EXPLORING AND RANKING CHALLENGES TO PASSENGER DRONE INTEGRATION IN INDIA'S AVIATION SECTOR

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Abstract
Drones, or unmanned aerial vehicles (UAVs), have emerged as transformative technologies with applications across logistics, healthcare, agriculture, and more. This study identifies and evaluates barriers to drone adoption in the passenger and humanitarian logistics sectors, focusing on developing nations. Using fuzzy multi-criteria decision-making (Fuzzy MCDM) ranks 12 key barriers. A survey of 60 experts informed the analysis, employing a 5-point Likert scale and triangular fuzzy numbers to capture uncertainty. Results prioritize legal, financial, operational, and societal barriers, highlighting challenges like regulatory constraints, financial costs, infrastructure limitations, and public acceptance. This integrated framework offers actionable insights to policymakers and stakeholders, addressing key factors hindering UAV adoption while paving the way for effective drone integration. This study identifies key barriers to passenger drone adoption in India using Fuzzy MCDM to prioritize challenges. Key barriers include the lack of a Code of Conduct for UAMs, which hinders standardized operations and safety protocols. Additionally, the absence of comprehensive laws for drone operations and an inadequate licensing framework for authorized drones impede their safe integration into airspace. Furthermore, the absence of a central regulatory body for passenger drones creates a fragmented and inconsistent approach to oversight, delaying progress in this emerging sector.

Keyword: Passenger drones, Fuzzy MCDM, UAV adoption barriers, Regulatory challenges, Public acceptance, Infrastructure limitations

1 Introduction

Recent years indicate that unmanned aerial vehicles (UAVs), commonly referred to as 'drones', possess the potential to emerge as a defining technology of the 21st century. A drone is an unmanned aerial vehicle, typically constructed from lightweight materials, capable of remote control or autonomous flight [1]. Drones are referred to by various terms, including remotely piloted aircraft (RPA), unmanned aerial vehicle (UAV), and unmanned aircraft system (UAS). Drones were first employed in military operations [2]. Drones have been increasingly utilized across various sectors, including package deliveries [3], humanitarian relief operations [4], agriculture, healthcare services [5], civil and construction applications [6], entertainment/media [7], public safety and security [8], and mining [9]. Drones integrate three fundamental principles of contemporary technology: data processing, autonomy, and extensive mobility. They facilitate access to novel spaces and allow for their analysis through innovative data collection methods. Capabilities once exclusive to the military are now progressively integrated into civilian sectors. Their structural, functional, and design versatility has generated significant demand for implementation across various sectors. They have been widely utilized in the military of various countries for surveillance, monitoring enemy activities, and targeting military operations [10]. Drones present various potential applications, including surveillance and sensing missions, as well as innovative logistics and passenger transportation solutions. The commercial utilization of drones presents significant economic opportunities.

Newly industrialized countries such as India and China are increasingly adopting drones in logistics and commercial sectors. In recent years, UAVs have seen increased utilization in India across various sectors beyond the military. The Indian UAV market is projected to reach $885.7 million by 2021 [11]. Developing countries with extensive rural areas require effective integration of UAVs into their logistics sector. Drones are widely utilized as surveillance and sensor devices in security services, geodesy, and agriculture; however, their application as transportation devices remains in the early stages of development. From a technical standpoint, delivery drones can currently lift weights of 2–3 kg and perform flight missions within an urban area. Furthermore, passenger drones, referred to as 'air taxis', have demonstrated their technical capability to transport individuals within or between urban areas [12]. The current emphasis on UAV technology is set to transform drone logistics, enabling unprecedented access to relief aid in regions lacking adequate infrastructure. Implementing UAVs in humanitarian logistics within developing countries necessitates an examination of existing systems in developed countries to enhance understanding of required actions [13]. Numerous obstacles presently hinder the effective integration of drone systems within a nation's humanitarian sector [14].

