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Περιβαλλοντική Νομοθεσία και μη Επανδρωμένα Εναέρια Οχήματα

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

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Ξάνθη, 02 Σεπτεμβρίου 2024

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DEMOCRITUS UNIVERSITY OF THRACE
SCHOOL OF ENGINEERING
DEPARTMENT OF ENVIRONMENTAL ENGINEERING

Environmental Legislation and Unmanned Aerial Vehicles (Drones)

DOCTORAL THESIS

Nikolaos Tsiamis

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Environmental Engineering, Economic, Technology and Legislation, Department of Environmental Engineering, Democritus University of Thrace

Xanthi,02 September 2024

Preface

This PhD entitled "Environmental Legislation of Drones" includes the research conducted at the Department of Environmental Engineering of the Democritus University of Thrace (DUTH).

The study was supervised by Professor Tsagarakis P. Konstantinos and the Thesis Advisory Committee comprises from Professor Papaefthimiou Spiros and Professor Nikolaou Ioannis.

The manuscripts presented in following section List of Publications, were published during the study, and enclosed as Appendices.

List of Publications

1. Tsiamis, N.; Efthymiou, L.; Tsagarakis, K.P. A Comparative Analysis of the Legislation Evolution for Drone Use in OECD Countries. Drones 2019, 3, 75. https://doi.org/10.3390/drones3040075
2. Tsiamis, N.; Efthymiou, L.; Tsagarakis, K.P. A Conceptual Framework for Economic Analysis of Different Law Enforcement Drones. Machines 2023, 11, 983. https://doi.org/10.3390/machines11110983

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Abstract

UAVs or drones have received increasing interest in recent years. Drones are used for several purposes, including scientific and commercial purposes, environmental monitoring, and crime prevention, including identifying perpetrators by law enforcement agencies.

The use of drones by environmental legislation enforcement is applicable in several areas, such as deforestation, illegal logging, poaching, smoke detection to prevent forest fires, environmental pollution, and unknown perpetrators. Drones are useful tool for law enforcement officers and help them detect perpetrators faster than traditional methods of surveillance.

In this thesis, the legislation for drones is investigated. We chose the OECD countries and pursued the first comparative analysis of the Organization for Economic Co-operation and Development (OECD) countries' national legislations to explore the similarities and differences in drone use and recommend improvements and homogenization. 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 policymakers 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. Environmental enforcement agencies should use drones to detect environmental perpetrators. Cost-effectiveness and economic impact are valuable tools for all projects. The idea of this thesis was to analyze in detail a methodological evaluation framework for the levelized cost of drone services for law enforcement purposes. We compared Phantom 4 Pro and Thunder-B vehicles based on the available data. Moreover, their levelized costs per surveillance time and trip distance are calculated. Our approach helps users to estimate the real costs of their vehicles' services and produce equations for rapid estimations. We observed economies of scale for time and distance and revealed differentiations per aircraft capacity, and the final is formulated in a case study. The case study includes a four (4) kilometer distance and compares the costs in a 4 km area constantly monitored by the two types of drones to support the best vehicle selection for detecting environmental perpetrators. We found that the use of Phantom 4 Pro in

environmental monitoring is more cost-effective than the Thunder-B. The result of this research is a useful tool for calculating the cost of used drones by law enforcement officers for their work. After all, cost research estimations are a valuable tool and will help policymakers include in environmental crime prevention programs, especially those that include UAV technology.

This thesis is organized as follows. In Chapter1, a general introduction including the environmental legislation and uses of drones in the recent years and especially the law enforcement agencies applications are provided. At the end of chapter 1, the applications of drones in economic activities are reported. In Chapter 2, the aim and objectives of this thesis is presented. In Chapter 3, the drone regulation in OECD countries is analyzed and is the first comparative analysis of 35 countries' national legislations, in order to explore the similarities and differences in drone technology. In Chapter 4, a conceptual framework for economic analysis of different law enforcement drones, are presented. Two types of drones are selected: Phantom 4 Pro and Thunder-B. Based on the data availability, we calculated the cost with real data per surveillance time and trip distance. We produced equations for rapid estimations, and we observed economies of scale for time and distance. In Chapter 5, based on data analyzed in Chapter 4 we described the case study. The results of the Case study, which took place in a four (4) kilometers distance, show the most cost-effective type of drone used for law enforcement officers. In Chapter 6, the main conclusion of the thesis is provided. In Chapter 7, the innovation of PhD thesis and recommendations for future research are presented. In Chapter 8, scientific references are listed, and at the end in chapter 9 are presented published papers as Appendices.

Keywords: drones, legislation, OECD, unmanned aerial vehicles, cost effectiveness, economics of drones, law enforcement, operating cost.

Περίληψη

«Περιβαλλοντική Νομοθεσία και μη επανδρωμένα Εναέρια Οχήματα»

Τα μη επανδρωμένα εναέρια οχήματα ή drones, τα τελευταία χρόνια εμφανίζουν αλματώδης ανάπτυξη. Χρησιμοποιούνται για διάφορους σκοπούς και χρήσεις όπως επιστημονικούς και εμπορικούς σκοπούς, για περιβαλλοντική επιτήρηση αλλά και από τις Υπηρεσίες επιβολής νομοθεσίας προς αναζήτηση παραβατών αυτής.

Η εφαρμογή της περιβαλλοντικής νομοθεσίας με την χρήση drones περιλαμβάνει διάφορες χρήσεις όπως την αποψίλωση των δασών, την παράνομη υλοτομία, το παράνομο κυνήγι, τον εντοπισμό των πυρκαγιών σε δασικές εκτάσεις, επιτήρηση της βιοποικιλότητας, φυσικές καταστροφές και εντοπισμό άγνωστων δραστών που μολύνουν το περιβάλλον. Η χρήση τους αποτελεί σημαντικό εργαλείο και βοήθημα στα χέρια των εφαρμοστών της νομοθεσίας για τον γρηγορότερο εντοπισμό των δραστών σε σχέση με τις παραδοσιακές μεθόδους επιτήρησης.

Στην παρούσα διδακτορική διατριβή διερευνήθηκε η νομοθεσία χρήσης των drones. Επιλέχθηκαν οι χώρες του ΟΟΣΑ και έγινε για πρώτη φορά μια συγκριτική ανάλυση των εθνικών νομοθεσιών των χωρών αυτών προκειμένου να εντοπιστούν ομοιότητες και διαφορές στον τομέα της τεχνολογίας των drones. Μεταξύ των 35 χωρών αυτών, οι 22 είναι χώρες-μέλη της ΕΕ και εντοπίστηκαν μεγάλη ποικιλομορφία. Η εκτεταμένη χρήση των drones παρουσιάζει ηθικά διλήμματα, τα οποία οι σχεδιαστές πολιτικών πρέπει να λάβουν υπόψη τους στο κοντινό μέλλον. Καταλήξαμε στην πρόταση για μια βασική νομοθεσία για τις διάφορες χρήσεις των drones, σύμφωνα με τα κριτήρια που αναλύθηκαν, θέτοντας συγκεκριμένα όρια και απαγορεύσεις. Οι δυνάμεις επιβολής της νομοθεσίας μπορούν να χρησιμοποιήσουν αυτά και να έχουν μια μεγάλη βοήθεια στον εντοπισμό των παραβατών της περιβαλλοντικής νομοθεσίας. Όπως σε όλα τα προγράμματα η οικονομική αποδοτικότητα και ο οικονομικός αντίκτυπος είναι πολύ σημαντικό κομμάτι. Αυτό αφορά και τις δυνάμεις επιβολής της νομοθεσίας. Με το σκεπτικό αυτό αναλύθηκε ένα μεθοδολογικό πλαίσιο αξιολόγησης από το κόστος χρήσης των drones για σκοπούς επιβολής της νομοθεσίας. Βασιζόμενοι στα στοιχεία που μπόρεσαν να συγκεντρωθούν συγκρίθηκαν δυο τύποι από drones: το Phantom 4 Pro και το Thunder-B. Επιπλέον, υπολογίστηκε το κόστος βάσει του χρόνου επιτήρησης με τα παραπάνω οχήματα, αλλά και βάσει της συνολικής διανυθείσας απόστασης και των

δυνατοτήτων του κάθε αεροσκάφους. Η προσέγγιση μας, βοηθά τους χρήστες να υπολογίσουν με πραγματικά στοιχεία κόστους και την χρήση μιας εξίσωσης, το κόστος χρήσης των οχημάτων. Παρατηρήθηκαν οικονομίες κλίμακος και τέλος εφαρμόστηκαν σε μια μελέτη περίπτωσης. Η μελέτη περίπτωσης περιλαμβάνει μια απόσταση τεσσάρων (4) χιλιομέτρων στην περιοχή της Ξάνθης, όπου τέθηκε το ερώτημα της συνεχούς επιτήρησης της περιοχής για τον εντοπισμό των παραβατών της περιβαλλοντικής νομοθεσίας με την χρήση των παραπάνω drones που αναλύθηκαν. Βρέθηκε ότι το Phantom 4 Pro κοστίζει λιγότερο από το Thunder-B και είναι οικονομικά αποδοτικότερο. Τα αποτελέσματα της έρευνας αυτής που πραγματοποιήθηκε αποτελούν ένα χρήσιμο εργαλείο για τον υπολογισμό του κόστους που θα αντιμετωπίσουν οι δυνάμεις επιβολής της περιβαλλοντικής νομοθεσίας για την πραγματοποίηση του έργου τους. Άλλωστε η οικονομική αποτίμηση αποτελεί ένα σημαντικό εργαλείο στα χέρια των σχεδιαστών πολιτικής και είναι απαραίτητο να περιλαμβάνονται σε κάθε σχεδιασμό περιβαλλοντικών προγραμμάτων αντεγκληματικής πολιτικής, αλλά ειδικότερα και προγραμμάτων που θα συμπεριλάβουν και την τεχνολογία των μη επανδρωμένων οχημάτων.

Η παρούσα διδακτορική διατριβή οργανώνεται ως εξής: Στο κεφάλαιο 1, υπάρχει μια γενική εξέταση της περιβαλλοντικής νομοθεσίας και των χρήσεων των drones στο πέρασμα των χρόνων αλλά και των εφαρμογών της χρήσης τους από τις δυνάμεις επιβολής της νομοθεσίας. Τέλος, οι εφαρμογές των drones, σε οικονομικές δραστηριότητες αναπτύσσονται στο τελευταίο μέρος του πρώτου κεφαλαίου. Στο κεφάλαιο 2, αναφέρονται ο σκοπός και οι στόχοι της παρούσας διατριβής. Στο κεφάλαιο 3, εξετάζεται η νομοθεσία από τις χώρες του ΟΟΣΑ και έγινε για πρώτη φορά μια συγκριτική ανάλυση των εθνικών νομοθεσιών των 35 αυτών χωρών προκειμένου να εντοπιστούν ομοιότητες και διαφορές στον τομέα της τεχνολογίας των drones. Στο κεφάλαιο 4, αναλύεται ένα μεθοδολογικό πλαίσιο αξιολόγησης από το κόστος χρήσης των drones για σκοπούς επιβολής της νομοθεσίας. Επιλέχθηκαν δυο τύποι drones το Phantom 4 Pro και το Thunder-B, και με πραγματικά στοιχεία κόστους βρέθηκε το κόστος χρήσης αυτών βάσει χρόνου και διανυθείσας απόστασης. Χρησιμοποιώντας μια εξίσωση υπολογίστηκε το κόστος των δυο αναλυθέντων drones και παρατηρήθηκαν οικονομίες κλίμακος. Στο κεφάλαιο 5, περιγράφεται η μελέτη περίπτωσης, όπου χρησιμοποιήθηκε η παραπάνω ανάλυση του κεφαλαίου 4. Τα αποτελέσματα της μελέτης περίπτωσης που έλαβε χώρα σε μια περιοχή τεσσάρων (4) χιλιομέτρων έδειξε το πιο οικονομικά αποδοτικότερο drone για τους εφαρμοστές της νομοθεσίας. Στο κεφάλαιο 6, παρέχονται τα συμπεράσματα της διδακτορικής διατριβής. Στο κεφάλαιο 7, παρουσιάζεται η καινοτομία της διατριβής και προτείνονται θέματα για μελλοντική έρευνα. Στο κεφάλαιο 8, παρατίθενται όλες οι βιβλιογραφικές αναφορές που χρησιμοποιήθηκαν στην παρούσα διατριβή και τέλος στο κεφάλαιο 9, παρουσιάζονται οι δημοσιευμένες εργασίες σε έγκυρα επιστημονικά περιοδικά.

Λέξεις κλειδιά: drones, νομοθεσία, ΟΟΣΑ, μη επανδρωμένα εναέρια οχήματα, οικονομική αποδοτικότητα, οικονομικά των drones, επιβολή νομοθεσίας, κόστος λειτουργίας.

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List of abbreviations

EU	European Union
UAV	Unmanned Aerial vehicles
USA	United States of America
OECD	Organization for Economic Co-operation and Development
TAEC	Total Annual Economic Cost
OCC	Opportunity cost of capital
CRF	Capital Recovery Factor

1. General Introduction

1.1 Environmental legislation

Environmental legislation includes water, waste management, air pollution, and climate change laws. Environmental protection has been an important issue since the EU was founded. The Treaty on the Functioning of the European Union (TFEU) [1] provides a legislative framework that aims to coordinate the policies between EU member states about economic, social, and environmental issues and protect the market, agriculture, environment, waste management, transport, and more principal areas. According to article 130r of the Treaty of Maastricht (1993) [2], environmental protection includes protection of the quality of the environment, human health, natural resources, and a worldwide enfacing of environmental problems. The Treaty of Amsterdam (1999) [3] established the environmental protection of all EU members, while with the Treaty of Lisbon (2009) [4], the issue of "climate change" became a specific goal of EU members. In 2021, the EU released the EU Climate Law [5]. In this Law, each EU member state shall reduce the emissions to net zero by 2050. Many directives, plans, programs, and policies in the EU regarding environmental protection and climate change have been established during the past years [6]. In Greece, environmental protection started in 1937 with Law 856, which defined two national parks in the country. Many laws have been voted about protecting forests, wetlands, and nature, such as Convention Ramsar in recent years [7]. In 1986, the most important Greek Law about environmental legislation was Law 1650 [8], which is still valid today with some modifications. Many ministerial decisions (type of legislation) and new law amendments have been adopted in the past years, but the main one is still Law 1650/1986. Moreover, many directives, decisions, and regulations were adopted in Greek legislation from EU regulations. In general, Greek legislation is a combination of international and EU environmental laws and less of a national attempt [7].

1.2 Unmanned Aerial Vehicles (Drones)

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 [9,10] using either fixed (airplane) or rotating (helicopter) wings. A UAV consists of a vehicle, ground control, and a data recording system [11]. 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) [12–15]. Drones vary in shape and size [16], and they are classified according to weight, flight range, flight altitude, autonomy, and purpose of use [15,17]. Drones, also known as unmanned aerial vehicles (UAVs), have received increasing interest in recent years for applications in various fields [18,19]. Drones are categorized by weight, flight range, purpose of flight, altitude capacity, etc. [15,17].

