applied sciences

MDPI

Review

Unmanned Aircraft Systems: A Latin American Review and Analysis from the Colombian Context

Gabriel J. Sánchez-Zuluaga [1,*], Luisa Isaza-Giraldo [1], Germán Darío Zapata-Madrigal [1], Rodolfo García-Sierra [2] and John E. Candelo-Becerra [1]

1 Grupo de Investigación Teleinformática y Tele Automática, Facultad de Minas, Universidad Nacional de Colombia, Sede Medellín, Carrera 80 No. 65-223, Campus Robledo, Medellín 050041, Colombia
2 HUB de Innovación del Grupo Enel Colombia, Bogotá 111711, Colombia
* Correspondence: gjsanchezz@unal.edu.co

Abstract: The usage of unmanned aircraft systems to complete routine, commercial, and industrial tasks has increased throughout the world, evidencing better profitability and reducing risks for operators. However, in some countries, there is a low implementation of unmanned aircraft systems, particularly in the electrical sector, due to a lack of appropriation or adaptation of technology to the local environment. Therefore, this paper presents an analysis of the uses of unmanned aircraft systems in the electrical industry worldwide and its possible application to a local context to identify how the expansion of unmanned aerial vehicles is helping various industries. The contribution of this paper is to show how the employment of unmanned aerial vehicles can help in any particular task in the electrical sector and the appropriation of these technologies in a country, showing a possible categorization of unmanned aerial vehicles based on future applications and current regulations. The analysis was carried out in the Colombian context, considering the current regulation and the impact of its use. This research considers safety, security, and privacy implications, including the reduction of personal harm with low operation costs. In addition, the importance of future implementations in Colombia is discussed as a topic of interest for any electrical company, researchers, and government entities.

Keywords: unmanned aircraft vehicle; unmanned aircraft system; electrical sector; Latin American regulation

Citation: Sánchez-Zuluaga, G.J.; Isaza-Giraldo, L.; Zapata-Madrigal, G.D.; García-Sierra, R.; Candelo-Becerra, J.E. Unmanned Aircraft Systems: A Latin American Review and Analysis from the Colombian Context. *Appl. Sci.* **2023**, *13*, 1801. https://doi.org/10.3390/app13031801

Academic Editors: Shanling Dong and Meiqin Liu

Received: 2 November 2022
Revised: 23 January 2023
Accepted: 24 January 2023
Published: 31 January 2023

1. Introduction

Nowadays, unmanned aircraft systems (UASs) have become easy acquisition vehicles for people. They are commonly used for inspection, photography, video, and entertainment [1,2]. However, they have also become a topic of great interest in terms of security, safety, and privacy [3]. UASs are characterized by their versatility, good maneuverability, stability, and capacity to carry different types of payload. All of these attributes make this aircraft a viable alternative to fly through difficult terrain and reach critical assets in the electrical grid. For example, this is useful for monitoring electrical towers and substations. In Colombia, despite many current projects with UASs, there is a lack of information on applications in the productive sectors, particularly in the electrical sector. Furthermore, the regulations also restrict its use in many areas, affecting the proper classification of aircraft.

The lack of research and practical applications in the productive areas of the UAS in Latin America and Colombia causes technological lags due to its absence, generating a slowdown in economies. This industry has recently grown rapidly, increasing its global market by USD 27.2 billion in 2020 and is projected to reach USD 58.6 billion by 2026 [4]. From a more general perspective, Latin America is considered a growing market for the use of these vehicles due to its complex topology, vegetation, biodiversity, and diverse climatology [5]. Hence, different theoretical and analytical research and some new applications are already underway. Therefore, complex operations, such as swarm intelligence, are becoming more important for performing sophisticated tasks and automatic target recognition to identify and classify objectives [6,7]. For agility and safety reasons, it may be more useful for a UAV to perform some tasks than a person who collects medical information in large urban tropical cities and rural communities, where there are more health problems that affect the population [8]. The monitoring and management of natural resources are more productive with this technology [9,10], and search and rescue operations are more efficient [11,12].

Some UAS reviews have been carried out in Latin America related to different community uses. Experience has been documented, mainly for training, the formalization of land ownership, post-disaster humanitarian aid, environmental activism [13], and other community purposes. There are reviews on wireless sensor networks for applications in communication systems or data communication networks [14,15], and even more specific topics, such as photogrammetry and remote sensing [16]. However, according to the search performed in the literature, there are no reviews in Latin America related to direct applications to the electricity sector.

In the Colombian context, some relevant applications have been carried out in recent years. Examples include monitoring high voltage transmission lines to check the state of mechanical elements and power lines, the transportation of medical equipment that improves the first aid response in rural areas, the protection of natural resources through continuous monitoring, precision agriculture to improve productivity in that sector [17], and other projects, such as the Enel-Codensa dragon drone, which is capable of burning kites and other electrical waste [18]. However, in Colombia, there are no review articles on UAS applications and regulations that can describe new usage, contributions to the scientific community, or special applications in productive sectors. The lack of appropriation or adaptation of technology to international experiences in the local environment is also evident.

Therefore, the main contribution of this work is to show how UASs can help in particular tasks and the opportunity to improve them. In addition, based on the analysis of the uses in the electrical industry worldwide, we determine the possible application to the Colombian context and the appropriation of these technologies in the country. Furthermore, based on their applications and current regulations, a categorization of UASs is proposed according to the electrical and commercial sectors of the country.

The rest of the document is divided into six more sections. Section 2 shows prior knowledge about drones. Section 3 presents the applications of UAVs in Latin America and Colombia. Section 4 presents the current UAS regulations. In Section 5, the paper discusses the opportunities and alternatives for UAVs in the electricity sector, considering regulations from different states. The discussion is provided in Section 6, and finally, the conclusions are presented in Section 7.

2. Background

Since their creation, UASs have been used in many fields because of their construction, sustainability in flight, versatility, and other characteristics of their application, as an industry that continues to expand.

2.1. Unmanned Aircraft across the Years

The preliminary designs were based on models manufactured by inventors, such as the so-called father of aeronautics, George Cayley, in 1809 [19], Felix du Temple, and A. F. Mozhaiski in 1857 [20] with model tests, technical calculations, and design of the full-size apparatus. Those pioneers provided ideas and layouts that have become the basis for current designs. Cayley, for example, made an adaptation of the whirling arm demonstrated first by Benjamin Roberts in 1747, adding a horizontal hinge at the arm's junction with the vertical drive shaft so that the arm acted as a lever. He took notes on sustainability and the direct proportionality between resistance and fluid density [19]. Furthermore, designs such as the F. du Temple airplane and the A. F. Mozhaiski engine designed in 1881 like a steam generator torpedo boat, adapted and tested in 1882 in an airplane, were the first step toward the future of aviation and the UASs themselves [20].

The first UAV device was created in Great Britain in 1916, the Ruston Proctor Aerial Target, based on designs by Nikola Tesla's radio control. Like many inventions, its evolution was dictated by World War II, so UAV technology was driven by the military industry, which upgraded it to its modern form in 1982 with battlefield UAVs, led by the Israeli Air Force to recognize the enemy position [21]. As stated above, the military industry has driven drone technology more than any other.

Today, drones are used for much more than military purposes and are common in companies offering delivery, mobility, and special services [22]. In addition, drone racing has recently become popular in the robotics research community. As the demands of the race change according to the terrain and difficult obstacles, it is pushing the limits of robotics, increasing its ability to respond using new control techniques and algorithms [23].

2.2. Classification of UAV

As a result of the evolution of engineering in the last 60 years, UASs are more efficient, smaller, and powerful. They also have better batteries and protection against signal errors. The term UAS was adopted by the Federal Aviation Administration (FAA) to separate it from drones and was used in the military industry. These vehicles can be classified according to their application, as they are commonly used with embedded cameras, GPS, accelerometers, energy sensors, thermal sensors, distance sensors, altimeters, mobile hotspots (access points), RFIDs, and wireless connections. Table 1 shows the classification of UAS by application in five large categories [24].

Table 1. Categorization of UAS by application, based on [24].

