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# Regulating Unmanned Aerial Vehicles “A Legal Framework for Global Airspace Governance”

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## Abstract:

This paper proposes an independent regulatory framework for Unmanned Aerial Vehicles (UAVs) to bridge gaps in existing aviation regulations. It critically examines current regulatory limitations in managing UAV advancements, with a focus on airspace management, privacy concerns, and the need for global cooperation. The study advocates for the integration of international standards and flexible legal models to support UAV operations. It also suggests strategies for harmonizing these operations to ensure security, accountability, and technological innovation

The paper has examined how global coordination is crucial in addressing the fragmented realms of UAV rules. The study has advocated for global standards led by ICAO so that data privacy regulations can be harmonized. Bilateral agreements are going to further allow for cross-border utilization by increasing coordination between different regions. And showcased that the establishment of the framework is vital by contemplating previously introduced aviation laws. Finally, this study has investigated ethical and

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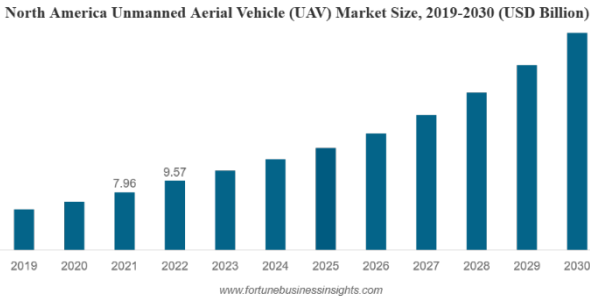
social implications reflecting the critical realms of public awareness through education.

**Keywords:** Aviation Law; Unmanned Aerial Vehicles (UAV); Regulatory Framework; Governance; International standards.

### 1. Introduction

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are aircraft that operate without onboard human pilots. Originally developed for military purposes, UAVs have now evolved into versatile tools used across various industries. These vehicles, often controlled autonomously or via remote control, offer greater operational range than traditional manned systems. Historically, UAVs were primarily used for defense and surveillance purposes (Mohsan et al., 2022).

The value of global UAVs market size was approximately USD 27.43 billion during 2022. It has been anticipated to increase from \$31.70 billion in 2023 to \$91.23 billion by 2030 (Mohsan et al., 2022). It exhibited at the CAGR of about 16.3% in forecast periods. North America was the dominant in this UAVs market with 34.89% market share in 2022. On the other hand, the market size for military drones has been predicted to increase from \$16.07 billion during 2024 to \$47.16 billion in 2032 at the CAGR of approximately 13.15% during the forecast periods.



**Figure 1. Projected UAV Market Size Growth (2022-2030). Source: Fortune Business Insights (2023), “Unmanned Aerial Vehicle (UAV) Market Size & Growth Analysis**

As “UAV” technology has continued to expand throughout different sectors, pre-existing regulatory frameworks’ inadequacies become evident. The core issue with the current legal models includes their inability to keep pace with advancements in these types of aerial vehicles. The existing laws have mainly focused on manned aircraft that lack flexibility when it comes to unmanned ones. As drones are used in delivery, recreation and surveillance, a regulatory gap becomes problematic.

The drones have played an important role in defense industries by contributing to military functions. The unmanned systems have permitted remote surveillance and precision strikes along with intelligence gathering in this sector. In agriculture, they help farmers through collecting information on crops’ health while optimizing irrigation to assist in smart farming approaches (Velusamy et al., 2021). Commercially, organizations such as Amazon experiment with unmanned vehicles for product delivery to revolutionize supply chains. They can also be utilized to gain information before risks happen to contribute to prevention management. They have been essential tools when it comes to public safety as they are leveraged for rescue missions alongside disaster response. However, the increasing usage of UAVs has presented new challenges highlighting the demand for regulatory frameworks to oversee their utilization.

Currently, this innovation has been overseen by aviation laws which were originally developed for manned aircraft. For example, the FAA or “Federal Aviation Administration” and EASA or “European Union Aviation Safety” have imposed limitations like the UAVs’ altitude limits and no-fly zones. However, such models have not been effective in entirely capturing these technologies’ different nature compared to conventional aircraft in operational range. Regulatory challenges have become evident in regard to

airspace management alongside privacy concerns to property or individuals. These vehicles function at a lower altitude added to their small size which makes it difficult to detect them. Such factors have caused issues in regard to collision avoidance in crowded locations (Yasin et al., 2020). They have also been equipped with cutting-edge sensors that contribute to infringing privacy rights whereas facts collected by them are vulnerable to misuse.

It is important to develop an independent regulatory framework for such unmanned aerial vehicles to focus on legal and technological implications along with the socio-economic realms. Legally, these independent models would offer clarity in overseeing UAVs by decreasing threats of legitimate ambiguities. Technologically, the regulatory structure is going to foster the incorporation of emerging technologies in UAVs into AI (Artificial Intelligence) by following legal rules. A flexible model would enable recent or upcoming technologies’ regulations without stifling advancements. Socio-economically, the independent framework is going to support the UAV sector’s development to assist in international economies. Clear rules would help to decrease risks concerns or legal disputes to make the UAV market more promising in various such as security sectors (Mohsan et al., 2022).

## **2. 2. Regulatory and Technological perspectives on UAV operations**

### **2.1 Current Regulatory Frameworks**

FAA of the United States: In the United States, the Federal Aviation Administration (FAA) regulates UAV operations through Part 107, which provides legal guidelines for commercial drone use. According to Law (2022), obtaining a remote pilot certification under this rule is necessary for flying UAVs, ensuring operators meet the regulatory requirements for

safe operation. The certificate has underscored the regulations to meet requirements along with processes for flying drones. According to the rule, the vehicles need to remain within the operators' VLOS (Visual Line of Sight) while staying below four hundred feet in altitude. The FAA's Part 107 primarily addresses smaller drones under 55 pounds, limiting its applicability for modern autonomous flights and commercial delivery applications. This restriction highlights the need for expanded regulations that encompass larger and more advanced UAV operations. The waiver systems have introduced ambiguities by needing case-by-case approvals. Therefore, it can be the FAA's "Part 107" gives a foundation for commercial functions. However, the waiver systems' dependency on discretionary approvals restricts scalability for operators.

EASA of Europe: The agency has governed UAVs' operations under the European Union Drone Regulation which came into effect in 2021. The organization has set up principles for flying drones by defining how they can be designed or manufactured. Fortońska (2021) stated that there are 3 types of categories such the open category applying to lower-threat operations. In this case, UAVs need to be less than twenty-five kilograms of weight without flying over restricted zones. The certified category has been for highest-threat posed by large unmanned vehicles employed for air mobility in urban areas. It can be mentioned that the EASA's risk-dependent strategy provides flexibility through categorizing drones' functions based on the risk level. On the other hand, the framework requires enhancements in defining standards for AI-powered aerial vehicles. The 3-category systems of this EASA offers useful distinctions but the classification can be inadequate when it comes to addressing swarm technologies.

