has long been determined by an orientation towards minimizing costs through deep geographical fragmentation of production, offshoring and concentration of individual production stages in countries with cheaper resources. This model provided scalability and increased efficiency, but created a critical dependence on remote suppliers and the stability of the global environment. The combination of modern challenges, including geopolitical tensions, disruptions to international logistics, increased protectionist practices, and military risks, led to a review of established approaches and a transition to models of friendly, regional localization of production, focused on increasing the stability and manageability of supply chains (table 1).

In modern conditions, the above transformation factors materialize through a shift in the logic of strategic decisions in supply chain management, with the criteria for choosing production and logistics configurations increasingly encompassing not only cost indicators but also the levels of geopolitical, institutional, and operational risks. Companies are reviewing the structure of their supply networks, abandoning excessive concentration of production in individual countries in favor of more

diversified and geographically balanced solutions. It is manifested in reducing the number of critical cross-border links, reducing dependence on a single supplier and forming alternative supply channels within friendly or regionally close jurisdictions [15].

Table 1

Key factors of the transformation of global supply chains and their impact on the transition to models of friendly and regional localization of production

Transformation factor	Character of manifestation in global supply chains	Impacts on the organization of production
Geopolitical instability	Sanctions, trade restrictions, and military risks	Limitations of cooperation with high-risk jurisdictions
Logistical failures	Interruption of routes, increase in transportation costs	Reorientation to regional supply chains
Increased transaction costs	Complexity of contracts, insurance and financial procedures	Decreasing attractiveness of deep offshoring
Technological changes	Automation, digital production management	Possibility of localization without loss of efficiency
Economic security needs	Critical import dependence in strategic sectors	Development of regional production ecosystems

Source: formed by the author based on [7, p. 82; 10, p. 294; 11, p. 17; 12, p. 12; 15, p. 5858]

At the industry level, such transformation has an applied dimension, namely the redistribution of production functions between global and regional sites. In industrial sectors with high sensitivity to supply disruptions, particularly in pharmaceuticals, mechanical engineering, and the production of electronic components, individual production-cycle stages are being returned to regions with a predictable regulatory environment and well-developed infrastructure [11, p. 17]. It allows reducing response time to changes in demand, minimizing downtime risk, and improving product quality control. In agri-food chains, regional localization helps reduce logistics losses, stabilize prices, and strengthen food security amid disruptions to international trade during crises. At the macroeconomic level, the implementation of models of friendly and regional localization is accompanied by the activation of state industrial policy to support localized production in strategic

sectors. Tax incentive instruments, industrial park development programs and support for innovative infrastructure create the prerequisites for the formation of regional production and logistics ecosystems. In combination with corporate strategies of supply diversification, this ensures the growth of global supply chain resilience, greater adaptability to external shocks, and the coordination of economic efficiency with the requirements of security and long-term development. Models of friendly and regional localization of production emerged in response to the growing instability of global value chains and the strengthening of requirements for their economic security and sustainability. They reflect the transition from the dominance of exclusively cost logic to approaches in which the spatial location of production, institutional compatibility of partners and risk management acquire a decisive importance. Within global value chains, these models shift the principles of production function distribution, strengthening the role of controlled, predictable production and logistics configurations (table 2).

Table 2

Economic features of models of friendly and regional localization of production in global value chains

Characteristics	Model of friendly localization of production	Model of regional localization of production
Criteria for selecting partners	Institutional and political compatibility of countries	Geographical proximity and regional integration
Spatial organization of production	Location in partner countries outside the same region	Concentration of production within the macroregion
Formation of added value	Global specialization with controlled risks	Strengthening regional value chains
Logistics structure	Diversified interstate routes	Shortened and stable logistics chains
Risk profile	Minimization of geopolitical and regulatory risks	Reduction of operational and transport risks

Source: formed by the author based on [9, p. 101; 10, p. 297; 11, p. 18–19; 7, p. 84; 8, p. 144]

