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MATHEMATICAL APPROACH TO THE FORMATION OF A METHODOLOGICAL BASIS OF ECONOMIC RATIONALITY OF INTERACTION OF ELEMENTS OF THE SYSTEM OF LOGISTICS MANAGEMENT IN AGRICULTURE

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ABSTRACT

The field of managing the logistics of agricultural products under significant dynamic changes in today's conditions requires the formation of new approaches using the possibilities of modern information tools. The article presents a systematic mathematical approach to logistics management in agriculture for conditions with an insignificant level of risk and under conditions of significant threats to the logistics processes of the agricultural industry. The presented study also examines the issue of analyzing the effectiveness of management actions in the logistics process, both operationally and strategically.

The developed mathematical approach takes into account a wide range of conditions for carrying out logistics activities - both at a low level of risk in the implementation of the logistics process, and in circumstances of significant threats that lead to the minimization of the reliability of logistics in the agricultural sector. This is especially important today, given the significant level of negative impacts on logistics processes due to military threats. The growth of these influences even leads to the destabilization of the world food market, and the threat of famine in some regions of the world.

The proposed mathematical approach takes into account both the emergence of new risks, the significantly increased dynamic nature of the effects on logistics activities in the agricultural sector of the economy, and the traditional specificity of the conditions for the implementation of logistics processes in the agricultural sector. The specificity of logistics management in the agricultural sector is due to the peculiarities of the agricultural production process; properties inherent in agricultural products, conditions of distribution of these products. This determines a wide range of tasks that must be performed by the logistics of the agricultural sector. This, in turn, creates a need for a highly adaptive dynamic approach when forming a set and combination of logistics tasks and goals. Algorithms, tools and methods were specially developed to implement this approach. In particular: the unification of target functions; the approach of flexible adaptive changes in the ranks of target functions to ensure the appropriate level of rationality of logistics process management; a compromise approach in the case of the need to simultaneously achieve a group of set goals or a group of goals; the approach of assessing the strategic impact of a management decision for operating not with static values of parameters, but with their trends over time. In general, this makes it possible to achieve the appropriate level of economic efficiency of agricultural logistics management even with dynamic changes in the conditions of its implementation and to ensure a high level of reliability of the logistics process even with an increase in the level of threats.

Keywords: mathematical approach, dynamic conditions, management efficiency, logistics, agriculture, economic rationality

JEL Classification: C61, O13, O18, R49

INTRODUCTION

Today, there is a generally recognized need for innovative changes in the agricultural sector. In particular, this concerns the introduction of modern digital technologies to increase the efficiency of logistics processes in the production and distribution of agricultural products [1]. The pace of implementation is currently slowing down due to the complexity of the tasks inherent in the management of logistics processes in the agricultural industry [2]. The complexity of agricultural logistics management tasks is due to the peculiarities of the production process of agricultural products (seasonal nature, dependence on the effective implementation of phytosanitary measures, significant level of influence of weather factors, etc.), properties of these products (possibility of rapid spoilage, the dependence of quality on physical characteristics of the environment, pests, etc. .) and distribution conditions (special requirements for storage and transportation, limited time of product delivery to the consumer, etc.) All these factors place significant additional requirements on the mathematical formalization of the interaction of elements of the logistics management system. In the conditions of military operations on the territory of Ukraine, these difficulties increase significantly. Nowadays the fact that the level of efficiency of agro logistics processes in Ukraine is the key to avoiding a global food crisis indicates the need to find ways and methods of forming a methodical basis for the economic rationality of the interaction of elements of the logistics management system. The need to take into account dynamic changes in the external conditions of the implementation of logistics processes, the characteristics of these processes, and the need to take into account changes in influencing factors in real-time complicate both the process of agrarian logistics and its mathematical formalization [3].

The presented study is devoted to the development of a mathematical approach to the formation of a methodological basis for the economic rationality of the interaction of the elements of the logistics management system in agriculture, both under the conditions of an insignificant level of risks in the process of transporting agricultural goods and under conditions of a significant level of threats. Also, the presented research examines the issues of analyzing the effectiveness of management actions both in operational and strategic terms.

LITERATURE REVIEW

Many researchers dealt with issues of improving agricultural logistics. A detailed systematic review of scientific works on the development and implementation of optimization models in the supply chain of agricultural products is also given in the work of Taskıner et al [4]. Chymosh's article [5] is devoted to the analysis of the modern world and Ukrainian trends in the development of transport logistics in the agricultural sector. In the scientific work of Kieti et al [6], an analysis of the economic rationality of the implementation of digital logistics management technologies in agriculture was carried out. The conclusions of Kieti et al [6] are important in the context of the presented article because in [6] the implementation of modern logistics management technologies in Kenya was studied, which, according to certain IT development trends, is close to the realities of Ukraine. Also, the scientific work of Kotenko et al [7], which provides a benchmark and competitive analysis of the port productivity model is interesting in view of the importance of sea transportation for the logistics process in Ukraine. From the same point of view, the analysis by Pavlova et al [8] of logistics processes on the world market and the activities of Ukrainian companies related to the field of agricultural logistics is useful. In the article Pavlova et al [8] point to a characteristic difference in the Ukrainian logistics process in the field of agriculture, which is connected with the fact that Ukrainian logistics companies "have to work with the volume of orders, which many times exceeds the volume of deliveries to domestic markets" [8].

This forces institutional structures to pay considerable attention to ensuring the strategic prospects of agricultural logistics in Ukraine, which determines the importance of strategic planning and forecasting the consequences of management decisions for the formation of the economic rationality of the interaction of the elements of the logistics management system in agriculture. "Government policy priorities for the stimulation of logistics processes" are studied in detail in the work of Pitel et al [9] and in the review article of Punel et al [10]. A certain complication in the formation of a methodical basis for effective logistics management in agriculture is that this problem has a rather broad nature. This led to the fact that scientists fragmented the general system task and engaged in the mathematical formalization of individual system elements of agricultural logistics products. For example, the substantial work of Velychko et al [11] is devoted to the improvement of agro-logistics management, but only for small enterprises.

