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A Comparative Analysis of the Legislation Evolution for Drone Use in OECD Countries

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Abstract: Drones have been employed for multiple uses, such as for military, surveillance, recreational, scientific, and research purposes. Their presence inside civil areas has necessitated the need to regulate their use. Towards this direction, many countries worldwide have issued national legislation, which vary on vehicle categorization according to the size, weight, flight altitude, purpose of use, and restrictions. In this study, we pursued the first comparative analysis of the Organization for Economic Co-operation and Development (OECD) countries' national legislations, in order to explore the similarities and differences in drone use and recommend improvements and homogenization. Some of the examined countries issued legislation during recent years of drone application, while others amended their existing legislative framework in order to catch up with drone technology evolution. Although from the 35 OECD countries 22 belong to the European Union, we observed much diversity among national legal frameworks. The intensive use of drones has led to severe ethical dilemmas that policy makers will need to address in the near future. We conclude with a proposal regarding the basic legislation for different uses according to the criteria that have been developed so far, followed by limitations and restrictions.

Keywords: drones; legislation; OECD; unmanned aerial vehicles

1. Introduction

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human operator on board that can be operated and be guided from a distance [1,2] using either fixed (airplane) or rotating (helicopter) wings. A UAV consists of a vehicle, ground control, and a data recording system [3]. UAVs may have several sensors (e.g., chemical, acoustic, GPS, thermographic, thermometer, altimeter, hydrometer, and camera) along with sensors of communication and recording instruments (e.g., hard disc, PC, tablet). All these together compose an unmanned aerial system (UAS) [4–7]. Drones vary in shape and size [8], and they are classified according to weight, flight range, flight altitude, autonomy, and purpose of use [7,9].

Recently, drones have become an important enforcement tool. Except for weapon machines [8–14], they are also employed for commercial purposes [2,8,10,11], research [15], and other purposes [16]. Drones have been used by the police in order to deal with illegal immigration [17], for border surveillance in USA [17–19], and in Europe by Frontex [16,20]. Furthermore, in some US states, the police use drones for crowd control, in accidents, crime tracing, for the monitoring of crime suspects [3], and in search and rescue operations [21]. Drones can also be used for commercial purposes [22], for example, delivery [23]. Drone deliveries are more environmentally friendly compared to vehicle ones [24]; thus, several companies (e.g., Amazon and Google) are preparing to offer drone delivery services [25].

Other recent drone applications include environmental protection, environmental law enforcement, and environmental crime prevention [26]. For example, in Africa, drones have been

used to deal with illegal poaching, which threatens the extinction of mammalian species [27], while in Italy, the police launched the "DroMEP" project, which involves the use of drones in environmental monitoring [28]. Drones have found applications in forest monitoring [29], illegal logging, deforestation, and smoke detection to prevent forest fires [15,30,31]. Small drones can be used for low-cost data collection for biodiversity [15], natural disasters [17,18], and wildlife monitoring and assessment [32]. Drones with executive programs can also be used for the detection of soil pollution and unknown perpetrators [33].

We find several other applications in sports [34]; search and rescue; identification of victims [35]; monitoring, analysis, and management of road traffic [36]; or for monitoring pedestrian behavior and accident prevention [37]. Low-cost drones with a camera on board have been used for public health purposes by detecting water spots to reveal mosquito breading areas responsible for malaria [38,39]. Drones can also be used to identify people with dementia much faster and more efficient than traditional methods [40]. They have also been used in construction to gather information for manufacturers [41]. Furthermore, drones can be used in agriculture for different applications such as: midseason crop health monitoring, irrigation equipment monitoring, and midfield weed identification [42,43]. Drones can be used by farmers for data acquisition and analysis and for continuously monitoring fields for learning and developing modern farm management skills [44].

