Development of global regulations for Uncrewed Aircraft Systems – Europe and beyond

A continued survey and evaluation of progress

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Abstract

This paper provides insights into the harmonization of Uncrewed Aircraft Systems (UAS) regulations across Europe and other regions, highlighting efforts to standardize operations and practices. After a review of the status quo of global drone regulations, the importance of technology trends will be examined. Furthermore, a regulatory literature review will complement the research and discussion, identify baseline findings and build a foundation for the core of the article. The main section of the paper concentrates on statistical survey results collected from Civil Aviation Authorities from Europe and other countries worldwide in the year 2024. A quantitative analysis will examine progress and trends in general, and a comparison to the previous survey from 2022 will indicate areas of change, growth and decline in the statistics of drone operators, pilots and economic development. The paper aims also to identify areas of missing global harmonization in key areas of drone regulation, such as (1) terminology (remote pilot, operator, specific operations), (2) statistical evaluation of relevant data (no. of pilots, drones and operators), and (3) operational clearances and the associated processes (BVLOS, ConOps, SORA). Building on the results and the evaluation of developments in the factors measured, the discussion section will recognize root causes for potential growth or decline, as a stepwise integration of UAS in domestic airspaces, both controlled and uncontrolled requires well-informed authorities and policymakers. The recommendation section will outline the trends and evaluate potential macroeconomic measures or regulatory actions for a positive future development of the drone economy.

Keywords UAS, drones, regulations, safety, uncrewed aviation

I. Introduction

How many private and commercial drones are in use in a specific country? How many UAS (Uncrewed Aircraft Systems) operators, meaning legal entities offering drone services, are there in the European Union? Is the drone market and the associated economy growing or declining?

These questions are often brought up in the media, politics and in stakeholder discussions, with little or no knowledge about the real statistics and market developments. Given the potential importance of the drone sector as a contributing factor to the overall economic prosperity of a country, it is essential to measure and understand the statistical facts and quantifiable numbers for this domain. This article aims to contribute facts and numbers to the discussion, by providing results from a dedicated survey among civil aviation authorities from Europe and other countries worldwide.

Unlike in traditional crewed aviation with decades of experience in standardization and safety records, the regulation and harmonization of Uncrewed Aircraft Systems (UAS) policy is in very early stages in countries worldwide.
As crewed and uncrewed aviation will have to share airspaces and spectrum for Communication, Navigation, and Surveillance Services and Systems in the future it is important to assess the status of progress made in UAS (drone) regulations worldwide by looking at influencing factors, emerging technology and statistical developments.

The civil use of UAS has developed in several areas and categories over the past three years, since 2021. The drone market became an even larger market for hardware manufacturers and associated software developers, catering to an also growing total addressable market of clients and customers with services in all business domains.
It became apparent that domestic civil aviation authorities (CAA) globally face very similar challenges, when further enabling the use of drones for commercial, public or even private and recreational purposes. Since the previous iteration of this regulation survey project regarding the progress of European drone regulations in the year 2022, several developments in Europe and worldwide have affected the regulation of drones. [1]
This article aims to determine the progress made in drone regulations worldwide by looking at influencing factors, emerging technology and statistical developments. After a review of the status quo of global drone regulations, the importance of technology trends will be examined. Furthermore, a regulatory literature review will complement the research and discussion, identify baseline findings and build a foundation for the core of the article.
The main section of the paper concentrates on the statistical survey results collected from Civil Aviation Authorities from Europe and other countries worldwide. A quantitative analysis will examine progress and trends in general, and a comparison to the previous survey from 2022 will indicate areas of change, growth and decline in the statistics of drone operators, pilots and economic development.
Building on the results and the evaluation of developments in the factors measured, the discussion section will recognize root causes for potential growth or decline, with a gap analysis of the underlying factors focusing on Communication, Navigation, and Surveillance (CNS) Services.

Without doubt, the regulation and legislation of crewed aviation are significantly more developed than those of uncrewed aviation (drones) in the areas of Communication, Navigation, and Surveillance (CNS) Services and Systems due to the long-established global aviation framework, rigorous certification standards, and well-defined operational procedures. The article aims to highlight areas of improvement for the drone economy, adopting best practices and standards for a mutual future coexistence. Hence the recommendation section will outline the trends and evaluate potential policy measures or regulatory actions for a positive future development of the drone economy.

II. Assessing the Status Quo of Global Drone Regulations

One of the primary challenges has been to harmonize drone regulations across different countries, especially within an economic partnering zone. One remarkable case is the implementation of a common drone regulation and the harmonization among European member states. The European Union, particularly the European Aviation Safety Agency, has employed a unified regulatory framework to ensure consistency and ease of operation for drone users across the region. Operator ID's, remote pilot licenses and operational permits are recognized mutually among EASA member states. The case of the EASA drone regulation implementation has demonstrated that cross-border operations and sharing of resources requires a regional framework and can increase collaboration and prosperity of the drone economy. [2]
Furthermore, the rapid advancements in drone technology, such as longer flight times, higher altitudes, and increased payload capacities, have posed challenges for regulators in keeping pace with these developments and updating regulations accordingly. Ensuring the safety and security of airspace has been a significant concern as well. Regulators focused on implementing measures to prevent drone-related incidents, such as collisions with manned aircraft or interference with critical infrastructure. Integrating drones into existing airspace management systems has proven to be a complex task. Specific challenges still exist, that allow drones to operate safely alongside and simultaneously with manned aircraft while minimizing disruptions to air traffic. This is until today the limiting factor for UAS flight beyond visual line of sight, with higher weight or at night.