A significant number of qualitative models of the logistics process, which are confirmed by practice, are devoted to the problems of distribution of fresh agricultural products (FAP), which are characterized by rapid spoilage, small batches and a significant frequency of deliveries. This problem was dealt with by Yan et al [12], Ingram et al [13], Kharsun [14]. They, in particular, indicated that the amount of losses in the organization of FAP logistics is strictly related to the efficiency of management. Solving this problem, Ni et al [15] apply BP and LSTM neural network methods, and Sanjaya et al [16] and

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Perdana et al [17] use the discrete-event simulation method, which contributes to improving the management of logistics networks used by small farms. Ghezavat et al. [18], while studying tomato logistics problems, used a mixed integer programming model, and Rocco et al. [19] used linear programming methods for the same tomatoes. Keshavarz-Ghorbani et al [20] used the general algebraic modelling language (GAMS) for the same purposes, and Flores et al [21] applied the framework modelling approach for the strategic design of logistics procedures for local fresh-food systems. Petrychenko et al [22] and Wang et al [23] focused on solving the problem of fuzzy data and proposed a fuzzy mathematical model [22] and a hybrid model [23] for the supply chain. Taghikhah et al [24] and Van Der Vorst et al [25] propose simulation models for supply chains. Pamu'car et al [26], Phochanikorn et al [27], Teng [28] offer different approaches to modelling management decisions to overcome sectoral barriers, in particular, cross-border agro-logistics. He et al [29] use 2E-MTVRPDS satellite data and a heuristic algorithm for this.

Data from Black Sea News (2021, November 16) and Black Sea News (2022, February 16) were used to conduct economic and mathematical calculations and test the proposed hypotheses [22, 23].

Unresolved aspects of the problem. A large number of scientific studies are devoted to the issue of ensuring the proper level of management of logistics processes in agriculture. For this, numerous mathematical models have been proposed and tested. However, the problem of developing a systematic mathematical approach to the formation of a methodical basis for the economic rationality of the interaction of the elements of the logistics management system in agriculture for conditions with an insignificant level of risk and under conditions of significant threats remains unexplored.

AIMS AND OBJECTIVES

The purpose of the article is to develop a systematic mathematical approach to the formation of a methodological basis for the economic rationality of the interaction of the elements of the logistics management system in agriculture for conditions with an insignificant level of risk and under conditions of significant threats.

The tasks of the article are mathematical formalization of the target functions of the logistics management system under the conditions of an insignificant level of risks and under conditions of significant threats; development of a dynamic approach when forming a set and combination of tasks and goals of logistics; formation of the mathematical basis of the algorithm for the unification of target functions; development of an algorithm for flexible adaptive changes in the ranks of target functions to ensure an appropriate level of rationality in managing the logistics process; development of a compromised algorithm for the case of the need to simultaneously achieve a group of set goals; development of an approach to assessing the strategic impact of a management decision for operating not with static values of parameters, but with their trends over time.

METHODS

To conduct the research, both general scientific and special research methods were used, namely: analysis and synthesis, comparison, system analysis, methods of mathematical formalization (vector analysis, graph theory, modelling of networks for ordering heterogeneous sequences, the minimax method), which help in the development a systematic mathematical approach to the formation of the methodological basis of the economic rationality of the interaction of the elements of the logistics management system. Using the method of content analysis, a review of scientific publications on the specified issues was carried out.

RESULTS

1. Hypotheses regarding the formation of a mathematical approach for creating a methodological basis for the economic rationality of the interaction of the elements of the logistics management system in agriculture.

In the course of the conducted research, in order to implement a mathematical approach to creating a methodological basis for the economic rationality of the interaction of the elements of the logistics management system in agriculture, the need to put forward the following hypotheses was determined:

- Hypothesis H1: Management efficiency should be the main target function of the logistics management system in conditions of insignificant levels of risks in the process of transportation of agricultural goods.
- Hypothesis H2: It is necessary to implement a variable dynamic approach when forming a set and combination of tasks and goals of logistics.

- Hypothesis H3: A comparative assessment of the level of economic rationality of the interaction of the elements of the agro-logistics management system during the implementation of each of the named target functions is required for the formation of the mathematical basis of the algorithm for the unification of target functions.
- Hypothesis H4: The introduction of flexible adaptive changes in the ranks of the target functions allows to ensure the appropriate level of rationality of the management of the logistics process.
- Hypothesis H5: The most effective version of the management decision in the case of the need to achieve a group of goals is the one that ensures the realization of the desired results simultaneously for all the set goals, possibly with a different level of convergence - that is, with a different level of closeness of the specified result to the full achievement of the goal.
- Hypothesis H6: It is advisable to evaluate the strategic impact of a management decision by operating not on static parameter values, but on their trends over time.

The substantiation and explanation of the proposed hypotheses are given in Table 1.

Table 1. Substantiation and explanation of the hypotheses, for which the mathematical formalization of the methodological basis of the economic rationality of the interaction of the elements of the logistics management system in agriculture is carried out.

Hypothesis	Substantiation of the hypothesis	Explanation
Hypothesis H1: Management efficiency should be the main target function of the logistics management system in conditions of insignificant levels of risks in the process of transportation of agricultural goods.	The efficiency of logistics management in the process of transporting agricultural goods determines the economic rationality of logistics activities and allows to achieve in the best possible way other target functions of the logistics process, in particular, minimizing the cost and time of transportation of products	This function can be represented by: an optimality function, which corresponds to the most rational set of means and/or ways of carrying out the logistics process for each management decision; the function of operational or strategic avoidance or reduction of the consequences of crisis situations; by the function of increasing the added value of each of the elements of the system; as a function of the ratio of management costs to the result, etc. The level of optimality of a management decision regarding the logistics process can be defined, in particular, as approaching the maximum economic effect from its implementation.
Hypothesis H2: It is necessary to implement a variable dynamic approach when forming a set and combination of tasks and goals of logistics.	Algorithms for the implementation of logistics management tasks should be as universal as possible in the selection and combination of logistics tasks and goals.	Since neither the conditions for the fulfilment of logistics management tasks nor the logistics functions are definitively established, the algorithm for implementing these tasks must be as adaptable as possible to the specified conditions and functions in real-time.
Hypothesis H3: A comparative assessment of the level of economic rationality of the interaction of the elements of the agro-logistics management system during the implementation of each of the named target functions is required for the formation of the mathematical basis of the algorithm for the unification of target functions.	The implementation of each of the selected target functions should not contradict the implementation of other target functions. Therefore, if different measurement units are used for the selected target functions, an algorithm for their unification should be proposed.	In the presence of not one target function, but a set of them, it is necessary to move away from the use of traditional methods of multi-objective and multi-parameter decision-making.
Hypothesis H4: The introduction of flexible adaptive changes in the ranks of the target functions allows to ensure the appropriate level of rationality of the management of the logistics process.	To reduce the number of calculations, it is proposed to use the method of the phased implementation of target functions, which is based on the assessment of their rank from the point of view of ensuring the economic rationality of agro-logistics management.	Since the task is both multi-objective and multi-parametric, it becomes necessary to introduce a single scale for measuring each of the target functions.
Hypothesis H5: The most effective version of the management decision in the case of the need to achieve a group of goals is the one that ensures the realization of the desired results simultaneously for all the set goals, possibly with a different level of convergence - that is, with a different level of closeness of the specified result to the full achievement of the goal.	It is extremely difficult to simultaneously achieve a group of goals in the dynamic conditions of the implementation of agro-logistics tasks. Therefore, it requires the implementation of a compromise approach.	As a mathematical basis of the algorithm for the unification of target functions, a comparative assessment of the level of economic rationality of the interaction of the elements of the agro-logistics management system during the implementation of each of the named target functions is proposed.
Hypothesis H6: It is advisable to evaluate the strategic impact of a management decision by operating not on static parameter values, but on their trends over time.	Under dynamic changes in the conditions of execution of logistics processes, a relevant assessment of the impact of a management decision on a significant perspective is a difficult task due, in general, to a high degree of parameter uncertainty. In this case, the assessment of the consequences, which is formed in the space of parameters by their trends in time, allows for solving this problem in the best way.	Each of the parameters can change over time according to its own trend, which will be different from the trends of other parameters. Therefore, the change over time in the influence of each of the parameters on the situation will affect the achievement of strategic management goals. Calculations of the results of these influences require significant amounts of time and resources of the information system. This makes it necessary to start their implementation according to a separate decision of the system administrator, who must be informed in detail about the distribution of the DSS download over time. And the operational assessment of the strategic impact of a management decision can be carried out permanently by studying trends in parameters over time.

