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Artificial Intelligence in Logistics and Distribution: The function of AI in dynamic route planning for transportation, including self-driving trucks and drone delivery systems

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Abstract

Artificial Intelligence (AI) is revolutionizing logistics and distribution by enhancing efficiency, reducing costs, and improving the overall delivery experience. One of the key applications of AI in this sector is dynamic route optimization, where machine learning algorithms analyze real-time data such as traffic patterns, weather conditions, and road closures to continuously adjust delivery routes. This reduces fuel consumption, optimizes delivery times, and mitigates operational disruptions. In parallel, autonomous delivery systems, including drones and self-driving trucks, are transforming last-mile and long-haul transportation by minimizing human intervention and increasing speed and reliability. AI-powered autonomous delivery systems leverage advanced technologies such as computer vision, sensors, and machine learning to navigate and make real-time decisions. Drones, for example, are already being utilized for time-sensitive deliveries, especially in remote or underserved areas, while self-driving trucks promise to revolutionize long-haul freight transportation with the potential for 24/7 operation, cost reduction, and increased safety. Despite the clear benefits, challenges such as regulatory frameworks, safety concerns, and public acceptance remain as significant barriers to large-scale adoption. This review explores the role of AI in dynamic route optimization, drones, and self-driving trucks within logistics, providing insights into how these technologies are currently being implemented and the challenges that lie ahead. It further discusses the potential for AI to reshape the future of logistics and transportation by driving innovation in automation, reducing operational inefficiencies, and contributing to the development of smarter, more sustainable supply chains. The future of AI in logistics promises a more integrated, cost-effective, and agile system that can adapt to global challenges and evolving consumer demands.

Keywords: Artificial Intelligence; Transportation; Drones; Self-Driving Trucks

1. Introduction

The increasing integration of Artificial Intelligence (AI) technologies has brought about a significant transformation in the logistics and distribution sector (Javaid et al., 2022). As the global economy becomes increasingly interconnected and customer expectations rise, the logistics sector is under pressure to optimize operations, reduce costs, and enhance service delivery. AI is playing a critical role in addressing these challenges by driving efficiencies across supply chains (Sanders et al., 2019). One of the most significant contributions of AI is in optimizing route planning and transportation

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management. Traditional logistics methods rely on static routes and time-consuming decision-making processes, often leading to inefficiencies and delays (Agupugo and Tochukwu, 2021). AI, with its ability to analyze vast amounts of data in real-time, has introduced a dynamic approach to route optimization, adjusting delivery paths based on factors such as traffic conditions, weather, and vehicle performance. By doing so, AI reduces fuel consumption, decreases delivery times, and improves overall cost-effectiveness (Agupugo *et al*., 2022). Furthermore, AI is transforming the logistics sector by enabling real-time tracking, predictive maintenance, and smart inventory management (Kaul and Khurana, 2022). AI-driven systems can forecast demand, optimize storage and retrieval, and ensure the timely replenishment of goods, thereby enhancing the efficiency of supply chains. In distribution, AI's role is also seen in reducing human error and improving safety. Automated systems, powered by AI, can perform tasks such as sorting and packaging with high precision, while machine learning algorithms help to predict potential disruptions in the supply chain, allowing for proactive adjustments (Kumar *et al*., 2022; Manuel *et al*., 2024). As a result, AI is rapidly becoming indispensable for logistics firms aiming to stay competitive in a fast-evolving global market.

This review aims to explore the transformative impact of AI in the realm of logistics and distribution, particularly focusing on its role in dynamic route optimization, autonomous delivery systems, drones, and self-driving trucks. The integration of AI in these areas has led to innovative advancements, streamlining operations, improving efficiency, and ensuring faster, more reliable delivery services. Specifically, the review will examine how AI algorithms enable real-time adjustments in route planning based on changing conditions, helping logistics providers to optimize their fleets and resources. Additionally, the review will delve into the deployment of autonomous delivery systems, such as drones and self-driving trucks, which are reshaping last-mile delivery and providing new opportunities for reducing operational costs and increasing delivery speed. By examining these key innovations, the review aims to highlight how AI is not only transforming the operational aspects of logistics but also creating new business models and opportunities for companies in the distribution sector. Furthermore, it will consider the potential benefits of these AI-driven technologies, including the reduction of human error, the enhancement of supply chain transparency, and the improved scalability of logistics operations. However, the review will also address the challenges posed by these innovations, such as technological limitations, regulatory concerns, and the impact on employment within the logistics sector. Ultimately, this review seeks to provide a comprehensive understanding of how AI is revolutionizing logistics and distribution, offering a glimpse into the future of a fully automated, AI-powered industry.

1.1. AI in Dynamic Route Optimization

Route optimization is the process of identifying the most efficient path for transportation in order to minimize costs, time, and resources (Qadir et al., 2021). It is an essential part of contemporary transportation logistics, where businesses strive to deliver goods to customers as quickly as possible while lowering fuel consumption and operating expenses. Route optimization entails choosing the best routes based on a number of factors, including delivery times, traffic patterns, road conditions, and vehicle capacity (Humagain et al., 2020). Traditionally, route planning was done manually or through basic software that utilized static data. However, this method faces several challenges, including unpredictable traffic congestion, varying weather conditions, road closures, accidents, and fluctuations in fuel prices. These factors can lead to delays, increased costs, and suboptimal resource utilization. As a result, the traditional approach to route planning often struggles to achieve the desired level of efficiency in a dynamic environment.

