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# LOGISTICS RISK ASSESSMENT AND THE DEVELOPMENT OF A RISK-ORIENTED CONTROLLING APPROACH UNDER UNCERTAINTY

*The object of research is the process of management and functioning of logistics systems of the European Union countries and Ukraine under conditions of uncertainty and crisis phenomena. The problem addressed is the lack of a methodologically formalized link between the type of logistics risk environment and the choice of a controlling model capable of ensuring efficiency and resilience of logistics processes. The results are based on internationally comparable indicators, including the logistics performance index, time to export procedures, the transport services cost index, and the political stability and absence of violence index. After data standardization, k-means cluster analysis identified three types of logistics risk environments in the European Union with different levels of risk exposure. This confirms the heterogeneity of logistics risk profiles across EU countries and limits the applicability of unified controlling models focused exclusively on efficiency. A comparative assessment of Ukraine relative to average cluster values revealed an extreme logistics risk environment. It is characterized by a 22–31% lower Logistics Performance Index, a 2.7–4.3 times longer time required for export procedures, a 24–35% higher transport services cost index, and a significant deterioration in institutional parameters compared with the average values of all EU clusters. A mechanism for selecting a risk-oriented logistics controlling model depending on the operating conditions of the system has been developed, which enhances the validity of managerial decisions and the resilience of logistics processes. A distinctive feature of the results is the proposed mechanism for selecting a risk-oriented controlling model depending on the type of logistics environment. The findings can be used by enterprises and logistics governance bodies to develop logistics risk monitoring systems, improve management accounting and logistics cost budgeting, and design anti-crisis solutions under conditions of uncertainty and crises.*

**Keywords:** controlling, logistics risks, supply chains, logistics risk environment, logistics system resilience.

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## 1. Introduction

The last decades are characterized from the point of view of logistics by its transformation from an auxiliary function into one of the key parameters of ensuring the competitiveness of enterprises. This is due to the implementation through logistics channels of a significant part of operational and financial decisions. Along with this, there is an increase in the uncertainty of the external environment and geopolitical risks, constant failures in global supply chains. All this contributes to the increase in the vulnerability of logistics systems to various challenges of various natures. It is in such conditions that logistics controlling, which focuses on controlling costs, deadlines and performance, is insufficient for making management decisions in situations where deviations are systemic or cascading in nature. Its main feature is the rapid spread between all types of flows: material, financial and information. The need to apply risk-oriented logistics controlling is due to the synthesis of logistics, which ensures economic efficiency, and the requirements aimed at the stability and continuity of supply processes. Within the framework of risk-based management, all risks are considered from the point of view of factors that affect planning, budgeting and op-

erational coordination. In the context of logistics, there is a change in management priority from control over individual operations to constant monitoring of all types of risks in the logistics network. This involves identifying critical problem areas and setting such threshold values of deviations that are aimed at forming anti-crisis management actions. Despite the growing scientific interest in the issues of logistics risks and the sustainability of supply chains, modern literature lacks an established approach to the interpretation of risk-based controlling in the logistics context. Existing studies, as a rule, focus either on controlling tools or on risk management procedures, without ensuring their methodological combination taking into account the specifics of the functioning of logistics systems. This necessitates the formation of a holistic methodological framework, which, on the one hand, allows for the systematization of logistics risks according to complementary criteria. That is, by source of origin, level of manifestation, logistics sphere, type of flow, scale of influence, predictability, level of turbulence of the environment. On the other hand, it creates opportunities for operationalization of the concept of functioning of the logistics system based on internationally comparable indicators and its connection with the choice of the appropriate controlling model.

Active development of scientific achievements in the context of supply chain management still does not have a single approach to defining logistics risks and the possibilities of their consideration in the management and controlling systems of logistics processes.

Logistics risks in scientific approaches to supply chain risk management are considered through their impact on delivery times, cost levels and continuity of material flows. The papers [1, 2] emphasis is placed on identifying risks and, accordingly, choosing response strategies. It should be noted that the analysis is applied mainly to individual operational links, without taking into account the possibility of systemic and multi-level risks within supply chains.

The next stage of research was aimed at generalizing risk management approaches and attempting a comprehensive classification of logistics risks. Thus, in [3], logistics risks are considered as risks that cover not only operational aspects, but also financial and institutional aspects, thus emphasizing their interdependence. However, these approaches are of an overview nature and do not involve the inclusion of analysis and assessment of logistics risks in the enterprise controlling system.

Global crisis events have formed a separate area of research, which singles out the vulnerability of supply chains. The paper [4] is devoted to the impact of external risks not only on individual logistics operations, but also on their impact on strengthening the structural imbalances of logistics systems, turning local failures into systemic disruptions. The paper substantiates the feasibility of moving from reactive to proactive risk management approaches. However, the role of controlling as a tool for continuous monitoring of the impact of risks on logistics processes has remained out of the scope of attention. In modern realities, in accordance with the concepts of supply chain management, the issue of sustainability and viability of logistics systems comes to the fore. In the paper [5], logistics risks are studied as a factor that determines the need to adapt the structure of logistics networks as a result of a complex disruption. The approach contributes to a deep understanding of the systemic nature of logistics risks. The disadvantage is the emphasis on operational and strategic decisions without defining a clear place for controlling in management.

Another group is forming studies that consider organizational and inter-firm factors of the stability of logistics systems. In particular, [6] prove that the development of communications in the middle of the chain affects the system's ability to recover from failures. But such works are aimed at considering behavioral and interactional aspects. Controlling as a tool for identifying risks and supporting management decisions in the logistics system remains out of focus.

In scientific works on the theory of management control, controlling is considered as a tool for coordinating strategic and operational decisions in conditions of uncertainty. In [7] it is emphasized that modern management control systems should go beyond measuring performance and integrate non-financial parameters and contextual characteristics of the enterprise's operating environment. Developing this approach, the feasibility of forming integrated management control systems capable of supporting decision-making in conditions of increased turbulence is substantiated in [8].

Attempts to combine controlling and risk management tools are also presented in works devoted to financial controlling and financial security of enterprises. Thus, in [9, 10] the effectiveness of adaptive controlling systems as a tool for managing financial stability in an unstable external environment is proven. However, these researches are focused mainly on the financial aspects of enterprises' activities and do not take into account the specifics of logistics processes and the multidimensionality of logistics risks.

Thus, the generalization of scientific approaches shows that the existing research on logistics risks, supply chain management and controlling remains fragmentary. Logistics risks are mostly analyzed

without systematic integration into controlling circuits, while logistics controlling is focused mainly on efficiency indicators and does not take into account the dynamics and configuration of risks. This justifies the expediency of forming risk-oriented logistics controlling, adapted to the conditions of the functioning of the logistics system, which determines the formulation of the problem of this research.

