



# Drone Technologies: Aviation Strategies, Challenges And Applications

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**Abstract:** Drones are shifting rapidly from military tools to civilian use in various industries such as construction, logistics, and agriculture. They have the ability to output a lot as a result of their capacity to reach areas that are hard to access. However, the increase in the use of drones poses a variety of challenges, including technological constraints as well as regulatory and privacy issues. The purpose of this literature review is to capture key aviation strategies, challenges and applications present in the technological field of drone operations while analyzing existing literature and reports. The analysis provides useful insights on the emerging technology trends, innovation changes and regulatory developments in the market concerning the market. Our investigation reveals that the future of drone technology is positive due to their advancements in autonomous navigation, battery life or expanding payload capacity. Drones still need to work on regulatory complexities, security and privacy issues. The use of artificial intelligence and blockchain can bridge the theoretical gaps with enhanced cybersecurity, powerful battery technology and collision-avoidance technology. The future implementation of various sectors is greatly dependent on the development of drones in the near future, which is why this is the focus of the various sectors.

**Keywords:** Drone technology, Autonomous Navigation, Control System, Unmanned Aerial Vehicle (UAV), Vertical Take-Off and Landing (VTOL), Path Tracking Algorithm, LiDAR Technology, GPS Spoofing, Unmanned Traffic Management (UTM), Last Mile Delivery, Agriculture, Solar Panels, Material Innovation.

## I. Introduction

An **unmanned aerial vehicle (UAV)**, or **unmanned aircraft system (UAS)**, commonly known as a **drone**, is an aircraft with no human pilot or crew on board. UAVs were originally developed through the twentieth century for military missions. The development of smart technologies and improved electrical-power systems led to a parallel increase in the use of drones for consumer and general aviation activities. Drone technology has had a transformative impact on many sectors including agriculture, passenger mobility, disaster management, surveillance, infrastructure, environmental conservation, logistics, entertainment industry, real estate, travel agencies and so on. Some of these are listed in Fig.1.1.

Even with these advancements, the use of drones in civilian settings has developed complicated issues that require both a plan and advanced technology. The important aspects include ensuring the safety and effectiveness of drone operations with the use of smart technology such as collision avoidance and VTOL which are vital for operation in cities and rural areas. In addition, effective control systems are critical for maintaining integrity and precision in flight, particularly during periods when precision is vital, such as during last mile delivery operations and emergency call outs. It does not matter what the particular purpose of these core elements is, it is the groundwork of efficient and secure use of drones in the present-day atmosphere.

The COVID-19 pandemic caused international lockdowns, causing widespread changes in how consumers shop, with many opting for online orders instead of going physical stores. This resulted in a dramatic increase in the demand for e-logistics. The use of drones for last-mile delivery has attracted much attention since it

promises to improve efficiency in the process. In the agricultural sector, drones have the potential to improve farm management and agricultural practices. They provide real time images, sensors, and mapping which allows farmers to monitor the state of crops, find diseases, and assess field conditions. The use of drones in post-disaster scenarios provides benefits like demand rescue team for search and rescue operations by reducing the need of time to search through large areas plus they give information about what direction to go when performing the rescue missions. More research is sought to substantiate the use of drones for travel, given the touted advantages of reduced congestion, cut back on time spent commuting, and reduced impact on the environment.

Craig Whitford explains that airspace is regulated in a manner that not only allows for a modified classification for drone use but also gives notice in advance of the intended use of a drone. Most conflicts between traditional aviation and the flight of unmanned aerial vehicles are associated with drones, so such a division increases the safety of flight activities. This approach limits the activities drones can part-take in. Consequently, the condition of their greater employment by the civilian aviation institutions calls for the integration of UAVs/drones in the requisite airspace. With the increasing rate of adoption of drones for different tasks, there is an increasing need for these devices to be fully integrated into a network, which would allow for effective and secure communication and information sharing. Drones have issues with shifting larger and heavier objects and this limits them to lighter equipment. The battery technology available today also limits the time drones spend combusting engines, with most commercial models, doing so for about 20-30 mins at most. Current areas of study are aimed at increasing the life of batteries or using solar energy.

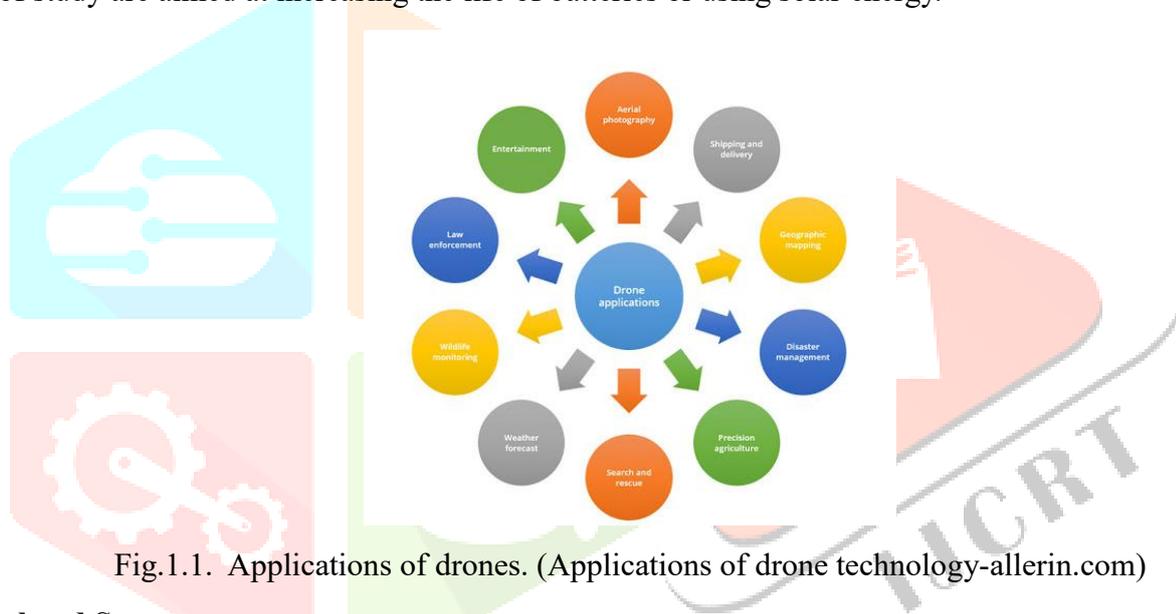


Fig.1.1. Applications of drones. (Applications of drone technology-allerin.com)

## 1.1. Related Surveys

This paper presents a thorough examination of drone technologies, emphasizing the fundamental strategies and application-oriented methods crucial for incorporating drones into vital civilian industries. This study seeks to pinpoint the challenges and opportunities ahead by analysing recent technological developments, application-specific approaches, and the regulatory environment. Topics including GPS spoofing, restricted payload and battery capacities, and changing regulatory landscapes will be examined closely, highlighting how tackling these obstacles can lead to safer, more efficient, and more broadly accepted drone operations across various sectors.

Many studies have explored various facets of drone technology, such as applications, control strategies, security issues, and operational efficiency. The various uses of drones in healthcare, military, and agricultural fields are illustrated in recent work by Emimi (2023)[1], which also identifies issues of payload and duration of flight. Similarly, Rashidzadeh and Molana (2021)[2] investigate drone delivery in perishable products supply chains, using a fuzzy goal programming methodology to enhance last-mile logistics sustainability. Other studies, such as Daud (2022)[3], evaluate the usefulness of drones in disaster assistance, emphasizing delivery, mapping, and search and rescue. These surveys constitute the basis through which current trends can be better understood and trends where drone technology may develop to improve control systems, extend ranges, and attend to privacy issues and regulatory pressures.

