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STRUCTURING THE MAIN RESEARCH AREAS, MODELS AND METHODS OF MARITIME TRANSPORT MANAGEMENT

This review aims to perform an intelligent analysis of various sources compiled based on modern scientific publications, industry and international conferences, market analytics, and development trends. The complexity and fragmentation of the research topics associated with the uncertainty of the influence of the external environment on the functioning of transport infrastructure facilities and global changes in the structure of relations are noted. It is shown that the development of transport logistics is characterized by the fact that simultaneously with its concept, there is a process of developing methodological foundations for new technologies for managing information support, processing and protection of information. Modern technologies for creating intelligent control systems are considered, and possible areas for improvement are indicated. The obtained information is structured into a basis on which trends in logistics development in maritime transport are laid: intelligent automation, robotics, big data analytics, the Internet of things, cybersecurity, cloud platforms, blockchain, and artificial intelligence. From the standpoint of maritime transport logistics, the advantages, disadvantages and areas of rational use of the proposed structuring are analyzed. This made it possible to identify promising areas of scientific research and provide a basis for constructing conceptual transportation models in complex operating conditions.

Keywords: maritime transport logistics, development trends, uncertainty, intellectualization, management, structuring.

INTRODUCTION

Information and communication technologies are the primary tools for modernizing the transport sector. Creating a single information space for all participants in the interactions characterizes them. The specifics of maritime transport require constant information exchange, network equipment and long-distance data transmission technologies, various server equipment, information architecture, and operating systems. Optimization of transport technologies is the central aspect of successful transportation management, which allows for a significant increase in efficiency, a reduction in costs, and an improvement in the quality of delivery.

Improving all stages of the transportation logistics chain is the key to the rational use and development of the entire transport system. The introduction of information technologies helps to increase reliability and reduce risks in transport logistics.

Modern technologies make it possible to track the movement of goods by sea in real time. This makes it possible to promptly respond to potential threats and ensure goods' safety at all transportation stages.

The number of publications on the problem of managing maritime transportation under challenging operation conditions and the external environment's unpredictable influence is constantly growing. Finding the information acceptable for solving specific transport management problems takes a lot of effort. To facilitate the search for the required sources, it is necessary to structure the available information by directions and modern trends in the development of the industry. This determines the relevance and necessity of this work.

ANALYSIS OF LITERATURE DATA AND STATEMENT OF THE PROBLEM

In transport logistics, information technology is used as a set of measures, software, and hardware for transmitting, processing and consuming information. Transport logistics tasks are solved not only in maritime transport but also in the area where there is a docking in the transportation of goods by different modes of transport and, consequently, between different data processing systems. The iterative nature of the decision-making process underlies the construction of mathematical models adequate to real transport processes and economic conditions, using optimization methods and searching for rational management solutions. The optimization problem consists of three components: variables (vessels, ports), restrictions on the use of these variables associated with the technical capabilities of the vessel and the target function that needs to be minimized or maximized. Searching for and analyzing information on the current state of such management models in the complex conditions of the transport industry is an extremely complex technical task since the keywords for the search are common and overlapping. Therefore, it is necessary to structure information by directions, tasks to be solved, results achieved, ways of using, methods of obtaining information, effectiveness and development prospects. Due to the specific nature of research on maritime transport associated with the uncertainty of the influence of the external environment, such structuring of information is timely and necessary.

This review of analytical materials presents materials for systematization, analysis and evaluation of information by processing a large volume of diverse information on the problem of sea transport in the conditions of dynamic changes in the external environment, obtained from SCOPUS and Web of Science abstracts, domestic and foreign literature, materials of international conferences and symposia, publications in periodicals.

To the unresolved parts of the general problem Information support for models and methods for managing the development of maritime transport technologies includes the creation of an analytical base of modern information and the latest achievements in the field of maritime transport logistics for the implementation of transport operations in difficult operating conditions of equipment.

GOAL AND OBJECTIVES OF THE STUDY

The aim of the work is the structuring of the main areas of research, models and methods of managing maritime transport.

The tasks of the work are:

- information base for a single information space on transport transportation in complex conditions of their functioning,
- identification of the main characteristics and directions of development of transport transportation management contained in development trends,
- determination of prospects for the development of maritime transport transportation in the dynamic influences of the external environment.

RESEARCH RESULTS AND THEIR DISCUSSION

Sea transportation plays an important role in international trade and is the main way of delivering goods between countries. Their advantages over other types of transportation include high load capacity, the ability to transport large-sized and heavy cargo, and availability of delivery to different coastal regions. One of the conditions for the successful development of sea freight transportation and infrastructure modernization is the optimal use of resources and technologies to support management decisions with information. Optimization of sea transport logistics processes is the search for and implementation of solutions that allow logistics operations to be performed faster and at lower costs.

Adapting existing sea transportation technologies to changing vehicle operating conditions is the essence of the ongoing transformational changes aimed at modernizing the industry.

