OPTIMIZATION OF MARITIME FREIGHT TRANSPORTATION USING ARTIFICIAL INTELLIGENCE: ECONOMIC GROWTH PROSPECTS FOR PORT OPERATORS

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Abstract
This article examines the characteristics of the maritime freight transportation market and the existing challenges. It analyzes the impact of artificial intelligence (AI) on the optimization processes of maritime freight transportation. Special attention is given to real examples of successful AI implementation in maritime logistics in the United States. The prospects for economic growth for port operators are explored.

Keywords: artificial intelligence, optimization of freight transportation, logistics, process automation, demand forecasting, economic growth, competitiveness, sustainable development.

Introduction

In the context of increasing globalization and rising volumes of international trade, the need for an efficient and reliable logistics system has become particularly urgent. Maritime freight transportation is the primary means of moving goods over long distances, connecting markets and facilitating the development of global trade. However, despite significant advancements in this area, the industry faces a number of serious challenges, such as delays, high operational costs, and insufficient process transparency. As the volume of data related to maritime transport continues to grow, traditional management methods become ineffective. Port operators must adapt to rapidly changing market conditions and technological advancements.

One of the most promising directions in addressing these challenges is the use of artificial intelligence (AI) technologies. It has already proven its effectiveness in various industries, and its potential in the logistics sector is of increasing interest. The use of AI offers solutions for analyzing and interpreting huge amounts of data, allowing operators to make more informed decisions and respond to challenges in real time. Despite the advantages, the implementation of AI in maritime freight transportation is not without risks and challenges. The aim of this article is to explore the impact of AI on the optimization of maritime freight transportation and to analyze the prospects for economic growth for port operators.

Main part. Challenges of maritime freight transportation

As the backbone of global trade, maritime freight transportation ensures the movement of goods around the world across oceans and seas. This mode of transportation is one of the most cost-effective, especially for large shipments. According to the UN, approximately 80% of global trade is transported by sea. From 1983 to 2022, container trade volumes increased annually by 7%. The share of container shipping in the dry cargo trade reached 23%, while it accounted for 16% of all cargo (fig. 1).

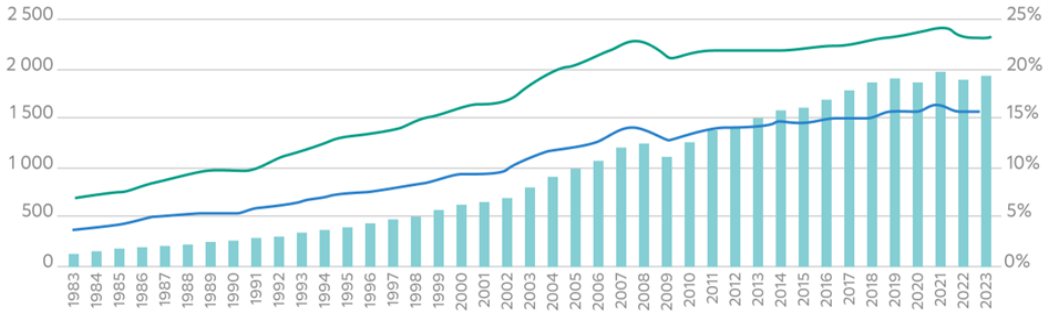

Figure 1. Global maritime container transport volumes, million tons [1]

Maritime freight transportation is characterized by high flexibility in route selection and scalability, allowing goods to be transported over long distances at minimal costs. Ports play a crucial role in this process, acting as important transshipment and distribution points for goods. Despite their advantages, maritime freight transportation faces a number of challenges.

One limitation is the traditional management methods for cargo flow in seaports, which rely on a combination of manual labor and standard operating procedures. The limitations of these methods manifest in insufficient flexibility and an inability to quickly adapt to changes in demand and external conditions. Another significant issue with traditional methods is the difficulty in accurately forecasting demand for port services. The forecasting methods used are based on historical data and standard trends, which do not account for possible sudden changes in global supply chains, seasonality, or the impact of economic and political factors. As a result, forecasts are often inaccurate, leading to either surplus or shortage of resources.

The human factor remains one of the main causes of inefficiency in cargo flow management. Errors in data processing, discrepancies in documentation, incorrect calculations, and delays in decision-making lead to significant financial losses. Furthermore, traditional methods poorly adapt to unexpected changes, such as equipment failures, changing weather conditions, or sudden fluctuations in demand [2].

All these factors combined create substantial costs for port operators, which include not only direct financial losses but also decreased competitiveness due to inefficient resource use and the inability to provide reliable and timely services. In the context of increasing trade volumes, such issues become increasingly critical, prompting the search for new solutions capable of enhancing cargo flow management efficiency and minimizing the impact of the human factor.

The potential of AI in optimizing maritime freight transportation

The field of computer science, such as AI, is focused on creating systems capable of performing tasks that require human intelligence [3]. It is a powerful tool that can significantly improve the efficiency of maritime freight transportation. Its application covers various aspects of logistics management, including demand forecasting, route optimization, and automation of port operations. The ability of AI to process huge amounts of data allows you to make more accurate and timely decisions, reduce costs and increase the reliability of supply chains [4]. It holds great potential for optimizing maritime freight transportation by offering solutions that can significantly boost efficiency and lower costs (table 1).