The commercialization of drones will significantly impact various sectors, including e-commerce, search and rescue operations, and healthcare supply chains. Drones are recognized for their potential to transform the logistics industry [2]. Drones offer several advantages over traditional transportation methods, including consistent high travel speeds, independence from physical road infrastructure, reduced distances between points, and the absence of traffic congestion [3]. Drones mitigate delays associated with road transportation, particularly for short-term deliveries, by utilizing aerial routes. Drone delivery exhibits significantly lower operational costs in comparison to truck delivery [2]. Drones are regarded as the future transportation mode for diverse applications within the logistics sector [3]. Recognizing and addressing challenges associated with drone logistics is essential for its acceptance by enterprises. This study encapsulates the ongoing socio-technical discourse regarding the utilization of civil drones for transportation and delineates the subsequent research aims to assist practitioners and policymakers in the implementation of drone logistics. (a) To identify the barriers to drone adoption in the logistics sector, (b) To rank the key challenges and sub-criteria to drone adoption in the passenger service sector.

2. Literature Review

The following section gives a detailed description of the various factors inhibiting the adoption of UAV technology in the humanitarian sector.

2.1 Legal factors- Laws must be properly established to enable the innovation to thrive before a sector can accept a new technology [2]. Countries around the world have different rules governing the use of UAVs; nonetheless, some laws must be followed while attempting to install a UAV system. Legal issues might make it difficult for a business to even begin utilizing drones, including limited fight licenses and the lack of insurance [15]. This is frequently the result of too stringent drone regulations that are unenforceable. Another factor is that trespass regulations limit the operational area of UAVs, which makes it more difficult for them to respond promptly to crises [16]. The stringent optical line of sight restrictions, which mandate that an operator remain within a specific radius when operating a drone, provide a comparable challenge.

2.2 Financial factors-According to Mohammed [17], financial obstacles are a major factor when introducing new technology, like drones, into humanitarian logistics. Commercial solutions are expensive; according to Doole [18], the typical delivery drone costs $4,800 USD per drone, which is nearly twice as much as an e-bike. Maintenance costs are also raised by specialization in the humanitarian sector. These expenses are also influenced by other elements, such as lost communication, bad weather, and damaged infrastructure. Although drones are more environmentally friendly, delivering big numbers is challenging due to their limited payload capacity. Drones are only appropriate for certain delivery scenarios in locations where alternative options might not be accessible, and their overall carrying capacity is therefore constrained.

2.3 Operational factors-According to Overstreet [19], numerous issues may impede the goal of relief and surveillance operations intended to deliver humanitarian supplies. These issues are operational impediments, whether they are caused by human error, environmental changes, or technical constraints. For instance, infrastructure devastation is a common consequence of natural catastrophes, which makes it difficult to use UAVs [20]. The area surrounding the disaster site may undergo chemical and biological changes as a result of damaged infrastructure. Because humanitarian-related UAV technology is still in its infancy, unpredictable weather conditions present another challenge in the field.

2.4 Air traffic management- According to Bauranov & Rakas [21], as drones develop and reach greater altitudes, they are anticipated to function in a variety of airspace classes. To guarantee smooth communication between air traffic control, drones, and other aircraft, new Unmanned Traffic Management (UTM) technologies will be required. Both controlled and uncontrolled airspace will be used for drone flights in cities to ensure safe takeoff, approach, and landing. With the establishment of "UAM corridors" where drones can communicate to prevent dangerous circumstances, the number of drones operating in urban airspace will progressively rise. New rules, protocols, and training will be required as operations grow. It will also be difficult for drone general aviation and commercial planes to communicate. Adequate data interchange capacity can be ensured by investing in IT infrastructure, such as 5G connectivity. The drone ecosystem will require automated drone monitoring systems [22].

2.5 Environmental impact-The environmental impact of traditional aviation is substantial, but because of their size, physical attributes, and operational conditions, drones have gotten less attention. Drones release 35% fewer carbon gases than gas-powered automobiles, small airplanes, and helicopters, while being unmanned aerial vehicles with electric drive. They do, however, also produce 28% more emissions than battery-electric cars. Depending on their payload, energy mix, architecture, and mode of electricity transfer to the battery, drones can also use energy. Drones' net emissions in relation to more conventional forms of transportation vary depending on their particular use case and local environment. According to Cohen [23], drones have the potential to decrease emissions in certain situations while simultaneously increasing them in others.

