

Architecture and applications of artificial intelligence systems in logistics

Phd Gunel Siyavush Novruzova

Ganja Branch of the Azerbaijan National Academy of Sciences (ANAS), Heydər Əliyev
prospekti 419, Azerbaijan, Ganja

gunel.novruzova91@mail.ru

Abstract. In the context of the digital transformation of the economy, the use of artificial intelligence technologies is becoming a key factor in improving the efficiency of logistics systems. Modern logistics processes are characterized by large volumes of data, high dynamism, and complex decision-making, making the use of intelligent information systems particularly relevant.

This article examines the architectural principles of building artificial intelligence systems used in logistics. The key components of such systems include data collection and storage modules, information processing and analysis systems, machine learning algorithms, and intelligent decision support mechanisms. The use of modern information technologies, including big data, cloud computing, and predictive analytics methods, enables the creation of effective solutions for managing logistics processes.

Particular attention is paid to the practical applications of artificial intelligence in logistics. These include optimization of transport routes, intelligent inventory management, demand forecasting, automation of warehouse operations, and supply chain management. The use of artificial intelligence algorithms helps improve forecasting accuracy, reduce operating costs, and enhance customer service.

The article also examines the key challenges of implementing intelligent systems in logistics infrastructure. These include the high cost of implementing these technologies, the need for integration with existing information systems, ensuring data security, and training qualified specialists in artificial intelligence and information technology.

Thus, the implementation of architectural solutions based on artificial intelligence systems opens up new opportunities for improving the efficiency and sustainability of logistics processes and plays a vital role in the development of modern transport and logistics systems.

Keywords: Artificial intelligence, logistics, intelligent systems architecture
Supply Chains, Forecasting and Optimization, Prescriptive Analytics, Process

Automation, Supply Chain Resilience, Inventory Management, Azerbaijan Logistics.

1 Artificial intelligence in modern logistics

1.1 Application of Artificial Intelligence in Supply Chain Management

Digital technologies, artificial intelligence (AI), and the Internet of Things (IoT) play a significant role in improving supply chain efficiency in manufacturing. These technologies significantly improve planning, forecasting, and resource management. The use of AI systems enables more accurate demand forecasting, optimized logistics operations, and reduced business risks [10], [11].

In recent years, AI-based technologies have been increasingly integrated into various fields, including search engines, medicine, manufacturing, and transportation. Logistics is also a key area where the use of intelligent technologies can significantly improve the efficiency of supply chain management processes [1],[11].

However, experience shows that many professionals and companies attempt to implement AI-based solutions without sufficient experience and the necessary competencies. As a result of unsuccessful experiments, they often become disillusioned with the new technologies and return to traditional management methods, using spreadsheets or even manual records [12].

Modern logistics also faces a number of significant challenges. The COVID-19 pandemic, political and economic conflicts, have disrupted traditional transport routes and global supply chains [3]. These circumstances necessitate the search for new approaches to managing logistics processes and optimizing delivery routes.

In the context of the Fourth Industrial Revolution, the implementation of modern digital logistics management systems is becoming a key challenge. Supply chains are a key factor in determining product costs, and inefficient logistics directly impacts

rising prices for consumer goods and, consequently, the economic well-being of the population [9].

This article examines the application of artificial intelligence technologies in logistics and analyzes the main challenges companies face when implementing intelligent systems. Particular attention is paid to the integration of AI-based software into logistics processes and the search for effective solutions to improve supply chain management efficiency.

Using the example of Azerbaijani logistics companies, the process of implementing AI-based software solutions in logistics operations is examined. Specifically, the experience of Azerbaijan Railways (ADY) and Azerbaijan Caspian Shipping Company (ASCO), which are actively implementing digital technologies and elements of intelligent systems to optimize transport and logistics processes, is analyzed [7], [8].

As part of their digital transformation programs, these companies are implementing modern information technologies, including big data analytics systems, machine learning elements, and digital logistics management platforms. The main goal of implementing these solutions is to increase the efficiency of transportation operations, optimize shipping routes, and improve supply chain management [16].

The implementation of intelligent systems has become especially relevant during the COVID-19 pandemic, when many traditional logistics routes have been disrupted. Under these circumstances, the use of digital platforms and analytical systems has enabled more efficient management of logistics flows and prompt decision-making based on real-time data analysis [12].

However, Azerbaijani companies also face a number of challenges specific to the implementation of artificial intelligence systems. Key issues include data security and privacy, the need to improve the quality and structure of information resources, and the need to train specialists with competencies in artificial intelligence and data analysis [14].

Despite these challenges, the implementation of digital technologies and intelligent systems significantly improves the efficiency of logistics processes. The use of automated management systems optimizes resource allocation, reduces operating costs, and increases the speed of processing logistics information [11],[12].

