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# Artificial Intelligence in Logistics

**Matthew N. O. Sadiku[1], Samuel A. Ajayi[2], Janet O. Sadiku[3]**

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Texas Southern University, Houston, TX, USA
[3]Juliana King University, Houston, TX, USA

## ABSTRACT

Artificial intelligence (AI) is a technology that is rapidly transforming the logistics industry. It refers to the use of algorithms and machine learning to automate and optimize various logistics processes. Artificial intelligence is truly a force to be reckoned with in the logistics industry, bringing incredible opportunities to automate routine tasks, improve efficiency, and reduce costs. AI in logistics revolutionizes operations through intelligent automation, predictive analytics, and optimization, enhancing everything from warehouse management to demand forecasting. The purpose of this paper is to explore the integration of artificial intelligence technology with logistics systems.

***KEYWORDS:*** *artificial intelligence, machine learning, AI, generative AI, logistics, supply chain, transportation.*

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## INTRODUCTION

AI is no longer a distant possibility but a current necessity in the logistics landscape. The dawn of AI has the potential to transform logistics and supply chain management radically. Compared with traditional logistics systems, the use of artificial modern logistics system intelligent technology can increase work efficiency by 25% and reduce logistics costs by about 31% [1]. AI continues to help logistics businesses improve efficiency, optimize resources, and drive the top line. It encourages logistics players to turn into the fast lane by early adopting and benefitting from AI: staying ahead of the competition by reacting quickly, using knowledge gained from data, optimizing processes and designing new business models.

## WHAT IS ARTIFICIAL INTELLENCE?

The term "artificial intelligence" (AI) is an umbrella term John McCarthy, a computer scientist, coined in 1955 and defined as "the science and engineering of intelligent machines." It refers to the ability of a computer system to perform human tasks (such as thinking and learning) that usually can only be accomplished using human intelligence [2]. Typically, AI systems demonstrate at least some of the following human behaviors: planning, learning, reasoning, problem solving, knowledge representation, perception, speech recognition, decision-making, language translation, motion, manipulation, intelligence, and creativity.

The 10 U.S. Code § 2358 define artificial intelligence as [3]:

1. "Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.
2. An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
3. An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
4. A set of techniques, including machine learning, that is designed to approximate a cognitive task.

5. An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision making, and acting."

AI provides tools creating intelligent machines which can behave like humans, think like humans, and make decisions like humans. The main goals of artificial intelligence are [4]:

1. Replicate human intelligence
2. Solve knowledge-intensive tasks
3. Make an intelligent connection of perception and action
4. Build a machine which can perform tasks that requires human intelligence
5. Create some system which can exhibit intelligent behavior, learn new things by itself, demonstrate, explain, and can advise to its user.

AI is not a single technology but a range of computational models and algorithms. The concept of AI is an umbrella term that encompasses many different technologies. AI is not a single technology but a collection of techniques that enables computer systems to perform tasks that would otherwise require human intelligence. The major disciplines in AI include [5]:

- Expert systems
- Fuzzy logic
- Neural networks
- Machine learning (ML)
- Deep learning
- Natural Language Processors (NLP)
- Robots

These computer-based tools or technologies have been used to achieve AI's goals. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. Figure 1 shows a typical expert system, while Figure 2 illustrates the AI tools. These tools are gaining momentum across every industry. Analytics can be considered a core AI capability.

## AI IN LOGISTICS

The landscape of logistics has undergone a significant transformation in recent years.

The logistics industry is facing unprecedented pressures, both externally and internally. Externally, supply chain vulnerabilities, aging infrastructure, labor shortages, and geopolitical uncertainties are creating significant disruptions. Internally, operational inefficiencies like poor data integration, outdated IT systems, and limited visibility across the supply chain further exacerbate these problems. A leading logistics player is harnessing AI agents to streamline operations, elevate efficiency, and create new value for customers [6]. AI trends are collectively transforming transportation, supply chains, and logistics. The role of AI in logistics is ultimately to streamline operations across order processing, inventory management, supply chain, and distribution in order to offer an enhanced customer experience. Greater efficiency and productivity, lower costs, reduced room for errors caused by human factors, and addressing labor shortages are some of the leading reasons companies are incorporating AI-driven technology into their operations.

