drones

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Systematic Review

Systematic Review on Civilian Drones in Safety and Security Applications

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Abstract: The employment of unmanned aerial vehicles, also known as UAVs, is expanding rapidly across various civil application areas. Some of these domains include real-time tracking, the provision of wireless coverage, sensing, searches and rescue, the delivery of goods, safety and surveillance, security, and safety checks of engineering structures. Smart UAVs represent the next technology revolution in UAV technology. They promise to provide new possibilities in various applications, notably lower risk and costs for civil infrastructure. The military has traditionally used unmanned aerial vehicles (UAVs) in countries such as the United Kingdom or the United States to partake in military and dangerous operations. The application and usage of these UAVs have become more commercial. Civilians can easily buy UAVs, commonly known as drones, from online platforms or shops. The main aim of this study is to review selected publications presenting previous efforts on using Civilian Drones in Safety applications. The study was accomplished using a systematic review research approach reviewing 45 publications. Drones have become more common, and it is crucial to understand how they work, especially since they entered the civilian domain. The research shows how civilian drones have been used in numerous safety applications, such as security cameras videotaping a house to ensure its safety.

Keywords: UAVs; drones; sensors; drone applications; safety and security

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1. Introduction

Drones are unpiloted and unmanned aircraft. They are sometimes known as unmanned aerial vehicles or UAVs for short [1]. They operate without a human pilot on board. They have different levels of autonomy. A drone can rely on its own systems that houses Light Detection and Ranging (LIDAR) detectors, sensitive sensors, all of which are used to calculate its movements and its surroundings, ensuring it does not crash while on its flight plan. This is known as autopilot or advanced autonomy [2]. It can also rely on a human controlling its movements, known as a remotely piloted autonomy. Drones come in different sizes and shapes depending on what task they are completing. They have varying travelling capabilities in the high and distance that they can go. Very close-range drones can travel up to three miles. These are commonly used by hobbyists. Meanwhile close-range drones can have a range up to 30 miles [3]. The longest-range drones can travel up to or beyond 400 miles and 3000 feet in the sky.

There are many purposes for them, ranging from collecting data for scientists to dropping groceries off or even finding people trapped under debris or avalanches. These drones are commonly used for dangerous tasks. They were originally created for aerospace industries as well as the military to aid in their tasks [4]. The drones were commonly used for safety applications such as ensuring that an area was safe for troops to move in to, or to see if someone was buried under rubble before rescue teams went in, and in some cases used in place of soldiers where drones are fitted with weapons such as bombs [4]. Over the years, drone technology has become mainstream and has slowly entered into civilian

hands due to their efficiency and the effective safety they can bring. Civilian drones can be used to carry groceries to the doorstep or to photograph any view a person wants from different angles or heights [5].

Drones can supplement human guards by conducting site inspections, obtaining aerial footage of resources, securing perimeters, and attempting to prevent break-ins [6]. They can also be used to patrol work sites. They can provide real-time data streaming around the clock because they are integrated with AI technologies [7]. On the other hand, the monitoring drone foreshadows the development of new applications for "tomorrow's security" due to the extraordinary observation and movement possibilities it offers, which are continually being improved by the most recent technological advances. Because of its wide range of applications and significant operational value, it is an invaluable air asset in complex or high-stakes circumstances, regardless of whether the situation involves public or private security [8]. Therefore, the success of a drone safety system is based, above and beyond its technical features, on its operations and maintenance functionalities, the application intelligence created, and its ability to be embraced by professionals [9]. In the performance of their duties, security officers can benefit significantly from using professional drones because they enable them to reduce potential dangers, foresee potential hazards, and respond to emergencies at an earlier stage. The expert drone is, therefore, exceptionally suitable for use in safety and security; it also meets the requirements of public safety and security, such as monitoring mega events or monitoring outdoor venues. Altawy et al. [10] also conducted a study on safety and security in sporting events. As a result, it is possible to incorporate it into the services offered by private security companies, where it would bolster the overarching risk management plan and work closely with team members of security officers. Therefore, the benefits are an increase in quality, a decrease in emissions, and a safety improvement. As a result of the substantial benefits that unmanned surface vehicles (USVs) provide in the areas of efficiency, costs, ecologic imprint, logistical support, and safety, this field is undergoing increased utilization and development. Altawy et al. [10] found that hobbyists using drones recreationally currently account for the vast majority of civilian drone usage.

This paper seeks to provide a comprehensive systematic review extracted from 45 published articles within the year of 2011 to 2021; in order to highlight the potential for using drones for safety and security purposes. In addition, it will enable the identification of different areas that could benefit from drones to achieve better security and safety outcomes. Moreover, the paper will be very beneficial for researchers, developers, and other stakeholders to have one reference that includes a summary of a wide range of references to refer to achieve future objectives, rather than spending more time on searching and reviewing.

