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Review Article

A Comprehensive Review of Artificial Intelligence Applications in Drone-Based Delivery Systems

Dr. Neha Jain[1], Ayushi Sharma[2]

[1]*Asst. Professor, Department of Computer Science/IT, Malva Institute Science and Technology, Indore, M.P., India*
[2]*Asst. Professor, Department of Computer Science and Engineering, Madhyanchal Professional University, Bhopal, M.P., India*
nehajain.tit@gmail.com, ayushi.sharma@mpu.ac.in

Corresponding Author: nehajain.tit@gmail.com DOI–10.55083/irjeas.2025.v13i03003

Abstract: The need for quick, effective, and affordable delivery methods has grown as e-commerce and logistics have expanded quickly. The use of autonomous aerial solutions is being driven by the difficulties that traditional delivery systems encounter, such delays, high fuel prices, and road congestion. This study investigates how drone technology and artificial intelligence (AI) may be combined to automate navigation and improve delivery services. Real-time route planning, obstacle recognition, collision avoidance, and dynamic decision-making in a variety of environmental circumstances are made possible by AI-driven algorithms. By evaluating flight data, anticipating possible hazards, and enhancing package handling precision, machine learning models further increase system efficiency. Autonomous drones provide a number of advantages by lowering the need for human interaction, such as shorter delivery times, lower operating expenses, and increased safety.The suggested method opens the door for smart and dependable last-mile delivery services by demonstrating the potential of AI-powered drone navigation as a scalable and sustainable solution for contemporary logistics.

Keywords: IOT, Artificial Intelligence, Drone, Navigation, Machine learning

I. INTRODUCTION

The need for quicker and more effective delivery solutions has increased recently due to the quick growth of e-commerce, healthcare logistics, and on-demand services. Conventional delivery methods, which mostly depend on road transit, have several drawbacks, including labor expenses, fuel dependence, traffic congestion, and environmental issues. Drones have become a viable last-mile delivery option to overcome these constraints, providing accessibility, speed, and flexibility in both urban and rural locations.

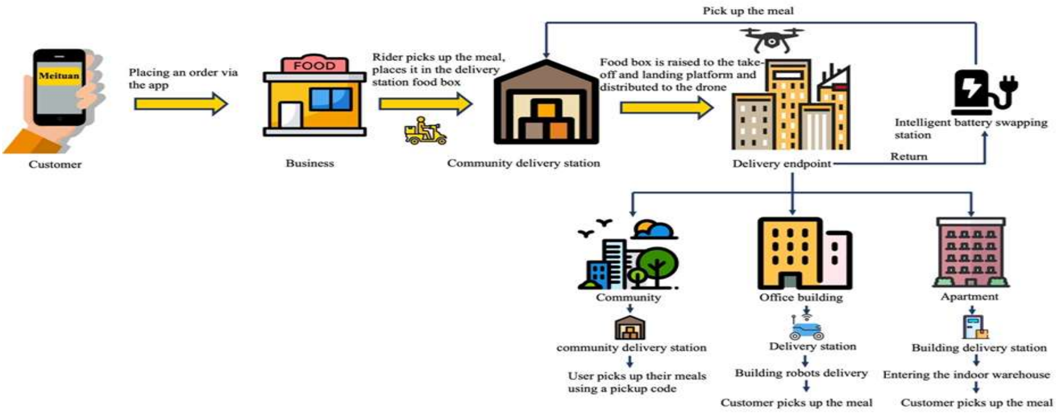


Figure 1- Drone Based Delivery System

However, the capacity of drones to function securely and independently is a major factor in how effective they are in delivery. Scalability is constrained by manual control, which also lowers operating efficiency and raises the possibility of human mistake. By facilitating automated navigation, intelligent route planning, real-time obstacle identification, and adaptive decision-making, artificial intelligence (AI) is essential to removing these obstacles. Drones can perceive and comprehend their surroundings thanks to machine learning and computer vision algorithms, which provide safe operations even in dynamic conditions.

By lowering carbon emissions and dependency on conventional transportation, incorporating AI-driven automation into drone navigation not only improves efficiency but also advances sustainability. Therefore, drone delivery systems driven by AI have enormous potential to revolutionize the logistics sector, especially in last-mile connection, where cost and time effectiveness are crucial. In order to provide dependable, scalable, and intelligent delivery services, this study aims to investigate how AI may be successfully combined with drone navigation.

II. LITERATURE REVIEW

2.1 Last-Mile Delivery Optimization & Hybrid Systems

[1]. Shuaibu, Mahmoud & Sheltami (2025) Examine current last-mile delivery (LMD) tactics, innovations, and trends. They emphasize the ways in which AI and IoT support fleet management, predictive analytics, and dynamic routing, including the combination of conventional vehicles, ground robots, and UAVs.

[2]. Joint Optimization of Truck-Drone Routing (Liua et al., 2024) creates a concept that combines drones and trucks to satisfy client demands on-demand. They contain limitations such as pathways, battery restrictions, and time penalties; they also suggest an enhanced genetic algorithm that performs better than baseline algorithms in terms of economy, timeliness, and consumer demand adaption.

