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INCREASING THE EFFICIENCY OF TRANSPORT BY OPTIMISING THE MANAGEMENT STRUCTURE OF COMPLEX LOGISTICS SCHEMES

A mathematical toolkit for modeling transportation processes under dynamic changes and conditions of uncertainty in the external environment has been developed. The informational analysis and synthesis of processes occurring in complex transportation and logistics systems, characterized by multifunctionality and a variety of structural relationship options, are presented. A classification of the main directions for integrating new information technologies into the management structure of complex transportation logistics systems has been proposed. The purpose and description of the structural components of the classification scheme provide a deeper understanding of their role in the overall system of integrated transportation logistics management. The modeling of management efficiency for transportation and logistics schemes has been performed, focusing on the distribution of cargo flows, volumes, routes, directions, and timing, depending on the dynamics of external stimuli and internal resource constraints, taking their uncertainty into account using sequential analysis and Markov chains. Mathematical models for optimizing transportation processes within complex logical schemes are considered. The ways and prospects for increasing the efficiency of multimodal transportation logistics schemes are outlined. Practical recommendations for applying specific mathematical models to complex transportation logistics systems are provided. It is shown that solving optimization problems for the management structure of complex logistics systems is most effectively achieved using structural and functional modeling based on quantitative and qualitative results with the help of computer models and algorithms. The optimization of the management structure of complex logistics systems aims to identify the most rational use of available resources to achieve predefined goals. This is its fundamental difference from traditional models and optimization problems under uncertainty and a lack of input information, where the enumeration of options is infinite. In contrast, the number of possible management options is strictly finite in the optimization of complex logistics management structures.

Keywords: optimization, modeling, transportation, logistics, management.

RELEVANCE OF THE TOPIC

Transport logistics is a supply chain and a strategic business guideline that allows you to adapt cargo delivery schedules to eliminate peak periods, respond to road conditions, etc. By actively identifying recurring problems, you can solve deep-seated issues and improve the quality of transportation [1]. The logistics management framework is a computer software system used to coordinate and organise logistics operations related to cargo tracking, inventory management, transportation and order processing [2]. Logistics management systems can increase the efficiency of transport companies, reducing logistics costs and increasing customer satisfaction [3, 4].

With a competent approach, transport logistics can be turned into a strategic initiative, the advantages of which are crucial for increasing profits and service transport logistics services. Services for the movement of goods play a large role not only within one state but also in international trade, especially in the conditions of division of labour and the growth of international economic relations. According to forecasts, approximately one-third of all world production produced over the next few years will be part of the international trade cycle.

Increasing freight volumes requires coordination in infrastructure facilities, ports, shipowners, railways, road and air transport. The effectiveness of freight management in transport logistics is determined by understanding the patterns of operation and optimising real processes, taking into account uncertainty [5]. The goal of the logistics approach is end-to-end management of material flows.

Transportation optimisation is the selection of the best alternative from a set of possible options in terms of the accepted optimality criterion and certain restrictions. Route optimisation is carried out with the mandatory inclusion of current routes, bottlenecks, detours, transport windows and traffic jams. Optimisation of packaging and loading processes is carried out by taking into account weight distribution, product type, and delivery sequence. Optimisation of the management structure of complex logistics schemes sets as its ultimate goal the organisation of cargo transportation and tracking of cargo along the route, which allows for more accurate planning and coordination of deliveries. In general, optimisation of transport logistics contributes to reducing financial costs, saving time, and improving the quality of service.

Modern logistics systems operate on transport and technological complexes consisting of vehicles, unloading and loading points, cargo movement routes. Optimization of such costs is determined by the characteristics of different types of transport [6].

For short-distance transportation, road transport is used, one of the advantages of which is high maneuverability and the ability to deliver cargo in small batches. Road logistics transportation is characterized by high speed, low investment, high flexibility, ease of adaptation to local conditions and does not require large infrastructure [7, 8]. Optimization of spatial layout nodes of the logical supply chain in the automotive industrial park is presented in [9]. The environmental component of automotive logistics is presented in [10]. The Vietnamese company Vietnam Presion Industry Company for the production of auto parts in [11] carried out work on minimizing transport costs by optimizing minimum distances for moving materials. The issue of optimizing the management structure of complex logistics schemes in road transportation is given close attention in world practice.

The essence of railway logistics is the organization of transportation using vehicles and infrastructure, planning, coordination and control of all stages of transportation and provision. Railway logistics management is a set of measures and actions aimed at coordinating and controlling all stages of transportation, ensuring the safety and efficiency of train traffic. In this case, delivery routes are optimized, special wagon designs, technological tools and software are used [12]. The model for optimizing a sustainable supply network in railway construction is presented in [13]. Optimization of the railway logistics management structure is a reliable means of increasing the efficiency of transport.