Table 1.1: Comparison of Related Surveys

Year	Author	Focus Area	Key Findings	Future Enhancements
2023	Emimi	Agriculture, military, medical drones	Drones have potential in medicine delivery, crop health monitoring, and surveillance.	Increase payload capacity and flight duration, address regional regulations
2021	Rashidzadeh, Molana	Delivery of perishable goods	Sustainable last-mile delivery using fuzzy goal programming for optimizing delivery efficiency	Address supply shortages, consider urban regulations
2022	Daud	Disaster management	Effective for mapping, rescue, and transport, especially in disaster scenarios	Enhance victim identification capabilities
2015	Velasco	Control strategy comparison	PID controllers found to be robust for stability and control in drone systems	Improve LQR and MPC for performance
2023	Omolara	Drone security and privacy	Identifies cyber and non-cyber threats, offers solutions for enhancing security	Implement regulations to improve public safety
	Our Survey	Key strategies and specialized methods are crucial for incorporating drones into vital civilian industries.	Current capabilities, advancements for specific uses, constraints, and possible upcoming innovations in drone technology.	Advances in autonomous navigation, lightweight materials, and energy-efficient designs may help overcome existing constraints.

## 1.2. Purpose of the survey

Our survey aims to analyze and identify the most effective drone technology strategies in various industries, such as agriculture, logistics, disaster relief, and urban mobility. We also aim to identify the current limitations of drone technology, including payload capacity, battery life, collision avoidance systems, regulatory issues, and cybersecurity measures.

### 1.3. Motivation

The swift growth of drone technology offers unparalleled possibilities in various sectors, including agriculture, logistics, disaster relief, and urban transportation. Drones are increasingly essential for enhancing operational efficiency, accessing hard-to-reach locations, and minimizing human presence in dangerous settings. Nevertheless, their incorporation into civilian and commercial uses faces obstacles, necessitating considerable progress in control, safety, and operational strategies. The necessity to tackle these issues has inspired this study, which seeks to deliver an in-depth examination of essential drone tactics and application-focused methods to enhance their efficiency.

Although drones have great potential, their broad usage is impeded by challenges like collision risks, regulatory limitations, cybersecurity issues, and limited battery capacity. Present-day technological solutions, including collision avoidance systems, vertical take-off and landing (VTOL) features, and sophisticated control mechanisms, continue to develop and need optimization to satisfy the requirements of more complex environments. Investigating these core technologies and pinpointing deficiencies in existing research is crucial for developing safer, more efficient, and dependable drone systems for various purposes.

This research is driven by the necessity for a systematic and comprehensive analysis of the drone ecosystem to grasp the opportunities and challenges for its expansion. Through the exploration of both universal and specialized strategies, along with significant regulatory and technological hurdles, this study seeks to offer insights that will facilitate the progress of drone technology. Tackling these obstacles and improving these strategies is vital for realizing the complete capabilities of drones, thereby fostering sustainable innovation in various industries.

### 1.4. Contribution of this survey

**Thorough examination of major operating strategies:** In this study, the fundamental technologies that are based on the fundamental drone strategies will be critically assessed. These basic drone strategies encompass control systems, VTOLs, and collision avoidance. These tactics are meticulously analyzed to enlighten readers regarding the crucial technologies allowing drones to function safely and efficiently in most contexts and applications.

**Analysis of Application-Specific Modifications:** The study explores how drone technology is customized to satisfy the specific requirements of four key applications: last-mile delivery, agriculture, disaster response, and urban transportation. For every application, we outline distinct tactics and advancements that allow drones to efficiently carry out tasks, emphasizing the variety of methods necessary to enhance their effectiveness.

**Recognition of Major Challenges in Drone Integration:** This survey highlights the key obstacles that need to be tackled for broader drone implementation by identifying and examining significant issues, including GPS spoofing, cybersecurity weaknesses, payload and battery constraints, and regulatory limitations. These challenges are essential factors for researchers and practitioners aiming to utilize drones in intricate or regulated settings.

**Understanding Future Trends and Research Needs:** This survey offers suggestions for forthcoming research and development based on existing trends and technological constraints. It emphasizes sectors requiring more progress in autonomy, energy efficiency, security, and regulatory frameworks, providing a guide for innovations that could greatly improve the functionalities and societal acceptance of drones.

### 1.5. Organization of the paper

Organization of this paper is depicted in the Fig.1.2. Section-1 contains an introduction. Section-2 contains the survey methodology. Section-3 provides three important strategies used in drones. Section-4 discusses in detail about different applications of drones. Section-5 gives insights on various challenges encountered in integrating drone technologies into different industries. Section-6 contains the results with a graph depicting future analysis. Finally, the conclusion is given in Section-7.

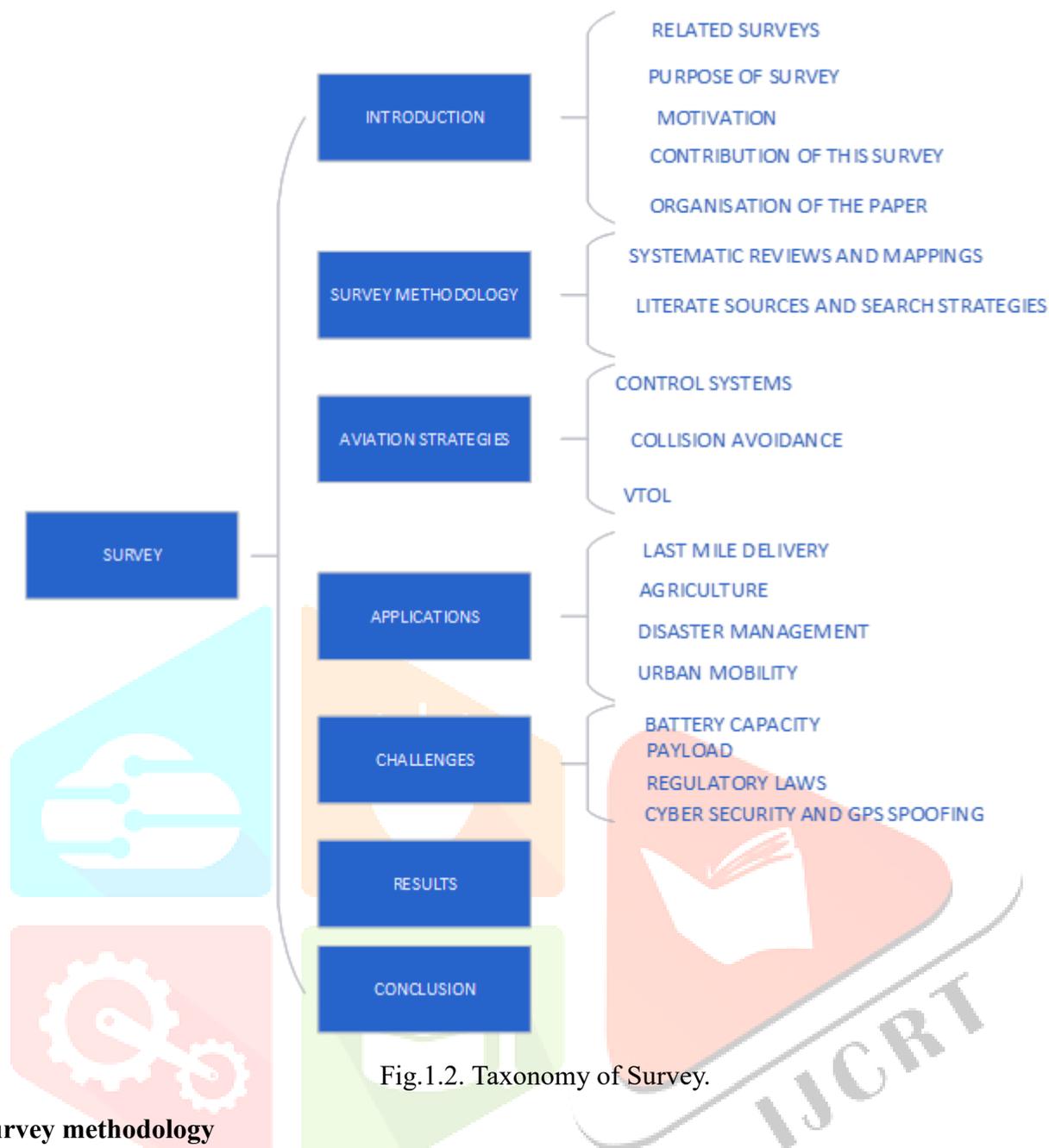


Fig.1.2. Taxonomy of Survey.

## II. Survey methodology

We utilized the systematic mapping approach suggested by [24] to perform this thorough review, which provides an in-depth systematic analysis of a particular subject.