Artificial intelligence, with its capacity to process large volumes of real-time data, has become a transformative tool in dynamic route optimization as shown in figure 1. Unlike traditional systems that rely on static data, AI systems are designed to make continuous adjustments to routes based on up-to-the-minute information, enhancing both flexibility and efficiency. AI-driven dynamic route optimization uses real-time data from multiple sources, such as traffic sensors, GPS devices, weather reports, and accident databases, to make adjustments to delivery routes as conditions change (Abduljabbar *et al*., 2019). This allows logistics companies to respond quickly to unforeseen events, such as traffic congestion, road closures, or adverse weather, which could otherwise disrupt scheduled deliveries. For example, if a traffic jam or an accident is detected along a planned route, the system can instantly suggest an alternate path, thus minimizing delays and maintaining efficiency. Machine learning algorithms also play a significant role in dynamic route optimization by leveraging historical data to predict future conditions. These algorithms can identify patterns in traffic flow, road usage, and weather conditions, enabling more accurate route predictions. For instance, if a particular stretch of road is frequently congested during certain times of the day or week, the AI system can factor this knowledge into future route planning, avoiding bottlenecks and reducing the likelihood of delays. Over time, as more data is collected and the machine learning models are trained on this information, the system becomes increasingly effective at predicting optimal routes, further enhancing the accuracy of logistics planning. The benefits of AI-driven dynamic route optimization are manifold. One of the primary advantages is fuel savings. By avoiding unnecessary detours, traffic jams, and inefficient routes, companies can reduce fuel consumption, which is not only cost-effective but also environmentally beneficial (Eliasson, 2021). Additionally, reduced delivery times directly translate to enhanced customer satisfaction, as products are delivered more quickly and reliably. The operational costs of logistics companies are also lowered, as more efficient routes result in lower wear and tear on vehicles, reduced labor costs, and improved fleet utilization.

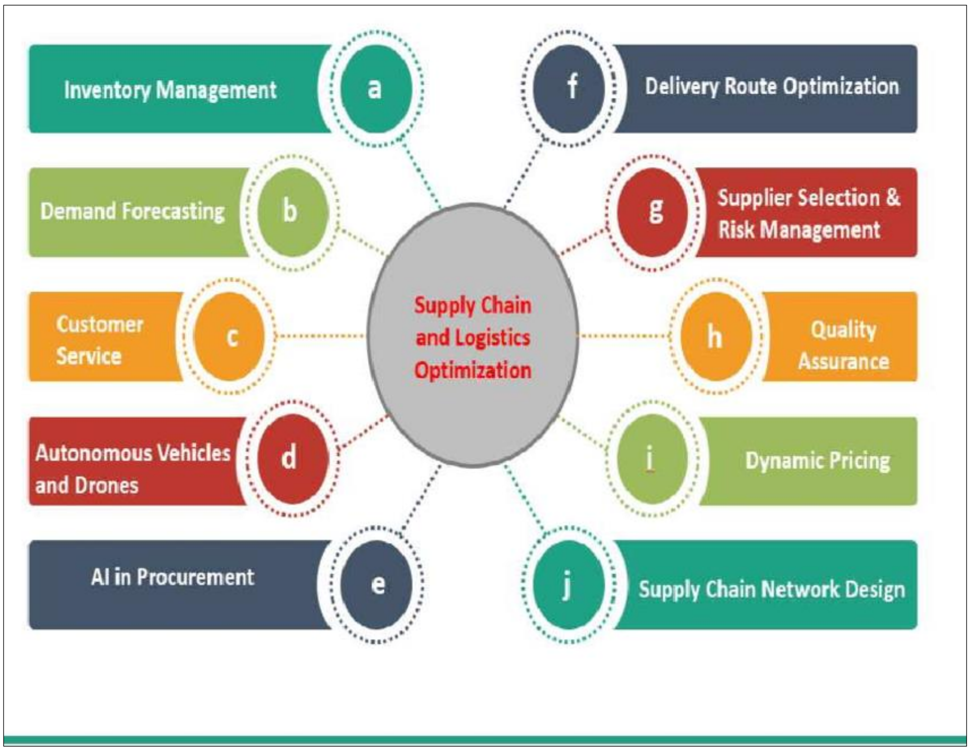

Figure 1 AI logistics and supply chain optimization (Aldoseri *et al.*, 2023)