Trends in the development of transport logistics include the following main areas:

- intelligent automation, robotization, digital transformation of sea cargo terminals and port facilities;
- big data analytics on traffic, distances, port congestion, route optimization, fuel consumption, delivery time;
- use of the Internet of Things (IoT) to track the status, position and movement of goods using GPS modules, sensors, accelerometers, Internet protocols and addresses, control systems;
- cybersecurity to protect digital systems and data of transport logistics;
- mobile applications for planning operations based on up-to-date data;
- blockchain of innovative technologies for registering and confirming transactions when checking the authenticity of documents and maintaining the integrity of information, which allows all participants in the transportation process to synchronize actions in real time;
- use of cloud platforms and technologies for logistics management and routing, planning, monitoring and control of transportation, which helps to increase the flexibility and scalability of transport systems and reduce costs;
- application of artificial intelligence in traffic management and demand forecasting and adaptation to emerging situations.

A review of domestic and foreign scientific sources devoted to the optimization of transport processes, mathematical modelling of sea transport technologies and new modern research areas in this area made it possible to identify the main areas of research, grouping them by methods of obtaining and analyzing information accompanying all the details of the transport process (Fig. 1).

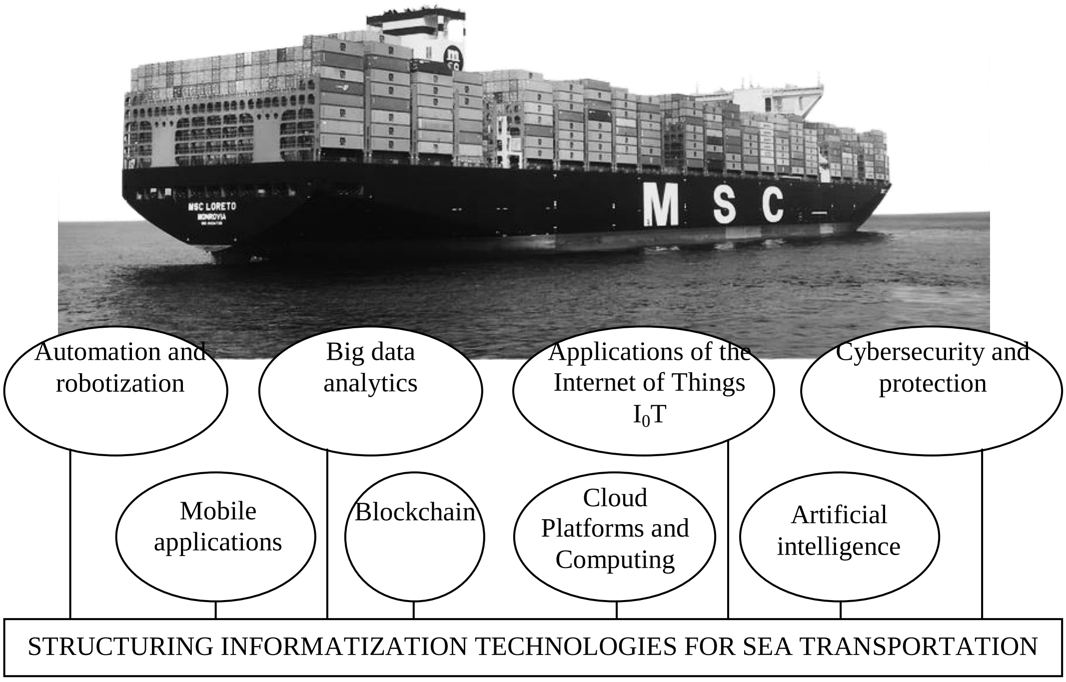

Fig. 1 - Structuring the main directions of research into the development of transport services

Intelligent automation and robotics

The most popular in the practical application of information technologies in transportation in difficult conditions of operation of transport facilities are works related to intelligent automation, robotics, digital transformation of sea cargo terminals, automation of port facilities, creation of software and hardware systems for remote control of operations.

Due to the complexity of the maritime transport infrastructure, modeling of ongoing processes is used to study the complex relationships between factors influencing the external environment and the risk of making unfounded decisions. International communications require optimization of routes and traffic safety when passing not only through open spaces, but also through deep-water channels. In [1], the channel management structure is considered from the standpoint of intelligent automation and robotics. Intelligent automation and robotics as one of the components of the trends in the development of maritime transport is described in [2] when developing an approach to optimizing the threshold values of factors based on a two-criteria nonlinear model when conducting port control. Recommendations are given for the selection of ranges of threshold values, weight points and optimization parameters when inspecting port control in Hong Kong. Digital twin technologies in management intelligence play a crucial role in the modernization and optimization of various sectors of maritime transport, shipbuilding, and operation. The integration of digital technologies into transport logistics provides additional value by increasing operational efficiency and sustainability [3]. Automatic identification of vessel tracking, real-time monitoring of maritime traffic using big data is described in [4].