Noise- If noise is not adequately controlled, it can be a significant barrier to drone integration. This is because of how people perceive noise as well as the actual drone noise, which is frequently high-pitched and typically ranges from 20 to 70 dB [24]. Drone noise may not be as disruptive in cities due to the background noise levels of traditional cars. However, drones may become more noticeable if they are close to residential areas and there is an increasing demand for quieter electric vehicles. One of the most commonly stated issues near airports and heliports is airplane and rotorcraft noise. The usage of helicopters in cities is probably going to be restricted soon due to the high noise level of rotorcraft. The social approval of aircraft use in urban airspace is taken into account while analyzing this issue.

2.6 Atmospheric conditions-According to Reiche [25], weather can present significant operational and safety risks for drones operating in urban areas. First, the safety risk and susceptibility of both the aircraft and its occupants to weather threats rise with aircraft size. There may be a variety of meteorological conditions, including crosswind, icing, and poor visibility. Consequently, carrying out low-altitude operations over cities may make these issues worse. Flight delays or cancellations may follow, but these are also common occurrences in commercial airline operations. It should be mentioned that in comparison to commercial aviation aircraft, aircraft flying in urban airspace will employ a significantly higher number of technical gadgets to enhance their safe operation. This could potentially affect the quality of their operation during adverse weather circumstances.

2.7 Infrastructure-Because drones are vertical, they need less room to take off and land. Drone infrastructure varies by location and destination, with comparatively cheap infrastructure found in rural locations. Adequate take-off and landing locations may be scarce in heavily populated urban regions, necessitating careful urban design. To guarantee equitable access, public funds or laws might be required. Drone transportation in urban airspace necessitates a large infrastructure, including IT, a vertiport networks, charging stations, and communication networks. Local resistance, expenses, and problems with multimodal integration are obstacles. Air traffic control, navigation infrastructure, and vulnerability to cyberattacks are all vital. Allocating radio channels for the drone ecosystem may be difficult due to limited resources [26].

2.8 Ensuring security of users-Straubinger [27], assert that preserving public safety and confidence depends on the security of UAM users. Drone flights put passengers at risk for assault, laser dazzle, and hijacking. Passenger safety can be improved by cutting-edge technologies like biometrics and traveler loyalty programs. To lower safety accidents, and regulations, airlines, and service providers must all adopt best practices. Vertiports, drones, and infrastructure must all be physically safe. Information system cybersecurity is essential.

Societal acceptance- According to Zielinski [28], societal acceptance problems like noise, pollution, invasions of privacy, and social justice issues make it difficult to implement the Urban Air Mobility (UAM) idea. All possible beneficiaries should be informed about UAM concerns through information campaigns. This issue has been brought to the attention of the European Aviation Safety Agency, which has expressed concerns regarding the application of UAM in urban areas despite its preliminary approval [29].

3 Research Methodology

This section describes a systematic method that combines exploratory factor analysis (EFA) and fuzzy multi-criteria decision-making (Fuzzy MCDM) to evaluate the obstacles for passenger drones. First, the barriers were ranked using fuzzy MCDM analysis. Next, underlying factors were extracted using exploratory factor analysis to group related barriers into more comprehensive, interpretable constructs. This revealed the dimensions that contribute to the passenger drones' progression challenges.

3.1 Sample size

The initiative involves 60 professionals from a range of disciplines, including environmental sciences, public policy, drone technology, urban planning, and aviation. The sample size was sufficient for EFA, in accordance with the conventional rule that a minimum of 5–10 respondents per variable are required for a successful factor analysis.