A profound restructuring of coordination mechanisms in global value chains accompanies the application of models of friendly and regional localization in

modern practice. Friendly localization is used mainly in sectors where legal certainty and trust between chain participants are critical, particularly in the production of complex equipment, the pharmaceutical industry, and industries with a high intellectual component. In such cases, companies locate production or assembly facilities in partner countries with common regulatory standards, thereby reducing the risk of contract interruption, simplifying product certification, and ensuring the stability of long-term investments. Regional localization, in turn, consolidates regional production cycles and contributes to the concentration of added value within integrated economic spaces. In industry, this is manifested in the formation of supplier and manufacturer clusters around key enterprises, which allows reducing transportation costs, increasing interaction speed, and improving adaptability to changes in market conditions [9, p. 101]. In agri-food and consumer chains, regional localization increases the reliability of supplying domestic markets, reducing dependence on fluctuations in global logistics [10, p. 297]. The combination of both models in hybrid configurations creates the possibility of balancing the advantages of global specialization with the requirements of sustainability, which is crucial for the functioning of value chains amid increasing turbulence in the world economy.

Optimization of global supply chains in modern conditions is a complex management process focused on harmonizing economic efficiency with the requirements of sustainability, reliability, and strategic autonomy. This approach departs from the one-dimensional logic of cost minimization. It uses multi-criteria decision-making models, treating the supply chain as a dynamic system capable of adapting to external shocks without losing functionality (table 3).

Table 3

Approaches to optimizing global supply chains by key efficiency and sustainability criteria

Optimization criterion	Content of the approach	Expected economic effect
Sustainability	Diversification of supply sources and reservation of critical links	Reducing the probability of production stoppage

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Optimization criterion	Content of the approach	Expected economic effect
Reliability	Formalization of standards and long-term contractual relationships	Increasing the stability of fulfillment of obligations
Cost efficiency	Digital inventory management and demand planning	Optimization of operating costs
Strategic autonomy	Localization of control over key resources and technologies	Reducing external dependence
System integration	Coordination of production and logistics solutions	Increase in overall chain efficiency

Source: formed by the author based on [1; 3, p. 5; 5; 6; 13, p. 599; 14, p. 2420–2421]

In practical terms, the application of the above approaches manifests in enterprises transitioning to hybrid supply chain management models that combine centralized strategic planning with decentralized operational flexibility. In manufacturing corporations, this is implemented by forming a portfolio of suppliers at different priority levels, where basic contracts ensure cost efficiency in stable conditions, and backup channels allow quick compensation for supply disruptions [5]. For example, in mechanical engineering and the electronics industry, such approaches enable reducing downtime by quickly reallocating orders across production sites. Digital optimization tools play a key role in the practical implementation of multi-criteria approaches, ensuring the integration of data on demand, inventories, production capacities and logistical constraints [14, p. 2420]. The use of analytical platforms and scenario analysis models allows you to assess the consequences of different supply chain configurations in terms of costs, order fulfillment time and risk level. In the consumer goods sector, such solutions help reduce excess inventory, while in the pharmaceutical sector, they ensure the stability of the supply of critical products. At the level of public policy, optimizing global supply chains involves supporting strategically important production segments and developing infrastructure, thereby increasing the autonomy of national economies without isolating them from international markets [6]. The combination of corporate and public management tools enables the formation of supply chains that can ensure

competitiveness, sustainability, and long-term economic security amid structural transformations of the world economy.

