The object of this study is the logistics operations of a motor transport company. The task addressed is to improve the effectiveness of assessing the state of efficiency in managing logistics activities of motor vehicle enterprises, regardless of the level of hierarchy of the motor vehicle enterprise. Underlying the research is the game chaos algorithm (GCA) applied for assessing the state of efficiency in managing the logistics operations of motor transport enterprises. Evolving artificial neural networks are used to train GCA.

A comprehensive model for assessing the effectiveness of the operation of logistics activities of motor transport enterprises was built.

The model is proposed to be used in the operational management of logistics activities of motor transport enterprises. In addition, the model built allows for the following:

– assessing possible risks of disrupting the task of providing goods and services in organizations and organizational networks;

– determining the influence of performance evaluation indicators of the logistic support system in organizations and organizational networks on each other;

– establishing the influence of a group of indicators for evaluating the effectiveness of logistics support in organizations and organizational networks on a separate indicator.

The study also proposes a method for evaluating the effectiveness of managing logistics activities of motor transport enterprises. The originality of the method is that it makes it possible to avoid hitting the global and local optimum due to additional improved procedures based on the use of game chaos theory.

The simulation results showed an increase in the effectiveness of assessing the operational efficiency of the management of logistics activities of motor transport enterprises at the level of 14–16 % due to the use of additional improved procedures

Keywords: logistics activity, motor transport companies, artificial neural networks, swarm algorithms

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DEVISING A METHOD FOR ASSESSING THE EFFICIENCY IN MANAGING LOGISTICS OPERATIONS OF MOTOR TRANSPORT ENTERPRISES

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1. Introduction

The functioning of modern logistics systems in organizations and organizational networks requires achieving the maximum level of efficiency of logistics activities in order to increase competitive advantages in the market [1].

Logistics systems must devise effective operation strategies that would integrate all aspects of their activity, related to taking into account the influence of external and internal factors, as well as possible risks [2]. In the operation strategies of many logistics systems of organizations and organizational networks, there should be a reorientation from the use of the general economic effect to a purposeful innovative strategy using a logistics approach [3].

Practically in all sectors of the economy there is an interplay between competitive positions, innovative potential, and the efficiency of logistics systems (LSs) [4]. Increasing the efficiency of LS can be achieved by reducing costs, improving product quality, applying innovations, producing new competitive products, and rendering high-level services [5].

Under such conditions, it is necessary to change the provisions of existing approaches to logistics activity [6]. This, in turn, requires the use of a modern and proven mathematical apparatus for managing the logistics operations of motor transport enterprises, which is capable of processing a large array of various types of data with a predefined reliability over a short period of time [7].

The existing approaches to the management of logistics systems in organizations and organizational networks are narrowly focused and aimed at researching only certain issues and do not allow for the following [1–7]:

– comprehensively and in a short time to identify and assess the risks of non-fulfillment of tasks for the provision of goods and services of logistics activities of motor transport enterprises;

– to process various types of data with different units of measurement, different in origin and sources of information;

– to identify new and unusual risks of not fulfilling the task of fulfilling the functions of logistical support of motor transport enterprises;

– to comprehensively assess the impact of indicators for evaluating the effectiveness of logistics systems in organizations and organizational networks;

– evaluation of the impact of a group of indicators on a separate indicator of the effectiveness of the functioning of logistics systems in organizations and organizational networks.

Therefore, research on devising new approaches for evaluating the effectiveness of managing logistics activities of motor transport enterprises is relevant.

2. Literature review and problem statement

The concept of portfolio-oriented management is proposed in works [1, 2]. It was established that the achievement of the balance of homogeneous organizational structural units, their functioning and development, regardless of the type of organizational structure used, can be effectively ensured through the application of methodological portfolio management approaches by enterprises. Among the shortcomings of the concept is the difficulty of taking into account multidimensional conditions and factors that are different in units of measurement and origin.

In [3], the hierarchical distributed model of the organizational structure of the distribution logistics management system was further developed through the synthesis of inter-organizational and inter-functional coordination models, which became the basis for finding a constructive solution in organizational logistics management systems. At the same time, in the specified model, there is no possibility of adjusting the indicators of the evaluation system of the organizational management system of distribution logistics.