In order to address the needs for managing the widespread use of drones, many countries worldwide have issued legislations on their use, by setting rules and restrictions for ensuring the safety and privacy of the population [45]. Towards this direction, this study consists of a comparative analysis of the respective legislations in the countries of the Organization for Economic Co-operation and Development (OECD). OECD countries are able to exchange opinions and practices on economic, social, and environmental issues, aiming to improving the quality of life and the world's economic and social situation [46]. The aim of this paper is to explore differences and similarities for the drone legal framework of the examined countries. We also conclude with legal recommendations, which can be a point of reference for future research on the subject.

The rest of the paper is structured as follows: Section 2 consists of the research methodology. Section 3 is an overview of the legislation for each examined country followed by an analysis of the published research regarding drone technology and applications. In Section 4 the legal frameworks are discussed, and recommendations for its harmonization are provided, while Section 5 consists of the overall conclusions and future research suggestions.

2. Materials and Methods

We selected all OECD countries, which are listed in alphabetical order as follows: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States of America [46]. The data were collected from official government websites of countries, ministries, civil aviation, and transport authorities.

A discussion is made based on size, weight, flight altitude, purpose of use, and restrictions with reference to legal documents and to the authority in charge. Typical characteristics reported in legislation are briefly presented as follows:

- Weight: the maximum mass of the aircraft at take-off;
- Flight altitude: the flight at an altitude above ground or sea;
- Purpose: conditions for approval of drone use including business, recreational, research, or other;
- Restrictions: prohibitions and limitations on drone use.

A comparative analysis of the legislation for drone use is performed, followed by recommendations for harmonizing and updating the legal framework.

3. Results

This section presents the analysis of the legal frameworks and the diachronic research volume trends, as recorded by the published papers in scholarly journals.

3.1. Analysis of the Legal Frameworks

In this section, a concise reference to the legislation of each OECD country is listed. The presented legal framework refers to the time the data for this project has been collected, (i.e., July 2018). However, as this is a dynamic topic, it is continuously being studied, and new legal updates may exist. In Table 1 there is a list of all studied countries, followed by the authorities in charge for drone regulation and the main legal documents that govern their operation.

Table 1. Legal authorities per country in charge of drone regulation.

Country	Authority	Legal Framework
Australia	Civil Aviation Safety Authority [47]	[48]
Austria	Austro Control [49]	[50]
Belgium	Civil Aviation Authority [51]	[52]
Canada	Transport Canada [53]	[54,55]
Chile	General Directorate of Civil Aviation [56]	[57]
Czech Republic	Civil Aviation Authority of Czech Republic [58]	[59]
Denmark	Danish Transport, Construction and Housing Authority [60]	[61]
Estonia	The Civil Aviation Authority of Estonia [62]	[63]
Finland	Finnish Transport Safety Agency [64]	[65]
France	Ministry of Ecological and Solidarity Transition [66]	[67,68]
Germany	Federal Minister of Justice and Consumer Protection of Germany [69]	[70]
Greece	Hellenic Civil Aviation Authority [71]	[72]
Hungary	The National Transport Authority of Hungary [73]	[74]
Iceland	The Icelandic Transport Authority [75]	[76]
Ireland	The Irish Aviation Authority [77]	[78]
Israel	The Civil Aviation Authority of Israel [79]	[80]
Italy	The Italian Civil Aviation Authority [81]	[82]
Japan	The Ministry of Land, Infrastructure, Transport and Tourism of Japan [83]	[84]
South Korea	Ministry of Land, Infrastructure and Transport of South Korea [85]	[86]
Latvia	The Ministry for Transport and Agriculture of the Republic of Latvia [87]	[88]
Luxembourg	The Directorate of Civil Aviation, under the Ministry of Transport in Luxembourg [89]	[90]
Mexico	The Ministry of Communications and Transportation of Mexico [91]	[92]
The Netherlands	The State Secretary for Transport, Public Works and Water Management of Netherlands [93]	[94]
New Zealand	The Civil Aviation Authority of New Zealand [95]	[96]
Norway	The Civil Aviation Authority of Norway [97]	[98]
Poland	The Civil Aviation Office of Poland [99]	[100–102]
Portugal	The Portuguese Civil Aviation Authority [103]	[104]
Slovakia	The Ministry of Transport and Construction of Slovak Republic [105]	[106]
Slovenia	The Civil Aviation Agency of the Republic of Slovenia [107]	[108]
Spain	The Safety Aviation Agency of Spain [109]	[110]
Sweden	The Transport Agency of Sweden [111]	[112]
Switzerland	The Federal Department of the Environment, Transport, Energy and Communications of Switzerland [113]	[114]
Turkey	The Directorate General of Civil Aviation of Turkey [115]	[116]
UK	Civil Aviation Authority of UK [117]	[118]
USA	Federal Aviation Administration of USA [119]	[120]