### 2.1. Systematic reviews and mappings-Research questions

For the kept papers, the following questions are taken into consideration.

**RQ1.** What are the key operational strategies, including collision avoidance, vertical take-off and landing (VTOL), and control systems, necessary for the secure and effective use of drones in diverse applications?

**RQ2.** In what ways do strategies tailored for specific applications differ among essential areas such as last-mile delivery, agriculture, disaster response, and urban transportation, and which innovations are fuelling these changes?

**RQ3.** What are the main technological and regulatory hurdles—like GPS spoofing, cybersecurity issues, payload constraints, battery duration, and legal limitations—that impact the broad acceptance and secure incorporation of drones in civilian and commercial areas?

**RQ4.** What developments and possible solutions are available to address the existing limitations of drone technology in order to facilitate its growth in varied and intricate environments?

## 2.2. Literature Sources and Search Strategies

To collect pertinent research on drone technology, several databases were utilized, such as ScienceDirect, Springer, MDPI, and ResearchGate. The keywords for the search comprised terms like "drone technology," "UAV uses," "collision prevention," "route tracking," and "cybersecurity related to drones." Boolean operators helped narrow the search, and particular filters like publication year and subject area (engineering, robotics, etc.) guaranteed relevance.

These criteria contributed to guaranteeing that the survey comprises a comprehensive, pertinent, and high-caliber collection of studies in drone technology.

Table 2.1: Number of Papers Collected Per Database

Database	Number of Papers
ScienceDirect	12
MDPI	5
Springer	1
ResearchGate	2
Others	4

### 2.2.1. Criteria for Inclusion and Exclusion

1. Articles released in the past decade to guarantee current information.
2. Research centred on drone technology uses, control methods, and cybersecurity.
3. Articles from peer-reviewed journals and conference proceedings to guarantee academic standards.

### 2.2.2. Criteria for Exclusion

1. Articles lacking significant data or empirical findings, like brief opinion pieces or studies not subjected to peer review.
2. Research that emphasizes only drone technology for military uses, excluding any context related to civilian or commercial applications.
3. Articles in languages aside from English, to guarantee accessibility and comprehension.

## III. Aviation Strategies

### 3.1. Control Systems

#### 3.1.1. Pid controllers

PID is a control algorithm that helps drones maintain stability and flight by adjusting motor speed in response to error. Table 3.1 gives the meaning of the term PID.

Table 3.1: PID term

PID term	Function
P	Proportional term that looks at the current error
I	Integral term that looks at the accumulation of past errors
D	Derivative term that predicts future errors

One of the papers considers the following control strategy:

Cascade PID Control System:

The cascade PID configuration used in the proposed control system indicates two levels, or loops, of control. The inner loop manages the pitch and roll of the drone. The main aim of this system component is to adjust two PID controllers to ensure stability in the two directions. The outer loop highlights navigation through control of speed, direction, and altitude. Three PID controllers comprise this loop, which adjusts these navigation-related settings. Five PID controllers are used in total with three for the outer loop and two for the inner loop [7].

Adjusting the PID Parameters:

- Every PID controller contains parameters that must be configured for peak performance: KR (gain), TI (integral time), and TD (derivative time). Two distinct tuning techniques are employed as shown in Fig.3.1:
- PID 1: Root Locus Design — a traditional method that modifies closed-loop poles (parameters linked to stability and response time) through a graphical approach known as Root Locus, illustrating how the system's behaviour evolves with changing PID gains.
- PID 2: Multi-Objective Optimization Design (MOOD) — This method[7] employs optimization strategies to attain the optimal balance across various performance goals.

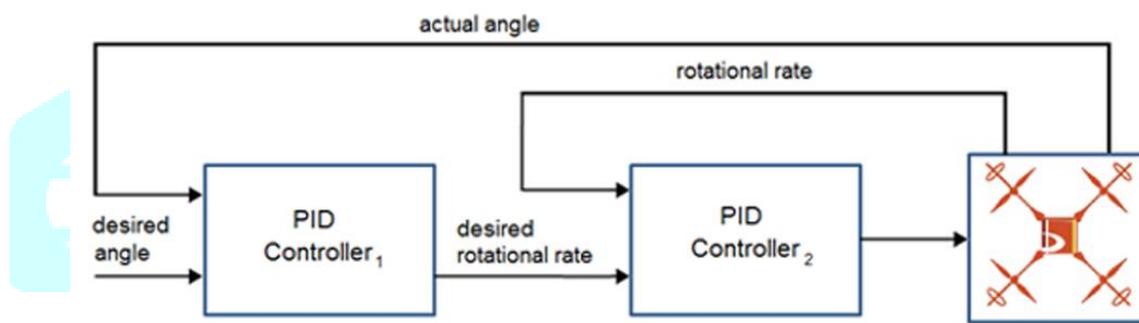


Fig.3.1. Cascade PID Control System[20].

MOOD (Multi-Objective Optimization Design):

This method[7] consists of three key stages:

- Defining the Multi-Objective Problem (MOP): The PID control system is optimized with seven established objectives. These consist of: Altitude and yaw settling time, which gauges how rapidly the drone stabilizes following a disturbance. Motor Utilization Integral (total energy consumed by motors). Total Variation for control surfaces: ailerons, elevators, yaw, and tilt.
- Optimization Method: Employs the SP-MODE-II approach, a dedicated optimization method that improves solution quality by emphasizing convergence (identifying the best possible solutions), diversity (ensuring a broad spectrum of choices), and pertinence (the relevance of solutions to real-world requirements).
- Multi-Criteria Decision Making (MCDM): Employs Level Diagrams to illustrate and choose the most balanced option from the optimized solution set based on the seven objectives.

This paper investigates two methods of tuning the PID controllers used in a drone's navigation and stability systems [7]. The second method, PID 2, applies MOOD to optimize for several performance objectives simultaneously, whereas the first method, PID 1, applies the traditional Root Locus technique. Optimizing many objectives balances the controller configurations and ensures that the system's response meets stability and efficiency requirements. PID controllers are essential to drones because they ensure precise movement and stability, which are both requirements for the overall functioning of the drone [7].

### 3.1.2. Vibration control

Vibrations are a serious problem for both crewed and uncrewed vehicles. For unmanned vehicles, which are often used for data and image gathering activities involving sensitive electronics, vibrations can potentially degrade mission performance. It has long been known that Harmonic Control (HC) is a successful technique for creating and implementing control laws intended to lessen vibrations in unmanned aerial vehicles. The key concept [14] is the use of correctly phased harmonic elements in the controls to reduce the vibratory components in the fuselage accelerations. At the root of HC algorithms is a representation of the structural response as a frequency-domain linear quasi-static model applicable to steady-state scenarios. The feedback is generated by information gathered from sensors placed throughout the fuselage. According to one of the documents, Harmonic Control is basically a discrete, frequency-domain technique that uses estimates of the previous cycle's disturbances to reduce them in the current cycle, assuming that the frequency response connecting the control inputs to the observed outputs at the desired frequency is fully known or continuously estimated [14].

Rotor imbalance is the most common cause of heightened vibration. To prevent screws from loosening during flight, it is advisable to apply a thin layer of grease on all contact surfaces of the frame, such as the motor bases and beneath the screw heads, while also lubricating the screw threads with grease [6].

### 3.1.3. Noise control

The integration of distributed or multi-rotor propulsion systems, typically favoured for agility, along with their closeness to urban regions, presents noise from drones as a complex problem. In a document from 2018, the European Aviation Safety Agency (EASA) outlined the noise level standard for drones as a constant 60 dB(A), assessed at a distance of 3 meters from the source. There are two fundamental approaches to managing the noise produced [20]: active and passive. Large airfoils and propellers have utilized active flow control techniques, but these approaches necessitate energy use. These techniques involve active alterations of airfoil shape or flow conditions, accomplished by either changing the airfoil's geometry and surface with actuators or influencing the local boundary layer using blowing and suction jets. Owing to the usual dimensions of the control systems and actuators, these technologies are inappropriate for the small-scale propellers used by MAVs. These remedies are primarily utilized on large drones that generate significant noise levels. These techniques consist of: (i) a synchro phaser, (ii) speakers arranged in a circle around the propeller, and (iii) tiny magnets oscillating in an electromagnetic field generated by the coil in the propeller frame. Conversely, passive flow control methods allow for the alteration of the boundary layer without requiring extra energy, which can be utilized to diminish noise production. The passive control techniques utilized to minimize noise production consist of serrations, use of porous materials, boundary layer tripping, and geometric optimization. We have explained two of the methods below [20].