In [5], it is shown that speed optimization has an impact on reducing fuel costs. This is a problem of management decisions. Theoretical fuel consumption functions have limitations due to weather conditions during voyages. Using Copernicus archive data as a source of big data, intelligent automation and optimization of a particle swarm, and the search for optimal Pareto solutions are performed using intelligent analysis and metaheuristic optimization based on a given route. Practical results are discussed.

When establishing a vessel's movement schedule by adjusting the speed and modes of the vessel's movement, the problem is formulated as a multi-objective optimization of taking into account various factors with the support of big data. Three objectives were pursued: minimization of distances between ports of departure and destination, minimization of total financial losses, and compliance of the average speed with restrictions on individual sections of the route. A compromise between the objectives was achieved by approximating Pareto solutions. The problem of multi-objective optimization was considered in [6] when designing sea deliveries for the fishery industry. An integrated problem of routing, location, and distribution of vessels is presented. Two objective functions are considered: maximization of resource coverage and minimization of the total cost of deliveries. An algorithm for multi-objective modeling based on k-means clustering is proposed.

Machine learning algorithms and models for high-quality forecasting of the estimated time of container ships applied to cabotage transportation using an automatic identification system and meteorological data with a reduction in the response time for decision-making and the use of a training data set are presented in [7]. The root-mean-square error in forecasting the arrival time of container ships was 19.5 min.

Container ships, approaching their destination, reach the waters of the anchorage, where they wait for their turn when the berth becomes free. Therefore, the exact schedule and time of their mooring are so important, since ports are often overloaded. The speed of arrival at a specific time is also important. Container ships do not require special preparation of holds, operate in moderate climatic conditions, without freezing of ship structures. A feature of their use is work in the directions of transitions without straits and narrows.

In [8], a decision-making mapping structure is proposed for managing the operations of seaports and container terminals. It is noted that the objects of management are characterized by fragmentation, complexity and uncertainty of properties relative to the potential capabilities of Industry 4.0 technologies. The proposed structure is adapted with a focus on digital technologies, automation and robotics.

In [9], analytical and management tools for forecasting the arrival time of ships and distributing the resources of a container terminal are described. A dynamic learning algorithm based on neural networks is proposed that reduces uncertainty intervals by taking into account terminal operations and rational distribution of workload.

The dynamics of operational decisions in the operation of the Constanta sea container terminal for the transportation of bulk cargo and issues of optimizing container handling operations by berth and port cranes are presented in [10]. The number of movements and the order of container retrieval are minimized, the optimal sequence of operations is searched for taking into account the statistical significance between operational indicators.

Sea transport is an alternative modal logistics for transporting goods over long distances. At the same time, such uncertainty characteristics as navigation and climate conditions, types of cargo, time frames of vessel operation by the port, and mooring times make their own adjustments to the transportation schedule. In [11], an algorithm of the decision tree model for predicting the time of stay of vessels in Brazilian ports is proposed. It is shown that the geographical and cargo characteristics of the transportation process can be used in the model for developing logistics planning of the waterway. In [12], critical success factors of the global shipping area are described. Interactions and digital displays express innovative potential, risk management capabilities, strategic and technological capabilities. Organizational and managerial ideas for setting priorities in resource allocation are considered. In [13], the creation of an automated and optimized decision support system using an integer linear programming model for order management with the definition of optimal loading configurations from peripheral warehouses to vehicles is described. The resulting system operation plan is aimed at ensuring efficiency and reducing non-value-added operations of transported goods in scenarios with a central shipping point and several peripheral warehouses. Computational tests conducted on a real example confirmed the efficiency of the proposed system.

The shipping industry at the present stage of its development is moving towards the integrated use of automation, information and intelligence. Intelligent shipping is a new form of integration of modern information, artificial intelligence and other high-tech elements. In [14], the state of affairs on the creation of an intelligent inland waterway container ship for the Beijing-Hangzhou Canal is presented. In it, the power system, propulsion device, and optimization of the engine room layout are integrated into the overall design.

By the end of 2023, the global logistics automation market reached $68.5 billion. According to Mortor Intelligence forecasts, this figure will exceed $109.7 billion in 2028. Logistics automation involves the use of equipment, control systems and software.

Big data analytics

Transport management under conditions of uncertainty of the external environment and risk requires a large amount of a priori input information, its processing and interpretation to obtain informed decisions. Issues of big data analytics in transport logistics are of interest from the point of view of their various practical applications.

A prototype of an intelligent decision support system for inland port logistics is presented in [15]. It is noted that port logistics is characterized by high complexity, fragmentation and uncertainty. A multi-agent simulation model of horizontal and vertical interaction between cargo agents is presented, which combines optimization dynamic modeling with elements of decision theory. The model allows us to estimate the probability of the influence of an intelligent decision support system on inland container transportation and to formulate an optimal strategy for cooperation between dynamic demand and supply of cargo agents in domestic container transportation.

