

REVOLUTIONIZING SUPPLY CHAINS: THE TRANSFORMATIVE ROLE OF ARTIFICIAL INTELLIGENCE IN LOGISTICS

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ABSTRACT

Artificial Intelligence (AI) is transforming logistics by significantly improving efficiency and reducing costs across supply chain operations. This review paper investigates AI's impact on logistics through a systematic synthesis of secondary data sourced from professional and industry publications, utilizing Google searches and AI tools such as ChatGPT with keywords including "AI in logistics" and "Logistics Automation." The research focuses on AI-driven optimizations in inventory management, route planning, and warehouse automation, supported by a synthesis of case studies of leading industry adopters. Findings indicate that AI implementation leads to substantial reductions in inventory and transportation costs and significant increases in warehouse productivity. Successful applications also enhance delivery reliability and customer satisfaction, although challenges such as high implementation costs and skill shortages remain. In conclusion, AI is revolutionizing logistics by streamlining operations and promoting sustainability, yet strategic investments are essential to overcome barriers and unlock future advancements like autonomous delivery systems.

Keywords: Artificial Intelligence, Logistics, Supply Chain, Automation, Optimization

INTRODUCTION

The rapid advancement of Artificial Intelligence (AI) has positioned it as a cornerstone of modern logistics, driving innovation across supply chain management. AI's ability to process vast datasets and automate complex tasks enables businesses to optimize operations, reduce costs, and enhance service quality. From autonomous vehicles to predictive analytics, AI is reshaping logistics by addressing inefficiencies and unlocking new opportunities (Mecalux, 2023).

This paper examines AI's impact on logistics through successful case studies and explores its benefits and challenges. The research addresses two key questions:

- How does AI optimize logistics processes, including cost reduction and efficiency improvements?
- What are the most successful examples of AI implementation in logistics, and what are their benefits and challenges?

Data for this study were sourced from Google searches (Google Scholar, etc..) and AI tools like ChatGPT and Gemini, using keywords such as "artificial intelligence in logistics," "AI use cases in logistics," and "benefits and challenges of AI."

MATERIAL AND METHODS OF WORK

This paper is a systematic literature review and synthesis of secondary data collected from professional and industry sources. The primary objective was to identify and structure the key applications, benefits, and challenges of Artificial Intelligence in supply chain management. Information was gathered using Google searches and AI-assisted tools, including ChatGPT and Gemini, with keywords such as “artificial intelligence in logistics,” “AI in supply chain management,” and “logistics automation.” Sources include industry reports, white papers, and corporate and professional publications, primarily from 2018 to 2024. The study analyzes case studies of companies like DHL, Huawei, FedEx, and Amazon to evaluate AI’s impact on logistics processes. The collected data were synthesized to identify and structure the key applications, benefits, and challenges of AI in logistics, providing a comprehensive overview of industrial best practices, and addressing research questions, focusing on AI’s role in optimizing operations and the associated benefits and challenges.

LITERATURE REVIEW

Artificial Intelligence (AI), defined as the development of systems capable of performing tasks requiring human intelligence, such as learning, reasoning, and decision-making, has emerged as a transformative technology across industries (Mecalux, 2023). Coined by John McCarthy in 1956, AI encompasses technologies like machine learning, natural language processing, and robotics, enabling applications from virtual assistants to autonomous systems (Levin, 2024). In logistics, AI is revolutionizing supply chain management by optimizing processes, reducing costs, and enhancing efficiency through data-driven insights and automation (Invoitix, 2023). This section reviews the literature on AI’s applications in logistics, focusing on inventory management, transportation, warehouse automation, demand forecasting, sustainability, and ethical considerations, while highlighting implementation challenges.

AI in Inventory Management

AI significantly enhances inventory management by leveraging predictive analytics to forecast demand with high accuracy. Algorithms analyze historical sales data, seasonal trends, and external factors like market conditions to optimize inventory levels, reducing overstocking and stockouts (Mecalux, 2023). Chopra and Meindl (2016) emphasize that AI-driven inventory systems enable just-in-time stocking, minimizing holding costs while ensuring product availability. Furthermore, AI-powered robots automate tasks such as picking, packing, and sorting in warehouses, improving operational speed and reducing human error (AI Business, 2022). Studies indicate that AI can decrease inventory carrying costs by up to 20% in large-scale operations, making it a critical tool for logistics efficiency (Rushton et al., 2021).

AI in Transportation and Route Optimization

Transportation is a key area where AI delivers substantial benefits. Advanced algorithms process real-time data on traffic, weather, and delivery schedules to determine optimal routes, reducing fuel consumption and delivery times (Invoitix, 2023). Palamar (2024) notes that AI-driven route optimization can lower transportation costs by 10–15% through dynamic adjustments to changing conditions. Additionally, AI automates task allocation and load planning, enhancing fleet utilization and reducing empty miles (TLS, n.d.). Research by Chopra (2021) highlights that AI’s ability to integrate multimodal transport data (e.g., road, rail, air) enables seamless coordination across supply chains, improving overall logistics performance.