In Table 2, a reference to 14 criteria, as they have been located in the in national legal frameworks, is presented. All countries set the criterion of flying distance restrictions. Among the 35 countries examined, 32 referred to weight classification and 31 to overcrowded flight restrictions, while 29 require flight permissions for drone flights. Several countries have distance restrictions from buildings or infrastructure, safety insurance requirements, drone registration procedures, and certification required for piloting.

Table 2. Reference to the criteria in national legal frameworks.

Countries.	Flying Distance Restrictions	Weight Classification	Over Crowed Areas Restrictions	Flight Permissions	Areas' Distance Restrictions	Drone Registration	Buildings' Distance Restrictions	Safety Insurance	Piloting Certificate	Purpose of Flights	Operators' Age Limitations	Operation Plan	Air Flight Zones	Weather Conditions	Sum
Australia	+	+	+	+	+				+	+					7
Austria	+	+	+	+	+	+				+					7
Belgium	+	+	+	+	+	+	+	+	+		+	+			11
Canada	+	+	+	+		+	+	+	+	+	+	+		+	12
Chile	+	+	+			+			+						5
Czech Republic	+	+	+	+		+	+	+		+					8
Denmark	+	+	+	+		+	+	+			+				8
Estonia	+		+	+			+								4
Finland	+	+	+	+	+	+	+	+	+		+				10
France	+	+	+	+	+	+	+	+	+	+		+		+	12
Germany	+	+	+	+	+		+	+	+						8
Greece	+	+	+		+	+	+	+	+	+					9
Hungary	+	+				+		+	+			+			6
Iceland	+	+	+	+	+	+	+								7
Ireland	+	+	+	+	+	+	+								7
Israel	+	+	+	+	+			+	+	+					8
Italy	+	+	+		+	+	+		+				+		8
Japan	+	+	+	+	+		+								6
South Korea	+	+	+		+	+	+	+							7
Latvia	+	+	+	+	+	+	+	+			+		+		10
Luxembourg	+	+	+	+				+	+						6
Mexico	+	+	+	+	+				+						6
The Netherlands	+		+	+		+		+	+	+	+				8
New Zealand	+	+	+	+	+		+		+						7
Norway	+	+		+	+	+	+	+	+			+			9
Poland	+	+	+	+	+	+	+	+	+	+	+				11
Portugal	+	+	+	+	+		+	+		+					8
Slovak Republic	+	+	+	+	+	+	+	+	+	+			+		11
Slovenia	+	+	+	+	+	+	+	+	+						9
Spain	+	+		+	+	+		+	+	+					8
Sweden	+	+	+	+	+	+		+		+					8
Switzerland	+	+	+	+	+			+							6
Turkey	+		+	+	+		+		+			+			7
United Kingdom	+	+	+	+	+	+	+	+	+	+					10
United States	+	+				+				+	+		+		6
Sum	35	32	31	29	26	24	23	23	22	15	8	6	4	2	

Following the classification of the key issues regarding national drone regulations, what has been observed is a different approach in legislation amongst the OECD countries, while in some countries the legislative framework is still under consideration. In some cases, the national regulations classified drones based on the vehicle's weight, whereas other classifications included flight altitude. All OECD countries, however, classified drones according to weight, with the exemption of Estonia, the Netherlands, and Turkey.

Figure 1 shows the countries on a world map classified according to the number of criteria found in their legislation. Only 2 countries had 4–5 criteria, 13 had 6–7 criteria, 12 had 8–9 criteria, 6 had 10–11, and only 2 countries had 12 criteria.