A number of strategies for sustainable maritime container transportation are proposed in [16] by optimizing fuel consumption, counteractions and disruptions in the transportation sector. A mathematical model for routing and planning ship traffic, loading and unloading containers taking into account weather disasters is proposed. A methodology for selecting alternative options based on big data analysis is presented.

For example of successful development and application of information technologies in the maritime transport industry is big data analytics for optimizing traffic flows. Among them, the work [17] should be noted, which presents a scenario-based machine learning approach to port logistics planning aimed at reducing the time required to handle the cargo volume of ships. Numerous uncertainty factors are noted, including weather conditions and mechanical problems. A mixed linear program and a genetic algorithm scheme for port logistics planning are proposed, taking into account the distribution of berths and the purpose of berth cranes.

In [18], a tool for optimizing costs and fuel consumption when modeling ship speeds in various weather conditions was developed. The results of experiments carried out in real conditions were used in routing and planning ship traffic in difficult weather conditions. In the development of this methodology, in [19] the integration of mathematical models into the risk management system for maritime transport was performed.

A solution to a similar problem for assessing the safety of water transport on the rivers of China is presented in [20]. Based on the theory of fuzzy logic and analysis of data on accidents in water transport, a structure for determining the environmental pollution index was built. The advantages of the proposed index over traditional fixed values of the index determined without taking into account uncertainty and risk are shown.

The considered trends of the problem of big data analytics in the structure of directions and developments in the optimization of transport transportation include optimization of the routing of transport transportation for seafood. In [21], transportation problems are limited by the specificity of cargo associated with time restrictions on the freshness of products and throughput windows. A stochastic solution for routing vehicles is proposed taking into account the transportation conditions. It is compared with the decision tree method, dynamic programming and ant colony optimization.

In [22], big data analytics is used to assess international multimodal connections. A new type of index and methods for measuring them are proposed in the interaction of rail transport and shipping, including the cost of cargo categories and delivery time, which are associated with the uncertainty of COVID-related transportation. The development of a methodology for assessing multimodal connections is associated with cargo tracking technology, a unified price control mechanism, and expansion of the capacity of transport corridors.

The use of big data analytics in [23] was carried out to analyze the causes of disasters related to the operation and management of ports. Ways and directions for preventing disasters with the implementation of intelligent operations are proposed. In [24], the application of big data is shown in the use of a digital twin of traffic management, travel time forecasting and intelligent routing of traffic flow. The digital twin characterizes a virtual computerized representation of an intelligent transport system for simulating and integrating data. A deep learning algorithm for dynamic processing of current information and support for route selection is proposed. Computational procedures for using data in congested traffic conditions made it possible to determine the most efficient route for a vehicle, minimizing travel time under uncertainty.

The use of big data analytics finds its application in container shipping. An interesting experience of managing container exchanges in the maritime area is described in [25]. To reduce the costs of managing container shipping, shipping companies lease containers from container leasing companies. Two shipping companies can exchange empty containers with each other in different ports to eliminate transportation costs for empty containers. To minimize costs, the carrier must find the maximum number of pairs of carriers that can exchange containers. The problem of maximum matching in a large common graph is solved. A distributed algorithm for solving this problem is proposed.

Modeling of transport and logistics schemes for maritime transportation using big data analysis is performed in [26]. Modern economic conditions are characterized by a large volume of generated data, the maximum use of which is an advantage in ensuring competitiveness [27]. The disadvantages of this group of structuring the main directions of developments to improve the management of transport transportation lie in the expert presentation of the analyzed information with qualitative and probabilistic assessments, which reduces the effectiveness of the methods considered.

Using the Internet of Things

In maritime transport, the application of the Internet of Things is used to improve ship-to-shore communications for intelligent traffic management and the creation of interfaces between ships, as well as to make the right management decisions when passing through locks and areas with heavy ship traffic. The Internet of Things is used to develop systems that support navigation in complex environments under adverse weather conditions to improve safety.

Among the trends in the development of transport and transport logistics, it is worth noting the work on the use of the Internet of Things, reflected in the proceedings of the IEEE Conference on Information and Safety in Transport [28], which includes research on diagnostic methods and malfunction of a marine engine, a differential positioning system based on deep learning, and optimization of transport modes.

Maritime transport makes a significant contribution to global economic development, but at the same time is a powerful source of air pollution. In [29], one of the ways to use the Internet of Things (IoT) to track the dynamics of transport and calculate the intensity of an air pollution source is presented. Based on the Gaussian optimization model, specific emission characteristics and influencing factors identified through simulation experiments, search algorithms and optimization templates on 86 vessels, the prospects for using remote environmental monitoring are shown.

To determine the routes of multimodal transportation under uncertain conditions of the Chinese transportation network, an optimized transportation system was created in [30] to regulate the time and cost of transportation under transshipment capacity constraints. The interval number ranking theory and the transformation of uncertain parameters into deterministic values using the weighted evaluation method were used. The optimization problem with multiple objectives is transformed into a single-objective problem. For sensitivity analysis, a particle swarm optimization algorithm and a hybrid algorithm for the influence of the risk coefficient were created.