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2. Mathematical formalization of ensuring the economic rationality of the interaction of elements of the logistics management system.

The efficiency of agro-logistics management can be considered from different points of view: at the level of elements - management subjects, subsystems consisting of groups of interconnected elements, and at the level of large agricultural holdings or even the industry as a whole. This approach makes it possible to consider the economic rationality of the interaction of the elements of the agro-logistics management system as a result of improving the economic condition (achieving the maximum economic effect from the implementation of a management action; maximizing the indicator return on assets - ROA, etc.) of the management entity, subsystem of management entities (for example, by region of location, by subordination, etc.) or improvement of the logistics system of an agricultural enterprise on the basis of a set of economic indicators before and after making relevant management decisions.

Therefore, management efficiency is chosen as the target function of the management system in the conditions of a negligible level of risks in the process of transporting agricultural goods (*Hypothesis H1*). This function can be represented by: an optimality function, which corresponds to the most rational set of means and/or ways of carrying out the logistics process for each management decision; the function of operational or strategic avoidance or reduction of the consequences of crisis situations; by the function of increasing the added value of each of the elements of the system; as a function of the ratio of management costs to the result, etc.

In this case, the methodical basis of forming the economic rationality of the interaction of the elements of the agro-logistics management system can be represented by the following algorithm.

At the first stage of algorithm implementation, the following is known:

- the primary state of the management entity, which is determined by a set of parameters $\underline{\theta}_1$;
- the desired direction of change of this state, which is determined by the first derivative of the management state at time t;
- the desired result of the management decision, which is determined by the set of parameters $\underline{\theta}_{pl}$.

We plan to complete the management action in the time interval $\delta t = t_2 - t_1$, where t_2, t_1 are the limit values of the specified time interval. As a result of the implementation of the management action, the management subject will have a state of θ_2. That is, there will be a change in the state of the subject of management, which can be determined as:

$$\delta\overline{\theta} = \overline{\theta}_2 - \overline{\theta}_1 \tag{1}$$

If the direction of change of vector $\delta\underline{\theta}$ coincides with the desired direction of change of the first derivative of the management state ($\frac{\partial\theta}{\partial t}$) then the result is positive, if not, then it is negative.

To assess the level of efficiency of the management process, it is necessary to evaluate the proximity of the value $\underline{\theta}_2$ to the planned value $\underline{\theta}_{pl}$ predicted before the start of the management process on the response surface of the state of the subject of management from its economic indicators $x_1, x_2, x_3, \ldots x_n$ (where $i = 1, 2, 3, \ldots n$ is the indicator index, and n is the total number of these indicators) and time t.

Achieving the planned value $\underline{\theta}_{pl}$ can be ensured in two ways: first, using the iterative method of step-by-step approximation, applying a new management action y_i at each step; secondly, applying the optimal management action y_{opt} at the beginning of the management process.

There are many approaches to finding the optimal management action. In the absence of the necessary computing resources, intuitive or expert approaches are most often used [32]. This study proposes to determine y_{opt} using a decision support system (DSS).

The optimal management action y_{opt} can be formalized as such a scalar element of the set of management decisions $\vec{y}$, that effectively ensures the implementation of the planned result $\underline{\theta}_{pl}$ with an acceptable level of error of approximation to this value ($\delta\underline{\theta}_{adm}$).

That is:

$$y_{opt} \in \vec{y}\ ;\ \delta\overline{\theta} \rightarrow \delta\overline{\theta}_{adm}\ ;\ \delta\overline{\theta}_{adm} = (\overline{\theta}_2 - \overline{\theta}_{pl}) \rightarrow min \tag{2}$$

As mentioned above, the level of optimality of a management decision can be defined, in particular, as approaching the maximum economic effect from its implementation. Then:

$$\begin{cases} \delta\vec{E} = (\vec{E}_{final} - \vec{E}_{\text{initial}}) \to max \\ \vec{E}\epsilon(\vec{E}_1, \vec{E}_2, \vec{E}_3, \dots) \end{cases} \quad (3)$$

where $\delta\vec{E}$ is the economic effect of implementing a management decision; $\vec{E}_{final}$ is a vector of an economic indicator (which in general can represent a group of indicators: $\vec{E}_{1final}, \vec{E}_{2final}, \vec{E}_{3final}, \dots$) after the implementation of a management decision; $\vec{E}_{initial}$ is a vector of an economic indicator (or a group of indicators) before the implementation of a management decision; $\vec{E}$ a vector of an economic indicator for determining the result of the implementation of a management decision; $\vec{E}_1, \vec{E}_2, \vec{E}_3 \dots$ are vectors of sets of economic indicators.

There are limitations to the realization of the acquisition of the value of the economic effect close to the maximum value (3). The most universal of these limitations is that the cost of measures required to provide options for a management decision cannot be greater than a certain, budgeted level or more than the operational and strategic effect of implementing a management decision. DSS should automatically determine the operational and strategic effect of the implementation of a management decision.

Important complicating circumstances of ensuring the appropriate level of optimality of the management decision in dynamic situations (*Hypothesis H2*) under conditions (2) - (3) are the following:

- the elements of the agro-logistics management system are subject to internal and external factors of influence during the implementation of management decisions in a dynamic mode, and this can worsen the result of the management decision;
- management of agro-logistics can be ensured not only by a direct information flow between the object and the subject of management but also, in accordance with the properties inherent in the systems, the subjects of management can receive indirect management signals from other elements of the system, which can affect the result both in a positive way (synergistic effect) and in a negative way ("interference minimum" of managerial influences).