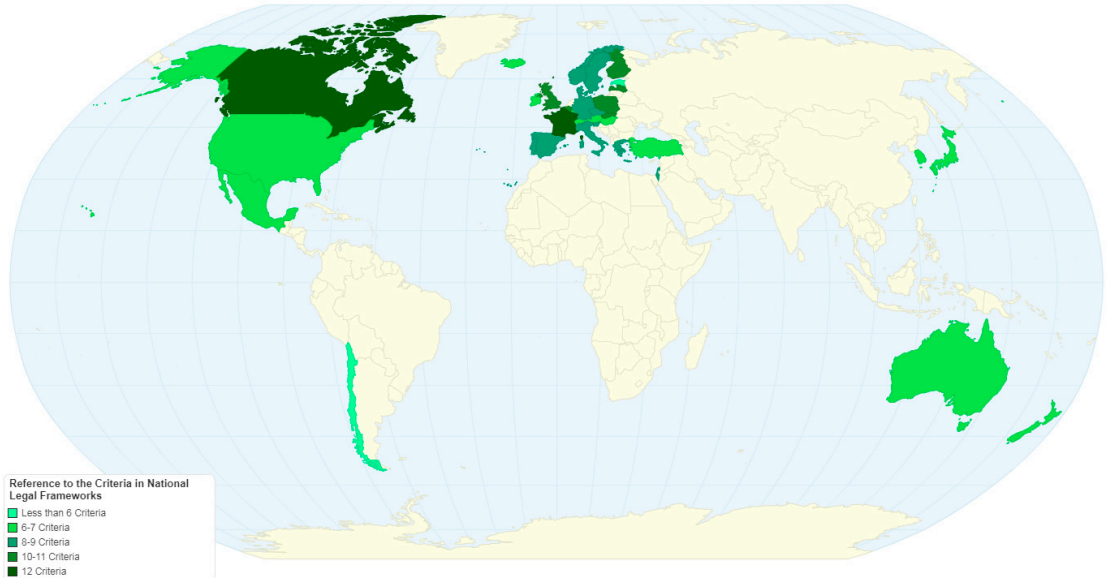


Figure 1. Criteria in the national legal frameworks for each OECD country.

In Japan and Turkey, the legislation was not advanced compared to the other countries. Some countries issued legislation during the very last years, and others amended their legislative framework in order to cover the needs of technology improvement. Many countries considered privacy seriously and posed restrictions for flights above people and public areas.

In the European Union (EU), where specific guidelines have been released, it is observed that every member state has set its own policy on the use of drones. For example, only Italy, Latvia, and Slovak Republic have legislated air traffic zones for drone use. The EU issued rules on safe use of drones in 2014 (2014/2243(INI)). However, most EU countries have yet to comply with the overall content of this regulation.

In Canada the legislative framework was stricter than all the other OECD countries. On the other hand, in USA the law follows a more liberal path. OECD countries followed a different approach in legislation about the purpose of flights. For example, Australia, Austria, Canada, Czech Republic, France, Greece, Israel, The Netherlands, Poland, Portugal, Slovak republic, Spain, Sweden, UK, and USA had guidelines with reference to the purpose of flights. All the other OECD countries do not give emphasis to such guidelines.

Figure 2, shows on a world map the requirements for registration and liability insurance for drone operators in all examined countries. Liability insurance for flights with drones was obligatory in all countries, except for Finland, Iceland, Japan, Mexico, New Zealand, Turkey, and USA. In Ireland and Netherlands, liability insurance was required only for flights for commercial purposes. In all countries, flights were permitted during daylight. Different regulations were observed regarding flight or vehicle registration requirements. In Australia, Canada, France, Hungary, Latvia, Luxembourg, Mexico, Portugal, Switzerland, Turkey, and the UK, drone registration was not required.