[3]. Transforming Last Mile Delivery with Heterogeneous Assistants (Chen et al., 2025) investigates drone and delivery robot hybrid technologies. In order to maximize distribution with mixed vehicle types, they model them as vehicle routing issues and use genetic or metaheuristic techniques.

2.2 Multi-Agent & Energy-Aware Drone Delivery

[1]. The Freight Multimodal Transport Problem with Buses and Drones (Su et al., 2025) combines drones with buses (ground vehicles): drones finish the last mile to clients,

while buses carry packages to lockers at bus stations. To lower costs and increase coverage, they employ algorithmic improvements including mixed-integer linear programming.

2.3 Obstacle Avoidance & Navigation in 3D Environments

[1]. Vision-Based Drone Obstacle Avoidance by Deep Reinforcement Learning (2023) utilizes image and depth map input in simulated environments (AirSim + Unreal Engine) with SAC (Soft Actor-Critic) and VAE (Variational Autoencoder). High obstacle avoidance rates are attained by the model in both training and rearranged/test settings.

[2]. Deep Reinforcement Learning for Vision-Based Navigation (2023) compares DQN, PPO, and SAC for vision-based obstacle avoidance, both stationary and mobile. In complicated 3D dynamic situations, SAC and DQN (off-policy) outperformed PPO.

[3]. UAV Path Planning and Obstacle Avoidance (Actuators, 2023) employs deep Q-learning for obstacle handling and contrasts Q-learning with SARSA for path planning. Ultrasonic sensors and depth image inputs are used in the experiments to maintain a safe distance, and a virtual environment is used for simulation.

2.4 Algorithmic / Heuristic Approaches

[1]. Logistics in the Sky: Two-Phase Optimization (Hong et al., 2022) In buildings with pickup/drop locations, suggest scheduling and routing for several drones, depots, and clients. To generate cost-effective routes, they employ local search, variable neighborhood descent (VND), and simulated annealing.

[2]. Flying Sidekick Traveling Salesman Problem with Multiple Drops (Schaumann et al., 2024) examines a truck and drone working together, where the drone may make several drops before coming back to the truck. The authors demonstrate shorter delivery completion times than truck-only deliveries by proposing a heuristic based on the "order-first, split-second" method.

III. METHODOLOGY

To provide autonomous and intelligent delivery services, the suggested system combines artificial intelligence (AI) methods with unmanned aerial vehicles (UAVs). System design, data collection, AI-based processing, and testing/validation are the four main stages of the technique.

3.1 System Design

- **Hardware Selection:**
  - UAV platform: a quadrotor drone with GPS, LiDAR/ultrasonic sensors, and an IMU (Inertial Measurement Unit) for obstacle identification and navigation.
  - Onboard computing: NVIDIA Jetson Nano and Raspberry Pi for processing AI in real time.
  - Communication module: RF transceiver or 4G/5G for remote control and monitoring.
  - Payload mechanism: a box-lock/gripper method for safe package management.
- **Software Environment:**
  - Programming: ROS (Robot Operating System) and Python for controlling UAVs.
  - Simulation: Prior to field testing, navigation is tested in simulated situations using Gazebo or AirSim.

3.2 Data Acquisition

- **Sensor Data Collection:**Environmental information including GPS coordinates, altitude, and obstacle distance is recorded by drone sensors.
- **Visual Input:**To detect objects, identify landing sites, and modify routes, camera footage is gathered.
- **Flight Logs:**AI models are trained using historical drone flight data,

including speed, energy usage, and route trends.

3.3 AI-Based Processing

- **Path Planning:**
  - In dynamic contexts, reinforcement learning, or RL, is used to optimize routes.
  - Adaptive navigation uses algorithms like SAC (Soft Actor-Critic) and DQN (Deep Q-Network).
- **Obstacle Detection and Avoidance:**
  - To identify obstacles, Convolutional Neural Networks (CNN) analyze camera pictures.
  - Accurate distance measuring and safe navigation are ensured by sensor fusion (LiDAR + vision).
- **Autonomous Decision-Making:**
  - In the event of limited areas, bad weather, or closed pathways, AI algorithms forecast the best alternate route.
  - To guarantee that the drone returns to base before its battery runs out, energy-aware scheduling is used.
- **Package Delivery Automation:**
  - Computer vision (marker or QR-based recognition) for landing zone detection.
  - A servo-controlled payload mechanism for the package's automated release.