Many AI features such as prediction, intelligent workflow automation, robotics, and vision recognition have demonstrated significant advantages in logistics companies and organizations. AI is already empowering decisions across the Defense Logistics Agency (the Nation's Logistics Combat Support Agency, with their symbol in Figure 3 [7]) with over 55 models in various stages of production, testing and use in areas like demand planning and supply chain risk management. The goal is to ensure that AI-driven decisions do not compromise security, quality or operational efficiency, ultimately protecting both the agency and the warfighter. Global players such as FedEx, UPS, and DHL have invested heavily in AI to maintain their competitive advantage. The DHL Logistics Trend Radar consolidates key logistics trends and serves as an invaluable strategic resource for their customers and the logistics community. Understanding emerging trends, recognizing potential use cases, and navigating the technical and ethical challenges require savvy partners [8].

## APPLICATIONS OF AI IN LOGISTICS

The potential of artificial intelligence (AI) in logistics is enormous. The growth projections for AI in logistics in the years ahead are staggering, signaling that its moment has truly arrived. AI in logistics boosts efficiency, cuts costs, and improves customer satisfaction through route optimization, demand forecasting, warehouse management, real-time tracking, predictive maintenance, smart traffic management, and chatbots for customer support. Figure 4 shows some use cases of AI in transportation and logistics [9]. Key applications of AI in logistics include the following [10-12]:

- *Order Processing:* This involves receiving orders, verifying them and updating inventory systems. AI comes into play early on in the process for error identification in order data, with the ability to identify, for example, if an order has an unusual combination of items or an incorrect address. By detecting patterns and anomalies that may indicate potential errors in future orders, this can help reduce errors in order fulfillment.