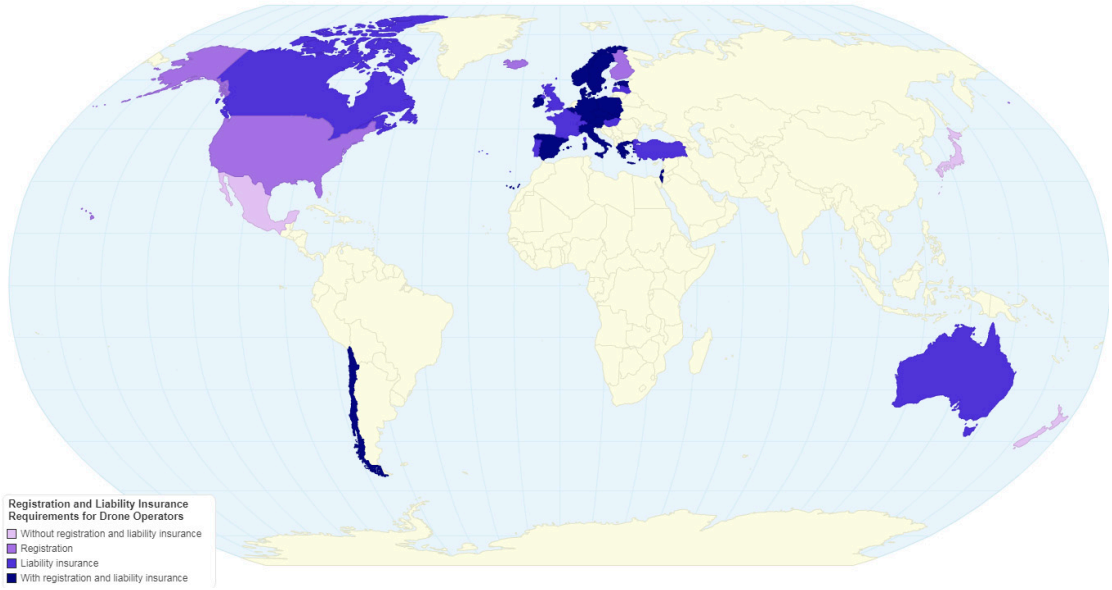


Figure 2. Registration and liability insurance requirements for drone operators in OECD countries.

The increasing use of drones has led several countries to enact new regulations regarding the use of drones and their operators. However, only a small number of countries have legislated regulations with specific restrictions. For example, in Luxembourg, Israel, and Germany, the maximum flight altitude is regulated to 50 m above ground, whereas in Belgium, the maximum flight altitude is 45 m. Said countries have legislated stricter laws than other OECD countries, where the maximum flight altitude is 90–150 m above ground.

Another flight restriction is the maximum distance from the operator, which varied from 30 to 500 m. Australia, Belgium, Estonia, Israel, Japan, Korea, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Sweden, and Turkey had strict regulations on the horizontal distance between the operator and the vehicle (flying drone), contrary to the rest of the countries, where the horizontal distance between the operator and the vehicle was about 100–500 m. The combinations of altitude and horizontal distance limitations per country are presented in Figure 3.

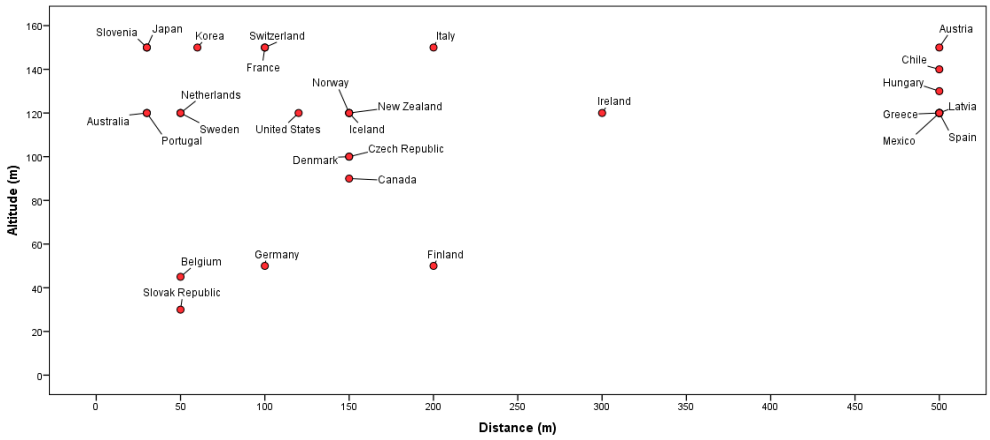


Figure 3. Maximum altitude and horizontal distance for drone flights according to national legislations.