The implementation of models of friendly and regional localization of production is accompanied by a set of scientific and practical problems caused by the structural inertia of global value chains and the heterogeneity of the institutional environment. One of the key challenges is the limited coherence of regulatory regimes across partner countries, which complicates harmonizing standards, certification procedures, and customs administration, increasing the time and financial costs of integrating localized production segments. Institutional asymmetry is also manifested in varying levels of protection for property rights and investments, which constrain long-term production decisions and increase the risk premium [15]. Rising transaction costs are another systemic challenge, as the transition to localized models often requires renegotiating contracts, forming new supply chains, and duplicating individual production functions. It reduces short-term cost efficiency and creates tension between sustainability and competitiveness, especially for industries with low margins. An additional factor is the growing administrative costs associated with monitoring compliance with environmental, labor, and technical standards across different jurisdictions. A significant limitation is the risk of market fragmentation, which manifests as reduced access to global production scales and the loss of specialization effects. The division of supply chains along geopolitical or regional lines can lead to reduced competition, slower technology diffusion, and the formation of parallel, less efficient production ecosystems [7, p. 80]. In the long term, this creates a threat of a technological gap between regions and increases uneven economic development. A separate problem is the limited resources and human resources base in localization regions, which complicates the rapid reproduction of complete production cycles and increases dependence on imports of critical components even within localized models. Added to this are financial risks associated with high capital costs for creating new production capacities and

infrastructure, as well as with the uncertainty of long-term demand in a changing global environment.

The practical application of models of friendly and regional localization of production to optimize global supply chains should be carried out in coordination with corporate strategies and the priorities of state economic policy, thereby minimizing the risks of fragmentation and preserving economic efficiency. At the corporate level, the key guideline should be the phased localization of critical production and supply segments with preliminary identification of bottlenecks in value chains. It is recommended to implement multi-level supply models that combine basic channels with higher cost efficiency and backup channels, with an orientation towards sustainability and reliability, and to use digital tools for scenario analysis and risk monitoring actively. At the level of production process management, it is advisable to form long-term partnerships with suppliers in friendly, regionally close jurisdictions, which ensure institutional compatibility, simplify the coordination of standards, and reduce transaction costs. Particular attention should be paid to the development of internal competencies, investments in automation, and increased production flexibility, which allow for compensating for potential increases in costs associated with localization without losing competitiveness. At the state level, recommendations focus on creating a favorable institutional environment for localized production by harmonizing regulatory procedures, developing customs and transport infrastructure, and introducing targeted incentives for investments in strategically important sectors. It is advisable to support programs for the development of industrial clusters and regional production ecosystems, which contribute to the concentration of added value, the spread of technologies and the growth of employment. In the context of post-crisis and post-war recovery, coordination of localization policies with international partners is particularly important to integrate national producers into regional value chains without losing access to global markets. The systemic combination of

corporate and state management tools allows using models of friendly and regional localization not as an isolated alternative to globalization, but as an adaptive mechanism for optimizing global supply chains, capable of ensuring a balance between sustainability, economic efficiency and strategic autonomy in the context of long-term structural changes in the world economy.

Conclusions. The article establishes that the transformation of global supply chains has a stable, structural nature and is driven by the growth of geoeconomic risks, the instability of international logistics, and the strengthening of economic security priorities. It is proven that models of friendly and regional localization of production constitute a long-term direction in the evolution of value-added chains, focused on combining economic efficiency with sustainability, reliability, and strategic autonomy. It is revealed that the main problems in implementing these models are the institutional heterogeneity of regulatory environments, the growth of transaction and administrative costs, the risks of market fragmentation, and the reduction in the effects of global specialization. It is substantiated that without interstate and corporate coordination, localization strategies can limit technological development and deepen regional asymmetries. Recommendations are formulated for the practical application of friendly and regional localization models, which involve the phased localization of critical segments, the use of hybrid supply models and digital risk management tools while maintaining integration into the international division of labor. It is shown that at the state level, the effectiveness of these processes is determined by the quality of the institutional environment, support for regional production ecosystems and coordination of localization policies with international partners. Prospects for further research include the quantitative assessment of the effectiveness and risks of localized supply chains, the analysis of hybrid configurations of global and regional models, and the study of the role of digital and institutional factors in ensuring their long-term sustainability.

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References

1. Skliarenko K. Big Data in logistics marketing for customer churn prediction and dynamic pricing. *Актуальні питання економічних наук*. 2025. № 16. DOI: https://doi.org/10.5281/zenodo.17439059.