Category	Use
Emergency	Search and rescue Natural disaster management Humanitarian help Ambulance aid
Monitoring and inspection	Real state infrastructure inspection Power lines inspection Insurance documentation
Earth sciences	Archaeology documentation Geography documentation Cartography documentation
Environmental	Soil moisture evaluation Gas level evaluation Agricultural crops monitoring
Defense and security	Traffic surveillance Drug monitoring Port security

3. Latin America and Colombia

Latin America represents a potential in the UAS market due to its special climatic and topographic characteristics [25]. In fact, several UAS applications are already working as we will analyze with the classification shown in Table 1.

3.1. Emergency

Due to the topology of South America, aid organizations mostly have trouble reaching remote populations. For this reason, some workshops have been carried out to perform humanitarian mapping in intricate places [26], helping rescue efforts at disaster sites. Furthermore, the community use of drones in many areas is emerging as a good economic alternative for many people who want to make a career in the use of drones and help other people [13].

3.2. Monitoring and Inspection

The global human population reached 8 billion in mid-November 2022 [27], and Latin America has one of the highest population growth rates after Africa and Asia. Its rise has also increased the energy power demand, requiring an increase in power system expansion and transmission line inspection [28]. Furthermore, vegetation detection has been implemented near high-voltage transmission lines using UAV and LiDAR technology [29].

Some applications in the civil engineering area must also be mentioned. This particular area has some of the most dangerous assessments for people. Digital image processing and UAV-captured images have been used to evaluate facades [30], assist in the inspection of complicated access constructions, and create a safety construction plan for high-rise buildings [31]. Although the literature shows some advances in research and projects, the use of UAS technology in the electrical sector remains low for Colombia and the Latin American region.

3.3. Earth Sciences

Some applications in this growing market are not regulated, such as in Mexico, where the use of drones in the community has become necessary due to its ability to accurately monitor and map the territory [32]. Real-time monitoring and characterization of Pululahua volcanic activity with software and hardware have been carried out, with ambient information and georeferentiation [33].

3.4. Environmental

Agricultural applications of UAS are the most common in South American countries. Using drones with remote sensors, the vegetation is being monitored to prevent pests [34]. These applications range from a more intricate examination of plants, such as analyzing their nitrogen levels [35], or estimating the height of the forage that will feed cattle [36]. Furthermore, the use of UAVs to classify and evaluate the development of the vegetable environment [37] and classify and monitor how different plantations evolve over time and different seasons [38,39] has helped the agronomical context. In another study, for example, UAVs have been used for the real-time monitoring of crops, allowing better understanding and quicker reaction to their needs [40]. The use of UAVs as monitoring tools could complement the work of park rangers in patrol tasks, especially in remote or difficult-to-access areas [41]. Another common application of UAVs is their use in precision agriculture (PA). This sector has been threatened by climate change, and the rapid increase in population is driving production to grow by 70% by 2050 [34], as in the AURORA project (Autonomous Unmanned Robotic Airship Remote Monitoring) in Brazil [42]. Furthermore, vegetation detection has been implemented near high-voltage transmission lines using UAV and LiDAR technology [29]. Additionally, the UAV-based monitoring of pollutant gases, which creates a vertical profile, has been proposed as an alternative to typical measurement stations due to its mobility [43].

In Colombia, some projects study PA to improve crops [44], mitigate the impacts of climate change in the country, and monitor environmental variables and lower layers of the atmosphere to prevent disasters with the help of a network, such as the air–ground integrated mobile edge network (AGMEN) [45].

3.5. Defemse and Security

In future smart cities [46], many applications of UASs can be implemented, but security operations will continue to be a priority in all South American regions due to the conflict present. It will help security forces in intelligence missions [17] through projects such as ART Quimbaya, bringing surveillance and reconnaissance critical infrastructure, border control, and photography [47]. Additionally, Brazil has deployed drones to monitor the Amazon rainforest and prevent environmental crimes [34].

Latin America represents a potential in the UAS market due to its special climatic and topographic characteristics [25]. Hence, applications of this technology are endless, e.g., precision agriculture by remotely sensing vegetation health [34], in future smart cities [46], to help security forces in intelligence missions [17] through projects such as ART Quimbaya, bringing surveillance and reconnaissance critical infrastructure, border control, and photography [47]. In recent years, population growth in the region has also increased the energy power demand, requiring an increase in power system expansion and transmission line inspection [28]. Some applications in this growing market are not regulated, such as in Mexico, where the use of drones in the community has become necessary due to its ability to accurately monitor and map the territory [32].

The real-time monitoring and characterization of Pululahua volcanic activity with software and hardware have been carried out, with ambient information and georeferentiation [33]. In Colombia, some projects study PA to improve crops [44] and mitigate the impacts of climate change in the country, and its use to monitor environmental variables and lower layers of the atmosphere to prevent disasters with the help of a network such as the air–ground integrated mobile edge network (AGMEN) [45]. Although the literature shows some advances in research and projects, the use of UAS technology in the electrical sector remains low for Colombia and the Latin American region.

4. Current Regulations for UAS

The regulations of the Federal Aviation Administration (FAA) in North America limit the altitude of the aircraft to approximately 122 m and the maximum speed to 161 km/h. In addition, they register the vehicle and the certified pilot. It should be noted that the FAA has issued a last-generation regulation that forces the entity in charge of air traffic to include UAVs in the North American aerial space through a transmission system included in ground radars [48], the same as the one that detects large aircrafts [49]. Similarly, the Communications and Transports Secretariat (SCT) of Mexico has a regulation under NOM-107-SCT3-2019 [50] that establishes the requirements for the operation of UAVs on Mexican soil. This document describes UAVs by use in three categories: Micro UAVs, Small UAVs, and Big UAVs. These have two subcategories: recreational and private noncommercial or commercial.

Every country has its own regulations as follows: General Directorate of Civil Aeronautics of Guatemala has a review called RAC101-UAV regulation [51]. The Nicaraguan Institute of Civil Aviation does not have a formal regulation, but is mentioned in Ley 595 of the rules of civil international aviation [52,53]. El Salvador published UAV regulations in 2018 by the Civil Aviation Authority, which describe the operating rules, limitations, and classification by use [54]. Furthermore, the Agencia Hodureña de Aeronáutica Civil (AHAC) of Honduras determines the rules RAC-02, annex 8, giving a classification of UASs as micro, mini, small, and large. They also classify UASs by commercial, private, and institutional [55], including registration documents for pilots. As in Honduras, Costa Rica has a similar classification with micro, small, light, and large categories and shares the same limitations [56]. Finally, to complete the Central American region, there is Belize, where there is no UAS regulation. Instead, it has a note on the Belize Department of Civil Aviation website [57] that accepts only applications for drone authorization from international drone operators.

In the same way, Panama, through its entity called the Civil Aviation Authority, rules the operation of UAS on its territory with the law AAC/DSA/DG/01-16 in 2016 [58]. The classification is similar to that described in the Central American region, with four classes, such as micro, small, light, and heavy. It can also be classified into two kinds of operations: civil and state. Venezuela also has an institution dedicated to UAS regulation called the National Institute of Civil Aviation, with almost the same classification: class 1 (mini), class 2 (light), class 3 (lightweight), and class 4 (heavy). Furthermore, a classification by operation has three possible uses: recreational, private, and commercial [59]. In Ecuador, the institution called the General Directorate of Civil Aviation, under the resolution DGAC-DGAC-2020-0074-R, regulates the operation of UAS in its range, but it is only categorized by commercial activities and only to avoid damage to third parties with insurance [60].

In Latin American countries such as Peru and Chile, the laws on unmanned aerial vehicles (UAVs) are not very clear on official government websites. However, both countries require users to register and certify both the pilot and ownership of the UAV in a national database. In Chile, certain official regulations are provided to the general public by the Director General of Civil Aviation [61,62]. In Peru, official information can be found on the website of the Ministry of Transport and Communications [63] and briefly mentions the registration, accreditation, and overflight permit that the owner or pilot must obtain before flying a UAV according to the law N° 30740 [64], but does not have a proper classification.

Both Uruguay [65] and Paraguay [66] have resolutions that regulate the use of remotely piloted aircraft (RPA), which are written in a similar manner. They both classify UAVs by weight and talk about which operations can be performed. On the other hand, Uruguay only needs explicit permission from the aeronautical authorities if the flight is for something other than sports or recreation. Bolivia and its Civil Aviation Authority classify airplanes according to their maximum take-off weight; planes from 0 to 199 g are considered small, and planes from 200 g to 35 kg are considered medium. Similarly, the small classification is used for recreational operations and the second for aerial work [67].