Thus, *the object of research* is the process of management and functioning of logistics systems of the European Union and Ukraine in conditions of uncertainty and crises.

*The subject of research* is the set of logistics risks (infrastructural, time, cost and institutional), as well as theoretical and methodological approaches, tools and mechanisms for their consideration in the system of risk-oriented logistics controlling, taking into account the conditions of the logistics system's functioning.

The research is aimed at assessing logistics risks and developing a mechanism for choosing a model of risk-oriented logistics controlling depending on the conditions of the logistics system's functioning.

*The aim of research* is to develop a methodological approach to the formation of risk-oriented logistics controlling based on the assessment of logistics risks in conditions of uncertainty.

To achieve the set aim, the following objectives are envisaged:

1) to substantiate the role of the conditions of the logistics system's functioning in the formation of a system of risk-oriented logistics controlling from the standpoint of a systems approach and the concept of risk-oriented management;

2) to carry out an empirical analysis of logistics risks using a cluster approach (using the example of the European Union countries), to conduct a comparative assessment of Ukraine's logistics indicators in relation to cluster characteristics, and to determine managerial implications for the formation of models of risk-oriented controlling of enterprise logistics.

## 2. Materials and Methods

The empirical basis of the research is a cross-sectional database of internationally comparable statistical data, formed by the countries of the European Union for the latest available period based on information from the World Bank and Eurostat. To assess logistics risks, the logistics efficiency index, the export transaction time index, the transport services cost index, and the political stability and absence of violence index were used. Based on these indicators, the EU countries were clustered, which allowed identifying the conditions for the functioning of the logistics system and forming reference profiles for the functioning of logistics systems. Ukraine was considered in the research as a separate crisis object of comparative analysis.

Taking into account the objectives set in the research, the following hypotheses were formulated and empirically tested:

- the logistics systems of the countries of the European Union are characterized by the presence of different conditions for the functioning of the logistics system, which differ in the combination of infrastructure, time, cost, and institutional risks;
- countries with a high level of logistics risks require the use of adaptive and anti-crisis models of controlling, focused on ensuring the continuity of logistics processes;
- the logistics system of Ukraine operates in an extreme risk environment, which determines the limited applicability of preventive models of controlling and actualizes the need for risk-oriented and anti-crisis management mechanisms.

The research methodology is based on a combination of systemic, process and risk-oriented approaches, which allows considering logistics as a complex multi-level system sensitive to external shocks and internal structural constraints. This approach ensures the coordination of analytical results of logistics risk assessment with practical tasks of forming a risk-oriented controlling system.

The following methods were used in the research process. The method of analysis and generalization was used to systematize scientific approaches to the interpretation of logistics risks, controlling and managing supply chains under conditions of uncertainty. The method of economic and statistical methods was used to process and analyze international logistics indicators. Data standardization methods were used to ensure the correctness of multivariate analysis. Cluster analysis method (*k*-means method) was used to typify the logistics systems of EU countries by the set of risk indicators. The method of comparative analysis of relative deviations was used to assess the logistics risks of Ukraine relative to typical cluster characteristics. The method of economic interpretation was used to substantiate the managerial implications and the choice of risk-oriented controlling models.

The information base of the research is official international statistical sources that ensure the comparability of logistics indicators between countries. In particular, data on the logistics efficiency index, the time of export operations, as well as the index of political stability and the absence of violence were obtained from open databases of the World Bank. They are formed within the framework of the Logistics Performance Index [11], Worldwide Governance Indicators [12] and World Bank Open Data [13].

Information on the dynamics of the cost of transport services was used on the basis of statistical materials from Eurostat [14], in particular, price indices for transport services calculated with the base year 2015. The use of these sources allows to ensure the reliability of the data, their international comparability and the correctness of the application of economic and statistical methods of analysis.

The use of the proposed methodological tools allowed to identify the conditions of the functioning of the logistics system, assess the position of Ukraine in relation to the countries of the European Union and form an analytical basis for building differentiated models of risk-oriented logistics controlling. The results obtained can be used in management accounting systems, logistics controlling and technological audit of logistics processes, in particular in conditions of crises, military threats and post-crisis recovery.

### 3. Results and Discussion

#### 3.1. Justification of the role of the conditions for the functioning of the logistics system in the formation of risk-based controlling

In the current situation, characterized by increasing unpredictability, unstable geopolitical situation and disruptions in global supply chains, logistics is becoming one of the riskiest functional areas of enterprise activity. This significantly complicates the processes of management coordination and reduces the effectiveness of traditional logistics control systems. They are mostly focused on monitoring costs, meeting deadlines and assessing performance, and do not take into account the dynamics and nature of logistics risks. Under such conditions, there is an urgent need to create risk-based logistics controlling as an integrated management system. It must be able to combine efficiency goals with the requirements of sustainability and continuity of logistics processes. At the same time, the development of such systems requires a deep understanding of the essence, structure and typical relationships of risks in logistics, as well as the characteristics of the logistics system in which they manifest themselves.

Therefore, the creation of risk-oriented logistics controlling is impossible without a full understanding of the diversity and complexity of logistics risks. Unlike financial or production risks, logistics risks relate simultaneously to material, monetary and information flows. They manifest themselves at different stages of management and arise under the influence of both internal factors and external institutional, infrastructure and security conditions. This necessitates the use of a comprehensive approach to their division, which allows simultaneously taking into account the source of occurrence, the level of occurrence, the functional area of logistics, the type of flow and the size of possible consequences.

It is this classification according to many features that creates a theoretical basis for further identification of typical risk situations and the selection of appropriate controlling tools depending on the logistics system.

To streamline logistics risks, a comprehensive approach is necessary, since they appear at different stages of management, cover different flows and have a different nature of impact. A single classification allows assessing logistics risks simultaneously by their origin, degree of detection, scope, type of flow, nature, predictability and magnitude of impact. Thus, this approach is a theoretical basis for risk-based logistics controlling, supply chain management in conditions of destabilizing internal and external risks.

Logistics risks during martial law in Ukraine acquire special importance, as they significantly affect the smooth operation of logistics systems. These risks include primarily damage to transport routes, changes in infrastructure, external threats. Research [15] confirms that logistics risk management in war conditions should primarily focus on timely identification of risks, determination of the main factors of influence, forecasting the consequences of management decisions and choosing risk management methods. The author identifies five key stages of the logistics risk management process, which confirms the need for a systematic approach to their analysis.

In [16], attention is paid to the national specificity of logistics risks, and specifically those that arise in wartime. The authors distinguish risks by their origin and functional area of logistics. This makes it possible to clearly distinguish risks into internal (related to organization, operations, technology) and external (political, economic, infrastructure). This approach is the basis for the formation of logistics management mechanisms.