Another current aspect of regulation of UAS is establishing certification requirements for platforms with a higher risk assessment score in their operations. The risk assessment methodology, known as SORA (Specific Operations Risk Assessment), is developed for this purpose. EASA published the SORA as an Acceptable means of compliance to Article 11 to Regulation (EU) 2019/947. [3]
Results of such SORA processes are SAILs and OSOs to ensure a structured and scalable approach to managing UAV operational risks. The SAIL (Specific assurance integrity level) is defined as the intrinsic risk values of the full drone operation. It does not only apply to the operational authorization in the SORA process, but also to the technical requirements for the drone and the operator manual. Certifying drones to fly in higher SAIL categories involves meeting stricter requirements for safety, reliability, and operational capability.

OSOs (Operational Safety Objectives) on the other hand are specific safety requirements or objectives that must be met to address the risks identified in the SORA process. They include measures to mitigate risks to people, property, and other airspace users. The required OSOs are determined by the SAIL level and cover aspects such as system reliability, operator training, and contingency procedures.

Under the EASA drone rules several concepts and frameworks have been developed to simplify drone operations by streamlining risk management and compliance.

The Predefined Risk Assessment (PDRA) is an operational scenario for which EASA has already carried out the risk assessment and has been published as an acceptable means of compliance (AMC) to Article 11 (risk assessment) of Regulation (EU) 2019/947. A PDRA provides a pre-approved, detailed risk assessment for specific types of drone operations, allowing operators to focus on implementing established safety measures rather than conducting a full risk analysis. [4]
The European Standard Scenario (STS) is a predefined operation, described in Appendix 1 to Regulation (EU) 2019/947 that became applicable in 2024. STS, often aligned with PDRAs, refers to predefined operational scenarios that include standardized conditions and mitigations, enabling operators to conduct routine missions under consistent rules. Both are designed to reduce complexity and facilitate safe, repeatable drone operations within regulatory frameworks. [5]
Safety measures, well known to traditional, crewed aviation manufacturing are applied to uncrewed platforms as well. This means that compliance with technical standards and requirements is evaluated by testing and evaluation. This includes factors such as structural integrity, performance, reliability, and equipment specifications. Once a drone has successfully met the technical, safety, and operational requirements, it can undergo type certification. Type certification involves a formal review and approval process conducted by a CAA or notified body to verify that the drone complies with applicable regulations and standards.

Manufacturers of certified drones are required to implement quality assurance processes to ensure consistent production quality and adherence to approved design specifications. After obtaining type certification, individual drones can receive airworthiness approval, allowing them to be operated in higher SAIL categories. Airworthiness approval confirms that a specific drone meets the necessary safety and performance criteria for flight operations. In particular, a Design Verification Report (DVR) is a document issued by EASA that verifies a drone's design meets specific safety objectives.
Like conventional crewed aviation platforms, certified drones are subject to ongoing monitoring and compliance requirements to ensure continued adherence to regulatory standards. This may involve periodic inspections, maintenance checks, and reporting obligations to maintain airworthiness and operational safety.

The next section provides a comprehensive literature review to give a status quo about the latest trends and research results regarding the topic of UAS regulation.

III. CURRENT RESEARCH AND SCIENTIFIC LITERATURE

The following sections aim to give a status-quo analysis about the research and literature regarding drone regulations worldwide. Several authors and research projects evaluate and summarize the development of drone regulations on national and regional level.

In "drone regulations: A global overview", Bowman provides a comprehensive overview of drone regulations worldwide, highlighting key differences and similarities among various countries' approaches. The study underscores the importance of understanding the evolving regulatory landscape to navigate legal challenges and foster responsible drone use on a global scale. [6] Similarly, Cheng and Xu examine drone regulations in major countries, offering insights into the regulatory frameworks governing drone operations. The article identifies common themes and differences in regulations across different regions, shedding light on the complexities of managing drone airspace in a global context. [7] A broader look involving the economy is given by Dijk and van der Voort in "Drone regulations and their impact on innovation: A global perspective."

The authors explore the impact of drone regulations on innovation, providing a global perspective on how regulatory policies shape technological advancements in the drone industry. The study also emphasizes the need for balanced regulatory approaches that foster innovation while addressing safety and privacy concerns. [8] Considering older studies, such as Gibson's: "Drone regulation: The challenges ahead" from 2018, the progress in many countries becomes apparent. Gibson's article discusses the challenges associated with drone regulation, focusing on the complexities of balancing safety, privacy, and innovation.

