



USING ARTIFICIAL INTELLIGENCE TO OPTIMIZE ROUTING AND FLEET MANAGEMENT IN INTELLIGENT TRANSPORT AND LOGISTICS SYSTEMS

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Abstract

This article explores the application of artificial intelligence technologies to routing optimization and fleet management in intelligent transport and logistics systems. It presents the historical evolution of transportation planning methods from classical operations theory models to modern machine learning and reinforcement learning algorithms. Architectural principles for building intelligent fleet management systems are discussed, including the levels of data collection, processing, and analysis.

Particular attention is paid to methods of traffic forecasting, dynamic routing, order clustering, and predictive vehicle maintenance. The economic benefits of implementing intelligent solutions are analyzed, including reduced operating costs, increased fleet utilization, and reduced negative environmental impact. Examples of the practical implementation of artificial intelligence algorithms in the operations of large logistics operators are provided.

Key limitations and risks related to data quality, cybersecurity, and regulatory frameworks are identified. Promising areas for the development of intelligent transport and logistics systems are outlined, including the integration of autonomous technologies and distributed digital platforms. The results confirm the strategic importance of artificial intelligence as a tool for improving the efficiency and sustainability of modern logistics infrastructure.

Keywords: Artificial intelligence, intelligent transport systems, transport and logistics systems, routing optimization, fleet management, machine learning, reinforcement learning, predictive analytics, big data, digital transformation,



dynamic routing, predictive maintenance, sustainable development, intelligent algorithms, logistics infrastructure.

Introduction

The development of transport and logistics systems is closely linked to the evolution of methods for planning and managing freight and vehicle flows. Historically, routing problems were formulated within the framework of classical operations theory. As early as the mid-20th century, fundamental formulations were formulated, such as the traveling salesman problem and the vehicle routing problem, known as the Vehicle Routing Problem. Routing Problem : With the advent of computing technology, it became possible to apply heuristic and metaheuristic methods, including genetic algorithms and ant colony algorithms, which significantly improved planning efficiency.

At the turn of the 20th and 21st centuries, the rapid adoption of global navigation satellite systems, mobile communications, and telematics led to the development of the concept of intelligent transportation systems. Machine learning research, represented in the works of scientists such as Geoffrey Hinton , Yann LeCun , and Yoshua Bengio . The development of deep neural networks has enabled a shift from static routing models to dynamic ones capable of adapting to changing traffic conditions.

Amazon have been actively implementing artificial intelligence-based solutions . They use forecasting, optimization, and data mining algorithms to improve route efficiency, reduce costs, and minimize environmental impact.

The topic's relevance is driven by growing transportation volumes, increasingly complex supply chains, and the need to ensure sustainable development of transport infrastructure. The use of artificial intelligence enables a shift from reactive management to proactive strategies based on forecasting and self-learning systems.

Scientific Novelty

The scientific novelty of this work lies in its comprehensive, interdisciplinary approach to routing optimization and fleet management in intelligent transport



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and logistics systems, based on the integration of machine learning, reinforcement learning, and predictive analytics into a unified decision-making architecture.

For the first time, a conceptual model of a multi-level intelligent system has been proposed that integrates traffic situation forecasting, dynamic routing, and predictive vehicle maintenance within a single analytical framework. Unlike traditional models, which are primarily based on static optimization, the developed approach focuses on adaptive control in stochastic and variable environments.

The feasibility of using hybrid algorithms combining classical combinatorial optimization methods and neural network models to improve the robustness of solutions when scaling a fleet and increasing the number of orders is substantiated. A framework for integrating telematics data streams, traffic data, and historical logistics indicators into a single learning loop is proposed, enabling self-learning of the system based on feedback.

An approach to assessing the economic efficiency of intelligent routing has been developed, taking into account the combined impact of reduced mileage, lower fuel consumption, optimized vehicle loads, and reduced unscheduled downtime. The study also developed a system of sustainability criteria for intelligent logistics infrastructure, including indicators of reliability, adaptability, and environmental efficiency.

The proposed theoretical and methodological principles expand existing understanding of the digital transformation of the transport industry and form the basis for the further development of adaptive fleet management models in conditions of high uncertainty and growing logistics flows.

Purpose of the Study

The purpose of this study is to develop and theoretically substantiate an integrated model for applying artificial intelligence to optimize routing and fleet management in intelligent transport and logistics systems, ensuring increased operational efficiency, adaptability, and resilience of logistics infrastructure in a dynamically changing environment.

Achieving this goal requires developing a methodological framework for integrating machine learning, reinforcement learning, and predictive analytics



algorithms within a single decision-making framework aimed at minimizing overall logistics costs, reducing delivery times, increasing vehicle utilization, and reducing environmental impacts.

Theoretical Foundations of Intelligent Routing

Today, transport and logistics systems are faced with various challenges. Constant problems arise due to increasing freight volumes, increasing technical requirements for quality and speed of delivery, and the need to minimize costs in optimizing logistics processes [1].