All OECD countries had restrictions for flights near airports, populated areas, and buildings or authorities. While most of the countries have legislated a minimum distance away from airports,

Austria, Italy, Korea, Turkey, the UK, Hungary, Estonia, Belgium, and Luxemburg have not determined a specific distance, rather than requiring a "safety distance" (Figure 4).

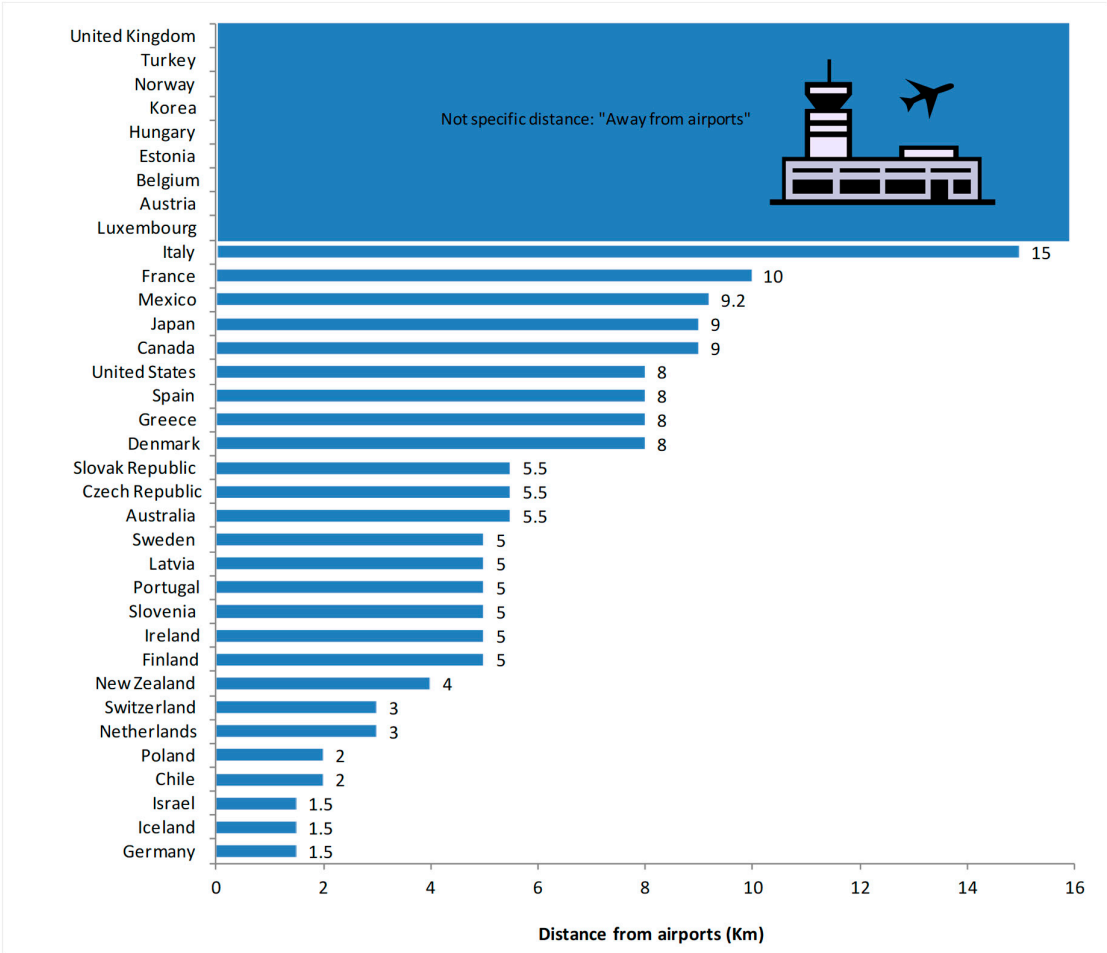


Figure 4. Minimum distance of drone flights from airports.