In work [5] it was established that the system of controlling transport and logistics services acts as a mechanism for coordinating and ensuring the interrelationships and interdependence of information flows between the levels and subsystems of the management of the transport and logistics system of the enterprise. This mechanism is based on a graph model describing the relationships between conditions and factors affecting the system of controlling transport and logistics services.

Paper [6] proposed a model of network consulting communication at the early stages of entrepreneurship. Among the shortcomings of the specified model is the lack of an opportunity to learn knowledge bases about the consulting communication of the enterprise.

In [7], a comparative evaluation of the performance of algorithms of the machine learning ensemble for forecasting cryptocurrency prices was carried out. The advantages and disadvantages of machine learning mechanisms for predicting cryptocurrency prices are given.

In work [8], the process of public management of the development of railway transport was decomposed on the basis of a systemic approach. This process is based on a structural-hierarchical approach. Among the shortcomings of the mentioned approach is the lack of possibility to adjust the conditions and factors that may appear during the management process.

Our review of the literature [1–8] demonstrated that each conventional model has advantages and disadvantages, and with regard to innovative models, there is a lack of sufficient practical experience in their application to confirm their effectiveness.

Further research may focus on the following:

– designing schemes for combining organizational structures, their additional modifications in order to build the most optimal structure with the allocation of key management functions for the implementation of tactical and strategic tasks;

– reduction of organizational levels of management to ensure greater flexibility of management;

– the development of virtual structures in the logistics management system and the replacement of the formalized hierarchy in the management organizational structures of the informal electronic network;

– integrated logistics management without aggregating functions into formal organizational units;

– building intelligent logistics management structures;

– development of clusters as an organizational form of logistics and supply chain management.

This determines the relevance of analyzing the mathematical apparatus based on the use of the theory of artificial intelligence.

In [9], the main advantages and disadvantages of cognitive algorithms are defined. The disadvantages of these approaches include the lack of consideration of the type of uncertainty, the inability to search in different directions by several agents.

Work [10] reports an approach focused on the search for hidden information in large data sets. The method is based on analytical baselines, variable reduction, sparse feature detection, and rule formation. The disadvantages of this method include the impossibility of taking into account different decision-making strategies, the lack of consideration of the type of uncertainty of the initial data.

Studies [11, 12] present an approach to the transformation of information models of objects to their equivalent structural models. This mechanism is designed to automate the necessary conversion, modification, and addition operations during such information exchange. The disadvantages of the approach include the impossibility of assessing the adequacy and reliability of the information transformation process, as well as the appropriate correction of the obtained models.

Work [13] proposed a method of fuzzy hierarchical evaluation, which makes it possible to evaluate the quality of library services. The disadvantages of the specified method include the impossibility of assessing the adequacy and reliability of the assessment and, accordingly, determining the assessment error.

Work [14] analyzed 30 of the most common Big-data algorithms. It has been established that the analysis of large data sets should be carried out in layers, take place in real time, and have the opportunity for self-learning, finding a solution in different directions and taking into account the noisy nature of the data.

Studies [15, 16] present approaches to the evaluation of various types of data for support and decision-making systems, based on the clustering of the basic set of input data, after which the system is trained based on the analysis. However, taking into account the static nature of the architecture of artificial neural networks, there is an accumulation of errors.

In [17], a comparative analysis of existing decision support technologies was carried out, namely: the method of analyzing hierarchies, neural networks, the theory of fuzzy sets, genetic algorithms, and neuro-fuzzy modeling. The advantages and disadvantages of these approaches were indicated. For tasks of assessing the state of hierarchical systems under conditions of risk and uncertainty, the use of the theory of artificial neural networks and gradient algorithms is justified.

Approaches to the structural-target analysis of the development of weakly structured systems were devised in [18]. At the same time, the problem is defined as the non-compliance of the existing state of the weakly structured system with the required one. In this case, the disadvantages of the proposed approaches include the problem of the local optimum, the lack of consideration of the computing resources of the system, as well as the inability to conduct a search in several directions.