GCAA (General Civil Aviation Authority), the UAE: The country's

civil aviation rules have ensured its airspace’s security by improving the aviation sector. The “UAS Registration and Operation guidelines” have overseen UAVs utilization by focusing on airspace safety. Alketbi, Dalalah & Dweiri (2024) said that it is required for every UAV to avoid flying over no-fly areas like airports, adhering to the Federal Decree-Law No (26) of 2022.

## **2.2 Comparisons of Technological Characteristics between UAVs and Conventional Aircraft**

**Size and weight:** The differences between them includes their sizes as UAVs can be small drones to larger ones used for military purposes like the MQ-9. Lee, Hess & Heldeweg (2022) mentioned that the smaller ones have less than one kg, whereas the larger drones can weigh more than 4700 kg. In contrast, traditional aircraft have been much larger transporting cargo. Chaurasia & Mohindru (2021) said that the UAVs’ lightweight feature has enabled them to be more flexible, evidenced by their functions in dense forests. On the other hand, their small sizes have issues like hardships to detect them in comparison to other aircraft.

Lee, Hess & Heldeweg (2022) mentioned that these varying drone sizes and weights affect airspace safety rules because of differing functional risks. Smaller ones have posed challenges for collision avoidance. Therefore, the independent regulation is required as the current laws are insufficient to address approaches on how to avoid such collisions caused due to drones. Larger vehicles need safety measures through establishing rules to navigate issues in airspace management.

**Applications:** The UAVs’ objectives have varied in comparison to traditional ones as they are developed for cargo delivery together with

passenger transport. In contrast, UAVs have diverse applications because of their flexibility resulting in their use in intelligence gathering and surveillance. Lee, Hess & Heldeweg (2022) mentioned that they have served various sectors, such as agriculture for crop monitoring and emergency response for disaster evaluation. Filmmakers have utilized these vehicles for capturing aerial shots whereas firms like Amazon explore drone delivery for the purpose of reducing delivery times. On the other hand, traditional aircraft have primarily been used for longer-haul functions throughout large distances while lacking capability of conducting localized missions.

### **2.3 Challenges in Existing Frameworks**

**Airspace security:** Airspace security is a significant challenge when applying aviation regulations to UAVs. Xu et al. (2020) noted that while traditional aircraft operate within controlled airspaces managed by Air Traffic Control (ATC), UAVs typically function in uncontrolled spaces with minimal ATC oversight. The technology's capability of being piloted by people without authorized aviation training has also raised questions. Recreational drone users have minimal training as opposed to traditional pilots, who undergo training by adhering to certification procedures.

**Privacy concerns:** A gap in aviation rules includes privacy concerns as the innovation is equipped with cutting-edge sensors that may invade privacy. They have also operated on private property to capture images without individuals' consent. Xu et al. (2020) stated that the recent aviation laws have not solved such problems as these regulations safeguard illegal surveillance, which can be hard to execute in regard to UAVs.

**Data safety:** Autonomous drones have caused challenges in data security through their sophisticated systems. These advanced features have been

able to collect and process a vast amount of information in real time. Such facts include sensitive data like geolocation, or sensor readings leveraged for scientific procedures. Xu et al. (2020) stated that cybersecurity threats have also been an issue for government drones engaged in infrastructure inspection.

### **3. 2.4 Rapid Technological Advancements**

**Artificial Intelligence (AI):** This technology is increasingly used in drones to allow for autonomous flight with the help of machine learning algorithms. Fan et al. (2020) said that automated drones can perform complicated missions such as precision agriculture without human assistance. AI has also permitted this technology to make decisions in real-time by preventing hardships like making adjustments in flight paths relying on changing situations.

**Deep learning (DL):** It allows UAVs to identify patterns in larger datasets so that their capability is improved. They become able to process information from radar systems and LiDAR. It has powered applications associated with computer vision that permit drones to classify objects and make decisions in real time.

**Artificial Neural Networks:** They mimic neural connections of the human brain for interpreting environmental data. It can also adapt to vigorous conditions as well as refine UAV responses over time. Such networks have allowed a drone to anticipate flight paths while optimizing fuel effectiveness.

**AI’s practical applications:** These technology-powered machines utilize SLAM or “Simultaneous Localization & Mapping.” It helps create

3D maps which enable accurate navigation in GPS-denied atmospheres like dense urban locations. Innovations assist in adjusting UAVs' paths dynamically so that collisions are avoided. Artificial intelligence-driven unmanned vehicles track own components by employing anomaly-detection algorithms. It predicts failures before their escalation with the help of decreasing downtime. A sensor fusion technique is used that helps process facts from ultrasonic sensors. It prevents obstacles by detecting them in real time in hazardous environments.

BVLOS (Beyond Visual Line of Sight) functions: UAV rules like the United States' FAA have required these innovations to stay within operators' sight line ensuring security. BVLOS has enabled the drones to fly beyond operators' visual ranges by utilizing GPS to navigate without manual assistance. Fan et al. (2020) said that BVLOS has the ability to transform logistics sectors or infrastructure inspections to allow for large-scale surveillance.

Technologies utilized in BVLOS functions: Its operations need advanced navigation and communication. Surveillance technologies such as GPS are required to ensure efficient flights. "Global Positioning System" or GPS has offered accurate location monitoring making sure that precise route planning is emphasized. "Inertial Navigation systems" (INS) rely on gyroscopes & accelerometers helping in maintaining stability. It works effectively during weak GPS signals primarily in remote areas.

Satellite communication allows for command & control linkages between a ground control station and drones to ensure constant communication. UTM systems have been used as these platforms employ geo-fencing as well as air traffic control coordination. An automated flight approval makes

sure that a UAV functions within specific airspaces.

Security measures: BVLOS requires security measures to mitigate threats like DAA (Detect & Avoid) mechanisms. Unmanned vehicles utilize multi-sensor fusion for detecting obstacles including dynamic (other aircraft) or static (buildings). Automatic Dependent Surveillance-Broadcast is leveraged to broadcast the UAV’s position. It assists in receiving signals from a nearby aircraft so that situational awareness is enhanced. Regulatory bodies

including ICAO mandate, this type of vehicle to undergo security evaluations.

Cybersecurity: The innovation has become advanced by depending on wireless communication added to cloud computing. Mohsan et al. (2023) stated that it has caused cybersecurity risks like hacking through unauthorized surveillance. The high-resolution sensors of this technology can also gather data linked with infrastructure details, raising questions about privacy. It is important for regulators to implement regulations to integrate the vehicles into public spaces to solve data protection threats.

Technology employed for information encryption: Modern encryption innovations are executed to protect UAV data from unauthorized access. End-to-end encryption is an appropriate method in this regard. It makes sure that facts remain inaccessible during their transmission between cloud storage and GCS/ground control stations. Public-Key Infrastructure has used online certificates to authenticate machines. It ensures that authorized operators have access to flight data.