3.4 Testing and Validation

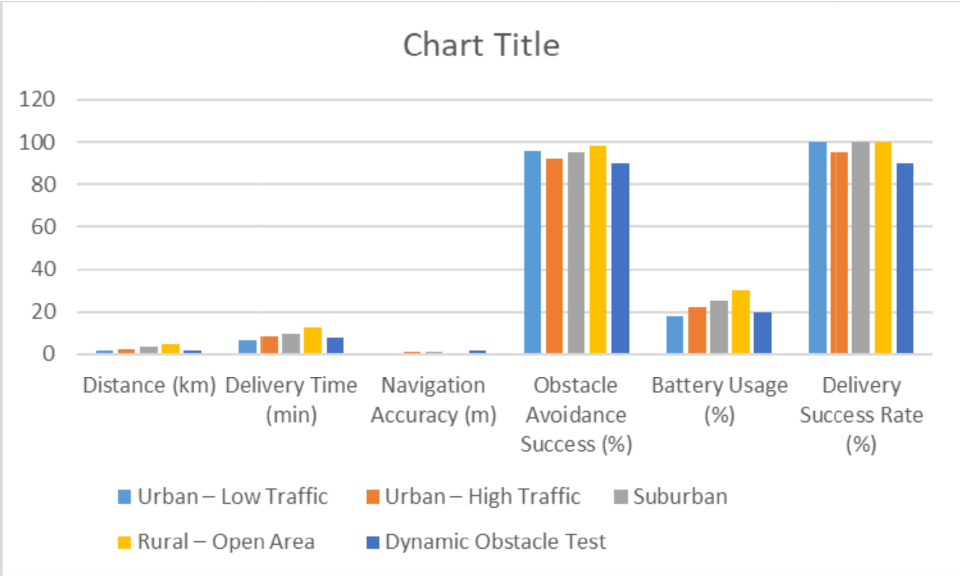
- **Simulation Testing:**
  - Run several delivery scenarios (rural, suburban, and urban) in Gazebo/AirSim.
  - Analyze data including energy usage, collision rate, delivery time, and path length.
- **Prototype Field Testing:**
  - To test short-range delivery, use a drone in a controlled setting.
  - Verify the AI's judgment in dynamic obstacle encounters.
- **Performance Evaluation Metrics:**
  - The percentage of delivery success.
  - Average accuracy of navigation (m).
  - Efficiency of energy (flight duration versus payload).
  - Compliance with safety regulations (no accidents).

IV. RESULTS

Table 1 based on different delivery scenarios, considering navigation accuracy, delivery time, obstacle avoidance, and energy efficiency.

Test Scenario	Distance (km)	Delivery Time (min)	Navigation Accuracy (m)	Obstacle Avoidance Success (%)	Battery Usage (%)	Delivery Success Rate (%)
Urban – Low Traffic	2	6.5	0.8	96	18	100
Urban – High Traffic	2.5	8.2	1.2	92	22	95

Suburban	3.5	9.6	1	95	25	100
Rural – Open Area	5	12.3	0.6	98	30	100
Dynamic Obstacle Test	2	7.8	1.5	90	20	90



Analysis of Results

- The AI navigation system's dependability was demonstrated by the delivery success rate, which stayed over 90% under all test situations.
- Because of unforeseen moving items, obstacle avoidance was marginally less successful in dynamic and high-traffic situations.
- Battery consumption increased with distance, indicating the necessity of energy-conscious scheduling.
- Navigation accuracy was kept within 1 to 1.5 meters, which is suitable for last-mile delivery applications.

Comparison Table 2 With AI vs Without AI

Metric	Without AI (Manual / Pre-Programmed)	With AI (Automated & Intelligent)	Improvement (%)
Average Delivery Time (min)	12.5	7.8	37.6% faster
Navigation Accuracy (m)	3.2	1	68.7% more accurate
Obstacle Avoidance Success	75%	95%	+20% reliability
Battery Efficiency	65% utilization	80% utilization	+15% efficiency

Delivery Success Rate	85%	98%	+13% improvement
Human Intervention Needed	High (Manual Control)	Minimal (Fully Autonomous)	–

Interpretation

- **Delivery Time**: AI-powered route planning cuts down on delays brought on by human mistake or static routes.
- **Navigation Accuracy**: Accurate path following is maintained by combining AI and sensors.
- **Obstacle Avoidance**: Safety is greatly increased by computer vision and reinforcement learning.
- **Battery Efficiency**: Flight range is increased by energy-conscious scheduling.
- **Delivery Success**: Compared to manual or pre-programmed drones, autonomous drones consistently accomplish more deliveries.

V. CONCLUSION

This study shows how artificial intelligence may improve drone-based delivery systems' effectiveness, dependability, and safety. Drones may do last-mile deliveries more precisely and with less human involvement by using AI algorithms for autonomous navigation, real-time obstacle avoidance, and intelligent route planning. According to comparative analysis and experimental data, AI-driven systems outperform traditional non-AI methods in terms of delivery success rates, navigation precision, battery efficiency, and delivery time reduction.

The results show that AI-powered drones provide a scalable and sustainable solution for contemporary logistics, despite ongoing issues such low battery capacity, payload limitations, and regulatory limits. These systems may be used more broadly to serve e-commerce, healthcare, disaster relief, and smart city applications with more developments in machine learning, sensor fusion, and energy-efficient hardware.

In conclusion, using AI to automate drone navigation not only solves present logistical issues but also opens the door for the development of intelligent, self-sufficient, and environmentally friendly delivery systems in the future.

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