In [31], route optimization in seasonal multimodal transportation under uncertainty of transportation time and seasonal fluctuations in the cold chains of transport logistics was considered. It was found that with an increase in temperature, cooling costs increase, which leads to an increase in total costs when it is necessary to reduce transportation time. The uncertainty of transportation time affects transportation costs. A scenario optimization model has been developed that controls costs and increases transportation efficiency, the implementation of which allows for appropriate management decisions to be made.

The transition to digital technologies in shipping and port operations is described in [32]. The problems associated with the use of the Internet of Things are considered: cargo volume, vessel sizes, service innovations. The idea of creating smart ports and platforms that combine cooperation and coordination of transport agents is put forward. The Maritime Logic Connect model has been developed to implement these interactions, which is a key factor in ensuring the long-term competitiveness of ports. The prospects for the digital transformation of shipping in the direction of optimized cargo handling, improved maritime procurement and logistics processes, and increased safety of transportation are described in [33]. The use of the Internet of Things in transportation from the point of view of spare parts supply chain management is described in [34]. Supply chain and spare parts logistics operations include high complexity and uncertainty of the movement of economic assets, global points of demand and supply, strict time windows, and the need for consolidation in regional warehouses. Effective logistics chain management is a set of proposals and recommendations for the supply chain of spare parts in the maritime sector.

The use of the Internet of Things to solve the problems of managing maritime transport in complex interactions with the external environment is reflected in the work [35]. It is noted that software solutions in the direction of organizing, managing and optimizing the actions of all agents of the transport process of transportation often do not have full integration and are used as support tools, rather than as an extension of the business. A modular scalable integrated platform for managing maritime transport logistics is presented, focused on business transportation with a large hardware infrastructure and adaptability to consumer demands.

The Internet of Things combines information, sensor, control and communication technologies for representing transport services. Difficulties in modeling the environment, platforms and tools do not always correspond to an adequate display of reality. In [36], an approach is presented that supports the integrated specification of multiple aspects of intelligent transport systems, the external environment, a network of sensors and actuators. The implementation framework of the proposed approach is carried out using a model editor to create specifications compatible with the code generator. Guidelines for the application of this framework are developed.

The main provisions for using the Internet of Things in transportation should be noted.

In their organization, intelligent systems using the Internet of Things comply with

– the principle of integration and reuse of data;
– the principle of systematicity for obtaining information at all levels of management;
– the principle of variability in the transmission of large volumes of data in a short time.

The need to implement intelligent systems using the Internet of Things in the transport sector is determined by the following factors:

– a large number of information flows, in which each cargo transportation is accompanied by various data;
– the need to record information;
– the interest of the consignee in information;
– the close connection of information with the final cost of transportation.

Cybersecurity of transport logistics data protection

Transport is one of the most vulnerable industries to cyber threats and attacks on the information technology systems of transport components. In maritime transport, cyber attacks and failures in information systems can lead to disruptions in fuel management, loading systems and control over the balance systems of large vessels. In 2023, the number of cyber attacks on transport companies increased by 36% compared to the previous year. The spread of digital technologies in transport logistics has led to increased transport efficiency and expanded revenue channels, so this sector is particularly vulnerable to cyber attacks. The main cybersecurity challenges in maritime transport include the insufficient use of operational technologies, new communication channels integrated into digital systems and their protection. For many companies in the maritime transport and logistics sector, large amounts of information are collected in an online platform where they automate the management and optimize the logistics and monitoring of vessels. To counteract the threats of transport attacks, robust models and algorithms are developed that are capable of identifying and ignoring small distortions, as well as filtering input data to detect anomalies and atypical deviations.

A practical cybersecurity approach to uncertainty and sensitivity analysis in supply chain optimization is presented in [37]. Statistical analysis and computation with intensive use of data supported by a cybernetic system are implemented through the integration of data management, mathematical modeling, uncertainty analysis and scenario sensitivity. Using cybersecurity software, optimal supply chain configurations with data visualization are determined.

The use of advanced information and communication technologies in organizing a cyber-physical system as a topological structure is presented in [38]. A strategy that takes into account multidimensional uncertainties in a cyber-physical model for joint optimization of navigation planning and routing, including potential route failures in cyberspace and renewable energy fluctuations in physical space. Based on the construction of the model, a three-level problem of minimizing the impact of route line failures in cyberspace while maintaining operating costs is formulated. The proposed strategy demonstrates greater system stability compared to other strategies.

A detailed consideration of cyber-physical systems with the inclusion of such components as electrical communication networks, industrial enterprises, transport networks, ports and shipping, many networked household appliances via the Internet of things is considered in [39]. It is shown that cyberspace in maritime transport is an element of cyberspace that needs to be managed from the standpoint of considering personnel relations. A cyberspace model is proposed that takes into account the range of possible attacks and ensures the security of representation protection.