Blockchain improves information immutability through recording flightlog in tamper-proof ledgers. It is applicable for regulatory adherence by ensuring that these logs stay verifiable. Edge computing is leveraged to process essential facts onboard instead of depending on cloud transmission. Safe cloud storage tools are implemented for MFA/Multi-Factor Authentication. AI-powered anomaly detection is also utilized to avoid unauthorized access.

Preventive mechanisms against data breaches: Role-dependent access control is executed ensuring only authorized people modify flight-related plans. Biometric authentication like facial recognition has been focused on for operators. On the other hand, machine learning/ML algorithms evaluate patterns linked with network traffic. It is capable of determining unusual activities indicating cyberattacks.

Swarm technology: It has enabled multiple drones to function coordinately as a team, creating concerns for regulators. Fan et al. (2020) said that UAV swarms are employed for military surveillance and entertainment for light shows alongside disaster response. These types of swarms cover large locations to gather data to perform roles more appropriately than a single UAV. The current regulatory models can be executed for a single UAV as they do not cover these complex dynamics of swarms.

## **2.5 Call for Independent Regulation**

Technological complexities: Drone technology has been advancing quickly compared to conventional aviation. Elmeseiry, Alshaer & Ismail (2021) mentioned that swarm innovations and BVLOS have been instances that previously established rules cannot address. Prior aviation laws have been built for manned aircraft to focus on security protocols alongside

the management of air traffic. As opposed to it, drones can fly without manual help in urban atmospheres beyond the operators’ sight. Moreover, autonomous ones need laws to highlight responsibilities to prevent privacy violations while adapting to UAV functions’ complications to ensure security.

International harmonization: The current regulations may vary between nations, resulting in confusion for global operators. Shokirov et al. (2020) stated that this varying rules across countries have also been a reason for inconsistencies in law enforcement uniformly. The absence of steadiness has created challenges for businesses seeking to emphasize drone-dependent services globally. Telli et al. (2023) mentioned that for this reason, the establishment of an independent legal model needs to be created by maintaining international standards. This harmonization is going to permit global collaboration so that innovation can be facilitated by safer UAV operations.

## **2.6 Discussions on different countries’ existing regulations**

### **The United States of America**

Operational limits: The FAA’s strengths include overseeing UAV rules in this nation with its Part 107 which governs small drones weighing approximately 55 pounds. Other advantages are that such rules have stated operational limits and licensing processes, such as limiting flights to only daylight hours and imposing four hundred foot-altitude restrictions for UAV performance. Knowledge tests also need to be passed to acquire the “Remote Pilot Certificate” ensuring that pilots understand lawful roles (Calandrillo, Oh & Webb, 2020). However, the limitation is that it has only emphasized small drones which is not applicable to larger automated ones

that require special permissions.

**Waivers:** The FAA includes waiver systems accommodating compound missions. It can be applied to bypass a few diminutions like flying over individuals and performing tasks at night. It has enabled greater creativity in drone delivery sectors, though it may be administratively slow. Users leveraging this system need to give in-depth risk analysis plans that may create delays while increasing monetary amounts for a business (Smyth, 2021). In contrast, the FAA's dependence on waivers can create legal uncertainties through introducing an inconsistent approval procedure as well as inadequately outlined guidelines. It may result in confusion among the operators in relation to compliance requirements and functional limitations, complicating regulatory dynamics for UAV applications.

**Future considerations:** Deficiencies remain in addressing security questions in populated locations evidenced by the FAA's effectiveness in managing BVLOS abilities. The country is more likely to prioritize enlarging airspace access in the upcoming times to improve air mobility.

### **The European Union**

**Categorization:** The EU's model has classified UAVs into 3 categories like open and specific alongside certified. The open category has covered low-threat functions for smaller vehicles, permitting them to fly within controlled spaces. The limitation includes staying below 120 meters to preserve the line of sight (Labib et al., 2021). On the other hand, the space category has been applied to moderate risk drones that fly in controlled areas. It is important for the operators to conduct an assessment to acquire authorization before performing tasks. In contrast, the certified class has covered higher-risk UAVs leveraged for cargo transport requiring

certifications. They should also adhere to operational standards to uphold the same airworthiness as manned aircraft.

U-space: The European Union has executed U-space as the airspace management strategy for the chosen technology. U-space has integrated a UAV into controlled zones through offering real-time monitoring or flight authorizations (Konert & Dunin, 2020). It has made sure that the system can perform alongside manual aircraft near airports. It can be learned that “U-space” has been an important element as far as EU’s efforts are concerned in terms of allowing for commercial tasks. The model has also offered information regarding scalable airspace management for the drones focusing on security and incorporation with the manned aircraft. It has promoted risk-based approaches that improve operational flexibility while making sure that safety is required in crowded airspaces.

#### The United Arab Emirates

Registration procedures: The UAV performance has been governed by the GCAA focusing on drones registration methods to ensure that every system fulfils security policies. They should be registered with the help of a platform called “My Drone Hub.” This virtual platform has given streamlined methods for owners so that they can acquire approvals (Kandeel et al., 2022).

No-fly zones: The country has designated “no-fly” areas around military installations and government buildings. The GCAA has employed geofencing to execute restrictions to focus on drone activity that can be limited to airspaces by preventing their entry without authorization. Urban locations like Dubai get assistance from this rule to prioritize public protection as users must seek approvals for commercial filming (Al Abdouli

& Sipos, 2024).

Promoting creativity: The nation has promoted UAV functions in different industries as per its Vision 2021 as well as Dubai 10X programs (Al Abdouli & Sipos, 2024). The governmental support has contributed to using the innovation in smart city initiatives to enhance emergency response. Such initiatives show the country's dedication to becoming an international centre for urban efficiency.

### **2.7 Lessons learned**

Risk-dependent categorization: The analysis of different countries' regulations have highlighted lessons such as the risk-based categorization. The EU has this kind of classification providing a framework for distinctness between high-risk military operations and lower-risk UAVs. It has allowed the arthritis to emphasize which type of drone is the riskiest that demands stricter rules (Tran & Nguyen, 2022).

Industry collaboration: This factor has been significant in shaping the legalized model where manufacturers and service givers would coordinate with each other for the technology's feasibility. The UAE has collaborated with private industries to focus on drone delivery while their smart city programs can exemplify industry involvement. Industry insights would assist in nurturing creativity and maintaining privacy concerns simultaneously (Tran & Nguyen, 2022).

Enforcement mechanisms: Adherence to UAV policies has required enforcement methods' efficient implementation. The US frameworks have illustrated the noteworthiness of manual and automated systems through audits to stop unauthorized operations. Clear strategies must be included by including fines in case of non-compliance (Tran & Nguyen, 2022) as it

improves public confidence in airspace security.