Taking into account the integral value of the influence of internal and external factors in a dynamic mode on the result of a management decision (*Hypothesis H2*) is proposed to consider according to the following algorithm:

$$\frac{dY}{dt} = \frac{dy_1}{dt} + \frac{dy_2}{dt} + \frac{dy_3}{dt} + \cdots ; \frac{dy}{dt} = \{0, \delta t_{\text{впл}} \gg T \ or \ y \le y_{min} \} \quad (4)$$

where Y is the integral value of the influence of internal and external factors; y_1, y_2, y_3 etc. - influence of each of the internal and external factors; $\delta t_{\text{впл}}$ is the maximum value of the time interval necessary to detect the result of the influence of internal and external factors; T is the time required to implement a management decision; y_{min} is the minimum value of the influence of internal and external factors that must be taken into account.

At the same time, it should be considered that the minimum value of the influence of internal and external factors (y_{min}), which must be taken into account during modelling, should be correlated with the value of the economic effect of the management decision $y_{min} = f(\delta\vec{E})$.

The modelling of management influence from a set of elements is proposed to be realized as a problem statement of organizing heterogeneous sequences of a system organized according to the network principle. The application of a model of a complex multi-element system using the method of ordering heterogeneous sequences significantly reduces the complexity of the task and accelerates its solution, which contributes to the increase in the effectiveness of management decisions.

Taking into account the possibility of hierarchical construction of some subsystems, for such cases we propose to solve the problem of arranging heterogeneous sequences as a problem of layer-by-layer (i.e., pseudo-hierarchical) implementation of network systems.

The proposed algorithm is implemented as follows: at the first stage, the logistics management system is considered as a complex of "black boxes", at the second stage, the input sequences of influences ($\vec{\beta}$) from objects that generate management signals directed to the management object are studied, then the output sequences of influences from the subject of management to other elements ($\vec{\alpha}$) are studied:

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$$(\vec{\alpha} \to \vec{\beta}): \{\alpha_p \to \beta_q\}, p = 1,2,3, \dots, m; q = 1,2,3, \dots k \quad (5)$$

where p, q are, respectively, the indices of the input and output sequences; m, k are respectively, the number of input and output sequences. If the input sequence α_1 uniquely determines the output sequence β_1, then we denote this relationship as $\alpha_1 \beta_1$. Comparison of $\alpha_p \beta_q$ relationships allows to reveal their strength and significance.

The network model as defined by Bazaluk et al [33] is as follows: we consider a directed graph $G = (V, E)$, where V is a set of vertices, E is a set of edges, and each edge (u, v) has a capacity $c(u, v)$ and the influence $f(u, v)$ which is proportional to its determined "weight" [33].

The implementation of the specified algorithm makes it possible to clarify the nature and strength of the influence of those elements of the management system that serve to redirect management signals, and which are identified at the stage of considering the management system as a complex of "black boxes".

Further, according to the algorithm of the logistics management system, we use the method of graph theory. In contrast to the traditional presentation of the transport problem by this method, the vertices of the graph are identified with elements that either generate management signals and answers about the performance result or receive\pass them. From the point of view of information theory, the indicated management signals represent data flows, so it is natural to identify them with the edges of a graph.

Then, mathematically, signal processing and transmission in the logistics management system can be represented as:

$$G = \{V, E, c, s, \tau\} \quad (6)$$

In contrast to the traditional presentation of the transport problem using the graph theory method, at the beginning graph (6) can be determined not completely, but only partially. For a complete definition of the graph (without which it is possible to obtain only a set of possible options, not a single solution to the problem), a mathematical approach to establishing the weight of connections between system elements is proposed. The specified mathematical approach can be represented as a reduction in the degree of irregularity of heterogeneous sequences of those elements of the logistics management system that produce, receive, process and transmit control signals, information for their generation and answers about the performance result.

This mathematical approach can be presented in a formalized way as:

$$C = \langle N, H, A, B \rangle \quad (7)$$

where N is the degree of disorder of heterogeneous sequences; H is a set of system elements; A is a set of relationships of system elements and operations associated with the specified relationships; B is a set of means of mathematical formalization of the problem (rules, restrictions, input and output conditions, etc.).

In this case, for the economic rationality of the interaction of the elements of the logistic process management system, the corresponding target function is formed as a vector opposite in direction to the vector of the so-called "degree of disorganization of heterogeneous sequences", because the disorganization of the system causes additional economic losses, which are caused by management inefficiency. The specified vector of the degree of disorder of heterogeneous sequences is equal to zero if the system is fully ordered.

The degree of irregularity of heterogeneous sequences is determined by two conditions: the influence weight, which must be a significant value greater than zero, and the number of elements of ordered sequences connected by the information flow.

At the next step of implementing the algorithm, the weight of each influence (both input and output) is determined:

$$a \in (a_{min}, a_{max}) \quad (8)$$

where a is the impact weight; a_{min}, a_{max} are the smallest and largest possible values of the impact weight.

It is proposed to define the indicated level as:

$$N_\alpha = \sum_z \sum_{i=1}^{z-1} P_i; \begin{cases} P_i = \{0, n_i \le n_z | 1, n_i > n_z\} \\ P_i = \{1, a_i > a_z | 0, a_i \le a_z\} \end{cases} \quad (9)$$

where P_i is the degree of order on the n_i-th element; i is the current value of the element index; z is the number of elements of ordered sequences; a_i is the current value of the impact weight; a_z is the specified minimum value of the impact weight, which should be taken into account during the analysis.

The process of ordering the sequence of elements of the management action transfer subsystem to the logistics process management system is considered complete when the influence of the transmitted signal becomes insignificant or the element to which the control signal has reached is the last on the graph in the signal transmission route.

An effective method for solving the problem of establishing and evaluating connections is, in addition to the expert method, the method of interpreting variants of graphic structures implemented according to the principle of a decision tree, which are formed on the basis of the analysis in the logistics process of all material and information flows and the coordination of the construction of an ordered graph in such a way as to provide an opportunity of its optimization.

The problem of forming an integral target function for determining an effective management solution may also be that for large and complex systems, an example of which is the logistics management system in agriculture, in some cases the management task may be the simultaneous achievement of not one goal, but a set of goals [34]. For example, the effectiveness of management can be considered from the point of view of ensuring the reliability, quality, and speed of cargo processing at all specified levels individually or by the totality of the specified tasks. It may also be appropriate to consider the management task as the achievement of a group of goals when harmonizing the interests of those elements of the agro-logistics system that have different owners.

