



# Innovative Approaches to the Development and Application of Software in International and Warehouse Logistics: Current Trends and Future Perspectives

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## Abstract

This study aims to explore the transformative role of advanced logistics software in optimizing supply chain operations. It highlights how cutting-edge technologies such as AI, IoT, and blockchain are integrated to enhance operational efficiency, reduce costs, and improve service delivery.

**Methodology** - The research applies a mixed-method approach, combining quantitative analysis of logistics performance metrics with qualitative case studies of companies that have implemented advanced logistics software. Data were collected from industry reports and academic literature to assess the impact of these technologies.

**Findings** - The analysis revealed that integrating advanced logistics technologies can reduce operational costs by 15-20% and improve delivery times by 25%, as evidenced by ARDI Express. Moreover, the adoption of modular software platforms enables firms to customize solutions based on their specific needs, ensuring flexibility and scalability. Companies like Amazon and Walmart have achieved significant improvements in route optimization and demand forecasting through AI-powered systems.

**Conclusion** - The study concludes that advanced logistics software is crucial for maintaining competitiveness in a dynamic market. Future research should focus on developing unified platforms tailored for small and medium enterprises (SMEs) and exploring the potential of AI in autonomous logistics systems.

**Keywords:** logistics software, supply chain optimization, modular systems, advanced technologies in logistics, autonomous logistics solutions

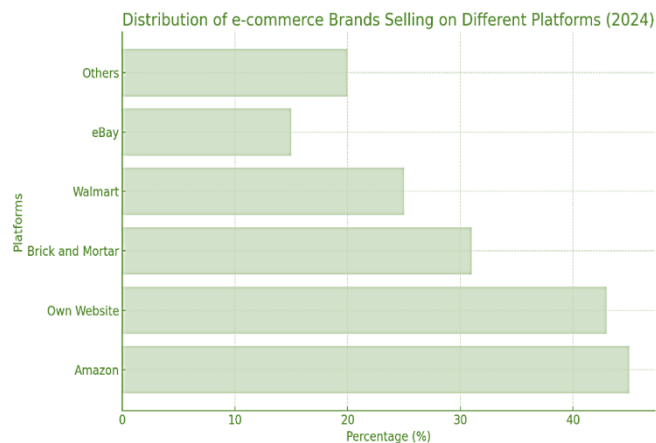
JEL Codes: L86, R41, O33

## Introduction

In today's world of e-commerce, efficient logistics is a critical success factor, ensuring the fast and reliable delivery of goods across international borders. As digital markets expand, the demand for innovative and cost-effective software solutions that help small and medium-sized enterprises (SMEs) optimize their logistics operations continues to grow.

The complexity of logistics increases due to frequent fragmented shipments of small consignments, which drive up costs and

prolong delivery times. Meanwhile, the rapid growth of platforms like Amazon, serving over six million active sellers, amplifies the need for effective solutions. As highlighted in the article *An Algorithm for Consolidating Small Shipments to Reduce Costs in International Logistics for E-commerce Businesses*, third-party sellers account for 59% of all sales on Amazon, underscoring the importance of integrated logistics systems in maintaining competitiveness (ModiLoud, 2024).



**Figure 1 Distribution of e-commerce brands on different platforms (2024)**

The evolution of logistics software reflects the growing business needs for automation, optimization, and increased transparency in logistics processes. Among the first widely adopted logistics management systems were WMS (Warehouse Management Systems), such as SAP Warehouse Management and Manhattan Associates WMS. These systems emerged in the 1980s, focusing on automating storage and goods handling operations, including inventory tracking, warehouse placement management, and order picking.

In the early 2000s, logistics systems gained new functionalities, enabling the integration of all supply chain management aspects. One such development was the introduction of TMS (Transportation Management Systems), including Oracle Transportation Management and JDA TMS (now Blue Yonder). These systems featured route planning, transportation management, delivery tracking, and transportation cost control.

Advancements in ERP systems, such as SAP S/4HANA and Microsoft Dynamics 365, allowed companies to integrate logistics operations with financial, production, and marketing processes. This integration ensured complete transparency across the entire supply chain and enabled swift responses to demand fluctuations or logistical disruptions.