#### **4. 3. Evaluation of UAV-Specific Regulatory Needs**

UAV technology has been incorporated into commercial along with civilian activities calling for a committed legal model to adhere to lawful principles. For this reason, it is required to evaluate the regulatory demands by prioritizing various UAV characteristics and operational atmospheres.

##### **3.1 Capabilities:**

Unmanned vehicles have varying sizes and payload capacities ranging from small drones to large ones used for military purposes. Such distinctiveness has a direct effect on administrative demands because of the different challenges presented by each UAV. It is crucial to emphasize restricting smaller ones' functional scopes to uphold security, as they are difficult to detect through radar systems (Emimi, Khaleel & Alkrash, 2023). Their operations in urban environments have also made airspace management complex while causing difficulties in collision avoidance. For this reason, laws should be made for altitude limitations to improve visibility standards with the help of onboard lighting for appropriate identification.

In the context of airspace management's technical details, it is noted that UTM systems are emphasized. It is a digital ATC system developed for enabling UAV functions beyond the visual line of sight. This system helps in managing air traffic for drones by utilizing geofencing and automated flight authorization. Real-time monitoring prevents unauthorized intrusions while avoiding collisions. Its main components are remote identification recognizing UAVs for airspace's tracking. Other methods for managing air traffic involves AI as predictive analytics maximize flightpaths relying on regulatory constraints. Cloud-dependent UTM tools have fostered airspace

allocation through decreasing issues of congestion.

Incorporating with pre-existing aircraft systems: UAVs are equipped with automatic dependent surveillance-broadcast/ADS-B transponders. It helps in broadcasting flights' information to ATC. Moreover, UTM platforms have interfaced with radar systems ensuring a flight does not interfere with commercial aviation. 5G networks are employed in terms of relaying flight-related information to ATC platforms. It can be said that UTM's integration with ATM (Air-Traffic Management) help UAVs co-exist with manned ones. It improves airspace's effectiveness while preserving flight security followed by regulatory compliance.

On the other hand, larger ones have required stringent legitimate oversight as they can carry heavy payloads by flying long distances automatically. Greater abilities have led to greater threats primarily when they are utilized for cargo delivery (Emimi, Khaleel & Alkrash, 2023). Such larger unmanned vehicles can also function alongside manned ones in controlled airspaces, raising the need for certification guidelines by including pilot training. It has been vital for laws to consider ethics in the case of drone usage in data collection for better operations.

Furthermore, autonomous drones' trends have been increasing as they can make informed decisions with humans' help, complicating administrative requirements. The utilization of artificial intelligence has also raised concerns regarding accountability during system failures. It has been necessary for regulators to develop guidelines regarding fail-scale methods and proper AI standards' execution.

### **3.2 Operational atmospheres:**

The regulations should focus on security in urban areas where these vehicles are leveraged for aerial photography. Urban airspace has been densely populated with infrastructure as well as buildings alongside people. The UAVs functioning in such environments face threats from environmental factors or mechanical failures (Kuenz, 2021). Therefore, urban regulations need to make sure that altitude limits are imposed to emphasize operational boundaries like no-fly locations around infrastructure.

On the other hand, those used in rural locations have fewer hindrances evidenced by their application in agriculture for pesticide spraying. In this context, laws should prioritize that UAVs are operated from secure distances to comply with data protection orders when collecting geospatial facts. Drones in rural locations function at a higher altitude, introducing threats associated with mid-air collisions (Bärfuss et al., 2022).

Restricted airspaces like government installations including military zones have presented administrative demands. It is required for the technology to have geofencing innovation so that entry into these areas can be prevented (Barrado et al., 2020). Moreover, operators in these airspaces should have higher certifications while submitting flight plans for approval from aviation authorities. Stricter penalties must be implemented to avoid unauthorized usage in such zones to prevent malicious activities.

### **3.3 Privacy concerns:**

These aerial vehicles or unmanned aircraft have been equipped with contemporary imaging technologies. Their sensor technology has contributed to collecting data, including video footage, to offer benefits to law enforcement. It has raised questions regarding privacy invasion

in densely populated locations. These aircraft can also gather private data when they fly over residential zones. The aviation laws have mainly developed because of manned aircraft that do not solve privacy concerns (Koh et al., 2023). The aerial vehicles have flown over much proximity to the ground that make them vulnerable to unauthorized information capture. It highlights stronger demands for UAV-specific laws to safeguard people's rights to privacy.

A key consideration for regulations includes upholding transparency during data collection. It has been necessary for the operators to inform people in case drones have cameras able to record data. It might include obtaining consent from them by informing property owners during flying in residential neighbourhoods. Consent must be made compulsory to ensure that the public is aware of being recorded. This factor has primarily been essential where the vehicles are leveraged for media coverage involving information collection (Koh et al., 2023). Regulations should be defined to outline UAV collected information's storage to restrict data distribution to authorized individuals.

### **3.4 Accidents' threats:**

Public safety has been one of the major reasons for concerns as UAVs operating in densely populated locations cause risks to property. It has highlighted the significance of mitigating such threats by establishing strict rules for drone testing. Such modulation must ensure that components undergo testing before their deployment in drones by upholding regularity across their functional life. Fail-safe methods like emergency landing mechanisms have been crucial when it comes to reducing the damage caused by accidents (Tomić, Čokorilo & Macura, 2020). They might leverage parachutes to minimize the adverse effects of crashes during

system failure whereas emergency landing processes would assist them to return safely during technical malfunctions.

Mid-air collisions are a critical risk occurring with manned aircraft as aerial vehicles function in lower altitudes compared to manned ones making them ineffective to be monitored by ATC (Air Traffic Control) systems. It has created a potential for drones to collide with others by entering in unauthorized areas showcasing the need for the usage of communication technology combined with ATC networks to avoid these issues. The enforcement of “no-fly” areas also should be followed around airports and military installations (Tomić, Čokorilo & Macura, 2020). It would contribute to decreasing the chances of accidents in sensitive zones where these unmanned aircraft’ incursions might interfere with critical operations.

### **3.5 Requirement for standardization:**

The requirement for standardized protocols is challenging due to the UAV industry’s international expansion. Organizations have sought opportunities through cross-border operations to reach out to more customers. However, inconsistencies in protocols between nations may create barriers in security standards along with licensing in airspace management. It has posed legal issues for the operators who are involved in global missions. Furthermore, bureaucratic differences have caused hardships for firms to execute standardized practices for conducting cross-border businesses as they need to adhere to multiple lawful models (Krichen et al., 2022).

Global regulatory harmonization is crucial to solve these issues with the help of the ITU (International Telecommunication Union) and “The International Civil Aviation Organization” or ICAO. Such agencies can

coordinate with aviation authorities in terms of creating a bureaucratic environment, making it hard for new technologies to navigate. Standardizing practices for airspace management is also going to prevent collision in mid-air by following protocols. Harmonizing privacy laws would also safeguard people's rights by offering principles for operators on data collection methods (Krichen et al., 2022).