1.3 Applications of drones

Recently, drones have become an important enforcement tool. Except for weapon machines [16,17,20–24] , they are also employed for commercial purposes [9,16,20,21], research [25], and other purposes [26]. They have been employed for several purposes, including forest monitoring [27,28], fire prevention [29], and deforestation and illegal logging [30], while Balcerzak et al. [31] demonstrate that unmanned aerial vehicles could be helpful for international firefighting and crisis management missions. In addition, unmanned aerial vehicles are an effective solution in agriculture [32], as images taken from high altitudes can be easily obtained and help farmers with crop growth monitoring [33,34], irrigation management [35], and crop health [36,37]. Small drones have also been used to monitor seagrass in coastal waters, which are sensitive to environmental changes [38]. Also, drones can be used for search and rescue [39], disaster management [40], geographic mapping applications [41,42], geology applications [43], archeological site observations [44], and weather predictions [45]. Finally, drones have been used for health purposes, including protection against malaria [46] and during the COVID-19 pandemic [47]. We find several other applications in sports [48]; search and rescue; identification of victims [49]; monitoring, analysis, and management of road traffic [50]; or for monitoring pedestrian behavior and accident prevention [51]. 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 [52,53]. Drones can also be used to identify people with dementia much faster and more efficient than traditional methods [54]. They have also been used in construction to gather information for manufacturers [55]. Furthermore, drones can be used in agriculture for different applications such as: midseason crop health monitoring, irrigation equipment monitoring, and midfield weed identification [56,57]. Drones can be used by farmers for data acquisition and analysis and for continuously monitoring fields for learning and developing modern farm management skills [58].

1.4 Applications for Law Enforcement Authorities

Drones have been used by the police in order to deal with illegal immigration [59], for border surveillance in USA [59–61], and in Europe by Frontex [26,62]. Furthermore, in some US states, the police use drones for crowd control, in accidents, crime tracing, for the monitoring of crime suspects [11], and in search and rescue operations [63]. Drones can also be used for commercial purposes [64], for example, delivery [65]. Drone deliveries are more environmentally friendly compared to vehicle ones [66]; thus, several companies (e.g., Amazon and Google) are preparing to offer drone delivery services [67].

Other recent drone applications include environmental protection, environmental law enforcement, and environmental crime prevention [68]. For example, in Africa, drones have been used to deal with illegal poaching, which threatens the extinction of mammalian species [69], while in Italy, the police launched the “DroMEP” project, which involves the use of drones in environmental monitoring [70]. Drones have found applications in forest monitoring [28], illegal logging, deforestation, and smoke detection to prevent forest fires [25,30,71]. Small drones can be used for low-cost data collection for biodiversity [25], natural disasters [59,60], and wildlife monitoring and assessment [72]. Drones with executive programs can also be used for the detection of soil pollution and unknown perpetrators [73].

Security forces have considered the advantages of using drones in line with the rapidly growing market and have actively involved them in law enforcement. In Italy, security forces have used drones for environmental monitoring [70], while in Africa they have been used for locating illegal poachers [69]. Boakye [74] found that aerial patrols can help detect crime and improve law enforcement effectiveness. Zhou et al. [75] also found that drones can be used for ship monitoring in terms of regulation violations.

The Police use drones for tracking missing people [76] and for traffic management as a viable solution against expensive manned helicopter searches [77]. In the USA, drones are used for water rescues and disaster response, traffic trash response, investigation of suspects, crime scene analysis, surveillance and crowd monitoring [78]. In Poland, Police used drones to sample domestic chimney exhaust gasses to prevent air pollution due to inappropriate fuels or burning materials [79].

Furthermore, drones can be used to protect cybersecurity [80], so it is necessary to initiate changes in legislation [81] due to citizens' privacy. However, the benefits from their use outweigh any ethical or security issues if well-regulated [82].

As the extensive use of drones tends to replace conventional modes of monitoring and surveillance, it is essential to refer to their costs calculated by a standard methodology for estimating economic reference values.

1.5 Applications of drones in economic activities

Authorities in various countries have incorporated their drone use into their legal systems, which may differ considerably [83]. Today, several applications can be identified in different fields of economic activity, which merits a discussion on the cost-effective use of drones. The literature is scarce, but some applications have been examined. For example, Sudbury and Hutchinson [84] calculated the cost based on the flight duration and conclude that Amazon's drone delivery of their packages is economically feasible [84]. Applications in health with the delivery of medical supplies are an essential need. Wright et al. [85] report that depending on geography and cargo characteristics, drone delivery could be a viable solution. Ochieng et al. [86] found that delivery with a motorcycle is more effective than drone delivery. However, as the delivery distance increases, drone systems become more effective than motorcycle delivery. Delivery with drones in hard-to-reach or inaccessible areas, like dense forests, may not yet be cost-effective. Still, technological improvements are expected to make this application cost-effective soon [87]. Sozzi et al. [88] compared the costs of fauna photos for vegetation indices taken by UAVs, airplanes, and satellites; they concluded that the cost depends on the analysis of the photos and the chosen platform. Finally, they concluded that drones have higher costs but could be more efficient than satellites or planes for taking high-resolution images in agriculture.

Yowtak et al. [89] calculated the delivery costs for grocery transport by comparing three different types of delivery (drones, engine vehicles, and battery vehicles). They concluded that each type of delivery has advantages and disadvantages. The economic cost comparison of the three types of delivery method found that UAVs still need to be more efficient. Christensen [90] employed a Monte Carlo simulation to estimate the cost and benefits of different scenarios of drone involvement in fire management. He concluded that there is a potential cost effectiveness of drone involvement in fire management compared to conventional control using helicopters. Zailani et al. [91] observed that using drones has high potential in blood product transportation. They found that drone transportation costs more than an ambulance, but they believe it is the best choice for developing nations. Borghetti et al. [92] compared vans, bicycles, scooters, and UAVs for last-mile delivery; they reported that UAVs could be the best choice for last-mile delivery if the package is small and light. However, UAVs experience some limitations, mainly derived from the restrictions posed by regulations. Finally, White et al. [93]estimated the cost and benefits of coastal surveying, comparing three alternatives: UAVs, manned aircraft, and walkovers. They concluded that the drone surveys were the most expensive method but faster than the other two, while walkover had the highest personnel cost.

Valerdi [94] provided cost metrics and a model based on weight and purchasing price for UAVs, developing a parametric cost model that relies on weight and endurance with the cost reference being pound/hour per thousand dollars. The authors of this study report limitations such as a lack of data availability. Malone et al. [95] estimated the ownership cost for UAV systems, including fixed and variable costs based, among other factors, on endurance, speed, altitude, payload, software design, and training of operators.

Banazadeh and Jafari [96] developed a framework to estimate the costs of aerospace systems. Then, they described a method as a case study scenario for estimating the cost of unmanned aerial vehicles. They used three indexes: "(1) acquisition cost; (2) acquisition cost divided by maximum takeoff weight; and (3) acquisition cost divided by empty weight" and concluded that this technique is better compared to others.

The above examples show that the literature on drone costs is scarce and not uniformly reported, as the technology is relatively new and expanding in scope. We see that drone technology is improving, which can reduce flight time costs. It is, therefore, essential to monitor parameters affecting costs related to UAV technology to give users an economic dimension for using this technology.

2. Aims and objectives

The aim of this thesis is the study of drone legislation and its applications on the environment.

In the first chapter, we selected all OECD countries to examine each member state's legislative framework on drones. 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. This aims to explore the differences and similarities between the drone legal frameworks of the studied countries, make legal recommendations, and become a point of reference for future research on the subject.

In the next chapter, we aim to introduce an economic evaluation methodology comparing the cost of using drones by law enforcement agencies. We selected two types of drones. Our cost analysis considered ideal weather conditions and did not include potential accidents or wearing equipment for longer assumed flights. Ideally, cost calculations will consider, among other factors, takeoff time, landing time, overlap time, hovering time, wind, precipitation, and other weather-related delays. Our analyses were based on hovering time, as the other times mentioned consist of a very small portion of a flight trip.

In the last chapter, we presented a case study in the Xanthi region comparing two selected drones. We selected a 4 km distance and the surveillance time lasted for 2 h per day of scoping to ensure compliance with environmental legislation in this area.

The research work of this thesis is divided into the following 3 chapters:

- A Comparative Analysis of the Legislation Evolution for Drone Use in OECD Countries
- A Conceptual Framework for Economic Analysis of Different Law Enforcement Drones
- Case study.

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

3.1. Introduction

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 [97]. Towards this direction, this study consists of a comparative analysis of the respective legislations in the countries of the Organization for Economic Cooperation 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 [98]. The aim 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.

3.2. 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 [98]. 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.

3.3. 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.

3.3.1. 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 (CASA) [99]	[100]
Austria	Austro Control [101]	[102]
Belgium	Civil Aviation Authority [103]	[104]
Canada	Transport Canada [105]	[106], [107]
Chile	The Directorate General of Civil Aeronautics of Chile [108],	[109]
Czech Republic	Civil Aviation Authority of Czech Republic [110]	[111]
Denmark	Danish Transport, Construction and Housing Authority [112]	[113]
Estonia	The Civil Aviation Authority (CAA) of Estonia [114]	[115]
Fnland	Finnish Transport Safety Agency [116]	[117]
France	Ministry of Ecological and Solidarity Transition [118]	[119], [120]
Germany	Federal Minister of Justice and Consumer Protection of Germany [121]	[122]
Greece	Hellenic Civil Aviation Authority[123]	[124]
Hungary	The National Transport Authority of Hungary [125]	[126]
Iceland	The Icelandic Transport Authority [127]	[128]
Ireland	The Irish Aviation Authority [129]	[130]
Israel	The Civil Aviation Authority of Israel [131]	[132]

Country	Authority	Legal Framework
Italy	The Italian Civil Aviation Authority [133]	[134]
Japan	The Ministry of Land, Infrastructure, Transport and Tourism of Japan [135]	[136]
South Korea	Ministry of Land, Infrastructure and Transport of South Korea [137]	[138]
Latvia	The Ministry for Transport and agriculture of the Republic of Latvia [139]	[140]
Luxembourg	The Directorate of Civil Aviation (DAC), under the Ministry of Transport in Luxembourg [141]	[142]
Mexico	The Ministry of Communications and Transportation of Mexico [143]	[144]
The Netherlands	The State Secretary for Transport, Public Works and Water Management of Netherlands [145]	[146]
New Zealand	The Civil Aviation Authority of New Zealand [147]	[148]
Norway	The Civil Aviation Authority of Norway [149]	[150]
Poland	The Civil Aviation Office of Poland [151],	[152], [153], [154]
Portugal	The Portuguese Civil Aviation Authority[155] ,	[156]
Slovakia	The Ministry Of Transport and Construction of Slovak Republic [157]	[158]
Slovenia	The Civil Aviation Agency of the Republic of Slovenia [159]	[160]
Spain	The Safety Aviation Agency of Spain [161]	[162]
Sweden	The Transport Agency of Sweden [163]	[164]
Switzerland	The Federal Department of the Environment, Transport, Energy and Communications of Switzerland [165]	[166]
Turkey	The Directorate General of Civil Aviation of Turkey [167]	[168]
UK	Civil Aviation Authority of UK [169]	[170]
USA	Federal Aviation Administration (FAA) of USA [171]	[172]

In Table 2, a reference to 14 criteria, as they have been located in the 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
Australia	+	+	+	+	+				+	+				
Austria	+	+	+	+	+	+				+				
Belgium	+	+	+	+	+	+	+	+	+		+	+		
Canada	+	+	+	+		+	+	+	+	+	+	+		+

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
Chile	+	+	+			+			+					
Czech Republic	+	+	+	+		+	+	+		+				
Denmark	+	+	+	+		+	+	+			+			
Estonia	+		+	+			+							
Finland	+	+	+	+	+	+	+	+	+		+			
France	+	+	+	+	+	+	+	+	+	+		+		+
Germany	+	+	+	+	+		+	+	+					
Greece	+	+	+		+	+	+	+	+	+				
Hungary	+	+				+		+	+			+		
Iceland	+	+	+	+	+	+	+							
Ireland	+	+	+	+	+	+	+							
Israel	+	+	+	+	+			+	+	+				
Italy	+	+	+		+	+	+		+				+	
Japan	+	+	+	+	+		+							
South Korea	+	+	+		+	+	+	+						
Latvia	+	+	+	+	+	+	+	+			+		+	
Luxembourg	+	+	+	+				+	+					
Mexico	+	+	+	+	+				+					
The Netherlands	+		+	+		+		+	+	+	+			
New Zealand	+	+	+	+	+		+		+					
Norway	+	+		+	+	+	+	+	+			+		
Poland	+	+	+	+	+	+	+	+	+	+	+			
Portugal	+	+	+	+	+		+	+		+				
Slovak Republic	+	+	+	+	+	+	+	+	+	+			+	
Slovenia	+	+	+	+	+	+	+	+	+					
Spain	+	+		+	+	+		+	+	+				
Sweden	+	+	+	+	+	+		+		+				
Switzerland	+	+	+	+	+			+						
Turkey	+		+	+	+		+		+			+		
United Kingdom	+	+	+	+	+	+	+	+	+	+				
United States	+	+				+				+	+		+	
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.

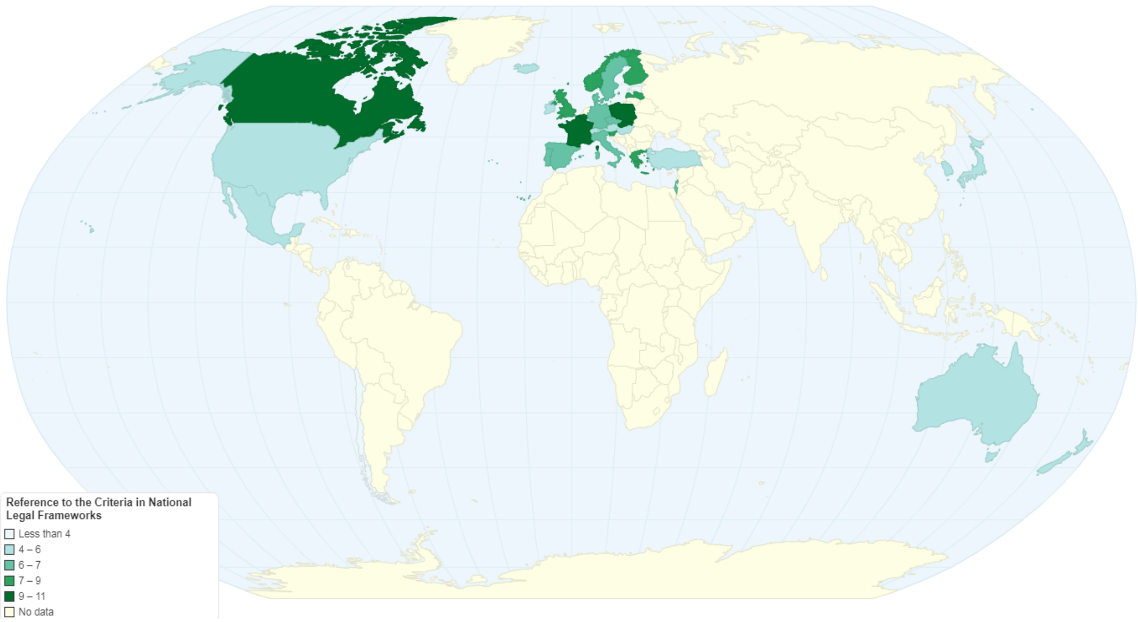


Figure 1. **Criteria in the national legal frameworks for each OECD country.**

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 in 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.