In the presence of not one target function, but a set of them, it is necessary to move away from the use of both the traditional method of multi-objective decision-making (MODM) and the method of multi-parameter (or many "attribute") decision-making (English - Multi-attribute decision making, MADM) [35-38]. Since the task of agro logistics, in general, is both multi-objective and multi-parametric, there is a need to develop an approach combining the specified methods.

Completing the task in such a setting is not possible without resolving the issue of coordination and unification of target functions *(Hypothesis H3).*

The conditions for this are the following:

- the implementation of each of the selected target functions must not contradict the implementation of other target functions;
- if different measurement units are used for the selected target functions, then an algorithm for their unification should be proposed.

As a mathematical basis of the algorithm for the unification of target functions, a comparative assessment of the level of economic rationality of the interaction of the elements of the agro logistics management system during the implementation of each of the named target functions is proposed.

Flexible adaptive changes in the ranks of the target functions (*Hypothesis H4*) allow to ensure the appropriate level of rationality of the actions of the logistics process management system.

To reduce the number of calculations, it is proposed to use the method of phased implementation of target functions. This method is as follows: one of the target functions is chosen as the main one, and, accordingly, all other target functions are defined as second-order functions.

In particular, in the conditions of war, in comparison with the time and even the cost of transporting goods. it becomes important to use the reliability of the logistics system as the main target function. The reliability of the system, in this case, is directly correlated with a set of target functions: the function of the reliability of logistics process management, the function of the reliability of the operation of infrastructure and auxiliary objects of transport systems, the function of the reliability of cargo delivery.

Then the following algorithm is used:

- the existence interval of the main target function is divided into subintervals, for example: subinterval of undesirable values;
- a zone of acceptable and desired values of the second-order target functions is distinguished on the response surface of the integral target function in the subinterval of the desired values of the main target function;

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- the optimum point of the specified functions is searched in the zone of acceptable and desired values of the target functions;
- in the case of non-coincidence of the optimums of the target functions, a point of compromise of all target functions is searched for in the area of acceptable and desired values of the target functions, with a step-by-step clarification of the conditions of this compromise in such a way that it simultaneously ensures both the formation of the economic rationality of the interaction of the elements of the agro-logistics management system and interests all concerned parties.

3. Analysis of the implementation of the method of the phased implementation of the target functions of logistics procedures under conditions of significant risks for logistics operations

As an example of using the reliability of the logistics system as the main target function, we will provide an analysis of the implementation of logistics procedures through the Ukrainian ports of the Sea of Azov in the period of time that preceded the large-scale military operations in this region. Without taking military risks into account, these logistical procedures were carried out according to the so-called "short arm" principle - i.e. the shortest route that would ensure the saving of transport costs and the minimization of time for the transportation of agricultural products. That is, the cost of transport services and the time of transportation would be the target functions of the implementation of logistics procedures under specified circumstances. Transport time is particularly important for agricultural products with a short post-harvest storage time. This would lead to the fulfilment of the task of economic rationality of the interaction of elements of the logistics management system under mathematical formalization using equation (3), i.e., achieving the maximum economic effect from the implementation of appropriate management decisions.

But, with significant risks, the reliability of transportation becomes the main target function. To assess the reliability of transportation, which must precede the implementation of the algorithm proposed above, an analysis of the delay of grain cargoes during their transportation by sea in the Sea of Azov, the Kerch-Yenikale Canal and in the Kerch Strait for the period from August 2020 to December 2021 is provided (Figure 1). As the analysis showed, the delay of transport vessels is the most significant risk factor for cargo transportation from Ukrainian ports of the Sea of Azov in the specified period.

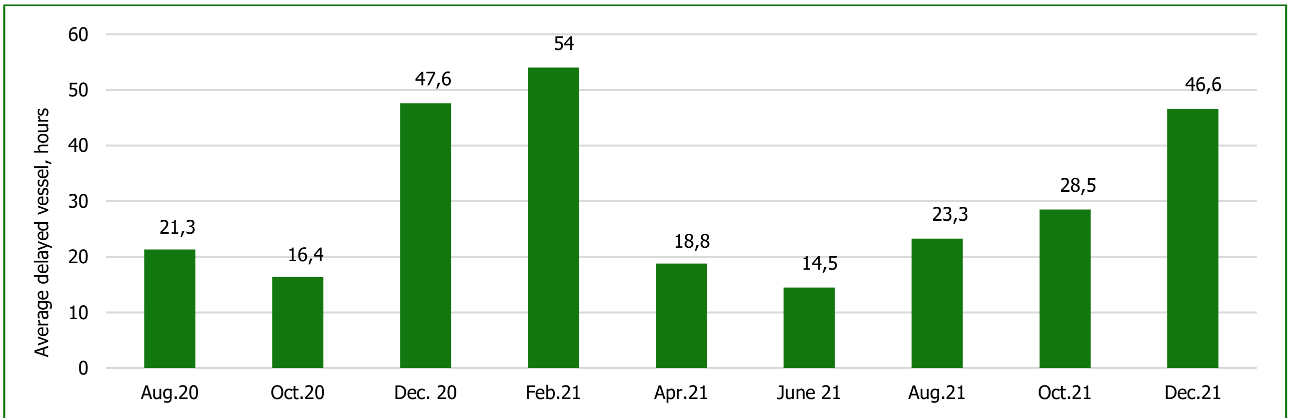

Figure 1. Changes in the average delay time of Ukrainian vessels in the Sea of Azov, the Kerch-Yenikale Canal and in the Kerch Strait for the period from August 2020 to December 2021 calculated per one vessel, hours. *(Source: own development using data [30, 31])*

When neutralizing this risk by choosing more expensive but less dangerous routes by logistics operators, in particular, using rail transport to Ukrainian seaports on the Black Sea coast - Odesa and Mykolaiv seaports, which were not yet blocked by the russian federation at that time, saving transport costs and minimizing transportation time were chosen as the main management target functions. But the level of transport costs and transportation time, in this case, was minimized from much higher starting positions due to the use of rail transportation to increase the reliability of cargo transportation. According to the conducted analysis, it was established that for logistics operators there was a certain acceptable value of the average delay time of ships, which led to a partial reorientation of cargo to the use of rail transport to the seaports of Ukraine, the transportation of cargo from which was not accompanied by a delay by the military forces of the russian federation. This threshold value was ~ 50 hours/vessel. This, in turn, led to the wave-likeness of the graph in Figure 1. This example demonstrates the rationality of the interaction of the elements of the logistics management system for the achievement of only one target function, which in a certain way simplifies the task. This example also illustrates that transportation reliability can also be considered as an economic target function. This is due to the fact that a decrease in reliability below certain threshold values is a condition for the need to immediately change the route of cargo transportation.