Furthermore, the use of modern information technologies improves customer service, increases the transparency of logistics operations, and strengthens the resilience of the transport and logistics infrastructure. As a result, the introduction of artificial intelligence elements is becoming an important factor in the development of Azerbaijan's logistics industry in the context of the digital economy [15].

The implementation of AI-based solutions in Azerbaijani logistics companies has already demonstrated tangible benefits. For instance, Azerbaijan Railways (ADY) has introduced predictive maintenance algorithms for its rolling stock and railway infrastructure. By analyzing historical performance data and real-time sensor information, AI systems can forecast potential equipment failures and recommend preventive maintenance. This reduces downtime, improves operational efficiency, and optimizes resource allocation.

Similarly, the Azerbaijan Caspian Shipping Company (ASCO) has integrated AI into its fleet management and cargo scheduling systems. Machine learning algorithms analyze shipping data, weather forecasts, and port conditions to optimize delivery routes and reduce fuel consumption. These solutions not only enhance operational performance but also contribute to environmental sustainability by minimizing greenhouse gas emissions.

Despite these advantages, several challenges remain. The high cost of implementation and integration of AI solutions, the need for continuous data quality monitoring, and the shortage of qualified personnel are key obstacles. Additionally, ensuring data security and handling sensitive commercial information remain critical concerns for companies adopting digital logistics technologies.

To overcome these challenges, Azerbaijani companies have adopted several strategies:

- 1. Pilot projects and gradual implementation – Testing AI technologies on specific routes or operations before scaling across the entire supply chain.**
- 2. Staff training and capacity building – Conducting workshops and training programs to ensure employees can effectively utilize AI-based systems.**
- 3. Collaboration with technology providers – Partnering with IT companies and startups to access cutting-edge AI solutions.**
- 4. Investment in data infrastructure – Implementing high-quality data collection and storage systems to feed AI algorithms with reliable information.**
- 5. Development of standard procedures – Establishing common protocols for AI use across logistics operations to simplify integration and ensure consistency.**

The future of AI in Azerbaijani logistics is promising. AI technologies are expected to expand beyond operational optimization to strategic decision-making, such as demand forecasting, risk management, and supply chain resilience. By leveraging AI, logistics companies in Azerbaijan can achieve greater efficiency, reduce costs, enhance service quality, and strengthen their competitiveness in regional and global markets.

2 The effectiveness and results of using artificial intelligence in supply chains

By implementing modern digital solutions, Azerbaijani logistics companies have achieved significant improvements in their operational efficiency. The use of digital logistics process management platforms has optimized customer interactions, reduced transaction processing times, and increased overall operational efficiency. Automation processes based on artificial intelligence technologies provide faster and more accurate pricing control and enhance companies' flexibility and resilience to changes in the global market [4].

Thus, practical experience in implementing digital solutions based on artificial intelligence confirms their effectiveness in optimizing logistics processes and supply chain management.

According to international studies, the implementation of artificial intelligence technologies in supply chain management significantly improves demand forecasting. Using root cause analysis methods, rather than just historical data, improves forecasting accuracy by 10-20%. This, in turn, helps reduce product storage costs by approximately 5% and increase company revenues by 2-3% [6].

The research findings also indicate that artificial intelligence technologies have significant potential to transform logistics and supply chain management operations. Artificial intelligence methods, particularly deep learning technologies, offer significant performance gains over traditional analytical tools. They enable more accurate data analysis in areas such as logistics route optimization, predictive equipment maintenance, and demand forecasting [13].

For example, intelligent routing systems can improve the efficiency of transportation operations, reduce fuel consumption, and shorten delivery times by leveraging real-time data and algorithms for continuously evaluating logistics parameters. These capabilities are crucial for both cost optimization and improving customer satisfaction [14], [16].

Furthermore, AI technologies are actively used to automate routine and repetitive logistics operations, such as sorting, picking, and moving goods within warehouses. Robotic systems and intelligent algorithms free employees from monotonous work, increase the speed of operations, and reduce the likelihood of errors. For example, modern automated sorting systems can process over a thousand parcels per hour with high accuracy [5], [14].

The interaction of humans and intelligent systems helps improve the overall efficiency of logistics processes. At the same time, employees are trained to work with new digital technologies and manage automated systems.

Artificial intelligence is also widely used to analyze large volumes of data, including sensor data, weather forecasts, transport information, and data from various information systems. This enables more accurate demand forecasting, optimized inventory management, and improved logistics planning [4], [12].