Our review of the literature [9–20] revealed that the common shortcomings of the above studies are as follows:

– no possibility of hierarchical processing of various types of data when evaluating the effectiveness of management of logistics activities of motor transport enterprises;

– the absence of the possibility of additional involvement of the necessary computing resources of the system when evaluating the effectiveness of the management of logistics activities of motor transport enterprises;

– failure to take into account the type of uncertainty and noisy data about information that circulates in the system of managing the logistics activities of motor transport enterprises;

– lack of mechanisms for in-depth learning of the knowledge bases of the logistics management system of motor transport enterprises;

– lack of prioritization of search in a certain direction under the management of logistics activities of motor transport enterprises.

3. The aim and objectives of the study

The purpose of our study is to devise a method for evaluating the effectiveness of managing logistics operations at motor transport enterprises. This will make it possible to increase the efficiency of assessing the state of logistic activity of motor transport enterprises with a given reliability and the development of subsequent management decisions. This will make it possible to develop software for intelligent decision support systems for managing the logistics operations of motor transport enterprises.

To achieve the goal, the following tasks were set:

– to build a model for evaluating the effectiveness of the operation of logistics activities of motor transport enterprises;

– to define the procedures for implementing a method for evaluating the effectiveness of managing logistics operations of motor transport enterprises.

4. The study materials and methods

The object of our study is the logistics activity of a motor transport company. The task addressed is to increase the effectiveness of assessing the state of efficiency of managing logistics operations of motor vehicle enterprises, regardless of the level of hierarchy of the motor vehicle enterprise. The subject of the study is the process of assessing the state of the logistic activity of motor transport enterprises using an advanced metaheuristic algorithm based on the theory of chaos, as well as evolving artificial neural networks.

The hypothesis of the study assumes the possibility of increasing the efficiency of assessing the state of management of logistics activities of motor transport enterprises while ensuring the predefined reliability of assessment at the level of 0.9.

The proposed method was simulated in the Mathcad 14 software environment (USA). The hardware of the research process is AMD Ryzen 5.

The basis of the research is the game chaos algorithm (GCA) for assessing the state of efficiency in managing the logistics operations of motor transport enterprises. Artificial neural networks that evolve are used to train GCA. The GCA optimizer is used in this study due to the fact that bio-inspired algorithms easily fall into the local optimum and reduce the convergence speed due to the adjustment of the speed of the algorithms. Evolving artificial neural networks make it possible to train not only parameters but also system architecture.

5. Devising a method for evaluating the effectiveness of managing logistics operations of motor transport enterprises

5. 1. Construction of a comprehensive model for evaluating the effectiveness of managing logistics operations of motor transport enterprises

In order to evaluate the effectiveness of logistics operations in motor transport enterprises, it is necessary to take into account external and internal factors; in addition, drivers related to both internal and external factors deserve special attention (Table 1).

Analysis of Table 1 allows us to conclude that the state of operation of motor transport enterprises is characterized by different units of measurement and origin (dimensionless, relative, numerical, verbal). One possible approach is to use the theory of artificial intelligence, namely its separate component – fuzzy cognitive models.

For this purpose, the study proposed an appropriate model of comprehensive assessment of the logistics activity of motor transport enterprises with an algorithm for calculating the effectiveness of functioning of the logistic activity of motor transport enterprises.

The complex mathematical model for evaluating the effectiveness of the operation of logistics activities of motor transport enterprises can be represented in the following form:

$$S_{la}=<\{IF\}, \{OF\}, \{MF\}, M>, \qquad (1)$$

where M is the goal of managing the logistics activities of motor transport enterprises; $\{IF\}$ – internal environment of logistics activities of motor transport enterprises S_{la}; $\{OF\}$ – external environment of logistics activities of motor transport enterprises; $\{MF\}$ – factors that refer to both external and internal factors.