The paper has been structured into five sections. Following this introduction, the research methodology is presented, followed by the findings from the systematic review, the findings from the meta-analysis, discussion, and conclusion. The references follow the main body.

2. Research Methodology

2.1. Research Desing (Qualitative Research Design)

The study used qualitative research design in order to do a systematic literature review. It's possible to conduct a systematic review using either qualitative or quantitative methods or a hybrid of the two [11]. The research topic and the breadth of the investigation both play a role in determining the methodology that will be utilised [12]. The term "mixed method" refers to an approach to research that combines qualitative and quantitative approaches within the same investigation. One way to compile research on a subject is through a systematic qualitative review, which involves searching in an organized manner for research evidence from primary qualitative studies and then bringing those findings together [13]. The question of whether or not it is necessary for the search to be comprehensive is currently being discussed. In a qualitative literature review, the data

from the studies are analysed using either a qualitative approach, a thematic approach, or a narrative approach. However, the study's objectives lead us to use qualitative systematic literature review. Using a qualitative research approach is to evaluate the factors and elements that implement the applications of drones in safety and security purposes.

2.2. Systematic Literature Review

As illustrated in Figure 1 for this study, a systematic review method has been used. A systematic review is a style of analysis that researchers carry out to find all different forms of evidence on a particular question [14]. This form of review is seen as a reliable source of evidence due to it critically reviewing and giving a summary of different research papers that can help with research. The papers and publications reviewed are known as secondary research and data. This data and research are done by someone else. These reviews are needed to establish a better understanding of the research field and to generate new data. This literature review is different from a systematic review. Unlike the literature review, which is also called narrative review, which represents all available information on a given subject or topic, whereas a systematic review attempts to find all the materials and resources available that answer a specific question the researcher has [15]. Therefore, a systematic literature review is used to identify the factors that lead companies and organizations to implement drone usage in safety and security.

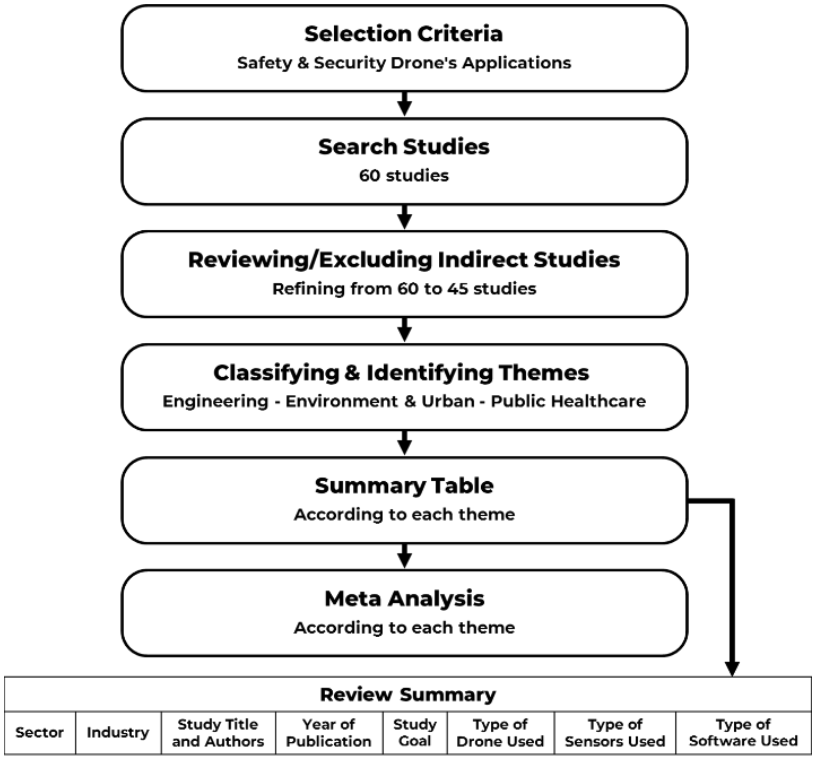

Figure 1. Research Design.

For those who are interested in UAV (drone) technology, the following contributions were made by researchers who used cyber security and safety to advance their work. The present investigation is supplemented by this systemic literature review (SLR), which offers these contributions. While searching for UAV papers about this particular field, we found thirty primary studies. In order to provide an up-to-date perspective of the UAV, we perform an analysis of the data that was collected by the different studies and present our findings. Our goal in conducting this review is to acquire a more in-depth understanding of the topic. This review aims to investigate the many different approaches that can be taken to improve the security of a wide variety of cybertechnologies. Through establishing

guidelines and making representations, we hope to stimulate additional research in this area. The following section will also discuss the numerous facets of UAV security in depth.