Furthermore, intelligent systems can predict potential equipment failures, enabling proactive maintenance planning and avoiding downtime. Artificial intelligence can also identify potential risks in supply chains, such as natural disasters, raw material shortages, or political instability, thereby increasing the resilience of logistics systems [5], [14].

Automating processes using AI technologies facilitates more efficient interactions between supply chain participants, including suppliers, manufacturers, and retailers. This increases the transparency of logistics operations and improves customer service.

The implementation of intelligent technologies also contributes to increased customer satisfaction, as companies are able to respond more quickly to requests and provide a higher level of service. However, the implementation of artificial intelligence systems requires significant investment, qualified specialists, and the resolution of issues related to data protection and security [1].

In the future, the development of artificial intelligence in supply chain management will occur in several directions. Further expansion of the use of intelligent technologies is expected as companies increasingly recognize their potential to improve efficiency and reduce costs. A key area will be the integration of artificial intelligence systems with existing enterprise information systems, enabling more effective data analysis and management decision-making [13].

Furthermore, special attention will be paid to issues of ethics and data protection, as well as ensuring transparency.

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3 ***The Impact of Artificial Intelligence on Supply Chain Efficiency***

Modern supply chains face high dynamism, large volumes of data, and the need for rapid decision-making. In this environment, artificial intelligence (AI) is becoming a key tool for improving the efficiency, resilience, and accuracy of management processes [14], [18].

AI systems process and analyze data from GPS, Internet of Things (IoT) sensors, RFID tags, and other digital sources, integrating it into a centralized platform for further analytics. This allows companies to obtain up-to-date information in real time on inventory status, delivery routes, and transportation conditions [18].

The examples of Azerbaijani companies such as ADY Logistics, Silk Way Airlines Cargo, and Port of Baku demonstrate that the implementation of intelligent systems optimizes logistics processes. These companies use AI to analyze transport flows, forecast demand, and automate warehouse operations, improving planning accuracy and reducing operating costs [1], [6], [10].

3.1.1 *Benefits of AI*

Supply chain resilience: AI improves visibility and control of processes, reduces risks, and enables faster response to logistics disruptions[11], [15].

Improving forecast accuracy: AI systems analyze historical and real-time data, enabling more accurate demand forecasts and identifying potential risks, such as supplier delays or adverse weather conditions[8],[18].

Operations optimization: Intelligent algorithms help automate routing, inventory management, and warehouse operations, reducing transportation costs, delivery times, and human error [14].

3.1.2 *The Wider Impact of AI*

The application of AI in supply chains promotes efficient and sustainable practices, reduces production and transportation costs, which directly translates into lower consumer prices and economic costs. AI-based automation and analytics enable more efficient resource management and minimize environmental impact, for example, by reducing carbon emissions [17].

Thus, the implementation of artificial intelligence in the logistics processes of Azerbaijani companies increases the efficiency and resilience of supply chains, improves decision-making, and opens new opportunities for the digital transformation of the country's transport and logistics industry [3], [4].

AI also provides prescriptive recommendations, suggesting optimal actions when challenges arise in logistics processes. For example, if a supply shortage is predicted, AI systems can recommend alternative suppliers or adjust delivery routes to ensure on-time delivery of goods [15]. Furthermore, AI technologies help improve supply chain resilience, reduce operating costs, and minimize negative environmental impacts. Optimizing the use of resources such as fuel and labor, as well as preventing unnecessary deliveries and excess storage, helps reduce carbon emissions and energy consumption [17], [18].

The study "Artificial Intelligence and Prescriptive Analytics for Supply Chain Resilience" [15] demonstrated that AI has significant potential to improve the efficiency of supply chain management (SCM). However, in practice, its use is still limited, covering only certain logistics and forecasting functions. Researchers emphasize the need to expand the application of AI beyond traditional machine learning, including autonomous robotics, which can provide significant improvements in productivity and operational speed [14]. Furthermore, the study emphasizes the importance of integrating various AI functions to unlock new opportunities and improve efficiency in SCM. Coordinated collaboration between academia and industry is recommended to maximize the potential of AI to create economic and social value in modern global supply chains [18].

In the Azerbaijani context, AI can become an indispensable tool for supporting management decisions in logistics, especially for companies such as ADY Logistics, Port of Baku, and Silk Way Airlines Cargo [1], [6], [10]. Figure 1 presents the "Strategic AI Resilience Framework" for supply chains, which demonstrates a structured approach to integrating AI technologies to enhance the resilience of logistics processes [11].

The framework includes identifying supply chain vulnerabilities, strategically integrating AI, and developing robust resilience strategies. It emphasizes the role of prescriptive analytics in proactively managing disruptions, as well as the creation of collaborative ecosystems to improve the transparency and flexibility of logistics operations. AI-powered analytics enables managers to make timely and informed decisions, reducing risks and increasing overall supply chain resilience in a dynamic marketplace [18].