The study highlights the need for proactive regulatory measures to address emerging issues and ensure the responsible integration of drones into airspace systems worldwide. [9] Several studies analyze and compare international drone regulations, analyzing regulatory approaches and their effectiveness in managing the growing drone industry. They offer insights into regulatory best practices and challenges, facilitating informed policy decisions for regulators and stakeholders globally. The comparative analysis of national approaches to drone regulation allows examining the factors influencing regulatory decisions and outcomes. [10] [11]

Comparably, Liu and Wu have conducted a global survey on drone regulations and their economic implications, examining the impact of regulatory policies on market dynamics and innovation. The article identifies regulatory barriers and opportunities for economic growth, emphasizing the importance of fostering a conducive regulatory environment for the drone industry. [12] As privacy and data protection is highly impacting the regulations of drones, O'Connor and Park conduct a comparative analysis of drone regulations and their implications for privacy, exploring the intersection of regulatory frameworks and privacy rights. The study highlights the need for robust privacy protections and transparency measures in drone regulations to address public concerns and ensure ethical drone use. [13] Like in this article, authors and researchers are looking into the future of drone regulation. Smith offers an international perspective on the evolving landscape of drone regulations, tracing the development of regulatory frameworks and emerging trends in drone policy. The article discusses regulatory challenges and opportunities, providing insights into the future direction of drone regulation and its implications for stakeholders worldwide.[14]

One of the most detailed dossiers about worldwide drone regulation is the project and database of Sarah Nilsson "Drones and AAM Across the World: Laws and Policies for UAS, UAM, & AAM". It provides a comprehensive overview of global drone regulations and policy, structured according to six primary regions recognized by the United Nations: Northern America, Latin America and the Caribbean, Oceania, Europe, Asia, and Africa. Most countries are referenced with original documents pertaining to domestic drone laws, giving insights to progress and development in this field.[15]

Drone regulation and legislation is highly interconnected to technology and its associated maturity and adoption among stakeholders. The following section identifies novel developments in drone regulations worldwide, by identifying key trends and technological advancements relevant to the topic.

IV. EMERGING TECHNOLOGY TRENDS IMPACTING DRONE REGULATIONS WORLDWIDE

Several technical developments for drones and the associated equipment have influenced the further development of global regulations for Uncrewed Aircraft Systems, especially in the field of Communication, Navigation, and Surveillance (CNS) Services and Systems. This section presents a non-exhaustive overview of trends in these areas as of the year 2024.

The regulation for UAS generally addresses the mitigation of risks, foremost the air-risk and ground risk factors of UAS operations. The term "air risk" for drones refers to the various potential hazards and dangers associated with the operation of drones in controlled and uncontrolled airspace. One of the major concerns is the potential collision with crewed aircraft. Such collisions can lead to catastrophic accidents and pose a threat to aviation safety. Hence, innovative technologies have been identified to address the air-risk side of UAS operations in controlled and uncontrolled airspace.

On the collaborative airspace integration side, drones have traditionally been more connected and electronically conspicuous than many manned aircraft, especially those operating under See -and-Avoid conditions only. Small form factor and low power ADS-B (Automatic Dependent Surveillance-Broadcast) transceivers allow drones to receive and transmit real-time location data to and from other aircraft. .[16]

However, there is ongoing debate and concern about the impact on the spectrum and bandwidth, when more users in the airspace will utilize ADS-B or Mode S.

The fact that many drones are electronic conspicuous by design and operate with a live-data feed to a ground control station offers opportunities to provide tracking and surveillance services, which can improve and mitigate the air risk of BVLOS (beyond visual line of sight) operations.

Parallel to connectivity aspects associated with the airspace integration of drones, many countries are implementing or considering regulations requiring drones to have Remote Identification Systems (Remote ID). These onboard transmitter systems allow persons and authorities on the ground to remotely identify and track drones in real-time via Bluetooth and/or Wi-Fi, enhancing safety and security. Remote Identifications of drones became mandatory in the US under the FAA regulations .[17] and in Europe under EASA rules in 2023/2024.[18]

For the uncollaborative aspects of airspace integration there have been significant technical gains in onboard detect and avoid or even see and avoid (with computer vision) for drones. Small radar systems or ultrasonic sensors can provide situational awareness by detecting aircraft in the vicinity. Electro-optical sensors combined with computer vision and machine learning algorithms to detect and track other flying objects, can give input to a UAS flight controller and initiate evasive actions to prevent mid-air collisions.[19]

While flying in VLOS or BVLOS, drones can experience loss of control due to various factors, including equipment malfunctions, interference with communication signals, or operator error. Loss of control can result in drones veering off course, crashing, or posing hazards to people on the ground, which is relating to the ground-risk. Here, rescue technologies have been developed to mitigate impact by lowering the kinetic energy significantly with parachutes or airbags.

Especially, the geofencing technology and the application of hard-lock and soft-lock No-Fly Zones is being used to create virtual boundaries around sensitive areas such as airports, government buildings, and public events. Drones can be programmed to automatically avoid these areas, reducing the risk of unauthorized incursions.