The issues of cybersecurity of information and communication technology solutions and digitalization in ports and shipping are clearly presented in [40]. New technologies of various types of digital systems, seaports and cybersecurity of such aspects of management as electronic navigation, coastal monitoring systems, intelligent shipping, radio communication technologies in the maritime sphere are described. Conceptual clarity is provided regarding the applicability of various technologies and systems.

Maritime shipping involves sailing in relative isolation from the main world. At the same time, new technologies, satellite data transmission, shore support system and other means of interaction require protection of their operations from existing risks and cybersecurity. Autonomous and unmanned vessels are especially exposed to the risk of cyberattacks. In [41], the relevance of cybersecurity for such vessels is analyzed. A picture of threats is presented, the existing regulatory framework, standards and guidelines for cybersecurity, editorial materials are considered.

The issue of the survivability of autonomous vessels during cyberattacks is devoted to the work [42]. The susceptibility, vulnerability and ability of a vessel to recover from a threat related to cybersecurity are studied. It was found that automated vessels are highly susceptible to cyberattacks, the consequences of which are associated with financial losses, damage to the vessel, and injuries. The future of maritime shipping is determined by the transition to automated vessels, which can provide significant financial and logistical advantages for shipping companies.

Cybersecurity measures in ports and maritime shipping are distributed unevenly. Distribution depends on the operation of global ports and shipping facilities. The article [43] is devoted to increasing the efficiency of threat detection and management. It is shown how the application of artificial intelligence algorithms in the field of ship operation and port security can strengthen cyber defense. Cybersecurity of the maritime industry, the integration of artificial intelligence for planning a comprehensive cybersecurity strategy are discussed. Specific options and development scenarios are considered. The issue of cybersecurity of the maritime transport industry using autonomous vessels is devoted to the work [44]. Autonomous shipping is the most promising technology that can radically change the shipping sector due to the introduction of unmanned vessels. Communication, data exchange and digital systems are of crucial importance in their functioning. Vulnerabilities for the emergence of cyber threats in them include hacking, data loss, unwanted interference. The safe operation of systems such as navigation and cargo movement management depend on protection from cyber threats. Hackers can potentially exploit the weaknesses of any of these systems.

In [45], the ways of implementing marine technologies are analyzed and cybersecurity issues are reflected. It is shown that the maritime industry is implementing stages of digital transformation, while paying increased attention to cyber protection of information and cybersecurity of solutions. The ways of implementing modern technologies using PcWorx software and wireless technologies are analyzed.

Mobile applications for planning operations

Mobile applications for planning operations based on current data from the functioning of intelligent transport systems include cellular networks and positioning devices using geographic information. In [46], an integrated algorithm for engineering optimization and support for vehicle planning in intelligent transport systems is proposed. The algorithm combines hardware and software components of intelligent transport systems and information support for the supply chain. Mobile phones, network positioning, and telephone networks regulating traffic flows are used for implementation.

In [47], mobile technical applications for safe navigation at sea are shown. An automatic system for vessel identification, planning, and control based on big data analytics is presented. An algorithm for an intelligent system and an adaptive neural network implementing the technology for finding the optimal route is developed. The results of the study represent a strategic resource for the technology for finding the required path.

Optimization of routing and safety in maritime safety applications is described in [48]. Monitoring of the vessel's performance, thrust, and rudder angle is performed using sensors installed on the vessel. The data received by the sensor is collected and sent to the Internet of Things (IoT) and then to the genetic algorithm of the classifier for determining the shortest path of data transmission to the cloud. As a result of this technology, the throughput of information increases and the optimal route is determined.

In the information space of maritime transport technologies, the spread of mobile computing and cloud servers is the driving force of revolutionary changes, in which the user uses several electronic platforms at the same time, with the help of which he can access all the necessary information. Mobile devices use their cell phones to check email, browse the Internet and can be integrated with cloud computing services. The Mobile-Cloud area extends the paradigm of integrating a mobile application into the cloud. In [49], a cloud computing architecture is proposed for integrating a mobile application with various services on mobile devices.

Sea transportation of bulk grain cargoes requires mandatory monitoring of their quality and preservation of their properties. In [50], a series of mobile applications is described: a sampler with a hardware device and sensors for measuring temperature, relative humidity, intergranular carbon dioxide in the delivery time profile. The transport logistics monitoring system contributes to the reduction of grain losses, sustainability and food security.

In [51] the use of cloud computing as a tool for promoting mobile applications in the maritime sector is considered. It is shown that using cloud technologies it is possible to quickly deploy mobile applications. The boundaries of artificial intelligence in transport in the implementation of freight transportation are presented in [52].

Mobile applications for planning operations based on current data help to maintain optimal conditions for cargo requiring temperature control. Sensors installed in containers reduce the likelihood of damage to cargo in transit. If the temperature inside begins to rise, sensors and mobile applications allow you to fix the problem in time. In addition to temperature, sensors monitor vibrations and other functional changes in maritime transport. Using Internet of Things sensors, you can monitor the condition of equipment by collecting data on vibrations, temperature and other parameters. They help to identify signs of wear and tear and perform maintenance in advance.