Numerous logistics firms have already started putting AI-powered dynamic route optimization systems into practice, proving the practical advantages of these technologies in practical settings (Agupugo et al., 2024). For instance, UPS has effectively implemented ORION (On-Road Integrated Optimization and Navigation), an AI-powered system. For more than 55,000 drivers globally, ORION analyzes real-time data, such as weather and traffic patterns, to modify routes. ORION can forecast the best routes and cut down on delivery time, fuel usage, and expenses by examining past delivery data. Since its implementation, UPS has reported savings of millions of dollars in fuel costs and a reduction in carbon emissions. FedEx, another global leader in logistics, also leverages AI for route optimization. The company uses an AI-based system called the FedEx SameDay Bot, which utilizes machine learning algorithms to optimize last-mile deliveries. This system incorporates real-time data on traffic, weather, and package volume to dynamically adjust delivery routes, enhancing efficiency and reducing delivery time. Additionally, FedEx is experimenting with autonomous delivery vehicles and drones, further utilizing AI to optimize delivery times and lower costs. These case studies highlight the growing role of AI in revolutionizing the logistics industry by enhancing route optimization. Both UPS and FedEx have demonstrated that AI-powered systems lead to significant improvements in efficiency, cost savings, and customer satisfaction (Sorooshian *et al.*, 2022). These examples underscore the potential for AI to transform the logistics industry, particularly in dynamic environments where unpredictability and real-time adjustments are crucial for maintaining optimal operations. AI-driven dynamic route optimization offers a powerful solution to the challenges faced by traditional route planning in logistics. By incorporating real-time data and machine learning algorithms, companies can enhance the efficiency, cost-effectiveness, and reliability of their operations. The examples from UPS and FedEx illustrate the practical benefits of AI in logistics, demonstrating that this technology is becoming an essential tool for organizations aiming to stay competitive in an increasingly complex global supply chain (Foster and Rhodenm, 2020; Agupugo *et al.*, 2022).

1.2. Autonomous Delivery Systems

In the logistics and distribution sectors, autonomous delivery systems are quickly becoming a game-changing technology (Dong et al., 2021). These systems distribute items without the need for direct human intervention by using self-driving vehicles, such as autonomous trucks and drones. The idea is based on the larger automation and digitization movement, which aims to increase customer happiness, save costs, and improve efficiency. As seen in figure 2, autonomous delivery systems use state-of-the-art technology like robots, machine learning, and artificial intelligence

(AI) to navigate, optimize, and carry out delivery operations. Drones for little packages and self-driving trucks for big or long-distance freight are two examples of autonomous vehicles in logistics (Graf and Anner, 2021). Drones, which are lightweight and capable of reaching remote or difficult-to-access locations, are particularly useful for last-mile delivery in urban or rural settings. Self-driving trucks, on the other hand, are designed for long-haul freight, capable of covering extensive distances with minimal human supervision. Both types of vehicles promise to revolutionize the delivery process, offering benefits such as improved delivery speed, reduced operational costs, and the ability to reach locations that would otherwise be difficult or expensive to service. As the technology matures, autonomous delivery systems are increasingly seen as a crucial part of the future of logistics, where speed, cost efficiency, and sustainability are paramount (Srinivas *et al*., 2022). Their implementation is anticipated to significantly reduce human labor costs, mitigate traffic congestion, and lower carbon emissions by optimizing fuel usage.

Artificial intelligence is at the core of enabling autonomous delivery systems to function efficiently and safely as shown in figure 2 (Garikapati and Shetiya, 202). AI facilitates various key functions, including navigation, decision-making, and ensuring the overall safety of the autonomous vehicles. One of the most crucial aspects of AI in autonomous delivery systems is its ability to process and analyze vast amounts of data in real time to make informed decisions about navigation and route planning (Bathla *et al*., 2022). AI-powered systems use a combination of sensors, cameras, and lidar to gather data about the vehicle's environment, such as the road conditions, obstacles, traffic, and pedestrians. Computer vision algorithms help the vehicle recognize objects, road signs, and other important elements of its surroundings. Machine learning models, trained on vast datasets, then allow the vehicle to predict and respond to potential hazards, navigate around obstacles, and determine the most efficient path for delivery. The AI system in autonomous delivery vehicles continuously processes data to make real-time decisions. For example, if a self-driving truck encounters a traffic jam, it can assess alternative routes in seconds based on real-time traffic data, weather reports, and historical data about road conditions. Additionally, AI enhances decision-making when it comes to identifying safe stopping points, optimizing fuel consumption, and determining the best parking or unloading zones at delivery destinations. Safety is another key area where AI plays a critical role. Autonomous delivery systems need to adhere to strict safety protocols, and AI ensures that the vehicle operates within those boundaries (Barrie *et al*., 2024). AI algorithms continuously monitor the vehicle's performance, detect malfunctions, and manage emergency situations. In the case of drones, AI helps in obstacle avoidance and precise landing, ensuring that deliveries are completed safely even in complex environments.