In [15], a systematic classification of logistics risks is provided:

- by type of flow – material, financial, information;
- by place of origin – procurement, production, transportation, storage, sales;
- by nature of impact on the logistics system – local, systemic, cascading;
- by nature of origin – commercial, technical, legal, force majeure;
- by degree of predictability – predicted and unpredicted.

Thus, the result of the analysis of scientific sources allowed to systematize logistics risks and create an integrated system that takes into account all the characteristic features and impact on the activities of supply chains. This approach, unlike existing one-dimensional classifications, is based on the synthesis of criteria that belong to the following aspects of logistics activities: organizational, functional, flow and system. This will allow not only to identify individual risks, but also to study their concentration in logistics activities, which forms risk-oriented controlling tools. A comprehensive classification of logistics risks is presented below in Table 1.

The above classification emphasizes the multifaceted nature of logistics risks and their ability to occur simultaneously in different aspects of management. Combining criteria such as flow type and functional area allows to trace how initial disruptions in material flows can turn into financial losses or information failures. This creates conditions for a chain reaction in the supply system.

Determining the scale of impact is extremely important for the transition from local risk management to a comprehensive analysis of the stability of logistics systems. Thus, this multifactorial classification forms a methodological basis for identifying typical risk situations and further developing adaptive logistics risk management tools.

Theoretical provisions on the multidimensional nature of logistics risks are confirmed in modern studies devoted to the impact of crisis events on the functioning of logistics systems. In [17], the issue of the impact of various crisis events on logistics services was investigated. It was found that all crises (economic, political, organizational, environmental and technological) significantly change the principles of the functioning of the logistics market, requiring companies to adapt to new conditions.

Table 1

Integrated approach to the classification of logistics risks according to the main assessment criteria

Classification criterion	Type of logistics risks	Manifestation in logistics processes	Orientation of controlling tools
Occurrence source	Internal, external	Disruption of process coordination	Separation of internal KPIs and key indicators of the external environment
Manifestation level	Micro, macro and meso levels	Dependence on infrastructure and regulatory constraints	Combination of corporate, industry and macroeconomic monitoring
Functional area of logistics	Purchase of goods and raw materials, production, transport, information base	Failures at the enterprise level, industry crises and systemic logistics crises	Building a process-oriented controlling system
Type of flow	Material, financial, information	Delays in deliveries, resource constraints, disruptions in production schedules	Harmonization of all types of indicators in the controlling system
Scale of influence	Local, systemic, multi-level	Increasing cost levels, loss of controllability	Transition to managing the sustainability of the entire network
Forecasting possibility	Predicted, unpredictable	Failures throughout the logistics network	Use of scenario analysis and stress testing
Functioning form	Stable, crisis, military	Single disruptions, need for crisis response	Application of monitoring of risks and critical deviations of indicators to ensure the continuity of logistics processes

There is a difference in demand for logistics services in the territories of regions remote from zones of active military conflicts and regions located directly in the conflict zone. In the first case, there is an increase in demand for logistics services. This directly affects the need for continuous supply of products and the development of transport and logistics infrastructure.

Research [18] proves that risk management in supply chains under conditions of uncertainty should be based on the experience of leading countries and include a comprehensive system of control of material, monetary and reporting flows. The author demonstrates a simplified model of the risk management system in supply networks, which takes into account the influence of internal and external threat factors.

Modern research on logistics risks has formed an idea of their complex nature and typical combinations. Risks in logistics systems rarely appear in isolation: primary violations, such as delivery delays or transport restrictions, can cause a consistent spread of interconnected threats in material, information and financial flows. This justifies the feasibility of analyzing not only individual risks, but also their configurations that form a systemic risk profile. This approach is the methodological basis of risk-oriented logistics controlling in conditions of uncertainty. Table 1 presents a developed comprehensive classification of logistics risks, which reflects their ability to arise simultaneously in different management areas: by functional areas, types of flows and scale of impact. This increases the likelihood that local failures in logistics can affect significant systemic disruptions in activities precisely through the interconnection of logistics processes and flows. In particular, the combination of criteria reflecting the type of flow, the functional area and the scale of impact allows to analyze how primary disruptions in material or information processes can cause secondary financial and organizational losses. This forms a chain-like sequential spread of failures in supply chains.

This indicates the limitations of approaches focused on managing individual categories of risks and requires a comprehensive analysis of common manifestations of risks in logistics networks.

The theoretical basis of the system approach is the concept of a viable supply chain [19]. The concept assumes that the sustainability of logistics systems can be achieved by combining flexibility, the ability to quickly recover after overcoming logistical problems and ensuring strategic stability of development. This concept is focused on forming the adaptive ability of the system to respond to various types of disruptions and maintain functionality in conditions of multi-level spread of failures.

Therefore, effective logistics risk management should take into account both the risks themselves and the characteristics of the environment within which supply chains operate. The degree of instability, the

reliability of the institutional environment, the state of the infrastructure and security factors form different conditions for the functioning of logistics systems, where the same dangers can cause different consequences. This leads to the need for their typology, because without this it is difficult to correctly select risk-based controlling tools for specific operating conditions.

The research [20] proposed an approach to the classification of information and logistics systems based on the principles of omnichannel, which corresponds to modern trends in digitalization and increased competition. This approach allows to assess how well different channels and elements of the logistics system work, make flow management more transparent and timely identify problematic areas of the infrastructure. As a result, this makes it possible to determine the level of development of the logistics system and outline the directions for its further improvement.

The conditions in which supply processes are carried out are becoming increasingly complex and less predictable. Therefore, logistics management can no longer be built according to universal templates – it must take into account the specific environment in which the system operates. Logistics processes occur in different institutional, economic, infrastructural and security conditions, which means that risks also manifest themselves differently. That is why typology of the conditions of operation of logistics systems is important not only as a way to organize these conditions, but also as a basis for the correct configuration of risk management systems.

The value of such an approach lies in the fact that it helps to understand how the characteristics of the environment affect the structure of risks and the choice of management decisions. Given a relatively stable and predictable external environment, the main attention is paid to operational and commercial risks. This allows to focus on reducing costs and increasing efficiency. The situation changes in times of crisis or during martial law. Infrastructure problems, regulatory restrictions and risks that directly affect the ability to carry out supplies come to the fore. In such circumstances, it is not enough to simply control costs or deadlines. It is necessary to assess various scenarios of events, test the system for stability and identify the most vulnerable areas of the logistics network. The conditions in which the enterprise operates affect the values of indicators, which requires a flexible approach to building a controlling system.

Typologizing the conditions of the functioning of logistics systems makes it possible to understand at what levels risks arise and what their nature is. At the enterprise level – internal business processes, digitalization and interaction with partners in supply chains. Sectoral and regional levels – the state of the infrastructure, market features and the activities of logistics associations.

Macro level – the economic situation, regulatory policy and the impact of international events. All these levels interact with each other, and therefore even small local failures can eventually grow into large-scale problems for the entire logistics network.