4. Mathematical formalization of the approach of simultaneous achievement of a group of goals of the logistics process

As was already mentioned above, for the tasks of logistics management in the agricultural sector, the task of simultaneous achievement of a group of goals often arises - by implementing, respectively, several target functions (*Hypothesis H5*).

The most effective option for a management decision in the case of the need to achieve a group of goals is the option that ensures the realization of the desired results simultaneously for all the set goals, possibly with a different level of convergence - that is, with a different level of proximity of the specified result to the full achievement of the goal. It is proposed to use an iterative algorithm to perform such a task.

Then the mathematical formulation of the problem looks like this:

$$\vec{\mu}[\mu_1(\vec{w}_1), \mu_2(\vec{w}_2), \mu_3(\vec{w}_3), \dots, \mu_n(\vec{w}_n)] \to opt \tag{10}$$

$$\begin{cases} \vec{w}_1, \vec{w}_2, \vec{w}_3, \dots, \vec{w}_n \in \vec{W} \\ (\vec{\mu}_1, \vec{\mu}_2, \vec{\mu}_3, \dots, \vec{\mu}_n) \in \vec{\mu} \\ (\vec{\mu}_1, \vec{\mu}_2, \vec{\mu}_3, \dots, \vec{\mu}_n) \exists (\vec{g}_1, \vec{g}_2, \vec{g}_3, \dots, \vec{g}_n) \end{cases} \tag{11}$$

where $(\vec{\mu}_1, \vec{\mu}_2, \vec{\mu}_3, \dots, \vec{\mu}_n)$ *is a group of vectors of a set of target functions;* $\vec{\mu}$ *is the resulting vector of the set of target functions;* $\vec{W}$ *is data vector of the management system as an invariant of the set of data;* $\vec{w}_1, \vec{w}_2, \vec{w}_3, \dots, \vec{w}_n$ *are data vectors separately for each of the target functions;* $\vec{g}_1, \vec{g}_2, \vec{g}_3, \dots, \vec{g}_n$ *are constraint vectors separately for each of the target functions.*

With this formulation of the problem, the search for an acceptable solution is a step-by-step movement of the response surface in the multidimensional space $(\vec{\mu}, \vec{W})$.

Achieving the value of the greatest economic rationality of the management decision should be considered in accordance with the time interval chosen to implement the goal of the logistics operation. This is due to the fact that for the entire set of options for management decisions, achieving an acceptable level of economic rationality at all horizons of logistics planning may be impossible. Therefore, it is proposed to consider three main horizons of achieving economic rationality in time: operational, medium-term and strategic.

Choosing the most rational management solution from the set of options offered by the automated information system can be a difficult task even for modern DSSs.

The complexity of the selection task is determined by:

- the need to harmonize the current management decision with previous and subsequent management decisions, which should represent a harmonized system, because inconsistency at some stages will lead to the appearance of new risks and unaccounted variants for destabilization of the managed system;
- the need to coordinate the specified decision on all time horizons; by the probable inequality of the economic rationality of the convergence of achieving the desired result for each target function from the entire available set of specified functions.

The inequality of the economic rationality of the convergence of achieving the desired result for each target function causes the need to solve a compromise task, that is, the need to give up the degree of achievement of the desired result of a separate target function in order to increase the degree of achievement of the result by another target function or a group of such functions. This limits the possibility of using traditional approaches to solve this problem, for example, the Pareto method, the MOORA method (abbreviation, Multi-Objective Optimization on the basis of Ratio Analysis), Kogger and Yu, and others. In particular, the possibility of unconditional use of the method of pairwise comparisons of decision options is limited. Therefore, in our opinion, it is possible to use a comprehensive analysis and simultaneous evaluation of all options to make a compromise decision.

In order to automate the selection of the most appropriate set of values of the target functions, the following algorithm is proposed: it is necessary to rank the set of target functions according to the priority of their achievement and, depending on the rank, to form the need to ensure one or another level of approximation of the specified target functions to the desired value.

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To implement this approach, the following method is proposed: the correspondence of the ranking of the set of target functions and the ranking of the level of their approximation to the desired value is checked.

If this correspondence is present, the search stops - the solution option meets the requirements. When there are several such options, their pairwise comparison is performed and the most rational option is chosen.

If the specified correspondence is violated, the intervals of approximation of the target functions to the desired value or the introduction of additional parameters or limitations of the target functions should be extended.

This makes it necessary to consider, in the general case, not one variant of a set of limitations, but a set of variants, which, in turn, leads to the appearance of a multitude of variants of target function sets:

$$\begin{cases} \vec{g} = (\vec{g}_1, \vec{g}_2, \vec{g}_3, \dots, \vec{g}_n)^K \\ \vec{\mu} = (\vec{\mu}_1, \vec{\mu}_2, \vec{\mu}_3, \dots, \vec{\mu}_n)^K \end{cases} \tag{12}$$

where K is the dimension of the multitude of options of limitations sets and, accordingly, the multitude of target function sets.

For further formalization, it is proposed to use the concept of the function of the deviation of the target function from the desired result.

In this case, the problem can be represented mathematically as the minimization of the deviation function (D). One of the variants of the deviation function can be chosen to approach the maximum of the economic effect $\delta\vec{E}$ in accordance with equation 3. Then:

$$\begin{cases} \min \delta\vec{E}\ [\vec{g}, \vec{\mu}(W)] \\ \vec{w}_i \in R^n | A\vec{w}_i \leq \vec{b}_i, \vec{w}_i \nexists \emptyset \end{cases} \tag{13}$$

where R denotes a relation in the terminology of set theory.

The problem of minimizing the deviation function is carried out as a procedure for matching two vectors: the vector of limitations ($\vec{g}$) and the resulting vector of the set of target functions ($\vec{\mu}$). This requires normalization of the level of approximation of the specified target functions to the desired value.

Since, in the general case, the deviation function can be represented as a set of deviation functions from the desired results of individual target functions:

$$\delta\vec{E} = \max\ [\delta\vec{E}_1(\vec{g}_1, \vec{\mu}_1), \delta\vec{E}_2(\vec{g}_2, \vec{\mu}_2), \delta\vec{E}_3(\vec{g}_3, \vec{\mu}_3), \dots, \delta\vec{E}_n(\vec{g}_n, \vec{\mu}_n)] \tag{14}$$

Then the following mathematical formalization can be used:

$$min\ max\ \{\delta\vec{E}_1[\vec{g}_1, \vec{\mu}_1(\vec{w}_1)], \delta\vec{E}_2[\vec{g}_2, \vec{\mu}_2(\vec{w}_2)], \dots, \delta\vec{E}_n[\vec{g}_n, \vec{\mu}_n(\vec{w}_n)]\} \tag{15}$$

Implementation of the minimax approach makes it possible to minimize possible economic losses when making a management decision using a multi-objective and multi-parametric selection of options through the maximum possible negative consequences of this decision.