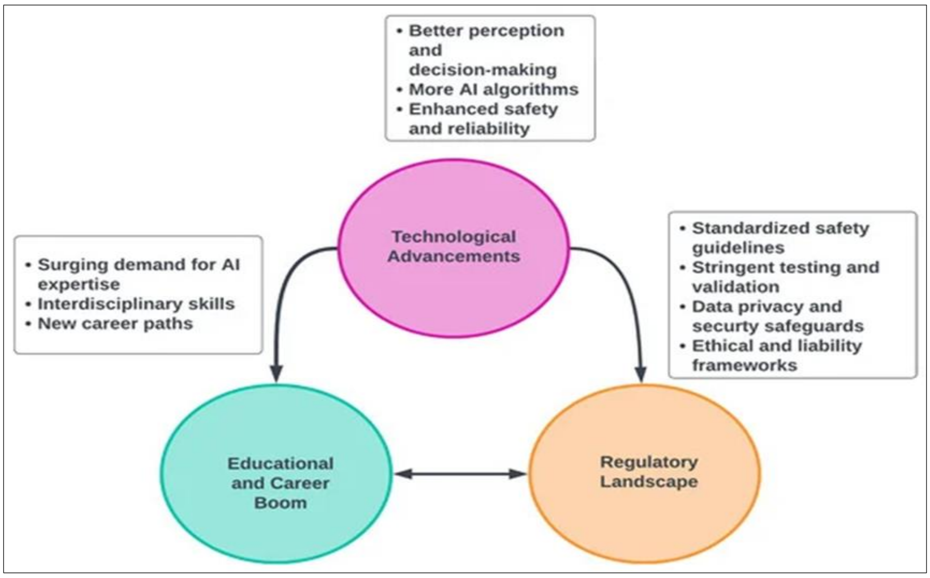

Figure 2 Advantages of AI in Autonomous vehicles (Garikapati and Shetiya, 2024)

The implementation of autonomous delivery systems improves distribution and logistics in a number of noteworthy ways. Speed is among the most important benefits. By avoiding human drivers' constraints, including shift hours or breaks, autonomous cars can work around the clock and speed up deliveries (Leonard et al., 2020). Particularly, drones can do last-mile deliveries in a matter of minutes, guaranteeing quicker client delight. AI also increases delivery precision. Packages can be precisely tracked by autonomous systems, which can also guarantee that they are delivered to the right place and reduce human mistake that comes with manual handling. AI also streamlines the route planning procedure, which lowers carbon emissions and fuel usage. This lowers operating expenses for businesses and advances environmental goals. Another significant advantage is cost savings. By automating delivery, companies can cut down on human labor costs and reduce the need for expensive infrastructure, such as large fleets of delivery vehicles and warehouses. Additionally, autonomous delivery systems are well-suited to difficult-to-reach areas, such as remote or congested urban zones, where traditional logistics might be inefficient or costly (Ducarme and Agrell, 2019). Despite these benefits, there are significant challenges associated with the widespread adoption of autonomous delivery systems. Safety is a primary concern. Ensuring that these vehicles operate without causing harm to pedestrians, other vehicles, or infrastructure requires rigorous testing, regulatory oversight, and fail-safe systems. The complexity of real-world environments such as varying weather conditions, unexpected road obstacles, and unpredictable human behavior presents hurdles that autonomous systems must overcome to function safely and reliably (James *et al*., 2020; Agupugo, 2023).

Many governments are still developing and refining policies to govern the use of autonomous vehicles on public roads and airspace (Topcu *et al*., 2020). These regulations need to balance innovation with safety, ensuring that these vehicles can operate safely in mixed traffic environments without compromising public safety or security. Public acceptance is another obstacle. Many consumers and businesses may be skeptical about the reliability and safety of autonomous delivery systems, particularly when it comes to drones flying in urban areas or self-driving trucks on highways. Public trust will be essential for the widespread adoption of this technology. Autonomous delivery systems, powered by AI, hold the potential to revolutionize the logistics and distribution industries (Abosuliman and Almagrabi, 2021). While they offer benefits such as speed, accuracy, cost reduction, and the ability to access hard-to-reach areas, the technology still faces challenges related to safety, regulation, and public acceptance. However, with ongoing advancements in AI and the continued development of regulatory frameworks, autonomous delivery systems are likely to become an integral part of the logistics ecosystem in the near future.