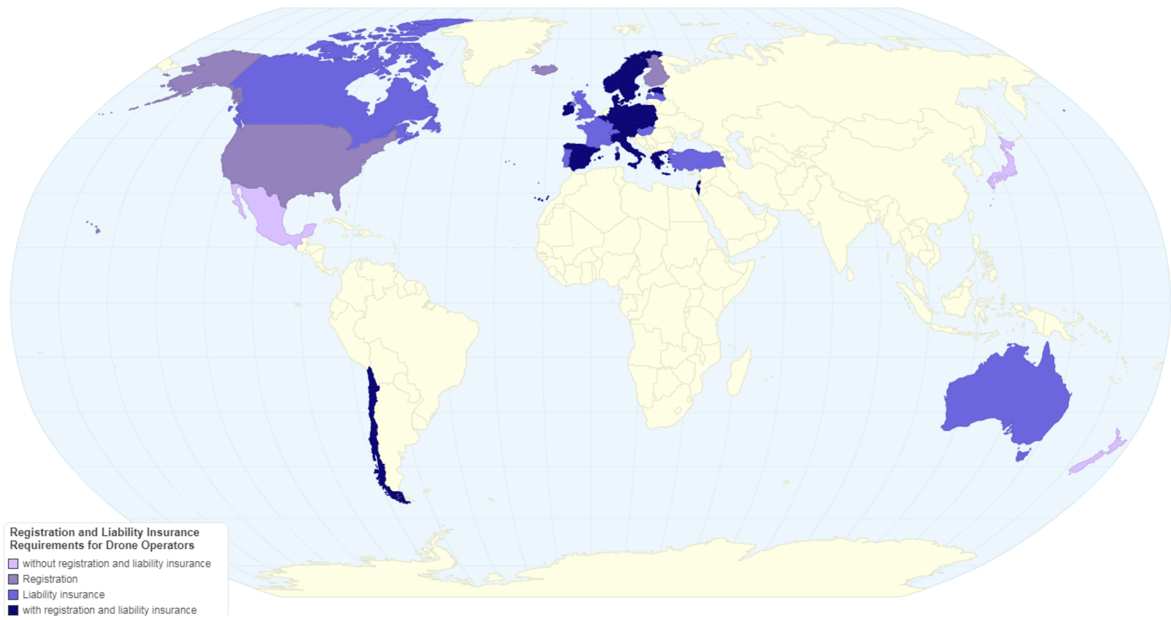


Figure 2. Registration and liability insurance requirements for drone operators in OECD countries.

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.

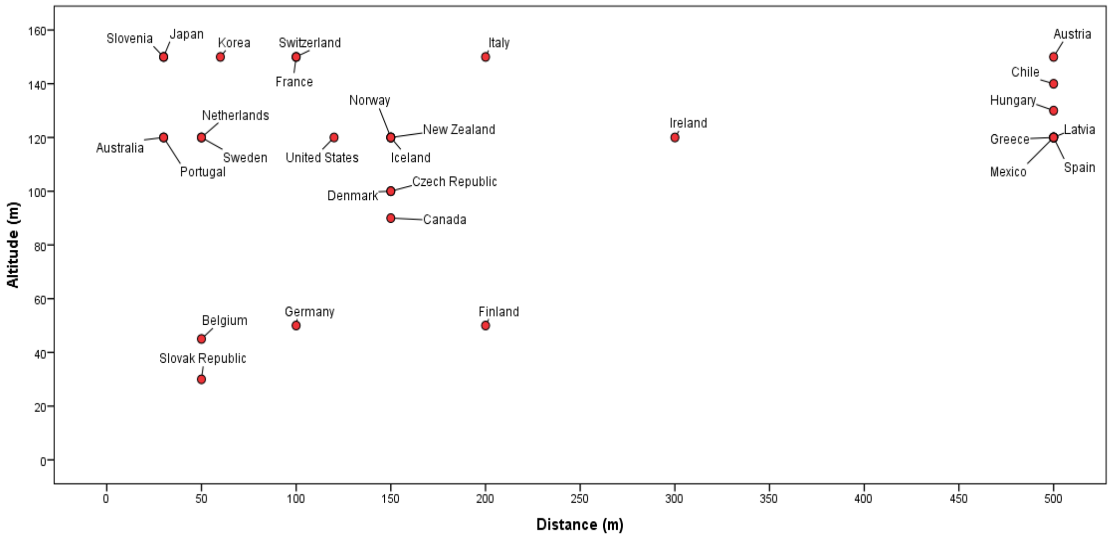


Figure 3. **Maximum altitude and horizontal distance for drone flights according to national legislations.**

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).

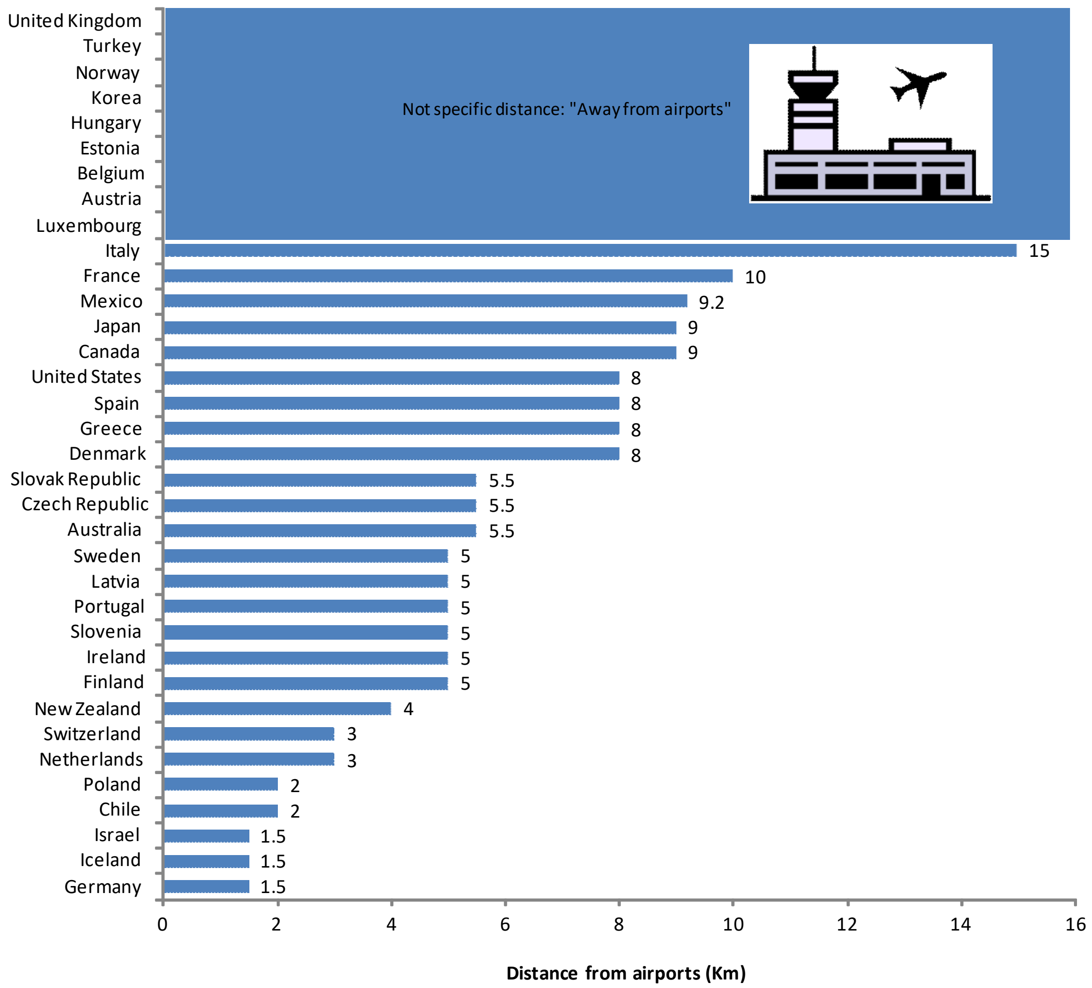
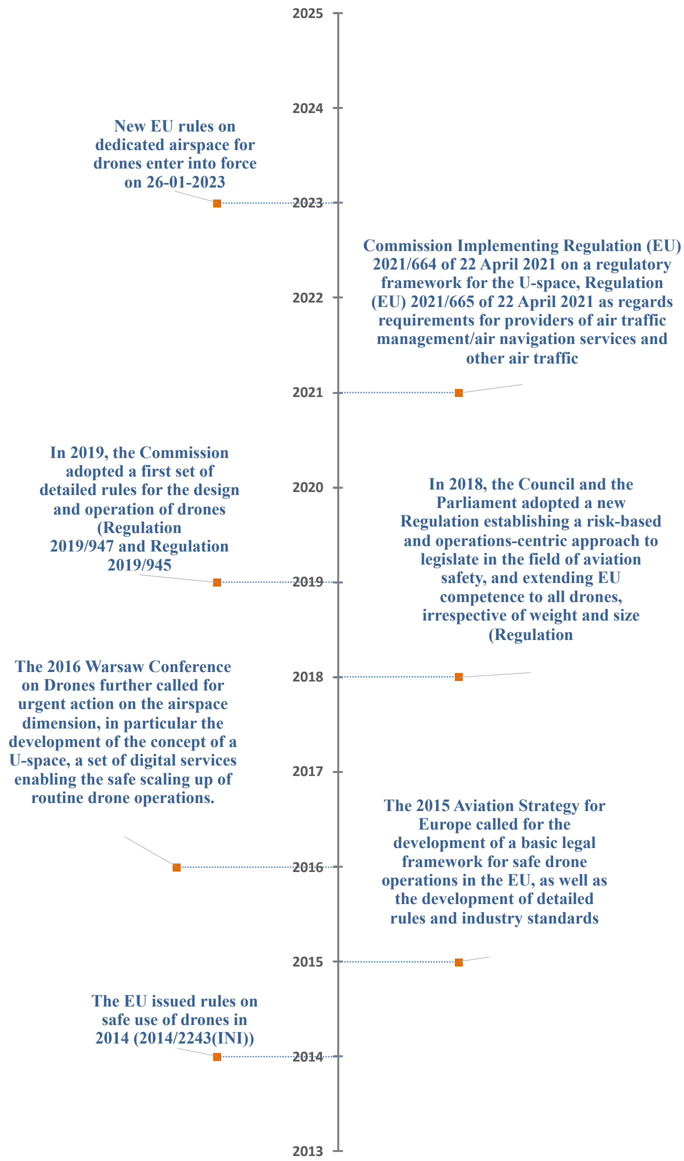


Figure 4. Minimum distance of drone flights from airports.

3.3.2. The EU regulations for drones



Source: https://transport.ec.europa.eu/news-events/news/drones-commission-adopts-new-rules-and-conditions-safe-secure-and-green-drone-operations-2021-04-22_en

Figure 5. Timeline of EU regulations for drones

As observed above, the EU issued rules on the safe use of drones in 2014 (2014/2243(INI)). However, most EU member states have yet to comply with the overall content of this regulation. Figure 5 shows the timeline of EU regulations for drones. The 2015 Aviation Strategy for Europe prioritizes the development of a basic legal framework for safe drone operations in the EU[173]. The 2016 Warsaw Conference discussed the development of the concept of a U-space for safer drone operation[173]. In 2018, the Council and the Parliament established Regulation 2018/1139 about drones without reference to weight and size[174]. In 2019, the Commission adopted Regulation 2019/947[175] and Regulation 2019/945[176], establishing rules and procedures for the operation of unmanned aircraft. These regulations adopted rules about categories (open specific or certified), abilities of pilots, the age of pilots, airworthiness of drones, and conducting an operational risk assessment. The Regulations required registration for unmanned aerial systems, and as prescribed by law, the flights should be in specified geographical zones. In 2021, the Commission implemented regulations 2021/665 [177] and 2021/666 [178] about U-space for drones. These regulations are mandatory for members-states of the EU, and they shall apply by 26-01-2023.

3.3.3. 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 6. 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.

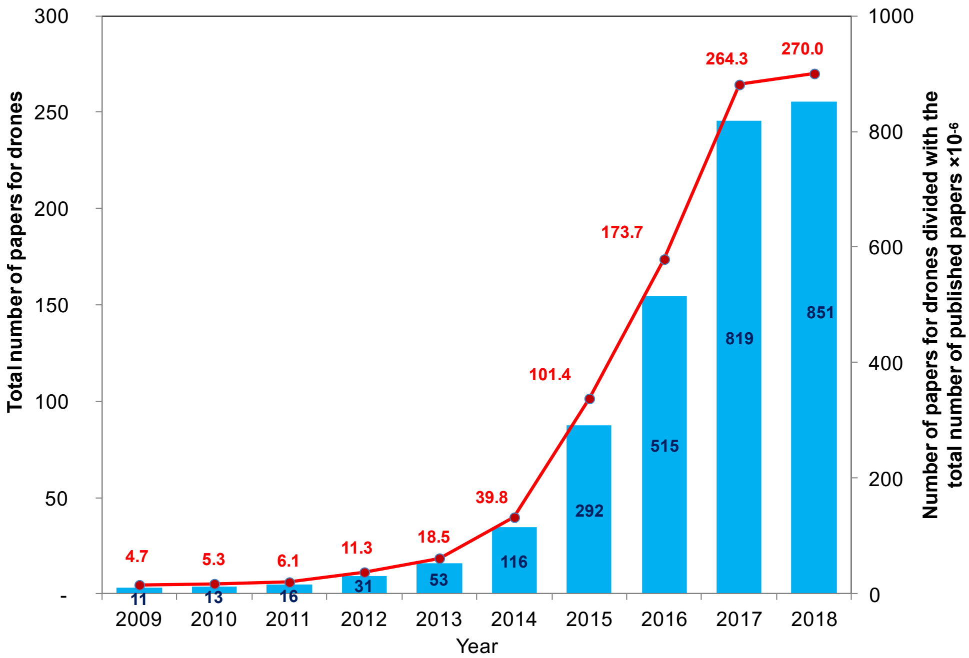


Figure 6. Evolution of papers published on drones per year.

3.4. 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 [64] presented an analysis on the legislation of drone use in Australia, USA, (UK and China), and the EU. Cunliffe et al. [25] analyzed the safe growth of lightweight drones in UK, whereas Chamoso et al. [22] 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 inin 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	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.

4. A Conceptual Framework for Economic Analysis of Different Law Enforcement Drones

4.1. Introduction

In this chapter, we aim to introduce an evaluation methodology and then compare the cost of using drones by law enforcement agencies. We analyzed two types of drones used by law enforcement officers, as well as by the Greek Police [179,180].

4.2. Materials and Methods

This section presents the methodological approach we followed for estimating the cost of drone use for monitoring and surveillance purposes. Due to data availability limitations, we selected two vehicles with access to some primary cost data. The first is the DJI Phantom 4 Pro, a slightly rotating wind semi-professional vehicle, while the second is the Thunder-B, a fixed-wing professional vehicle. These two types were selected because law enforcement in Greece has used them, so our estimations apply to real case applications and can benefit users. Apart from the manual reference data, we benefited from any information from personal contacts and press releases, but obtaining cost data from manufacturers was challenging. When necessary, we made assumptions and discussed them as follows: First, our cost analysis considered ideal weather conditions and did not include potential accidents or wearing equipment for longer assumed flights. Ideally, cost calculations will consider, among other factors, takeoff time, landing time, overlap time, hovering time, wind, precipitation, and other weather-related delays. Our analyses were based on hovering time, as the other times mentioned consist of a very small portion of a flight trip.

4.2.1. Vehicle Description and Characteristics

Phantom 4 Pro weighs 1375 gr using a 6000 mAh LiPo battery for operation and propellers for flight with 350 mm diagonal size. The battery flight capacity is about 30 min with 1.5 h of charging time. Its maximum flight time is 30 min, and its maximum wind speed resistance is 10 m/s, without rain. It has a maximum ascent speed of 5 m/s and a maximum descent speed of 4 m/s.