The proposed algorithm is similar to the method of structural-parametric optimization, but, unlike it, the goal of this algorithm is not to solve the problem of system synthesis, but to solve the problem of optimizing the management decision for the existing system.

The process of interactive implementation of the specified algorithm allows decision-makers to clarify the uninterpreted parameters that were used in the formation of the proposed options. This leads to an increase in the level of economic rationality of the specified decisions.

The proposed approach allows to algorithmize the process of forming a compromise solution for a multi-objective problem (*Hypothesis H5*). But the practical implementation of this approach can be complicated since the choice of a compromise solution can be based on uninterpreted or insufficiently interpreted parameters that could not be clarified at the stage of interactive implementation of the algorithm. In this case, the specified choice can be implemented on the basis of an expert assessment or the use of an automatic decision selection system by sorting through the interpretation options of uninterpreted parameters and fragmenting the intervals of implementation of undefined parameters. This, on the one hand, significantly increases the number of decision options, but, on the other hand, allows managers who are authorized to make decisions to expand their options.

To avoid subjectivity when making a decision, a possible variant of the interactive implementation of the specified algorithm is also a way of limiting the number of goals of a multi-objective problem.

It is proposed to evaluate the strategic impact of a management decision by operating not on static parameter values, but on their trends over time (*Hypothesis H6*).

Each of the parameters can change over time according to its own trend, which will be different from the trends of other parameters. Therefore, the change over time in the influence of each of the parameters on the situation will affect the achievement of strategic management goals. These calculations require much more time and resources of the information system. This makes it necessary to start their implementation according to a separate decision of the system administrator, who must be informed in detail about the distribution of the DSS download over time. The analysis of changes in data trends can take place, for example, by arranging data by the time of receipt of reports to the database from system elements that belong to management entities.

The implementation of the algorithm of the dynamic problem, first of all, requires checking the presence or absence of a change in time of the limitations and evaluating the change of the parameters of the problem in time. For this purpose, a hypercube of data and a hypercube of their limitations are formed. A two-dimensional section of each of the hypercubes looks like a matrix and is used further to illustrate the corresponding stages of the algorithm. Next, in order to take into account, the dynamic change, the first-time derivative of the data in each of the cells of the specified hypercubes is determined:

$$\begin{cases} \begin{bmatrix} \frac{\partial w_{11}}{\partial t} & \cdots & \frac{\partial w_{j1}}{\partial t} \\ \vdots & \ddots & \vdots \\ \frac{\partial w_{1i}}{\partial t} & \cdots & \frac{\partial w_{ji}}{\partial t} \end{bmatrix} = \begin{bmatrix} w_{11}^* & \cdots & w_{j1}^* \\ \vdots & \ddots & \vdots \\ w_{1i}^* & \cdots & w_{ji}^* \end{bmatrix} \\ \begin{bmatrix} \frac{\partial g_{11}}{\partial t} & \cdots & \frac{\partial g_{j1}}{\partial t} \\ \vdots & \ddots & \vdots \\ \frac{\partial g_{1l}}{\partial t} & \cdots & \frac{\partial g_{ji}}{\partial t} \end{bmatrix} = \begin{bmatrix} g_{11}^* & \cdots & g_{j1}^* \\ \vdots & \ddots & \vdots \\ g_{1i}^* & \cdots & g_{ji}^* \end{bmatrix} \end{cases} \quad (16)$$

where i, j are the number, respectively, of lines and columns in a two-dimensional section of the data hypercube; w^* is an abbreviated notation of the first derivative of data in time; g^* is an abbreviated designation of the first derivative of time data limitations.

The next stage of the algorithm is the determination of the first derivatives of the target functions. A two-dimensional section of the hypercube of the target functions looks like this:

$$\begin{bmatrix} \frac{\partial \mu_{11}}{\partial t} & \cdots & \frac{\partial \mu_{j1}}{\partial t} \\ \vdots & \ddots & \vdots \\ \frac{\partial \mu_{1l}}{\partial t} & \cdots & \frac{\partial \mu_{ji}}{\partial t} \end{bmatrix} = \begin{bmatrix} \mu_{11}^* & \cdots & \mu_{j1}^* \\ \vdots & \ddots & \vdots \\ \mu_{1i}^* & \cdots & \mu_{ji}^* \end{bmatrix} \quad (17)$$

where μ^* is an abbreviated designation of the first derivative of the target functions in time.

Then:

$$\mu_{ji}^* = \langle w_{ji}^*, g_{ji}^*, R \rangle \quad (18)$$

where R is the set of connections $w_{ji}^*, g_{zl}^*, \mu_{mn}^*$ with other elements of the data hypercube.

When forming an array of data relations (H), the mathematical representation will have the following form:

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$$(\mu_{ji}^*, w_{ji}^*, g_{ji}^*, R) \in H \quad (19)$$

The need for the interpretation and use of data relations is primarily because the values of μ_{ji}^*, w_{ji}^* and g_{ji}^* have an indirect connection in time when the task is dynamic.

In order to increase the economic rationality of the use of DSS, in turn, it is necessary to form connection manager programs and programs to parameterize detected connections.

The need to take into account the dependence of the arrays of the first derivatives of the target functions on the set of connections of the data hypercube in time is due to the complex, systemic nature of management decision-making in the field of agricultural logistics; mutual consistency of some data with others, etc.

Implementation of the specified steps of the algorithm provides an opportunity to minimize the first derivative of the deviation function:

$$\min \frac{\partial D}{\partial t} (g^*, \mu^*) \quad (20)$$

with the following search for the minimax value:

$$\min \max \left[\frac{\partial D_1}{\partial t}\left(\frac{\partial \vec{g}_1}{\partial t}, \frac{\partial \vec{\mu}_1}{\partial t}\right), \frac{\partial D_2}{\partial t}\left(\frac{\partial \vec{g}_2}{\partial t}, \frac{\partial \vec{\mu}_2}{\partial t}\right), \frac{\partial D_3}{\partial t}\left(\frac{\partial \vec{g}_3}{\partial t}, \frac{\partial \vec{\mu}_3}{\partial t}\right), \dots, \frac{\partial D_n}{\partial t}\left(\frac{\partial \vec{g}_n}{\partial t}, \frac{\partial \vec{\mu}_n}{\partial t}\right)\right] \quad (21)$$

The proposed mathematical formalization provides an opportunity to evaluate the deviation of the target functions from the desired strategic value under dynamic changes in their parameters, which is especially important for fast-moving risks of significant magnitude, in particular, inherent in logistics operations in wartime.