An important element of world logistics is maritime transportation, which provides global coverage of most countries in the world. More than 10 billion tons of various cargo are transported by sea vessels annually. Maritime logistics systems, in addition to sea transportation, also include warehousing of goods in ports, as well as distribution of cargo flows. Often, maritime transportation is part of multimodal delivery along complex routes, which also includes transportation by other modes of transport [14]. The peculiarity of maritime logistics is that it does not depend on the availability of roads and has significant flexibility in choosing routes. In addition, sea vessels are more reliable than other modes of transport, and container transportation by sea is considered a reliable means of preserving cargo. However, when implemented, they require additional transport to deliver cargo to a ship or to seaports, including insurance against loss of cargo due to shipwreck, fire, piracy. In addition, the impact of external environmental fluctuations is characterized by situations of uncertainty and risk, which significantly change the state of maritime transportation and the achievement of the final target functions of transportation. [15] describes the results of ship accident prediction using a complex regional logistics transport system and the use of sequential analysis and exponential approximation. [16] proposes a scheme for multimodal maritime transportation with low logistics costs by optimizing the distribution of transport resources while ensuring the minimization of carbon emissions. Optimization of maritime logistics is directly related to the safety and delivery times of cargo to its destination.

Aviation logistics is an integral part of the modern global logistics system along with other modes of transport. The main driving force of its development is the trend towards globalization, which creates a demand for fast, reliable and safe deliveries. Compared to other types of transportation, air transportation is distinguished by the speed of delivery, the possibility of complex routes, and the preservation of perishable goods. Logistics management of air transportation using intelligent data analysis, various metrics, and multilayer perceptron algorithms for data balancing is presented in [17]. Aviation logistics is aimed at the globalization of transport and the widespread use of artificial intelligence.

The problems of organizing transport logistics are related to loading, routing, and empty mileage. Violations of the rhythm of receipts and dispatches of goods caused by shortcomings in the transport and transshipment process management system, shortcomings in the processing capacities and capacities of seaports, the presence of sections of road routes that differ in the quality of coverage, throughput, permissible speed and periodically arising traffic jams, as well as shortcomings in the scientific and methodological basis for the selection and calculation of the main parameters of complex logical schemes do not allow the implementation of logistics chains for the movement of goods that meet to the criteria of service quality. Therefore, optimization of the structure of management of technological operations of complex logistics systems and their routes is becoming relevant. For this purpose, technologies and tools of mathematical modeling are used. A necessary condition for increasing the efficiency of transport using logistics is the widespread implementation of mathematical methods that allow finding rational and logical arguments when making management decisions to substantiate them.

PROBLEM STATEMENT

Transport modelling is divided into analytical and simulation. Analytical modelling is based on exact solutions, simplifications, and established laws, which have limited application in uncertain conditions. One of the ways to increase the efficiency of freight transportation management in conditions of uncertainty and risk is the creation of simulation models. Simulation modelling is designed to simultaneously take into account all relevant factors and, limitations, and trends of the dynamic series, predict properties and behaviour in different situations, making adequate management decisions on this basis. The methods used in this case allow you to quickly change the management structure and choose the most optimal option [18-20]. A well-developed simulation modelling methodology is equally acceptable for managing the transport logistics of one specific type of transport, although, in practice, cargo delivery to the consumer is carried out by several types of transport.

The problems of solving management tasks under conditions of uncertainty of environmental impact are determined both by the large dimension of the management influences and the dimension of the constraint systems. Existing methods, models, and algorithms for solving similar classes of optimization problems do not allow for the full overcoming of these difficulties; therefore, it is necessary to develop new approaches and mathematical models of intellectual support suitable for transport logistics. The purpose of the work is to create a mathematical toolkit for modeling complex integrated transportation, which describes and records the properties of the state of freight transportation and its constituent elements in the dynamics of their changes.

The tasks of the work are:
- analysis and synthesis of mathematical models of transport management,
- classification of information technologies of transport logistics of complex systems,
- synchronization of computational and information processes,
- modeling of the efficiency of transport and logistics schemes.

MATERIALS AND METHODS

The materials of the work were technical features of transport, multimodal delivery of goods along complex routes, modern logical schemes.

Methods used in the work: statistical, deterministic, probabilistic, stochastic, discrete, dynamic, continuous.

PRESENTATION OF THE MAIN MATERIAL

The modern transport logistics market is a competitive environment, the management efficiency of which requires the implementation of new digital tools and methods based on the use of advanced information technologies, models and algorithms that allow for the support of making informed management decisions.