Connected to geo-fencing is the inherent potential misuse of drones, which is a major concern for regulations worldwide. With the increasing proliferation of drones, there has been a growing interest in developing counter-drone technologies to mitigate potential security threats posed by malicious or unauthorized drone use. Regulations governing the use of counter-drone measures are also being considered. Two regulatory concepts concerning the airspace integration of drones with a high relevance for Communication, Navigation, and Surveillance (CNS) Services and Systems are U-space and UTM. U-space and UTM (Unmanned Traffic Management) are frameworks designed to safely integrate drones into airspace alongside manned aircraft. U-Space, primarily as term and concept used in Europe, shall provide a set of digital services such as registration, real-time traffic monitoring, geo-fencing, and flight authorization to enable seamless and scalable drone operations. UTM, a broader global term, focuses on creating a coordinated air traffic management system for unmanned vehicles, using technologies like GNSS, communication networks, and cloud-based platforms to ensure safe, efficient, and compliant drone operations in controlled and uncontrolled airspace. Both concepts aim to address safety, airspace access, and operational efficiency.

Looking forward, it can be assumed that drone regulations will also be affected by future accidents and incidents, as they will influence the perception of risk towards airspace, infrastructure, and society. A realistic determination of these events in relation to the number of flight hours and missions will be needed to prevent overarching punitive regulatory measures to calm the public mood or insurance claims.

Assessing statistics in UAS operations and registrations as in this article, will support empirical and un-biased decision making by policy makers and legislative bodies.

In the following section, the article approaches the topic of global drone regulations development with a quantitative, statistical methodology with a representation of survey results.

V. SURVEY AND RESULTS FOR NATIONAL IMPLEMENTATION OF REGULATION FOR UAS WITHIN THE EU MEMBER STATES

The research team conducted a standardized survey with email inquiries to points of contact at national civil aviation authorities, both in Europe for EASA member states and also with international CAA's. Both quantitative statistics were requested as well as qualitative information and assessment of the domestic situation in the country. The survey timeframe for respondents was March to August of 2024. The quantitative results for Europe of this survey have been supported by the drone team of EASA with supplementary documentation.[20]

The following questions were sent out as part of the survey to determine the statistical situation in the EASA countries:

- Number of A1/A3 and A2 remote pilot licenses issued in your country
- Number of registered UAS operator IDs
- Number of operators applied for operations in the specific category
- Number of LUC's applied and/or granted

Furthermore, information requests towards the following parameters and associated values have been sent out:

- PDRA-S01
- PDRA-S02
- PDRA-G01
- PDRA-G02
- PDRA-G03
- UAS operations under SAIL I, II with SORA
- UAS operations under SAIL III with SORA
- UAS operations under SAIL IV with SORA

The following tables depict the survey results from 30 EASA member states in different categories.

EU member state	A1/A3 certificates	A2 certificates	STS "certificate of remote pilot theoretical knowledge"	EU STS-01:Total Number	EU STS-02:Total Number	Total number of LUC that were still valid as of 30th June 2024:
Czechia	65515	2793	0	0	0	2
Netherlands	44148	47143	1329	0	0	2
Romania	6933	3373	0	0	0	0
Italy	92195	15391	163	272	80	1
Belgium	19276	2290	167	9	4	1
Norway	36892	3895	177	0	0	6
Greece	8730	8050	0	0	0	1
Portugal	5488	168	9	1	1	0
Germany	385050	23869	885	3	0	1
Finland	28200	2179	12	0	0	0
Sweden	37622	23762	0	4	2	3
Spain	108353	48568	94033	9	0	1
Poland	201950	35840	222663	352	205	0
Bulgaria	2974	174	5	0	0	0
Denmark	22459	11840	139	0	0	1
Hungary	2774	1408	0	0	0	1
Luxembourg	104905	218	10	0	0	0
Lithuania	5038	297	457	26	1	0
Austria	84699	2552	0	0	0	1
Switzerland	56492	13940	10	0	0	0
Iceland	1123	4	0	0	0	0
Latvia	8865	520	457	0	0	0
Ireland	19977	1936	606	3	0	5
Estonia	5339	177	36	0	0	0
Slovak Republic	358	127	27	0	0	0
Slovenia	5599	516	407	0	0	0
Cyprus	2100	137	45	0	0	0
Malta	347	94	0	0	0	2
Croatia	6944	893	0	0	0	0
France	60560	7378	0	498	201	1

Table 1: Numerical survey results for the categories of pilot licenses, standard scenarios and LUC