- *Picking and Packing:* This takes locating the items ordered, packing them and preparing them for shipping. Here, automated methods can reduce human error and optimize warehouse efficiency by collecting products that are shelved in the same location at the same time, even across multiple orders. Robots controlled by AI significantly reduce picking times. AI can optimize product picking—when warehouse staff gather products to fulfill an order—by uncovering order patterns and suggesting that products frequently ordered together be moved to the same part of the warehouse. AI algorithms can also assist in planning the most efficient warehouse routes for product pickers to fulfill orders.
- *Shipping:* AI is used in shipping to optimize carrier selection, transportation routes, labeling parcels, arranging transportation, and sending the products to the customer, as well as to monitor shipment status and identify potential delays or issues.
- *Route Optimization:* This is a critical aspect of logistics, as it determines the most efficient route for goods to travel from one point to another. In logistics, this is done by considering various factors such as distance, traffic conditions, and delivery schedules. By using AI to analyze large volumes of data, logistics companies can optimize their delivery routes to reduce fuel costs, improve delivery times, and enhance driver safety. AI algorithms can process data from various sources such as traffic sensors, GPS tracking, and weather forecasts to determine the best possible route. AI analyzes real-time data to find fastest, most fuel-efficient routes, maximizing cargo space and reducing delays. AI can also be used to optimize routes based on weather conditions, taking into account factors such as rain or snow.
- *Inventory Management:* This is a critical function for any ecommerce business. The success of an ecommerce business depends partly on how effectively it manages its inventory. Inventory management is the process of managing and tracking the goods that a business has in stock. It involves managing inventory levels, ordering and restocking products, and ensuring that inventory is managed efficiently. However, inventory management can be a challenging task and artificial intelligence (AI) can be a game-changer. AI-powered inventory management systems can help ecommerce businesses make better inventory decisions by automating many of the manual processes involved. AI predicts demand with high accuracy, optimizing stock levels to prevent overstocking and stockouts. Figure 5 shows a representation of AI in inventory management [8].
- *Warehouse Management*: Today there are warehouses whose operating principles can no longer be understood by human observers because they are managed by artificial intelligence. In these warehouses, products are no longer grouped by category and simply positioned next to one another, as we are familiar with from supermarkets, for example. AI technologies lead to a reduction in warehouse inventories and faster cycle times. Autonomous mobile robots (AMRs) handle picking and transport, increasing productivity and filling labor gaps. Warehouse employees and supervisors have to communicate with one another promptly in order to respond to changes or disruptions.
- *Logistics Management:* A subset of supply chain management, logistics management involves the transportation of raw materials and the movement and storage of products. Logistics managers are constantly on the hunt for more efficient ways to manage this process. Now that AI is being built into different applications and devices, logistics managers have ever more precise tools at their disposal. Logistics managers are starting to use new AI capabilities to improve transportation efficiency, for example, by analyzing traffic and weather patterns to help identify the most fuel-efficient transport routes and avoid costly delays.
- *Fleet Management:* AI capabilities built into fleet management applications can help managers determine the best mix of for-hire carriers versus private fleet carriers. In addition, these tools can help autonomously assign loads to drivers and adjust the start times for shipments based on historical internal and external data.
- *Predictive Maintenance:* This is a proactive approach to maintenance that uses data analysis and machine learning algorithms to predict when maintenance is required, helping logistics companies to identify problems before they occur. It is a technique used to predict when maintenance tasks, such as equipment repairs or replacement, are required. The use of predictive analysis in the logistics sector is becoming increasingly important as businesses seek to reduce costs and improve efficiency. Predictive maintenance is a critical area in which artificial intelligence is transforming the logistics industry since downtime can be costly in delays and lost revenue. By using AI to analyze data from machines, businesses can identify issues before

they become serious and take preventative action that minimize business disruption. There are four pillars of predictive maintenance: data acquisition, data transfer, data evaluation, and measures to maintain functionality.

## BENEFITS

AI creates smarter, faster, and more resilient supply chains with benefits like lower fuel use, reduced errors, and better resource allocation. AI can be used to automate routine tasks in order to reduce costs, improve efficiency, and provide better customer service. As shown in Figure 6 [9], the benefits of AI in transportation and logistics include less manual work, sustainability, improved decision-making, cost savings, dynamic pricing, and better customer experiences. Thus, the benefits include the following [10,13]:

- *Less Manual Work:* Integrating AI in transportation helps transition from traditional, paper-based systems to automated digital workflows, reducing paperwork and enhancing operational accuracy. Automated processes eliminate manual data entry errors and allow staff to focus on higher-value tasks.
- *Sustainability:* Sustainable development is a philosophy of development that aims to meet the needs of the present while protecting the rights of future generations. It seeks to achieve a balance between the society, economy, and environment. Logistics optimization is. a relevant endeavor in achieving sustainability goals. Researchers emphasize the need for cleaner transportation options, sustainable production, and eco-friendly logistics to meet the challenges presented by a growing population and finite natural resources. The green logistics framework illustrates the complex relationship between logistics activities and their environmental impacts and costs.
- *Predictive* Capabilities: These capabilities of AI have made demand forecasting easier. When inventory is behind the demand schedule, businesses lose money. Network planning and demand planning are becoming more efficient thanks to AI, which enables merchandisers to be more proactive. AI enables more accurate demand forecasting by analyzing historical data patterns alongside external factors such as weather, economic indicators, and social trends.
- *Smart Decision-making*: AI logistics solutions collect, process, and analyze large datasets from various sources like IoT sensors, GPS, and operational data to make informed decisions. At the same time, machine learning algorithms predict trends and optimize routes so one can anticipate needs and efficiently allocate resources.
- *Cost Reduction:* Companies optimize expenditures by choosing cost-effective routes, managing fuel usage, and scheduling maintenance to avoid expensive last-minute fixes. AI saves money on fuel, labor, inventory holding, and prevents losses from fraud or disruptions.
- *Better Customer Experience*: AI-powered systems allow for real-time tracking and updates, keeping clients informed throughout the shipping process. At the same time, they boost confidence and trust. AI offers accurate delivery estimates (ETAs) and faster service through optimized processes. AI-powered chatbots provide instant answers to common logistics queries, improving customer experience.
- *Process Automation:* It can be tedious to perform repetitive tasks such as processing orders, scheduling deliveries, or filling out endless paperwork. Using intelligent algorithms and robotic process automation (RPA), businesses can combine artificial intelligence and logistics to handle these time-consuming operations. This means fewer errors, faster operations, and happier employees who can focus on more important tasks.