2.3. Inclusion and Exclusion Criteria

This article aims to conduct a literature review on safety and security using unmanned aerial vehicles (UAVs), specifically focusing on cybersecurity problems and potential solutions applicable to this context. The study selection criteria were applied to select the papers most pertinent for the review. After compiling the results of the search, the information was run through Google scholar to locate the most relevant papers. The criteria used to decide which papers should be included and which should be excluded from the primary studies are outlined. The search string pertaining to UAVs in safety and security was utilised to search through the hundreds of research papers available. Following the removal of duplicates and studies that were not relevant to the topic at hand, there were 45 research papers left to evaluate using the inclusion and exclusion criteria. Following the application of the criteria, there were a total of 60 papers retained. The discovery of two and three additional papers through snowballing in different directions brought the total number of papers included in this SLR up to 45.

2.4. Data Extraction

Since we now have our complete set of research papers, the next step is to plot out how we will extract information from them. Considering that safety and security are connected to the subject that we are discussing, the first thing that we look for safety and security through UAVs. We are looking for those papers that contain extensive information regarding the safety of UAVs, and in order to evaluate it, we will use the information on UAVs that was provided by other papers. In order to conduct additional research, we created two categories and then divided the papers into those categories. These classifications are as follows:

The UAV: Its Functions and Use-Cases Threats, attacks, and potential countermeasures are discussed with regard to safety and security.

2.5. Selection Criteria of Sampling

This study focused on civilian drones in safety and security application as the criteria for inclusion in this review, hence, 60 articles have been reviewed and only 45 articles included (Figure 1). This allows us to see all possible research that show similar results or similar hypotheses or understanding on how civilian drones can be utilized in safety and security applications. Another selection criterion was to only cover publications within the period of 10 years from 2011 to 2021, to see if past observations and findings align with present ones. Each review will note down the aim of the study, the method used within the study, their findings as well as recommendation for future research and conclusions. That have been useful to establish and refine classification diagram to represent the four candidate industries for drones' application in safety and security purposes along with three key areas within each industry.

2.6. Meta-Analysis

Meta-analysis is an important component of this systematic review because it allows for the analysis of previous studies' summarized findings in Table 1, to identify trends and features within the studies conducted. In other words, it involves analyzing the analyses of other studies to gain a deeper understanding of the data [16]. Therefore, meta-analysis has been used in this study to establish when and where studies were focused, a high of systems used basic GPS and camera within the application, in addition to the use of advanced sensors and software.

Table 1. Findings from SLR.

(a). Engineering							
Sector	**Industry**	**Study Title and Authors**	**Year of Publication**	**Study Goal**	**Type of Drone Used**	**Type of Sensors Used**	**Type of Software Used**
Engineering	Construction 1/9	Usability assessment of drone technology as safety inspection tools. Irizarry et al. [17]	2012	To see if using drones is beneficial in a construction site where it is known to be dangerous.	Aerial quadcopter.	- Camera being able to record and take photos.	- An iPad and iPhone. - A software to switch the views between bottom and front cameras and an emergency reset button to turn the drone's motors off.
Engineering	Construction 2/9	Utilizing drone technology in civil engineering. Tkáč and Mésároš [18]	2019	It reviews the types of drones that can be used in civil engineering and their components. It mentions the benefits of how drones can be used.	Mentions 4 types of drones that can be used in civil engineering: fixed wing drones; multi rotor drones; single rotor drones; and fixed wing hybrid VTOL drones.	- Integration of laser scanning and aerial photogrammetry. - Remote Monitoring and Progress Reports. - Equipment Tracking and Automating. - Surveys of buildings and landscapes. - Topographic Mapping. - Thermal Imaging recording.	N/A
Engineering	Construction 3/9	Site inspection drone: A solution for inspecting and regulating construction sites. Ashour et al. [19]	2016	The study created their own drone and experimented with it to see if it could inspect a construction site.	Site Inspection Drone (SID).	- IR camera - Range finder - RBG camera - Depth sensor	N/A
Engineering	Construction 4/9	A review on potential applications of unmanned aerial vehicles for the construction industry. Dastgheibifard and Asnafi [20]	2018	Identifying benefits and applications of drone usage in the construction industry.	UAV	N/A	3D mapping