Such typology is a starting point for building risk-oriented controlling. It allows to determine which indicators need to be monitored, how often, what deviation limits are considered acceptable, and what to pay attention to first of all in management. In other words, it is possible to move from a standard set of KPIs to a flexible system of indicators only when it is clear in what conditions the logistics systems of the enterprise operate. This helps to align strategic goals with real risks and make management decisions more justified and practical.

Thus, the distribution of the conditions of logistics systems operation by type helps to move from formal risk analysis to the construction of a management system that actually takes into account the operating conditions of the enterprise and can flexibly respond to changes. It is the determination of the type of conditions of operation of logistics systems that creates the prerequisites for the transition to risk scenario management taking into account the context of the operation of logistics networks. This approach constitutes the methodological basis for the implementation of risk-oriented logistics controlling in conditions of uncertainty.

In modern conditions of increasing uncertainty, increasing geopolitical risks and disruption of global supply chains, logistics is becoming one of the most risk-saturated areas of enterprise activity. This necessitates the rethinking of traditional approaches to controlling and the formation of management systems that can take into account the impact of risks on the parameters of logistics processes. At the same time, an analysis of the scientific literature indicates the absence of a well-established interpretation of the concept of “risk-oriented logistics controlling”, which justifies the expediency of its formation based on the synthesis of related theoretical approaches.

In [10] it is stated that controlling is a tool for coordinating strategic and tactical decisions of the enterprise based on a systematic analysis of the results of its activities, which contributes to increasing the efficiency of management. In [9], controlling is considered as a tool for supporting the financial security of the enterprise in unstable operating conditions and emphasizes its adaptive nature. Thus, in modern theory, controlling acquires the features of a dynamic system that is able to respond to changes in the external environment of business operation and adapt to these changes.

Controlling in logistics is aimed at coordinating costs, terms and effectiveness of logistics processes, which must coincide with the goals of the enterprise. At the same time, the disadvantages of traditional models of controlling logistics are that they focus mainly on internal indicators of efficiency, namely, costs, productivity, compliance with deadlines. The influence of external risks is insufficiently taken into account. That is why their practical value decreases in conditions of uncertainty and especially in wartime.

Further evolution of management systems is associated with the implementation of the principles of risk-based management and the concept of integrated enterprise risk management, within which risk is considered as a key parameter for making management decisions. Thus, in [21] the concept of integrated enterprise risk management is characterized as a multifaceted system for identifying, assessing and monitoring threats that can prevent the achievement of strategic goals of the enterprise. In [22] it is emphasized that in times of crisis the concept of integrated enterprise risk management is transformed from a formal risk management system into an effective strategic management tool that strengthens the resilience of the enterprise in the face of external influences.

The implementation of risk-based management in logistics makes it possible to ensure the stability and continuity of logistics processes, and does not simply affect the reduction of costs. Logistics risks are

multifaceted, they include infrastructure risks, time delays, cost changes, as well as instability in the legal and political environment. In [5] it is proven that the stability of logistics systems is achieved not by eliminating each risk separately, but by adapting management mechanisms to different conditions of the risk environment.

Analysis of existing approaches to the theoretical essence of controlling, complex risk management and logistics risk management allows to provide our own definition of the concept of risk-oriented controlling of logistics.

Based on the above theoretical principles, risk-oriented controlling of logistics should be considered as a combination of three approaches:

- 1) controlling as information and analytical support and coordination;
- 2) risk-oriented management as an approach to the systematic consideration of risks in the management process;
- 3) logistics risk management as a direction that is particularly sensitive to the influence of the external environment.

The authors proposed the following definition of risk-oriented controlling of logistics. This is a holistic system of information and analytical support for management decisions, integrating controlling and risk management tools, aimed at managing logistics risks taking into account the type of risk environment and ensuring the sustainability of logistics processes. The purpose of risk-based logistics controlling is to adapt logistics processes to a specific type of risk of the conditions of operation of logistics systems, reduce costs, ensure uninterrupted supply and increase the stability of logistics systems in conditions of instability and crisis situations.

Fig. 1 shows a conceptual scheme of controlling, integrated risk management of the enterprise and logistics risks. It is a flexible system that allows to combine logistics costs, terms and the level of stability of logistics processes in accordance with the influence of external conditions of operation of logistics systems.

Thus, the created theoretical and methodological basis of risk-oriented controlling of logistics taking into account threats requires empirical research. To operationalize the conditions of functioning of logistics systems and identify typical configurations of risks, it is advisable to apply methods of multidimensional statistical analysis, in particular clustering. This allows to carry out typology of logistics systems according to a number of factors covering infrastructure, time, cost and institutional aspects, which lays the foundation for the transition to quantitative assessment of logistics risks, the results of which will become the basis for further practical research.

### 3.2. Empirical substantiation of the impact of logistics risks on the formation of a risk-oriented controlling system

The empirical research is based on statistical data for the latest available period. The information base is formed on the basis of the World Bank reports [11–13] and Eurostat [14]. The choice of these international sources allows for a correct comparison of indicators of different countries and ensures the reliability of the conclusions obtained.

To assess logistics risks, a system of indicators has been formed that reflects the infrastructure, time, price and institutional aspects of the functioning of logistics systems. Thus, the analysis is based on the following indicators:

- logistics efficiency index;
- time for carrying out export operations;
- transport services cost index (as a proxy indicator of cost risks according to Eurostat);
- level of political stability and security factor.

The choice of these indicators is due to the need for comprehensive coverage of key aspects of the functioning of logistics systems in conditions of uncertainty. Thus, the logistics systems efficiency index allows to assess the infrastructure conditions for the functioning of logistics systems. It acts as an integral indicator and reflects the state of the

transport infrastructure, the work of customs and the level of logistics services. The time component of the logistics risk assessment is represented by the indicator “time to carry out export operations”. It allows to assess the vulnerability of logistics processes to administrative pressure and legal restrictions. The price dimension is determined through the transport services cost index using a proxy indicator of cost logistics risk, calculated according to Eurostat data using 2015 as the base period for comparison. The institutional environment and its risks are reflected through the index of political stability and absence of violence, calcula-

ted by the World Bank within the framework of the World Governance Indicators system. It reflects the level of reliability of transport corridors and the continuity of logistics flows. The synthesis of these indicators allows to form a holistic picture for risk-oriented logistics controlling, taking into account micro- and macroeconomic factors.

To systematize the selected indicators and determine their practical significance for the system of risk-oriented logistics controlling, Table 2 summarizes the correspondence between indicators of logistics risks, types of risk, and aspects of controlling.