Expression (1) for the dynamic system:

$$\forall t \in \{1,...,T,...\} S_t =$$
$$=\begin{cases} s_1^{(t)} F_1\left(\varphi_{1,1}\left(s_1^{(t-1)},...,s_1^{\left(t-L_1^1\right)}\right), \varphi_{1,N}\left(s_N^{(t-1)},...,s_N^{\left(t-L_1^N\right)}\right)\right)\times\iota_1, \\ s_2^{(t)} F_2\left(\varphi_{2,1}\left(s_1^{(t-1)},...,s_1^{\left(t-L_2^1\right)}\right), \varphi_{2,N}\left(s_N^{(t-1)},...,s_N^{\left(t-L_2^N\right)}\right)\right)\times\iota_2, \\ ... \\ s_N^{(t)} F_N\left(\varphi_{N,1}\left(s_1^{(t-1)},...,s_1^{\left(t-L_N^1\right)}\right), \varphi_{N,N}\left(s_N^{(t-1)},...,s_N^{\left(t-L_N^N\right)}\right)\right)\times\iota_N, \end{cases} \qquad (2)$$

where S is a multidimensional time series characterizing the change in the state of operation of the logistic activity of motor transport enterprises; $S_t=\left(s_1^{(t)},s_2^{(t)},..,s_N^{(t)}\right)$ – a time slice of the state of logistics activity of motor transport enterprises represented in the form of a multidimensional time series at the t-th time point; $s_j^{(t)}$ – value of the j-th component of the multidimensional time series at the t-th time point, which characterizes the change in the state of the logistics activity of motor transport enterprises; L_j^i – maximum value of the time delay of the i-th component relative to the j-th, which characterizes the value of the efficiency of information processing, in relation to the state of logistics activities of motor transport enterprises; φ_{ij} – operator for taking into account the interaction between the i-th and j-th components of the multidimensional time series; F_1 – transformation to obtain $s_i^{(t)}$, $i=1,..., N$; N is the number of components of a multidimensional time series; ι is an operator for taking into account the degree of awareness of the state of logistics activity of motor transport enterprises.

Table 1

Factors affecting the operational efficiency of logistics activities of motor transport enterprises

External environment factors $\{OF\}$		
External environmental factors of direct influence (OI)	Suppliers	Conditions offered by suppliers
	Competitors	Availability of similar services, their quality and cost
	Consumers	Consumer demand and requirements
	Intermediaries	Quality and cost of outsourcing services
	Market conditions	Market growth rates, price sensitivity, market conditions
Factors of the external environment of indirect influence (II)	International and local events	Security stability in the country or the scale of the events taking place
	Political factors	Policy favorability, state support
	Socio-demographic factors	Composition and size of the population, standard of living
	Economic factors	Gross domestic product, interest rate, inflation rates, raw material and energy prices, exchange rates
	Legal factors	Legislative requirements, stability of the legal field of the state
	Geographical conditions	Availability of a resource base, favorable conditions for conducting logistics activities
Factors of the internal environment $\{IF\}$		
Information and communication factors		Level of information support, speed of information exchange and processing, relations with the public
Financial factors		Structure and liquidity of assets, provision of own working capital, level of profitability, fixed assets, expenses, and profits
Organizational and managerial factors		Quality of planning and decision-making, organizational structure, strategic planning
Factors that relate to both internal and external $\{MF\}$		
Labor resources		The level of qualification of the workforce, training, and motivation of personnel
Infrastructure		Development of logistics infrastructure
Innovative and investment capacity		The level of investment attractiveness of the country, enterprise
Environmental factors		The degree of pollution of the ecosystem, the level of impact of logistics activities on the environment, environmental restrictions
Technological factors		Scientific and technological progress in the country, the level of automation at the enterprise

From expression (2), it can be concluded that the expression makes it possible to describe the state of logistics activities of motor transport enterprises taking into account time delays. Delays are necessary for the collection, processing, and generalization of information, and also take into account the degree of awareness of the logistics activities of motor transport enterprises. The specified expression (2) also makes it possible to describe processes that have both quantitative and qualitative units of measurement.

A comprehensive assessment of the effectiveness of the operation of logistics activities of motor transport enterprises consists of the following sequence of actions:

Action 1. Input of initial data. Initial data on the logistics activities of motor transport enterprises are entered.

Action 2. Construction of a model of external factors of the functioning of logistics activities of motor transport enterprises.