In essence, the technology has continued to progress being an integral part of different industries and therefore this framework is essential to solve issues for accountable drone functions.

#### **4. Proposed Regulatory Framework**

Considering the ever-changing and evolving technology of the UAVs the time has come to unify the international arena under one umbrella which would both serve the purpose of regulating the technology and its uses as well as give enough room for its growth with minimal intervention to the aviation industry laws and regulations. Therefore, several key principles are proposed.

##### **4.1 Key Principles**

**Accountability:** A regulatory framework should be built to govern unmanned aerial vehicles to address issues by maintaining accountability. This factor has been crucial for manufacturers and operators to be held accountable for their activities outlined in the model. Operators' responsibilities include making sure that compliance is maintained in regard to airspace limitations and security protocols. In addition to this, certifications have also been necessary for them to be appropriately trained so that they can gain knowledge on legal responsibilities during operations (Mazur et al., 2022). On the other hand, manufacturers also need to be

responsible for manufacturing drones to fulfil safety standards. Defects in this technology’s software may result in accidents and therefore clear principles are required to address defects.

Therefore, it can be said that operators should adhere to privacy regulations, airspace limitations and security protocols. It has required training initiatives and compulsory certifications to improve awareness regarding liability. Manufacturers are also liable in case of any defects in UAV-linked software or hardware that result in operational failures. For this reason, a liability regime needs to be established to clearly differentiate between 3rd-party liability, manufacturer liability and operator liabilities. It has ensured compensation methods for hindrances caused by drone-associated incidents. Operators are responsible for breaches of airspace laws, whereas a regulatory model must address a 3rd-party, including software developers. An insurance scheme might be put in place to fortify accountability. This strategy is aligned with pre-existing aviation frameworks that improve public protection.

Regulatory flexibility for UAV-associated technological advancement: The technological advancements’ pace in relation to UAVs include autonomous control along with unique applications in surveying which may hamper existing modulation’s capacity. An overly restrictive regulatory model could stifle innovation, limiting the economic potential of UAVs. The framework should prioritize flexibility to accommodate emerging technologies, ensuring that regulations evolve alongside advancements.

Collaboration with these vehicles’ developers and sector experts have been crucial to predict changes to upgrade protocols accordingly. It has also involved streamlined procedures for approving the technology where

experimental functions are trialled (Mazur et al., 2022).

Mitigating environmental effects of UAVs: UAVs' environmental effects have been a vital consideration as they can pose challenges like noise pollution, hindrances for wildlife as well as battery disposal. It has shown that the legitimate model must combine standards for reducing drones' environmental footprint. It may involve noise level limitations in the natural atmosphere alongside principles for sustainable battery disposal methods like recycling (Ramos-Romero et al., 2022). The operators have to analyse UAV functions' environmental effects in ecological areas to make sure that animal habitats are not disturbed.

Environmental effects are reduced with the help of noise reduction innovations. Noise results from motor vibrations as well as aerodynamic disturbances. For this reason, low-noise propellers should be leveraged for aerodynamic maximization. These kinds of designs have advanced material engineering that decreases sound emissions. Conventional brushed motors produce mechanical friction resulting in high noise levels. Brushless motors have eliminated friction by decreasing energy consumptions & sound emissions.

Waste management approaches are important to ensure by battery recycling. In this regard, lithium-ion batteries have degraded over time and therefore they must be discarded safely. Manufacturers may collaborate with electronic-waste recycling agencies to recover nickel or cobalt from an old battery. Biodegradable resins can replace non-recyclable components. Frames made from thermoplastics have the capacity to decrease waste generation.

## 4.2 Certification and compliance framework

- Operators’ licensing: Commercial users accompanied by individual hobbyists should follow licensing obligations depending on the size and complexity of unmanned aircraft’. This type of certification must uphold tiered systems showcasing threats’ varying levels so that operators would know their various responsibility kinds (Merkert, Beck & Bushell, 2021).
- Recreational users: They operate drones of less than two kg in weight that require basic training covering airspace strategies or privacy considerations.
- Commercial users: They are engaged in aerial photography highlighting the significance of rigorous training to understand flight control.
- Autonomous users: They handle large ones for logistics and air mobility leading them to possess certifications on AI-powered control systems.
- Manufacturer certification: They must follow strict guidelines ensuring the innovation can meet environmental and other safety requirements (Merkert, Beck & Bushell, 2021). It has been essential for them to ensure production of reliable products adhering to software related obligations.
- Design: The features include collision-avoidance mechanisms together with geofencing technologies while covering technical principles to prioritize structural integrity for flight stability. Different types of materials are selected during

UAV-manufacturing involving carbon fibre composites. These materials are lightweight which is accompanied by its higher strength nature. They are not corroding unlike metals that makes them suitable for functioning in humid environments. Polycarbonate is prioritized because of its durability evidenced by its ability to provide higher impact resistance. Kevlar composites withstand temperatures making it an ideal choice for ensuring vehicles' operations in extreme circumstances. On the other hand, aluminium gives balances between durability & lightweight properties. Titanium is preferred due to its high-performance capacity. Structural designs involve using aerodynamic frame as well as fixed wing. These features contribute to long-endurance goals. Streamlined airframes reduce drag by improving fuel effectiveness. Rotary-wing ones employ foldable arms for enhancing manoeuvrability whereas blended-wing ones increase lift (Merkert, Beck & Bushell, 2021).

- Software certificates: Certificates in software development are crucial for automated drones to understand the nuances of AI.

Environmental standards: Certificates involve adherence to battery disposal methods to follow other mandates related to noise emission rates around wildlife reserves to minimize environmental footprint.

Maintenance standards: Maintenance has been one of the vital factors when it comes to ensure UAVs' longer-term security for autonomous functions. An independent, legitimate model should outline maintenance obligations so that drones can remain in proper working conditions (Merkert,

Beck & Bushell, 2021). In the context of maintenance processes, it can be said that routine inspections are conducted before and after every flight. It has helped to detect issues before their escalation through checking for loose connections. Battery health is checked at optimal voltage, whereas sensor calibration is verified to check GPS precision. Propeller inspection has been conducted for periodic servicing and firmware ensures software is updated for maximum performance. Preventive maintenance methods involve environmental protection through applying coatings. It safeguards UAV components from extreme temperatures or humidity.

Repair techniques are 3D printing regarding replacement parts evidenced by prototyping's usage. Customization also permits durable, lightweight parts' creation catered to specific models. Furthermore, Internet of Things/IoT tracking equips aerial vehicles with sensors. They transmit diagnostic facts to maintenance groups so that teams can monitor in real time.

Routine inspections: Mandatory inspections are vital on a regular basis for industrial unmanned vehicles by performing checks on rotors.

Manufacturer-approved preservation providers: It is critical for manufacturers to designate service centres that are approved for maintenance to conduct repairs by qualified individuals.