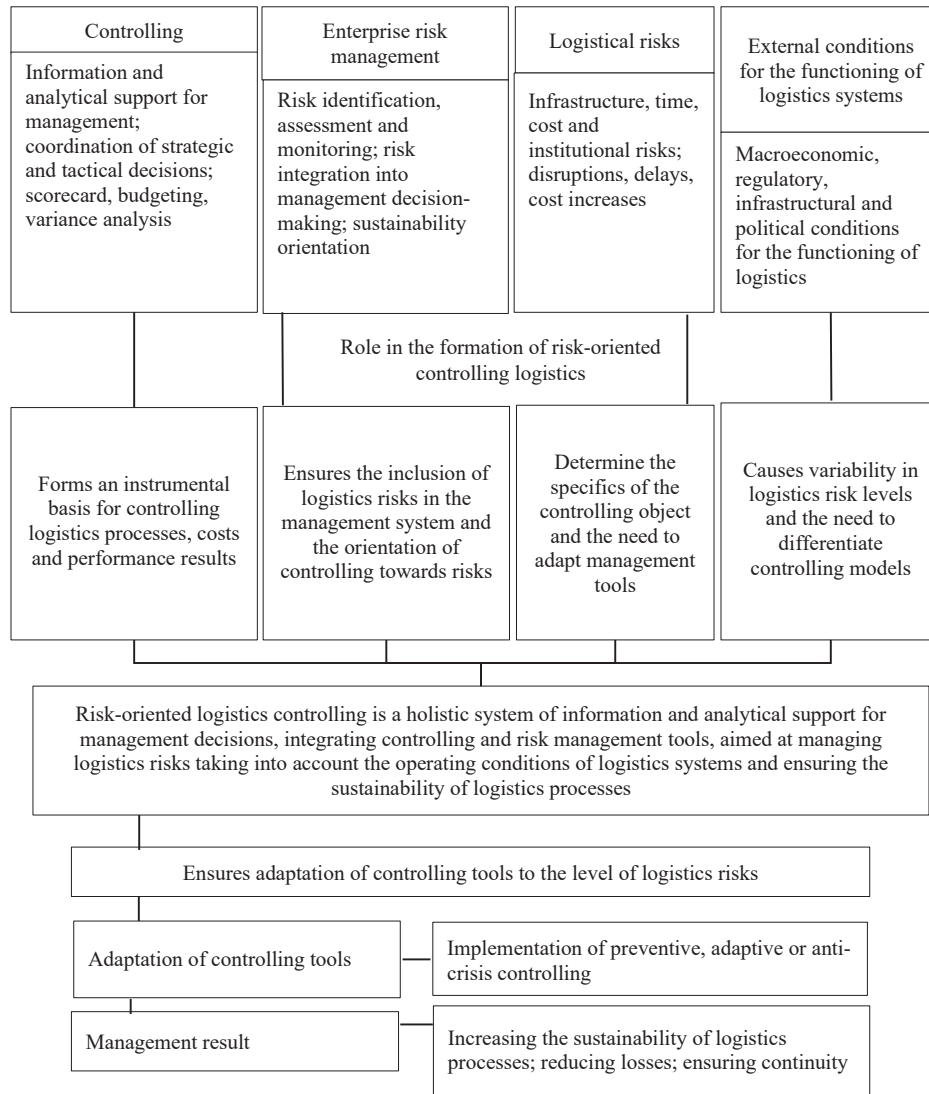


Fig. 1. Conceptual scheme of synthesis of controlling, integrated enterprise risk management and logistics risks in formation of risk-oriented controlling of logistics (compiled by authors on the basis of [5, 9, 10, 15–22])

Table 2

Logistics risk indicators in the risk-based controlling system

Indicator	Type of logistics risk	Scope of application in the risk-based controlling system
Logistics efficiency index	Infrastructural, operational	Controlling the efficiency of supply processes and assessing the material flow system
Export transaction time	Time regulatory	Controlling the duration of logistics cycles, managing delays and identifying "bottlenecks"
Transport cost index	Cost logistics risk	Controlling logistics costs, budgeting and analysis of deviations
Political stability and violence index	Institutional, systemic	Controlling within the framework of anti-crisis management and management of exogenous risks

Note: compiled by the authors based on [11–14]

Table 3

Grouping of countries by levels of logistics risks

Cluster	Logistic risk level	Countries
Cluster 1	Moderate	Croatia, Czech Republic, Estonia, Italy, Latvia, Lithuania, Poland, Portugal, Slovakia, Slovenia, Spain
Cluster 2	High	Bulgaria, Cyprus, Greece, Hungary, Malta, Romania
Cluster 3	Low	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden

Note: calculated by the authors based on [11–14]

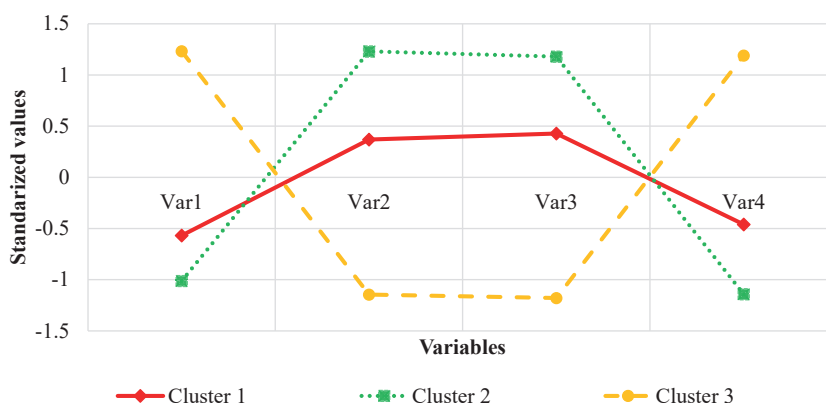


Fig. 2. Profiles of average values of logistics indicators within the clusters of EU countries: Var1 – logistics efficiency index; Var2 – export transaction time; Var3 – transport services cost index; Var4 – political stability and absence of violence index

These indicators are formed by international organizations based on unified international approaches. They allow for a correct comparison of countries with each other and can be used in the procedure of cluster analysis of logistics risks [11–14].

In order to correctly compare the indicators, they were standardized, which made it possible to level out differences and avoid the influence of different units of measurement and avoid the dominance of individual indicators in the formation of clusters. The grouping of countries was carried out using the k-means method, which is based on minimizing the distances between objects within the cluster [23].

The number of clusters was selected at the level of three, which corresponds to the logic of dividing countries by the level of logistics risks into countries with a low level of the specified risk, moderate and high risk. In the research, the analysis was carried out for the countries of the European Union, which operate in similar institutional conditions and use comparable statistical indicators. As a result of the clustering, the average values of indicators (indices) within each group were determined, which allowed to describe the conditions of the functioning of logistics systems in the EU countries.