Action 3. Construction of a model of the internal factors of the functioning of the logistics activity of motor transport enterprises.

Action 4. Building a fuzzy cognitive model of the functioning of logistics activities of motor transport enterprises.

Fuzzy cognitive model (FCM) (Fig. 1) [19] is used to evaluate the interrelationships of system factors that affect the efficiency of logistics operations of motor transport enterprises.

This model makes it possible to obtain initial data for determining the influence of system factors on the efficiency of the operation of logistics activities of motor transport enterprises using fuzzy models based on fuzzy neural production ANFIC networks.

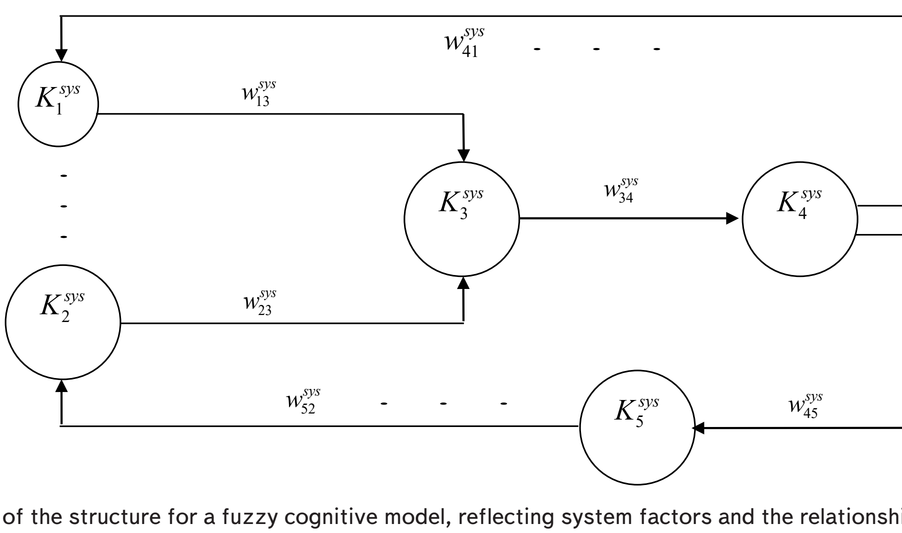

Fig. 1. A variant of the structure for a fuzzy cognitive model, reflecting system factors and the relationships between them

At the verbal level, the task of assessing the interrelationships of the system factors of the logistics activities of motor transport enterprises can be described in the following form:

1) assignment of a set of concepts K_i^{sys}, characterizing the factors of logistic activity of motor transport enterprises;

2) setting a set of concepts K_j^{dan}, characterizing the identified sources (dangers of occurrence) of risks in the system of logistics activities of motor transport enterprises;

3) formation of the structure of a fuzzy cognitive model for assessing the interrelationships of system factors $K=(K^{dan}, K^{sys})$ of the logistics activity of motor transport enterprises;

4) description of the state or meaning of the concepts of logistics activity of motor transport enterprises based on a scale of real numbers limited to the range [−1, 1];

5) determining the technique and defining the direct impact of the concepts of logistics activity of motor transport enterprises on each other $w_{ij}, K_j^{sys} = w_{ij} K_i^{sys}$;

6) determining the technique for accumulating the direct influence of several concepts of logistics activity of motor transport enterprises on one $K_j^{sys} = K_j^{sys} + \sum_{j=1}^{N} w_{ij} K_i^{sys}$;

7) determining the mechanism of indirect influence of concepts of logistics activity of motor transport enterprises $K_i \xrightarrow{l} K_q : d_l = \left(K_i, K_{Z_1^l}, K_{Z_1^l}, \ldots, K_{Z_n^l}, K_q\right)$, $l = 1, \ldots, m$, where m is the possible number of paths between concepts K_i and K_q;

8) building a model of the dynamics of logistics activities of motor transport enterprises $K_j^{sys}(t+1) = K_j^{sys}(t) + \sum_{i=1}^{N} w_{ij} K_i^{sys}(t)$.

This is the end.