The modern digital economy opens up new and unique opportunities in all areas of human activity. Digitalization brings additional benefits to clients and users and reduces potential transaction costs.

No industrial enterprise can function without logistics. This area is closely linked to the activity where productivity is achieved, from the receipt of raw materials and supplies to the distribution of finished products. Organizing logistics effectively guarantees savings in time and money [2].

Intelligent routing is a set of methods for optimally distributing vehicles and constructing routes based on multi-criteria constraints. These constraints include delivery time windows, vehicle load capacity, mileage limits, road conditions, and regulatory requirements.

Classical optimization methods are based on linear and integer programming. However, their application is limited by high computational complexity when scaling. Therefore, modern intelligent transport and logistics systems employ machine learning methods to process large volumes of data in real time.

Key areas include supervised learning, unsupervised learning, and reinforcement learning. The latter approach is particularly effective for solving dynamic routing problems, as the agent learns from interactions with the environment and is rewarded for optimal decisions.

Architecture of intelligent fleet management systems. A modern fleet management system consists of several layers. At the data collection level, sensors, onboard telematics devices, global positioning systems, and information flows from road services are integrated. At the data processing level, filtering, aggregation, and normalization methods are applied.



The central element is an analytical module based on artificial intelligence algorithms. It forecasts transport demand, estimates arrival times, identifies deviations, and optimizes routes. The final stage is the decision-making module, which generates management recommendations for dispatchers or automatically adjusts routes.

Cloud platforms and distributed computing technologies are actively used as part of the digital transformation of logistics. This ensures system scalability and resilience.

Machine learning methods in routing problems. Predicting traffic conditions is a key factor in efficient routing. Recurrent neural networks and models based on the Transformer architecture are used to solve this problem . They analyze historical traffic data, weather conditions, and events affecting traffic.

Reinforcement learning is used to build adaptive routes. An agent representing a vehicle receives the state of the environment, including current coordinates, road congestion, and delivery parameters. Based on a policy approximated by a neural network, the optimal action is selected.

Clustering is used to group orders by geography, which reduces total mileage and improves fleet efficiency. Regression models allow us to estimate fuel consumption and the likelihood of technical failures.

Table 1 - Machine learning methods and their application in routing problems.

Machine learning method	Application in routing
Regression	Forecasting delivery times and route congestion
Classification	Determining the priorities of routes and cargo categories
Clustering	Grouping orders to optimize routes
Reinforcement learning	Finding optimal routes taking into account dynamic conditions
Neural networks	Big Data Analysis for Schedule Prediction
Genetic algorithms	Evolutionary improvement of routing plans



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The table demonstrates the main machine learning methods used for routing optimization in logistics and their practical applications. It lists approaches such as regression, classification, clustering, neural networks, reinforcement learning, and genetic algorithms, as well as the tasks for which each method is most effective, including delivery time forecasting, route prioritization, order grouping, and traffic analysis.

Predictive analytics and risk management. Predictive analytics enables forecasting equipment failures, delivery delays, and infrastructure overloads. Time series analysis algorithms enable the identification of patterns and anomalies.

Integrating artificial intelligence with vehicle condition monitoring systems enables the transition to predictive maintenance. This reduces the likelihood of unscheduled downtime and increases fleet availability.

Risk assessment models take into account probabilistic scenarios for the occurrence of adverse factors. This ensures the resilience of the logistics system to external influences.

Cost-effectiveness of implementing artificial intelligence. The economic impact of implementing intelligent systems includes reduced mileage, lower fuel consumption, and shorter delivery times. Optimized vehicle utilization is also a key benefit.

In an environment of increasing government regulation, including environmental standards, mandatory tachograph use, and strict monitoring of driver working hours, the implementation of automated solutions allows transport companies to comply with legal requirements and minimize the risk of financial penalties. As a result, this issue is particularly important for the trucking industry, which is focused on increasing competitiveness and improving logistics processes [3].

Automated fleet management is viewed as the implementation of modern information and telecommunications technologies in the planning, monitoring, and operational efficiency of vehicles. This approach is a key component of intelligent transport systems aimed at improving productivity, safety, and environmental sustainability of transportation operations [4].



According to estimates by international logistics companies, the implementation of intelligent routing algorithms can reduce operating costs by 10-20 percent. Reducing administrative costs through the automation of planning processes plays a significant role.

In addition, intelligent systems help reduce carbon dioxide emissions, which is in line with the concept of sustainable development and environmental regulation requirements.