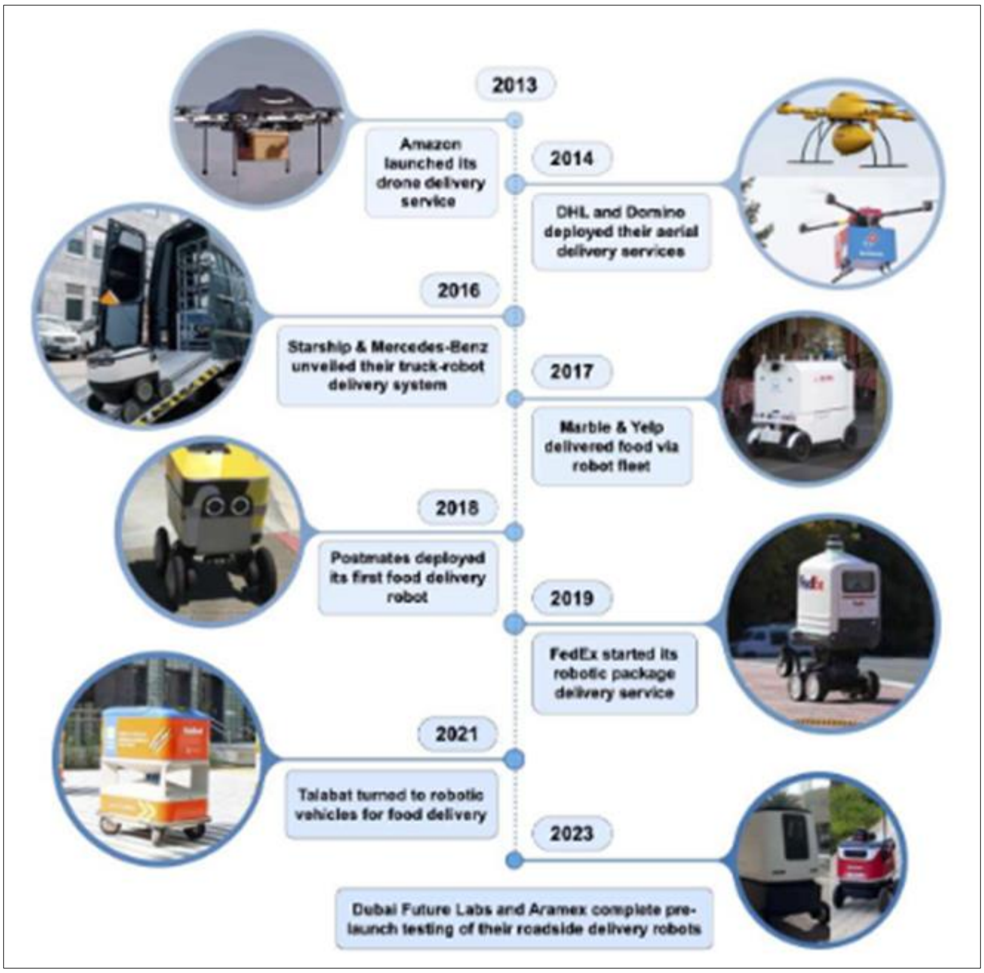

Figure 3 Examples of unmanned LMD services that have been implemented in the real world since 2013 are listed chronologically (Shaklab et al., 2023)

1.3. Drones in Logistics

Unmanned aerial vehicles, or drones, are quickly becoming a crucial component of the transportation and logistics industries. Table 1 lists some features of drones in logistics. These tiny, remotely piloted or autonomous aerial vehicles are being used more and more for distribution, particularly in situations where conventional delivery techniques are impractical (Smith et al., 2022). In sectors like last-mile deliveries and access to isolated places that could otherwise be costly or difficult to service, drones provide a number of benefits (Borghetti et al., 2022). They are ideal for last-minute deliveries of consumer items, groceries, and medical supplies because they can transport tiny to medium-sized products. The concept of drones in logistics revolves around using UAVs to deliver goods directly to customers or businesses, bypassing the need for traditional delivery vehicles. This method is particularly advantageous for urban environments, where traffic congestion can delay deliveries, as well as in rural or hard-to-reach areas where infrastructure is limited or inefficient. Drones can navigate directly to specific coordinates, avoiding ground-level traffic and obstacles, significantly cutting delivery times.

One of the most notable impacts of drones in logistics is their potential to revolutionize last-mile delivery. This final leg of the delivery process, from a local distribution center to the end consumer, is traditionally the most costly and time-consuming part of the supply chain. Drones, particularly those capable of autonomous flight, promise to streamline this process, lowering operational costs, increasing efficiency, and enhancing the overall customer experience (Mohamed *et al.*, 2022). In addition to last-mile deliveries, drones also provide access to remote regions that traditional delivery methods may struggle to reach. For example, in areas with poor road infrastructure, drones can quickly deliver essential goods such as medical supplies, food, and emergency equipment, saving time and potentially saving lives in critical situations.

Table 1 Emphasizes a number of drone-related logistics aspects (Smith *et al.*, 2022)

Aspect	Description	Examples
Applications	Tasks drones perform in logistics.	Last-mile delivery, inventory management, surveillance, and emergency response.
Advantages	Benefits of using drones in logistics.	Reduced delivery time, cost savings, improved accessibility to remote areas, and environmental benefits.
Limitations	Challenges associated with drones in logistics.	Limited payload capacity, battery life, weather dependency, and regulatory issues.
Technology Features	Key technological aspects enabling drone operations in logistics.	GPS navigation, real-time tracking, automated piloting, and AI-based route optimization.
Key Players	Companies leading drone integration into logistics.	Amazon (Prime Air), UPS (Flight Forward), and Zipline (medical supply deliveries).
Regulations	Legal and regulatory frameworks influencing drone use in logistics.	FAA rules, airspace management policies, and drone certification requirements.
Sustainability Impact	Contribution of drones to sustainable logistics practices.	Reduced carbon emissions, minimized traffic congestion, and reduced fuel consumption.

Artificial intelligence plays a crucial role in maximizing the capabilities of drones in logistics. AI technologies enable drones to operate autonomously, navigate complex environments, and optimize delivery routes without direct human intervention. One of the key AI applications in drone logistics is navigation. Drones must be able to fly from one point to another with high precision, avoiding obstacles such as buildings, trees, or power lines, and adapting to changing conditions in real time (Mohsan *et al.*, 2022). AI systems use sensors, cameras, and radar to gather data about the drone's surroundings, and machine learning algorithms process this data to make autonomous decisions, such as adjusting flight paths or altitude to avoid obstacles. Path planning is another important application of AI in drones. AI-powered algorithms can analyze factors like weather, wind conditions, and airspace restrictions to determine the most efficient flight path for the drone. By continuously collecting and analyzing data, AI systems can optimize routes in real time, ensuring that deliveries are completed on time and with minimal risk. AI also plays a key role in delivery management, ensuring that drones follow secure and efficient processes. For instance, AI systems can monitor a drone's battery levels, ensuring that it has enough charge to complete the delivery and return to its base safely. Additionally, AI can help with fleet management by coordinating multiple drones to avoid congestion in busy airspaces and optimize the dispatch of drones based on delivery schedules and locations. Another critical application of AI in drones is obstacle detection and avoidance. Drones are equipped with a variety of sensors, such as cameras, lidar, and ultrasonic sensors, that constantly scan their environment (Wilson *et al*., 2021). AI-powered systems process this sensor data to detect potential obstacles in the drone's flight path and take corrective action in real time. This ability to autonomously avoid obstacles ensures that drones can operate safely in dynamic and unpredictable environments.