End-of-end disposal: The disposal should be managed in environmentally accountable ways by considering UAVs' secure decommissioning.

### **4.3 Risk-based classifications of UAV-airspace & Traffic management**

Classification of UAV operations' airspace: An airspace is categorized depending on proximity to infrastructure and risk levels. The purpose

includes making a balance between operational freedom and creativity while preserving public security (Nouacer et al., 2020). Tired classification procedures have been an efficient method to ensure various UAV functions can be regulated given their differing risk levels.

**a. Class A: High risk (Restricted airspace)**

- Airports: The possibility of mid-air collision between UAVs and manned aircraft can occur near airports. Drones need to be prevented from entering within five kilometres from airports' perimeter.
- Critical infrastructure: It involves regulating vehicle operations in the vicinity of power plants and nuclear facilities.
- b. Class B: Moderate risk (Urban airspace)
- Altitude limitations: Low-altitude functions must be limited in urban locations under 400 feet AGL or "above ground level" to reduce conflicts with manual aircraft.
- No-fly zones: The establishment of no-fly areas is crucial to restrict them near hospitals or schools to uphold public security.
- c. Class C: Low risk (Rural airspace)
- BVLOS operations: Only certified operators would be able to conduct such operations by maintaining safety protocols such as UAV monitoring with the help of GPS.
- Range flexibility: Functioning at a high altitude can be permitted in open airspace exemplified by its allowance up to five hundred feet AGL.

- UTM (Unmanned Traffic Management) systems: The integration of UTM systems is necessary to manage the increasing volume of UAVs in airspaces.
- Tracking in actual-time: Vehicles must have GPS systems to track data in actual-time so that ATC can access it to uphold situational awareness.
- Flight approvals: UTM system’s usage is important in restricted airspace for the submission of flight plans while receiving flight approvals to ensure adherence to local airspace laws.

#### **4.4 Incorporations with pre-existing aviation rules**

##### **4.4.1 Contemplating pre-existing laws:**

- Airspace integration: The previously established frameworks for manual aircraft have classified airspaces into various classes providing a strong foundation for airspace management as far as drones are concerned. The new model can integrate such categories by modifying them as per UAVs’ needs exemplified by class A for zones near airports that would follow strict protocols (Merkert & Bushell, 2020).
- b. Operator certification: Existing laws have created licensing standards for operators for operating aircraft by qualified pilots. A new UAV model is going to adopt the same kind of strategy, tailoring to complexity levels such as commercial pilots may be subjected to certification procedures similar to those needed for private pilots by including passing both practical tests and written exams.
- c. Safety rules: Conventional aviation regulations have focused

on safety in operations alongside aircraft designs. Such principles are going to be adopted by the independent structure by setting standards like structural integrity to fulfil safety provisions (Merkert & Bushell, 2020).

#### **4.4.2 Diverging from preceding laws:**

- **Autonomy:** The autonomous aerial vehicles can work without the help of human control as opposed to traditional aircraft. This divergence has required fresh approaches to security as they present issues in determining accountability during an accident.
- **b. Data security:** Manned airplane laws have not been designed with such concerns because they work at higher altitudes without having cutting-edge data-gathering innovation (Merkert & Bushell, 2020).
- **c. Management of Air Traffic:** The prior ATC can manage airplanes in controlled atmospheres in contrast to UAVs. For this reason, the latest legitimate model will introduce UTM systems particularly executed for high-density atmospheres where unmanned ones can function by upholding guidelines.

#### **4.5 Global coordination**

##### **4.5.1 Problems of fragmented regulations for UAVs:**

a. **Inconsistency:** Airspace classifications have varied between nations, creating hardships in navigating cross-border airspace. For instance, operators certified to BVLOS in Europe cannot be permitted to perform the same type of tasks in the US without acquiring separate permits. These inconsistencies disrupt businesses' ability to scale functions internationally due to increased complications (Kapustina et al., 2021).

b. Privacy concerns: Data safeguarding obligations have varied in nations as GDPR oversees personal data storing in the EU, whereas other nations may have no particular drone-linked rules. Such a fragmented strategy has created legal uncertainty by complicating data flows across borders for firms engaged in mapping. Divergent security grades have also caused issues as a few countries have extensive certification programs, whereas others can have relaxed requirements resulting in security concerns. In addition to this, the absence of standardized maintenance across borders may also increase the threat of accidents, added to liability disputes (Kapustina et al., 2021).

#### **4.5.2 Preferences for global coordination:**

a. ICAO leadership: It is a UN (United Nations) agency that governs global air traffic with a number of initiatives like the Chicago Convention (1944) working in coordination with IATA. This organization can play an important role in establishing international standards such as developing internationally recognized grades for operators while giving a unified structure to bridge the gaps between varying national policies. The ICAO develops regulations for UAVs under the RPAS or “Remotely Piloted Aircraft Systems” model. Primary initiatives are SARPs or “Standards and Recommended Practices” for UAV’s incorporation into airspace. The ICAO’s regulations also include guidelines related to UTM (Unmanned Aircraft systems Traffic Management). This organization has focused on certifications & functional security which ensures UAV’s adherence to global aviation laws.

b. Multilateral agreements: These agreements have been significant by involving different countries as nations having well-defined drone structures like the EU and the US might work cohesively to create contracts

for mutual recognition so that individuals certified in a nation can operate in other places to nurture cooperation between countries. Moreover, it has been essential for the nations to collaborate with each other to execute interoperable UTM processes enabling a UAV to smoothly transition between several jurisdictions (Kapustina et al., 2021).

As far as international agreements are concerned, it can be said that EASA (European Union Aviation Safety Agency) rules need to be followed other than ICAO. EASA has enforced the EU Drone Regulation (2019/947 & 2019/945) categorizing UAVs based on risk levels. In terms of bilateral agreements, the EU-U.S. aviation security agreements stress mutual recognition regarding UAV manufacturing. Cross-border co-ordination also should be enhanced with the help of certification procedures. It has been essential for nations to align their operational regulations and pilot licensing to prevent conflicts across borders. Cybersecurity laws must be focused on as aerial vehicles collect large datasets which demand privacy. Therefore, sharing best efforts is vital in regard to remote pilot verification added to data encryption. Best practices regarding airspace defense have boosted security. It is noted that global agreements as well as cross-border cooperation facilitate innovation while focusing on uniform safety.

## **5. Challenges in Developing an Independent UAV Framework**

### **5.1 Technological progress:**

Automated systems: Autonomy is a technological growth due to the rise of artificial intelligence-powered systems. Drones do not need human intervention to make decisions as they use real-time facts. Autonomy has improved their effectiveness in surveillance while introducing challenges like raising concerns regarding responsibility resulting in the establishment

of explicit standards to keep up with evolving AI abilities (Quamar et al., 2023).