AI in Warehouse Automation

Warehouse automation is another domain transformed by AI. AI-powered Warehouse Management Systems (WMS) streamline operations like sorting, picking, and transporting goods, increasing throughput and accuracy (AI Business, 2022). Rushton et al. (2021) report that AI-driven robots can process orders up to three times faster than manual labor, significantly boosting productivity. Moreover, AI enables real-time monitoring of goods flow and inventory, optimizing

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space utilization and reducing operational bottlenecks (Mecalux, 2023). According to a study by McKinsey (2023), companies adopting AI in warehouses can achieve a 30% reduction in operational costs, underscoring its economic impact.

AI in Demand Forecasting

Accurate demand forecasting is critical for efficient logistics, and AI excels in this area by analyzing complex datasets, including consumer behavior, economic indicators, and historical trends (TIMOCOM, 2020). Palamar (2024) argues that AI's predictive capabilities allow companies to anticipate demand fluctuations, enabling proactive inventory and resource planning. A study by Lee and Lee (2020) found that AI-based forecasting models improve accuracy by 25–40% compared to traditional methods, reducing stockouts and excess inventory. This precision enhances supply chain responsiveness and customer satisfaction, positioning AI as a cornerstone of modern logistics strategies (Chopra, 2021).

AI and Sustainability in Logistics

Sustainability is an emerging focus in logistics, and AI contributes by optimizing resource use and reducing environmental impact. AI-driven route optimization minimizes fuel consumption, lowering carbon emissions, while predictive analytics reduces waste through efficient inventory management (UNITE.AI, 2024). Sarkis et al. (2021) highlight that AI can support green logistics by enabling circular supply chains, where materials are reused or recycled based on predictive models. For example, AI systems can optimize reverse logistics for product returns, reducing environmental footprints (Bowersox et al., 2020). Industry reports suggest that AI adoption in logistics could reduce global logistics-related emissions by 10% by 2030 (McKinsey, 2023).

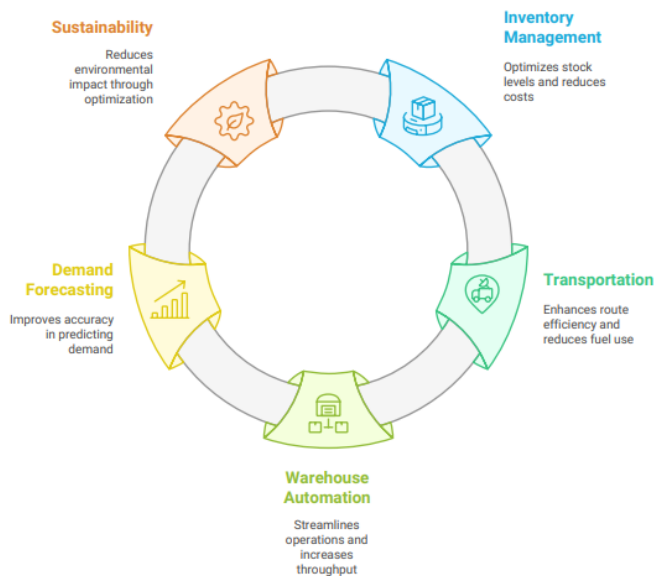


Figure 1. The impact of AI on Logistics.

This figure 1 illustrates how artificial intelligence enhances logistics through five key areas:

- **Inventory Management:** Optimizes stock levels and reduces costs.
- **Transportation:** Increases route efficiency and lowers fuel usage.
- **Warehouse Automation:** Streamlines operations and boosts throughput.
- **Demand Forecasting:** Improves prediction accuracy for demand.
- **Sustainability:** Minimizes environmental impact via optimization.

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Ethical and Social Considerations

Despite its benefits, AI in logistics raises ethical and social concerns. Data privacy is a significant issue, as AI systems rely on large datasets that may include sensitive customer information (DOBA Fakulteta, 2023). Ensuring compliance with regulations like GDPR is critical to maintaining trust (Sarkis et al., 2021). Additionally, AI-driven automation may lead to job displacement, particularly for low-skilled workers, raising concerns about social equity (Finance.si, 2023). Research by Frey and Osborne (2017) estimates that 47% of logistics jobs are at risk of automation, necessitating reskilling programs to mitigate workforce disruption. Ethical AI deployment requires balancing efficiency gains with social responsibility (Lee & Lee, 2020).