## CHALLENGES

The enormous potential benefits of using AI in transportation and logistics do not come without challenges. The logistics industry faces the challenge of increasing efficiency, reducing costs, and minimizing environmental impact. A significant challenges for logistics firms is their struggle to meet rising customer expectations for faster, personalized, and seamless deliveries. Employees are sometimes intimidated by new applications and may resist adoption. Other challenges include [10]:

- *High Cost*: Implementing AI technology often requires significant investment in hardware, software, and infrastructure, which can be costly. For smaller companies or those with limited budgets, these expenses may be prohibitive and prevent them from fully adopting AI technology. The cost of hiring and training employees who are skilled in AI technology increases the overall cost of implementation and maintenance.
- *Privacy:* Computer vision and audio AI rely on surveillance technology. If people perceive the methods as invasive, the result can be lower morale, higher work-related stress, and counterproductive behaviors. When using AI systems to handle sensitive customer data,

historical cybersecurity breaches have left businesses lacking in confidence when it comes to technology solutions. In this case, it is important to consider if AI is appropriate to embed - some processes may lend themselves to other forms of automation.

- *Ethical Considerations:* Ethical considerations cannot be overlooked. And therefore, enterprises must maintain human control over critical decisions and establish clear accountability frameworks. As AI rapidly scales up, ethical considerations have become an important near-term trend that examines the implications of AI to ensure its responsible development and deployment. The security of data and algorithms, bias, and transparency are important. The logistics industry will likely face heightened regulatory scrutiny in the coming years. Ethical end use can also be encouraged by soliciting consumer feedback on perceived biases in route planning or AI results.
- *Integration with Existing Systems:* Integration with existing systems is essential for sustainable implementation. Integrating new AI capabilities into a legacy on-premises logistics application can be a daunting task, often requiring a systems integrator.
- *Collaboration:* Collaboration between companies and technology providers drives future innovation and competitive advantage in the logistics industry. Research could explore establishing guidelines that promote transparency, accountability, and inclusivity. This might involve collaborative efforts, bringing together experts from the fields of technology, ethics, law, sociology, and psychology to build a cohesive and comprehensive blueprint for ethical or responsible AI use.

## CONCLUSION

AI, as many experts concede, is still in the early stages of development when it comes to applications in operational logistics. Many organizations, however, remain uncertain about how best to implement it. The logistics industry is beginning to see the value of AI in improving production and delivery. Through the use of AI technologies, logistics providers are not only able to differentiate themselves from the competition, but also to increase their returns.

AI and logistics are all about applying artificial intelligence technologies to streamline logistics operations. By implementing various uses of AI in logistics, businesses can reap the rewards and stay ahead of the competition. With the continued advancement of AI technology, the possibilities for the logistics industry are endless: data integration and compatibility, scalability, accurate forecasting, bridging gaps in skills, improving efficiency, etc.