2. Коробкова О. М. Інноваційні підходи до підвищення ефективності митної брокерської діяльності в США. *Здобутки економіки: перспективи та інновації*. 2025. № 23. DOI: https://doi.org/10.5281/zenodo.17511239.

3. Kaptosv L. RESTful API design for geospatial logistics platforms using type script and laravel. *Journal of Information, Technology and Policy*. 2025. Vol. 3, № 1. P. 1–13. DOI: https://doi.org/10.62836/jitp.2025.515.

4. Kaptosv L. Using Redis for caching optimization in high-traffic web applications. *International Journal of Advanced Multidisciplinary Research and Studies*. 2025. Vol. 5, № 4. P. 1714–1722. DOI: https://doi.org/10.62225/2583049X.2025.5.4.4839.

5. Hasenko Y. Implementation of MRP systems as a tool for improving inventory management efficiency in FMCG companies. *Актуальні питання економічних наук*. 2025. № 16. DOI: https://doi.org/10.5281/zenodo.17551471.

6. Hasenko Y. Enhancing the environmental safety of logistics processes through optimal supply planning. *Здобутки економіки: перспективи та інновації*. 2025. № 20. DOI: https://doi.org/10.5281/zenodo.17898105.

7. Сандул М. Трансформаційні фактори розвитку глобальних ланцюгів постачання. *Міжнародна економічна політика*. 2023. № 1 (38). С. 78–101. DOI: https://doi.org/10.33111/iep.2023.38.04.

8. Попадинець Н. М., Бондарчук М. К., Сембай Н. М. Просторова трансформація регіональних ринків логістичних послуг та їх вплив на розвиток легкої промисловості України. *Трансформаційна економіка*. 2024. № 2 (07). С. 142–146. DOI: https://doi.org/10.32782/2786-8141/2024-7-22.

9. Маєвська Н. Альтернативні моделі управління ланцюгами доданої вартості мікро- та малих агровиробників. *Сталий розвиток економіки*. 2024. № 1 (48). С. 99–104. DOI: https://doi.org/10.32782/2308-1988/2024-48-13.

10. Macchion L., Fornasiero R. Global-local supply chain configurations for different production strategies: a comparison between traditional and customized productions. *Journal of Fashion Marketing and Management: An International Journal*. 2021. Vol. 25, № 2. P. 290–309. DOI: https://doi.org/10.1108/JFMM-12-2019-0269.

11. Cohen M. A., Lee H. L. Designing the right global supply chain network. *Manufacturing & Service Operations Management*. 2020. Vol. 22, № 1. P. 15–24. DOI: https://doi.org/10.1287/msom.2019.0839.

12. Nandi S., Sarkis J., Hervani A. A., Helms M. M. Redesigning supply chains using blockchain-enabled circular economy and COVID-19 experiences. *Sustainable Production and Consumption*. 2021. Vol. 27. P. 10–22. DOI: https://doi.org/10.1016/j.spc.2020.10.019.

13. Yakavenka V., Mallidis I., Vlachos D., Iakovou E., Eleni Z. Development of a multi-objective model for the design of sustainable supply chains: the case of perishable food products. *Annals of Operations Research*. 2020. Vol. 294, № 1. P. 593–621. DOI: https://doi.org/10.1007/s10479-019-03434-5.

14. Sodhi M. S., Tang C. S., Willenson E. T. Research opportunities in preparing supply chains of essential goods for future pandemics. *International Journal of Production Research*. 2023. Vol. 61, № 8. P. 2416–2431. DOI: https://doi.org/10.1080/00207543.2021.1884310.

15. Zhu G., Chou M. C., Tsai C. W. Lessons learned from the COVID-19 pandemic exposing the shortcomings of current supply chain operations: a long-term prescriptive offering. *Sustainability*. 2020. Vol. 12, № 14. Article 5858. DOI: https://doi.org/10.3390/su12145858.