3.2 Data Collection

The responses of 12 questions were collected from 60 experts and by using 5-point Likert sacle with linguistic words mapped to fuzzy triangular numbers (TFNs). To quantitatively represent qualitative judgments, linguistic terms such as "Very Low,""Low,""Moderate,""High," and "Very High" were mapped to corresponding Triangular Fuzzy Numbers (TFNs). The mapping assigns numerical ranges to these terms as follows: Very Low (VL): (0, 0, 1), Low (L): (0, 1, 2), Moderate (M): (1, 2, 3), High (H): (2, 3, 4), and Very High (VH): (3, 4, 5).

These terms facilitated the transformation of qualitative assessments into quantitative values, making them amenable to fuzzy logic-based analysis [30, 31].

3.3 Ranking Main Barriers by Fuzzy MCDM Analysis

The initial stage in developing the problem structure was to identify and categorize the impediments. Fuzzy MCDM is used to rank the 12 barriers that have been identified. This method prioritizes barriers according to their perceived importance while taking into account expert perspectives and managing decision-making uncertainties.
A research of their mutual influence was conducted by comparing barriers pairings using a language scale that was then converted into triangular fuzzy numbers to allow for uncertainty and quantify the effect strength. A more precise and flexible prioritization process was made possible by this approach.

- Fuzzy Membership Function Assignment

Triangular Fuzzy Numbers (TFNs) were created by combining the experts' evaluations of the scales' relative significance to represent the group's overall viewpoint. The uncertainty in expert opinions is captured by TFNs, which use three numbers to indicate the range of possible outcomes.
The formula was used to calculate each subscale's aggregated fuzzy number (Equation 1):

$$\tilde{A}_{scale} = \frac{1}{N}\sum_{i=1}^{N}\tilde{A}_i$$

Where:
$\tilde{A}_i$ = represents the TFN assigned by the i^{th}expert.
N = 60, the number of experts.
This aggregation ensured a consensus-based representation of expert opinions while retaining the imprecision inherent in individual responses [32].

- Defuzzification

The complete Triangular Fuzzy Numbers (TFNs) were defuzzed into discrete values using the weighted average method. This method creates a single, unique value by calculating the weighted average of the triangle fuzzy numbers' lower, middle, and upper values based on their respective relevance or frequency. The defuzzified crisp values, which indicate the exact prioritizing of the scales, allow for clearer decision-making while maintaining the uncertainty and variability present in the expert evaluations [32, 31].
The formula used was (Equation 3):

$$Crisp\,Value = \frac{(a + 4b + c)}{6}$$

Where: a, b, and c represent the lower, middle, and upper bounds of the triangular fuzzy number, respectively.
This formula balances the influence of the most likely value (b) and the range of possible values (a and c), providing a robust measure of central tendency.

- Ranking of Scales

By using the defuzzified crisp values for each scale to rank the barriers, the items were clearly prioritized. This ranking allowed for a comparison of the relative importance of each scale and identified the key enablers for the development of passenger drones. Focused decision-making was made possible by the analysis's identification of the critical components, ensuring that the development and implementation of passenger drone technology gave priority to the most significant factors.

- Ranking Formula

The sharp, defuzzed values on the scales were sorted in descending order. This ranking algorithm identified the most significant scales, with greater relevance indicated by higher, more distinct values. By arranging the scales from greatest to lowest, the study created a clear hierarchy of barriers that show which factors are most crucial for the advancement of passenger drones and should be given precedence in future projects.

Rank = Order of Crisp Values (C)

This ranking process helped prioritize efforts and resources for enhancing the identified barriers.