5. 2. Procedures for implementing the method of evaluating the effectiveness of managing logistics operations of motor transport enterprises

To assess the effectiveness of the management of logistics activities of motor vehicle enterprises, the study uses an improved metaheuristic algorithm based on the chaos game algorithm. This approach is used to generate individuals with stronger randomness and characteristics, improved global search capabilities, and reduced probabilities of hitting a local optimum:

Action 1. Input of initial data characterizing the logistics activity of motor transport enterprises. In the specified action, the initial data on the logistics activity of the motor vehicle enterprise are entered. The basic model of the logistics activity of the motor vehicle enterprise is being initiated. As a basic model, the model proposed in chapter 5. 1 of this study is used.

Action 2. Generation of a random sequence of search agents.

Assuming that there are N individuals in a group, each of which has d characteristics, and each function has a corresponding range of values in the interval $\left[x_{i,\min}^j, x_{i,\max}^j\right]$, the value is controlled within the allowable range. Expression to initialize the creation of random agents:

$$x_i^j(0) = x_{i,\min}^j + rand \cdot \left(x_{i,\max}^j - x_{i,\min}^j\right), \begin{cases} i = 1, 2, \ldots, N, \\ j = 1, 2, \ldots, d, \end{cases} \quad (3)$$

where $x_i^j(0)$ is the j-th eigenvalue in the i-th agent, $x_{i,\min}^j$ is the minimum range of this value, $x_{i,\max}^j$ is the maximum range of the eigenvalue, *rand* is a random number in the interval [0, 1].

For this group, the matrix of connections takes the following form:

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_i \\ \vdots \\ X_N \end{bmatrix} = \begin{bmatrix} x_1^1 & x_1^2 & \cdots & x_1^j & \cdots & x_1^d \\ x_2^1 & x_2^2 & \cdots & x_2^j & \cdots & x_2^d \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ x_i^1 & x_i^2 & \cdots & x_i^j & \cdots & x_i^d \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ x_N^1 & x_N^2 & \cdots & x_N^j & \cdots & x_N^d \end{bmatrix}. \quad (4)$$

After obtaining the agents that have been initiated, their respective fitness values are calculated for each agent.

At each iteration of the algorithm calculation, the following information is obtained:

– the current optimal agent for the entire set of agents, written as the globally best (GB);

– a randomly selected part of agents from the entire population of agents with the calculated average value of their fitness (AF);

– currently selected agent – which is a X_i candidate decision. These three variables form a temporary triangular region that can be explored and updated, and for the most part the GB remains unchanged.

Action 3. Generation of two random agents to explore the search space.

Based on the three received pieces of information, two random agents are generated to explore the search space, which determine the priority search direction. It is assumed that the global optimal solution GB is constant during the entire iterative process of exploration by agents in the search space.

Action 4. Determining the initial search speed of the agent search area.

In the course of the specified action, the initial speed of movement of each agent from the set of agents is determined:

$$v_i = (v_1, v_2 \ldots v_S), v_i = v_0. \quad (5)$$

Action 5. Formation of a set of triangles in the search space.

The main purpose of creating search triangles is to find optimal values in the entire search space.

At the first iteration, X_1 and AF_1 are generated, and the triangle enclosed in GB, X_1 and AF_1 forms a temporary section in the search space, which will allow us to perform a search study of the search section.

On the second iteration, X_2 and AF_2 are generated, and the triangle enclosed in GB, X_2 and AF_2 forms a new temporary search area. Next, the i-th generation of X_i and AF_i, as well as the current GB again contain a new temporary search area, allowing not to leave any part of this search area unexplored.

By the N-th iteration, X_N and AF_N are generated, and the current GB covers the last temporary search area, completing the search traversal of this part of the search space. Although the global optimal solution GB may change during iterations, the generation of X_i and AF_i is not related to the current global optimal solution and will only have an effect when forming a temporary triangular region.

Action 6. Search for a global solution.

To use a game approach, let's assign each value of the color of the cube to a corresponding variable: X_i – blue, AF_i – green, and GB – red.