In particular, the countries that have more explicit legislation in the Latin American region are Argentina and Brazil, where the former has an explicit regulation that includes more than 70 articles and deals with application areas, weight classification, technical characteristics, specifications of the nature of operation, necessary authorizations, and regulation of different uses [68]. The second controls the flight rules; the registration with the government entity explains the authorizations required for projects that seek to work with UAVs and the certificates that must be obtained [69]. In summary, as seen in Table 2, there are regulations by use in 44.4% of the region and by size in the other 44.5%, some of them being shared in each resolution. Furthermore, Guyana and Suriname do not have any classification like the other members of Latin America, and their regulations are insufficient. Typically, UASs can be placed into groups based on their maximum take-off weight.

Table 2. Latin America overview of the current status of UAV regulations and classification.

Type of Classification for Regulation	Countries
Use	Mexico, El Salvador, Honduras, Venezuela, Ecuador, Perú, Paraguay, Uruguay
Takeoff mass	Costa Rica, Guatemala, Nicaragua, Panamá, Colombia, Chile, Bolivia
Fully regulated	Argentina, Brazil

On the other hand, the European Union Aviation Safety Agency (EASA) has a document called Easy Access Rules for Unmanned Aircraft Systems [70]. This document expresses the rules and procedures of UAS operations and determines three general categories of operation: open, specific, and certified. The first category, called open, has a maximum take-off mass of less than 24 kg. The remote pilot ensures that the UAV is kept at a safe distance from people, that it does not fly over groups of people, and that it has a visual line of sight (VLOS) at all times. It is limited to 120 m from the closest point on the Earth's surface, and the UAV cannot carry dangerous payloads.

The second category, called specific, refers to those cases where one of the requirements laid down in the open category is not met. Operations are carried out with an unmanned aircraft with a maximum characteristic dimension of up to 3 m and a typical kinetic energy of up to 34 kJ, less than 150 m above the surface. In the second category, aircrafts are limited to uncontrolled airspace operations. In the third category, some operations shall be grouped in the certified category only where the operation is carried out under any of the following conditions: over the assembly of people, when it involves the transport of people, or involves the carriage of dangerous goods that can cause high risk to third parties in the event of an accident [70]. As in Europe, the Asian continent has its regulations on UAS. On the website https://drone-laws.com (accessed on 20 July 2022), there is a complete database updated by volunteers with creative commons licenses, discriminated by countries and their legislation. Almost all have similar regulations on aircraft types, operations, and limitations [71].

The Colombian statute is controlled by the Unidad Administrativa Especial de Aeronáutica (UAEAC), which governs the use of UAVs under the RAC 91 regulations, specifically in Appendix 13 [72]. These standards indicate a classification into three different levels for UAS, and its limitations are shown in Table 3.

- Class A: The operation of the UAS is allowed under the limitations established by UAEAC RAC 91, Appendix 13, and it has a maximum take-off weight between 250 g and 25 kg; it does not require authorization due to its low risk.
- Class B: This kind of UAS exceeds the maximum take-off weight and is up to 150 kg; therefore, UAEAC always requires authorization, even though its operation may involve low risk.
- Class C: This last classification of UAS corresponds to aircraft that exceed 150 kg at maximum take-off weight and are used to overfly international airspace or transportation for which, for now, their operation in Colombian airspace is not authorized. The authorization for this type of UAS is only for scientific research and development and is highly restrictive from UAEAC [73].

Table 3. Operation limits by UAEAC authority, based on [73].

Class A	Class B	Class C
Maximum takeoff weight 25 kg	Maximum takeoff weight 150 kg	Class C are mainly experimental aircraft in the country, so, the operations are carried out by duly recognized or authorized public, or private entities for the exclusive purposes of scientific research, innovation, and development.
Maximum speed 80 km/h.	Maximum speed 100 km/h.	
Visual Line of Sight (VLOS) up to 500 m, horizontally during all flights.	Visual Line of Sight (VLOS) up to 750 m, horizontally during all flights.	
The operation cannot be directly over the public, crowds, buildings, cities, or other populated areas.	Every flight must be up to 123 m over earth or water.	
The entire operation must be daytime only. It is only allowed at night in open spaces and unpopulated areas, free of obstacles, and the UAS must have bright lights to see it.	Visibility conditions cannot be less than 5 km from its location.	
Every flight must be up to 123 m over earth or water.	Minimum distance from clouds is 150 m.	
Visibility conditions cannot be less than 5 km from its location.	Its operation cannot be carried out from an aerodrome, heliport or in its vicinity within a radius of 3 km.	
Minimum distance from clouds is 150 m.	Any operation that requires aerial works other than image capture requires authorization from the UAEAC.	
The operation may only be carried out within Class G airspace (not regulated).	Rescue and search operations, or similar missions that hinder those carried out by authorities or rescue organizations, cannot be carried out.	

Table 3. *Cont.*

Class A	Class B	Class C
Sprinkling activities may not be executed.	A person may only operate one UAS at a time, except for those cases in which the UAEAC authorizes swarm-type operations.	
Its operation cannot be carried out from an aerodrome, heliport or in its vicinity within a radius of 3 km.	Animals cannot be transported. However, the UAS can be used in agricultural tasks in which certain types of live insects are used for the control of pests authorized by the UAEAC.	
Object transport activities of any kind may not be accomplished.	Explosive, corrosive, biological risk materials, weapons, or any type of merchandise considered dangerous or prohibited may not be transported.	
Autonomous operations will not be possible.	Operations may not be carried out less than 3.6 km from border areas or cross-border limits with neighboring states.	
Explosive, corrosive, biological risk materials, weapons, or any type of merchandise considered dangerous or prohibited may not be transported.	In application of the general rules on the right of way and collision avoidance, a UAS must always give way to any other manned aircraft that is using the same airspace.	

5. Opportunities and Alternatives

5.1. Some General Applications

Nowadays, unmanned aircraft vehicles are present in many human activities, helping in difficult situations [74,75], bringing innovative ideas [76] and new possibilities in many other industry applications [77]. UASs have the ability to do things that were not possible before [78]. With their help, we can reach places where piloted aircraft cannot [79], and even futuristic applications become reality [80]. Two technologies are mixed in [81], using a facial recognition UAS with the aim of helping reduce violence and crime in Latin America. Researchers used a handmade UAV and a commercial embedded system board, based on a convolutional neural network to build a database implemented on the board. Furthermore, research has been carried out to achieve a forest inventory [82], and maximum power tracking for UAVs [83].

Electrical mobility has been a world revolution. UAVs are part of this e-mobility, and all the systems involved can be improved [84,85], giving them more autonomy by improving their beyond visual line of sight (BVLOS) [86], such as certain applications, which need accuracy to reach intricate places and precision tasks [87], and ecosystems in industry 4.0, where data traffic digitization is necessary and the use of drone networks is expanding [88]. In applications such as deliveries, large companies are testing UAS to complete these tasks, but the performance of drone deliveries must be optimized and human harm avoided [89].

With all the opportunities, applications, and research presented above, it is necessary to consider the vulnerability of UAS due to their omnipresent operations on the internet of things (IoT) and industrial internet of things (IIoT) systems [90]. Furthermore, security and privacy are other issues to consider [22] and, even more, public safety, precisely because they are vulnerable to cyberattacks and can be used as signal sniffers, signal jammers, or in any other harmful way [91]. Taking into account the versatility of uses, these aspects of UAS must be reinforced to improve them [92], making them safer.

5.2. Electrical Sector Applications

In the installations of electricity companies, it is becoming more common to employ different methods to perform regular jobs that were previously performed manually. The structural aspects of the power lines should be monitored to keep the power distribution running in countries. Therefore, the use of UASs helps such companies as the Korea Electric Power Corporation (KEPCO) perform diagnostics on their distribution and power lines through a drone project [93]. Similarly, other electric utility companies have begun to use UASs to inspect vegetation near power lines, insulators, and substations to prevent damage and failures [49].