The optimal geometry method emphasizes determining the ideal propeller shape to reduce the energy needed to achieve a specific propulsive force (or to enhance the thrust generated by a given power) under particular operating conditions (interpreted as a blend of airspeed, altitude, and propeller RPM). In designing a silent propeller, it is essential to incorporate acoustic standards, and typically an iterative approach is used. Initially, the ideal propeller from an aerodynamic perspective is identified (i.e., with peak efficiency). Subsequently, the resulting propeller undergoes additional modifications to enhance its acoustic characteristics. This represents the "traditional" method for designing quiet propellers [20].

With an advanced boundary layer tripping mechanism along the suction side of a propeller blade, the wideband noise of a propeller may be decreased significantly without penalties to the aerodynamic performance. A boundary layer tripping system, discussed in the next works, utilizes an elementary strip of aluminium adhesive tape for testing control technique. The noise reduction system is associated with the reduction of BL noise due to the forced transition of the BL's flow from laminar to turbulent. Different types of noise are generated by the laminar boundary layer (LBL) and the turbulent boundary layer (TBL). Narrow band peaks appear in the frequency domain due to the very powerful and loud tonal sounds from the LBL. This is caused by an aeroacoustic feedback loop that incorporates the noise the TE produces at one specific frequency and LBL oscillation. Moreover, Tollmien–Schlichting (T-S) boundary layer waves were facilitated by the small laminar separation bubble present ahead of the TE that enhanced earlier findings. Strong narrow band tones were found in this condition [20] due to the presence of an aeroacoustic feedback loop and T-S's improvement. The aeroacoustic feedback loop is busted by the utilization of a transition strip to facilitate the transition of flow

from laminar to turbulent in nature. Instead of tone noise, the shift is changed with the help of tripping mechanism from 80% to 5% chord[20].

### 3.2. Collision Avoidance

Collision avoidance refers to drone navigation strategies that keep UAVs from running into obstacles in their surroundings. To ensure safe flying, especially in intricate and changing external environments, it requires real-time decision-making and course planning.

In [21], a novel method is proposed which is a distributed-type collision avoidance approach based on the elastic collision principle, which utilizes D2D information sharing to prevent collisions between UAVs along with a variable weighting mechanism to improve efficiency. It's referred as ECP-AS and advanced ECP-AS, for multi-UAV applications. Here, the advanced ECP-AS method outperformed the original ECP-AS.

#### ECP-AS and Advanced ECP-AS Overview

The study, "A Novel Collision Avoidance Strategy with D2D Communications for UAV Systems," [21] presents two innovative techniques of collisions to be avoided by an unmanned aerial vehicle (UAV): ECP-AS (Elastic Collision Principle-Aided Strategy) and improved ECP-AS. Both techniques have now been explained in detail.

- Elastic Collision Principle-Aided Strategy, or ECP-AS:
  - The concept of elastic collision, upon which this method is based, allows UAVs to change their trajectories in a way that they avoid collisions but retain their flight paths as much as possible.
  - Since ECP-AS is a distributed approach, it does not demand central control, which makes it appropriate for multi-UAV applications where an autonomous operating mode is essential.
  - The strategy aims at minimizing the possibility of collision while ensuring that UAVs may get to their destinations in a reasonable amount of time.

#### Advanced ECP-AS:

- The improved version introduces adjustable UAV weightings to enhance the original ECP-AS. This enhances a more advanced collision avoidance strategy with regard to specific UAV unique traits and priorities.
- It has been proven that sophisticated ECP-AS has a better performance compared to the pristine ECP-AS in terms of arrival time and the distance between UAVs during flight, which reduces the possibility of collision. Additionally, the algorithm introduces a weighting parameter so that UAVs that need to reach their targets the first may do so without changing the flight direction too much [21] [23].

#### Future Scope (optimization)

- The methods can be further enhanced by integrating machine learning algorithms to predict and adapt to dynamic environments, improving collision avoidance in complex airspaces with multiple UAVs [21].
- Additionally, the incorporation of real-time data from various sensors and communication networks, such as 6G, could significantly enhance the effectiveness and responsiveness of these collision avoidance strategies [21].

#### Limitations:

- One limitation is that the performance of ECP-AS and advanced ECP-AS may be affected by the maximum speed constraints of UAVs, which can lead to increased collision probabilities if not managed properly [23].
- Furthermore, the reliance on distributed communication may pose challenges in scenarios with limited connectivity, potentially hindering the effectiveness of the collision avoidance strategies [22].

Elastic Collision Principle: Here, the UAVs are assumed as spherical objects that can collide and rebound which conserving their momentum in the collision.

D2D Communications: It allows to operate in a distributed manner while facilitating the sharing of location and velocity information among multiple UAVs

According to [21], collision avoidance methods in UAV's are classified into 2 categories-

- Active Methods (Centralized Methods):
  - Centralized Control: These methods rely on a centralized control unit, which continuously tracks the flight path and conditions of the UAVs. This facilitates collision avoidance by effectively coordinating the movement of several UAVs [21].
  - Limitations: Since the centralized system cannot sense or govern unmanaged UAVs, the active techniques face challenges once they arrive. It can produce probable collision risks in this regard [21]. Their utility may be limited in remote areas or during natural disasters where communication infrastructure may be destroyed because of their reliance on a steady cellular network connection [21].
- Negative Methods (Distributed Methods):
  - Autonomous Operation: Negative methods equip UAVs with their own flight control functions, allowing them to perform collision avoidance independently without relying on a centralized system [21].
  - Flexibility and Suitability: These technologies are useful for a range of applications, including those outside of cellular coverage zones, because they are beneficial in settings where centralized control is impractical [21].
  - Performance Improvement: By improving the effectiveness of negative techniques, the study aims to raise the safety and dependability of UAV operations in a variety of situations [21].

To enable autonomous UAV flight, a robust network for flight route control is essential. The following are some methods implemented and are in future research.

- Game Theory-Based Method, Non-Orthogonal Multiple Access (NOMA), Dynamic Route Control Method, Trajectory and Energy Efficiency Optimization, Self-Adaptive UAV Trajectory Method, Mobile Edge Computing[21]
- Rule-based approaches, geometry-based approaches, artificial potential field algorithms, numerical optimisation methods, and learning-based methods [23].

The main objective of UTM's detection and avoidance capabilities is to steer each UAV to the least amount of distance from other UAVs, manned aircraft, and no-fly zones during the in-flight stage of geofencing with multiple no-fly zones while considering sensor uncertainties.

Differential geometry concept:

The consideration of irregularly shaped obstacles in tactical de-confliction is a key element of a UTM solution expanding the operational boundary to challenging environments. As most algorithms assume them to be that the obstacles have circular or elliptical shapes/ large in scale and as 4D polygons(reduces efficiency). The proposed algorithm[23] is validated by both theoretical and numerical analysis.

A probabilistic–geometric collision avoidance system is proposed in this research [23] that can take into account the sensor uncertainties of several invader UAVs as well as various unevenly shaped no-fly zones.

Three key performance criteria—safety, scalability, and efficiency—are defined, and the numerical simulations show that the proposed algorithm indeed works correctly for the given performance criteria. The results are also compared with two widely used collision avoidance methods: particle swarm optimization and artificial potential field.

Therefore, the following is a summary of this paper's contribution [23]: The proposed new collision detection and avoidance algorithm achieves the following characteristics: - Multiple irregularly shaped obstacles and moving intruders can be considered in tactical de-confliction; - Uncertainties in the relative position of UAVs are considered in determining the collision avoidance maneuver by using the collision probability; - The differential geometry concept can be used to analytically prove the minimum separation for safety. analytical

and numerical verification of the proposed algorithm's performance. proof of the efficiency, scalability, and safety of the proposed method compared to other known benchmark algorithms.