The purchase cost is EUR 1699. A battery replacement costs EUR 189, and a thermal camera costs about EUR 2149. The charger costs EUR 99, and the standard annual service from the mother company is EUR 169 excluding the cost of damaged spare parts [181], while the software is provided for free by the company. The lifetime of batteries varies from 300 to 500 cycles [182]. We will consider 400 charges as an average battery life in our estimations. Thunder-B is a "small tactical unmanned aerial vehicle (UAV) developed by Israeli company BlueBird Aero Systems," which is also used by the Greek police. It weighs 32 kilograms (kg), and its flight range is 150 kilometers (km). The maximum flight altitude is 16,000 feet (ft) (4870 m), while it can remain in the air for 24 h with one fuel tank or 12 h depending on the payload, speed, and weather conditions. It has a tank of 12 liters (L), and its maximum flight speed is 32–72 knots (kt) (16–37 m/s or 60–137 km/h). Also, it can fly with an airspeed of up to 45 knots (kt) and in rain of up to 10 millimeters/hour (mm/h). The Thunder-B requires a mobile system involving hardware and sensors at different costs, depending on extras, from USD 100,000 to USD 200,000. Based on press releases, the cost of purchasing a Thunder-B system (drone, software, and hardware) is EUR 200,000. However, obtaining written cost data has not been possible, despite our efforts, for this vehicle. There should be one annual service as reported by the manufacturer.

The Phantom 4 Pro can be operated by one operator, while the Thunder-B needs two operators. The operator's cost is calculated according to the average salary of police officers with 10 to 15 years in service, estimated at EUR 20,820 per year [183]. Table 4, summarizes the essential characteristics of the two studied vehicles.

Table 4. Characteristics of Phantom 4Pro and Thunder-B drones

UAV Characteristics	Phantom 4 Pro	Thunder-B
Wingspan	350 mm	4 m
Weight	1.375 kg	32 kg
Maximum speed	S-mode: 45 mph (72 kph) P-mode: 31 mph (50 kph)	137 kph Cruise speed 80 kph
Flight range	5 km	150 km
Endurance	30 min	up to 24 h/12 h with cargo capsules/vtol

Operating altitude		1820 m/6000 ft
Maximum altitude	19,685 ft/6000 m	4870 m/16,000 ft
Temperature range	0–40 °C	
Covert operation		Aprox. 500 m
Cost	EUR 1699	EUR 100,000–200,000
Fuel source	-	12 lt
Payload		up to 4 kg
Wind speed resistance	10 m/s	
Airspeed	10 m/s	60–137 kmh/32–72 knots
Battery	6000 mAh LiPo	-
Severe weather operation	Without rain and in winds of up to 10 m/s	In winds of up to 45 knots and rain of up to 10 mm/h

4.2.2. Cost Calculation Methodology

In this section, we detail how to estimate the cost of flight time of the two vehicles, based on the unit cost. These costs will be calculated based on the Total Annual Economic Cost (TAEC) formula:

$$\mathbf{TAEC} = (C_c \times CRF) + C_a \qquad \textbf{(1)}$$

The Capital Recovery Factor (CRF) is given by:

$$\boldsymbol{CRF} = \frac{\boldsymbol{r(1+r)^t}}{\boldsymbol{(1+r)^t - 1}} \qquad \textbf{(2)}$$

where C_c is the capital/purchasing cost

- C_a is the annual operation and maintenance cost.
- *t* are the years of operation and
- *r* the opportunity cost of capital (*OCC*).

By calculating the annual equivalent cost, we can refer to a unit for levelized incurred costs; that is, per kilometer or hour. Also, we considered the lifetime of a thermal camera and a charger to be 5 years, alongside the lifetime of batteries of 400 charge cycles. Each battery-charging kilowatt hour (kWh) cost is calculated according to the Greek electricity market based on March 2021 [184]. The price of fuels is EUR 1.575 based on prices in March 2021 when we ran the analysis. We consider that the speed of the drones is about the average speed reported in their manuals. Also, this study assumes that for Thunder-B, the service cost is 2.5% of the purchase cost, as no data were provided. Furthermore, we considered the number of operators that are necessary for surveillance flights. The law enforcement officer's wage was considered to be the same for the two drones regardless of the level of operating risk or the characteristics of each drone. Finally, the basic software cost was not calculated separately because the software for the Phantom 4 Pro is free (open), and that for the Thunder-B drone is included in the purchase cost. Thus, any software or future development cost cannot be separated from the purchase or maintenance costs we have considered.

4.2.3. Unit Cost Calculation

In this section, we describe the basic cost elements and any assumptions considered to compare the cost of flight time of the two vehicles based on the unit cost. These costs were calculated based on the TAEC provided by Formulas 1 and 2. We considered the lifetime of the drones to be 5 and 10 years for the Phantom 4 Pro and Thunder-B, respectively, with an OCC of 5%. We also considered the Phantom 4 Pro and Thunder-B drones' 5 km of surveillance for different flight times. This study assumes that the service cost for the Thunder-B drone is 2.5% of the purchase cost. We assume this drone can fly with one full tank for 16 h (out of the 24 h reference value). Thus, this drone needs 0.75 L of fuel per hour. The price of fuel is EUR 1.575. For the Phantom 4 Pro, one operator is necessary for half an hour of surveillance. Therefore, two operators with two vehicles are needed for surveillance flights from 1 to 8 h. The second operator will fly the second drone as soon as the first lands to change the battery, so the surveillance is uninterrupted, and vice versa. For a 10 to 16 h period, we need four operators and two vehicles, due to the second shift involved. On the other hand, a Thunder-B drone needs two operators for surveillance periods between 0.5 and 8 h and four operators (a second shift) for 8 to 16 h periods.

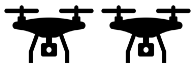
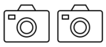
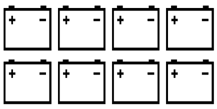
4.3. Results

This section presents analytical cost estimations for a specific 4 h trip, flight costs for different distance levels, and flight cost per hour. With this case scenario, we assume that the aggregated annual surveillance period is 1460 h if a 4h flight for each day of the year is necessary. We then calculated the cost per kilometer of flight, considering the vehicle's travel distance capacity per time. This is an analytical approach intended for budgeting law enforcement applications. Finally, we provide a case study example based on our findings.

4.3.1. Cost Estimations for 4h Flight

Considering a typical flight surveillance period of 4 h, the flight cost, with the best possible details for each of the two drone types selected, was calculated. The different needs of the necessary units for achieving the planned time flights are presented in Appendix A. The required number of units for the 4-h case, we selected to present, are shown in Table 5.

Table 5. **Individual number (no) of units considered for the uninterrupted 4 h surveillance period, per vehicle**

Units	Phantom 4 Pro	Thunder-B
Drones (no)		
Camera (no)		
Personnel (no)		
Fuel (L)	N/A	
Batteries (no)		N/A
Charger (no)		N/A

4.3.1.1. Cost Estimations for Phantom 4 Pro

The purchase cost for two Phantom 4 Pro drones is EUR 3398 with an estimated economic life of 5 years. The necessary cost for equipping the vehicles with two thermal cameras is EUR 4298. The cost of the batteries is EUR 1512. We need eight batteries for 4 h flight surveillance per year. After this load, they will be worn out and will have to be replaced. The cost of three chargers is EUR 297. As discussed in Sections 3.2 and 3.3, all this equipment is necessary for 4 h uninterrupted operation. The equivalent operation and maintenance (O&M) costs of this equipment are EUR 338 for service, EUR 39.42 for energy, and EUR 41,640 for the two operators. Table 6, shows the calculations of annuitized capital and annual O&M costs, which result in a TAEC of EUR 45,451.20

Table 6. **Total annual cost estimations for Phantom 4 Pro**

Costs	Units	Cost per Unit (EUR)	Cost (EUR)	*t*	*CRF*	Annual Cost (EUR)
Vehicle	2	1699	3398	5	0.231	784.85
Thermal camera	2	2149	4298	5	0.231	992.73
Battery	8	189	1512	1	1.050	1587.60
Charger	3	99	297	5	0.231	68.60
						3,433.78
Basic service						338
Energy						39.42
Operator						41,640
Sum of O&M						42,017.42
TAEC						**45,451.20**

The DJI Phantom 4 Pro has a flight range of 5 km. So, the total covered kilometers are 7300 km [surveillance (1460 h), ∗ range of flight (5 km)]. Therefore, to calculate the total cost per hour, we divided the total cost by the total operating hours. The above calculation gives 45,451.20/1460 = EUR 31.13/h

4.3.1.2. Cost Estimation for Thunder-B

We consider the Thunder-B drone system to have a purchase cost of EUR 200,000, with camera and software costs embedded. Based on our research methodology, we calculated the CRF and TAEC the same way as with the Phantom 4 Pro. The Thunder-B drone's lifetime is estimated to be ten years, with two operators needed per flight. The annual service cost is estimated to be EUR 5000. The total annual cost was calculated to be EUR 25,900.91. We consider that a fuel tank is sufficient for a 16 h flight. This type of drone needs 0.75 L of fuel per hour. So, the annual fuel cost is EUR 1724.63 for 4 h flights. The cost for the four operators is the same as for the operators of the Phantom 4 Pro, equaling EUR 41,640. The annual cost is EUR 74,265.54 (Table 7).

Table 7. **Total annual cost estimation for Thunder-B**

Costs	Units	Cost per Unit (EUR)	Cost (EUR)	*t* (yr)	*CRF*	Annual Cost (EUR)
Vehicle	1	200,000	200,000	10	0.1295	25,900.91
SUM						25,900.91
O&M						
Basic service						5000
Fuels						1724.63
Operator						41,640
SUM						48,364.63

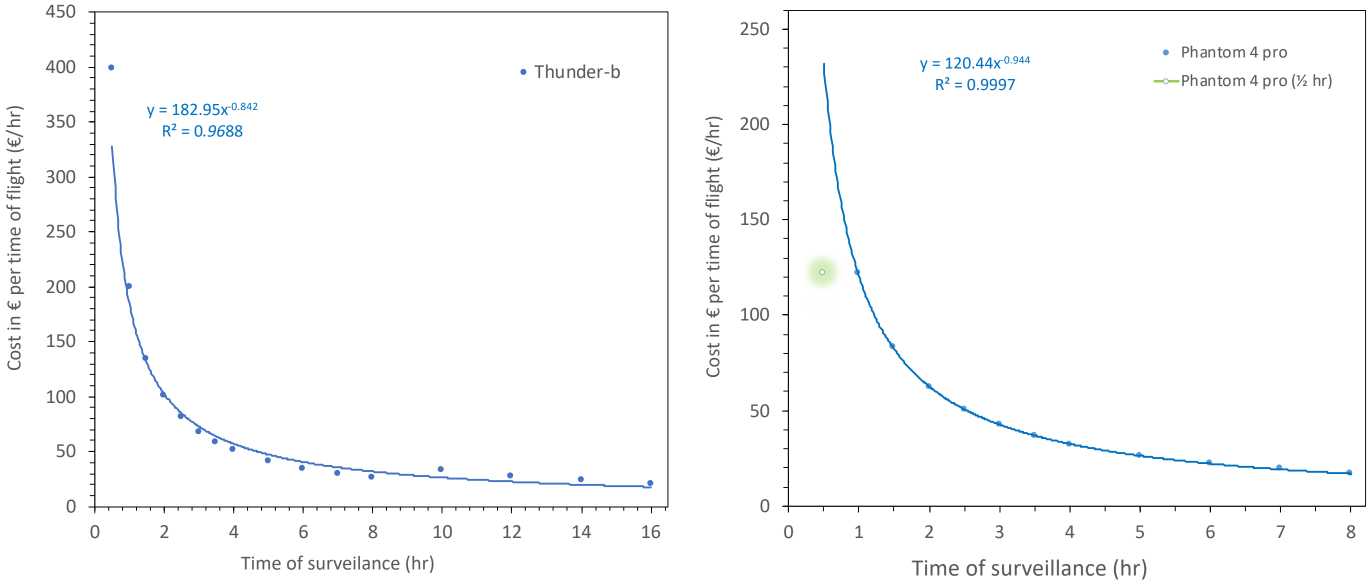
TAEC	74,265.54

The cost per hour and km are given if we divide the total annual cost by the total covered km and the total functional hours. With this case scenario, we concluded that the total monthly monitoring hours are 1460. The Thunder-B drone has a range of 50 km flights. So, the total covered kilometers are 73,000 km [surveillance (1460 h), ∗ range of flight (50 km)]. To calculate the total cost for the user per hour, we divide the total cost by operating hours to calculate the unit cost per hour. This gives 74,265.54/1460 = EUR 50.87/h.

4.3.2. Cost Estimations per Flight Duration

Based on the analytical estimations of the previous section, we proceeded with further calculations per flight duration from 0.5 to 16 h of surveillance per day for the Thunder-B drone (Figure 7a) and from 0.5 to 8 h of surveillance per day for the Phantom 4 Pro drone (Figure 7b). Therefore, the total annual flight times equaled 182.5, 2920, and 5840 annual hours for 0.5, 8, and 16 surveillance hours per day, respectively. Economies of scale are shown graphically and from the estimated equations of Cost = $a \cdot x^b$, where x is flight time or distance covered. The "b" coefficient was estimated with a negative sign for both equations due to the aforementioned economies of scale. All calculations followed the fitted equations except for the 0.5 h surveillance period with the Phantom 4 Pro drone, as observed in Figure 7. We believe that a 0.5 h flight is a short period compared to the analysis we performed, and it is calculated separately; thus, it does not contribute to the regression of Figure 7. If we take, for example, the cost of surveillance for a 1 h trip, we see that the cost drops from about EUR 200/hr to about EUR 100/hr if the trip lasts 2 h for the Thunder-B.

Similarly, the cost of surveillance for a one-hour trip and two two-hour trips is about EUR 122 and EUR 62, respectively, for the Phantom 4 Pro drone. However, it is evident that the Phantom 4 Pro costs less than the Thunder-B for all calculated times. Figure 7 shows an excellent rapid cost estimation for different surveillance trips,



(a) **(b)**

Figure 7. Cost per time-of-flight (a): Thunder-B drone and (b): Phantom 4 Pro drone.

In Figure 8, we calculated the cost of surveillance per km based on the drones' typical average speeds. We calculated the cost per km for the Thunder-B drone when the trip lasts 50 km (a). On the other hand, we calculated the cost per km for the Phantom 4 Pro drone when the trip lasts 5 km (b). All points fit the equations Cost = $a \cdot x^b$, with similar evidence of economies of scale. In this case, the cost per kilometer for the Phantom 4 Pro drone is higher than that for the Thunder-B drone at all points. For example, 4 h of surveillance will cost EUR 1.02 per kilometer for a Thunder-B drone, while a Phantom 4 Pro drone will cost EUR 6.23 per kilometer. Although the two vehicles may be used for different applications, we present these values as an example of comparison and how this methodology can help estimate service costs.