Another application in the electrical industry is carried out: the use of deep learning to build a real-time power line detection network, based on convolutional neural networks from images of visible light and infrared images taken by several UAVs, to avoid other self-driving drones colliding with electrical power facilities [94]. Similarly, the British Columbia Transmission Corporation (BCTC) has considered including UAVs in routine and emergency line inspections to prevent injuries to their employees and reduce costs and greenhouse gas emissions. BCTC has around 18,000 km of high-voltage transmission lines through the mountains of British Columbia and uses helicopters with crew inspectors; this type of work is considered dangerous and expensive, and the advantages of using UAVs have been seen to replace them [95]. At the same time, visual inspection has become an advantage to apply in rural electrical installations [96].

Electrical discharges caused by the corona effect are identified with digital image processing applications. In a fog environment, insulators are prone to discharges; therefore, observation and analysis of the phenomenon can help improve the maintenance of the infrastructure [97]. In addition, image correction technology is shown using data analysis [98] to establish the corresponding relationship between an original image and a distorted image. This is applied to the inspection of electrical assets to obtain the best-quality images. Several studies have been developed to assess the integrity of the transformer core and windings, using frequency response analysis and visual analysis to assess the integrity of the transformer core and windings. Together, these techniques are capable of detecting various deformations of the windings [99].

For example, the Central American region is interconnected between six countries: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. They transmit more than 300 MW in power lines up to 230 kV [100]. Although this region could be a good place to use drones, their use is still in its early stages. Similarly, in Brazil, due to a combination of large-scale centralized expansion projects and small-scale distributed generation, the power system now comprises solar 1.31, wind 12.9, nuclear 2, biomass 14.7, fossil fuels 26.9, and hydro 102.2 gigawatts as of July 2018. With this growth and its critical infrastructure [101], this country has one of the largest aerial power line structures in the world with a length of up to 95,000 km, and companies such as Companhia Hidreléctrica do Sao Francisco (CHESF) are researching with UAS to monitor its lines [102] with long-range UAS that have inspection platforms and various prototypes [103].

Let us continue our analysis with Peru, where electrification increased by 97% and generation by 186% in 2015, after the company Statkraft took full control of operations in six regions of Peru in 2014. They started a program named the Performance Improvement Program (PIP) to reduce costs by 15% throughout 2016, 2017, and 2018. Part of this program was the drone inspection project, which was responsible for monitoring the company infrastructure [104]. Similar to Peru, Chile with the company Enel has a program to monitor distribution power lines [105]. In Panama, Empresa de Transmisión Eléctrica S.A. (ETESA) acquired drones to assist in inspection and design tasks [106]. Other Latin American countries are beginning to incorporate UAVs into their operations, as seen at the International Air and Space Fair (FIDAE) in Santiago de Chile in 2018, where last-generation drones were exhibited, showing many possible applications of UASs in the continent [107].

5.3. Proposed Re-Categorization

The experience shown above can be used to develop research projects in multiple applications in Colombia and the Caribbean region, with an alliance between universities and electricity companies taking advantage of the gaps in regulation compared to European or US standards, due to its importance in local applications in the electrical sector and others. Therefore, the authors present a possible classification of UASs based on future applications and current regulations in Colombia and other countries, as shown in Table 4.

The main missions of UAV can be divided into two groups: the first is application, and the second is use and level. These two divisions can be categorized as recreational, industrial, and commercial. Regarding the division by application, the recreational category considers two types of operators: non-certified and certified. In addition, the industrial category has three type of operators: Class I, Class II and Class III. Furthermore, a commercial category is proposed with two subcategories: Commercial Type I and Commercial Type II. Regarding the division by usage and training level, it uses the same three categories. Level I of training is required to perform recreational usage, but when the operation compromise assemblies of people or overpass other rules by type of aircraft, it requires level II training and certification. All industry practices require training and certification. Depending on the aircraft and use, the operator must perform levels III, IV and V. Finally, in the commercial case, levels III and IV of training and the appropriate certification will be carried out.

Table 4. Proposed recategorization for the use of UASs in Colombia.

Main Division	Category	Type	Classification
Application	Recreational	Non-Certified	Does not require a certification but requires first level of training
		Certified	Requires certification and second level of training
	Industrial	Class I	Requires certification and third level of training
		Class II	Requires certification and fourth level of training
		Class III	Requires certification and fifth level of training
	Commercial	Class I	Requires certification and third level of training
		Class II	Requires certification and fourth level of training
Usage and level	Recreational	Level I	Training level required for non-certified users
		Level II	Training level required for certified users
	Industrial	Levels III, IV and V	Trainig level required for industrial certifications, the required level depends of the usage and aircraft type
	Commercial	Levels III and IV	Training level required for commercial certifications, the required level depends of the usage and aircraft type

In addition, for anyone who desires to pilot any kind of UAV under any of the above categories, a mandatory training is proposed with five levels. However, this training would not require any certification for the recreational subcategory, and would increase its difficulty level according to the complexity of the UAV usage.

All operations must be within a visual line of sight (VLOS) of up to 500 m horizontally during all flights. All restrictions for class A operations in Table 4 and the European rules of EASA eRules in the open category, subcategory A1 apply. Unlike the first subcategory, all restrictions of UAEAC class A operations are applied, with exceptions for some autonomous operations, and for EASA open category A2 eRules [70] training level 2 is required. The industrial type I subcategory is similar in characteristics to recreational, but with permission to monitor structures and rural power lines, where there are few buildings or large assemblies of people, as shown in Table 4. Small payloads are allowed, and VLOS up to 750 m horizontally is required during all flights, even when the drone is flying on its own. Training level 3 is also required. UAEAC class A operation limits and EASA category open subcategory A3 must be met.

In addition to these rules, as presented in Table 4, the industrial type 2 subcategory needs level 4 of training and certification, and power lines and other important infrastructure can be monitored in building-based cities. Its mid payload may be some certified instruments or tools to complete its tasks. The UAEAC class A operating limits and the EASA specific category apply. The last subcategory, industrial type III, requires all certifications granted by the authorities. It can carry large payloads and is suitable for autonomous operations beyond VLOS (BVLOS). This involves the transport of people, the carriage of dangerous goods, or the conduction of large groups of people. The industrial category in type III of the categorization proposed in Table 4 is particularly good for work with heavy loads, such as laying power lines, loading special materials, or rescuing operators. For this subcategory, the UAEAC class C rules and the EASA certified category apply. Finally, the commercial type I is similar to industrial type I, but is used for commercial purposes only and applies the same regulation as well. The case of commercial type II is similar to industrial type III and is restricted by the same rules.

6. Discussion

Despite the benefits discussed above, UAVs still have many things to consider that need to be closely monitored. Some of these need to be addressed globally because they are capable of scaling established boundaries, and, due to the rapid emergence of commercial UAVs for anyone (hobbyists) and other professional uses, regulations are changing all over the world. It is paramount to keep people safe, and for this reason, it is important to periodically review aircraft to prevent crashes, technical malfunctions, or misuse by operators [108]. As in other countries, there is a government agency in Colombia that regulates the use of UAVs. However, due to corruption issues, there is a concern that people who want to hurt others will use them to do so. Moreover, this entity does not keep track of maintenance, which needs to be performed regularly.

Another issue with using commercial or hobbyist UAVs is navigation and communication modules, which are vulnerable to various security breaches [91]. Generally, there is no encrypted radio signal to control drones. The IEEE 802.11 standard is used in Wi-Fi networks and some vehicles are controlled this way, which is also vulnerable to hijacking [92]. Unfortunately, UAVs can be used to smuggle drugs, contraband, or espionage. In the wrong hands, even with security breaches, it can be used as a weapon against people. Privacy is also one of the main issues associated with the use of commercial UAVs due to their remote control of embedded gadgets, raising privacy concerns related to the use of UAVs. In addition to the problems mentioned above, they can also be hacked to obtain personal information.

Regarding the use in electrical power applications, due to Colombian regulations, they are limited to using class B and class C to perform monitoring tasks or lay power lines between towers. It is important to note that class C is not well regulated and is limited exclusively to scientific research, innovation, and development. Therefore, larger or special payloads must be considered in conceptual designs and must be properly authorized by UAEAC. Furthermore, the current regulation does not consider other classes of UAS that are currently being used in other countries. All of these considerations may make it difficult for energy companies to adopt these innovations on a massive scale.