The integration of new information technologies into the practice of managing complex transport logistics schemes is presented in Fig. 1.

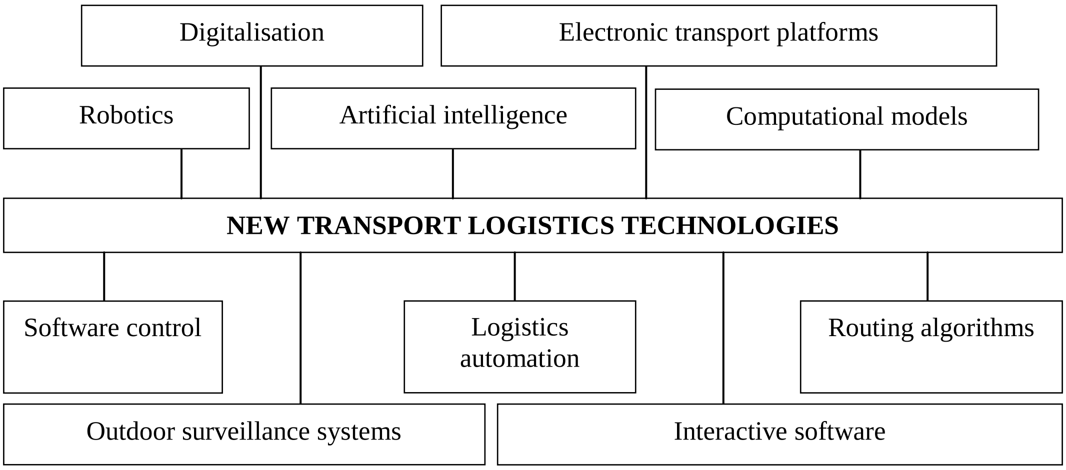

Fig. 1. Classification of new information technologies in transport logistics

The purpose and description of the structural components of the proposed classification allows for a deeper understanding of their role in the overall system of integrated transport logistics management.

Digitalization is a key factor in transport logistics systems for processing and analyzing data that are included in intelligent systems for managing and tracking cargo at all stages of its movement. The use of digitalization in intelligent management systems requires logistics companies to respond quickly to their decisions [21]. Therefore, many optimization processes are related to the level of operational management. Coordination of operational strategic decisions on logistics management is described in [22]. In [23] describes a method for optimizing transport logistics resources based on a digital twin in an intelligent cloud environment. The method is based on optimizing and building a cloud resource change aimed at minimizing the number of vehicles.

Electronic transport platforms for digital logistics provide acceleration of document flow. The preparation of paper documentation on delivery and cargo clearance accounts for 10-15% of transport costs. With the help of properly structured data, new routes can be found [24, 25].

Robotization is a promising trend in digital logistics that automates the inventory process in warehouses, which reduces operating costs.

Artificial intelligence in transport logistics is manifested through the Internet of Things in transport (I_0T), to create containers and packaging, which facilitates tracking of goods and fixing possible delays in transit. At its core, it is based on digital supply chains (DSC) and information and communication support [26]. The use of Internet of Things technology to optimize the quality of supply management of the logistics system, tracking trends and predicting possible accidents is described in [27]. Supply chain optimization based on (I_0T) allows you to improve the quality of information transmission and reduce the risk of its asymmetry.

Computational models of logistics processes are a reflection of the logistics system for studying its properties and possible behavior options. The results of the model study should reveal the properties of the system that are not reflected and embedded in the source material.

Software control in the form of application programs for solving linear programming problems and optimizing high-dimensional systems ILOG is implemented in the logistics model of vertically integrated transport companies.

External surveillance systems, geoinformation schemes and geopositioning devices allow for the integration of warning systems into logistics, control the location of vehicles and RFID cargo radio frequency coding systems.

Interactive software in transport logistics allows for the automatic distribution of tasks between performers and the development of the least expensive routes. The information base contains:

- documentation formation,
- general route status,
- cargo movement dynamics,
- control functions.

Interactive software allows for consolidated transportation, combining several orders for different clients in one trip. Interactive monitoring programs are adapted to work in different countries.

Logistics automation consists in automatically arranging locations in the desired sequence and choosing the shortest route. This reduces the risk of errors, reduces travel time, and makes it possible to fulfill large orders.

Routing algorithms in logistics allow processing the flow of incoming information, planning and compiling routes, coordination, cost accounting, optimal distribution of load, parking spaces, temporary traffic jams, etc.

A synthesis of mathematical models of intelligent support for transport logistics is presented in Fig. 2.