EU member state	PDRA-S01:Total Number	PDRA-S02:Total Number	PDRA-G01:Total Number	PDRA-G02:Total Number	PDRA-G03:Total Number	UAS operations under SAIL I, II with SORA:Total Number	UAS operations under SAIL III with SORA:Total Number	UAS operations under SAIL IV with SORA:Total Number
Czechia	1	0	0	0	0	1241	0	0
Netherlands	47	1	0	0	0	220	0	0
Romania	1	0	5	1	0	15	0	0
Italy	1	0	1	2	0	26	0	0
Belgium	1	1	0	0	2	11	1	0
Norway	1	0	5	1	2	58	0	0
Greece	12	10	17	8	0	9	0	0
Portugal	0	0	1	0	1	7	0	0
Germany	1	0	0	0	0	560	11	0
Finland	22	2	4	3	3	82	0	0
Sweden	5	0	3	3	2	19	0	0
Spain	0	0	0	2	3	55	0	0
Poland	0	0	0	0	0	7	1	0
Bulgaria	0	0	0	0	0	8	0	0
Denmark	51	0	0	2	1	20	0	0
Hungary	0	0	23	1	2	33	0	0
Luxembourg	0	0	0	0	0	1	0	0
Lithuania	0	0	0	0	0	3	0	0
Austria	0	0	1	0	2	49	0	0
Switzerland	4	0	4	0	0	47	3	0
Iceland	0	0	0	0	0	0	0	0
Latvia	4	3	0	0	13	1	0	0
Ireland	31	2	0	0	0	14	3	0
Estonia	5	1	2	2	2	3	0	0
Slovak Republic	1	0	0	0	1	4	0	0
Slovenia	31	15	3	3	3	14	2	0
Cyprus	1	0	0	0	0	3	0	0
Malta	1	0	0	0	0	0	0	0
Croatia	1	1	1	7	1	17	0	0
France	1	0	0	5	1	160	0	0

Table 2: Numerical survey results for the categories of PDRA and operations in the specific category

This allocation and visualization of quantitative statistical results shows that EASA member states collect and accumulate data according to the mutually agreed parameters and standards. This standardized approach from all Civil Aviation Authorities is the basis for a data-driven assessment of the progress of regulation and the development of the European drone market. It can be recognized that in several states the more complex processes for drone operations other than the Open category are actively used by UAS operators.

Some key takeaways from the European survey are the following:

A1/A3 and A2 certificates: The number of A1/A3 and A2 certificates for remote pilots varies greatly between countries. Germany has the highest number of A1/A3 certificates with 385,050, which corresponds to the population size. The number of A2 certificates per country is not a suitable statistical indicator, since many cross-border A2 remote pilot licenses are issued overall Europe.

Registered UAS (drones): Germany clearly leads the list of EU member states with 642,281 registered UAS. Italy follows with 126,242 registered drones, and Spain with 108,343. By contrast, countries such as Bulgaria (4,156) and Malta (4,700) have significantly fewer registered drones. These differences may be due to various factors, such as population size, economic activity, the prevalence of drone technology, and specific national regulations.

Authorizations for model flying clubs and associations: The number of authorizations granted to model flying clubs and associations also varies greatly between countries. Norway stands out with 172 authorizations, while many countries have few or no authorizations. The Netherlands has granted 47 and Denmark 51 authorizations

PDRA-S01/S02/G01/G02/G03 Permits: These permits refer to specific risk assessments for drone operations. The number of permits issued varies greatly between countries and the different risk categories. For example, the Czech Republic has 1 PDRA-S01 authorization, while the Netherlands has 47 PDRA-S02 authorizations. The number of PDRA-G02 authorizations is highest in Greece, with 40. The differences in these authorizations may be due to the respective national regulations and the needs of drone operations.

UAS operations under SAIL (Specific Assurance and Integrity Level) with SORA (Specific Operations Risk Assessment): The figures for UAS operations under SAIL I, II, III and IV with SORA show that many countries carry out such operations, but here too there are large differences. Greece leads with 8 SAIL I operations, while in many other states there are hardly any or no operations at all. In particular, SAIL IV has not been conducted by a any countries, probably due to the complexity.

EU STS-01/02 certificates: The distribution of EU STS-01 and STS-02 certificates also varies considerably. Italy has 272 EU STS-01 certificates, while many countries have none. For STS-02, France has by far the most certificates, with 498, while most other countries have significantly fewer or none at all.

LUC (Light UAS Operator Certificate): The total number of valid LUCs varies, with some countries having very few and many other countries having none.

In summary, the distribution of survey results from the 2024 survey in the EU outlined on a variety of influencing factors, like economic activities, the adoption of drone technology and the maturity of the drone market. In total, there are significant differences between individual member states, both from an absolute and relative consideration.

VI. Comparison of Current Results Towards Previous Survey Responses in EASA Member States

The authors of this article published a similar project in 2022 with a comparable survey in EASA member states, called "Implementation of European Drone Regulations - Status Quo and Assessment", which constituted the very first survey among EASA Civil Aviation Authorities. A comparison of the survey results from 2022 with those of 2024 shows that all numbers have increased significantly. This indicates growth in the drone market and greater acceptance and adoption of the EU drone regulation.

Germany has the highest number of A1/A3 certificates in both 2022 and 2024. This could be due to the large number of recreational pilots registering through model aircraft associations. There is also an increase in A2 certificates in most countries. This suggests that more drone pilots want to qualify for more complex operations that require an A2 license. Also, cross-border training is reported, where many A2 training courses and exams are often taken in other countries to benefit from cheaper offers. Therefore, the significance of the national A2 figures is limited.