Using the experience of companies that have researched and implemented UAS technologies in their processes, it is possible to adapt techniques to a Colombian context, considering its climate, bioresources, topography, extension, conflicts, and demand, producing its own developments for the successful implementation of UASs in the electricity sector, combining advanced inspection techniques with the experience of its own company, in addition to some UAS projects being run in the country [109]. The proposed categorization is intended to help review the current regulation to include other categories due to its use, size, and commercial application, to address emerging uses of UASs.

7. Conclusions

This article provided an overview of the current state of UAS applications around the world, highlighting the Colombian perspective, opportunities, and challenges. The integration of UASs into routine inspections and monitoring tasks has been quickly accepted. Reviewing guidelines is important to understand how misuse can affect critical infrastructures. Furthermore, Colombia can improve its process of embracing this technology and prepare for the future by considering other prospects in addition to the cases of the United

States or Latin America. Other experiences can be considered, such as European and Asian research and even local experiences. The reclassification of UASs that the authors suggest in this document is intended to be a guide for reviewing the laws in the country on how it can be used for commercial, industrial, and recreational applications. Performing monitoring and operating tasks with traditional systems can be more expensive than those performed with UASs. In this direction, operations have already been carried out in fields such as agriculture, precision fumigation, and the monitoring of climatological variables, reducing costs and increasing profits. More research is required to deal with problems caused by sharing the same airspace among UASs and other manned aircraft, as it can represent a risk. Furthermore, conventional radar systems, which are widely implemented, cannot detect these small aircraft, which is necessary to avoid collisions or any other damage. Although in Colombia there are already experiences and investigations about UASs engaged by transmission and distribution power companies, there are not many documents to help with this future work.

Future work can be applied by collecting and analyzing findings on UAS deployments throughout the country or the Latin American region to contrast them with the categorization proposed in this document and the current regulation, seeking greater technological appropriation and expansion of its use.

Author Contributions: Conceptualization, G.J.S.-Z.; methodology, G.J.S.-Z. and L.I.-G.; writing original draft preparation, G.J.S.-Z., L.I.-G. and J.E.C.-B.; writing, review, and editing, G.J.S.-Z., L.I.-G. and J.E.C.-B.; visualization, G.J.S.-Z., L.I.-G. and J.E.C.-B.; validation, resources, supervision, project administration, and funding acquisition, G.D.Z.-M. and R.G.-S. All authors have read and agreed to the published version of the manuscript.

Funding: The research project received funding from Minciencias-Colombia under project number 79926. This project is in the hedge fund of the National Program of Science, Technology, and Innovation in Energy and Mining and the policies to foster CT+I.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors thank the Grupo de Investigación Teleinformática y Tele Automática, Facultad de Minas, Universidad Nacional de Colombia, Sede Medellín.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Whitehead, K.; Hugenholtz, C.H. Remote sensing of the environment with small unmanned aircraft systems (UASs), part 1: A review of progress and challenges. *J. Unmanned Veh. Syst.* **2014**, *2*, 69–85. [CrossRef]
2. Kharchenko, V.; Prusov, D. Analysis of unmanned aircraft systems application in the civil field. *Transportation* **2012**, *27*, 335–343. [CrossRef]
3. Huttunen, M. Civil unmanned aircraft systems and security: The European approach. *J. Transp. Saf. Secur.* **2019**, *12*, 83–101. [CrossRef]
4. Research and Markets. Global UAV Drones Market Report 2022: The Historical Significance and the Current Day Developments—Forecast to 2026. 19 January 2022. Available online: https://www.prnewswire.com/news-releases/global-uav-drones-market-report-2022-the-historical-significance-and-the-current-day-developments---forecast-to-2026-301463721.html (accessed on 20 July 2022).
5. Sánchez Jiménez, G.; Mulero Valenzuela, M.; Saumeth Cadavid, E. *Vehículos Aéreos no Tripulados en Latinoamérica*; Technical Report—Information & Design Solutions, S.L.; ISSUU: Palo Alto, CA, USA, 2013.
6. Silva, D.M.P.F.; de Oliveira, L.F.F.; Macedo, M.G.M.; Filho, C.J.A.B. On the Analysis of a Swarm Intelligence Based Coordination Model for Multiple Unmanned Aerial Vehicles. In Proceedings of the 2012 Brazilian Robotics Symposium and Latin American Robotics Symposium, Fortaleza, Brazil, 16–19 October 2012; pp. 208–213. [CrossRef]
7. Alves Ribeiro, V.H.; Reynoso-Meza, G.; dos Santos Coelho, L. Multi-Objective Model Selection for Unmanned Aerial Vehicles Automatic Target Recognition Systems. *IFAC-PapersOnLine* **2017**, *50*, 11607–11612. [CrossRef]

8. Lee, G.O.; Vasco, L.; Márquez, S.; Zuniga-Moya, J.C.; Van Engen, A.; Uruchima, J.; Ponce, P.; Cevallos, W.; Trueba, G.; Trostle, J.; et al. A dengue outbreak in a rural community in Northern Coastal Ecuador: An analysis using unmanned aerial vehicle mapping. *PLoS Neglected Trop. Dis.* **2021**, *15*, e0009679. [CrossRef] [PubMed]
9. Guevara-Bonilla, M.; Meza-Leandro, A.S.; Esquivel-Segura, E.A.; Arias-Aguilar, D.; Tapia-Arenas, A.; Meléndez, F.M. Uso de vehículos aéreos no tripulados (VANTs) para el monitoreo y manejo de los recursos naturales: Una síntesis. *Rev. Tecnol. Marcha* **2020**, *33*, 77–88. [CrossRef]
10. Stankovic, M.; Hasanbeigi, A.; Neftenov, N. *Use of 4IR Technologies in Water and Sanitation in Latin America and the Caribbean*; Technical Report; Inter-American Development Bank: Washington, DC, USA, 2020.
11. Chaves, A.N.; Cugnasca, P.S.; Jose, J. Adaptive search control applied to Search and Rescue operations using Unmanned Aerial Vehicles (UAVs). *IEEE Lat. Am. Trans.* **2014**, *12*, 1278–1283. [CrossRef]
12. Briceño, C.; Noel, M.F.; Chácara, C.; Aguilar, R. Integration of non-destructive testing, numerical simulations, and simplified analytical tools for assessing the structural performance of historical adobe buildings. *Constr. Build. Mater.* **2021**, *290*, 123224. [CrossRef]
13. Vargas-Ramírez, N.; Paneque-Gálvez, J. The Global Emergence of Community Drones (2012–2017). *Drones* **2019**, *3*, 76. [CrossRef]
14. Castellanos-Sanabria, Y.A.; Rodríguez-Pirateque, G.W. UAV systems for multipurpose heterogeneous networks: A review of design, development and performance. *Aeronaut. Aerosp. Open Access J.* **2020**, *4*, 121–140. [CrossRef]
15. da Cruz, E.P.F. A Comprehensive Survey in Towards to Future FANETs. *IEEE Lat. Am. Trans.* **2018**, *16*, 876–884. [CrossRef]
16. Berra, E.F.; Peppa, M.V. Advances and Challenges of UAV SFM MVS Photogrammetry and Remote Sensing: Short Review. In Proceedings of the 2020 IEEE Latin American GRSS & ISPRS Remote Sensing Conference (LAGIRS), Santiago, Chile, 22–26 March 2020; pp. 533–538. [CrossRef]
17. Sánchez Pinzón, B.F.; Tapia Ortega, J.R.; Rosa, P. Drones: Aspectos generales y aplicaciones sociales. *Vis. Electron.* **2016**, *10*, 262–273. [CrossRef]
18. Grupo ENEL. La Innovación Que Llega Volando. 2019. Available online: https://www.enel.com.co/es/historias/a201908-la-innovacion-que-llega-volando.html (accessed on 28 September 2022).
19. Ackroyd, J.A.D. Sir George Cayley, the father of aeronautics Part 2. Cayley's aeroplanes. *Notes Rec. R. Soc. Lond.* **2002**, *56*, 333–348. [CrossRef]
20. Sobolev, D.A. Du temple and Mozhaiskii: Was either of them the first to flight test an aeroplane? *Hist. Technol.* **1994**, *11*, 393–401. [CrossRef]
21. Justin, F. The History of Drones (Drone History Timeline from 1849 to 2019). 2020. Available online: https://www.dronethusiast.com/history-of-drones/ (accessed on 28 September 2022).
22. Alwateer, M.; Loke, S.W. Emerging Drone Services: Challenges and Societal Issues. *IEEE Technol. Soc. Mag.* **2020**, *39*, 47–51. [CrossRef]
23. Loquercio, A.; Kaufmann, E.; Ranftl, R.; Dosovitskiy, A.; Koltun, V.; Scaramuzza, D. Deep Drone Racing: From Simulation to Reality With Domain Randomization. *IEEE Trans. Robot.* **2020**, *36*, 1–14. [CrossRef]
24. Mitka, E.; Mouroutsos, S. Classification of drones. *Am. J. Eng. Res.* **2017**, *6*, 36–41.
25. Villagrán, C.; Hinojosa, L.F. History of the forests of southern South America, II: Phytogeographical analysis. *Rev. Chil. Hist. Nat.* **1997**, *70*, 241–267.
26. Sánchez Zoque, L.M. Talleres de Mapeo Humanitario en Mocoa, Putumayo, Colombia. 2017. Available online: https://openstreetmapcolombia.github.io/2017/05/07/taller-mapeo-mocoa/ (accessed on 20 July 2022).
27. United Nations. Population. 2022. Available online: https://www.un.org/en/global-issues/population (accessed on 20 July 2022).
28. Sánchez, W.A. *COHA Report: Drones in Latin America*; Technical Report; COHA: Washington, DC, USA, 2014.
29. Jardini, M.G.M.; Jardini, J.A.; Crispino, F.; Simões, A.J.M.; Souza, J.M.S.D.; Santos, W.L.D. Vegetation detection close to transmission lines using cloud data points from lidar in Brazil. In Proceedings of the Modelling, Simulation and Identification/858: Intelligent Systems and Control, Calgary, AB, Canada, 16–17 July 2018; ACTAPRESS: Calgary, AB, Canada, 2018; pp. 163–168. [CrossRef]
30. de Sousa, A.D.P.; de Sousa, G.C.L.; Maués, L.M.F. Using digital image processing and Unmanned Aerial Vehicle (UAV) for identifying ceramic cladding detachment in building facades. *Ambiente* **2022**, *22*, 199–213. [CrossRef]
31. Martinez, J.G.; Masoud, G.; Alarcón, L.F. UAV Integration in Current Construction Safety Planning and Monitoring Processes: Case Study of a High-Rise Building Construction Project in Chile. *J. Manag. Eng.* **2020**, *36*, 05020005. [CrossRef]
32. Vargas-Ramírez, N.; Paneque-Gálvez, J. Desafíos normativos para el uso comunitario de drones en México. *Investig. Geogr.* **2020**, *102*, 1–14. [CrossRef]
33. Llugsi Cañar, R.; Lupera, P.; Chango, R.; Ledesma, F.; Suarez, A. Estudio básico del comportamiento ambiental en la caldera del volcán inactivo Pululahua utilizando un sistema de adquisición y procesamiento de datos basado en UAV. *Rev. Politics* **2019**, *43*, 29–36. [CrossRef]
34. Radoglou-Grammatikis, P.; Sarigiannidis, P.; Lagkas, T.; Moscholios, I. A compilation of UAV applications for precision agriculture. *Comput. Netw.* **2020**, *172*, 107148. [CrossRef]
35. Gordillo-Salinas, V.M.; Flores-Magdaleno, H.; Ortiz-Solorio, C.A.; Arteaga-Ramírez, R. Evaluation of nitrogen status in a wheat crop using unmanned aerial vehicle images. *Chil. J. Agric. Res.* **2021**, *81*, 408–419. [CrossRef]