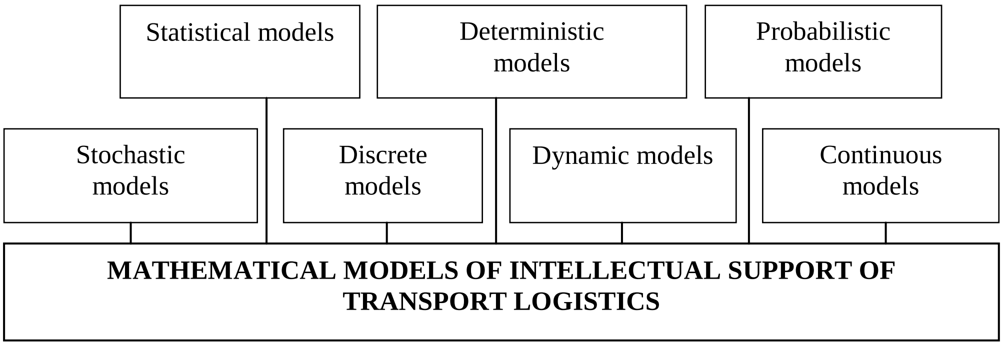

Fig. 2. Synthesis of mathematical models of intellectual support of transport logistics

Statistical processing of logistics information is intended for operational improvement of business efficiency by optimizing logistics costs for transportation operations. Statistical models require the availability of data for a long period of time when used [28, 29]. Their practical implementation under uncertainty consists in creating simulation-statistical models based on repeated reproduction of processes that are implementations of random variables with subsequent processing of information by methods of mathematical statistics.

Deterministic models are based on the assumptions that the initial information about the system parameters is uniquely described by the corresponding equations that have a single solution. A variety of such modeling is analytical representations of the freight transportation process. Deterministic models are used in the analysis of specific scenarios that occurred in both past and future events. In the context of uncertainty of external disturbances, deterministic models are not effective enough.

The use of probabilistic models assumes that part of the initial information is deterministic, and the other part is replaced by statistical characteristics of random variables and functions. Probabilistic models allow us to take into account random and unpredictable factors that exist in real life. In transport logistics, this is the density of traffic on highways, the probability of accidents, downtime due to weather conditions on the highway, etc. Models of this type allow us to predict oncoming and passing flows of freight traffic, optimize vehicle routes, and coordinate the actions of participants [30]. This is especially relevant in the context of the accelerated development of global transport networks and the growth of transportation volumes. It is promising to link together the formalization of the risks of not achieving the main goal of transportation with probabilistic models of local states of transport systems and implementation scenarios. Such a model will allow us to describe the probable states of the transport system based on statistical data. Stochastic models are built on the basis of probabilistic concepts. They are based on the determination of the probability distribution function of the variables underlying the studied process and random unforeseen excitations from the external excitation. They preserve the logical structure and sequence of alternation of stages of cargo passage along the route. When using them, there is no need to establish statistical dependencies of the sought-after quantities. Optimization of stochastic management of transport logistics using the separation of transitions of Markov processes, Monte Carlo methods, cause-and-effect structures is presented in [31].

Dynamic models reflect the interactions of the stages of cargo movement along the route. Their feature is external and functional similarity. The factors analyzed in dynamic models include the speed on the route, the time of forced delays on the road, changes in the duration and speed regime of passing individual difficult sections, and the time of reloading to other types of transport. Various subsystems of transport logistics can be in both static and dynamic states. The transition from one state to another is carried out using transition functions. The model of dynamic planning of decisions on supply chain optimization in the Chinese automotive industry is described in [9]. Dynamic models that reproduce the information field for optimizing the organization of grain transportation are described in [12].

Discrete mathematical models are based on the study of the behavior and functionality of the transport system over time. In this state of the transport system, only the moments of events change, and between these states the system changes.

The model operates only at discrete time intervals in anticipation of subsequent events in the course of the analyzed transport process. Such factors in the transport logistics of complex complex movements by various modes of transport include the moments of loading on the transport, the moments of unloading, warehousing, clearance and customs clearance [19]. The prospects of this type of models for transport logistics lie in taking into account the uncertainty and risk caused by possible extreme situations during the operation of vehicles. System calculation methods with elements of discrete mathematics and graph theory allow describing the state of the transport system.

Continuous mathematical models are used for continuous monitoring of transport systems that change in time, exerting operational influences on the management system. The implementation of models is carried out in terms of derived variables using differential equations [8]. In transport logistics, they can be used for various types of transport and complex schemes, observing the fast-moving processes of preservation of perishable goods, temperature, humidity and deformation processes of movement.