Blockchain

Blockchain is a distributed ledger technology that allows transactions to be recorded in a ledger in several places at the same time without involving a central authority or intermediaries. The advantages of blockchain are the elimination of the need for standardization of electronic data exchange and the need for a common format for this data when structuring messages.

In the context of accelerating digitalization, one of the promising areas for solving management problems is the adaptation of blockchain technologies to maritime transport. These tools ensure transaction transparency, clarity of the cargo delivery process and reduce risks associated with the human factor.

Blockchain, due to such characteristics as immutability, tracking, management and provenance, allows for the creation of system solutions for recording key performance indicators and distributing incentives. In [53], current exercises of a blockchain-based incentive system for maritime transport operations for the delivery of goods in accordance with the port resource schedule are proposed. A prototype of the Solana blockchain-based system has been implemented.

Using blockchain technologies, it is possible to block unauthorized access to data for recording information about vessels, global risks and their impact on transportation. There are several initiatives to apply blockchain technology in the field of container shipping, documentation and customs clearance.

Playing a key role in the global transportation system, they face numerous problems related to port congestion, delivery delays, complex documentation, difficulties in tracking containers. Blockchain provides decentralization, transparency and controllability of transactions and the ability to track cargo. In [54], a distributed governance model of blockchain is proposed, facilitating the shared responsibility of tracking and monitoring hazardous materials in real time from the point of departure to the destination.

An interesting use of blockchain as a resource for combating corruption in the global shipping industry is [55]. The use of blockchain digital technologies for full disclosure of transactions, reducing uncertainty, insecurity and ambiguity is described. A model for identifying interactions of institutional entities with technical resources of the industry and the conditions for their implementation is proposed.

In [56], the use of blockchain for coordinating information along supply chains is analyzed. It is shown that blockchain technology can form a new decentralized dynamic ledger management structure for container shipping supply chain and interactions between dispersed parties.

It is worth noting the following general provisions about blockchain technology. Blockchain is a technology of decentralized storage and distribution of transaction records based on cryptographic methods of information protection, allowing to exclude intermediaries. It is used to create cybersecurity technologies, representing a common digital notebook. Blockchain is a method of secure storage and transmission of data in the form of a chain of blocks, each of which contains information about the previous one. Blockchain technology is an advanced database mechanism that allows to organize open exchange of information within a business network. The blockchain platform, maximally protected from hacker attacks and interference of government services, is completely open to users. Blockchain in logistics is used to track the movement of goods. Each stage of the supply chain is recorded in the system, and participants in the process see information about the status and location of the cargo.

Using cloud platforms

Cloud platforms are a set of tools designed to run and use applications remotely. Today, no other industry working with transport demonstrates such a level of dependence on digitalization and analytics. In its practical activities, it provides access to computing resources from any device connected to the Internet. Cloud services have emerged due to the development of Internet speeds, the growth of computing power and the leap in the capabilities of network equipment. Cloud computing integrates automation in the logistics and supply chain process. It helps to increase transparency, scalability, flexibility and cost savings.

Prioritization of traffic is necessary when ships resort to expensive satellite communications, which entail high latency and have a narrow bandwidth. Near the coastline, ships can switch to 5G-based communications

and use the capabilities of cloud computing. There are three main categories of cloud computing models - infrastructure as a service, platform as a service, software as a service. In [57], a cloud network testbed is proposed that supports network schedule generation to simulate satellite and 5G communications between an edge cloud located on board a vessel and another edge cloud located on board another vessel or on shore. Potential applications include emulating peer-to-peer communications and mesh networks.

Conventional maritime information technologies such as the Internet of Things and artificial intelligence place computing nodes far from data collection points. This situation is limited by the real-time requirements for message processing. Cloud computing decentralizes computation, storage, and network resources to ensure efficient data processing. In [58], cloud computing architecture, emerging applications, examples, and future possibilities for maritime data management are discussed, providing references for optimization of control and navigation. Similar works devoted to mobile cloud computing are [59, 60]. Mobile cloud computing has a number of disadvantages such as low bandwidth, mobile status monitoring, limited storage capacity for mobile learning [61].

The transition to cloud computing provides a huge advantage from reducing IT costs. In addition, businesses receive bonuses: instant updates of the necessary software, disaster recovery capabilities, and expanded functionality for collaboration.

Cloud solutions also play a key role in ensuring data security. In logistics, where information about cargo, its condition, and location must be protected, they help prevent leaks when exchanging messages between mobile IoT devices and corporate servers.

Artificial intelligence

The use of artificial intelligence opens up broad prospects for its application in maritime transport. One of the promising areas of this topic is the creation of autonomous vessels capable of independently analyzing the navigation situation and making decisions without the participation of the crew. A number of countries such as Norway, Denmark, and Finland are already actively testing prototypes of future unmanned vessels. According to experts, mass production of such vessels will begin in the next decade.