36. Rodríguez Bianco, G.; Triñanes Morixe, I. Uso de un UAV para Estimar la Altura del Forraje. Master's Thesis, Universidad de la República, Montevideo, Uruguay, 2018.
37. Easdale, M.H.; Umaña, F.; Raffo, F.; Fariña, C.; Bruzzone, O. Evaluación de pastizales patagónicos con imágenes de satélites y de vehículos aéreos no tripulados. *Ecol. Austral.* **2019**, *29*, 306–314. [CrossRef]
38. González Musso, R.F.; Rabino, A.L.; Azzaro, F. Uso de un Vehículo Aéreo No Tripulado (VANT) como método de monitoreo de la sanidad forestal en plantaciones de coníferas en Patagonia Norte, Argentina Quebracho. *Rev. Cienc. For.* **2020**, *28*, 88–99.
39. Estrada Zúñiga, A.C.; Vásquez, J.Ñ. Detección e identificación de comunidades vegetales altoandinas, Bofedal y Tolar de Puna Seca mediante ortofotografías RGB y NDVI en drones "Sistemas Aéreos no Tripulados". *Sci. Agropecu.* **2021**, *12*, 291–301. [CrossRef]
40. Oviedo Bayas, B.; Silva Castro, K.F.; Zhuma Mera, E. Red de drones autónomos utilizando una arquitectura de red para uso alternativo de levantamiento de información agrícola a pequeña escala. *Conrado* **2021**, *17*, 69–80.
41. López Ortiz, M.J.; Mencia, E.; Jara Céspedes, A.J.; Manabe, A.; Fleitas, F. Vehículo Aéreo No Tripulado (VANT) una herramienta para la conservación de las áreas silvestres protegidas del Paraguay. *Rev. Cient. UCSA* **2020**, *7*, 14–17. [CrossRef]
42. Jorge, L.A.C.; Brandão, Z.N.; Inamasu, R.Y. Insights and recommendations of use of UAV platforms in precision agriculture in Brazil. In Proceedings of the Remote Sensing for Agriculture, Ecosystems, and Hydrology XVI, Amsterdam, The Netherlands, 23–25 September 2014; Volume 9239, pp. 313–330. [CrossRef]
43. Vargas, V.S.; Lange, V.D. Sistema aéreo de medición de gases contaminantes basado en un UAV, resultados preliminares. *Acta Nova* **2015**, *7*, 194–212.
44. Castellanos, G.; Deruyck, M.; Martens, L.; Joseph, W. System Assessment of WUSN Using NB-IoT UAV-Aided Networks in Potato Crops. *IEEE Access* **2020**, *8*, 56823–56836. [CrossRef]
45. Jaimes, L.G.; Calderon, J.M. An UAV-based incentive mechanism for Crowdsensing with budget constraints. In Proceedings of the 2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, USA, 10–13 January 2020; pp. 1–6. [CrossRef]
46. Khan, M.A.; Alvi, B.A.; Safi, A.; Khan, I.U. Drones for good in smart cities: A review. In Proceedings of the International Conference on Electrical, Electronics, Computers, Communication, Mechanical and Computing (EECCMC), Vaniyambadi, India, 28–29 January 2018; Volume 28.
47. Corporación de la Industria Aeronáutica Colombiana S.A.—CIAC. Fabricación ART Quimbaya. Available online: https://www.ciac.gov.co/productos-y-servicios/proyectos/ (accessed on 28 September 2022).
48. Federal Aviation Administration. *Code of Federal Regulation. PART 107—Small Unmanned Aircraft Systems*; Federal Aviation Administration: Washington, DC, USA, 2016.
49. Ogan, R.T.; Lott, D.; Paden, W. Electrical Transmission Line Inspection using Unmanned Aircraft. In Proceedings of the 2019 SoutheastCon, Huntsville, AL, USA, 11–14 April 2019; pp. 1–7. [CrossRef]
50. Diario Oficial de la Federación. *Que Establece los Requerimientos para Operar un Sistema de Aeronave Pilotada a Distancia (RPAS) en el Espacio Aéreo Mexicano*; NORMA Oficial Mexicana NOM-107-SCT3-2019; Diario Oficial de la Federación: Mexico City, Mexico, 2019.
51. Dirección General de Aeronautica Civil—Guatemala. *Regulaciones de Aviación Civil de Guatemala*; Technical Report RAC-101; Dirección General de Aeronautica Civil—Guatemala: Ciudad, Guatemala, 2013.
52. Instituto Nicaragüense de Aeronáutica Civil—INAC. Restricción para uso de Drones en Nicaragua. Available online: https://www.inac.gob.ni/2014/11/restriccion-para-uso-de-drones/ (accessed on 28 September 2022).
53. Instituto Nicaragüense de Aeronáutica Civil—INAC. ¿Qué son los Drones? Available online: https://www.inac.gob.ni/2015/11/que-son-los-drones/ (accessed on 28 September 2022).
54. Autoridad de Aviación Civil (AAC)—El Salvador. *RAC VANT: Regulación de los Vehículos Aéreos No Tripulados*; Technical Report; Autoridad de Aviación Civil (AAC)—El Salvador: San Salvador, El Salvador, 2021.
55. Agencia Hondureña de Aeronáutica Civil. *Registro de Operadores y Limitaciones de Operación de Sistemas de Aeronaves Pilotadas a Distancia (RPAS)*; Technical Report; Agencia Hondureña de Aeronáutica Civil: Tegucigalpa, Honduras, 2016.
56. Dirección General de Aviacion Civil—Costa Rica. *Operaciones con Sistema de Aeronave Piloteada a Distancia (RPAS)*; Technical Report; Dirección General de Aviacion Civil—Costa Rica: San José, Costa Rica, 2021.
57. Department of Civil Aviation, Belize. Drone Requirements for International and Local Drone Operators. Available online: https://www.civilaviation.gov.bz/index.php/drones (accessed on 28 September 2022).
58. Autoridad Aeronática Civil—Panamá. *Requisitos para Operaciones de Aeronaves Pilotadas a Distancia*; Technical Report; Autoridad Aeronática Civil—Panamá: Panama City, Panama, 2016.
59. Ministerio del Poder Popular para el Transporte, Venezuela. Legislación Venezolana en Materia de Aeronaves Pilotadas a Distancia (RPAS). Available online: https://www.inac.gob.ve/wp-content/uploads/2017/09/Informe-RPA-FINAL.pdf (accessed on 29 September 2022).
60. Dirección General de Aviación Civil—Ecuador. *Resolución Nro. DGAC-DGAC-2020-0110-R Operación de Aeronaves Pilotadas a Distancia (RPAs)*; Technical Report; Aviación Civil—Ecuador: Quito, Ecuador, 2020.
61. Dirección General de Aeronáutica Civil—Chile. *Normas para la Obtención de Certificado de Operador Aéreo (AOC)*; Technical Report; Dirección General de Aeronáutica Civil: Santiago, Chile, 2021.
62. Dirección General de Aeronática Civil—Chile. *Operaciones de Aeronaves Pilotadas a Distancia (RPAS) en Asuntos de Interés Público, que se Efectúen Sobre áreas Pobladas*; Technical Report; Dirección General de Aeronáutica Civil: Santiago, Chile, 2020.