A summary of information support for the application of mathematical models for transport logistics of complex schemes is presented in Table 1.

Table 1 – Adaptation of mathematical models to complex transport logistics schemes

	Statistical models	Determin-istic models	Probabilistic models	Dynamic models	Discrete models	Continuous models	Stochastic models
Principle of operation	Optimiza-tion of logical costs for operational activities	Formulas, laws, equa-tions	Accounting for random and unpredictable factors	External and functional similarities	System state in discrete time intervals	Observation of cargo handling processes	Distribution functions of probabilistic variables

Manifestations	Statistical characteristics of functions and processes	Analytics of transportation and transportation conditions	Probabilistic modeling of local states of transport processes	Interaction of cargo movement elements	Accounting for risks and extreme environmental interactions	Integral and differential equations of fast-moving processes	Random fluctuations of the external environment
Prospects	Use in the automation of logistics	Use of robotics in transport logistics	Study of possible scenarios for the implementation of extreme situations	Development of routing algorithms for complex logistics schemes	Accounting for uncertainty and risk in the operation of vehicles in emergency modes	Information support of technological processes of cargo handling	Logistic structures for constructing multifunctional plans along complex routes

When modeling complex transport logistics systems, a combination of deterministic, analytical, probabilistic, stochastic and simulation-statistical methods should be used that reflect multifactorial non-stationary control processes through the reproduction of transitions from one state to another in accordance with operational rules. Such modeling is a technically difficult to implement complex task of managing technical systems characterized by multifunctionality and diversity of the structure of relations. In addition to the synthesis of mathematical models, its solution and implementation require sequential analysis in control systems of variable processes under conditions of uncertainty [30].

The real process of moving vehicles in structural-functional modeling corresponds to a sequential transition from one state to another. Cargo transportation systems in multimodal transportation include transshipment, and sometimes processing of cargo along the way in transport nodes, stations, terminals. The peculiarities of modeling such systems are in building a sequence of transport operations that are used during cargo service.

Optimization of the management structure of complex logistics schemes sets itself the goal of finding the most rational options for using available resources aimed at achieving the intended goals. This is its fundamental difference from traditional models and optimization tasks in conditions of uncertainty and lack of input information, where the search for options is infinite and only some ordering in estimates, criteria and convolutions is required. Such criteria can be the statistical criteria of Laplace, Wald, Savage, Hurwitz, as well as additive and multiplicative convolutions.

In the task of optimizing the management structure of complex logistics schemes, the number of possible management options is strictly unique and only one that satisfies the available resources needs to be found. Such a task has a unique solution, which can be achieved by a consistent analysis of complex management systems.

The mathematical description of the management of complex transport logistics schemes should begin with the establishment of the main tasks to be solved: the organization of transportation and their implementation.

In the organization of transportation, the information components will be:
- construction of a network organizational structure,
- specification of the passage of stages,
- establishment of controlled subsystems,
- determination of functional relationships between subsystems,
- coordination of interactions with subsystems,
- formation of a management model.

In the direct implementation of transportation, the information components will be:
- number of system components,
- number of discrete states,
- number of transitions of system states,
- transition probabilities,
- number of steps in the transition of the system from one state to another.

To build a network organizational structure, we will introduce the following notations. Let us denote by M the total number of control subsystems: types of transport, transportation conditions, resource constraints, speed and delivery time, etc., by U the set of options for solving control problems, and by V^n the set of possible control alternatives. Then, according to the information analysis of the available input data, the process of modeling complex transport logistics systems will have the form [30].

$$V^n = \{v_j^n\} = \prod_{i=1}^{M} U_j$$

$$U_j = \{U_{j(I_j)}\}; \quad j = \overline{1, N^n}; \quad I_j = \overline{1, S}; \quad N^n = \prod_{i=1}^{M} S_i$$

where i – number of control subsystems $i = 1{,}M$; j – number of stages of the route; n – number of possible options for routes between control points; I – is the number of possible implementations of the management system; S – is the number of organisational measures.

The quantitative characteristics of these values are limited by available resources.

Reliability indicator of the selected system option $v \in V^n$ cognitively through $p(v)$, then $0 \leq p(v) \leq 1$. The technical and economic characteristics of this option are denoted by $g_i(v)$, $g_i(v) \geq 0$. The quantitative values of these characteristics in the overall spectrum of tasks are determined by limiting constraints and resources. The available resource level of the selected control option for the j-th system characteristic, which, according to the accepted notation, represents the number of stages of the route, is denoted by g_i*. This parameter is characterised by its minimum and maximum permissible values, which is indicated by the indices $i = 1{,}n$, $n \leq N$ for the upper level and $i = n{+}1{,}N$ for the lower level.