The basic ideas include estimating the probability of collision with uncertainties and applying these results to detect conflicts and update avoidance strategies. This addresses research gaps since most UAV collision avoidance algorithms are based on circular obstacle avoidance and not much is known about how sensor uncertainties impact collision avoidance performance.

A future direction of this research[23] is suggested as an extension to fully utilise cooperative UAVs' flight plans. While the current approach is applicable to uncooperative UAVs with their position and velocity measured from the sensors, the efficiency could be improved by further utilising the flight plan and manoeuvre strategy in the case of cooperative UAVs. The research objective will be to provide an analytical safety guarantee compared with other learning-based methods.

### 3.3. Vertical take-off and landing (VTOL)

A VTOL (vertical take-off and landing) aircraft is one that is capable of taking off and landing vertically without needing a runway. The UAV offers greater benefits compared to the fixed wing UAV when conducting inspection and surveillance activities. A drone, or rotary wing UAV, can perform VTOL (vertical take-off and landing) and is capable of flying in areas where fixed wing UAVs cannot, thanks to its excellent manoeuvrability. The VTOL multi-rotor drone is capable of flying in narrow and confined areas, taking off vertically, and, crucially, hovering; it can also possess intricate control systems based on flight tasks[20].

Four motors are combined in a cross or plus formation in the Quad1 or Quad X. It is possible to control the four-rotor VTOL multi-rotor drone in its movement by varying the rotational speed of each motor. This type of VTOL multi-rotor drone rotates two opposed rotors counterclockwise and the other two opposing rotors clockwise in order to fly and hover. The relative speed of the opposing rotors controls the roll and pitch motion of Quad1 or Quad X. The yaw movement of the four-rotor VTOL multi-rotor drone is accomplished by adjusting the relative clockwise and counterclockwise speeds of the rotors. A VTOL multi-rotor drone moves upwards by increasing the speed of every rotor simultaneously. Other VTOL multi-rotor drone models include octocopters, hexacopters, and so on. Some of the hardware parts that comprise the VTOL multi-rotor drone system include the flight control board, IMU sensors, Electronic Speed Controllers (ESCs), brushless DC motors, batteries, propellers, and RC transmitter/receiver [20].

Due to their simple but effective control, PI and PID controllers are widely used in the majority of industrial applications all over the world today. Along with this conventional approach, in the literature, research works on different types of control systems such as fuzzy controllers, sliding mode controllers, and hybrid controllers - PI-fuzzy, heuristic-based fuzzy controllers are published. These control mechanisms are applied in a number of applications, such as the control of power in wireless sensor networks and control of the speed of a DC motor. PI and PID controllers are preferred for VTOL multi-rotor drones because of the simple and effective control mechanism with ease of usage in embedded systems. Two PID controllers are implemented for each of the axes that include pitch, yaw, and roll to ensure stable flight by VTOL multi-rotor drones. The necessary rotating speed to maintain stability at the desired angle is produced by the primary controller. The motor torques are changed by the second controller. The intended rotational rate produced by the primary controllers and the rotational rate acquired from the gyro sensor serve as the controller's inputs. To fine-tune the ideal PID settings, the fundamental motion tests must be carried out before take-off. VTOL multi-rotor drones may malfunction or crash during flight due to improperly set parameters in the flight controller. As a result, these control parameters need to be appropriately set before the flight missions [20].

## IV. Applications

Autonomous drones, which can fly beyond visual line of sight (BVLOS), increase productivity, reduce costs and risks, maintain site safety and security, ensure regulatory compliance, and protect human workers during a pandemic, have recently started revolutionizing a number of industries. They can also be used for consumer-related jobs such as package delivery, which Amazon Prime Air has already proven, and critical medical supply deliveries.

#### 4.1. Last-mile delivery

Last-mile delivery is perhaps the most significant, costliest, and ecologically harmful activity in the whole supply chain that involves getting the goods to the final customer as quickly as possible. Sustainability has to be a part of the last-mile logistics plan and not an add-on because, regardless of the economic challenges, last-mile delivery still faces social and environmental barriers to operations that serve to uphold social and environmental norms.

In order to decrease the amount of time (makespan) required for the truck and drones to service every customer together, this paper [16] investigates the multi-visit traveling salesman problem with multiple drones (MTSP-MD).

The three complex sub-issues that make up the MTSP-MD problem are the traveling salesman challenge with precedence restrictions, the drone flight challenge with payload capacity and energy endurance limitations, and the synchronization challenge between the truck route and the drone timings [16].

For last-mile delivery in sparsely populated areas with a dispersively spread community and infrastructure providing adequate airspace for drone operations, this delivery method may present potential cost savings and better service quality, despite obstacles such as high population density, tall buildings, and strict urban airspace regulations.

The first study explaining the scenario of combining both a delivery vehicle and a drone for package distribution logistics was called the Flying Sidekick Traveling Salesman Problem (FSTSP). FSTSP analyzes the synchronization problem between the truck's route and the drone's flights and restricts the drone to delivering a single package each flight.

The mFSTSP has the following assumptions:

(1) a drone can carry at most one package, and (2) at most one drone is allowed to be launched from or retrieved into a truck.

Automated systems that can handle the launches and recoveries of multiple drones at the same time should be developed to increase system efficiency and lower labor costs.

Experimental Verification: Solomon's benchmark test cases were used to assess the proposed algorithm. Results indicate a significant reduction in costs when using many visits, different drones, and drones with enhanced payload and endurance capabilities [16].

Hence, the benefits of trucks outweigh the disadvantages of drones, and vice versa: the benefits of drones outweigh the shortcomings of vehicles. These complementary skills form the basis of a new strategy called "last mile delivery with drone," where the truck delivers the drone near customer locations, which then serves customers within its flight range, enhancing usability and increasing flexibility in scheduling.

Several studies have been recommended. To achieve better service quality, as summarized above, all the efforts referred to above [16] aim to reduce the truck and drone's time to take their rounds and return back to the depot.

Research and Industry Implications: The results demonstrate some promising and observable advantages of implementing drone technology into logistics delivery procedures and a fertile ground for academic research and future practitioner applications in logistics [16].

This paper investigates a novel variation of TSP-D based on the assumptions of Murray and Chu regarding FSTSP in 2015 [17]. The delivery completion time—that is, the time it takes for the truck and the drone to return to the depot—is aimed to be reduced in FSTSP. We propose a new version, min-cost TSP-D, that reduces the system's total operating cost into two separate components. In the first part, we talk about truck and drone transportation costs. In the second part, we discuss the idle time a vehicle must incur waiting for the other during the launching of the drone. To avoid confusion, we refer to the FSTSP as min-time TSP-D in the next section.

To solve the min-cost TSP-D, we present a MILP model in this study [17] along with two heuristics: a Greedy Randomized Adaptive Search Procedure (GRASP) and a heuristic called TSP-LS that was adapted from Murray and Chu's (2015) research. While GRASP employs our unique split algorithm and local search strategies, TSP-LS is based on an existing heuristic.

Further research may focus on suggesting even more powerful metaheuristics based on our division technique. Another interesting avenue of research could also be the generalization of proposed approaches to more complex problems like many vehicles or different drones.

**Function of the Min-Cost Objective:** The authors observe that the min-cost objective function for the Traveling Salesman Problem with Drone (TSP-D) has not been well explored when put into a real-world application. This gap creates a need to further research TSP-D in cutting operational costs, including waiting times between the truck and the drone and transportation costs [17].

**Comparison with Existing Models:** Although related problems, such as the Heterogeneous Delivery Problem (HDP) and other TSP variations, have been studied in previous research, they did not focus on the min-cost objective function within the context of TSP-D. This failure to focus on cost reduction within a real-world delivery setting creates a significant gap in the literature [17].

**Performance Analysis:** The existing work also failed to adequately examine the performance of min-cost versus min-time solutions for larger TSP-D scenarios. The impact of such choices on the overall efficiency of delivery has been less researched and is apparent through the different usages of drones for both goals, in which minimum-cost solutions utilize drones more than minimum-time solutions [16] [17].

**Operational Cost Factors:** The study emphasizes the importance of incorporating operational costs, such as the delays and the fines that accumulate while cars wait for one another. Since this component has not been well studied in previous studies, it is a crucial area for future investigations [17].