For the first *Seed* (X_i), since the current seed is generated based on X_i, the colors that can be selected are green and red, this die has three green sides and three red sides. When the color is red, individuals in X_i will move towards GB, if it is green, individuals in X_i will move in the direction of AF_i, otherwise they will move in other directions:

$$Seed_i^1 = X_i + \alpha_i \times (\beta_i \times GB - \gamma_i \times MG_i),\ i = 1,2,...,N, \quad (5)$$

where X_i is the current candidate solution, GB is the global optimal solution, MG_i is the average value of the agents in a certain range, β_i and γ_i are a random integer 0 or 1 used to simulate the probability of rolling the dice and thus control the direction of the agents, and α_i is a randomly generated factor used to limit the distance the agents move in the method. After that, the second individual is created in the same way using GB:

$$Seed_i^2 = GB + \alpha_i \times (\beta_i \times X_i - \gamma_i \times MG_i),\ i = 1,2,...,N, \quad (6)$$

where α_i is a randomly generated coefficient for simulating the agent's movement restriction, while β_i and γ_i represent a random integer 0 or 1 used to simulate the probability of a dice roll.

The third person will be generated with AF_i as the starting point, the cubes have three blue sides and three red sides. The formula for $Seed_i^3$ implementation is as follows:

$$Seed_i^3 = MG_i + \alpha_i \times (\beta_i \times X_i - \gamma_i \times GB),\ i = 1,2,...,N. \quad (7)$$

The values of the parameters involved in the formula and the principle of the direction of movement are the same as for $Seed_i^1$ and $Seed_i^2$.

To achieve a compromise between exploration and exploitation, the coefficient α_i is controlled:

$$a_i = \begin{cases} rand, \\ (\delta \times rand) + 1, \\ 2 \times rand, \\ (\varepsilon \times rand) + (\sim \varepsilon), \end{cases} \quad (8)$$

where δ and ε are random integers in the interval [0, 1], and *rand* is a uniformly distributed random number in the interval [0, 1].

Action 7. Verification of hitting the global optimum. At this stage, the condition of the method hitting the global optimum is checked according to the determined criterion for evaluating the effectiveness of managing the logistics activities of motor transport enterprises.

Action 8. Global restart procedure.

If the population of agents remains the same after T iterations, the population is likely to fall into a local optimum. Therefore, the candidate solution will be initialized randomly to accelerate the departure from the global optimum.

Action 9. Training knowledge bases.

In this study, a training method based on evolving artificial neural networks is used to train the knowledge bases of each agent of the algorithm. The method is used to change the nature of movement of each agent, for more accurate analysis results in the future.

End of algorithm.

The effectiveness of the method for evaluating the effectiveness of the management of logistics activities of motor transport enterprises is compared with the swarm optimization algorithms listed in Table 2. The comparison involved unimodal and multimodal functions.

As can be seen from Table 2, increasing the efficiency of decision-making is achieved at the level of 14–16 % due to the use of additional procedures.

6. Discussion of results related to devising a method for evaluating the effectiveness of managing logistics operations of motor transport enterprises

A comprehensive model for assessing the effectiveness of the operation of logistics activities of motor transport enterprises has been built.

The model is proposed for use in the course of operational management of the logistics activities of motor transport enterprises. This will make it possible to increase the efficiency of data processing and transmission and the reliability of decisions by the persons who make them.

Table 2

Effectiveness of optimization algorithms in solving the task of evaluating the effectiveness of managing the logistics activities of motor transport enterprises

Algorithm ID	Calculation duration (sec)	Optimal variables		Optimal cost (arbitrary units)
		GB	MG_i	
Algorithm for the optimization of a pack of walruses	0.7280271	0.3845792	40.312284	5882.8955
Particle swarm algorithm	0.7480269	0.3845797	40.312282	5882.9013
Flying squirrel algorithm	0.7690308	0.384581	40.312476	5882.9077
Artificial bee colony algorithm	1.1950157	0.64038	60.549321	7759.8234
Ant colony algorithm	0.7780271	0.3845792	40.312284	5882.9013
The proposed method	0.7194994	0.345819	39.386517	5909.3749
Algorithm of a pack of monkeys	0.911517	0.4510723	46.230782	6270.8621
The bat swarm algorithm	0.8344267	0.4164052	43.217775	6003.8497
Locust swarm algorithm	0.7784599	0.3858127	40.320627	5890.2105
Genetic algorithm	1.5622593	0.4813024	47.695987	10,807.366
Algorithm for optimization of a flock of cats	1.1300127	1.1576349	44.110061	11,984.417
Algorithm of invasive weeds	1.55006	0.6231249	63.139483	9998.6395
Firefly swarm algorithm	1.406417	0.7832762	58.253368	10,920.286