Within the framework of research, Ukraine is considered as a separate object of analysis and is not included in the clustering procedure. A comparative assessment of logistics risks was carried out by comparing the values of the relevant indicators of Ukraine with the values of the average indicators of the relevant clusters of EU countries. The calculation of deviations was carried out in percentages according to the formula

$$\Delta_{UA,i} = \frac{X_{UA} - \bar{X}_i}{\bar{X}_i} \cdot 100\%$$

where  $X_{UA}$  – the value of the relevant indicator for Ukraine;  $\bar{X}_i$  – the average value of the indicator for the  $i$ -th cluster of EU countries.

Analysis of the obtained deviations will allow to identify the directions in which the logistics system of Ukraine deviates from the average European ones, which is a condition for the formation of priorities for risk-oriented logistics controlling.

For the correct interpretation of deviations, the indicators were classified into stimulants and de-stimulators from the position of logistics risks. The stimulants include the logistics efficiency index and the index of political stability and absence of violence. Their growth indicates a decrease in risk, and to the de-stimulators – the time of export operations and the index of the cost of transport services, the growth of which indicates an increase in risk. Accordingly, the sign of the deviation is determined taking into account the economic essence of each indicator.

Focusing on average cluster characteristics and relative deviations allows to generalize the results obtained and use them for making management decisions in the field of logistics under conditions of uncertainty.

According to the results of the cluster analysis of the European Union countries, three clusters were identified that characterize different conditions for the functioning of logistics systems. The composition of the formed clusters is given in Table 3.

To generalize the characteristics of the formed clusters, the average values of the indicators for each cluster were calculated, which makes it possible to form an idea of the typical conditions for the functioning of logistics systems. The results obtained indicate that the formed clusters differ in the values of the logistics indicators and confirm the presence of different levels of logistics risks within the sample. This allows to consider the differences between the formed clusters. A visual representation of the logistics risk profiles within the selected clusters is shown in Fig. 2.

The results of the research (Fig. 2) demonstrate significant differences between the countries of the European Union in terms of the total level of logistics risks. The heterogeneity of the indicators is due to the different intensity of manifestation of risk-forming factors in logistics systems. This justifies the feasibility of considering the formed clusters from the point of view of their internal structure and sources of risk.

The first cluster was formed by countries with a balanced ratio between the level of infrastructure development and the impact of security and regulatory restrictions. The logistics system of these countries operates in a moderate risk zone, however, stability depends on changes in the external environment. Within this cluster, the values of key logistics indicators approach the averages for the sample. Therefore, there is a need for constant risk monitoring and prompt response to external risks.

The second cluster includes countries with the most problematic conditions for the functioning of logistics systems. Countries included in this cluster have low logistics efficiency, long terms of export operations and high transport costs. The combined impact of these factors causes a high level of uncertainty and significantly affects the sensitivity of logistics processes. Under such conditions, the application of stricter management approaches focused on increased control of time parameters and costs, as well as on minimizing operational losses, becomes a priority. This indicates the need to transition to a strict risk management model with an emphasis on increased control of time parameters of logistics processes.

The third cluster, on the contrary, demonstrates the highest resistance to destabilizing influences. Minimal logistics costs, optimized delivery times and institutional stability allow these countries to maintain high performance even in the face of exogenous shocks. It is this set of characteristics that ensures the continuity of logistics processes, which is the key competitive advantage of this group.

The results of the cluster analysis show that the countries of the European Union differ significantly in the combination of infrastructure, time, cost and institutional characteristics of logistics systems. The formed groups reflect different conditions for the functioning of logistics systems, and not formal territorial or economic associations, which is fundamentally important for further applied interpretation of the results within the framework of risk-oriented controlling.

This approach allows to move from a general comparison of countries to the formation of differentiated management decisions adapted to the conditions in which the logistics systems of enterprises operate.

Within the framework of this research, Ukraine is considered as a separate crisis object of comparison. This makes it possible to compare its logistics indicators with the parameters of the functioning of logistics systems in the countries of the European Union and to justify the feasibility of using special anti-crisis approaches to logistics management.

To quantitatively assess logistics risks, a comparative analysis of the main logistics indicators of Ukraine with the average cluster indicators of the European Union countries was conducted. The results of the comparative analysis are presented in Table 4.

**Table 4**  
Comparison of logistics indicators of Ukraine and average cluster indicators of the EU countries

Indicator	Ukraine	Cluster 1 (moderate risk)	Cluster 2 (high risk)	Cluster 3 (low risk)
Logistics efficiency index	2.80	3.61	3.35	4.08
Export transaction time	4.50	1.87	2.60	1.04
Transport cost index	135.0	108.8	116.0	99.8
Political stability and violence index	-0.60	0.64	0.45	0.89

The data in Table 4 indicate the presence of significant discrepancies between the values of Ukraine's logistics indicators and the average cluster indicators of the EU countries, which indicates an increased level of logistics risks. Such discrepancies reflect the functioning of the logistics system of Ukraine in conditions of instability and indicate the existence of a significant logistical load.

To assess the deviations of Ukraine's indicators from the average values of the corresponding clusters of the EU countries, the percentage deviations of the studied indicators were calculated (Table 5).

**Table 5**  
Deviations of Ukraine's logistics indicators from the average cluster indicators of the EU countries, %

Indicator	Deviation from cluster 1	Deviation from cluster 2	Deviation from cluster 3
Logistics efficiency index	-22	-16	-31
Export transaction time	+170	+73	+330
Transport cost index	+24	+16	+35
Political stability and violence index	-135	-233	-168

The data presented in Table 5 indicate that the value of key logistics indicators in Ukraine differs significantly from the average levels recorded in the corresponding clusters of European Union countries. The totality of the identified deviations indicates the concentration of logistics risks and the formation of an unfavorable environment that differs from the conditions of operation of logistics systems in European Union countries.

Taking into account the results of grouping and comparative assessment, it is advisable to proceed to the generalization of management consequences associated with the formation of a system of risk-oriented controlling of logistics enterprises. The identified differences between the conditions of operation of logistics systems determine the need for a differentiated approach to the choice of controlling tools, shifting the emphasis from preventive monitoring to adaptive and anti-crisis management mechanisms depending on the level of risks. A generalized characteristic of the relevant models of risk-oriented controlling is given in Table 6.

The generalization of the results of the empirical analysis allowed to form a conceptual mechanism for making management decisions in the field of logistics (Fig. 3), which is based on a combination of assessing the intensity of logistics risks with the selection of relevant risk-oriented controlling tools. The proposed mechanism ensures the adaptability of the management system to changes in the external environment and is based on the patterns identified during the cluster analysis.