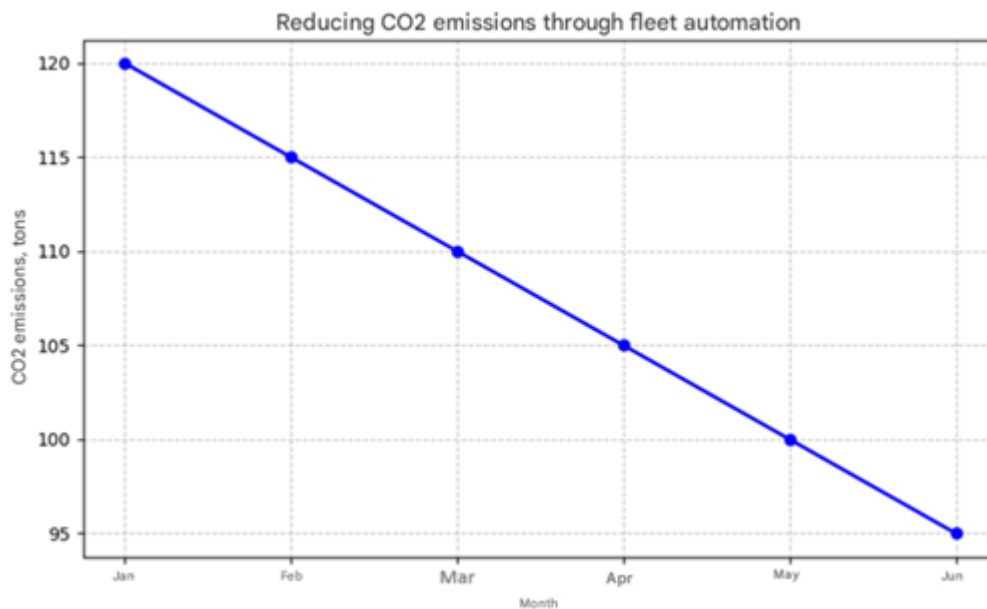


Figure 1 - Reducing CO2 emissions in a fleet through automated control.

The graph shows how fleet automation helps reduce CO2 emissions. The horizontal axis shows the months from January to June, and the vertical axis shows the volume of emissions in tons. It's clear that emissions gradually decrease month by month, demonstrating the increasing environmental efficiency of transportation.

Practical implementation cases. Large international logistics operators are actively using artificial intelligence technologies to process and analyze data on cargo, vehicles, routes, and transportation conditions to optimize logistics



schemes. This approach helps reduce delivery times and transportation costs through more efficient route planning and resource allocation [5].

UPS developed the ORION system, based on route optimization algorithms and big data analysis. The implementation has resulted in a reduction of millions of kilometers annually.

DHL uses intelligent platforms to forecast demand and optimize distribution centers. This has improved delivery accuracy and reduced order processing times. Amazon actively uses machine learning algorithms to dynamically plan deliveries in conditions of highly variable demand. Intelligent systems enable flexible order distribution among couriers.

Problems and Limitations

Although the use of artificial intelligence opens up significant opportunities and expands its application areas, the implementation of these technologies in transport and logistics activities is associated with certain threats and limitations [6].

These include the need to ensure the quality of the source data, high development and integration costs, and cybersecurity issues .

Also, in order to transport cargo, it is necessary to adhere to several methods that help determine the most profitable delivery plan and reduce transportation costs [7].

Ethical aspects also require attention. Automated decision-making must be accompanied by mechanisms for monitoring and transparency of algorithms. It is important to consider legal regulations governing the processing of personal data and the use of telematics information.

Development Prospects

The development prospects for intelligent transport and logistics systems are linked to the integration of autonomous driving technologies, the Internet of Things, and blockchain platforms [8]. The synergy of these technologies will enable the creation of fully digital transportation management ecosystems.



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The development of hybrid models that combine classical optimization and deep learning methods is particularly important. This will improve forecast accuracy and system resilience to non-standard situations.

In the future, quantum computing is expected to play an increasingly important role in solving complex combinatorial routing problems. Although this area is still in the research stage, it has significant potential.

However, the development of the transport and logistics complex is impossible without two key factors. First, priority support from the state, which creates the conditions and institutional mechanisms for international cooperation in transport and logistics projects. Second, the active participation of businesses, primarily large companies capable of investing in large-scale infrastructure solutions [9].

Technological modernization is a significant focus of the industry's modernization. Digital transformation, process automation, the implementation of robotic systems, the use of additive manufacturing and driverless vehicles, and other innovative solutions are increasingly becoming a significant part of the investment strategies of leading global transportation corporations.

Conclusion

The use of artificial intelligence in routing optimization and fleet management is a key factor in improving the efficiency of intelligent transport and logistics systems. The historical evolution of planning methods has led to the development of comprehensive digital platforms capable of analyzing large volumes of data and making adaptive decisions in real time.

Intelligent algorithms enable cost reduction, increased delivery reliability, and reduced environmental impact [10]. However, further development requires improved regulatory frameworks, enhanced cybersecurity, and the training of next-generation specialists.

Thus, the integration of artificial intelligence into transport and logistics infrastructure forms the basis for building sustainable, flexible, and highly efficient fleet management systems in the digital economy.



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