However, our model additionally allows for the following:

– possible risks of disruption of the task of providing goods and services in organizations and organizational networks are assessed;

– the influence of the performance evaluation indicators of the logistic support system in organizations and organizational networks on each other is determined;

– the influence of a group of indicators for evaluating the effectiveness of logistics support in organizations and organizational networks on a separate indicator is determined.

It is advisable to implement the specified model as algorithm and software when identifying and defining challenges and threats to logistics support in organizations and organizational networks.

The study also proposed a method for evaluating the effectiveness of managing logistics operations of motor transport enterprises.

The advantages of the proposed method are due to the following:

– the initial speed of each agent of the algorithm is taken into account (Step 4), which makes it possible to determine the priority of the search by each agent in the specified search direction, in comparison with works [9–13, 19, 20];

– the use of the procedure of global restart of the algorithm, which achieves the ability of the algorithm to go beyond the current optimum and improve the research ability of the algorithm (Action 7), which achieves a reduction in the time for evaluating the logistics activities of motor transport enterprises, compared to [9–13, 19, 20];

– the universality of solving the task of evaluating the logistics activity of motor transport enterprises due to the hierarchical nature of their description (Actions 1–9, Table 2), in comparison with papers [10–16, 19];

– the possibility of simultaneously searching for a solution in different directions (Actions 1–9, Table 2);

– the adequacy of the obtained results (Actions 1–9), in comparison with [9–20];

– the ability to avoid the local extremum problem (Actions 1–9);

– the possibility of in-depth training of agents' knowledge bases (Action 9), in comparison with studies [9–20].

Disadvantages of the proposed method include:

– lower accuracy of processing one type of data due to gradient search;

– loss of credibility of the obtained solutions when searching for a solution in several directions at the same time;

– lower assessment accuracy compared to other assessment approaches.

Our method will allow for the following:

– to carry out an assessment of the state of logistics activity of motor transport enterprises;

– to determine effective measures to increase the effectiveness of the assessment of the effectiveness of the management of the logistics activities of motor transport enterprises while maintaining the given reliability;

– to reduce the use of computing resources by decision support systems.

The limitations of the study are as follows:

– the need to have an initial database on the state of logistics activities of motor transport enterprises, the need to take into account the delay time for collecting and proving information;

– time limits for the transmission of information messages in the system;

– the need for a primary base of destructive influences on the logistics support system in organizations and organizational networks.

It is advisable to use the proposed method to solve the tasks of assessing the state of logistics activities of motor transport enterprises under conditions of uncertainty and risks characterized by a high degree of complexity.

7. Conclusions

1. A comprehensive model for assessing the effectiveness of the operation of logistics activities of motor transport enterprises has been built.

The model is proposed for use in the course of operational management of the logistics activities of motor transport enterprises. This will make it possible to increase the efficiency of data processing and transmission and the reliability of decisions by persons who make them.

However, our model additionally allows for the following:

– possible risks of disruption of the task of providing goods and services in organizations and organizational networks are assessed;

– the influence of the performance evaluation indicators of the logistic support system in organizations and organizational networks on each other is determined;

– the influence of a group of indicators for evaluating the effectiveness of logistics support in organizations and organizational networks on a separate indicator is determined.

2. The method for evaluating the effectiveness of managing logistics operations of motor transport enterprises has been implemented. The originality of the method is that our method makes it possible to avoid hitting the global and local optimum due to additional improved procedures based on the use of game chaos theory. The simulation results showed an increase in the effectiveness of assessing the operational efficiency in managing logistics activities of motor transport enterprises at the level of 14–16 % through the use of additional improved procedures.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The manuscript has associated data in the data warehouse.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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