Modern AI-driven systems like Körber Supply Chain Software and FourKites offer capabilities such as demand forecasting, real-time route optimization, and risk management. Cloud technologies from Amazon Web Services (AWS), Microsoft Azure, and Google Cloud provide data storage, real-time analytics, and easy access to information from anywhere in the world.

Thus, contemporary logistics software has evolved from mere automation tools into powerful technology suites that offer businesses strategic advantages in competitive markets.

However, modern software solutions still fall short of meeting the challenges posed by hybrid warehouses, which combine proprietary and third-party storage facilities. This creates a significant gap between the growing business demands and the available technologies for managing warehouse processes.

## 2. Literature Review

The evolution of logistics software is one of the key topics in contemporary scientific research, with significant focus on its development and implementation. Early systems were aimed at automating basic operations, such as inventory management and transportation. Over time, these systems have transformed into sophisticated tools that integrate advanced technologies, including artificial intelligence (AI) and cloud solutions.

### 2.1. Integration of Artificial Intelligence in Logistics

A. Villanueva-Eslava in the article "Artificial Intelligence and Logistics Services: A Systematic Literature Review," examines the impact of AI on key aspects of logistics (Villanueva-Eslava, 2023). The authors highlight that AI enables the automation of decision-making processes, including demand forecasting, warehouse, and transport route optimization. Special attention is given to the use of deep learning algorithms, which analyze historical data and current conditions to predict potential disruptions. The study emphasizes the implementation of chatbots for customer communication and automated monitoring systems that track shipment status in real-time, reducing the risk of delays.

### 2.2. The Potential of Automation in Logistics

Benjamin Nitsche, in the article "Exploring the Potentials of Automation in Logistics and Supply Chain Management," provides an in-depth analysis of the advantages and limitations of automation in supply chains (Nitsche, 2021). The author examines automated storage and retrieval systems (AS/RS) and robotic complexes that perform loading, unloading, and sorting tasks without human intervention. The implementation of unmanned transport vehicles for internal logistics reduces cargo handling time and improves operational accuracy. Automated transportation systems in urban environments, such as drones and autonomous delivery vans, enable rapid delivery to hard-to-reach areas.

Cross-docking is one of the key strategies that optimizes logistics operations by minimizing the storage time of goods in warehouses. This methodology involves goods arriving at a distribution center and being immediately redirected to the end consumer or the next delivery point, with minimal storage. Implementing cross-docking significantly reduces storage costs, optimizes delivery routes, and speeds up order processing.

The success of this strategy largely depends on the use of modern software. Specifically, Warehouse Management Systems (WMS) and Transportation Management Systems (TMS) ensure efficient coordination among suppliers, distributors, and customers. These solutions automate sorting processes, track goods in real time, and plan optimal delivery routes.

An essential component of cross-docking implementation is the use of automation technologies, such as RFID and barcode scanners, integrated with WMS. These tools provide fast and accurate inventory tracking, minimizing the risk of errors and delays. Research presented in the article "Strategy for Organizing Cross-Docking in Supply Chains" shows that introducing automated solutions into cross-docking processes can reduce cargo handling time by 30-40% and significantly lower logistics costs.

Furthermore, cross-docking is widely utilized in supply chains with high turnover rates, such as retail and e-commerce. Specialized software supports accurate forecasting and ensures uninterrupted logistics operations even during peak periods. This is particularly crucial for companies operating in competitive environments, where speed and accuracy of delivery are key success factors.

### 2.3. The Role of Digital Platforms and Autonomous Vehicles

J. Turienzo offers a comprehensive analysis of the impact of digital platforms and autonomous vehicles on logistics processes (Turienzo, 2024). Platforms such as Flexport and Freightos enhance data exchange between supply chain participants, from suppliers to end consumers. They provide transparency at every stage of transportation, from order placement to delivery. The integration of autonomous vehicles—Tesla's trucks and Zipline's drones—will reduce transportation costs and minimize the human factor in logistics operations.

Key software functionalities in logistics include inventory management, order fulfillment, and route optimization. Warehouse Management Systems (WMS), such as SAP Warehouse Management, facilitate efficient inventory tracking and storage. By automating order picking and placement, they ensure accuracy and reduce the risk of errors. Inventory management helps optimize

costs by maintaining a balance between demand and product availability.