63. Ministerio de Transportes y Comunicaciones—Perú. MTC: Conoce los Requisitos Para Operar un Drone. 2019. Available online: https://www.gob.pe/institucion/mtc/noticias/50511-mtc-conoce-los-requisitos-para-operar-un-drone (accessed on 28 September 2022).
64. Ministerio de Transportes y Comunicaciones—Perú. *Ley que Regula el Uso y las Operaciones de los Sistemas de Aeronaves Pilotadas a Distancia (RPAS)*; Technical Report 30740; Plataforma digital única del Estado Peruano: Lima, Peru, 2018.
65. Dirección Nacional de Aviación e Infraestructura Aeronáutica—Uruguay. *Resolución 291-2014*; Technical Report; Dirección Nacional de Aviación e Infraestructura Aeronáutica: Montevideo, Uruguay, 2014.
66. Dirección Nacional de Aeronáutica Civil—Paraguay. *Reglamento de Aeronaves Pilotadas a Distancia (RPA) y Sistemas de Aeronaves Pilotadas a Distancia (RPAS)*; Technical Report; Dirección Nacional de Aeronáutica Civil: Asunción, Paraguay, 2017.
67. Dirección General de Aeronáutica Civil—Bolivia. *Regulación para el Uso de Aeronáves no Tripuladas (RPAs)*; Technical Report; Dirección General de Aeronáutica Civil: La Paz, Bolivia, 2020.
68. Administración Nacional de Aviación Civil. *Reglamento de Vehículos Aéreos no Tripulados (VANT) y de Sistemas de Vehículos Aéreos no Tripulados (SVANT)*; Technical Report; Ministerio de Transporte: Buenos Aires, Argentina, 2020.
69. Agência Nacional de Aviação Civil—Brazil. *Regulamento Brasileiro da Aviação Civil Especial—Requisitos Gerais para Aeronaves Não Tripuladas de Uso Civil*; Technical Report; Agência Nacional de Aviação Civil (ANAC): Brasília, Brazil, 2021.
70. European Union Aviation Safety Agengy—EASA. Easy Access Rules for Unmanned Aircraft Systems (Regulations (EU) 2019/947 and 2019/945). Available online: https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu (accessed on 28 September 2022).
71. Drone Laws. Drone Laws in Asian Countries. Available online: https://drone-laws.com/drone-laws-in-asian-countries-2/ (accessed on 28 September 2022).
72. Aeronáutica Civil—Colombia. *ABECÉ: Reglamentación y Manejo de Drones en Colombia*; Aeronáutica Civil: Bogotá, Colombia, 2022.
73. Reglamentos Aeronáuticos de Colombia. *Unidad Administrativa Especial de Aeronáutica Civil—Colombia*; Technical Report; Unidad Administrativa Especial de Aeronáutica Civil: Bogotá, Colombia, 2020.
74. Tariq, R.; Rahim, M.; Aslam, N.; Bawany, N.; Faseeha, U. DronAID: A Smart Human Detection Drone for Rescue. In Proceedings of the 2018 15th International Conference on Smart Cities: Improving Quality of Life Using ICT & IoT (HONET-ICT), Islamabad, Pakistan, 8–10 October 2018; pp. 33–37. [CrossRef]
75. Munawar, H.S.; Hammad, A.W.A.; Waller, S.T. Disaster Region Coverage Using Drones: Maximum Area Coverage and Minimum Resource Utilisation. *Drones* **2022**, *6*, 96. [CrossRef]
76. Stolfi, D.H.; Brust, M.R.; Danoy, G.; Bouvry, P. SuSy-EnGaD: Surveillance System Enhanced by Games of Drones. *Drones* **2022**, *6*, 13. [CrossRef]
77. Guo, Y.; Jia, X.; Paull, D.; Zhang, J.; Farooq, A.; Chen, X.; Islam, M.N. A Drone-Based Sensing System to Support Satellite Image Analysis for Rice Farm Mapping. In Proceedings of the IGARSS 2019—2019 IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, 28 July–2 August 2019; pp. 9376–9379. [CrossRef]
78. Atherton, J.; MacArthur, A.; Hakala, T.; Maseyk, K.; Robinson, I.; Liu, W.; Honkavaara, E.; Porcar-Castell, A. Drone Measurements of Solar-Induced Chlorophyll Fluorescence Acquired with a Low-Weight DFOV Spectrometer System. In Proceedings of the IGARSS 2018—2018 IEEE International Geoscience and Remote Sensing Symposium, Valencia, Spain, 22–27 July 2018; pp. 8834–8836. [CrossRef]
79. Hassanalian, M.; Abdelkefi, A. Classifications, applications, and design challenges of drones: A review. *Prog. Aerosp. Sci.* **2017**, *91*, 99–131. [CrossRef]
80. Loke, S.; Alwateer, M. Decision-Making for Drone Services in Urban Environments: A Simulated Study on Clients' Satisfaction and Profit Maximisation. In Proceedings of the 2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI), Leicester, UK, 19–23 August 2019; pp. 550–557. [CrossRef]
81. Herrera, D.; Imamura, H. Design of facial recognition system implemented in an unmanned aerial vehicle for citizen security in Latin America. *ITM Web Conf.* **2019**, *27*, 04002. [CrossRef]
82. Corte, A.P.D.; da Cunha Neto, E.M.; Rex, F.E.; Souza, D.; Behling, A.; Mohan, M.; Sanquetta, M.N.I.; Silva, C.A.; Klauberg, C.; Sanquetta, C.R.; et al. High-Density UAV-LiDAR in an Integrated Crop-Livestock-Forest System: Sampling Forest Inventory or Forest Inventory Based on Individual Tree Detection (ITD). *Drones* **2022**, *6*, 48. [CrossRef]
83. Murdoch, S.; Reynoso, S. Design and Implementation of a MPPT circuit for a Solar UAV. *IEEE Lat. Am. Trans.* **2013**, *11*, 108–111. [CrossRef]
84. Adib, A.; Afridi, K.K.; Amirabadi, M.; Fateh, F.; Ferdowsi, M.; Lehman, B.; Lewis, L.H.; Mirafzal, B.; Saeedifard, M.; Shadmand, M.B.; et al. E-Mobility—Advancements and Challenges. *IEEE Access* **2019**, *7*, 165226–165240. [CrossRef]
85. Goh, C.S.; Kuan, J.R.; Yeo, J.H.; Teo, B.S.; Danner, A. A 100% solar-powered quadcopter with monocrystalline silicon cells. In Proceedings of the 2019 IEEE 46th Photovoltaic Specialists Conference (PVSC), Chicago, IL, USA, 16–21 June 2019; pp. 2829–2834. [CrossRef]
86. Davies, L.; Bolam, R.C.; Vagapov, Y.; Anuchin, A. Review of Unmanned Aircraft System Technologies to Enable Beyond Visual Line of Sight (BVLOS) Operations. In Proceedings of the 2018 X International Conference on Electrical Power Drive Systems (ICEPDS), Novocherkassk, Russia, 3–6 October 2018; pp. 1–6. [CrossRef]