3.2. Research Trends

To justify the increased interest for drone applications, we ran a search in the Scopus database (as for June 2019) using the keywords "drones" and "unmanned aerial vehicles" between 2009 and 2018. Our research resulted in 2717 published journal papers, as shown in Figure 5. There was an increasing trend, from 11 papers published in 2009 to 851 published in 2018. We also show the ratio of drone-related papers to the total number of papers published per year in the Scopus database, which also followed an ascending trend, from 4.7×10^{-6} in 2009 to 270.0×10^{-6} in 2018.

This boost in published research indicates the current and forthcoming technology and industrial revolution of drone use for several purposes, which needs further regulation.

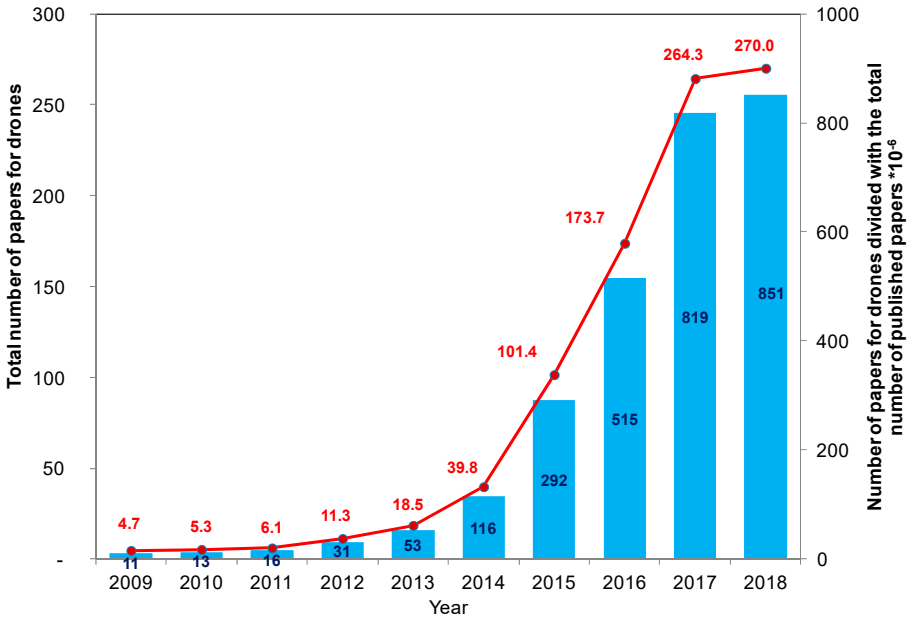


Figure 5. Evolution of papers published on drones per year.

4. Discussion

Despite OECD countries being able to exchange opinions and experiences on many aspects, including emerging technologies, the national regulations on drones demonstrate high diversity. Although among OECD countries there are groups of countries, such as those belonging to the European Union, that have released specific guidelines, it is observed that every member state has set its own policy on the use of drones. It is, therefore, recommended that a single policy on drone use should be implemented among the OECD countries.

This analysis focused on 14 criteria located in the national legislations based on size, weight, flight altitude, purpose of use, restrictions, insurance, and registration requirements. Based on the aforementioned comparative analysis, we identified the differences and similarities between national legislations on the use of drones.

Former studies limited their results to specific countries or groups of countries, or presented the use of drones for commercial purposes, without specific analysis of the relevant legislation. For example, Cracknell [22] presented an analysis on the legislation of drone use in Australia, USA, other countries (UK and China), and the EU. Cunliffe et al. [15] analyzed the safe growth of lightweight drones in UK, whereas Chamoso et al. [12] discussed the use of drones in Spain with reference to Spanish and European legislation. To the best of our knowledge, this is the first time that the legislative framework for the use of drones in so many countries is examined, highlighting major similarities and differences.