*In practice, the implementation of AI in Azerbaijani logistics companies has already produced tangible benefits. For example, **ADY Logistics** has introduced predictive maintenance systems for its railway infrastructure and rolling stock [1]. By analyzing historical performance data and real-time sensor inputs, AI algorithms can forecast potential equipment failures and recommend preventive maintenance. This reduces downtime, improves operational efficiency, and ensures more reliable service for customers [10].*

Similarly, **Port of Baku** has integrated AI technologies into its cargo handling and storage management systems [6]. Machine learning algorithms analyze incoming shipment data, port traffic, and environmental conditions to optimize container placement, reduce congestion, and accelerate cargo processing. These improvements result in faster turnaround times, lower operational costs, and higher service quality [6], [10].

Silk Way Airlines Cargo has leveraged AI for fleet management, route optimization, and demand forecasting. By considering factors such as weather conditions, air traffic, and cargo priorities, AI models can recommend the most efficient flight schedules and alternative routing in case of disruptions [14], [18]. This not only enhances operational performance but also supports sustainability by reducing fuel consumption and carbon emissions [17].

Despite these advantages, several challenges remain. The high costs of AI implementation, the need for highly skilled personnel, and the requirement for continuous data quality monitoring are key obstacles [12]. Furthermore, AI systems require careful integration with existing IT infrastructures, which can be complex and resource-intensive.

To address these challenges, Azerbaijani companies are implementing several strategies [3], [10]:

Pilot projects and incremental deployment – testing AI solutions on selected routes or operations before scaling them across the entire supply chain [11].

Employee training and skill development – organizing workshops and courses to ensure staff can effectively utilize AI tools [12].

Collaboration with technology providers – partnering with local and international IT firms and startups to access advanced AI solutions and expertise [18].

Investment in robust data infrastructure – creating reliable systems for data collection, storage, and processing to feed AI models with accurate and timely information [19].

Standardization of AI processes – developing unified protocols for AI application across logistics operations to ensure consistent and effective results [13].

Looking forward, AI is expected to play an even more central role in the logistics sector of Azerbaijan. Its applications are likely to expand from operational optimization to **strategic decision-making**, including supply chain risk management, resource allocation, and predictive scenario planning [11], [15]. By leveraging AI technologies, logistics companies in Azerbaijan can improve efficiency, reduce costs,

enhance service quality, and strengthen their competitive position in regional and global markets [3], [4].



Fig. 1. Examples of AI visualizations in supply chains

Artificial intelligence (AI) and digital technologies play a key role in improving the efficiency and resilience of supply chains. Using data from various sensors, GPS, and RFID tags, AI enables the collection and analysis of information in real time, enabling more accurate inventory management, optimized delivery routes, and reduced operating costs. Anticipating potential disruptions and changes in demand helps mitigate risks and improve logistics process planning. Automating routine operations reduces the likelihood of errors and increases task completion speed.

AI also helps reduce international costs and improve environmental sustainability by optimizing the use of resources such as fuel and labor, and reducing excess supply and storage. Despite its high efficiency, AI implementation requires investment and qualified specialists, which is an important factor in the digital transformation of logistics systems.

3.1.3 Key Challenges of AI Implementation in Logistics

Key challenges include:

High cost of technology implementation and adaptation [12], [14];

Difficulty of integration with existing systems [13], [16];

Need for ongoing maintenance and modernization [12], [16];

Ensuring data security and protection against unpredictable failures [12], [16];

Dependence on the quality of training data, which can lead to errors in decision-making [14], [18].

3.1.4 Solutions to Implementation Challenges

The following approaches can be used to successfully implement digital technologies in logistics:

Gradual implementation and pilot projects: Testing technologies in specific areas of the supply chain allows for identifying problems and optimizing processes without significant financial outlays.

Investing in staff training: Conducting training and professional development programs ensures the effective use of new tools [12], [18].

Public and private grants: Financial support from the government or investors reduces the burden on companies and accelerates technology implementation [3], [10].

Partnerships with technology companies: Collaborating with IT companies and startups allows for the use of advanced solutions on favorable terms.

Creating unified standards and platforms: Standardizing technologies facilitates the integration of various systems and reduces compatibility issues.

3.1.5 The Future of AI in Logistics

While AI effectively handles common failures, human expertise remains necessary for decision-making in rare or unpredictable situations [15], [18]. In the future, AI systems will continue to improve the efficiency and resilience of supply chains by integrating with existing information platforms and improving forecasting, but human oversight will remain an essential element of logistics processes [16].

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