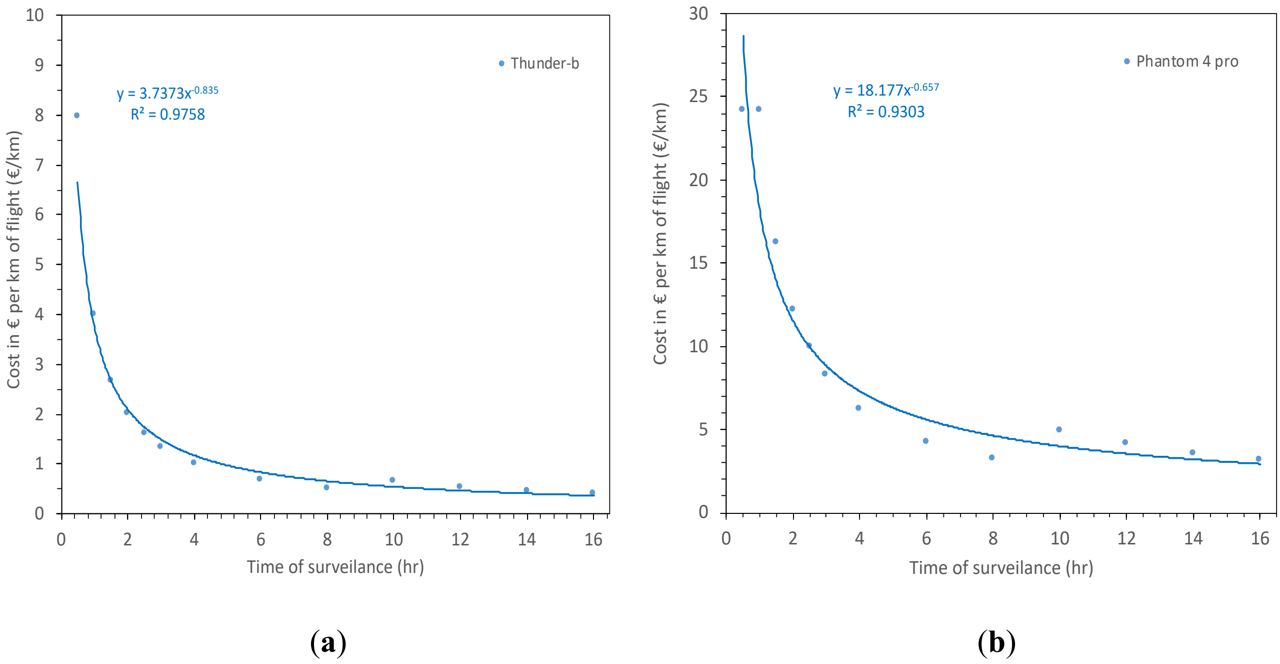


Figure 8. **Cost per km of flight for** (a)**: Thunder-B drone (50 km surveillance) and** (b)**: Phantom 4 Pro drone (5 km surveillance).**

5. Case study

We finally presented a case study using the two drones and concluded which was the best choice based on cost estimates.

5.1. Materials and methods

We presented a case study in the Xanthi region. We selected a 4 km distance starting from the old town of Xanthi, crossing the Kosinthos River, a peri-urban grove of trees, and ending in the nearby village of Kimmeria. The peri-urban grove of trees and river constitute a small sample of flora and fauna. The surveillance time was assumed to last 2 hours (h) per day. The surveillance aimed to identify potential perpetrators of littering, setting fire to the grove, and polluting the Kosinthos water body via illegal discharges or waste dumping. We used the two drones analyzed in the previous section, the Phantom 4 Pro and the Thunder-B drones.

5.2. Case study analysis

In our case study of surveillance by the enforcement authorities, we selected a small area in Xanthi, city, located in Greece. We used the two drones analyzed in the previous section. The 4 km surveillance area is shown in Figure 9, as an abstract from google maps. The line shows the distance, starting from the old town of Xanthi, crossing the Kosinthos River, a peri-urban grove of trees, and ending in the village of Kimmeria. The peri-urban grove of trees and river constitute a small sample of flora and fauna of the region.

Figure 9. **Surveillance area, from the old town of Xanthi to Kimmeria village.**

The surveillance time lasted for 2 h per day of scoping to ensure compliance with environmental legislation in this area. The surveillance aimed to provide identification of perpetrators of littering, setting fire to the grove, and polluting the Kosinthos water body.

In this case study, the distance was short, and we needed two Phantom 4 Pro drones with four batteries for two hours of uninterrupted surveillance. One battery lasts 30 min and needs charging for 1.5 h. The maximum speed of the Phantom 4 Pro is 50 km/h. If we fly the Phantom 4 Pro with an average speed of 25 km/h, it will cover the distance of 4 km in 9.6 min. So, the Phantom 4 Pro drone surveillance will be able to cover the distance two and a half times with one battery charge. The journey is short, and the surveillance will be almost continuous. Therefore, for two hours of surveillance in this area, four Phantom 4 Pro batteries per day, two vehicles, two operators, two thermal cameras, and three chargers are necessary to retain the flying capacity. The summary of employing the Phantom 4 Pro drone for this case study is presented in Figure 10. We also state the limitations of our assumptions; that is, that there will be surveillance from a specified height, no significant winds or precipitations, and no other risks (i.e., operating risk), which would inevitably affect costs.

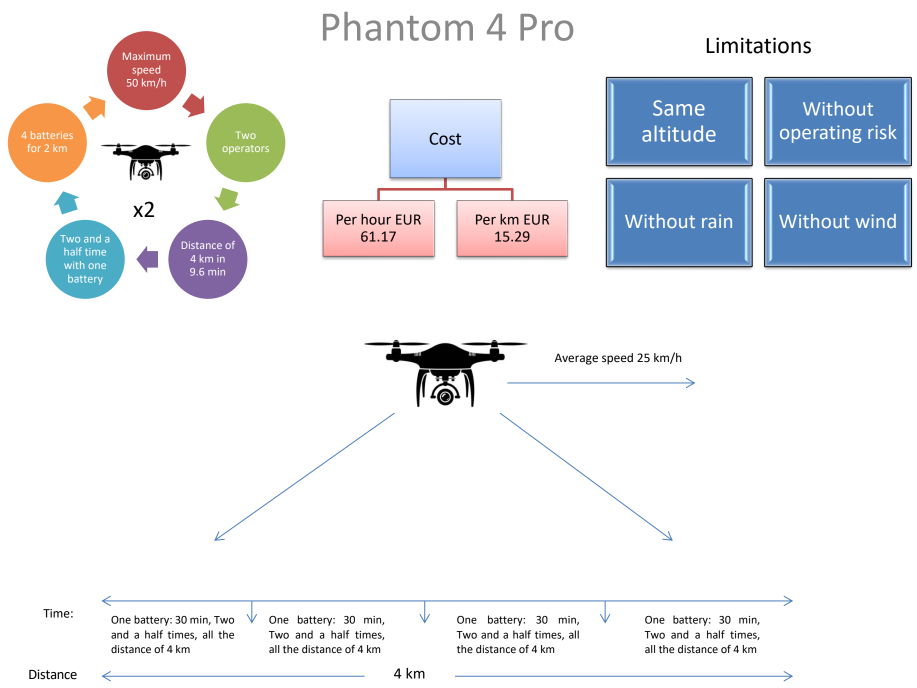


Figure 10. **Surveillance with Phantom 4 Pro.**

On the other hand, we needed one Thunder-B drone for two hours of surveillance. Also, a 1.5 L tank and two operators are necessary. The maximum speed of the Thunder-B drone is 137 km/h. In this case, the drone can fly at a recommended cruise speed of 80 km/h (note that 66 km/h speed is the minimum possible cruise speed). Under these circumstances, it will cover a distance of 4 km in 3.6 min. So, using the Thunder-B drone for will cover the distance faster than the Phantom 4 Pro, but the time period is also short, so the surveillance is continuous. The summary of employing the Thunder-B drone for this case study is presented in Figure 11.

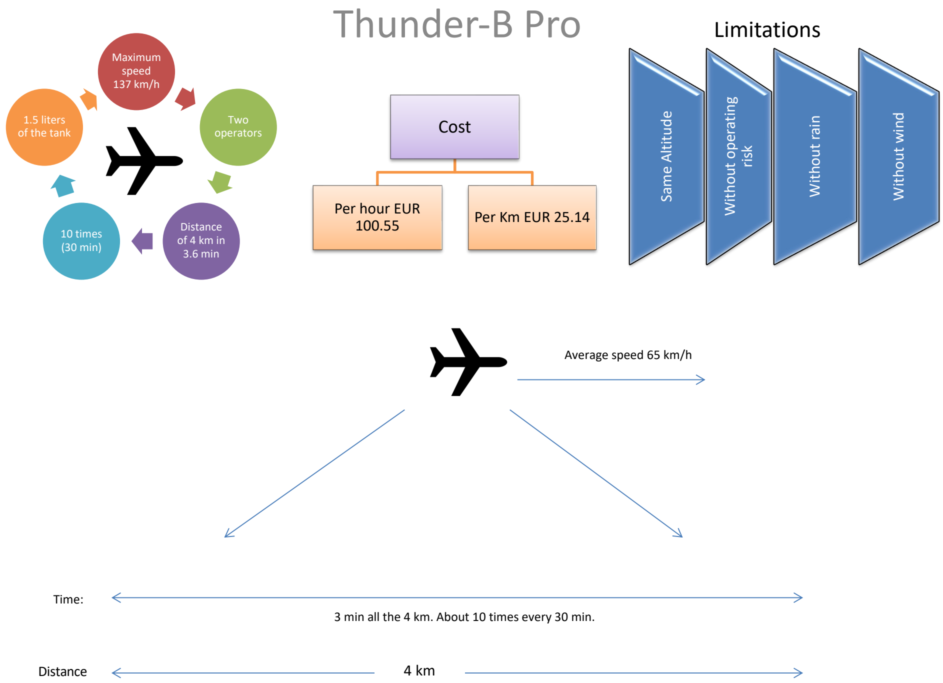


Figure 11. **Surveillance with Thunder-B drone.**

Using the functions from Section 4.2.2, we assume the costs for one-year surveillance. In this case, the cost of the Phantom 4 Pro per hour is EUR 61.17 and per kilometer is EUR 15.29, while the cost of the Thunder-B drone per hour is EUR 100.55 and per kilometer is EUR 25.14.

This approach has some limitations. The flight will occur at the same altitude, assuming no operating or personal risk. We accepted that flights would occur in clear weather without rain and wind. The software cost was not calculated separately as discussed, and we assumed no critical accidents would occur.

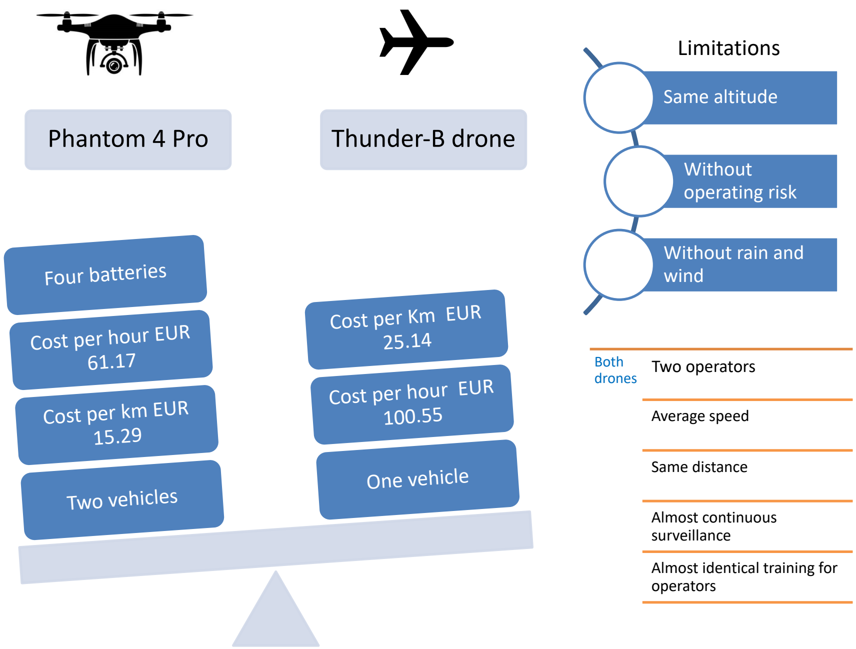


Figure 12. Comparison between Phantom 4 Pro and Thunder-B drones.

As noticed, the cost of the two drones is quite different. The cost of the Phantom 4 Pro is lower than that of the Thunder-B, while surveillance is continuous for both vehicles. We are thus able to select the first drone because it has a lower cost (Figure 12). The cost is reasonable compared to traditional methods of monitoring; for instance, with patrol cars. Furthermore, when observation is continuous, violation of the law can be minimized, and law enforcement officers using drones are more efficient. On the other hand, law enforcement officers can save time and operate in a safer working environment, and perpetrator identification is faster. Finally, in the case of a drone accident, the damage is limited to equipment and not to human lives.

5.3. Discussion

In this work, we compared and levelized costs for two drones, the Phantom 4 Pro and Thunder-B, used for surveillance. The calculated cost for these drones concerns their use and not the total ownership. Valerdi [51] proposed that cost depends on weight and endurance calculated on pound/hour per thousand dollars. On the other hand, Malone et al. [52] described an estimation of total ownership cost for UAV systems. In this work, we calculated the unit cost of drones to be able to compare them.

We analyzed the operating cost for each drone's different time durations and distances. We observed that if the surveillance hours increased, the operating cost for these drones decreased due to economies of scale. The cost per kilometer constantly decreased if the km covered increased. On the other hand, we saw that the operating cost of the Phantom 4 Pro drone was lower than that of the Thunder-B drone. As shown in Figure 7, the cost of one or two hours of surveillance for a Phantom 4 Pro drone is lower than that for a Thunder-B drone. For Phantom 4 Pro, we conducted our analysis used batteries that last for half an hour and then should be replaced once the drone has landed.

Furthermore, there are additional restrictions on adverse weather conditions. The Phantom 4 Pro cannot fly in rain, snow, or wind. In contrast, Thunder-B drones can operate in rainy and windy conditions. Combining the covered distance with a fuel tank leads us to conclude that this drone covers more are than the smaller Phantom 4 Pro drone. As revealed from the cost analysis, the Thunder-B drone is cost-effective for large uninterrupted missions for up to 16 h of surveillance.

As revealed from the case study, for 2 h of constant surveillance in an area of 4 km distance with the examined drones, the cost with Phantom 4 Pro was EUR 61.17/h or EUR 15.29/km, while with the Thunder-B drone, the equivalent costs were EUR 100.55/h and EUR 25.14/km, respectively. The analysis we performed for this case study also has some limitations. We considered the same altitude, average speed, no operating risks or accidents, and ideal environmental conditions. The average speed of these drones differs based on the reference range. The cost is lower for the Phantom 4 Pro than for the Thunder-B, so we selected the first one based only on cost figures (Figure 12).

Employing drones for surveillance can add an extra cost for law enforcement agencies. Still, this case study shows that the cost is reasonable and can be more efficient than conventional methods. We assumed continuous surveillance without operational accidents or risks. On the other hand, law enforcement officers can save time via faster and more efficient drone monitoring in place of conventional patrolling. Real-time data collection is a significant aid for law enforcement officers in many sections, such as perpetrator identification, recognition of missing people, environmental monitoring in real time, aviation environmental violations, prevention of air pollution, or water rescues and disaster response. Drones are increasingly applied in various fields for law enforcement officers. So, their working efficiency is high in terms of safety and surveillance. The working environment is also safer because drone use decreases potential personnel risks. For example, if a drone crashes, the cost is lower than that of a human-crewed helicopter, where the pilot's life is the highest protected good in all societies. UAV technology helps to fight crime in a cost-effective manner. Law enforcement policymakers should include aerial surveillance in crime prevention programs. Indeed, there are also issues about the use of drones [185], especially concerns about the violation of human rights, which will not be analyzed here but only mentioned as there is an ongoing debate.

Data availability is a limitation of this work. We also recognize some further limitations on assumptions made on operating cost, altitude, average speed, environmental conditions, personal risk, and environmental impact, as the operating costs depend on these factors. Significantly, the cost will increase if the altitude of the drone flight is higher than calculated because the drone will need more energy. In the same way, if the speed is increased or the wind is strong, the drone requires more power for the same flight. Also, accidents will increase costs because if drones crash or land accidentally, further repair work and spare parts are necessary. Additionally, the cost will be increased if the environment is challenging (e.g., complex landscapes, rivers, or topography).