Artificial intelligence technologies make it possible to analyze data from various sources and meteorological conditions in real time, predict the development of the navigation situation and recommend a course without grounding and collisions, optimally place cargo in the terminal, and reduce downtime.

Artificial intelligence technology has changed the logistics paradigm, creating the core of Industry 4.0 for making fast and accurate decisions in uncertain situations when processing large volumes of data. Since logistics is based on multilingual data flows, logistics systems controlled by artificial intelligence lead to new ideas and increased efficiency. In the work [62], a global supply chain and logistics management using neural machine translation of transport logistics operations is developed.

The integration of artificial intelligence in promoting sustainable development of maritime transport, shipping and port operations is considered in the work [63]. By solving the emission problem, optimizing the use of transport efficiency, artificial intelligence offers transformative potential in fuel optimization, route planning, intelligent energy management and logistics. Practical examples for the port of Rotterdam illustrate the success of the implementation.

Artificial intelligence is revolutionizing and shaping the working environment, not only representing an innovative task, but also the operating conditions creating unique opportunities in various areas of maritime transport logistics. In [64], an artificial intelligence approach to the implementation of business processes of the information flow of orders for shipment to the warehouse is considered. An algorithm for recognizing the text of consignment notes is developed to reduce the workload on personnel. Technical improvements and structural changes are made. The use of artificial intelligence to improve the efficiency of maritime transport logistics in warehousing is reflected in the work [65].

In maritime transport, such a development as intelligent navigation of ships has appeared. In the work [66], it is shown that the use of intelligent navigation reduces the possibility of human error, reduces carbon emissions, and improves logistics. Deep learning and multi-scale target detection algorithms are considered.

Of particular scientific interest is the carbon accounting system for real-time marine fleet decorbonation developed in [67], which uses machine learning models to track carbon emissions at 15-minute intervals. The structure of the system includes such factors as vessel navigation characteristics, weather, and sea conditions. By integrating it with a cloud computing platform, shipping companies can improve their voyage planning and route adjustments to optimize operational efficiency.

The use of sensors to monitor equipment parameters and ship tracking, the implementation of an electronic cartographic and information system on board ships to improve navigation safety, provides digitalization of fleet transformations. [68] notes that these transport efficiency improvement tools are fundamental to improving transport productivity.

While AI has shown significant advances in fuel efficiency, emission reduction, environmental monitoring, planning and optimization of operations, it has a number of challenges such as high implementation costs, data privacy issues and response difficulties. Continued development of AI technologies can contribute to significant progress towards sustainability and efficiency in maritime shipping.

CONCLUSIONS

Key trends and modern research technologies are specified based on the completed review of trends in the development of maritime transport logistics. Given the importance of the maritime sector in the global economy, companies trying to remain competitive must actively implement advanced technologies. The areas of interest in the prospective development of transport transportation show increased attention to research on automation, computer engineering, general knowledge in information technology, artificial intelligence, cloud computing, cybersecurity, and integrating technologies. Progress in information technology allows for solving completely new engineering problems.

The presented structuring made it possible to identify the main areas of use of information technology in maritime transport logistics, most often encountered in applications and practical applications, and to determine the main paths along which the development of the transport industry is taking place. It is shown that the development of logistics of transport transportation is characterized by the fact that simultaneously with its concept, there is a process of developing methodological foundations for new technologies for managing information support, processing and protection of information.

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***П. Мовчан, О. Шарко*. Структурування основних напрямів досліджень, моделей та методів управління морським транспортом**

Цей огляд має на меті виконати інтелектуальний аналіз різноманітних джерел, складених на основі сучасних наукових публікацій, галузевих і міжнародних конференцій, ринкової аналітики та тенденцій розвитку. Відзначено складність та фрагментарність тематики дослідження, пов'язану з невизначеністю впливу зовнішнього середовища на функціонування об'єктів транспортної інфраструктури та глобальними змінами структури відносин. Показано, що розвиток транспортної логістики характеризується тим, що одночасно з її концепцією відбувається процес розробки методологічних засад нових технологій управління інформаційним забезпеченням, обробкою та захистом інформації. Розглянуто сучасні технології створення інтелектуальних систем управління та вказано можливі напрями вдосконалення. Отримана інформація структурована в основу, на якій закладаються тренди розвитку логістики на морському транспорті: інтелектуальна автоматизація, робототехніка, аналітика великих даних, Інтернет речей, кібербезпека, хмарні платформи, блокчейн та штучний інтелект. З позицій морської транспортної логістики проаналізовано переваги, недоліки та напрямки раціонального використання запропонованої структуризації. Це дало змогу визначити перспективні напрямки наукових досліджень та створити основу для побудови концептуальних транспортних моделей у складних умовах експлуатації.

Ключові слова: морська транспортна логістика, тенденції розвитку, невизначеність, інтелектуалізація, менеджмент, структурування.

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