Transportation Management Systems (TMS), like Oracle Transportation Management, significantly improve route planning and transportation control. These systems analyze logistics costs and forecast optimal delivery methods, considering traffic constraints and weather conditions.

AI-based solutions, such as Körber Supply Chain Software, leverage machine learning algorithms to forecast demand and optimize logistics routes in real time. This is particularly relevant for reducing delivery times in rapidly changing market conditions.

Additionally, cloud platforms like AWS and Microsoft Azure facilitate easy data access, providing analytics and monitoring of logistics processes from anywhere in the world. They support coordination across different company departments and simplify integration with suppliers and customers.

Modern logistics software actively incorporates AI, the Internet of Things (IoT), blockchain, and predictive analytics to optimize processes. AI enables the analysis of large data sets, such as weather conditions, road congestion, and historical traffic data, to dynamically optimize delivery routes. For example, the implementation of AI in DHL has reduced fuel costs and shortened delivery times by optimizing the "last mile" (DHL Freight Connections, 2023).

Hybrid fulfillment models combine centralized, decentralized, and dropshipping approaches, creating flexible systems that can adapt to changes in demand. These models enable companies to simultaneously leverage internal resources and external providers for order fulfillment, resulting in shorter delivery times and improved customer service levels. Intelligent algorithms within hybrid models automatically determine the most efficient delivery method, taking into account costs and customer preferences, thereby enhancing operational efficiency and reducing expenses.

A successful example of hybrid model implementation is Gymshark, analyzed in the article "Approaches to Developing Hybrid Fulfillment Models for E-Commerce." The company combines centralized warehouses for high-demand products with localized fulfillment centers, allowing for faster delivery times and optimal inventory levels. By using advanced inventory management systems, Gymshark can swiftly respond to consumer demand changes and maintain high service quality.

The article "Methods and Approaches to Integrating Innovative Technologies in 3PL Provider Management: From Automation to Artificial Intelligence" explores the use of innovative methods in logistics, particularly blockchain and AI technologies.

## 2.4. Blockchain

Blockchain is one of the most revolutionary technologies in logistics, offering significant improvements in supply chain transparency, security, and efficiency. Its primary function is decentralized data storage, where each transaction is recorded as an immutable block, forming a chain that cannot be altered without the consensus of all system participants.

Advantages of Blockchain in Logistics:

1. **Transparency.** All supply chain participants have real-time access to up-to-date information, minimizing opportunities for fraud.
2. **Smart Contracts.** Automation of operations, such as payment upon delivery, reduces costs and accelerates financial transactions.
3. **Security.** Data is protected by cryptographic algorithms, preventing unauthorized access and modification.
4. **Tracking and Auditing.** Easy access to the history of all transactions simplifies quality control and compliance with regulatory requirements.

5. **Speed and Efficiency.** Instant data exchange between participants reduces document processing time and improves delivery time predictions.

In practice, blockchain is already utilized by leading logistics companies. Platforms such as Flexport and Maersk TradeLens integrate blockchain to manage freight data. This significantly reduces document processing time, minimizes customs delays, and improves delivery time accuracy. While traditional record-keeping systems may take days to process information, blockchain provides immediate data access.

Despite its potential, blockchain implementation faces challenges. The primary obstacle is the high cost of initial integration, which can be a barrier for small and medium-sized enterprises. Additionally, the need to harmonize standards among various supply chain participants complicates the process. However, these efforts are justified, as blockchain can deliver substantial long-term cost savings.

## 2.5. AI

Artificial intelligence (AI) is widely applied in logistics software to optimize various processes, significantly enhancing operational efficiency and accuracy. Here are some key AI applications in logistics that drive improvements across the industry.