We have collected all practices, criteria, and restrictions reported in legislation in OECD countries and have proposed a common legislation framework. This proposal consists of the basic requirements that each country should legislate. This way, all countries will present some basic similarities in legislation for equal opportunities for drone uses and operators. Specific conditions may allow for further detailing a country's legal framework. This proposed framework suggests reference to the purpose of drone use, necessity for piloting training skills and qualifications, flight registration, classification per weight, permitting authority, insurance, accidents' record, and penalties, as detailed in Table 3.

Table 3. Recommendations for a homogenous legal framework.

Purpose of Use	Certification for Pilots	Flight Online Registration	Size Classifications					Flight Altitude (Without Special License)	
			100 gr	< 4 kg	4–25 kg	25–150 kg	> 150 kg	120 m	150 m
Commercial and industrial	✔	✔		✔	✔	✔	✔		✔
Recreational and infotainment		✔	✔	✔				✔	
Scientific/research	✔	✔	✔	✔	✔	✔			✔
Surveillance and security	✔	✔	✔	✔	✔	✔	✔		✔
Agriculture	✔	✔		✔	✔	✔	✔		✔
Enforcement Monitoring	✔	✔	✔	✔	✔	✔	✔		✔
Search and rescue and first aid	✔	✔		✔	✔	✔	✔		✔
Infrastructure	✔	✔		✔	✔	✔	✔		✔
Environmental management	✔	✔	✔	✔	✔	✔	✔		✔

Concerning the purpose of use, drones should be classified with reference to at least commercial, recreational, scientific/research, surveillance and security, agriculture, monitoring, search and rescue, first aid, infrastructure, or environmental management categories. Each vehicle could be suitable for one or more categories.

In the case where special permissions for flights are not obligatory, we suggest that drones should fly at a maximum altitude of 120 m and at a distance of 500 m from the operator. The Civil Aviation Authority of each country should regulate and supervise every flight, whereas the operator should immediately report to a special database every accident. Finally, in case of legal violations, criminal penalties and fees should be enforced to the operators of drones.

We suggest that every drone should have a unique number that will be its identity. For this purpose, every owner should register the vehicle's characteristics online in a database. Furthermore, this unique number should be set on the vehicle in order to be recognized in case of accident or loss. The owner of the vehicle should visit the online database before they start a flight and register data such as: the operator's license, the flight plan, the type of vehicle, the purpose and the flight duration, the operator's credentials, and the insurance contract. Flight permission should be issued by the authorities after request by the owner of the vehicle, considering the meteorological conditions (expected pressure, wind, visibility, temperature, precipitation, etc.). The authorities should notify the operator about flight permissions and limitations. This flight permission should be provided with a unique number that will enable the authorities to inspect the flight.

5. Conclusions

The use of drones has been growing fast during the last years, and, to the best of our knowledge, this is the first time a paper has discussed the legislation on their use for a large number of countries worldwide. The purpose of this work was to give a brief presentation and a comparative analysis of OECD countries' regulations regarding drone use. Among the 35 countries examined, we identified many differences in legislation, which can be attributed to the different timings of enacting the legal framework in relation to tremendous technology improvements. Many countries pay much attention to privacy and set restrictions on flights above people and public areas. Despite the fact EU has issued a single policy on drone use, many countries have legislated different restrictions and piloting requirements, while the criteria to categorize the vehicle's size, weight, flight altitude, and use also

differ per country. Meanwhile, the intensive use of drones raises a lot of ethical dilemmas, such as privacy, personal data, and so on, that people in charge will have to face in the near future. A more detailed legislative framework is necessary, mainly regarding limitations and restrictions per use as well as the way in which security authorities will be able to effectively control drone flights. A homogenous legal framework will provide smooth and safe drone technology use while still being able to revisit the requirements for permissions and restrictions, which is necessary along with technology development and maturation.

We consider this work as a starting point to further look into regulation and legislation for drone use, with an emphasis on the dynamic nature of this technology and a legal framework that will be flexible enough to follow technology improvements.

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