Restrictions on no-fly zones are also enforced by artificial intelligence. Drones must follow all applicable laws and regulations and stay out of the restricted airspace surrounding government buildings, airports, and other critical areas (McTegg et al., 2022). By preventing drones from accessing certain no-fly zones, AI-based geofencing solutions can guarantee adherence to aviation laws. Numerous businesses are already utilizing AI and drones to revolutionize logistics. For instance, Amazon's Prime Air uses drones to deliver products to clients in 30 minutes or less. AI plays a major role in the service's route planning, obstacle recognition, and regulatory compliance. Amazon uses drones for logistics with the specific goal of cutting delivery times and providing clients with quicker and more effective services (Bassey et al., 2024). Drones have already been used in certain regions for experimental deliveries, demonstrating the feasibility and benefits of this approach. Another company that has successfully integrated drones into its logistics operations is Zipline, which uses drones to deliver medical supplies to remote and hard-to-reach areas in countries like Rwanda and Ghana. Zipline's drones are equipped with AI-powered systems to ensure accurate deliveries and avoid obstacles during flight. The company's drones have been credited with saving lives by delivering blood, vaccines, and essential medicines to hospitals in rural areas with limited infrastructure. However, the widespread use of drones in logistics faces several challenges, particularly related to regulatory frameworks. Governments around the world are developing new policies and guidelines to manage drone operations and ensure safety and privacy (Lee *et al*., 2022). For example, the Federal Aviation Administration (FAA) in the United States has implemented regulations regarding drone flight altitudes, no-fly zones, and operational limits. As drone usage scales up, these regulations will need to evolve, potentially allowing drones to operate in urban airspace alongside traditional aircraft while ensuring safety and minimizing risks. Drones are revolutionizing logistics by offering faster, more efficient delivery solutions, particularly for last-mile deliveries and remote areas (Polydoropoulou *et al*., 2022). AI plays a central role in enabling these systems to operate autonomously and safely, powering navigation, path planning, obstacle detection, and delivery management. While there are still regulatory hurdles to overcome, companies like Amazon and Zipline are demonstrating the vast potential of drones in transforming global supply chains. The continued development of drone technology, supported by AI advancements, will likely play a significant role in the future of logistics.

1.4. Self-Driving Trucks in Logistics

Self-driving trucks, also known as autonomous trucks, represent one of the most transformative innovations in the logistics and transportation industry (Engholm *et al*., 2020). These vehicles are equipped with advanced artificial intelligence (AI), sensors, and autonomous driving systems that enable them to operate without the direct involvement of human drivers as shown in figure 3 (Shaklab *et al*., 2023). Initially designed to support long-haul freight operations, autonomous trucks aim to address some of the most pressing challenges in logistics, including driver shortages, efficiency constraints, and high labor costs. The shift from human-driven trucks to AI-driven autonomous vehicles is a natural progression in the evolution of transportation technology. Traditional long-haul trucking involves significant human labor, with drivers spending long hours on the road and facing challenges such as fatigue and regulatory restrictions on driving time. Autonomous trucks, powered by AI and machine learning, offer the promise of continuous operations, improved safety, and enhanced logistical efficiency. By removing the need for human drivers, these vehicles can operate around the clock, significantly reducing transportation costs and enhancing the speed and reliability of deliveries. Autonomous trucks have the potential to revolutionize the logistics industry by enabling faster, more cost-effective, and safer long-haul transportation. As the technology matures, these vehicles are expected to reduce the dependency on human drivers, streamline supply chains, and optimize freight delivery networks, making them a critical element of future logistics strategies (Fritschy and Spinler, 2019; Sun *et al*., 2022).

Artificial intelligence plays a critical part in self-driving trucks since it allows the vehicles to function independently of human interference. Numerous essential features of autonomous trucks, such as decision-making, route planning, and navigation, are powered by AI technology (Di and Shi, 2021). By using sophisticated algorithms to evaluate data from several sensors and cameras, these technologies enable the car to identify impediments, forecast traffic, and make wise decisions while driving in real time. The application of machine learning algorithms, which allow the vehicle to learn and adapt from actual driving experiences, is one of the main elements of artificial intelligence in autonomous trucks. The truck can detect traffic signs and signals, navigate complicated roads, and react to changing road conditions like construction zones, detours, or accidents thanks to these algorithms. As the truck gathers more data during its journeys, the system continuously improves its decision-making capabilities, enhancing both safety and efficiency. In addition to machine learning, autonomous trucks rely on an integrated system of LIDAR (Light Detection and Ranging), cameras, and sensors to monitor the truck's surroundings in real time (Grigorescu *et al*., 2020). LIDAR provides high-resolution, three-dimensional mapping of the environment, allowing the vehicle to detect obstacles, such as pedestrians, other vehicles, and road hazards. Cameras help the system interpret visual cues, such as traffic signals and lane markings, while other sensors, such as radar and ultrasonic sensors, support the truck in detecting nearby objects and maintaining safe distances from other vehicles. By combining data from these various sensors, the AI system can make precise, informed decisions about vehicle movement and navigation, ensuring safe operation in dynamic and unpredictable environments. The AI systems can analyze vast amounts of real-time data, including traffic patterns, weather conditions, and road closures, to identify the most efficient and safe routes (Shaygan *et al*., 2022). This ability to dynamically adjust routes based on current conditions helps minimize delays and optimize fuel consumption, contributing to cost savings and improved delivery timelines.