### Benefits of AI in Logistics:

- **Demand Forecasting.** AI enables accurate demand predictions by analyzing vast amounts of data, including historical sales, seasonal fluctuations, and market trends. This helps companies optimize inventory levels and reduce the risk of overstocking or stockouts. For example, Walmart's AI-driven forecasting system uses data on weather, traffic, and other factors to predict demand and adjust inventory in real-time, reducing costs and improving product availability for customers [PYMNTS.com, 2024].
- **Route Optimization.** AI can analyze real-time data, such as weather conditions, traffic, and road congestion, to select the most efficient delivery routes. DHL, for instance, uses AI to dynamically adjust delivery routes in real-time, avoiding traffic jams and cutting delivery times, which reduces fuel costs and lowers CO2 emissions (DHL Freight Connections, 2023).
- **Warehouse Process Automation.** AI is actively used to automate warehouse operations, where AI-based systems manage inventory, order processing, and returns. These systems optimize the picking process, improving accuracy and reducing handling times. This minimizes human error and boosts warehouse efficiency, a crucial factor for large logistics companies.
- **Intelligent Monitoring Systems.** AI-driven monitoring systems can detect anomalies in the supply chain and provide early warnings of potential issues. For example, Amazon's AI system forecasts potential delivery problems, enabling real-time adjustments to routes or other supply chain stages to ensure timely and uninterrupted deliveries (US About Amazon, 2019).

The use of AI provides logistics companies with competitive advantages by reducing costs, optimizing inventory management, and improving delivery accuracy. This not only enhances operational efficiency but also positively impacts customer satisfaction and overall productivity.

## 2.6. Internet of Things (IoT)

The Internet of Things (IoT) plays a pivotal role in transforming logistics processes by enhancing efficiency, transparency, and adaptability. Implementing IoT in logistics enables companies to

optimize inventory management, track shipments in real time, and automate warehouse operations.

Key Advantages:

- **Inventory Management.** IoT sensors installed in warehouses and vehicles provide continuous monitoring of inventory levels, temperature, and humidity. This allows for automatic stock replenishment and prevents shortages or overstocking. For instance, IoT technology is widely used in logistics to improve process efficiency and ensure more accurate control over the movement of goods from supplier to end consumer (Inbound Logistics, 2024).
- **Shipment Tracking.** The use of GPS trackers and RFID tags enables real-time tracking of shipment locations. This enhances supply chain transparency and allows for prompt responses to potential delays or issues. Combining IoT with cloud-based GPS systems facilitates tracking individual cargo batches and their conditions (Humayun, 2020).
- **Warehouse Process Automation.** IoT sensors integrate with Warehouse Management Systems (WMS), automating the processes of receiving, storing, and picking goods. This reduces order processing times and increases accuracy. For example, the Parcelive device by UK-based company Hanhaa leverages IoT technology to provide real-time cargo status updates (Inbound Logistics, 2024).
- **Route Optimization.** IoT sensors in vehicles collect data on speed, fuel consumption, and road conditions, enabling the optimization of delivery routes, reducing costs, and shortening delivery times. IoT data can be utilized to optimize routes, cut fuel expenses, and improve delivery speed (Biz4Intellia, 2024).

### 2.7. Predictive analytics

Predictive analytics is an essential component of modern logistics software, enabling companies to forecast future events and optimize operational processes. By using historical data, statistical models, and machine learning algorithms, predictive analytics assists in inventory management, order fulfillment, and route optimization.

- **Inventory Management.** Predictive analytics allows for accurate demand forecasting, which helps optimize inventory levels. This prevents stockouts or overstocking, reducing storage costs and improving customer service levels. For example, companies that have implemented predictive analytics have been able to reduce stockouts by up to 98% and cut excess inventory by 50%.
- **Order Fulfillment.** Predictive analytics optimizes order fulfillment processes by forecasting delivery times and potential delays. This enables companies to efficiently plan resources and ensure timely delivery to customers. For instance, using predictive analytics can reduce planning time by up to 90% and deliver the best long-term ROI.
- **Route Optimization.** Predictive analytics analyzes data on traffic, weather conditions, and other factors affecting deliveries to optimize routes. This reduces transportation costs and shortens delivery times. For example, logistics programs help select the best routes, monitor driver hours, and communicate with truckers.

The implementation of predictive analytics in logistics software allows companies to improve operational efficiency, reduce costs, and enhance customer service, which is critical in today's competitive environment.

### 2.8. Digital Twins

Digital twins play a crucial role in optimizing warehouse and transportation processes by integrating physical and digital systems to enhance operational efficiency and transparency.

Digital twins create virtual models of warehouse spaces, enabling real-time tracking of goods movement, inventory management, and space planning. This helps reduce order processing time, improve accuracy, and lower costs. For example, GE Digital uses digital twins to monitor and optimize warehouse operations, increasing efficiency and reducing expenses (Digital Twins, 2023).