Table 1. Application of AI in optimizing maritime freight transportation [5, 6]

Areas of application	Description	Examples
Demand forecasting	Analyzing data on trade, economics, and weather to forecast changes in demand for freight transportation.	The ability to predict an increase in demand for the transportation of certain goods, allowing operators to prepare in advance for higher workloads.
Route optimization	Utilizing machine learning algorithms for dynamic route optimization of vessels, taking into account weather conditions, port congestion, and other factors.	The capability to suggest the most efficient routes, reducing fuel costs, minimizing delays, and lowering the carbon footprint.
Port operations management	Automating processes in ports using AI to optimize logistics, traffic management, and resource allocation.	In the port of Los Angeles, AI helps to minimize truck traffic congestion.
Data analysis and reporting	Collecting and processing data to create reports and analytics, helping operators make more informed decisions.	Real-time data analysis, providing detailed performance reports and forecasts to enhance efficiency.
Vessel monitoring and support	Predicting the technical condition of vessels and planning preventive maintenance based on data.	Predicting the need for vessel repairs, which reduces the likelihood of accidents and increases operational reliability.
Supply chain optimization	Improving coordination among various participants in supply chains, including suppliers, carriers, and customers, through the use of AI.	Optimizing logistics processes, lowering costs, and improving delivery speed.

The application of AI in optimizing maritime freight transportation opens up new opportunities for enhancing efficiency and reducing costs in this vital industry. Utilizing AI for demand forecasting allows for more accurate resource planning, preventing both underloading and overloading. Route optimization through AI reduces fuel costs and delays, while simultaneously lowering the carbon footprint. In ports, AI automates logistics and resource management, reducing vessel idle time and increasing overall productivity. Monitoring vessel conditions and managing supply chains with AI enhances reliability and mitigates risks associated with technical failures and delivery delays. These AI applications not only improve operational efficiency and resilience but also contribute to better environmental performance, making AI an essential tool for achieving sustainable development in maritime logistics [7]. The use of AI opens new avenues for optimizing all aspects of maritime freight transportation, strengthening its role in the global economy.

A successful example of AI implementation is the **Port of Los Angeles**, where an automated container terminal has been launched, with all container handling operations performed by robotic stacker trucks without human intervention. The terminal's productivity has increased by 30% in 2023 [8].

Another example is the experience of the shipping and logistics company **Crowley Maritime**, which has implemented AI to optimize its container transportation and management operations. They used AI to analyze data on cargo flows and optimize warehouse operations, resulting in reduced costs and improved demand forecasting accuracy [9]. These examples illustrate that the integration of AI into maritime logistics contributes not only to increased operational efficiency but also to economic benefits, providing significant competitive advantages and promoting more sustainable industry development.

Prospects for economic growth for port operators

The growth of international trade is positioning port operators as critical links in the logistics chain. Their efficiency and ability to adapt to new challenges not only determine their own success but also influence the overall dynamics of the industry. With the implementation of modern technologies such as AI and process automation, new horizons for economic growth are opening up for port operators.

Increasing competitiveness is one of the main factors of economic growth of port operators [10]. The introduction of automated management systems helps reduce cargo processing times and minimize the likelihood of errors. Utilizing technologies such as remote-

controlled port crane systems and automated warehouse solutions significantly accelerates loading and unloading processes, thereby enhancing the overall efficiency of port operations [11]. The application of AI-based algorithms and analytical tools for route planning and resource management helps to minimize transportation costs and improve coordination among all participants in the supply chain. This, in turn, increases the reliability and predictability of goods delivery. Leveraging predictive analytics to forecast cargo loads and develop effective work schedules allows for significant reductions in vessel idle time. Establishing strategic alliances with other supply chain participants, such as carriers, logistics companies, and manufacturers, helps improve coordination and information sharing. This can lead to more efficient solutions and an overall increase in productivity.

The implementation of AI significantly impacts the **profitability of port operators** by enhancing efficiency, reducing costs, and improving service quality. The use of AI allows you to automate routine tasks such as container flow management, cargo movement coordination and equipment monitoring. This reduces operation times, minimizes errors, and decreases the need for human labor.

The use of AI optimizes the use of resources such as equipment, fuel and labor. Through data analysis, AI can predict when and where additional resources will be needed, helping to avoid unnecessary costs associated with equipment maintenance or labor expenses. It also improves the quality of service by attracting new customers and retaining existing ones. By analyzing customer data and preferences, operators can offer more personalized and competitive services. Quick processing of requests, transparent cargo tracking, and accurate delivery time predictions increase customer satisfaction, fostering loyalty and repeat orders. In summary, AI enables port operators not only to enhance operational efficiency and reduce costs but also to improve service quality and develop new products and services, leading to significant increases in profitability.

The implementation of AI across various sectors, including port operations, opens **substantial potential for job creation in information technology** and data analysis. This trend drives demand for specialists who can develop, support, and analyze AI systems.

The analyzed prospects demonstrate that the strategic implementation of AI can become an important factor in the modernization of port infrastructure, improving customer service and optimizing costs. In the long term, this could lead to significant economic growth for port operators, fostering their more sustainable development and strengthening their positions in the global market.

Conclusions

The importance of AI for the future of maritime freight transportation cannot be overstated. It provides numerous opportunities for process optimization, efficiency enhancement, and cost reduction. From automating terminal operations to forecasting demand and improving customer service, AI is transforming traditional approaches to supply chain management.

The application of AI contributes to increased safety and resilience in maritime transportation. Monitoring systems and predictive analytics allow for the early identification of potential risks and the prevention of incidents, which is crucial in an unstable global economy. The implementation of AI also opens new horizons for innovation in related sectors such as logistics, information technology, and sustainable development. This creates a synergistic effect, promoting economic growth and regional development.

Optimizing freight transportation through AI opens new opportunities for economic growth among port operators, providing them with a competitive edge on the international stage. In the face of increasing demand and pressure for efficiency in port operations, AI has become an indispensable tool for achieving strategic goals.

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