4 Data Analysis

Expert opinions were solicited from 60 domain specialists to evaluate each subscale of the enablers identified in the study. For example, under the Regulatory Framework scale, expert responses were distributed across the scales as follows:

Table 1 Response from experts

	VL	L	M	H	VH
1. Lack of a Code of Conduct for Urban Air Mobility (UAMs)	0	1	2	18	39
2. Threats of Terrorism and Misuse of Drones	3	9	10	13	25
3. Insufficient Security Protocols for Airspace Control	6	5	10	17	22
4. Inadequate Licensing Framework for Authorized Drones	0	1	4	16	39
5. Privacy Concerns Related to Drone Operations	14	17	13	8	8
6. Poor Control Over Unauthorized and Spy Drones	16	14	16	6	8
7. Unclear Pathway Design for Drone Navigation	1	4	8	11	36
8. Passenger Safety Risks in Drone Operations	5	4	10	18	23
9. Absence of Standardized Safety Features for Drones	3	6	8	15	28
10. Lack of Comprehensive Laws for Drone Operations	0	2	4	12	42
11. Absence of a Central Regulatory Body for Passenger Drones	0	0	10	9	41
12. Limited Simulation and Training Infrastructure for Drone Operations	2	2	8	16	32

These steps lay the groundwork for prioritizing the enablers for passenger drones in the Indian aviation sector using Fuzzy MCDM.

4.1 Aggregate Expert Responses into Fuzzy Numbers

For each scale, the responses from 60 experts were aggregated into Triangular Fuzzy Numbers (TFNs). The aggregation process involves weighting the TFNs for each linguistic term based on the proportion of experts who chose that term. The formula used for this aggregation is:

$$\tilde{A}_{scale} = \frac{1}{N}\sum_{i=1}^{N}\tilde{A}_i$$

Where: $\tilde{A}_i$ = represents the TFN assigned by the i^{th}expert.

N = 60, the number of experts.

This aggregation ensured a consensus-based representation of expert opinions while retaining the imprecision inherent in individual responses.

Table 2 Lack of a Code of Conduct for Urban Air Mobility (UAMs)

Term	TFN	Number of Experts	Contribution to Aggregated TFN
VL	(0, 0, 1)	0	(0.000, 0.000, 0.000)
L	(0, 1, 2)	1	(0.000, 0.017, 0.033)
M	(1, 2, 3)	2	(0.033, 0.067, 0.100)
H	(2, 3, 4)	18	(0.600, 0.900, 1.200)
VH	(3, 4, 5)	39	(1.950, 2.600, 3.250)

Aggregated TFN for "Lack of a Code of Conduct for Urban Air Mobility (UAMs)": $\tilde{A}$ = (0, 0, 0) + (0, 0.017, 0.033) + (0.033, 0.067, 0.1) + (0.6, 0.9, 1.2) + (1.95, 2.6, 3.25) = (2.583, 3.583, 4.583)

In similar way, the aggregated TFN for the remaining 11 barriers of Passenger Drone Integration in India's Aviation Sector were also calculated. The aggregated TNF values are given in Table 3

4.2 Normalize the Aggregated TFNs

To ensure comparability across subscales, the aggregated TFNs were normalized by dividing each TFN by the maximum upper limit among all subscales. For the Regulatory Framework scale, the highest upper limit was 3.967

Normalization formula: $\tilde{A}_{scale} = \frac{\tilde{A}}{\max(\widetilde{A})}$

For the Regulatory Framework scale, the highest upper limit was 3.967

The aggregated TFNs for the five subscales of Regulatory Framework are

Table 3 Aggregated TFNs of Regulatory Framework

S. No.	Scales	Aggregated TFN	Normalized TFN
1.	Lack of a Code of Conduct for Urban Air Mobility (UAMs)	(2.583, 3.583, 4.583)	(0.564, 0.782, 1.000)
2.	Threats of Terrorism and Misuse of Drones	(1.850, 2.800, 3.800)	(0.404, 0.611, 0.829)
3.	Insufficient Security Protocols for Airspace Control	(1.833, 2.733, 3.733)	(0.400, 0.596, 0.815)
4.	Inadequate Licensing Framework for Authorized Drones	(2.550, 3.550, 4.550)	(0.556, 0.775, 0.993)
5.	Privacy Concerns Related to Drone Operations	(0.883, 1.650, 2.650)	(0.193, 0.360, 0.578)
6.	Poor Control Over Unauthorized and Spy Drones	(0.867, 1.600, 2.600)	(0.189, 0.349, 0.567)
7.	Unclear Pathway Design for Drone Navigation	(2.300, 3.283, 4.283)	(0.502, 0.716, 0.935)
8.	Passenger Safety Risks in Drone	(1.917, 2.833,	(0.418, 0.618,