Challenges of AI Implementation

Implementing AI in logistics presents several challenges. High initial costs for technology, infrastructure, and training can deter adoption, particularly for small and medium enterprises (Finance.si, 2023). Integration with legacy systems is often complex, requiring significant technical expertise (DOBA Fakulteta, 2023). A shortage of skilled AI professionals further limits implementation, with estimates suggesting a global deficit of millions of data scientists by 2030 (McKinsey, 2023). Cybersecurity risks are also a concern, as AI systems are vulnerable to data breaches (DOBA Fakulteta, 2023). Finally, employee resistance to automation, driven by fears of job loss, can slow adoption, necessitating change management strategies (Finance.si, 2023).

Future Directions

The literature points to a promising future for AI in logistics, with advancements in autonomous delivery systems, smart warehouses, and predictive analytics expected to drive further innovation (UNITE.AI, 2024). AI Business (2021) predicts that by 2030, over 50% of global logistics operations will incorporate AI-driven automation, enhancing efficiency and sustainability. Emerging technologies like blockchain and IoT, combined with AI, are expected to create fully integrated, transparent supply chains (Chopra, 2021). However, addressing implementation challenges, such as cost, skills, and ethics, will be critical to realizing AI's full potential in logistics (Sarkis et al., 2021).

RESULTS: ADDRESSING THE RESEARCH QUESTIONS

Research question 1: How does AI optimize logistics processes, including cost reduction and efficiency improvements?

AI optimizes logistics processes by automating tasks, enhancing decision-making, and leveraging real-time data analytics, leading to significant cost reductions and efficiency improvements. In inventory management, AI employs predictive algorithms to forecast demand, analyzing historical sales, seasonal trends, and market conditions to minimize overstocking and stockouts (Mecalux, 2023).

In transportation, AI optimizes routes by processing real-time data on traffic, weather, and delivery schedules, reducing fuel costs and delivery times by 10–15% (Palamar, 2024). Automated task allocation and load planning further enhance fleet efficiency, minimizing empty miles (TLS, n.d.).

Warehouse automation is another critical area, where AI-powered Warehouse Management Systems (WMS) streamline sorting, picking, and transporting goods. AI-driven robots process orders up to three times faster than manual labor, boosting productivity and reducing operational costs by up to 30% (AI Business, 2022). Real-time monitoring optimizes goods flow, reducing bottlenecks and enhancing space utilization (Mecalux, 2023).

Research question 2: What are the most successful examples of AI implementation in logistics, and what are their benefits and challenges?

Several industry leaders have successfully implemented AI in logistics, showcasing its benefits while navigating significant challenges. DHL employs AI for route optimization and demand forecasting, reducing fuel costs and improving delivery efficiency. This has enhanced

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resource allocation and customer satisfaction, with optimized routes lowering transportation expenses (DHL, 2020). However, DHL faced high initial costs and integration complexities when adopting AI systems (Finance.si, 2023).

Huawei integrates AI to enhance delivery reliability, improving delivery time estimates by 30–80% and boosting efficiency by 30%. This enables better shipment tracking and cost savings, increasing customer trust (Mladipodjetnik.si, 2018). Challenges included a shortage of AI experts and cybersecurity risks associated with handling large datasets (DOBA Fakulteta, 2023).

FedEx uses AI for predictive analytics and delivery optimization, forecasting demand to minimize delays and operational costs. This improves service reliability, with fewer delivery errors (FedEx, 2021). However, employee resistance to automation and the need for extensive training posed implementation hurdles (Finance.si, 2023).

Amazon’s Kiva system, powered by AI, automates warehouse operations using mobile robots, accelerating order processing and reducing costs. AI-driven demand forecasting optimizes inventory, supporting Amazon’s e-commerce growth (Villarreal, 2018). Despite these benefits, Amazon encountered challenges like high infrastructure costs and data privacy concerns, requiring robust cybersecurity measures (DOBA Fakulteta, 2023).

Benefits Across Examples: These cases highlight common benefits, including increased productivity, reduced operational costs (e.g., fuel, storage, labor), improved delivery accuracy, and enhanced customer satisfaction. AI’s automation reduces errors, while predictive analytics and route optimization streamline operations (TLS, 2020; Podjetna Slovenija, 2024).

Challenges Across Examples: Common challenges include high initial investment costs, particularly for technology and training (Finance.si, 2023). Integration with existing systems is complex, often requiring significant technical upgrades (DOBA Fakulteta, 2023).

Future Implications: These examples underscore AI’s potential to transform logistics, but successful implementation requires addressing these challenges through strategic investments, workforce training, and robust data security. The adoption of autonomous delivery systems and smart warehouses, as seen in systems like UPS’s ORION, will further enhance efficiency and sustainability, shaping the future of logistics (UNITE.AI, 2024).