Taking into account the introduced notations, the general mathematical model of the processes of managing complex logistics schemes of transport will look like:

$$p(v) \rightarrow \max;$$
$$g_i(v) \leq g_i^*, \quad i = \overline{1, n};$$
$$g_i(v) \leq g_i^*, \quad i = \overline{n+1, N};$$
$$v = (v_1, \ldots, v_j, \ldots, v_M) \in V^n = \prod_{j=1}^{M} U_j$$

Here p, g_i functions of a discrete argument.

The multiplicative reliability function is called a sequential system, i.e., a system in which the failure of any subsystem k leads to the failure of the entire system. In this case, partial failures do not affect each other. In this case.

$$p(v) = \prod_{j=1}^{M} p_i(v_j)$$

This means that to ensure the reliability of logistics systems, it is necessary to choose a management alternative $v_j^n \in V^n$ in such a way as to ensure the successful completion of all tasks assigned to the system with probabilities of failure not less than the specified levels p_k^*, $k = 1{,}n$.

With this in mind, the mathematical model is transformed as follows

$$p(v) = \prod_{j=1}^{M} p_j\left(V_{j(I_j)}\right) \rightarrow \max;$$
$$p_k(v) = \prod_{j \in L_k}^{M} p_j\left(v_{j(I_j)}\right) \geq p_k^*, \quad k = \overline{1, r},$$
$$g_i(v) = \prod_{j=1}^{M} g_{i_j}\left(v_{j(I_j)}\right) \leq g_i^*, \quad i = \overline{1, n};$$
$$v = (v_1, \ldots, v_j, \ldots, v_M) \in V^n = \prod_{j=1}^{M} U_j$$

In the direct implementation of the transportation process, the information component is a dynamic process of changing the states of transport systems. The real process of moving goods along a route in the model of managing complex transport logistics schemes corresponds to a discrete time transition, which is defined as a Markov process. In this process, the current state of the cargo along the route does not depend on past states, cataclysms and histories of the cargo being located at the point of the route under consideration.

When modeling complex logistics schemes of transport, an important aspect is to establish the interactions of the model components and transport transitions. Events are considered as the state of the transport system, and the transportation itself is a change in the system over time.

Transition probabilities P_{ji} do not depend on the moment of time, but only on j and i and are represented as a transition matrix P [31].

$$P = \begin{vmatrix} P_{11} & P_{12}\dots & P_{1n} \\ P_{21} & P_{22}\dots & P_{2n} \\ P_{n1} & P_{n2}\dots & P_{nn} \end{vmatrix}$$

where $0 \le P_{ji} \le 1$, $\Sigma^{n}_{i=1} P_{ji} = 1$

The Markov chain is assumed to be homogeneous since the transition probability P_{ji} systems from the state of i in a state of j does not depend on the vehicle location number on the route $P_{ji}(n)$.

Probability $P_{ji}(n)$ can be found using the Markov inequality

$$P_{ji}(n) = \sum P(m)P(n-m)$$

where m – the number of steps by which the logistics system moves from a state i into a state of j.

Any condition S_j can be reached from another state in a finite number of transitions. The probability of moving from one state to another is the same regardless of the number of intermediate states that must be passed through to reach the goal.

Conditional probability $P_{ji}(S)$ does not depend on the current state, i.e.

$$P_{ji}(S) = P_{ji}$$

where i – the number of the previous state,

j – the number of the nastupnogo stanu,

n – number of system components,

The transition probabilities can be represented by the following equations

$$P(x_0 = S) = q_0(S)\forall_{S\in E}$$

where $\forall$ – quantum of comprehensiveness,

S – discrete states,

q_0 – the probability of finding the system at a given time $t_0 = 0$,

x_0 – point of reference,

E – the number of possible system states.

The probability of the system passing through the stages of the route is expressed as follows

$$P(x_{n+1} = S_{n+1} \mid x_n = S_n) = P(S_n, S_{n+1})\forall(S_{n+1}, S_n)$$

Transitions are possible only at points in time corresponding to the route points. By multiplying the row vector of the transition matrix P by the transition probability matrix, we obtain the probability distribution at a certain point of the route.

The complex use of intellectual support for organizational activities and transportation processes themselves in the form of structural and functional modeling is presented in Fig. 3.