**Table 6**  
Formation of a system of risk-oriented controlling of logistics taking into account the conditions of operation of logistics systems

Conditions for the functioning of logistics systems	Key features of the logistics system	Predominant logistics risks	Controlling model	Risk-based controlling tools
Low level of logistics risks	Predictable transaction times, relative cost stability, high level of logistics process organization, institutional certainty	Predominantly operational and cost risks	Preventive controlling (emphasis on preventing deviations and maintaining the achieved level)	Logistics performance indicators, logistics cost planning and budgeting, plan-actual variance analysis, contract management
Moderate level of logistics risks	Uneven transaction times and costs, increased sensitivity of logistics processes to changes in the external environment, increasing role of flow coordination	Operational, time, contractual risks, risks of interaction of material and information flows	Adaptive risk-oriented controlling (focus on making sound adjustments to management decisions in accordance with environmental changes)	Scenario analysis, flexible budgeting, monitoring key logistics risks, safety stock management, logistics route adjustments
High level of logistics risks (crisis environment)	Infrastructural limitations, constant delays, increasing logistics costs, instability of institutional conditions	Systemic, cascading, institutional and financial risks	Anti-crisis controlling (ensuring the stability and continuity of logistics processes)	Assessment of liquidity of logistics flows, analysis of sensitivity of terms and costs to extreme changes in the external environment, operational monitoring of risk events, development and implementation of business continuity plans

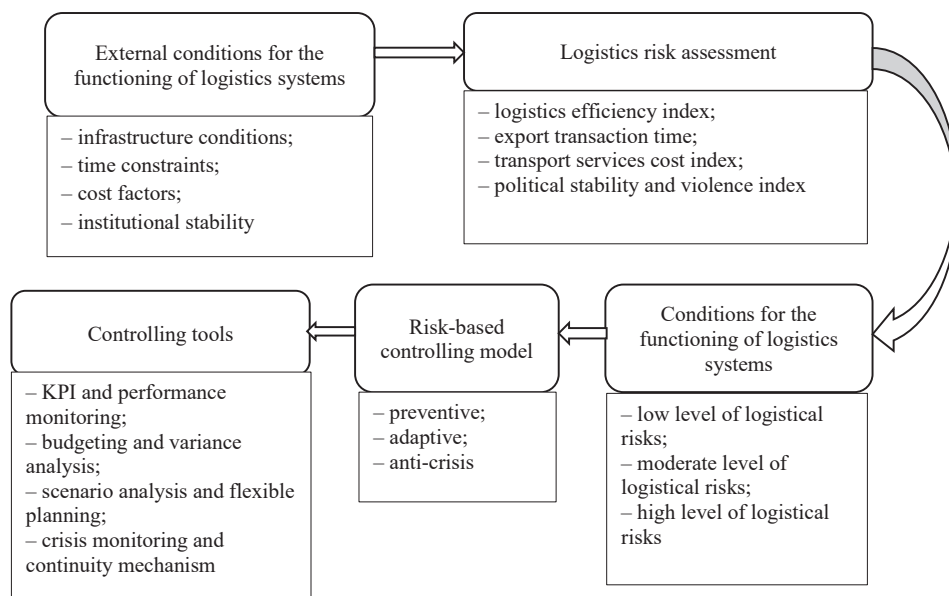


Fig. 3. Mechanism of formation of risk-oriented controlling of logistics depending on the conditions of functioning of logistics systems

At the same time, Table 6 reflects the generalized static characteristics of models of risk-oriented controlling depending on the conditions of functioning of logistics systems, while Fig. 3 represents the dynamic logic of transformation of results of assessment of logistics risks into corresponding management decisions.

The proposed conceptual scheme reflects the logic of transition from analysis of external parameters of functioning of logistics systems to formation of management decisions within risk-oriented controlling. Within the framework of this approach, cluster analysis is used as a tool for generalization of multidimensional logistics indicators, which allows to separate the conditions of functioning of logistics systems and to link them with corresponding management scenarios.

Unlike unified approaches to formation of controlling tools, the proposed mechanism is based on the principle of its adaptation to specific parameters of functioning of logistics systems within which the enterprise operates. This logic involves coordinating the results of analytical assessment with the areas of management influence and reducing the time gaps between the identification of risks and the implementation of corrective decisions. At the same time, it contributes to the formation of a flexible controlling system capable of functioning in conditions of increased turbulence and macroeconomic instability.

In this context, the integration of cluster analysis into the logistics management system creates a methodological basis for the development of differentiated models of risk-oriented controlling, aimed at increasing the stability of enterprises and maintaining the continuity of logistics processes in crisis conditions.

The proposed differentiation of controlling models can be used by enterprises as a basis for building a logistics risk monitoring system, forming internal supply management regulations and developing anti-crisis plans to ensure the continuity of logistics processes. The results obtained can be integrated into the management accounting system, budgeting of logistics costs, as well as into the internal audit procedure of logistics operations.

The results shown in Table 6, confirm that the effectiveness of the risk-based logistics controlling system is determined by the compliance of its instruments with the conditions of the functioning of the logistics systems in which the enterprise operates. Such an approach increases the ability of enterprises to adapt management decisions to the level of logistics risks and strengthens their resilience in conditions of uncertainty and crisis influences.

The conclusions obtained justify the expediency of considering Ukraine as an extreme logistics system that goes beyond the typical risk conditions characteristic of the countries of the European Union and requires the use of special approaches to logistics management at the enterprise level.

Comparison of the results of the cluster analysis of the logistics systems of the European Union countries with the logistics indicators of Ukraine creates a basis for the formation of a differentiated approach to risk-based controlling of the logistics of enterprises. This approach is based on taking into account the heterogeneity of the results shown in Table 6 confirm that the effectiveness of the risk-based logistics controlling system is determined by the compliance of its instruments with the conditions

of the functioning of the logistics systems in which the enterprise operates, and differences in the combination of infrastructure, time, cost and institutional factors.

Within the framework of the proposed logic, for enterprises operating in an environment with a low level of logistics risks, it is advisable to use preventive controlling, focused on optimizing costs and maintaining the achieved level of efficiency of logistics processes. Under conditions of moderate risk load, adaptive controlling takes priority, which involves the use of scenario analysis, flexible budgeting and regular review of management decisions taking into account changes in the external environment. In crisis conditions, the key role in the functioning of logistics systems is played by anti-crisis controlling, aimed at ensuring the continuity of logistics processes, liquidity control and prompt response to risk events.

The results obtained indicate that the formation of a risk-oriented logistics controlling system should be based on the conditions of the functioning of the logistics system in which the enterprise operates. The proposed approach provides a move away from unified management solutions in favor of flexible and anti-crisis management mechanisms that increase the ability of enterprises to maintain stability in conditions of macroeconomic instability and increased uncertainty.