Moreover, the Phantom 4 Pro battery lifetime is considered to be 400 cycles. The basic software cost was not calculated separately because the software for Phantom 4 Pro is free (open) and the software for the Thunder-B drone is included in the purchase cost. Thus, any software or future development cost cannot be separated from the purchase or maintenance costs we have considered. Furthermore, there are no available real data for costs related to cyber security, navigation, software, and the impact of accidents; we excluded it to ensure our calculations were clear and feasible. Additionally, a law enforcement officer's wage was considered the same for the two drones regardless of the level of operating risk or the characteristics of each drone, which is the case in the region of our case study. Note that by this, we do not mean to oversimplify our approach, but to provide a practical and integrated way to obtain reasonable cost estimations and comparisons. Nevertheless, any assumptions are based on the available data and experience since no previous studies have analyzed the cost of using drones. Most researchers analyze the unit cost from the perspective of construction and ownership purchase rather than from their use. Cost values based on the data provided by the companies should be further validated with statistical and empirical findings following the extended use of the studied models. Also, the fast improvement of UAV technology itself may render the concluded costs outdated soon. Nevertheless, valid economic conclusions can be drawn by applying the same principles in this work.

6. 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 and revise the requirements for permissions and restrictions, which is necessary along with technology development and maturation.

Moreover, the use of drones by law enforcement has been increasing in recent years. Some law enforcement applications need to be constantly observed, while others are partial. Economic analysis is essential for all purposes, as well as for security forces to be able to budget surveillance duties in advance. We describe a methodology that can be used for calculating levelized costs per flight time or distance covered and produce equations for further calculations. These equations show economies of scale in flight time and vehicle size. Economic data are necessary to integrate UAV technology into operational activities for entrepreneurial and security protection. Our case study shows that drones can be cost-effective for law enforcement monitoring. As an example, we showed how to estimate the monitoring cost. Last but not least, policymakers could include UAV technology in crime prevention programs.

7. Novelty and recommendations for future work

7.1. Novelty

This thesis focused on the application drone's legislation on environment. A precise research on the drone's legislation among the OECD member states revealed the different approaches of countries on this area.

This study is the first economic analysis of drone use employing real data on a life-cycle cost basis. Drones can be used in environmental monitoring. In the Case study of Kosinthos river we compared the operational cost of two selected drones (Phantom 4 pro and Thunder-B). The results of this research showed that the operational costs among selected types of drones are differentiated. The policymakers should estimate the operational cost of environmental surveillance when planning environmental protection programs. The results of this thesis are a valuable tool on calculating the cost of environmental protection.

7.2. Recommendations for future work

This PhD thesis provides analysis of the legal and economic data of drones. This work is a starting point for further research on regulation and legislation for drone use, emphasizing the dynamic nature of this technology and a legal framework that will be flexible enough to follow technology improvements. Furthermore, suggestions for future works include keeping detailed records of all fixed and variable costs to produce more informative equations for more vehicles. Also, flight records under different weather conditions can add more precision to the estimations. Another suggestion, in terms of cost efficiency is training users and creating a repository of cost data from various vehicles. Finally, further research should involve the comparison of these findings with other conventional means of surveillance.

8. References

1. Official Journal of the European Union Consolidated Version of the Treaty on the Functioning on the European Union. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:12012E/TXT:en:PDF.

2. Treaty on European Union *Treaty on European Union*; 1993;

3. Treaty of Amsterdam *Treaty of Amsterdam Amending the Treaty on European Union, the Treaties Establishing the European Communities and Certain Related Acts*; 1999;

4. Treaty Of Lisbon *Treaty Of Lisbon Amending the Treaty on European Union and the Treaty Establishing the European Community.*; 2009;

5. *Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 Establishing the Framework for Achieving Climate Neutrality and Amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')*; 2021;

6. European Commission Επισκόπηση Της Νομοθεσίας Της ΕΕ Για Τις Περιβαλλοντικές Εκτιμήσεις Το Γενικό Πλαίσιο Του Κεκτημένου Της ΕΕ 2016.

7. Mpoutakidis, D.; Soutsas, K. Greek and European Legal Framework Environmental and Ecological Laws: An Interactive Application. *Procedia Technology* **2013**, *8*, 27–36.

8. *Για Την Προστασία Του Περιβάλλοντος*; 1986; Vol. 1650, p. 16;.

9. Rao, B.; Gopi, A.G.; Maione, R. The Societal Impact of Commercial Drones. *Technology in society* **2016**, *45*, 83–90.

10. Clarke, R. Understanding the Drone Epidemic. *Computer Law & Security Review* **2014**, *30*, 230–246, doi:https://doi.org/10.1016/j.clsr.2014.03.002.

11. Stelmack, K. Weaponized Police Drones and Their Effect on Police Use of Force. *Pitt. J. Tech. L. & Pol'y* **2014**, *15*, 276.

12. Thompson, R.M. Drones in Domestic Surveillance Operations: Fourth Amendment Implications and Legislative Responses.; Congressional Research Service, Library of Congress, 2012.

13. Han, Y.-G.; Cho, Y.; Kwon, O.; others The Use of Conservation Drones in Ecology and Wildlife Research. *Journal of Ecology and Environment* **2015**, *38*, 113–118.

14. Koh, L.P.; Wich, S.A. Dawn of Drone Ecology: Low-Cost Autonomous Aerial Vehicles for Conservation. *Tropical conservation science* **2012**, *5*, 121–132.

15. Saranya, C.; Pavithira, L.; Premsai, N.; Lavanya, H.; Govindarajan, R. Recent Trends of Drones in the Field of Defense. *International Journal of Electrical and Appliances* **2015**, *1*, 47–55.

16. Balasingam, M. Drones in Medicine—the Rise of the Machines. *International journal of clinical practice* **2017**, *71*, e12989.

17. Klemas, V.V. Coastal and Environmental Remote Sensing from Unmanned Aerial Vehicles: An Overview. *Journal of coastal research* **2015**, *31*, 1260–1267.

18. Merz, M.; Pedro, D.; Skliros, V.; Bergenhem, C.; Himanka, M.; Houge, T.; Matos-Carvalho, J.P.; Lundkvist, H.; Cürüklü, B.; Hamrén, R.; et al. Autonomous UAS-Based Agriculture Applications: General Overview and Relevant European Case Studies. *Drones* **2022**, *6*, doi:10.3390/drones6050128.

19. Mohsan, S.A.H.; Khan, M.A.; Noor, F.; Ullah, I.; Alsharif, M.H. Towards the Unmanned Aerial Vehicles (UAVs): A Comprehensive Review. *Drones* **2022**, *6*, doi:10.3390/drones6060147.

20. Luppicini, R.; So, A. A Technoethical Review of Commercial Drone Use in the Context of Governance, Ethics, and Privacy. *Technology in Society* **2016**, *46*, 109–119.

21. Finn, R.L.; Wright, D. Unmanned Aircraft Systems: Surveillance, Ethics and Privacy in Civil Applications. *Computer Law & Security Review* **2012**, *28*, 184–194.

22. Chamoso, P.; González-Briones, A.; Rivas, A.; Bueno De Mata, F.; Corchado, J.M. The Use of Drones in Spain: Towards a Platform for Controlling UAVs in Urban Environments. *Sensors* **2018**, *18*, 1416.

23. Rothe, D.L.; Collins, V.E. The Normality of Political Administration and State Violence: Casuistry, Law, and Drones. *Critical Criminology* **2014**, *22*, 373–388.

24. Haidari, L.A.; Brown, S.T.; Ferguson, M.; Bancroft, E.; Spiker, M.; Wilcox, A.; Ambikapathi, R.; Sampath, V.; Connor, D.L.; Lee, B.Y. The Economic and Operational Value of Using Drones to Transport Vaccines. *Vaccine* **2016**, *34*, 4062–4067.

25. Cunliffe, A.M.; Anderson, K.; DeBell, L.; Duffy, J.P. A UK Civil Aviation Authority (CAA)-Approved Operations Manual for Safe Deployment of Lightweight Drones in Research. *International Journal of Remote Sensing* **2017**, *38*, 2737–2744.

26. Marin, L.; Krajčíková, K. Deploying Drones in Policing Southern European Borders: Constraints and Challenges for Data Protection and Human Rights. In *Drones and unmanned aerial systems*; Springer, 2016; pp. 101–127.

27. Bossoukpe, M.; Faye, E.; Ndiaye, O.; Diatta, S.; Diatta, O.; Diouf, A.A.; Dendoncker, M.; Assouma, M.H.; Taugourdeau, S. Low-Cost Drones Help Measure Tree Characteristics in the Sahelian Savanna. *Journal of Arid Environments* **2021**, *187*, 104449, doi:https://doi.org/10.1016/j.jaridenv.2021.104449.

28. Manfreda, S.; McCabe, M.F.; Miller, P.E.; Lucas, R.; Pajuelo Madrigal, V.; Mallinis, G.; Ben Dor, E.; Helman, D.; Estes, L.; Ciraolo, G. On the Use of Unmanned Aerial Systems for Environmental Monitoring. *Remote sensing* **2018**, *10*, 641.

29. Lloret, J.; Garcia, M.; Bri, D.; Sendra, S. A Wireless Sensor Network Deployment for Rural and Forest Fire Detection and Verification. *Sensors* **2009**, *9*, 8722–8747, doi:10.3390/s91108722.

30. Lawlor, K.; Olander, L.; Boyd, W.; Niles, J.; Madeira, E. Addressing the Causes of Tropical Deforestation: Lessons Learned and the Implications for International Forest Carbon Policy. International Forest Carbon and the Climate Change Challenge Series–Brief Number 5. June. *Nicholas*

Institute for Environmental Policy Solutions, Duke University **2009**.

31. Balcerzak, A.T.; Jasiuk, B.E.; Fellner, C.A.; Feltynowski, D.M. The Polish Perspective of Using Unmanned Aerial Vehicle Systems in International Firefighting and Crisis Management Missions - Legal and Technological Analysis. In Proceedings of the 2021 International Conference on Unmanned Aircraft Systems (ICUAS); 2021; pp. 1478–1487.

32. Herwitz, S.R.; Johnson, L.F.; Dunagan, S.E.; Higgins, R.G.; Sullivan, D.V.; Zheng, J.; Lobitz, B.M.; Leung, J.G.; Gallmeyer, B.A.; Aoyagi, M.; et al. Imaging from an Unmanned Aerial Vehicle: Agricultural Surveillance and Decision Support. *Computers and Electronics in Agriculture* **2004**, *44*, 49–61, doi:https://doi.org/10.1016/j.compag.2004.02.006.

33. Han, L.; Yang, G.; Yang, H.; Xu, B.; Li, Z.; Yang, X. Clustering Field-Based Maize Phenotyping of Plant-Height Growth and Canopy Spectral Dynamics Using a UAV Remote-Sensing Approach. *Frontiers in Plant Science* **2018**, *9*, 1638, doi:10.3389/fpls.2018.01638.

34. Shafian, S.; Rajan, N.; Schnell, R.; Bagavathiannan, M.; Valasek, J.; Shi, Y.; Olsenholler, J. Unmanned Aerial Systems-Based Remote Sensing for Monitoring Sorghum Growth and Development. *PLoS ONE* **2018**, *13*, e0196605, doi:10.1371/journal.pone.0196605.

35. Ronchetti, G.; Mayer, A.; Facchi, A.; Ortuani, B.; Sona, G. Crop Row Detection through UAV Surveys to Optimize On-Farm Irrigation Management. *Remote Sensing* **2020**, *12*, doi:10.3390/rs12121967.

36. Mora, A.; Vemprala, S.; Carrio, A.; Saripalli, S. Flight Performance Assessment of Land Surveying Trajectories for Multiple UAV Platforms. In Proceedings of the 2015 Workshop on Research, Education and Development of Unmanned Aerial Systems (RED-UAS); IEEE: Cancun, Mexico, November 2015; pp. 1–7.

37. Albetis, J.; Jacquin, A.; Goulard, M.; Poilvé, H.; Rousseau, J.; Clenet, H.; Dedieu, G.; Duthoit, S. On the Potentiality of UAV Multispectral Imagery to Detect Flavescence Dorée and Grapevine Trunk Diseases. *Remote Sensing* **2019**, *11*, 23.

38. Riniatsih, I.; Ambariyanto, A.; Yudiati, E.; Redjeki, S.; Hartati, R. Monitoring the Seagrass Ecosystem Using the Unmanned Aerial Vehicle (UAV) in Coastal Water of Jepara. In Proceedings of the IOP Conference Series: Earth and Environmental Science; 2021; Vol. 674.

39. Półka, M.; Ptak, S.; Kuziora, Ł. The Use of UAV's for Search and Rescue Operations. *Procedia Engineering* **2017**, *192*, 748–752, doi:https://doi.org/10.1016/j.proeng.2017.06.129.

40. Griffin, G.F. The Use of Unmanned Aerial Vehicles for Disaster Management. *Geomatica* **2014**, *68*, 265–281, doi:10.5623/cig2014-402.

41. Zulkipli, M.A.; Tahar, K.N. Multirotor UAV-Based Photogrammetric Mapping for Road Design. *International Journal of Optics* **2018**, *2018*, 1–7, doi:10.1155/2018/1871058.

42. Koeva, M.; Muneza, M.; Gevaert, C.; Gerke, M.; Nex, F. Using UAVs for Map Creation and Updating. A Case Study in Rwanda. *Survey Review* **2018**, *50*, 312–325, doi:10.1080/00396265.2016.1268756.

43. Giordan, D.; Adams, M.S.; Aicardi, I.; Alicandro, M.; Allasia, P.; Baldo, M.; De Berardinis, P.; Dominici, D.; Godone, D.; Hobbs, P.; et al. The Use of Unmanned Aerial Vehicles

(UAVs) for Engineering Geology Applications. *Bulletin of Engineering Geology and the Environment* **2020**, *79*, 3437–3481, doi:10.1007/s10064-020-01766-2.

44. Smith, S.L. Drones over the “Black Desert”: The Advantages of Rotary-Wing UAVs for Complementing Archaeological Fieldwork in the Hard-to-Access Landscapes of Preservation of North-Eastern Jordan. *Geosciences* **2020**, *10*, doi:10.3390/geosciences10110426.

45. Leuenberger, D.; Haefele, A.; Omanovic, N.; Fengler, M.; Martucci, G.; Calpini, B.; Fuhrer, O.; Rossa, A. Improving High-Impact Numerical Weather Prediction with Lidar and Drone Observations. *Bulletin of the American Meteorological Society* **2020**, *101*, E1036–E1051, doi:10.1175/BAMS-D-19-0119.1.

46. Stanton, M.C.; Kalonde, P.; Zembere, K.; Hoek Spaans, R.; Jones, C.M. The Application of Drones for Mosquito Larval Habitat Identification in Rural Environments: A Practical Approach for Malaria Control? *Malar J* **2021**, *20*, 244–244, doi:10.1186/s12936-021-03759-2.

47. Kunovjanek, M.; Wankmüller, C. Containing the COVID-19 Pandemic with Drones - Feasibility of a Drone Enabled Back-up Transport System. *Transport Policy* **2021**, *106*, 141–152, doi:10.1016/j.tranpol.2021.03.015.

48. Tanaka, K.; Tochihara, N.; Sato, T.; Koike, H. A Real-Time Image Processing Framework with an Aerial Overhead Camera for Sports. In Proceedings of the Proceedings of the 2018 International Conference on Advanced Visual Interfaces; 2018; pp. 1–5.

49. Karaca, Y.; Cicek, M.; Tatli, O.; Sahin, A.; Pasli, S.; Beser, M.F.; Turedi, S. The Potential Use of Unmanned Aircraft Systems (Drones) in Mountain Search and Rescue Operations. *The American journal of emergency medicine* **2018**, *36*, 583–588.

50. Khan, M.A.; Ectors, W.; Bellemans, T.; Janssens, D.; Wets, G. UAV-Based Traffic Analysis: A Universal Guiding Framework Based on Literature Survey. *Transportation research procedia* **2017**, *22*, 541–550.