The adoption of self-driving trucks in logistics offers numerous benefits, both for the transportation industry and for society at large (Ryan, 2020). One of the most significant advantages is increased efficiency. Autonomous trucks are capable of operating 24/7, removing the limitations imposed by driver fatigue and regulatory restrictions on driving hours. This continuous operational capacity allows companies to optimize their delivery schedules and improve supply chain efficiency. Furthermore, AI systems can ensure that trucks follow optimal routes, avoiding traffic congestion and other delays, leading to faster deliveries and reduced fuel consumption. Another key benefit of self-driving trucks is the potential for reduced labor costs. Human drivers account for a substantial portion of operational expenses in the transportation industry (Combs *et al*., 2019). By replacing human drivers with autonomous systems, logistics companies can significantly reduce wages and benefits. Additionally, the reduction in human errors, which can result in accidents, insurance claims, and legal fees, can lead to overall cost savings.

However, the widespread adoption of autonomous trucks also presents several challenges that must be addressed. One of the primary concerns is safety. While AI systems are designed to reduce human errors, there are still concerns about the ability of self-driving trucks to handle complex driving scenarios, such as navigating in adverse weather conditions or responding to sudden changes in traffic patterns. Autonomous vehicles must be thoroughly tested and validated to ensure that they can safely operate in diverse environments (Rajabli *et al*., 2020). There are also significant legal and regulatory hurdles that must be overcome before autonomous trucks can become mainstream. Governments worldwide need to develop and implement regulations that govern the operation of autonomous vehicles, including guidelines for safety standards, licensing, and insurance. These regulations must address liability in the event of an accident involving an autonomous truck, as well as the need for data-sharing between manufacturers and regulators to ensure compliance with safety requirements. Public perception is another challenge to the widespread adoption of self-driving trucks. Many people are concerned about the potential job displacement caused by automation, especially in the trucking industry, where millions of drivers are employed globally (Mohan and Vaishnav, 2022). Additionally, there are concerns about the safety and reliability of AI systems, with some members of the public questioning whether autonomous trucks can be trusted to operate safely on public roads.

Numerous businesses are already testing self-driving trucks and attempting to incorporate them into the logistics sector. For instance, the electric self-driving truck known as the Tesla Semi is being developed by Tesla and is anticipated to transform long-distance trucking. The Tesla Semi can travel great distances on its own thanks to a combination of electric power and sophisticated AI technologies. Tesla's AI-powered technology promises to increase safety, boost efficiency, and lower operating costs. Similarly, as part of its larger goal to create completely autonomous cars, Waymo, Alphabet's (Google's parent company) autonomous driving unit, has begun testing self-driving trucks. Waymo's autonomous trucks can drive safely on highways thanks to their LIDAR, cameras, and AI algorithms. Other companies, such as Uber Freight and Embark, are also exploring self-driving trucks, with a focus on optimizing freight logistics and improving safety. Self-driving trucks represent a transformative shift in the logistics and transportation industry. By leveraging AI for navigation, route planning, and real-time decision-making, these trucks offer increased efficiency, reduced labor costs, and the potential for continuous, 24/7 operations (Tsolakis *et al*., 2022). However, challenges related to safety, regulation, and public perception must be addressed before autonomous trucks can achieve widespread adoption. As companies like Tesla, Waymo, and others continue to test and refine their autonomous truck technologies, the future of logistics is likely to see a significant shift toward AI-driven transportation solutions.

1.5. Future Directions and Emerging Trends

The future of artificial intelligence (AI) in logistics and transportation depends on how well it integrates with other cutting-edge technologies like blockchain, 5G connectivity, and the Internet of Things (IoT), in addition to its independent capabilities. These technologies' confluence will produce potent synergies that have the potential to greatly improve logistics operations' sustainability, efficiency, and transparency (Ayan et al., 2022). Together, AI and IoT create a strong ecosystem in which AI deciphers and evaluates data gathered from IoT sensors installed in cars, warehouses, and moving cargo. Real-time asset and shipment tracking is made possible by IoT devices, which also provide vital information on temperature, location, humidity, and condition while in transit. For example, AI-powered route optimization can be based on real-time traffic, weather data, and IoT-enabled sensors, improving delivery speed and reducing fuel consumption. 5G technology plays a pivotal role in this integration by enabling faster and more reliable data transfer between devices, vehicles, and centralized systems (Pham *et al*., 2020). With its low latency and high bandwidth, 5G facilitates the continuous transmission of real-time data from a large number of devices, allowing AI systems to react swiftly to changing conditions and make immediate adjustments. This capability is essential for time-sensitive logistics operations, particularly for industries such as perishable goods or e-commerce deliveries, where precision is critical. In addition, blockchain offers a secure, transparent, and decentralized framework for managing the vast amounts of data generated by AI and IoT systems. Blockchain can ensure the traceability of goods across the supply chain, creating a reliable and immutable record of every transaction (Rejeb *et al*., 2019). This enhances transparency, reduces fraud, and provides real-time proof of delivery and condition of goods, which is particularly important in industries requiring compliance with strict regulations, such as pharmaceuticals or food products. Together, AI, IoT, 5G, and blockchain have the potential to transform logistics and transportation, providing real-time visibility, optimizing operations, and increasing security and trust across the supply chain (Vaghani *et al*., 2022).