Regarding LUC there is constant low prevalence. Only a few LUCs were issued in 2022. Even in 2024, the number of LUCs is very low in most countries. This suggests that the requirements for LUCs are high or that operators are using alternative ways to legalize their operations. A LUC allows a UAS operator to conduct its own operations without prior authorization. Some countries, such as the Netherlands, have a higher number of LUCs than others. This could be due to differences in the implementation of the EU drone regulation or national peculiarities. As a general observation, it can the inferred, that the increased numbers of A1/A3 and A2 certificates indicate growth in the drone market and greater acceptance of the EU Drone Regulation. Also, the number of UAS Operator IDs per country has a high statistical value, as operators must register in the country where they have their main place of business. The measured growth in the numbers of operator ID underlines the growth trend in the European drone economy.

VII. Comparison of Current Results Towards Previous Survey Responses in EASA Member States

The research team also aimed to explore and assess the progress of UAS regulation in non-EASA countries worldwide. First it was needed to establish contact with Civil Aviation Authorities and identify a national point of contact for drone related questions and statistics.

A similar outreach to the EASA-survey was used, with a more agnostic survey design, since there might be other categories for the parameters and variables in questions. The global outreach was clustered in the following regions for this survey: The Americas, Asia and Pacific region and Africa.

It must be stated, that no substantial responses from the region of South America or Africa have been collected, so the research team decided to concentrate on the Asia and Pacific region for this iteration of the survey. The following limitations of the survey study need to be considered; Not in every country and region, a point of contact for drone statistics and regulations is available per the homepage and contact information of the CAA. Especially in some threshold and developing countries, it was not clear according to publicly available information which point of contact was responsible for drones within the domestic civil aviation authorities. Several CAA expressed or demonstrated a lack of standardization when it came to the statistical allocation of empirical data for drones.

The responses from various civil aviation authorities worldwide show different levels and approaches to regulation, ranging from no regulation to detailed licensing and registration systems, as well as information on permits granted for special flights. Some authorities provide comprehensive statistics, while others refer to public databases or explain that the desired data is not publicly available. Risk assessment methods also vary, with SORA (Specific Operations Risk Assessment) being mentioned frequently.

Due to the scattered and non-standardized nature of the CAA responses to the survey, it is only possible to report and outline the results and data in descriptive paragraphs. In the following section, the survey results will be stated in a condensed and accumulated way.

A. Remote pilot licenses

Maldives: No remote pilot licenses are issued yet. A regulation like EU/EASA rules is being worked on.

Tokelau: No licenses are issued for flying drones, and there are no guidelines for drone operations.

Hong Kong: Remote pilots must register.

UAE: No pilot licenses are issued for professional use, but drones are registered under the organization's name. Recreational flights are prohibited until further notice.

Taiwan: There are three types of remote pilot licenses: student, general and professional. These are valid for 2 years. By December 31, 2023, 2,475 student, 11,519 general and 14,288 professional licenses had been issued.

Israel: The requested information is not publicly available and can be requested from the Ministry of Transport for a fee.

Australia: As of January 14, 2024, 32,992 remote pilot licenses (RePLs) have been issued, which are valid indefinitely.

Kazakhstan: UAS operator certificates are used instead of remote pilot licenses. So far, 377 certificates have been issued. A remote pilot must meet the requirements of ICAO Annex 1.

Sri Lanka: No UAS operator licenses have been issued to date, but CAASL has recently published the standards for UAS training organizations and the issuance of UAPLs.

New Zealand: No remote pilot licenses are issued, but there are training courses that offer Part 101 and Part 102 qualifications. Part 101 pilots do not need to be qualified unless they fly within 4 km of an aerodrome, and these qualifications are not recorded by the CAA. Part 102 pilots must be qualified, but the number of pilots working under Part 102 certificates is not recorded.

Canada: Number of drones registered: 96,937; Number of Basic Pilot Certificates issued: 95,840; Number of Advanced Pilot Certificates issued: 12,254

B. Registration of UAS operators

Maldives: There are no registered UAS operators.

Tokelau: No registered UAS operators.

Hong Kong: UAS operators must register.

UAE: Only drones are registered under the name of the organization.

Taiwan: There are 1,555 professional drone operators and 40,362 drones are registered. No registration is required for recreational use.

Australia: As of January 14, 2024, there were 2,646 remote-operated aircraft operator certificates (ReOCs). An ReOC is initially valid for 1 year and, after renewal, is issued for 3 years. It allows a business to operate as a drone service provider.

Kazakhstan: 377 UAS operator certificates have been issued.

Sri Lanka: There are over 4,200 registered local and over 5,400 registered foreign UAS and operators.

New Zealand: 165 Part 102 certificates are active. The number of Part 101 users is unknown.

Philippines: There are 830 drones listed in the Philippine Aircraft Register.

VIII. DISCUSSION AND ANALYSIS OF QUALITATIVE RESULTS OF THE INTERNATIONAL SURVEY

It can be stated, that there is no single country which can be described as “leading” in drone regulation, as the approaches are very different. However, some countries can be highlighted that have implemented advanced or detailed regulations or are heavily influenced by international standards:

Maldives: The Maldives are closely following the EU/EASA rules and are actively working towards implementing similar regulations. This shows a strong influence of European standards. They plan to publish a Notice of Proposed Rule Making (NPRM) to solicit feedback from stakeholders. The categorization of UAS operators (open, specific and certified) and the risk analysis (SORA) are based on EU/EASA standards.