51. Sutheerakul, C.; Kronprasert, N.; Kaewmoracharoen, M.; Pichayapan, P. Application of Unmanned Aerial Vehicles to Pedestrian Traffic Monitoring and Management for Shopping Streets. *Transportation research procedia* **2017**, *25*, 1717–1734.

52. Hardy, A.; Makame, M.; Cross, D.; Majambere, S.; Msellem, M. Using Low-Cost Drones to Map Malaria Vector Habitats. *Parasites & vectors* **2017**, *10*, 1–13.

53. Amenyo, J.-T.; Phelps, D.; Oladipo, O.; Sewovoe-Ekuoe, F.; Jadoonanan, S.; Jadoonanan, S.; Tabassum, T.; Gnabode, S.; Sherpa, T.D.; Falzone, M.; et al. MedizDroids Project: Ultra-Low Cost, Low-Altitude, Affordable and Sustainable UAV Multicopter Drones for Mosquito Vector Control in Malaria Disease Management. In Proceedings of the IEEE Global Humanitarian Technology Conference (GHTC 2014); IEEE, 2014; pp. 590–596.

54. Hanna, D.; Ferworn, A.; Lukaczyn, M.; Abhari, A.; Lum, J. Using Unmanned Aerial Vehicles (UAVs) in Locating Wandering Patients with Dementia.; IEEE, 2018; pp. 809–815.

55. Li, Y.; Liu, C. Applications of Multirotor Drone Technologies in Construction Management. *International Journal of Construction Management* **2019**, *19*, 401–412.

56. Veroustraete, F. The Rise of the Drones in Agriculture. *EC agriculture* **2015**, *2*, 325–

327.

57. Marinello, F.; Pezzuolo, A.; Chiumenti, A.; Sartori, L. Technical Analysis of Unmanned Aerial Vehicles (Drones) for Agricultural Applications. *Engineering for rural development* **2016**, *15*, 870–875.

58. Mahajan, U.; Bundel, B.R. Drones for Normalized Difference Vegetation Index (NDVI), to Estimate Crop Health for Precision Agriculture: A Cheaper Alternative for Spatial Satellite Sensors.; 2016; Vol. 22, p. 31.

59. Roma, A. Drones and Popularisation of Space. *Space Policy* **2017**, *41*, 65–67.

60. Shishkov, B.; Hristozov, S.; Janssen, M.; Van den Hoven, J. Drones in Land Border Missions: Benefits and Accountability Concerns. In Proceedings of the Proceedings of the 6th International Conference on Telecommunications and Remote Sensing; 2017; pp. 77–86.

61. Brumfield, E. Armed Drones for Law Enforcement: Why It Might Be Time to Re-Examine the Current Use of Force Standard. *McGeorge L. Rev.* **2014**, *46*, 543.

62. Tikanmäki, I. Possibilities to Operational Use of Remotely Piloted Aircrafts in Finland. *Information Systems Thesis* **2011**, *34*, 49–51.

63. Villasenor, J. “Drones” and the Future of Domestic Aviation [Point of View]. *Proceedings of the IEEE* **2014**, *102*, 235–238.

64. Cracknell, A.P. UAVs: Regulations and Law Enforcement. *International Journal of Remote Sensing* **2017**, *38*, 3054–3067.

65. Sky Taxi to Fly in Dubai from July Available online: https://www.bbc.com/news/av/technology-39003397/sky-taxi-to-fly-in-dubai-from-july (accessed on 24 March 2018).

66. Goodchild, A.; Toy, J. Delivery by Drone: An Evaluation of Unmanned Aerial Vehicle Technology in Reducing CO2 Emissions in the Delivery Service Industry. *Transportation Research Part D: Transport and Environment* **2018**, *61*, 58–67.

67. The Economics of Drone Delivery. Available online: https://spectrum.ieee.org/automaton/robotics/drones/the-economics-of-drone-delivery.

68. Florescu, E.; Glenn, J.C. Environmental Security Rising on the International Agenda. *Development, Environment and Foresight* **2015**, *1*, 6–23.

69. Cheteni, P. An Analysis of Anti-Poaching Techniques in Africa: A Case of Rhino Poaching. *Environmental economics* **2014**, 63–70.

70. Massarelli, C.; Muolo, M.R.; Uricchio, V.F.; Dongiovanni, N.; Palumbo, R. Improving Environmental Monitoring against the Risk from Uncontrolled Abandonment of Waste Containing Asbestos. The DroMEP Project.

71. Paneque-Gálvez, J.; McCall, M.K.; Napoletano, B.M.; Wich, S.A.; Koh, L.P. Small Drones for Community-Based Forest Monitoring: An Assessment of Their Feasibility and Potential in

Tropical Areas. *Forests* **2014**, *5*, 1481–1507.

72. Wallace, P.; Martin, R.; White, I. Keeping Pace with Technology: Drones, Disturbance and Policy Deficiency. *Journal of Environmental Planning and Management* **2018**, *61*, 1271–1288.

73. Capolupo, A.; Pindozzi, S.; Okello, C.; Fiorentino, N.; Boccia, L. Photogrammetry for Environmental Monitoring: The Use of Drones and Hydrological Models for Detection of Soil Contaminated by Copper. *Science of the Total Environment* **2015**, *514*, 298–306.

74. Boakye, J. Enforcement of Logging Regulations in Ghana: Perspectives of Frontline Regulatory Officers. *Forest Policy and Economics* **2020**, *115*, 102138, doi:https://doi.org/10.1016/j.forpol.2020.102138.

75. Zhou, F.; Pan, S.; Chen, W.; Ni, X.; An, B. Monitoring of Compliance with Fuel Sulfur Content Regulations through Unmanned Aerial Vehicle (UAV) Measurements of Ship Emissions. *Atmospheric Measurement Techniques* **2019**, *12*, 6113–6124, doi:10.5194/amt-12-6113-2019.

76. Golcarenarenji, G.; Martinez-Alpiste, I.; Wang, Q.; Alcaraz-Calero, J.M. Efficient Real-Time Human Detection Using Unmanned Aerial Vehicles Optical Imagery. *International Journal of Remote Sensing* **2021**, *42*, 2440–2462, doi:10.1080/01431161.2020.1862435.

77. Rosenfeld, A. Are Drivers Ready for Traffic Enforcement Drones? *Accident Analysis & Prevention* **2019**, *122*, 199–206, doi:https://doi.org/10.1016/j.aap.2018.10.006.

78. DANIELS, J. (DOUG) DRONES FOR POLICE, FIRE & OTHER EMERGENCY RESPONDERS Senior Law Enforcement Training Officer Remote Pilot-In -Command Ohio Peace Officer Training Academy Direct Line: (740) 845-6304 Available online: https://ceas.uc.edu/content/dam/aero/docs/fire/DRONES%20FOR%20POLICE%2C%20FIRE%20%26%20OTHER%20EMERGENCY.pdf (accessed on 30 May 2021).

79. Scentroid Future of Sensory Technology Police Using Scentroid's Drone Environmental Monitoring to Combat Smog Available online: https://scentroid.com/police-using-scentroid-dr1000-flying-lab-to-combat-smog/ (accessed on 23 March 2021).

80. Pyzynski, M. Cybersecurity of the Unmanned Aircraft System (UAS). In Proceedings of the 2020 International Conference on Unmanned Aircraft Systems (ICUAS); 2020; pp. 1265–1269.

81. Bassi, E. From Here to 2023: Civil Drones Operations and the Setting of New Legal Rules for the European Single Sky. *Journal of Intelligent & Robotic Systems* **2020**, *100*, 493–503, doi:10.1007/s10846-020-01185-1.

82. Konert, A.; Dunin, T. A Harmonized European Drone Market ? B□□ New EU Rules on Unmanned Aircraft Systems. *Advances in Science, Technology and Engineering Systems Journal* **2020**, *5*, 93–99, doi:10.25046/aj050312.

83. Tsiamis, N.; Efthymiou, L.; Tsagarakis, K.P. A Comparative Analysis of the Legislation Evolution for Drone Use in OECD Countries. *Drones* **2019**, *3*, 75, doi:10.3390/drones3040075.

84. Sudbury, A.W.; Hutchinson, E.B. A Cost Analysis of Amazon Prime Air (Drone Delivery). *Journal for Economic Educators* **2016**, *16*, 1–12.

85. Wright, C.; Rupani, S.; Nichols, K.; Yasmin, C.; Matiko, M. What Should You Deliver by Unmanned Aerial Systems?

86. Ochieng, W.O.; Ye, T.; Scheel, C.; Lor, A.; Saindon, J.; Yee, S.L.; Meltzer, M.I.; Kapil, V.; Karem, K. Uncrewed Aircraft Systems versus Motorcycles to Deliver Laboratory Samples in West Africa: A Comparative Economic Study. *The Lancet Global Health* **2020**, *8*, e143–e151, doi:10.1016/S2214-109X(19)30464-4.

87. Dr. Meier, P.; Mr. Bergelund, J. *Field-Testing the First Cargo Drone Deliveries in the Amazon Rainforest*; 2017;

88. Sozzi, M.; Kayad, A.; Gobbo, S.; Cogato, A.; Sartori, L.; Marinello, F. Economic Comparison of Satellite, Plane and UAV-Acquired NDVI Images for Site-Specific Nitrogen Application: Observations from Italy. *Agronomy* **2021**, *11*, doi:10.3390/agronomy11112098.

89. Yowtak, K.; Imiola, J.; Andrews, M.; Cardillo, K.; Skerlos, S. Comparative Life Cycle Assessment of Unmanned Aerial Vehicles, Internal Combustion Engine Vehicles and Battery Electric Vehicles for Grocery Delivery. *Procedia CIRP* **2020**, *90*, 244–250, doi:10.1016/j.procir.2020.02.003.

90. Christensen, B.R. Use of UAV or Remotely Piloted Aircraft and Forward-Looking Infrared in Forest, Rural and Wildland Fire Management: Evaluation Using Simple Economic Analysis. N.Z. j. of For. Sci. 45, 16 (2015)., doi:https://doi.org/10.1186/s40490-015-0044-9.

91. Zailani, M.A.; Azma, R.Z.; Aniza, I.; Rahana, A.R.; Ismail, M.S.; Shahnaz, I.S.; Chan, K.S.; Jamaludin, M.; Mahdy, Z.A. Drone versus Ambulance for Blood Products Transportation: An Economic Evaluation Study. *BMC Health Services Research* **2021**, *21*, doi:10.1186/s12913-021-07321-3.

92. Borghetti, F.; Caballini, C.; Carboni, A.; Grossato, G.; Maja, R.; Barabino, B. The Use of Drones for Last-Mile Delivery: A Numerical Case Study in Milan, Italy. *Sustainability* **2022**, *14*, doi:10.3390/su14031766.

93. White, S.M.; Schaefer, M.; Barfield, P.; Cantrell, R.; Watson, G.J. Cost Benefit Analysis of Survey Methods for Assessing Intertidal Sediment Disturbance: A Bait Collection Case Study. *Journal of Environmental Management* **2022**, *306*, 114386, doi:https://doi.org/10.1016/j.jenvman.2021.114386.

94. Valerdi, R. Cost Metrics for Unmanned Aerial Vehicles. In *Infotech@ Aerospace*; 2005; p. 7102.

95. Malone, P.; Apgar, H.; Stukes, S.; Sterk, S. Unmanned Aerial Vehicles Unique Cost Estimating Requirements. In Proceedings of the 2013 IEEE aerospace conference; IEEE, 2013; pp. 1–8.

96. Banazadeh, A.; Jafari, M.H. A Heuristic Complexity-Based Method for Cost Estimation of Aerospace Systems. *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering* **2013**, *227*, 1685–1700, doi:10.1177/0954410012461987.

97. Clarke, R. The Regulation of Civilian Drones' Impacts on Behavioural Privacy. *Computer Law & Security Review* **2014**, *30*, 286–305.

98. OECD The Organization for Economic Co-Operation and Development (OECD)

Available online: http://www.oecd.org/about/ , accessed on 19 January 2018).

99. Australian Government Civil Aviation Safety Authority. Flying Drones/Remotely Piloted Aircraft in Australia. Available online: Available online: https://www.casa.gov.au/aircraft/landing-page/remotely-piloted-aircraft-system (accessed on 22 February 2018).

100. Australian Government. Federal Register of Legislation. Available online: vailable online: https://www.legislation.gov.au/D etails/F2017C00742 (accessed on 22 February 2017).

101. Control, A Welcome to Austro Control! Available online: Available online: https://www.austrocontrol.at/jart/prj3/austro_control/main.jart?rel=en (accessed on 22-03-2018).

102. Austro Control Operation of Unmanned Aerial Vehicles - Drones Available online: Available online: https://www.austrocontrol.at/jart/prj3/austro_control/main.jart?rel=de&content-id=1374135213843 (accessed on 20-02-2017).

103. Drones Drones in Belgium Available online: Availabe online: https://mobilit.belgium.be/nl/luchtvaart/drones (accessed on 20-05-2017).

104. Federal Public Service Mobility and Transport Belgian Civil Aviation Authority Aviation Safety Information Leaflet: Drone Flying. Available online: Available online: https://mobilit.belgium.be/sites/default/files/resources/files/asil_2017_01_drone_flying.pdf (accessed on 01-03-2018).

105. Government of Canada Flying Your Drone Safely and Legally Available online: Available online: http://www.tc.gc.ca/en/services/aviation/drone-safety/flying-drone-safely-legally.html (accessed on 01-02-2018).

106. Government of Canada Canadian Aviation Regulations, SOR/96-433, by Aeronautics Act. Available online: Available online: https://laws-lois.justice.gc.ca/eng/regulations/SOR-96-433/FullText.html#s-602.41 (accessed on 01-02-2018).

107. Department of Transport Interim Order No. 9 Respecting the Use of Model Aircraft. Available online: Available online: http://www.gazette.gc.ca/rp-pr/p1/2018/2018-06-16/html/notice-avis-eng.html#ne6 (accessed on 31-05-2018).

108. The Directorate General of Civil Aeronautics of Chile (DGAC). The Directorate General of Civil Aeronautics Available online: Available online: https://www.dgac.gob.cl/ (accessed on 12-02-2018).

109. DGAC Chile. How to Operate a Drone in Chile? Available online: Available online: https://www.dgac.gob.cl/como-operar-un-dron-en-chile/ (accessed on 12-02-2017).

110. The Civil Aviation Authority of Czech Republic. The Civil Aviation Authority of Czech Republic Available online: Available online: http://www.caa.cz/ (accessed on 23-01-2018).

111. Civil Aviation Authority of Czech Republic Available online: Available online: http://lis.rlp.cz/predpisy/predpisy/dokumenty/L/L-2/data/effective/doplX.pdf (accessed on 20-03-2018).

112. Danish Transport Construction and Housing Authority Available online: Available online: http://www.trafikstyrelsen.dk/da/droneregler (accessed on 05-04-2018).

113. Danish Transport Construction and Housing Authority Danish Transport Construction and Housing Authority Available online: Available online: http://www.trafikstyrelsen.dk/EN.aspx (accessed on 05-04-2018).

114. Republic of Estonia Civil Aviation Administration Aviation Act. Available online: Available online: https://www.ecaa.ee/en/how-operate-ua (accessed on 21-04-2018).

115. Republic of Estonia, C.A.A.C Civil Aviation Authority (CAA). Available online: Available online: https://www.ecaa.ee/en (accessed on 21-04-2018).

116. Finnish Transport Safety Agency Finnish Transport Safety Agency Available online: Available online: https://www.trafi.fi/en (accessed on 05-04-2018).