In transportation, digital twins are used to model logistics routes, monitor vehicle conditions, and predict delivery times. This enables route optimization, reduces fuel costs, and improves customer service. For instance, Cisco Systems is developing network infrastructure to support digital twin technology at factories and logistics centers, improving efficiency and lowering costs (Hapag-Lloyd, 2024).

The implementation of digital twins in logistics processes allows companies to achieve significant improvements in productivity, cost reduction, and enhanced customer service.

### 2.9. Real-Time Tracking

The implementation of real-time tracking systems allows for continuous monitoring of the location of goods, vehicles, and inventory levels. This provides:

- **Inventory Management.** Accurate representation of inventory levels helps avoid shortages or overstocking, optimizing warehouse operations.
- **Route Optimization.** Data on traffic and road conditions enables quick adaptation of delivery routes, reducing transportation time and fuel costs.
- **Improved Customer Experience.** With access to up-to-date information, customers can track their shipments and receive accurate estimated arrival times.

Companies like TomTom and Google Maps actively use real-time data for route optimization. Using GPS data, these systems allow logistics operators to quickly respond to traffic changes or weather conditions. For instance, if a traffic jam occurs on a route, the system automatically suggests an alternative path, reducing delivery time and fuel costs. In logistics, this not only enables real-time tracking of shipments but also allows coordination of driver actions, ensuring precise information on the estimated time of arrival (Rtslabs, 2024).

### 2.10. Predictive Maintenance

Predictive maintenance utilizes data analytics and machine learning to forecast potential failures in equipment or vehicles. This allows for:

- **Reduced Downtime.** Scheduled maintenance is performed before issues arise, minimizing the risk of operational disruptions.
- **Lower Repair Costs.** Early detection of potential faults helps avoid costly repairs.
- **Increased Efficiency.** Keeping equipment in optimal condition ensures uninterrupted logistics operations.

General Electric, which actively implements predictive maintenance, uses sensors and analytics systems to monitor equipment status at its logistics centers. This allows the company to predict when maintenance is needed, preventing unexpected failures. For example, vehicles equipped with IoT sensors can transmit data on the condition of key systems, such as the engine or brakes. If the system detects a potential fault, it recommends maintenance before a problem occurs. As a result, the company

reduces equipment downtime, ensuring the continuity of logistics processes (Rtslabs, 2024).

**2.11. Problems and Limitations**

The implementation and integration of logistics software, despite its numerous benefits, are associated with several key challenges that can impact business process efficiency. One of the most significant issues is the high initial costs. Developing, purchasing, and implementing modern technologies such as Warehouse Management Systems (WMS) or Transportation Management Systems (TMS) require substantial investments. These costs include expenses for hardware and software, staff training, and updating existing infrastructure. For small and medium-sized enterprises, these expenses can pose a significant barrier to digital transformation.

Another critical issue is data security. Logistics systems collect and process large volumes of sensitive information, including customer data, delivery routes, and internal operations. Protecting this information from unauthorized access and cyberattacks is becoming increasingly important, especially in light of the growing number of cyber threats. Technologies such as blockchain help enhance transparency and reliability, but they also require additional resources to ensure security.

Adapting staff to new technologies is another challenge. Even the most advanced systems cannot function optimally without proper staff training. The introduction of new software often involves the need for training sessions and ongoing employee support. This not only requires time and financial resources but can also lead to resistance among employees who are accustomed to older methods of working.

**3. Data and Methodology**

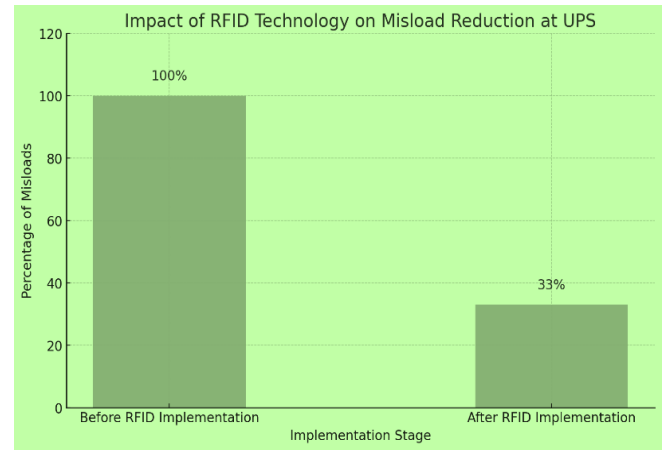
In the study "Innovative Methodology for Optimizing Supply Chains for E-commerce," approaches based on innovative methodologies for supply chain optimization in e-commerce are explored. Specifically, the focus is on freight consolidation, which reduces logistics costs and improves delivery efficiency. According to ARDI Express, applying methods of consolidating small shipments into larger ones for centralized dispatch can reduce logistics costs by 15-20% and shorten delivery times by 25%.