**Using Innovative Algorithms:** The lack of good solution strategies for TSP-D has seen the development and application of newer algorithms, for example, Greedy Randomized Adaptive Search Procedure (GRASP), and betterment of algorithms that have previously been used. These algorithms require more research, particularly in regard to execution time and quality of solutions.

**Using Drone technology for blood supply:**

Delivering perishable products such as blood through a supply chain is known to be very challenging, especially when it comes to last-mile delivery. The paper of doing so sustainably is discussed in Document [2]. Discuss its sustainability with this as an example.

They propose a multi-objective mathematical framework that quantifies the sustainability of final-mile delivery while considering the adoption of drones impacts on the carbon emissions, cost, and social advantages. Using a numerical example to illustrate the efficacy and viability of the suggested model, the solution approach, and the impact of drone technology on achieving all three dimensions of sustainability, a proactive fuzzy goal programming method is used to address the model and assess the degree of sustainability achievement. It is also compared with the conventional methods.

Among the questions asked are:

- 1) How can drone technology be applied to attain all three sustainability goals in the last-mile delivery of the blood supply chain?
- 2) Which aspect of sustainability does drone technology have the greatest impact on?
3. How many blood distribution facilities have drones assigned to them that can maximize last-mile delivery sustainability?
- 4) Which aspect of drone technology contributes most to attaining sustainability?

The PFGP method is a powerful approach to addressing the sustainability difficulties in last-mile delivery, particularly with reference to blood supply chains, because it allows goal prioritizing, controls uncertainty, and produces better results than traditional techniques.

## 4.2. Agriculture

In agriculture, drones provide various advantages for enhancing farm management and streamlining agricultural methods. They offer live imagery, sensor information, and mapping functions, enabling farmers to check crop health, identify diseases, and evaluate the general state of their fields. This data facilitates decision-making based on evidence for resource distribution, accurate input application, and focused actions[1].

Agricultural drones, also known as agricultural unmanned aircraft systems (UAS) or agricultural drones (UAVs), have emerged as ground-breaking tools in modern farming practices. These drones are specifically designed and equipped to address a variety of agricultural jobs and problems, offering farmers and the farming industry as a whole numerous benefits. Drones used in agriculture are used for a variety of activities, including mapping, crop observation, and analysis. Farmers can observe the health status of their crops, identify diseases, and observe the overall condition of their farms through agricultural drones, which take high-resolution aerial images with high-resolution imaging devices, such as multispectral or thermal cameras. Improving crop yield and optimizing resources can result from using such data to make informed decisions regarding pest control, fertilization, and irrigation. Because they allow for the application of inputs such as fertilizers, insecticides, and herbicides with precision, drones play a major role in precision agriculture [1].

Through the use of GPS and onboard sensors, agricultural drones can accurately and precisely focus on particular sections of a field, reducing waste and guaranteeing optimal resource utilization. This method, referred to as variable rate application, can lead to savings in costs, sustainability for the environment, and enhanced crop productivity. Apart from managing crops, agricultural drones assist in surveying and mapping land. Through the acquisition of high-resolution images and the application of photogrammetry methods, drones can produce precise 3D maps, digital elevation models, and orthomosaic images of farming terrains. This information assists in land surveying, mapping field boundaries, and developing digital farm models, allowing farmers to enhance field design, examine terrain differences, and efficiently plan irrigation and drainage systems. In addition, agricultural drones have shown their efficiency in crop spraying tasks. Fitted with advanced spraying technology, these drones are capable of accurately delivering pesticides, herbicides, and other agrochemicals to crops, providing benefits like decreased chemical use, precise application, and enhanced safety for agricultural workers. The use of agricultural drones has resulted in enhanced efficiency, lower expenses, and better productivity in farming methods. These drones could transform the agricultural sector by delivering farmers precise and prompt data, enabling precision farming methods, and enhancing resource management. Nonetheless, issues regarding regulations, privacy issues, and the incorporation of drone technology into current agricultural frameworks must be resolved for the extensive acceptance and enduring application of agricultural drones[1].

#### **4.3. Disaster management**

Farmers may monitor crop health, detect diseases and evaluate the overall condition of their fields using agricultural drones that can capture high-resolution airborne photos using advanced imaging equipment such as multispectral cameras or thermal cameras. This information can lead to better crop yields and efficiency in resource consumption through better choices in pest control and fertilization and more efficient irrigation. Because they make inputs such as fertilizers, herbicides, and insecticides easier to apply exactly, drones form a large percentage of precision agriculture [1]. Thus, using drones during a disaster has a number of benefits: they reduce the time required to locate victims and the ensuing response time by swiftly covering a large area, and they provide vital information to rescuers about the route to take during search and rescue operations. Furthermore, by using sensors like vibration, heat, binary, and noise detection, drones can find live victims who are buried beneath debris. These are indicative of the usefulness of drones in emergency situations and their potential as crucial tools for taking aerial photographs [3].

Drones have been widely utilized in the aftermath of floods, landslides, rockfalls, forest fires, hurricanes, tsunamis, volcanoes, earthquakes, and even the Chernobyl nuclear accident. Studies indicated that drones offered considerable advantages in disaster management over traditional methods, particularly regarding cost and efficiency. For instance, drones outperform first responder data by providing high-resolution images quicker than satellite imagery and GPS surveying. Drones proved to be useful for evaluating erosion and flooding since they offered detailed and ongoing 2D and 3D information while requiring little on-site time. Furthermore, drones have demonstrated greater flexibility regarding resources and timing, enabling remote revisits to the research location. Moreover, drones can exchange information more effectively in the early phases of a disaster through the creation of a drone aerial photo sharing web platform. The application of drones in search and rescue has grown in recent years, along with the effectiveness of rescue operations. A group of drones instead of just one drone proved to be more efficient. A Remotely Piloted Aircraft (RPA) system outfitted with various sensors, like a video camera, an avalanche beacon, and a tool carrier for devices such as a laser, a release hook, and a searchlight are practical and adept at helping in evaluating situations and making decisions during significant incidents[3].

Lidar sensors, also called light detection and ranging sensors, emit laser beams and measure how long it takes for the light to return to the drone. This information is used to create incredibly accurate 3D models of the terrain, buildings, and other objects on the ground. The LiDAR reference frame and the Global reference frame are different reference frames required to be produced to integrate LiDAR sensor model into a trajectory simulator. As shown in Fig.4.2, the LiDAR reference frame is positioned near the LiDAR sensor's origin, with its x-axis oriented perpendicular to the device. On the other hand, the Global reference frame indicates a Cartesian coordinate system that corresponds to the navigation environment of the UAV. The trajectory simulator incorporates the UAV's relative position to provide accurate modelling, allowing the LiDAR sensor to be correctly aligned and oriented during trajectory execution[1].

DEMs (Digital Elevation Models) can be integrated with airborne LiDAR (satellite imagery) to evaluate topographical shifts before and after a typhoon and to measure variations in landslide volume. Moreover, the LiDAR sensor can be attached to a drone as an instrument for geomatics technology[3].

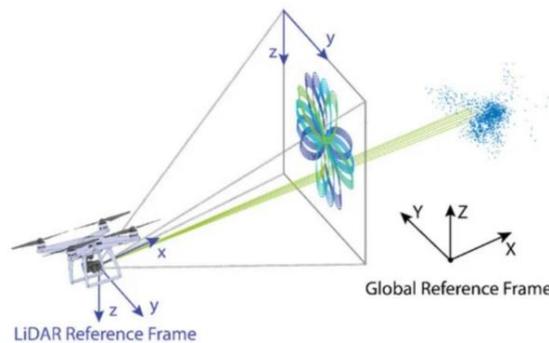


Fig.4.2. LiDAR sensor[1].

Medical deliveries, surveillance and monitoring, identification of fever-infected people with a thermal camera, communication through an onboard loudspeaker or QR code flag, and three different logistical tasks such as transporting necessities, medical supplies, and disinfectants are just a few of the ways that drones can be used to help manage pandemics. Area monitoring or surveillance is the most common application for UAVs. Global in nature, drones have been used for the most basic surveillance purposes in almost every country that has been affected by the COVID-19 outbreak. Based on the findings and observations of the study, the flights produced photographs for areas which are primarily within the drones' visual range that is a few hundred meters [15].