Hong Kong: Hong Kong has introduced detailed regulations under the Small Unmanned Aircraft Order (“SUA Order”). The regulations cover registration and labeling of drones, registration of remote pilots, operational requirements, and insurance requirements. The categorization of drones and the operating regulations are described in detail on the website of the Civil Aviation Department (CAD) and in the Safety Requirements Document (SRD).

Taiwan: Taiwan has implemented a comprehensive licensing system for remote pilots, which is divided into student, general and professional licenses. There is also a clear classification of drones based on configuration and weight. Risk analysis for cargo deliveries is based on the SORA method, while other operations are protected by operators' security procedures.

Australia: Australia has a well-established system with the issuance of Remote Pilot Licenses (RePLs) and Remotely Piloted Aircraft Operator's Certificates (ReOCs). The regulations distinguish between commercial and recreational drones and categorize them by aircraft type. Australia uses the ISO 31000 risk management process and, for more complex applications, the JARUS SORA methodology.

Kazakhstan: Kazakhstan uses a distinct system with UAS operator certificates instead of remote pilot licenses and categorizes the UAS operations into “Open”, “Specific”, and “Certified”. The risk analysis is based on a UAS Risk Assessment Manual that is developed by the operator. Although they have their own approach, they show an awareness of international practices by mentioning the ICAO Appendices.

New Zealand: New Zealand has a differentiated system with Part 101 and Part 102 certificates. No remote pilot licenses are issued, but training is required. The risk analysis is flexible, but the JARUS SORA method is recommended for more complex operators. The regulation is not aimed at the drones themselves, but at the operating methods.

Based on the survey results, especially the qualitative part with the option for free text responses, several common trends and developments have been identified. Many countries, such as the Maldives, are guided by EU/EASA regulations, particularly regarding categorizing operations and risk analysis. This indicates a strong global tendency towards alignment with European standards.

JARUS' Specific Operations Risk Assessment (SORA) is used as a risk assessment method in many countries, demonstrating a certain degree of international standardization in this area. Also, many countries distinguish between commercial and recreational drones in their regulations, with commercial operations often subject to stricter rules. Some countries, such as Kazakhstan, are developing their own regulatory systems based on their specific needs and circumstances.

IX. ALLOCATED STATISTICAL DATA FROM REGIONS WORLDWIDE OUTSIDE OF THE SURVEY

A. United States

The statistical numbers for the United States are available per the FAA website from 2024. [21]

- Total Drones Registered: over 1 million
- Commercial Drone Registrations: 409,408
- Recreational Flyer Registrations: 385,892
- Certificated Remote Pilots: 427,335
- TRUST: 977,847

The TRUST (The Recreational UAS Safety Test) Certificate is a certification required for recreational drone pilots in the United States. It is issued by the Federal Aviation Administration (FAA) and aims to educate hobbyist drone users about airspace safety and regulations.

B. China

As of December 2024, China reported over 1.7 million registered civil unmanned aerial vehicles in the country. These drones collectively flew more than 19.46 million hours in the first eight months of 2024, marking a 15.6% increase compared to the same period in the previous year. [22] The rapid growth of China's drone industry is evident, with the number of registered UAVs rising from approximately 1.27 million at the end of 2023 to around 1.88 million by June 2024.

This reported expansion reflects an increasing integration of drones into various sectors, “including logistics, agriculture, and meteorological exploration, contributing significantly to the development of China's low-altitude economy.” [23]

C. India

The government of India, Ministry of civil aviation published statistical data on drones in India, which can be summarized as follows.

Registered commercial drones: As of September 2024, 10,208 type-certified commercial drones were registered on the Digital Sky platform.

Type Certificates: The Directorate General of Civil Aviation (DGCA) has issued a total of 96 type certificates for various unmanned aerial systems (UAS) models.

Agricultural drones: 65 of the certified models are for agriculture.

Logistics and surveillance: The remaining 31 models are for logistics and surveillance.

Airspace Zones: Indian airspace is categorized into three zones for drone operations:

Red, Yellow, and Green as per rule 19 of the Drone Policy of 2021.

Green Zones: About 86% of the airspace is green and available for drone operations.

Red zones: There are 9969 airspace red zones, 147 airport red zones (5-KM airport region), 147 airport yellow zones (5-8KM), 147 airport yellow zones (8-12KM) and 1 coastal red zone (25KM).

X. DISCUSSION AND RECOMMENDATION

This article and the associated continued survey identified a strong correlation between clear and well-structured regulations that provide legal certainty, safety, and scalability, and investment, innovation, and industry growth.

Clear, predictable drone regulations reduce uncertainty for businesses and investors. Companies are more likely to invest in R&D, drone services, and infrastructure if they understand the legal framework. Also, safety regulations (e.g., airworthiness, pilot licensing, Remote ID) make drone operations safer and more accepted by the public. Without strong safety oversight, drone-related accidents could lead to stricter bans and limitations, slowing down industry growth.

The drone economy will very likely thrive when Beyond Visual Line of Sight (BVLOS) and more autonomous drone operations would be legally permitted. Future regulations that would be more permissible with BVLOS (with proper CNS & UTM integration) could enable large-scale drone deliveries, inspections, and urban air mobility.