The methodology includes the use of specialized software for route optimization and warehouse process management. Algorithms that consider demand, load capacity constraints, and delivery routes are employed, which helps reduce the number of empty trips and cut transportation time.

To assess the effectiveness of these methods, simulations were conducted using data from real logistics operations. The analysis was done by comparing traditional delivery methods with innovative ones based on freight consolidation principles and hybrid fulfillment models. The study's results demonstrate that optimized models enable greater flexibility in inventory management and significantly reduce operational costs.

**4. Findings and Discussions**

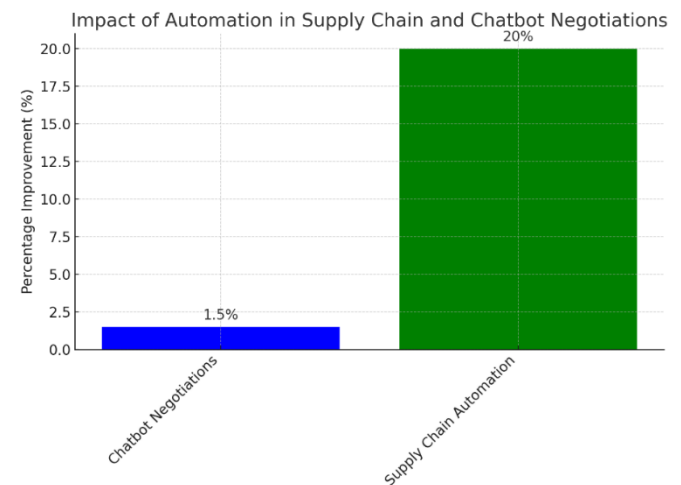
Several companies have successfully implemented advanced logistics software, achieving significant results. For example, UPS, through the implementation of RFID technology in its "Smart Package Smart Facility" program, reduced loading errors by 67%. This not only led to a reduction in operational costs but also improved delivery accuracy to 97.6%, as stated in their 2024 annual report.



**Figure 2 Impact of RFID technology on reducing UPS loading errors, 2024**

Amazon uses artificial intelligence to optimize routes and forecast demand. Their systems analyze real-time data, considering road conditions and weather, allowing for quick responses to changes and optimizing delivery times. This has significantly improved operational efficiency, reduced fuel costs, and ensured more accurate delivery time adherence.

Another example is Walmart, which has also integrated AI to manage its supply chain. The use of this technology enables the company to forecast demand and adjust its inventory in real time, ensuring optimal resource utilization and enhancing the customer experience. For instance, a chatbot negotiated with 68% of suppliers contacted, saving 1.5% and extending payment terms. Supply chain automation is estimated to improve average unit costs by about 20%. A notable customer-focused result is the development of platforms like Text to Shop, which use natural language understanding to enhance the shopping experience



**Figure 3 Impact of Automation in Supply Chain**

As a result, Walmart was able to reduce delivery times and improve operational accuracy through effective last-mile management.

ARDI Express implemented freight consolidation methods by combining small shipments into larger ones for centralized dispatch. This led to a 15-20% reduction in logistics costs and a 25% decrease in delivery time.