117. Finnish Transport Safety Agency. Use of Remotely Piloted Aircraft and Model Aircraft. Available online: Available online: https://www.trafi.fi/filebank/a/1483970125/4a6ac53bf4b1cb434d7f85a15f36dde0/23661-OPS_M1-32_RPAS_2016_eng.pdf (accessed on 05-04-2018).

118. Ministry of Ecological and Solidarity Transition Ministry of Ecological and Solidarity Transition Available online: Available online: https://www.gouvernement.fr/en/composition-of-the-government (accessed on 15-04-2018).

119. Article L6211-3 Available online: Available online: https://www.legifrance.gouv.fr/affichCodeArticle.do?cidTexte=LEGITEXT000023086525&idArticle=LEGIARTI000023075496&dateTexte=&categorieLien=cid (accessed on 15-04-2018).

120. Decree of 17 December 2015 on the Use of Airspace by Aircraft Operating on Board NO,. Available online: Available online: https://www.legifrance.gouv.fr/eli/arrete/2015/12/17/DEVA1528469A/jo (accessed on 15-04-2018).

121. Federal Ministry of Justice and Consumer Protection Air Traffic Regulation Available online: Available online: https://www.bmjv.de/DE/Startseite/Startseite_node.html (accessed on 03-02-2018).

122. Federal Minister of Justice and Consumer Protection Air Traffic Licensing Regulations (LuftVZO). Available online: Available online: http://www.gesetze-im-internet.de/luftvzo/BJNR003700964.html#BJNR003700964BJNG000102308 (accessed on 03-02-2018).

123. Civil Aviation Authority of Greece Regulation. Available online: Available online: http://epae.elao.gr/index.php/epaegeneralinfo/epaelaw (accessed on 10-03-2018).

124. Hellenic Civil Aviation Authority Regulation –General Framework for Flights of Unmanned Aircraft Systems - UAS. Available online: Available online: http://epae.elao.gr/images/stories/documents/FEK2010B9.pdf, https://dagr.hcaa.gr/docs/HCAA%20UAS%20Regulation.pdf (accessed on 10-03-2018).

125. National Transport Authority National Transport Authority Available online: Available online: http://www.nkh.gov.hu/en/web/english/ (accessed on 02-01-2018).

126. Ministry of Innovation and Technology Traffic Authority. Rationality, National Interest, Lawfulness. Available online: Available online: http://www.nkh.gov.hu/kereses?p_p_id=regenssearch_WAR_mediacenterportlet&p_p_lifecycle=0&p_p_mode=view&_regenssearch_WAR_mediacenterportlet_keywords=unmanned (accessed on accessed on 23-02-2016).

127. Icelandic Transport Authority. Safe, Productive & Efficient Transport Available online: Available online: https://www.icetra.is/ (accessed on 28-04-2018).

128. Icelandic Transport Authority Remotely-Controlled Aircraft (Drones). Available online: Available online: https://www.icetra.is/aviation/drones/ (accessed on 28-04-2018).

129. Irish Aviation Authority. Drones Available online: Available online: https://www.iaa.ie/general-aviation/drones (accessed on 11-03-2018).

130. Irish Aviation Authority Irish Aviation Authority Small Unmanned Aircraft (DRONES) and Rockets Order, 2015. Available online: Available online: https://www.iaa.ie/docs/default-source/publications/legislation/statutory-instruments-(orders)/small-unmanned-aircraft-(drones)-and-rockets-order-s-i-563-of-2015.pdf?sfvrsn=26f50bf3_6 (accessed on 10-03-2018).

131. Ministry of Transport Civil Aviation Authority Director of Regulations and Standards. The Civil Aviation Authority of Israel. Available online: Available online: http://en.caa.gov.il/index.php (accessed on 28-04-2018).

132. The Civil Aviation Authority. EN-ROUTE. Available online: Available online: http://en.caa.gov.il/index.php?option=com_content&view=article&iotype=w&id=408&Itemid=272&lang_ovrrde=ENG (accessed on 28-04-2018).

133. Enac Italian Civil Aviation Authority Enac, Italian Civil Aviation Authority Available online: Available online: https://www.enac.gov.it/en (accessed on 01-07-2018).

134. ENAC Italian Civil Aviation Authority Remotely Piloted Aerial Vehicles. Available online: Available online: https://www.enac.gov.it/sites/default/files/allegati/2018-Sep/Regulation_RPAS_Issue_2_Rev_4_eng.pdf (accessed on 02-07-2018).

135. The Ministry of Land, I., Transport and Tourism,. the Ministry of Land, Infrastructure, Transport and Tourism Available online: Available online: http://www.mlit.go.jp/en/index.html (accessed on 01-04-2018).

136. Civil Aeronautics Act.

137. Ministry of Land Infrastructure and Transport (Korea). Ministry of Land, Infrastructure and Transport Available online: Available online: http://www.molit.go.kr/english/intro.do (accessed on 19-04-2018).

138. The Ministry of Land Transport and Maritime Affairs. Aviation Safety And Security Act. Available online: Available online: http://www.moleg.go.kr/english/korLawEng?pstSeq=52720 (accessed on 19-04-2018).

139. The Ministry for Transport and Agriculture of the Republic of Latvia. The Ministry for Transport and Agriculture of the Republic of Latvia Available online: https://www.zm.gov.lv/en/zemkopibas-ministrija/statiskas-lapas/minister?nid=1118#jump (accessed

on 06-03-2018).

140. Cabinet of Ministers Regulations Procedures for the Conduct of Unmanned Aerial Vehicles and Other Types of Aircraft Which Do Not Qualify as Aircraft Available online: https://www.vestnesis.lv/op/2016/231.1 (accessed on 06-03-2018).

141. The Directorate of Civil Aviation (DAC). The Directorate of Civil Aviation (DAC) Available online: https://dac.public.lu/direction/index.html (accessed on 24-03-2018).

142. Direction de l'Aviation Civile. General Conditions for Unmanned Aircraft System (UAS) Operations within the Luxembourg Airspace. Available online: https://dac.public.lu/actualites/2016/11/UAS-2016/index.html (accessed on 24-03-2018).

143. Ministry of Communications and Transportation Ministry of Communications and Transportation Available online: Available online: https://www.gob.mx/sct (accessed on 23-02-2018).

144. Ministry of Communications and Transportation. It Will Regulate the Use of Unmanned Aircraft (Drones), SCT. Available online: Available online: http://www.sct.gob.mx/fileadmin/DireccionesGrales/DGAC-archivo/modulo3/co-av-23-10-r4.pdf (accessed on accessed on 23-02-2018).

145. Government of Netherlands. Rules for Recreational Use of Drones. Available online: Available online: https://www.government.nl/topics/drone/rules-pertaining-to-recreational-use-of-drones, (accessed on 28-04-2018).

146. Law Bank of Netherlands. Model Flying Arrangement. Available online: Available online: http://wetten.overheid.nl/BWBR0019147/2015-11-07#Artikel5,%20http://wetten.overheid.nl/BWBR0019147/2015-11-07 (accessed on 28-04-2018).

147. Civil Aviation Authority of New Zealand Civil Aviation Authority of New Zealand Available online: Available online: https://www.caa.govt.nz/ (accessed on 01-03-2018).

148. Civil Aviation Authority of New Zealand. Unmanned Aircraft. Available online: Available online: https://www.caa.govt.nz/unmanned-aircraft/ (accessed on 01-03-2018).

149. The Civil Aviation Authority of Norway's The Civil Aviation Authority of Norway's Main Objective Is to Contribute to Safe Civil Aviation in Norway Available online: Availabe online: https://luftfartstilsynet.no/en/ (accessed on 16-04-2018).

150. Civil Aviation Authority -Norway. About Drones/RPAS. Available online: Available online: https://luftfartstilsynet.no/en/drones/commercial-use-of-drones/about-dronesrpas/regulations-of-drones/ (accessed on 16-02-2018).

151. The Civil Aviation Office The Civil Aviation Office of Poland. Available online: Available online: http://www.ulc.gov.pl/pl (accessed on 15-02-2018).

152. Government Legislation Center. The Act of July 3, 2002 - Aviation Law,. Available online: Available online: http://dziennikustaw.gov.pl/DU/2002/1112/1 (accessed on 09-04-2018).

153. Government Legislation Center. Regulation of the Minister of Transport, Construction and Maritime Economy of June 3, 2013 Regarding Qualification Certificates Available online:

Available online: http://www.dziennikustaw.gov.pl/DU/2013/664/1 (accessed on 08-04-2018).

154. Polish Aviation Centenary. Safe Sky - Regulations on Flying Drones in Poland. Available online: Available online: http://www.ulc.gov.pl/en/270-english/current-information/3806-safe-sky-regulations-on-flying-drones-in-poland, http://dziennikustaw.gov.pl/DU/2013/440/ (accessed on 15-02-2018).

155. The Portuguese Civil Aviation Authority The Portuguese Civil Aviation Authority Available online: Available online: https://www.anac.pt/vPT/Generico/Paginas/Homepage00.aspx (accessed on 18-04-2018).

156. Portugese Civil Aviation Authority TEM MÃO NO TEU DRONE Available online: Available online: https://www.voanaboa.pt/regulamento (accessed on 18-04-2018).

157. The Ministry Of Transport And Construction Of The Slovak Republic The Ministry Of Transport And Construction Of The Slovak Republic Available online: Available online: https://www.mindop.sk/en (accessed on 03-04-2018).

158. Transport Authority. Register Aircraft Available online: Available online: http://letectvo.nsat.sk/letova-sposobilost/register-lietadiel-slovenskej-republiky/ (accessed on 03-04-2018).

159. Official Gazette of the Republic of Slovenia. Official Gazette of the Republic of Slovenia Available online: Availabe online: https://www.uradni-list.si/ (accessed on 02-04-2018).

160. Official Gazette of the Republic of Slovenia. Rulebook on Ultralight Aircraft Installations, Page 14084. Available online: Available online: https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina/89174#kljucna_pravila (accessed on 02-04-2018).

161. The Safety Aviation Agency of Spain The Safety Aviation Agency of Spain Available online: Available online: https://www.seguridadaerea.gob.es/lang_en/la_agencia/organizacion_y_funciones/default.aspx (accessed on 10-03-2018).

162. Government of Spain Resolución Directora Available online: Available online: https://www.seguridadaerea.gob.es/lang_en/cias_empresas/trabajos/rpas/marco/resolucion_directora/default.aspx, (accessed on 10-03-2018).

163. The Transport Agency of Sweden The Transport Agency of Sweden Available online: Available online: https://www.transportstyrelsen.se/en/road/ (accessed on 02-05-2018).

164. Transport Stylersen. New Rules for Drones on February 1, 2018. Available online: Available online: https://www.transportstyrelsen.se/sv/luftfart/Luftfartyg-och-luftvardighet/Obemannade-luftfartyg-UAS/nya-regler-for-dronare/ (accessed on 02-05-2018).

165. The Federal Department of the Environment, T., Energy and Communications (DETEC),. The Federal Department of the Environment, Transport, Energy and Communications (DETEC). Available online: Availabe online: https://www.admin.ch/gov/en/start/departments/department-of-environment-transport-energy-communications-detec.html (accessed on 11-02-2018).

166. The Federal Department of Environment, T., Energy and Communication,. DETEC

Regulation on Aircraft of Special Categories Available online: Available online: https://www.admin.ch/opc/de/classified-compilation/19940351/index.html#a5 (accessed on 11-02-2018).

167. Directorate General of Civil Aviation Procedures for Permit to Fly (PtoF). Available online: Available online: http://web.shgm.gov.tr/en/s/2222-procedures-for-certificate-of-special-flight-permit (accessed on 21-02-2018).

168. The Directorate General of Civil Aviation of Turkey. İNSANSIZ HAVA ARACI SİSTEMLERİNİN AYRILMIŞ HAVA SAHALARINDAKİ OPERASYONLARININ USUL VE ESASLARINA İLİŞKİN TALİMAT (SHT-İHA). Available online: Available online: http://web.shgm.gov.tr/doc5/sht-iha.pdf (accessed on 10-05-2018).

169. The Civil Aviation Authority of UK The Civil Aviation Authority of UK Available online: Available online: https://www.caa.co.uk/home/ (accessed on 01-03-2018).

170. Civil Aviation Authority of UK. Unmanned Aircraft and Drones. Available online: Available online: https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=415 (accessed on 01-03-2018).

171. Federal Aviation Administration (FAA). Regulations and Guidelines Available online: Available online: https://www.faa.gov/ (accessed on 15-02-2018).

172. United States Department of Transportation. Unmanned Aircraft Systems.

173. Mobility and Transport, European Commission Drones: Commission Adopts New Rules and Conditions for Safe, Secure and Green Drone Operations Available online: https://transport.ec.europa.eu/news-events/news/drones-commission-adopts-new-rules-and-conditions-safe-secure-and-green-drone-operations-2021-04-22_en?prefLang=el.

174. Official Journal of the European Union *Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on Common Rules in the Field of Civil Aviation and Establishing a European Union Aviation Safety Agency, and Amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and Repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (Text with EEA Relevance.)*; 2018; Vol. Regulation (EU) 2018/1139;

175. Official Journal of the European Union *Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the Rules and Procedures for the Operation of Unmanned Aircraft*; 2019; Vol. Regulation (EU) 2019/947;

176. Official Journal of the European Union *REGULATION (EU) 2019/945 of 12 March 2019, on Unmanned Aircraft Systems and on Third-Country Operators of Unmanned Aircraft Systems*; 2019; Vol. REGULATION (EU) 2019/945;

177. Official Journal of the European Union *Commission Implementing Regulation (EU) 2021/665 of 22 April 2021 Amending Implementing Regulation (EU) 2017/373 as Regards Requirements for Providers of Air Traffic Management/Air Navigation Services and Other Air Traffic Management Network Functions in the U-Space Airspace Designated in Controlled Airspace*; 2021; Vol. Regulation (EU) 2021/665;

178. Official Journal of the European Union *Commission Implementing Regulation (EU) 2021/666 of 22 April 2021 Amending Regulation (EU) No 923/2012 as Regards Requirements for Manned Aviation Operating in U-Space Airspace*; 2021; Vol. Regulation (EU) 2021/666;

179. Τα Ηλεκτρονικά "Γεράκια" Της ΕΛ.ΑΣ. Available online: https://www.zougla.gr/greece/article/i-enaeri-filakes-kata-tou-eglimatos (accessed on 5 February 2021).

180. ΕΛΙΣΜΕ ΓΕΕΘΑ 20181127 1.2 Δημήτριος Γκριτζάπης «Επιχειρησιακή Δράση ΣμηΕΑ Στην ΕΛ.ΑΣ.» Available online: https://www.slideshare.net/helissme/20181127-12 (accessed on 4 February 2021).

181. DJI Phantom 4 Pro Available online: https://www.dji.com/gr/phantom-4-pro/info#specs (accessed on 20 February 2021).

182. What's the Best Battery? Available online: https://batteryuniversity.com/article/whats-the-best-battery (accessed on 20 March 2021).

183. Ανάλυση Του Μισθολόγιου Των Αστυνομικών Available online: http://policenet.gr/article/ανάλυση-του-μισθολόγιου-των-αστυνομικών (accessed on 3 March 2021).

184. Υπολογισμός Κόστους Ηλεκτρικές Ενέργειας Για Κάθε Οικιακή Συσκευή Available online: https://www.helppost.gr/dei/ypologismos-reuma-katanalosi/ (accessed on 25 March 2021).

185. Tsiamis, N.; Efthymiou, L.; Tsagarakis, K.P. A Comparative Analysis of the Legislation Evolution for Drone Use in OECD Countries. *Drones* **2019**, *3*, 75, doi:10.3390/drones3040075.

9. Appendices