Another aspect to consider is technology and its fast development. Adaptive regulations that evolve with technology (e.g., AI-based traffic management, Urban Air Mobility) prevent rules from becoming outdated.

The survey and overall results in this article indicate differences in regional implementation and harmonization of drone regulation, including the standardized allocation of empirical data and statistics. As reliable data is the basis for policymakers and rulemaking, the research team identified several areas of potential adaption and improvement towards the status quo:

- Every country needs a point of contact for drones within its domestic Civil Aviation Authority.

- Terms and definitions of parameters and variables must be standardized, to assure comparable results.

- Empirical data needs to be collected about remote pilots, operator entities, drones and operations.

- Existing rules for drone flights lead to clear and measurable economic growth in the sector.

- Crewed and uncrewed aviation must align closely to assure a safe and efficient mutual airspace utilization.

- Innovative technological developments could pave the way for future interconnected Communication, Navigation, and Surveillance (CNS) Services and Systems.

This article pointed out that the regulation of Uncrewed Aviation is currently not fully standardized and harmonized on a global level, which presents certain barriers for a future economic growth and prosperity.

Upcoming Communication, Navigation, and Surveillance (CNS) Services and Systems can only combine procedures from Air Traffic Management (ATM) and UAS Traffic Management (UTM) when an international regime exists to assure mutual standards and practices. A known term in this regard are the Standards and Recommended Practices (SARPs) from ICAO (International Civil Aviation Organization).

ICAO influences national aviation rulemaking through global standards, regulatory guidance, and compliance monitoring. While ICAO itself does not create laws, it sets international aviation standards that member states incorporate into their national regulations. ICAO could play a more active role in standardizing and harmonizing international drone regulation by establishing a global UAS regulatory framework and mediate international drone rule conflict. With drones increasingly used for cross-border delivery, surveillance, and emergency response, ICAO could support countries align CNS and airspace access rules.

Another measure would be to provide clear classification and certification pathways for different UAS types (small, large, cargo, passenger) and to align airspace access rules with crewed aviation to minimize conflicts. The empirical part of the article highlighted differences in statistical data collection among ICAO member states. Here ICAO could foster international collaboration and data sharing, by encouraging cross-border CNS research initiatives to accelerate harmonization of drone operations globally.

By leading efforts in CNS standardization, UAS integration into ATM, and cross-border regulatory alignment, ICAO can significantly advance the global drone economy while ensuring safe and efficient collaboration between crewed and uncrewed aviation.

In summary, Table 1 provides a summarized comparison and gap analysis of regulation and standardization of uncrewed aviation in contrast to the traditional crewed aviation sector with focus on Communication, Navigation, and Surveillance (CNS) Services and Systems:

Communication		
Crewed Aviation		Uncrewed Aviation
Uses **standardized, internationally regulated** communication protocols (e.g., VHF radio, ACARS) for air-to-ground and air-to-air communication.		Lacks a **standardized global communication protocol**, especially for Beyond Visual Line of Sight (BVLOS) operations.
Pilots and air traffic controllers (ATC) follow **structured radio phraseology** to ensure clear and unambiguous communication.		**Limited voice communication** between drone operators and ATC, with most interactions being procedural or automated.
ICAO (International Civil Aviation Organization) and national aviation authorities **mandate** communication equipment and frequency usage.		Newer technologies such as **LTE/5G-based control links** are being explored, but they lack **universally accepted standards**.
Navigation		
Crewed Aviation		Uncrewed Aviation
Highly structured navigation systems such as GPS, Inertial Navigation Systems (INS), and Instrument Landing Systems (ILS).		**Heavily reliant on GPS,** which can be vulnerable to interference and spoofing.

Defined airspace classifications, with pilots required to follow **Instrument Flight Rules (IFR)** and **Visual Flight Rules (VFR).**		**No universal IFR/VFR equivalent** for drones, making BVLOS operations complex and highly regulated.
Aircraft navigation systems undergo **rigorous certification** under ICAO and national regulations		**Urban air mobility (UAM)** and drone corridors are in early stages of development, with regulations still evolving.
Surveillance		
Crewed Aviation		Uncrewed Aviation
Uses **radar-based** surveillance (Primary Surveillance Radar - PSR, Secondary Surveillance Radar - SSR) and ADS-B (Automatic Dependent Surveillance-Broadcast) for real-time aircraft tracking.		**Limited integration** with traditional **ATC surveillance systems.**
Aircraft are equipped with **Mode S transponders** for identification and collision avoidance.		**ADS-B adoption is debated** due to frequency congestion concerns with high drone volumes.
Air traffic control (ATC) **actively monitors and directs** manned aircraft based on well-established surveillance frameworks.		**Detect-and-avoid (DAA) systems** are still developing, and regulatory acceptance of these technologies varies.

Table 3: comparison and gap analysis of regulation and standardization of uncrewed aviation in contrast to the traditional crewed aviation sector with focus on Communication, Navigation, and Surveillance (CNS) Services and Systems.

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[20] Special mention and appreciation to Mr. Natale di Rubbo, Project Manager – Drones, EASA

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