87. Grando, R.B.; Pinheiro, P.M.; Bortoluzzi, N.P.; da Silva, C.B.; Zauk, O.F.; Piñeiro, M.O.; Aoki, V.M.; Kelbouscas, A.L.S.; Lima, Y.B.; Drews, P.L.J.; et al. Visual-based Autonomous Unmanned Aerial Vehicle for Inspection in Indoor Environments. In Proceedings of the 2020 Latin American Robotics Symposium (LARS), 2020 Brazilian Symposium on Robotics (SBR) and 2020 Workshop on Robotics in Education (WRE), Natal, Brazil, 9–12 November 2020; pp. 1–6. [CrossRef]
88. Beke, É.; Bódi, A.; Katalin, T.G.; Kovács, T.; Maros, D.; Gáspár, L. The Role of Drones in Linking Industry 4.0 and ITS Ecosystems. In Proceedings of the 2018 IEEE 18th International Symposium on Computational Intelligence and Informatics (CINTI), Budapest, Hungary, 21–22 November 2018; pp. 000191–000198. [CrossRef]
89. Perreault, M.; Behdinan, K. Delivery Drone Driving Cycle. *IEEE Trans. Veh. Technol.* **2021**, *70*, 1146–1156. [CrossRef]
90. Sharma, V.; Choudhary, G.; Ko, Y.; You, I. Behavior and Vulnerability Assessment of Drones-Enabled Industrial Internet of Things (IIoT). *IEEE Access* **2018**, *6*, 43368–43383. [CrossRef]
91. Vattapparamban, E.; Güvenç, İ.; Yurekli, A.İ.; Akkaya, K.; Uluağaç, S. Drones for smart cities: Issues in cybersecurity, privacy, and public safety. In Proceedings of the 2016 International Wireless Communications and Mobile Computing Conference (IWCMC), Paphos, Cyprus, 5–9 September 2016; pp. 216–221. [CrossRef]
92. Altawy, R.; Youssef, A.M. Security, Privacy, and Safety Aspects of Civilian Drones: A Survey. *ACM Trans. Cyber-Phys. Syst.* **2016**, *1*, 1–25. [CrossRef]
93. Jung, N.J.; Choi, M.H.; Lim, C.W. Development of Drone Operation System for Diagnosis of Transmission Facilities. In Proceedings of the 2018 21st International Conference on Electrical Machines and Systems (ICEMS), Jeju, Republic of Korea, 7–10 October 2018; pp. 2817–2821. [CrossRef]
94. Choi, H.; Koo, G.; Kim, B.J.; Woo Kim, S. Real-time Power Line Detection Network using Visible Light and Infrared Images. In Proceedings of the 2019 International Conference on Image and Vision Computing New Zealand (IVCNZ), Dunedin, New Zealand, 2–4 December 2019; pp. 1–6. [CrossRef]
95. Toth, J.; Gilpin-Jackson, A. Smart view for a smart grid—Unmanned Aerial Vehicles for transmission lines. In Proceedings of the 2010 1st International Conference on Applied Robotics for the Power Industry, Montreal, QC, Canada, 5–7 October 2012; pp. 1–6. [CrossRef]
96. Michalec, D. Unmanned Aerial Systems: Current State of the Technology and Relevance to Rural Electric Utilities. In Proceedings of the 2016 IEEE Rural Electric Power Conference (REPC), Westminster, CO, USA, 15–18 May 2016; pp. 102–110. [CrossRef]
97. Prasad, D.S.; Reddy, B.S. Study on Corona Activity Using an Image Processing Approach. *IEEE Trans. Ind. Appl.* **2017**, *53*, 4008–4014. [CrossRef]
98. Chen, Z.; Peng, T.; Gong, S.; Li, L.; Bai, D.; Zheng, R. Image Correction Technology Supporting Power Device Monitoring. In Proceedings of the 2018 IEEE 3rd International Conference on Signal and Image Processing (ICSIP), Shenzhen, China, 13–15 July 2018; pp. 260–264. [CrossRef]
99. Aljohani, O.; Abu-Siada, A. Application of digital image processing to detect transformer bushing faults and oil degradation using FRA polar plot signature. *IEEE Trans. Dielectr. Electr. Insul.* **2017**, *24*, 428–436. [CrossRef]
100. Elizondo, M.; Vallem, M.; Samaan, N.; Makarov, Y.; Vyakaranam, B.; Nguyen, T.; Muñoz, C.; Herrera, R.; Midence, D.; Shpitsberg, A. Transmission reinforcements in the Central American regional power system. In Proceedings of the 2016 IEEE Power and Energy Society General Meeting (PESGM), Boston, MA, USA, 17–21 July 2016; pp. 1–5. [CrossRef]
101. Ferreira, R.; Corredor, P.H.; Rudnick, H.; Cifuentes, X.; Barroso, L. Electrical Expansion in South America: Centralized or Distributed Generation for Brazil and Colombia. *IEEE Power Energy Mag.* **2019**, *17*, 50–60. [CrossRef]
102. Adabo, G.J. Unmanned aircraft system for high voltage power transmission lines of Brazilian electrical system. *Auvsi'S Unmanned Syst.* **2013**, *2*, 1556–1563.
103. Kumar, V.M.; Nageswara Rao, B.; Farooq, S. A Detailed Review on Pin Fin Heat Sink International. *J. Energy Power Eng.* **2016**, *10*, 1006–1015. [CrossRef]
104. Caparó Acurio, J.W.; Lay-Siu Su-Mund, D.K. Statkraft: Inspector Drone. Master's Thesis, Universidad de Piura, Piura, Peru, 2019.
105. ENEL. Drones y Cámaras Termográficas HD, las Nuevas Tecnologías que Utiliza Enel Distribución. Available online: https://www.enel.cl/es/conoce-enel/prensa/news/d201905-drones-y-camaras-termograficas-hd-tecnologias-enel-distribucion.html (accessed on 28 September 2022).
106. IT NOW. ETESA Incorpora Drones para Inspección y Diseño Eléctrico. 2019. Available online: https://www.itnow.connectab2b.com/post/etesa-incorpora-drones-para-inspecci%C3%B3n-y-dise%C3%B1o-el%C3%A9ctrico (accessed on 28 September 2022).
107. Agence France-Presse (AFP). Los mil Usos de los Drones en América Latina. Available online: https://www.revistalideres.ec/lideres/usos-drones-americalatina-industria-mercado.html (accessed on 28 September 2022).
108. Stöcker, C.; Bennett, R.; Nex, F.; Gerke, M.; Zevenbergen, J. Review of the Current State of UAV Regulations. *Remote Sens.* **2017**, *9*, 459. [CrossRef]
109. Grupo de Energía de Bogotá. La Tecnología de Drones Despegó en Transmisión del GEB. Available online: https://www.grupoenergiabogota.com/transmision/revista-inergia/sostenibilidad/la-tecnologia-de-drones-despego-en-transmision-del-geb (accessed on 28 September 2022).