### 3.3. Discussion of the research results

The empirical part of the research was constructed as a sequence of interconnected stages. At the first stage, a system of indicators for assessing logistics risks was formed, reflecting the key characteristics of the functioning of logistics systems. Then, the source data was standardized in order to ensure their comparability. The next step was the clustering of EU countries using the k-means method, which allowed to identify groups with similar conditions for the functioning of logistics systems. The resulting clusters were interpreted as types of environments for the functioning of logistics systems, which differ in the level and structure of logistical risks. On this basis, a comparative assessment of Ukraine's position relative to the formed clusters was carried out. The final stage was the justification of the mechanism for choosing a risk-oriented logistics controlling model taking into account the type of environment. The applied approach allowed to move from a descriptive analysis of indicators to their structured interpretation in the context of identifying types of logistics risks and integrating the assessment results into the management decision-making system.

The empirical analysis demonstrates that the formation of logistics controlling in conditions of uncertainty and crises requires risk orientation as a key parameter of management decisions. The use of a cluster approach to the analysis of logistics systems of the European Union countries based on infrastructure, time, cost and institutional characteristics made it possible to distinguish the conditions for the functioning of logistics systems. The differences between them are determined not only by the intensity of logistics risks, but also by the specifics of their combination and management consequences, which limits the use of unified models of logistics controlling focused exclusively on efficiency indicators.

The results obtained correspond to the provisions of the theory of supply chain risk management, according to which logistics risks are systemic in nature and are realized through the interdependence of material, financial and information flows. The identification of cascading effects of logistics disruptions is consistent with the conclusions [5] regarding the ability of local failures to escalate to the level of systemic disruptions in the functioning of logistics networks. At the same time, unlike predominantly operationally oriented approaches, the proposed research expands existing developments by including the analysis of logistics risks in the controlling contours, which strengthens the analytical component of logistics management.

A comparison of the logistics indicators of Ukraine with the average cluster values of the European Union countries has shown the formation of extreme conditions for the functioning of logistics systems. It is characterized by a combination of infrastructure limitations, long time delays, increased logistics costs and a low level of institutional stability, which significantly complicates the functioning of logistics systems and increases the need for the application of specialized anti-crisis management solutions. Such results confirm the conclusions of researches devoted to the impact of crisis and geopolitical shocks on logistics systems, in particular, regarding the increasing role of systemic and institutional risks in crisis conditions [4]. At the same time, the obtained quantitative assessments allow to specify the directions of the logistics load and move from a general description of the crisis environment to the formation of applied management solutions.

The differentiation of risk-based controlling models proposed in the research in accordance with the conditions of operation of logistics systems allows expanding scientific ideas about the possibilities of management control in logistics. The results obtained show that under conditions of low level of logistics risks, preventive controlling tools focused on optimizing costs and maintaining the effectiveness of logistics processes remain effective. In environments with moderate risk load, the importance of adaptive tools increases, primarily scenario analysis and flexible budgeting, which corresponds to modern approaches to building integrated management control systems [7, 8].

The most meaningful conclusions were obtained regarding the functioning of controlling in crisis conditions of the functioning of logistics systems. Under such conditions, tools focused exclusively on efficiency control gradually lose priority. Instead, a key role is played by anti-crisis controlling aimed at ensuring the continuity of logistics processes, managing the liquidity of logistics flows and promptly identifying risk events. This approach develops the research position in the field of adaptive controlling and financial security of enterprises [9, 10], extending them to the logistics sphere, taking into account the multidimensional nature of logistics risks.

The practical significance of the results obtained is that they can be used in practice both at the level of enterprises and at the level of logistics management bodies. The proposed approach makes it possible to build risk-oriented controlling systems taking into account the conditions of operation of logistics systems. Typology of logistics systems can serve as the basis for the formation of logistics risk monitoring systems, the selection of key control indicators, the establishment

of acceptable deviation limits and the adjustment of management accounting of logistics costs. The results obtained can be used in the development of scenarios for responding to supply disruptions, the preparation of anti-crisis plans and the evaluation of management decisions in unstable conditions.

The results obtained are distinguished by the possibility of integrating logistics risks into the controlling system based on the typology of the conditions of operation of logistics systems. This is what forms the prerequisites for the transition from existing management approaches to a differentiated choice of controlling tools taking into account the level and structure of risks. Unlike existing approaches based on efficiency control, the proposed approach is based on the multidimensional nature of logistics risks and their interaction, which significantly increases the adaptability of management decisions.

At the same time, the research has certain limitations. First, the analysis is based on macro-level indicators, which does not allow direct transfer of results to the level of individual enterprises. Second, to take into account the dynamics of logistics risks, it is advisable to use data for more than one period. Third, the insufficient number of indicators does not allow to cover all possible aspects of logistics risks, with technological development and digitalization.

Given the results obtained, further research should focus on expanding the list of indicators for assessing logistics risks, in particular by including digital and technological aspects. Another important step is the use of panel data, which will allow to better track how risks change over time. In addition, a promising direction is the adaptation of the proposed approach to the level of enterprises, taking into account industry characteristics and the impact of digitalization on logistics processes.

The features of the results obtained are the development of a mechanism for selecting a model of risk-oriented logistics controlling, taking into account the specific conditions of the functioning of the logistics system. The research also established the relationship between the level of logistics risks and the appropriateness of using the appropriate controlling tools, and cluster analysis was used as a methodological basis for risk typology. The feasibility of using a differentiated approach to logistics management in conditions of uncertainty and crisis phenomena was substantiated. A feature of the results obtained is the integration of controlling and risk management within a single analytical system, which, unlike their traditional separate use, ensures a coordinated consideration of the conditions of the functioning of the logistics system, risk parameters and controlling tools when making management decisions.

#### 4. Conclusions

1. It has been established that logistics risks are systemic and multidimensional in nature. They are formed under the influence of four key groups of factors: infrastructure, time, cost and institutional. The generalization of scientific approaches has allowed to systematize logistics risks according to at least 7 classification features (source of occurrence, level of manifestation, functional area, type of flow, scale of influence, predictability, form of functioning). This has made it possible to move from a fragmentary analysis of individual risks to a comprehensive assessment of the conditions of functioning of logistics systems. It has been proven that under conditions of increased turbulence, traditional controlling models, focused mainly on cost and time control, lose their effectiveness due to the inability to take into account systemic and cascading risks.

2. The conditions of functioning of logistics systems in the countries of the European Union have been identified based on cluster analysis using the k-means method. As a result, the conditions of functioning of logistics systems in the countries of the European Union have been identified. Clusters with low, moderate and high levels of logistics

risks include 10, 11 and 6 EU countries, respectively, which quantitatively confirms the heterogeneity of logistics systems in terms of risk load. A comparative assessment of Ukraine relative to average cluster values has shown the formation of extreme conditions for the functioning of logistics systems. They are characterized by a decrease in the logistics efficiency index by 22–31% and an increase in the time for export operations by 2.7–4.3 times. There is also an increase in the cost index of transport services by 24–35% and a significant deterioration in institutional parameters.

### Conflict of interest

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

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The manuscript has no associated data.

### Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented paper.

### Authors' contributions

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