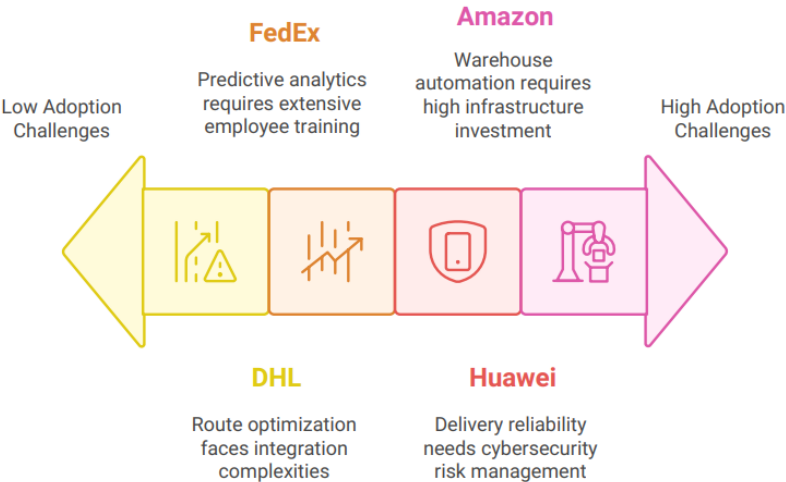


Figure 2. AI in logistics: Balancing benefits and implementation challenges.

The figure 2 shows a flowchart of AI adoption challenges in logistics, progressing from low to high adoption. FedEx faces predictive analytics requiring extensive employee training, DHL deals with route optimization and integration complexities, Huawei addresses delivery reliability and cybersecurity risk management, and Amazon requires warehouse automation with high infrastructure investment. Icons and a color gradient (yellow to pink) illustrate the transition.

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DISCUSSION: BENEFITS AND CHALLENGES OF USAGE AI IN LOGISTICS

Based on the reviewed literature, Table 1 and Table 2 summarize the key benefits and challenges associated with the use of AI in logistics.

Table 1. Benefits of usage AI in logistics.

Benefit	Source
Process Automation – automates tasks like order processing and inventory management, reduces errors, and increases efficiency	TLS, 2020
Route Optimization – calculates optimal routes to minimize transportation costs	Podjetna Slovenija, 2024
Demand Forecasting – provides accurate predictions, reduces storage costs, and improves inventory planning	TIMOCOM, 2020
Warehouse Automation – AI-driven robots enhance speed and accuracy in warehouses	Invoitix, 2023
Customer Satisfaction – personalizes services and improves delivery reliability	TLS, 2020

Table 2. Challenges of usage AI in logistics.

Challenge	Source
High Initial Costs – requires significant investment in technology and training	Finance.si, 2023
Integration Complexities – merging AI with existing systems can be technically challenging	Finance.si, 2023
Skill Shortages – a lack of AI experts hinders adoption	DOBA Fakulteta, 2023
Data Security – handling large datasets increases cybersecurity risks	DOBA Fakulteta, 2023

CONCLUSION

Artificial Intelligence has emerged as a cornerstone of modern logistics, driving automation, optimizing processes, and enabling predictive capabilities that redefine supply chain efficiency. Companies like DHL, Amazon, and Huawei exemplify AI's transformative impact, achieving cost savings, faster deliveries, and improved customer satisfaction. However, challenges such as high initial investments, integration hurdles, and cybersecurity risks must be addressed to fully harness AI's potential.

Looking ahead, AI will continue to revolutionize logistics through autonomous delivery systems, smart warehouses, and advanced demand forecasting. Its ability to adapt to dynamic market conditions positions AI as a critical enabler of sustainable and resilient supply chains. This research highlights AI's dual role as both a disruptor and an innovator, urging businesses to embrace technological advancements while fostering workforce readiness and robust data governance.

This study has several limitations. First, its reliance on qualitative secondary data limits the ability to conduct primary empirical analysis, such as quantitative assessments of AI's impact on specific logistics metrics. The use of Google searches and AI tools like ChatGPT may introduce bias in source selection, potentially overlooking niche or non-digital publications. Second, the focus on large corporations (e.g., DHL, Amazon) may not fully represent the experiences of small and medium enterprises, which face different resource constraints. Third, the study's scope is limited to current AI applications, with less emphasis on emerging technologies like blockchain or IoT, which could further transform logistics. Finally, the lack of longitudinal data restricts insights into the long-term sustainability and scalability of AI implementations.

Future research should address these limitations by incorporating primary data through surveys, interviews, or case studies with logistics firms, particularly smaller enterprises, to capture diverse perspectives. Quantitative studies could measure AI's impact on specific metrics, such as return on investment or carbon footprint reduction, providing more precise insights. Exploring the

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integration of AI with emerging technologies, such as blockchain for transparent supply chains or IoT for real-time tracking, could uncover new optimization opportunities.

DECLARATIONS OF INTEREST STATEMENT

The authors affirm that there are no conflicts of interest to declare in relation to the research presented in this paper.

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