BVLOS: The other issue includes capabilities of BVLOS that enlarge a UAV’s applications to enable it to perform surveillance as well as pipeline inspection. It has increased collision threats and added to airspace violations because this creative system is not under pilots’ visual control. There have been several obligations limiting visual sight lines to reduce safety problems, however, regulators should create fresh policies due to the increased viability of BVLOS (Quamar et al., 2023). Developing such policies can be problematic near airports where accident probabilities are higher. Moreover, international treaties like the “Convention on International Civil Aviation” and the “Chicago Convention” must be adapted to manage this BVLOS. It can be done through integrating provisions for the drones’ operations along with promoting the data-sharing protocol among countries. Collaborative models such as ICAO’s “Unmanned Aircraft Systems” model may also improve international regulatory consistency.

Rapid pace of innovation: The chosen technology has been progressing at a faster pace with progress in swarms and UAVs’ “high-altitude long-endurance” capacity. It has increased cybersecurity vulnerabilities alongside airspace congestion, leading to possibilities of misuse. It is required for the legitimate new version to focus on flexibility for amalgamating emerging advancements with public security. In contrast, prioritizing adaptable rules can be challenging to keep up with evolving innovativeness (Javaid et al., 2022).

## **5.2 Stakeholder resistance:**

Military UAV users: It has primarily emphasized reconnaissance with working in sensitive spaces leading to advocating for confidential rules (Golam, Lee & Kim, 2020). This flexibility would permit conducting tasks without oversight to preserve national sovereignty through transparency so that operational readiness is not disrupted.

Commercial users: They are utilized in logistics and agriculture seeking laws to nurture creativity with minimal constraints. Such stakeholders have been concerned with the economic potential that often resists legalized models and therefore imposing strict controls is crucial by focusing on altitude restrictions added to performance hours. (Vaigandla, Thatipamula & Karne, 2022).

Recreational users: These types of users have represented stakeholders resistant to obligations restricting the freedom to fly whereas imposing burdensome registration demands. UAVs have been seen as tools for recreational users, viewing stern orders as stifling. The challenge lies in ensuring public security while upholding the freedom of such users. Resistance from such groups may slow down legal procedures when hobbyist firms lobby against overregulation (Tomczyk et al., 2023). They also may not gain knowledge on threats related to ungoverned drone deployment, making them ineffective supporters for the framework.

## **5.3 Financial costs:**

Government costs: Creating the model would have been expensive for government bodies because of administrative costs. It includes the creation of new bureaucratic bodies along with the enlargement of the existing ones like UAV authorities for managing these innovation-specific policies. The

UTM systems’ establishment has required heavy investments in personnel to train them on how to use this system appropriately. Resources have also been significant in tracking the technology’s efficiency in preventing disruptions (Ali, Kaur & Abbas, 2022).

**Financial burden:** Complying with the newly introduced policies may be monetarily burdensome for commercial users. The entities have an investment in geofencing or tracking systems to fulfil guidelines. Such aspects can be expensive for medium and small-sized enterprises showing an interest in entering this market. In addition to this, businesses have to spend a huge amount of money on training due to the stringent nature of principles (Ali, Kaur & Abbas, 2022). Costs are essential to focus on buying contemporary equipment, creating monetary barriers for SMEs to enter this market. Financial burden can also include expenses for navigating hurdles like adhering to data safeguarding laws as well as applying for permits.

**Monitoring budgets:** Ensuring compliance has presented challenges by increasing ongoing costs. The authorities should track the operations continuously while updating emerging technological policies. Inspection mechanisms to audit performance have created monetary constraints for both users as well as regulators. Updates on a daily basis have been necessary while retraining personnel can demand budgets (Ali, Kaur & Abbas, 2022).

## **6. 6. Legal and Ethical Implications**

### **6.1 Legal issues:**

**Liability concerns:** Questions have arisen in relation to who can be held accountable in the event of an accident. The newly established lawful model can consider such concerns to focus on security. It can be mentioned

that assigning has become challenging because of the autonomous nature of such vehicles. (Konert & Balcerzak, 2021). The latest legalized structure can be considered “product liability” where manufacturers are going to be held responsible for making defective products.

Responsibilities for an UAV accident have extended beyond liability involving broader concerns regarding operational accountability. The dynamics have been complex when several parties are engaged in the maintenance, creating confusion as to who should be held responsible in cases of UAV-linked incidents. For instance, there are many stakeholders in commercial operations like maintenance workers or 3rd-party service givers. Therefore, the newly introduced framework needs to emphasize acquiring essential permits while complying with guidelines such as avoiding no-fly zones (Konert & Balcerzak, 2021). Pilots failing to fulfil the obligations would be held accountable for an accident even if incidents occur due to direct control. In the UAE, the legal framework is heavily strict on liability principles as in UAE’s Federal Law No.12 of 2019; where it states that Operators are liable for any damages as a result of their activities, regardless of fault. In light of similar proceedings for UAV operations, it can address the challenge of attributing fault in cases like privacy violations or mid-air collision (Altamimi & Farooqui, 2024).

Clearly defined roles involve establishing liability like an operator’s legal responsibility. An operator is held responsible for property damage or accidents caused by flying in a restricted area. Manufacturers are also responsible in case of accidents due to technical failures. Insurance needs to be made mandatory to safeguard against financial threats linked with accidents. Insurance requirements are based on the UAV’s purpose, size and type. Small ones might demand basic liabilities coverage as opposed

to commercial ones, which require high coverage limits. A specialized insurance plan is preferred as far as military drones are concerned. Appropriately trained operators' role is necessary to decrease the possibility of legal disputes. They should pass in “knowledge & safety” exams as these exams evaluate how much knowledge they have in terms of understanding aviation rules. Moreover, practical flight analysis ensures an operator may securely control a flight in various kinds of environments.

Global law adherence: Global law adherence has become a critical problem as drones work across borders. In cases of fact-gathering across countries' borders, it has been required to comply with global rules like those implemented by the ICAO. The latest independent model must follow these existing approaches to be effectively executed by maintaining principles. The new one also has to consider fines or legalized actions if anyone unintentionally violates global statutes. It is also vital to clarify operators' roles added to other involved persons' roles to make the framework appropriate in mitigating threats to UAVs' protected performance (Sabino et al., 2022).

## **6.2 Ethical considerations:**

Surveillance: The technology has been equipped with contemporary cameras to help in gathering facts including video footage and thermal imagery without being observed. It has raised questions about people's privacy as they fly over homes capturing information without consent. Ethically, this unrestricted utilization has posed risks to individuals as they are subjected to without their approval. In this context, the independent legal structure can come into play to address problems by limiting the surveillance objectives in public areas. Consent must also be obtained to collect personal information with the help of government organizations

(Wang, Christen & Hunt, 2021).