The application of AI in logistics to promote sustainability is one of the most exciting potential future directions. Businesses in the logistics sector are under pressure to lower their carbon footprint and implement more sustainable practices as environmental issues throughout the world worsen (Moshood et al., 2021). AI has the potential to significantly lower carbon emissions and optimize fleet energy use, improving the environmental friendliness of logistics operations. By ensuring that cars travel the most fuel-efficient routes, AI-driven optimization algorithms can assist logistics organizations in lowering their overall carbon emissions (Dewi et al., 2021). AI can assist in lowering the total distance traveled, reducing fuel consumption and emissions, by taking into account real-time data such as weather, traffic patterns, and road closures. Additionally, AI can be used to improve the operational efficiency of fleets by dynamically scheduling deliveries, optimizing load management, and reducing idle times for vehicles. This is particularly important as companies strive to meet global emissions targets and governmental regulations aimed at reducing carbon footprints. Moreover, AI can help manage and optimize fleet energy consumption, particularly in the context of electric vehicles (EVs). As the logistics industry increasingly adopts electric and hybrid vehicles, AI systems can be employed to monitor battery levels, optimize charging schedules, and predict the best routes for EVs based on their energy needs. AI algorithms can also assist in predicting the optimal time to recharge vehicles, ensuring that they remain operational while minimizing unnecessary energy consumption (Tong *et al*., 2019). Looking further into the future, AI has the potential to drive the development of green logistics, which prioritizes environmental sustainability while maintaining efficiency. AI-based systems could enable the integration of renewable energy sources into logistics operations, such as solar or wind energy to power electric vehicle fleets or warehouses (Singh *et al*., 2022). AI can also assist in the design of sustainable supply chains by optimizing packaging, reducing waste, and enhancing the circularity of logistics operations, all of which can contribute to reducing environmental impacts.

Longer future, artificial intelligence may be crucial to the decarbonization of global supply networks. AI will play a key role in transforming logistics into a more sustainable sector by fusing AI-driven optimization with carbon-free transportation choices, renewable energy sources, and sustainable materials (Rolandsson et al., 2020). AI-powered solutions will probably become crucial for businesses looking to meet their environmental targets while preserving their competitive edge as governments and customers place an increasing amount of importance on sustainability. Blockchain, IoT, and 5G combined with AI will produce a logistics ecosystem that is intelligent, effective, and transparent. Simultaneously, the potential of AI to drive sustainable logistics practices will contribute to reducing carbon emissions, optimizing energy consumption, and enabling the transition to greener supply chains. As AI continues to evolve and intersect with other technologies, the logistics industry is poised to become more efficient, resilient, and environmentally responsible in the years to come (Klumpp and Zijm, 2019; Dauvergne, 2022).

2. Conclusion

Artificial Intelligence (AI) is revolutionizing the logistics and distribution sector by propelling advancements in drones, self-driving trucks, autonomous delivery systems, and dynamic route optimization. Transportation logistics are being revolutionized by AI's capacity to assess real-time data, forecast the best routes, and make decisions on its own. Supply chain efficiency is increased by the use of AI-powered solutions for dynamic route optimization, which lower delivery times, fuel consumption, and operating expenses. Drones and self-driving trucks are examples of autonomous delivery systems that increase efficiency by enabling quicker and more economical delivery methods, especially in last-mile or rural places where human drivers encounter several obstacles.

The benefits of AI in logistics are clear: enhanced speed, reduced costs, increased operational efficiency, and improved safety. AI technologies enable logistics companies to respond swiftly to disruptions, optimize their fleets, and maintain service levels despite fluctuating conditions. Moreover, with AI applications in navigation, path planning, and real-time decision-making, logistics operations can adapt to dynamic environments and improve both sustainability and service quality. These advancements represent a major shift in how goods are transported, stored, and delivered.

As technology advances like 5G, IoT, and blockchain make supply chains more effective, transparent, and safe, artificial intelligence's involvement in logistics and distribution will only grow in the future. But before these technologies can be widely used, issues including public trust, safety concerns, and regulatory compliance must be resolved. Businesses must embrace the possibilities of automation and data-driven decision-making, engage in AI innovation, and incorporate these technologies into their operations if they want to stay competitive in the logistics sector. By doing this, businesses will put themselves at the forefront of a quickly changing sector while simultaneously increasing efficiency.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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