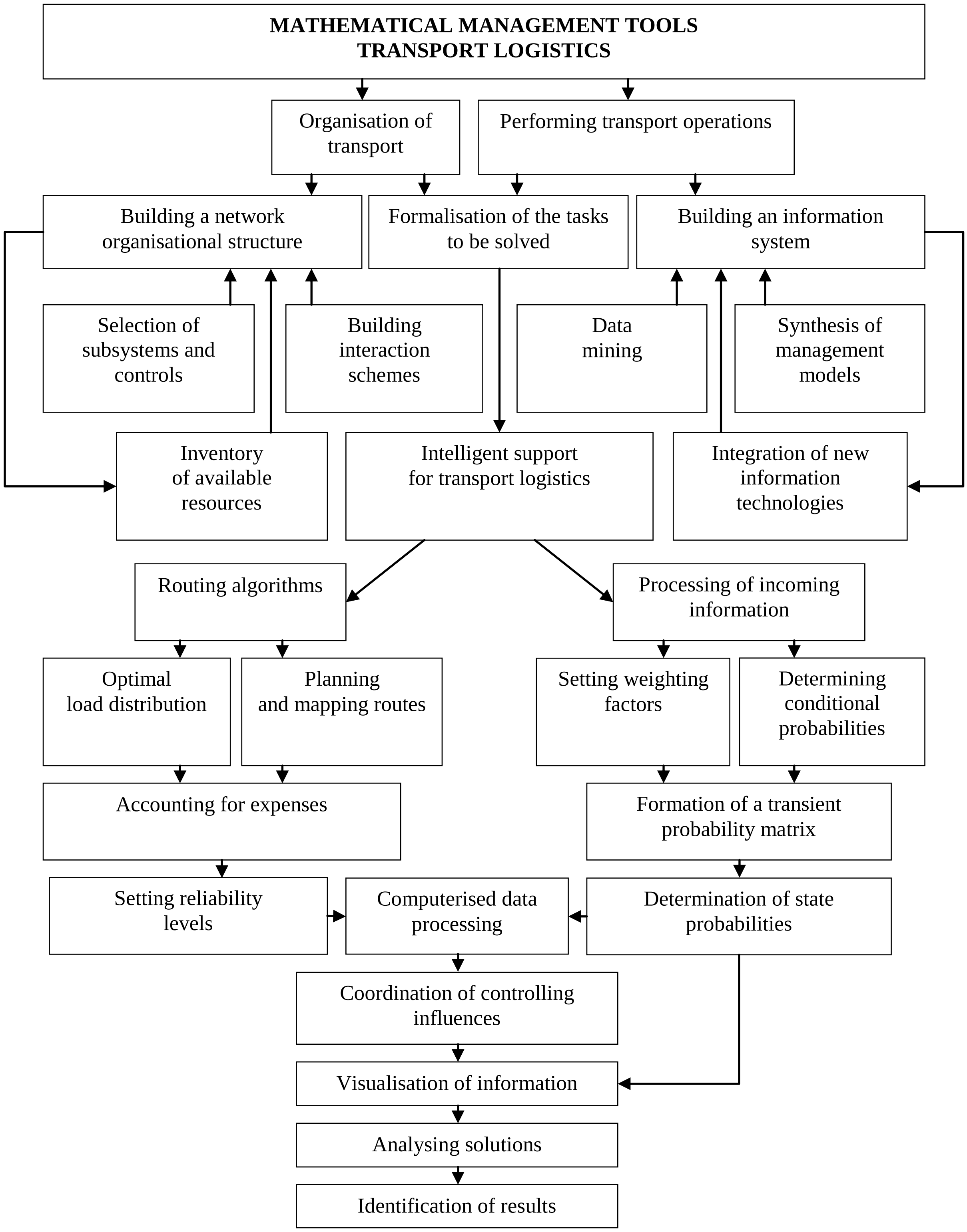

Fig. 3. Structural and functional sequence of complex logistics systems management

The essence of information analysis of processes occurring in transport and logistics systems is to collect the necessary information, exchange it with subsystems, analyze and process its use. The task of information synthesis includes substantiation of the necessary volume and forms of information presentation, methods and means of its processing, inventory and storage. Both of these areas of study are an effective means of building and researching transport logistics information systems.

The main determining factor in the analysis of a problem situation is the formalization of tasks and the establishment of the causes of its occurrence. When identifying a problem and ways to solve it, one should take into account the expansion of the problem and the identification of other related problems, without which it cannot be solved. The formulation of the problem usually occurs at the verbal level as logical statements. Goals can be both formalized and poorly structured. They must be translated into tasks. This stage is the most important because incorrect setting of goals leads to new problems.

Using simulation modeling as a method of optimizing individual sections of the transport system, we can obtain the following scheme for implementing mathematical tools for managing complex logistics schemes (Fig. 4).

