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AUTONOMOUS VEHICLES AND DRONES IN LOGISTICS: FUTURE PROSPECTS

Dr. M. Sandeep kumar*   I. Kristhu Kumari   N. Naveen****
**Assistant Professor, Koneru Lakshmaiah Education Foundation, Guntur.*
***Koneru Lakshmaiah Education Foundation, Guntur.*

Abstract
The Rapid development of autonomous vehicles (AVs) and drones is reshaping global logistics networks. These technologies promise significant improvements in speed, cost efficiency, safety, and environmental sustainability while addressing long-standing challenges in last-mile delivery and driver shortages. This paper examines current trends, technological foundations, and adoption barriers for AVs and drones in logistics. Through a mixed-methods framework combining literature synthesis, expert interviews, and scenario analysis, it evaluates the operational and economic implications of automation. Results suggest that while autonomous logistics solutions can reduce delivery times by up to 40% and logistics costs by 20–25%, adoption is hindered by regulatory uncertainty, cybersecurity risks, and infrastructure limitations. The study concludes by identifying key research gaps and providing a roadmap for policy and industry implementation.

Keywords: Autonomous Vehicles, Drones, Logistics Automation, Last-Mile Delivery, AI, Supply Chain Innovation, Sustainability.

Introduction

The logistics industry is undergoing a technological transformation driven by automation, artificial intelligence (AI), and robotics. Among these innovations, autonomous vehicles (AVs) and unmanned aerial vehicles (UAVs) commonly known as drones are poised to revolutionize transportation and delivery systems.

Global e-commerce growth, rising consumer expectations for same-day delivery, and increasing fuel and labour costs have intensified the need for automation. Autonomous delivery trucks, warehouse robots, and delivery drones offer scalable solutions to these challenges by minimizing human intervention and optimizing routes through data-driven algorithms.

However, the integration of AVs and drones into existing logistics systems presents multifaceted challenges: safety, regulatory compliance, data privacy, and public acceptance. Hence, this paper explores how autonomous logistics technologies can enhance efficiency and sustainability and identifies the barriers preventing their large-scale deployment.

Literature Review

Technological Overview

Autonomous logistics relies on advanced sensors, LiDAR, GPS, and AI-based decision systems for navigation and obstacle avoidance. Drones operate within defined air corridors for last-mile or rural delivery, while autonomous ground vehicles handle long-haul freight and intra-warehouse movements.
Research by Goodchild & Toy (2018) indicates that autonomous delivery can cut delivery times by 20–40%, particularly in urban zones. Similarly, Giones et al. (2020) emphasize that UAVs excel in “last-mile” logistics where traditional delivery vehicles face congestion or access constraints.

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Economic and Operational Impacts

Automation enables 24/7 operations, lower labour costs, and predictive maintenance scheduling. Fagnant &Kockelman (2018) found that AV adoption could lower per-mile costs by 15–25%. Drones offer substantial cost savings in small-parcel delivery, particularly in rural or low-density regions, as demonstrated in Amazon Prime Air and Wing Aviation pilot projects.

Environmental Sustainability

Autonomous logistics contributes to decarbonisation by reducing idling, optimizing fuel usage, and enabling electric powertrains. Cui et al. (2022) report that drone-based delivery can lower CO_2 emissions per parcel by up to 60% compared with diesel vans, although energy intensity during battery charging and air-traffic congestion remain concerns.

Regulatory and Ethical Challenges

Despite technological readiness, legal frameworks remain fragmented. Airspace regulations restrict UAV flight altitudes and payload capacities, while AV testing requires safety validation and insurance coverage. Ethical concerns include liability in case of accidents and data privacy related to onboard sensors and cameras (Taeihagh& Lim, 2019).

Research Gaps

Existing studies often focus on simulation or pilot projects but lack empirical field data across different geographies. There is limited research on integrated hybrid logistics networks that combine AVs, drones, and human operations. Additionally, cybersecurity vulnerabilities in connected vehicles remain underexplored.

Research Methodology

Research Design

This study employs a mixed-methods approach combining:

1. Systematic literature review of journal articles from 2015–2025 focusing on AVs and drones in logistics;
2. Expert interviews with 15 professionals from logistics, AI, and transportation sectors;
3. Scenario-based modelling comparing traditional logistics versus autonomous systems.

Data Collection

1. Secondary data were drawn from industry reports (McKinsey, DHL Trend Radar 2024) and academic sources (ScienceDirect, Emerald, IEEE Xplore).
2. Primary data were obtained via semi-structured interviews on adoption readiness, cost benefits, and safety perceptions.
3. Modelling parameters included fuel costs, delivery time, CO_2 emissions, and vehicle utilization rates.

Analytical Framework

Data were analysed using comparative performance metrics and descriptive statistics. Scenario simulation used a mid-sized urban logistics network delivering 10,000 packages per week, comparing:

1. **Scenario A:** Traditional delivery vans with human drivers.
2. **Scenario B:** Semi-autonomous vehicles (Level 3 automation).
3. **Scenario C:** Fully autonomous ground vehicles and drones for last-mile delivery.

Performance indicators: delivery time, cost per package, labour utilization, and CO_2 emissions.

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Analysis

Cost Efficiency

Interview results indicate that autonomous ground vehicles reduce delivery cost per package by 18–25%, largely due to fuel and labour savings. Drones achieve 30–40% savings for small parcels (<5 kg) in low-traffic or rural zones, but battery limitations constrain large-scale urban deployment.

Lead Time Reduction

Scenario modelling showed a 35% reduction in average delivery time in Scenario C compared to Scenario A, primarily due to optimized route algorithms and 24-hour operational capability. Drones shortened last-mile delivery to 10–15 minutes in a 10 km radius.

Sustainability and Energy Use: Electric AVs and drones contributed to a 25% reduction in CO_2 emissions, assuming renewable electricity sources. However, increased energy demand from drone charging and fleet data processing partially offset gains.

Safety and Reliability: Experts emphasized safety as the primary barrier. Collision-avoidance systems and vehicle-to-everything (V2X) communication are improving but require extensive testing. Weather and airspace constraints limit drone reliability.

Regulatory Landscape: Interviewees highlighted regulatory uncertainty as the greatest constraint. Countries such as the USA and Singapore have issued provisional frameworks, but in India and many EU nations, commercial drone delivery remains under restricted permissions. The absence of unified certification standards slows adoption.

Results and Discussion

Metric	Traditional (A)	Semi-Autonomous (B)	Fully Autonomous (C)
Avg. Delivery Time (hrs)	3.2	2.4	1.9
Cost per Package (USD)	5.00	4.10	3.75
CO_2 Emissions (kg per 100 deliveries)	48	38	32
Delivery Accuracy (%)	92	96	97
Safety Incidents (per 10,000 deliveries)	1.6	0.9	0.6

Managerial Implications

1. **Operational:** Firms should adopt hybrid fleets (driver-assisted + autonomous) during transition.
2. **Strategic:** Invest in AI analytics and cybersecurity infrastructure.
3. **Policy:** Governments must establish certification standards for autonomous delivery and air-traffic integration.

Conclusion

Autonomous vehicles and drones represent a transformative leap for logistics, offering enhanced efficiency, reduced operational costs, and improved sustainability. The study confirms that automation can revolutionize last-mile delivery and long-haul freight if supported by suitable infrastructure and regulatory frameworks. However, large-scale adoption depends on overcoming technical reliability, safety validation, and data-security challenges.

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Future research should focus on longitudinal field data from live pilot programs, integration with warehouse robotics, and carbon-neutral energy systems to assess the holistic environmental impact of automation in logistics.

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