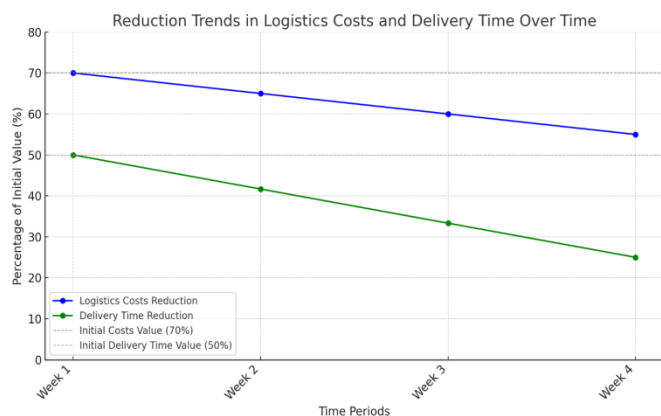


Figure 4 Reduction Trends in Logistics Costs and Delivery Time Over Time

The use of specialized software for route optimization and warehouse process management has contributed to a reduction in the number of empty trips and an increase in transportation efficiency.

## 5. Conclusion

The logistics software market is experiencing steady growth, driven by the need for supply chain optimization and the integration of innovative technologies. It is expected that the development of this market will accelerate significantly in the coming years, leading to increased demand for digital solutions.

Key players in the market include companies like SAP SE, Oracle Corporation, and Manhattan Associates. These companies provide comprehensive solutions for supply chain management, warehouse operations, and transportation. Such platforms enable the integration of all business processes, automate data processing, and provide flexibility in managing operations. For example, Oracle's cloud technologies support scalability and reduce infrastructure costs, while SAP SE actively integrates artificial intelligence for demand forecasting and logistics process optimization.

The future development of the logistics software market is focused on the implementation of innovations such as artificial intelligence, the Internet of Things (IoT), and blockchain. These technologies enhance efficiency through the automation of key processes, reduce costs, and improve transaction transparency in supply chains. For instance, blockchain significantly enhances data security and minimizes fraud risks, while IoT enables real-time tracking of cargo and vehicle conditions.

The research conducted confirms that the implementation of modern logistics software (LMS) significantly enhances supply chain efficiency. Specifically, the use of innovative technologies such as AI, IoT, and blockchain allows for the automation of processes, route optimization, and improved inventory management. According to ARDI Express, the application of freight consolidation methods helps reduce logistics costs by 15-20% and cut delivery time by 25%.

Despite significant progress, the logistics software market faces challenges such as high implementation costs, system compatibility issues, and data security concerns. To foster further development, it is crucial to address these issues and create standardized solutions that are accessible to a wide range of businesses, including small and medium enterprises.

The modern logistics market demands the integration of innovations that can ensure high efficiency, flexibility, and adaptability. Given the diverse needs of companies, there is a need to develop software that integrates all key innovations such as warehouse management, transportation logistics, freight consolidation, predictive analytics, and intelligent optimization

algorithms. However, universal solutions must account for the specifics of each business.

A modular approach is the optimal way to develop such software. It involves creating separate modules, each performing a specific function. For example, a company specializing in small shipments might use a module for freight consolidation and route optimization while leaving other modules, such as warehouse management or predictive maintenance, inactive. Meanwhile, a large retailer could opt for all modules to integrate all processes into a single system.

The advantages of this approach are clear. Companies can save on implementation costs by paying only for the functionalities they need. Furthermore, it provides scalability: as the business grows, new modules can be easily added without the need to replace the entire software system. The flexibility offered by the modular approach allows businesses to quickly adapt to changing market conditions.

The implementation of modular software also facilitates staff training. Employees will only need to learn the functions they will use, significantly reducing the time and resources spent on adaptation. Additionally, such systems simplify maintenance and updates, as individual modules can be updated independently without affecting other parts of the software.

The development of such tools will enhance efficiency and competitiveness, allowing businesses to remain flexible and ready to adapt to changes in the dynamic logistics market.

Future research could focus on integrating artificial intelligence to create autonomous logistics systems, which would involve the use of autonomous vehicles and automated warehouses. Additionally, a promising direction is the development of unified platforms for small businesses, providing access to advanced logistics technologies at an affordable price, thereby enhancing the competitiveness of small enterprises in the global market.

## Data Availability

The data supporting the findings of this study are available within the article and its supplementary materials. Additional data are available upon request from the corresponding author at [tovtstolisigor7@gmail.com](mailto:tovtstolisigor7@gmail.com).

## Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

## Supplementary Materials

Supplementary materials related to this article, including raw data and extended analysis, can be found at <https://ardiexpress.com/>, or are available upon request from the corresponding author.

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