	Operations	3.833)	0.836)
9.	Absence of Standardized Safety Features for Drones	(2.033, 2.983, 3.983)	(0.444, 0.651, 0.869)
10.	Lack of Comprehensive Laws for Drone Operations	(2.567, 3.567, 4.567)	(0.560, 0.778, 0.996)
11.	Absence of a Central Regulatory Body for Passenger Drones	(2.517, 3.517, 4.517)	(0.549, 0.767, 0.985)
12.	Limited Simulation and Training Infrastructure for Drone Operations	(2.267, 3.233, 4.233)	(0.495, 0.705, 0.924)

4.3 Defuzzification and Ranking

To rank the scales, the aggregated fuzzy numbers were defuzzified into crisp values using the weighted average method:

$$Crisp\ Value = \frac{(a + 4b + c)}{6}$$

Where a, b, and c represent the lower, middle, and upper bounds of the triangular fuzzy number, respectively.

The defuzzified crisp values for each scale were used to rank the enablers. The ranking provided insights into the relative importance of the scales, identifying the most critical factors for the progression of passenger drones.

Table 4 Ranking of Scales

S. No.	Scales	Aggregated TFN	Crisp Value	Rank
1.	Lack of a Code of Conduct for Urban Air Mobility (UAMs)	(2.583, 3.583, 4.583)	0.782	1
2.	Threats of Terrorism and Misuse of Drones	(1.850, 2.800, 3.800)	0.613	9
3.	Insufficient Security Protocols for Airspace Control	(1.833, 2.733, 3.733)	0.6	10
4.	Inadequate Licensing Framework for Authorized Drones	(2.550, 3.550, 4.550)	0.775	3
5.	Privacy Concerns Related to Drone Operations	(0.883, 1.650, 2.650)	0.368	11
6.	Poor Control Over Unauthorized and Spy Drones	(0.867, 1.600, 2.600)	0.359	12
7.	Unclear Pathway Design for Drone Navigation	(2.300, 3.283, 4.283)	0.717	5
8.	Passenger Safety Risks in Drone Operations	(1.917, 2.833, 3.833)	0.621	8
9.	Absence of Standardized Safety Features for Drones	(2.033, 2.983, 3.983)	0.653	7
10.	Lack of Comprehensive Laws for Drone Operations	(2.567, 3.567, 4.567)	0.778	2
11.	Absence of a Central Regulatory Body for Passenger Drones	(2.517, 3.517, 4.517)	0.767	4
12.	Limited Simulation and Training Infrastructure for Drone Operations	(2.267, 3.233, 4.233)	0.707	6

Results

1. *Lack of a Code of Conduct for Urban Air Mobility (UAMs)* (Crisp Value: 0.782, Rank: 1**)**
The absence of a well-defined code of conduct for Urban Air Mobility (UAMs) is a significant issue and the highest priority, highlighting the need for comprehensive guidelines to standardize operations, ensure safe and efficient drone usage in urban areas, and promote reliable integration into urban airspaces.

2. *Lack of Comprehensive Laws for Drone Operations* (Crisp Value: 0.778, Rank: 2**)**
Concerns over terrorism, the potential misuse of drones, and the absence of comprehensive legal frameworks highlight the urgent need for advanced security measures, surveillance systems, and laws that address the growing complexities of drone operations, including airspace rights, liability, and privacy.

3. *Inadequate Licensing Framework for Authorized Drones* (Crisp Value: 0.775, Rank: 3**)**
The lack of robust security protocols for managing airspace and the absence of a streamlined licensing process underscore the critical need for stringent air traffic control systems and a robust licensing framework to ensure that only qualified operators manage drones, minimizing operational risks.