Table 1. *Cont.*

Engineering	Construction 5/9	Utilization of Drone Technology to Improve Tower Worker Safety and Productivity. Ciarletta [21]	2017	The aim was to see if rates of injury or death of inspectors could be reduced if drones were used in their place and what benefits they have.	UAV drone	-	Imagery and videos	GPS
Engineering	Construction 6/9	UAS4SAFETY: The potential of unmanned aerial systems for construction safety applications. Gheisari et al. [22]	2014	It aims to see if drones can be used in a live construction site by experimenting with a drone and seeing what people prefer.	A.R Drone	-	Cameras	N/A
Engineering	Construction 7/9	Unmanned aerial vehicles in construction and worker safety. Howard et al. [23]	2018	The aim of the study is to understand how UAVs can be used in the construction industry as well as the hazards they bring.	UAV	N/A		N/A
Engineering	Construction 8/9	UAS-BIM based real-time hazard identification and safety monitoring of construction projects. Alizadehsalehi et al. [24]	2017	This study aims to improve safety during construction and pre-construction phases by integrating BIM, data capturing and drone technology. In their paper, they present a framework for monitoring construction safety in real-time in an accurate and an approximate manner.	Remotely Piloted Vehicle (RPV), Remotely Operated Aircraft (ROA), Remote Controlled (RC) Helicopter, Unmanned Vehicle Systems (UVS) and Model Helicopter.	N/A		GPS

Table 1. *Cont.*

Engineering	Construction 9/9	Virtual Design Review and Planning Using Augmented Reality and Drones Sreeram et al. [25]	2018	The aim of this study is experimenting with a combined model of Augmented Reality and Drones in order to provide design review and planning beforehand constructing, where human access is difficult and not safe all the time.	UAV	N/A	Unity and Maya
Engineering	Mining Industry 1/3	Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry. Lee and Choi [26]	2016	It considers whether drone technology is beneficial in the mining industry.	- UAV with fixed wings. - Fixed-wing UAV with a triangular glider. - UAV with rotary wings.	- Infrared thermal imaging camera. - RGB camera - Infrared camera - Laser scanner	3D geological modelling
Engineering	Mining Industry 2/3	A comprehensive review of applications of drone technology in the mining industry. Shahmoradi et al. [27]	2020	The aim of the study is to review the different drones being used in the mining industry as well as their applications.	Mentions some types of drones being used in the mining industry: - Fixed-wing and rotary-wings drones - Multirotor - Helium gas balloon	Mentioned sensors: - Infrared sensors - RGB Sensors - Stereo Cameras - Laser Range Finders - Ultra-Wideband Radar - Hyperspectral Sensors - Magnetic Sensors - Visible and Near-Infrared Spectral Range - Air Quality Sensors - Ultrasonic sensors	N/A

Table 1. *Cont.*

Engineering	Mining Industry 3/3	A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry. Stroud and Weinel [28]	2020	The study examines how maintenance workers perceive the integration of drone technology into the steel industry in European countries.	N/A	N/A	N/A
Engineering	Smart Cities 1/2	The drone-following models in smart cities. Dung and Rohacs [29]	2018	The study reviews different models that follow drones, especially with their increasing use in smart cities.	- Markov drone - SD models	N/A	N/A
Engineering	Smart Cities 2/2	Drones for good in smart cities: a review. Khan et al. [30]	2018	In the last few decades, the term drone is rarely used without mention of combat or target killing. As with all technologies and innovations, their value depends on their use and who is using them. Drones have only been associated with military applications. The paper notes other safe ways for drones to be used, especially in a smart city.	UAV	N/A	N/A

Table 1. *Cont.*

(b). Environment & Urban							
Environment & Urban	Environmental Monitoring 1/3	Fast and safe gas detection from underground coal fire by drone fly over. Dunnington and Nakagawa [31]	2017′	The study aims to see if a gas sensor mounted on a drone is as effective as physical sample-taking or as effective as sensors mounted in the ground. It wanted to see if the drone with the sensor could produce similar results to other sensors and other research in the area.	N/A	- Gas sensor technology includes infrared, electrochemical, catalytic, metal oxide, conductive polymer and terahertz spectrometry - Dragger X-am 5600- senses gas and was mounted on the drone	N/A
Environment & Urban	Environmental Monitoring 2/3	Drone applications for environmental management in urban spaces: A review. Gallacher [32]	2016	It tries to review if drone usage is acceptable in environmental management, looking at urban spaces in particular.	Micro drones	Aerial sensing: Electromagnetic spectrum (visible light, infrared, ultraviolet), Atmospheric composition, Data collection from detached sensors (e.g., camera traps, sound recorders, animal tracking devices).	- Delivery - Broadcast—Dispersal of liquids, gases, or particulates over a wider area. Retrieval—Collection of samples for later analysis.
Environment & Urban	Environmental Monitoring 3/3	UAV for surveillance and environmental monitoring. Sharma et al. [33]	2016	It reviews how drones, and their applications, can be used to monitor an environment. It is more of a literature review.	- Quadcopter - Multirotor	- Radio Transceiver - Temperature and smoke sensor	- Flight controller - Brushless direct current motors - Lithium Polymer Batteries - Video telemetry - Data telemetry R.F. module - GPS - Electronic speed controller