Slow changes of parameters over time are not subject to the direct involvement of the algorithm of the dynamic problem. Slow changes according to known regularities can include, for example, changes in parameters related to the influence factor of "ageing" of the technological equipment of the transport infrastructure. In order to take slow changes into account, it is worth using standard procedures for detecting tendencies towards slow changes in parameters, establishing patterns of their changes, and, if necessary, verifying each change by an expert and subsequent automatic correction of static data values. This approach allows to simplify calculations and, accordingly, to rationally use of the resources of the information system, which is especially important for logistics procedures with dynamic changes in the conditions of their implementation.

DISCUSSION

Having analyzed the conditions of management of agricultural logistics, the authors came to the conclusion that the dynamism of the implementation of logistics processes has increased significantly nowadays. The conditions for conducting logistics activities in many areas of the world have become much tougher. The example of Ukraine, whose economy is largely connected with the efficiency of the logistics of agricultural products, shows the impact of significant risks on the level of fulfilment of the tasks set before agricultural logistics. Thus, the provision of food security for a significant number of people on all continents, as well as the state of the world economy, depends on the fulfilment of these tasks. To solve this problem, all tools are important, in particular, digital tools for improving the management of agro-logistics. Studies have shown that agricultural logistics is mainly focused on solving the problems of small and medium-sized farms, problems of distribution of fresh agricultural products, complications of agro-logistics due to rapid spoilage, small batches and significant frequency of deliveries. That is, researchers are mainly focused on solving individual fragments of the logistics problem in the agrarian industry, and agricultural production and, accordingly, the logistics of its products, is a complex multi-level system. For effective management of a system of such complexity, the formation of a new mathematical apparatus is required. The creation of such a mathematical apparatus is a prerequisite for the formation of a methodical basis for the economic rationality of the interaction of the elements of the logistics management system in agriculture. For the development of this apparatus, a group of hypotheses was introduced in the presented study and original methods of solution were proposed. Application of these methods, for example, minimax to minimize economic losses when making a management decision using a multi-objective and multi-parametric selection of options, interactive implementation of algorithms, formation of a hypercube of data and a hypercube of their limitations can lead to a significant level of load on computer systems. This, in some cases, calls for the use of special equipment, which is not always available even in large agricultural holdings. Therefore, it creates a perspective for further improvement of the proposed mathematical approaches and algorithms that implement them.

CONCLUSIONS

On the basis of the proposed hypotheses, the implementation of which is substantiated during the research, a systematic mathematical approach, implemented in the above algorithms, was developed for the formation of the methodological basis of the economic rationality of the interaction of the elements of the logistics management system in agriculture. The specified mathematical approach takes into account a wide range of conditions for carrying out logistics activities - both with a high level of reliability of the logistics process and under conditions of significant threats that lead to the minimization of the reliability of agro-logistics. Taking into account the specific conditions of the logistics processes of the agrarian industry, due to the peculiarities of the production process, the properties of agricultural products, the conditions of distribution, a highly adaptive dynamic approach was created when forming a set and combination of tasks and goals of logistics. For this, algorithms, tools and methods were developed: unification of target functions; the approach of flexible adaptive changes in the ranks of target functions to ensure the appropriate level of rationality of logistics process management; a compromise approach in the case of the need to simultaneously achieve a group of set goals or a group of goals; the approach of assessing the strategic impact of a management decision for operating not with static values of parameters, but with their trends over time. In general, this makes it possible to achieve the appropriate level of economic efficiency of agricultural logistics management, even under difficult conditions and an increase in the level of threats.

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МАТЕМАТИЧНИЙ ПІДХІД ДО ФОРМУВАННЯ МЕТОДИЧНОЇ ОСНОВИ ЕКОНОМІЧНОЇ РАЦІОНАЛЬНОСТІ ВЗАЄМОДІЇ ЕЛЕМЕНТІВ СИСТЕМИ УПРАВЛІННЯ ЛОГІСТИКОЮ В СІЛЬСЬКОМУ ГОСПОДАРСТВІ

Сфера управління логістикою сільськогосподарської продукції за значних динамічних змін в умовах сьогодення потребує формування нових підходів за використання можливостей сучасних інформаційних засобів. У статті представлено системний математичний підхід до управління логістикою в сільському господарстві для умов із незначним рівнем ризику та за умов значних загроз логістичним процесам аграрної галузі. У представленому дослідженні також розглядаються питання аналізу ефективності управлінських дій логістичним процесом і в оперативному, і в стратегічному плані.

Розроблений математичний підхід ураховує широкий спектр умов проведення логістичної діяльності: і за невисокого рівня ризику виконання логістичного процесу, і в обставинах значних загроз, які призводять до мінімізації надійності логістики в сільськогосподарський галузі. Це є особливо важливим сьогодні, з огляду на значний рівень негативних впливів на логістичні процеси через військові загрози. Зростання цих впливів призводить навіть до дестабілізації світового продовольчого ринку, загрози голоду в деяких регіонах світу.

Запропонований математичний підхід ураховує появу нових ризиків, значно збільшений динамічний характер впливів на логістичну діяльність в аграрному секторі економіки, так само й традиційну специфіку умов реалізації логістичних процесів в аграрній галузі. Специфіка управління логістичною діяльністю в аграрному секторі обумовлена особливостями процесу сільськогосподарського виробництва; властивостями, які притаманні сільськогосподарській продукції, умовами дистрибуції цієї продукції. Указане обумовлює широкий спектр завдань, які має виконувати логістика аграрного сектора. Це в свою чергу викликає потребу в створені високоадаптивного динамічного підходу при формуванні набору й комбінації завдань та цілей логістики. Для реалізації цього підходу були спеціально розроблені алгоритми, інструменти й методи. Зокрема: уніфікації цільових функцій; підходу гнучких адаптивних змін

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рангів цільових функцій для забезпечення належного рівня раціональності управління логістичним процесом; компромісного підходу для випадку необхідності досягнення одночасно групи поставлених цілей; підходу оцінки стратегічного впливу управлінського рішення за оперування не статичними значеннями параметрів, а їх трендами в часі. Загалом це дозволяє досягти належного рівня економічної ефективності управління аграрною логістикою навіть за динамічних змін умов її реалізації та забезпечити високий рівень надійності логістичного процесу навіть при зростанні рівня загроз.

Ключові слова: математичний підхід, динамічні умови, ефективність управління, логістика, сільське господарство, економічна раціональність

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