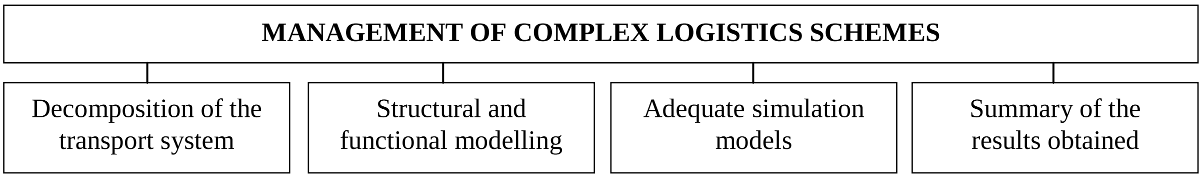

Fig. 4. Implementation of mathematical tools for managing logistics schemes

The components of the above diagram are designed to perform the following operations:

- decomposition is intended for the distribution of the transport system into some structural elements that affect the performance of the system as a whole.

- structural-functional modeling is intended for the description of complex technical processes of organizations and the sequence of actions taking into account various random factors (defects in the arrival schedule, deterioration of weather conditions, breakdowns and accidents).

- adequate simulation models are intended for adjusting control influences in different implementation options.

- generalization of the obtained results is intended for determining the degree of improvement of the analyzed logistics schemes.

The presented scheme allows synchronizing the operation of transport operations, based on traffic intensity, throughput capacity of individual sections of transport routes, optimal number of vehicles, delivery time, determination of the most loaded sections of the route.

Analysis of Fig. 1 and Fig. 2 allows us to establish the possibility of using specific information models in modern technologies for integrating artificial intelligence into logistics activities. Using the logistic concept, description of the mathematical model, limitations and conditions of possible implementation in complex freight transportation routes, one can obtain new scientific knowledge [33].

The process of system functioning can be imagined as a set of a certain number of sequences of local processes. The moments of completion of local processes in each sequence form a flow of main events that change the state of the system.

The prospects for using mathematical models for transport logistics of complex schemes can be determined by establishing their correlations with the advantages and capabilities of new information technologies.

CONCLUSIONS

1. The management structure of complex logistics schemes is a computer software system characterized by multifunctionality and diversity of relations. For its solutions and implementation, a developed mathematical toolkit for modelling the management of complex logistics schemes based on sequential analysis and synthesis of mathematical models under conditions of uncertainty is required.

2. It is shown that for solving the tasks of managing complex logistics schemes, the most promising is using structural-functional modelling based on quantitative and qualitative results using computer models and algorithms. Structural-functional modelling of processes and individual links of transport according to complex logistics schemes should be developed by the complete reflection of the existing patterns of technological connectivity and consistency of functioning both within individual modes of transport and between them.

3. In order to increase the efficiency of transportation, a set of statistical, dynamic, deterministic, stochastic and probabilistic models with discrete and continuous time and various details of specific types of transport logistics schemes with the integration of new information technologies are used for modelling.

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Шарко О., Дорошенко О. **Підвищення ефективності транспорту шляхом оптимізації структури управління складними логістичними схемами**

Розвинуто математичний інструментарій моделювання транспортних перевезень у динаміці їх змін за умов невизначеності зовнішнього оточення. Наведено інформаційний аналіз та синтез процесів, що відбуваються в складних транспортно-логістичних системах, що характеризуються багатофункціональністю та різноманіттям варіантів структури відносин. Запропоновано класифікацію основних напрямів інтеграції нових інформаційних технологій у структуру управління складних схем транспортної логістики. Призначення та опис структурних складових схеми класифікації дозволяє глибше зрозуміти їхню роль у загальній системі комплексного управління транспортною логістикою. Виконано моделювання ефективності управління транспортно-логістичними схемами розподілу вантажопотоків. Розглянуто математичні моделі оптимізації процесу перевезень за складними логічними схемами. Намічено шляхи та перспективи підвищення ефективності мультимодальних логістичних схем транспортних перевезень. Отримано практичні рекомендації щодо застосування конкретних математичних моделей у складних схемах транспортної логістики. Показано, що при вирішенні завдань оптимізації структури управління складних логістичних схем найперспективніше використання структурно-функціонального моделювання на основі кількісних та якісних результатів за допомогою комп'ютерних моделей та алгоритмів. Підвищення ефективності транспортних перевезень із боку управлінської складової досягається

шляхом удосконалення системи регулювання процесами своєчасного реагування на зміни умов перевезень.

Ключові слова: оптимізація, моделювання, транспортні перевезення, логістика, управління.

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