A unique use of area surveillance can be attained by adding or substituting the on-board visual camera with a thermal imager. The reasoning behind the flight principles utilized in area monitoring can be utilized here too; the goal of flight is to specifically identify patients exhibiting febrile symptoms. The objective is to identify individuals with fever-like symptoms to minimize the transmission of the infection. Most drone applications have been utilized to assist law enforcement by deploying loudspeakers, including maintaining social distancing; limiting large gatherings in parks, streets, and squares when feasible; disbanding groups, likely consisting of acquaintances and friends; ensuring face masks or gloves are worn as necessary; or vacating the area or returning to one's own residence. Utilizing a QR code rather than a loudspeaker can be beneficial in various locations, including border crossings, shopping mall parking areas, congested highways, and large-scale events or sports gatherings, where the process of crossing a border or gate is involved. A point-to-point delivery is nothing but a very simple logistics operation at its core, but its implementation occurs in a pretty unusual setting that makes it even more interesting. In this perspective, the uniqueness of the places of departure and arrival is always a reason for attention. No matter whatever endpoint is taken into consideration, the base stays the same. It could be that the source is a hospital or other medical facility that has a connection to the health service, such as a place for sample or collection. On the other hand, the other endpoint is always considered flexible; for a more complex application, it is almost a place close to the person's home. The disinfectant is used similarly to the spray liquid; the pump takes the disinfectant to the surface by hovering above a set area at a specific height and velocity with the established liquid flow. Some of the critical factors affecting the surface covering include the droplets' properties [15].

#### 4.4. Urban Mobility

Passenger drones, often referred to as 'air taxis', have demonstrated their technical capability to carry passengers inside or between urban areas. This signifies not only a significant moment in aviation history but also the onset of a new age where low altitude airspace could represent the 'third dimension' of transport. As

indicated in the paper[4] we reviewed, passenger drones might alleviate the congestion on busy streets and enable quicker travel through the skies[4]. Another paper[10] addresses visual taxiway extraction for UAV. A taxiway is a path that an aircraft follows when traveling to or from a runway. The actions performed include aligning the visual observation with the map and consistently updating the map based on visual observation. In particular, GPS measurements and the taxiway map are combined to create a set of potential prior centreline distributions, and an observed centreline distribution is derived from image processing methods. Then, the GPS measurement errors are corrected and the accuracy of centerline extraction is improved by evaluating errors using Kullback-Leibler Divergence (KLD). The improved centreline extraction is then used to replace the pertinent area on the taxiway map with the updated locational data, thereby ensuring that the map is contextually appropriate [10]. Another work [5] uses a combination of a Cascade PID controller with techniques of route tracking to create a path tracking algorithm. The strategies section covered the cascade PID controller. Here are the two approaches for path tracking:

**Intermediate Points Creation:** To enhance path consistency, the drone navigates through intermediate waypoints situated between the starting and ending points of each segment. This approach enables more seamless transitions and minimizes divergence from the intended route[5].

**Velocity Limiter:** This method confines the drone's reference speed to guarantee it consistently faces the upcoming waypoint. By adjusting the direction, this method rectifies discrepancies and minimizes overshooting, leading to enhanced tracking precision[5].

A different paper focuses on the area coverage problem with obstacles and describes an area allocation scheme that combines clustering and graph approaches [8]. The proposed method offers collision-free subregions without conducting any overhead of visibility checks. The proposed algorithm has two stages [8]. Collision-free subareas are built first. This ensures that, throughout the mission, there are no collisions between UAVs or between UAVs and obstacles. In the second section, the subregions are rearranged to identify the division that shortens the longest UAV route. In this way, each drone may complete almost the same number of missions [8].

Despite all these strategies, urban mobility has yet to reach its full potential. Issues such as battery capacity and a large payload pose the challenge. More experts who agree with the adoption of commercial drone use argue that the (urban) population will be more vulnerable to the adverse effects of widespread drone use. These adverse effects may undermine public acceptance, which is why, in addition to technological and legal constraints, acceptance is identified in all publications as one of the three main barriers to the use of drones for transportation. However, it is also possible to highlight possible remedies intended to deal with the problem.

## V. Challenges

### 5.1. Battery capacity

As a consequence of the undesirable environmental impacts from fossil fuel-driven engines, various options for numerous vehicles have been established. Due to their excellent acceleration and high rate of response to changes in power load, although their low range restricts them from applications in UAVs, batteries represent a very interesting candidate. To avail their fast dynamic response and high range for UAV missions, one such hybrid system, comprising a battery (NMC type Li-ion) and a fuel cell (Proton Exchange Membrane), was proposed by one of the studies. Overall performance of the integrated battery and fuel cell system was emphasized by the investigation. Assessment of stability in response to unanticipated circumstances during flight, which is likely in any UAV operation and may require extra alternatives, requires the system's dynamic reflexes, such as changing power load demands [18].

### 5.2. Payload

A UAV's payload capacity refers to its capability to raise and carry any load. Lifting capacity ranges from a couple of grams to multiple hundred kg. A larger payload allows for more accessories, but it results in reduced flight durations, increased power consumption, and bigger sizes. Sensors and cameras are common payloads.

Table snapshot (Fig.5.1.) from the paper explains the uses and specifications of with the types, capacity, range prototypes and applications of different UAV devices.

UAV specifications and applications are used to classify items (Sivakumar et al., 2021).

Sno	Type	Max Mass	Working (M)	Valve range	Lift capacity (KG)	Time To Fly	Prototype	Gliding Mechanism	Applications
1	Minatare	200 g	50	5	Less than 0.2	6-8	Minatare type by kogon	Multicopper	Diversion
2	Micro	2 kg	Less than 90	25	0.2-0.5	45	Based on disco parrot	Wing is fixed	Secret defense, Detecting task.
3	Mini	20 kg	150 < 300	40	0.5-10	18	DJI Spreading wings	Multicopper	Photography, cinematography
4	Small	25-50 kg	<1500	150	5.0-50	180	Scout B330 UAV Helicopter	Multicopper	Military transport of commodities in remote regions
5	Tactical	Above 50 kg	<3000	200	25-200	1800	Predator B	Fixed Wing	Target capturing and armed calculations

Fig.5.1 UAV specifications [19].

Like a coin, drone remote sensing technology includes two parts. It is also lacking in some areas. It has a modest capacity, limited power, and a limited payload. However, these shortcomings can still be made up for using different approaches and continue to advance related technologies. Advances in remote sensing science and technology have made some sophisticated remote sensors, including multi-spectrum, hyper-spectrum, and various high-resolution image sensors, lighter and better in quality. This makes it possible to utilize UAV remote sensing in other locations [19].

### 5.3. Regulatory laws

Drones/UAVs currently provide various functionalities in the civilian sector in addition to their military applications. The use of drones will expand considerably in the future. The Drone Rules 2021 were established to foster the manufacturing, utilization, and implementation of drones across India. Regulatory measures are implemented to guarantee advance notification of drone activities and to manage the airspace for drone operation by classifying the airspace. This improves the safety of flight operations and minimizes conflicts between drones and regular air traffic. This method restricts the use of drones. Consequently, incorporating UAVs/drones into civilian airspace is necessary to enhance their utilization. With the continual rise in the use of small, unmanned aircraft systems, there is an increasing need for a regulatory framework and operational procedures to guarantee safe drone usage. Consequently, there are global initiatives to establish a standard UAS (unmanned aircraft system) traffic management (UTM) system, along with its operational principles and regulations. The Ministry of Civil Aviation released Drone Rules 2021, which detailed the regulatory framework for the advancement of drone use in India[13]. UTM refers to the management of airspace to facilitate various drone operations in areas lacking air traffic services. UTM services present a solution by equipping operators to jointly handle drone-to-drone risks. Other collision risk management strategies, such as sending and evaluating Notices to Air Missions (NOTAMs), are inefficient for automated, nearby activities at a high operational pace. The demand for integrating drone operations into civil airspace has increased due to the continuous demand for Unmanned Aircraft Vehicles (UAVs) and their many applications. The need to utilize UAS in civil airspace to conduct vital functions for disaster management, agriculture, national security, and research is fast-growing.