UAVs' military deployment: Drones have been an integral aspect as far as modern military is concerned adding an extra layer of moral intricacy. They have been leveraged to allow for reconnaissance and targeted strikes with no risks to military personnel. In contrast, ethical implications in this context have been profound regarding its misuse. The liberated version of the framework should solve ethical issues by restricting the lethal usage of force to ensure that the deployment would comply with global humanitarian laws. Transparency has also been vital to disclose criteria to redress avenues in regard to collateral damages (Wang, Christen & Hunt, 2021).

Making a balance between privacy and creativity: The drones have been creative because of increasing technological advancements. On the other hand, their capability of intruding upon personal lives amalgamated with surveillance's possibilities. The independent model would contribute to fostering innovation while motivating approaches to minimizing privateness threats. The utilization of privacy-safeguarding features needs to be considered in terms of protecting people's identities captured by sensors. Such measures are going to assist this chosen industry to develop through ensuring ethical principles' compliance (Hall & Wahab, 2021).

In addition to this, ethical considerations also include preventing unauthorized fact-gathering. UAVs are deployed for research or journalism unintentionally invading private spaces. For this reason, geofencing limitations are required in this regard so that they are not operated in areas such as near government buildings or private residences. Furthermore, data usage causes ethical & lawful challenges. Law enforcement organizations apply them in crowd monitoring. Improper oversight has resulted in

violations of civil liberties. Data encryption should be focused on to prevent cyberattacks as well as safeguard UAV-transmitted data.

### **6.3 Social implications:**

**Public trust:** Public perceptions have been impacted by distress over surveillance potential added to security. However, several people perceive it as suspicious because of a lack of clarity in relation to data monitoring in urban settings. People feel that they have been intruded upon through higher-resolution sensors capturing images (Hall & Wahab, 2021). Furthermore, causing accidents by a UAV in public locations has resulted in concerns regarding accountability contributing to damaging trust among persons. An independent legalized version would assist in transparent communication by highlighting rules on how to operate the technology upholding ethics.

**Public engagement:** Public acceptance can be hampered due to a lack of knowledge of this creative system’s positive abilities. Misinformation may result in resistance against its adoption in urban settings where the vehicles are visible affecting daily life. For this reason, making investments in educational campaigns has been significant to explain their usage in enhancing logistics or emergency response. Public involvement is another crucial aspect through feedback channels to enable community members to talk about issues they face. It would build a sense of ownership assisting in nurturing positive perspectives around the creative system (Ayamga, Akaba & Nyaaba, 2021).

**Transparency:** There is a demand for maintaining transparency to facilitate public acceptance through the framework to make operations subject to oversight. Transparency has involved creating awareness among individuals to incorporate creativity into their regular life. In addition to this,

unlawful capturing of images would lead to consequences including fines (Ayamga, Akaba & Nyaaba, 2021). The transparent enforcement method is going to reassure people that the usage is monitored so that grievances can be addressed through legal means. UAV flights' clear labelling like numbers, visible identification can help in increasing translucency whereas a permission request for flights around sensitive locations can further improve trust in regulatory procedures.

## **7. Conclusion and Recommendations**

In conclusion, UAVs play diverse roles ranging from military operations to logistics, underscoring the necessity of an independent regulatory model. The analysis highlights the importance of implementing a flexible framework capable of adapting to rapid technological advancements. Such adaptability is crucial to ensuring the legal system can keep pace with evolving UAV technologies. The rigid structure might stifle creativity, resulting in missed chances in industries benefiting from this technology. Regulatory sandboxes being first used in the UK by the Financial Conduct Authority (FCA) and spreading to the world, defined as "a 'safe space' in which businesses can test innovative products, services, business models and delivery mechanisms without immediately incurring all the normal regulatory consequences of engaging in the activity in question would be a better method to allow regulators in terms of assessing threats while motivating sector collaboration.

Regulatory sandboxes have many pros & cons such as their advantages are risk assessment capacity. Regulators identify threats like cybersecurity vulnerabilities before full-scale execution. It has fostered policy adjustments in real-time by relying on test-outcomes which ensures rules evolve with

modern technological improvements. In contrast, disadvantages are limited scopes as findings cannot entirely represent practical-world issues because of controlled conditions. However, its integration into drone governance helps strike balances between ensuring safety and nurturing innovations. Policymakers play an essential part in this by shaping a flexible regulatory model for operations.

Clear accountability is necessary for facilitating trust among the public, as autonomous drones blur the line of accountability for violations. Defining responsibilities among software developers and manufacturers is going to clarify lawful roles to decrease ambiguity during an accident. Education is also important when it comes to an efficient framework to make the public understand the creative system’s pros and cons. Education campaigns can be leveraged to inform people alongside the operators. Offering accessible training resources may contribute to cultivating a culture of sensible drone function alleviating privacy violations.

Global coordination is also essential in making the framework cohesive, given the technology’s cross-border realms. Harmonizing policies across nations may foster seamless UAV performance, primarily for commercial users such as surveillance. The regulatory bodies’ improvements have been imperative to enforce the rules, leading both global and national aviation authorities to work cooperatively. These authorities must work cohesively to comply with safety standards with the help of adequate resources. Therefore, it can be said that regulators would unlock new opportunities through the independent model while protecting public interests by improving societal advantages.

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## تنظيم قوانين الخاصة بالطائرات من دون طيار: بناء إطار قانوني لحوكمة المجال الجوي العالمي

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### ملخص البحث:

تقترح الورقة تقديم إطار قانوني مستقل عن القانون الجوي وذلك للمجال الخاص بالطائرات من دون طيار (UAV) لمعالجة الثغرات المتواجدة في القانون الجوي القائم. بحيث تم دراسة العوائق والمعوقات ومحدودية تطبيق هذه القوانين على تطور مجال الطائرات من دون طيار، مع الأخذ بعين الاعتبار قوانين إدارة المجال الجوي، وقانون الخصوصية، والتعاون الدولي. توصي الورقة بدمج وتحديث بعض المعايير الدولية لدعم عمليات الطائرات من دون طيار، كما تقترح عدد من الإستراتيجيات لضمان الأمن والمسائلة وتشجيع التطور التكنولوجي

تناولت الورقة البحثية أهمية التنسيق الدولي لبناء إطار قانوني مدعوم من قبل منظمة الطيران المدني الدولي (ICAO) سعياً لخلق تناغم بين مختلف المعايير ذات الصلة والارتقاء بمنظومة الطائرات من دون طيار والقوانين ذات العلاقة من مثل قانون حفظ البيانات. كما أن الاتفاقيات الثنائية بين الدول في توحيد المعايير ستعزز من المنظومة؛ إذ إنها تدعم القوانين الجوية القائمة وتمهد لمجال سريع التطور بصورة ممنهجة. وأخيراً تم بحث الأثر الأخلاقي والاجتماعي للمقترح والتأكيد على أهمية نشر الوعي حوله

**الكلمات الدالة:** القانون الجوي، الطائرات من دون طيار، اللوائح التنظيمية، الحوكمة، المعايير الدولية

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