4. *Absence of a Central Regulatory Body for Passenger Drones* (Crisp Value: 0.767, Rank: 4**)**
A comprehensive and streamlined licensing framework, combined with a centralized regulatory body, is crucial to effectively authorize and regulate drone operations, ensuring compliance with safety standards while promoting consistency and efficiency in governance.

5. *Unclear Pathway Design for Drone Navigation* (Crisp Value: 0.717, Rank: 5**)**
Addressing privacy concerns and the need for clearly defined navigation pathways is essential to protecting individuals' rights, promoting drone adoption, improving operational efficiency, and reducing mid-air collisions, thereby ensuring the safe integration of drones into shared airspace.

6. *Limited Simulation and Training Infrastructure for Drone Operations* (Crisp Value: 0.707, Rank: 6**)**
The top concern highlights the need for stringent monitoring systems to prevent unauthorized drone operations and address potential threats, while the limited availability of simulation and training infrastructure underscores the importance of investing in advanced training facilities to enhance operator readiness, safety, and efficiency.

7. *Absence of Standardized Safety Features for Drones* (Crisp Value: 0.653, Rank: 7**)**
Ambiguities in pathway design for drone navigation and the lack of standardized safety features underscore the need for well-defined aerial routes and consistent safety measures across different drone models to ensure safe and efficient operations.

8. ***Passenger Safety Risks in Drone Operations*** **(**Crisp Value: 0.621, Rank: 8**)**
Passenger safety risks are a significant concern, emphasizing the need for strict adherence to operational protocols, the implementation of fail-safe mechanisms, and advanced real-time monitoring systems to build public trust and ensure safe drone operations.

9. ***Threats of Terrorism and Misuse of Drones*** **(**Crisp Value: 0.613, Rank: 9**)**
Standardizing safety features across drone models is critical for fostering trust and ensuring operational reliability, while security threats highlight the need for stringent measures, including improved tracking systems and legal deterrents, to prevent misuse.

10. ***Insufficient Security Protocols for Airspace Control*** **(**Crisp Value: 0.6, Rank: 10**)**
The absence of overarching legal frameworks for drone operations underscores the need for legislation that addresses various aspects of drone integration and safety, while the lack of adequate security protocols for airspace control raises concerns about unauthorized access, highlighting the need for robust surveillance and control measures.

11. ***Privacy Concerns Related to Drone Operations*** **(**Crisp Value: 0.368, Rank: 11**)**
The establishment of a central regulatory authority is essential for unified governance and streamlined decision-making regarding passenger drone operations, while privacy issues emphasize the importance of clear policies and technological solutions to prevent drones from infringing on personal privacy.

12. ***Poor Control Over Unauthorized and Spy Drones*** **(**Crisp Value: 0.359, Rank: 12**)**
The lack of adequate simulation and training facilities hinders operator preparedness, highlighting the need for investments in training infrastructure, while poor control over unauthorized drones, ranked as the top concern, underscores the necessity for enhanced detection and countermeasure technologies to safeguard against potential threats.

5 Summary of Findings

In conclusion, the top four barriers that have been ranked as obstacles to the growth of Urban Air Mobility (UAM) bring to light significant regulatory and governance disparities that need to be addressed in order to realize its full potential. Due to the necessity of established norms to guarantee safety, ethical operations, and public trust, the absence of a Code of Conduct for UAMs was regarded as one of the most significant issues. In a similar way, the lack of comprehensive legislation governing drone operations is indicative of the urgent requirement for clear legal frameworks that can effectively regulate both commercial and passenger drones. One of the most significant challenges that has surfaced is the inadequacy of the licensing system for permitted drones. This is because it hinders the capacity to certify and regulate drone operators, which is necessary for assuring compliance and competency. Finally, the lack of a centralized regulating agency for passenger drones was a key factor. This is because it highlights the fragmented nature of oversight, which in turn leads to variations in safety standards, operational rules, and enforcement methods. A comprehensive and multi-faceted approach will be essential to overcoming these barriers and fostering sustainable growth in the sector.

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