Currently, India's Unmanned Aircraft Traffic Management System Since drone and unmanned aerial vehicle (UAV) operations in India's civil airspace are still in its infancy, two basic rules govern drone operations in India [13]:

Operation advance notice: Regulations have been established to ensure that drone operations in designated areas are reported to the appropriate agency before they start.

Airspace Division: India has divided its airspace to reduce problems between drone operations and aviation activities. In some areas, drone use is prohibited; in others, prior authorization and notice are needed. The current UTMS limits the mobility of drone operations by only allowing drone use in restricted skies. Effective integration of UAVs into civil airspace is necessary for improving drone use and operations.

Preparations for the exercise of improvised use also require that the drones be able to operate under normal flights conditions without infringing on the normal flow of air traffic. Moreover, standardization of protocols and requirements on drones' operation technology should be done to reduce risks and uncertainties associated with their use and ensure safe aircraft operations.

## 5.4. Cyber Security and GPS(Global Positioning System) Spoofing

Multiple layers of drone vulnerabilities exist, including the sensor level, where hackers could introduce erroneous data and cause interruptions to operations. The integrity and management of drones are also threatened by problems like virus, jamming, and hijacking, which are frequently taken advantage of via radio frequency modules or unsecure communication routes.

Apart from listing the risks that impact the operation of drones, the paper[12] discusses concerns over cybersecurity and drone solutions. Drone security hazards fall into nine categories of different types: physical, software, hardware, and communication threats. Among these is GPS spoofing, an important category of cyberattack shown in Fig. 5.2. Mimicking GPS signals will lead an attacker to be able to outsmart the navigation system of a drone and possibly ground or reroute the drone. This strategy is very dangerous because civilian GPS signals are not encrypted and can therefore be manipulated.

The countermeasures proposed in order to boost security include cryptographic techniques, machine learning-based anomaly detection, and intrusion detection systems (IDS) [12]. Several disadvantages of these methods are increased latency and computing demands. The research study underlines the need for robust encryption, secure protocols, and continuous monitoring to reduce risks from GPS spoofing and other cyber threats; it further advises that these drawbacks be addressed in future research.

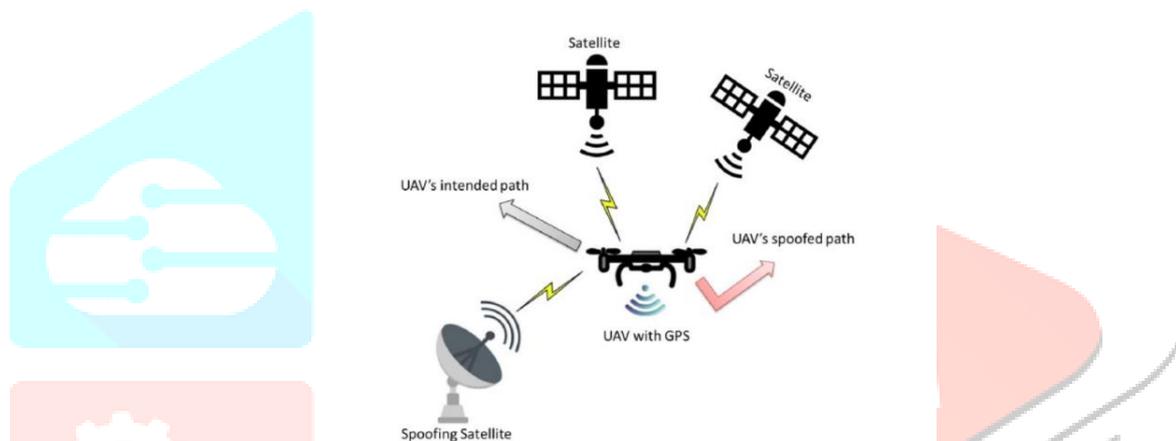


Fig.5.2. GPS Spoofing[1].

## VI. Results

The Fig.6.1 depicts the anticipated expansion of the worldwide drone market between 2021 and 2030. Beginning with a market value of \$28.5 billion in 2021, the industry is projected to undergo consistent yearly growth, anticipating a total of approximately \$260 billion by 2030. This trend indicates a growing acceptance in different sectors like logistics, agriculture, and urban transportation. The significant increase highlights the growing uses of drone technology and indicates a vibrant market fuelled by progress in autonomy, payload capacity, and regulatory backing for commercial drone applications.

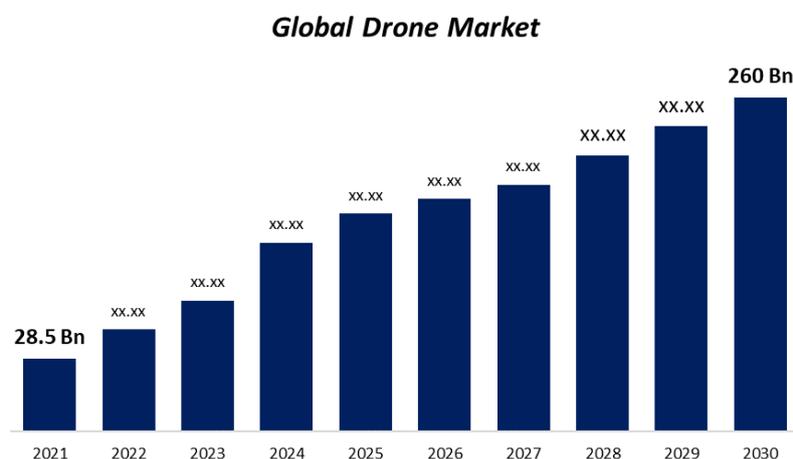


Fig.6.1. Global drone market(Global Drone Report-SphericalInsights).

The survey emphasizes the efficacy of basic operational strategies like collision avoidance, vertical take-off and landing (VTOL), and sophisticated control systems in improving drone performance in multiple applications. Collision avoidance, utilizing technologies such as LiDAR and machine vision, has shown significant advancements in reducing collisions with both airborne and ground obstacles, greatly enhancing operational safety. VTOL features enhance agility, particularly in limited city areas, while advanced control systems, such as PID controllers and multi-objective optimization methods, have improved the stability and precision of drones in path tracking. Even with these advancements, these core strategies still need refinement to meet various environmental and technical challenges.

Strategies specific to applications are essential for customizing drone usage across various sectors. For instance, last-mile delivery drones utilize accurate navigation algorithms and real-time obstacle detection, enabling them to function efficiently in intricate urban environments. In farming, drones use GPS-directed routes and advanced imaging to oversee crops and deliver resources effectively, thus reducing crop disruption. Disaster management drones, conversely, depend on rapid deployment and flexible navigation to navigate obstacles and access remote or dangerous areas, providing essential assistance in rescue operations. In the meantime, urban mobility drones encounter densely populated areas. Different algorithms and methods are utilized, yet it encounters public disapproval and environmental influences.

The survey further highlights various notable obstacles that hinder broader acceptance. Cybersecurity concerns, especially GPS spoofing, put drones at risk of possible manipulation and security vulnerabilities. Dealing with these threats through encryption and signal verification methods is becoming more essential. Additionally, constraints on payload and battery lifespan hinder the functionality of drones, since their restricted carrying capacity and brief flight durations necessitate regular recharging or battery replacements for prolonged missions. Moreover, intricate regulatory structures impede the use of drones in crowded or vulnerable regions, highlighting the necessity for uniform protocols regarding airspace integration and privacy.

## VII. Conclusion

In spite of many obstacles, there is significant promise for upcoming developments in drone technology. New advancements in self-driving navigation, lightweight substances like Carbon fibres, woven into a fabric and embedded in a resin matrix (usually epoxy), provide unparalleled strength and stiffness, and energy-saving designs may assist in overcoming existing constraints. Innovations like AI-powered control systems, hybrid battery options with solar panels that remove the necessity for charging stations, and dynamic path-tracking algorithms demonstrate potential for boosting the efficiency and safety of drones. Solar panels can be expensive and not as effective when compared to other fuel sources which might be the reason for its unlikely use. Upcoming studies on these subjects set the foundation for wider uses and more sustainable incorporation of drones in various sectors.

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