By analyzing data, AI can predict future production and transportation volumes, leading to more efficient resource utilization. The future of the logistics sector with AI is bright. Artificial intelligence is essential for lowering expenses, saving time, boosting productivity and improving efficiency. More information on AI in logistics is available from the books in [14-25] and the following related journals:

- The AI Journal
- AI Magazine
- Journal of Business Logistics

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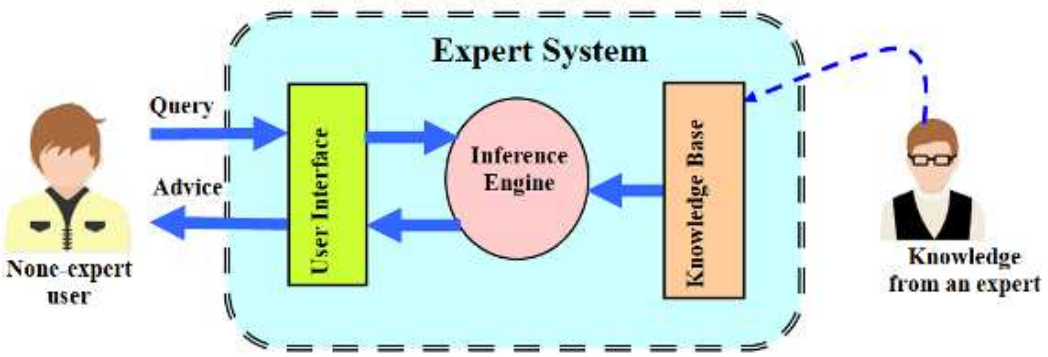


**Figure 1 A typical expert system.**

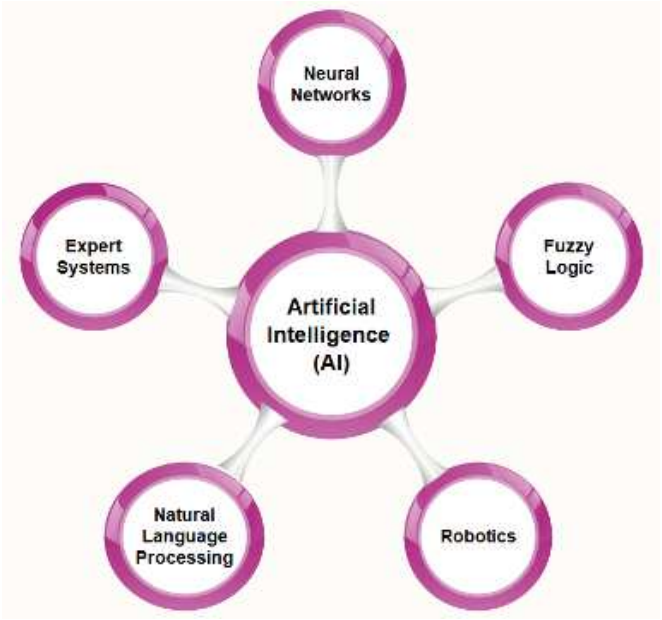


**Figure 2 AI tools.**


**Figure 3 Symbol of Defense Logistics Agency [7].**

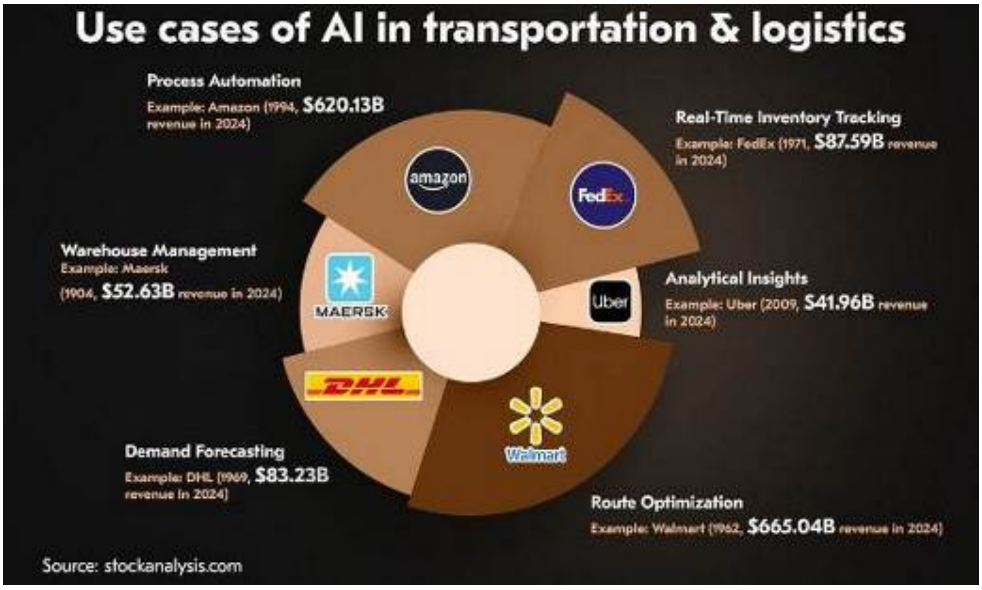


**Figure 4 Some use cases of AI in transportation and logistics [9].**

**Figure 5 A representation of AI in inventory management [8].**

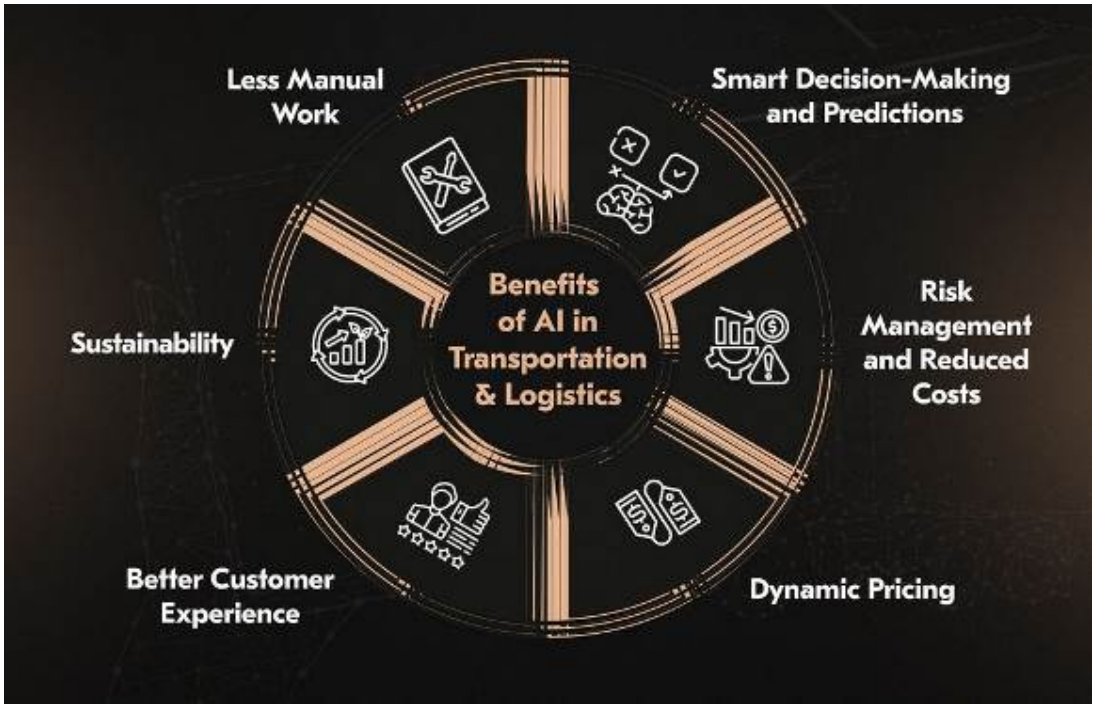


**Figure 6 Some benefits of AI in transportation and logistics [9].**