Table 1. *Cont.*

Environment & Urban	Urban Management 1/2	Drone flight planning for safe urban operations. Besada et al. [34]	2020	The paper researches an unmanned traffic management system that is used to collaboratively plan flights considering traffic constraints and limitations.	- Parrot drone - Pixhawk or Ardupilot autopilots	Tactical conflict detection and resolution process- checks for potential future loss of the drone separating from their intended flight plan, etc.	Unmanned Traffic Management program, or the European U-Space concept from SESAR program Mapping information using google maps is downloaded into drones
Environment & Urban	Urban Management 2/2	Pedestrian and bicycle volume data collection using drone technology. Kim [35]	2020	The aim of the study is to see if drones can differentiate between pedestrians and bicycles and if they can be used to notify people of conflicts. It consider how they can be used for future planning of roads.	DJI Phantom 4 Pro drone	N/A	- Aerial imagery - Three-axis gimbal stabilized camera with a wide-angle lens and 4k videos
Environment & Urban	Traffic Management 1/3	Applications of unmanned aerial vehicles (UAV) in road safety, traffic, and highway infrastructure management: Recent advances and challenges. Outay et al. [36]	2020	This was a detailed literature review giving a history on drone usage in road safety, traffic, and highway infrastructure management.	UAV	N/A	N/A
Environment & Urban	Traffic Management 2/3	Unmanned Aircraft System traffic management: Concept of operation and system architecture. Jiang et al. [37]	2016	The study does a literature review, seeing if unmanned drones can be used to organise traffic.	UTM (Unmanned traffic management drone)	Ground based radar	- GPS - TCAS (a collision system)

Table 1. *Cont.*

Environment & Urban	Traffic Management 3/3	Drone-assisted multi-purpose roadside units for intelligent transportation systems. Saputro et al. [38]	2018	The paper proposes the use of autonomous drones to assist first responders in ITS scenarios by providing an RSU that serves multiple purposes.	Flying RSU	- IEEE 802.11p is the core communications technology - A public LTE coverage		Swarm aerial proxy control
(c). Public								
Public	Security Organization/ First Responders 1/3	Unmanning the police manhunt: Vertical security as pacification. Wall [39]	2013	It notes the use of drones from armies to comestic use to being used by the police in public spaces within the US. It notes issues stopping domestication such as the Federal Aviation Administration, which blocked widespread access to both public and private spaces for the use of national airspace. It notes the benefits of the usage of drones to ensure effective security	- Civil and commercial UAVs - Honeywell T-Hawk drones - Shadow hawk - Wasp III - US Predator drone	Scope technologies tracking devices, geospatial satellite-tracking devices, Closed-Circuit Television		N/A

Table 1. *Cont.*

Public	Security Organisation/ First Responders 2/3	Using public network infrastructures for UAV remote sensing in civilian security operations. Daniel and Wietfeld [40]	2011	Many new application areas, such as in-depth reconnaissance and surveillance of major incidents, can be realized on this basis. The article reviews the current state of the art and research activities related to UAV communication.	Civilian concepts of operations (CONOPS) for UAV	CBRN detection	ISM-based Air-to-Air (A2A) Links - 3D-visualization, UI for decision support and route planning
Public	Security Organisation/ First Responders 3/3	A Survey on Robotic Technologies for Forest Firefighting: Applying Drone Swarms to Improve Firefighters' Efficiency and Safety. Roldán-Gómez et al. [41]	2021	The study aims to see if drone usage is beneficial for firefighters and if they support it.	Quadcopter drone has a Size and weight: No more than 1600 × 1600 × 800 mm unfolded and 15 kg including drone and payload.	Surveillance and monitoring sensors	Navigation: Fusion of IMU measurements, visual odometer and GPS/GLONASS/GALILEO signal. - A GNSS receiver
Public	Public Security 1/8	Drone-assisted public safety networks: The security aspect. He et al. [42]	2017	The study looked at how to use UAVs for the public safety network, their benefits, and the risk of something going wrong.	Traditional UAVs	- GPS - Wireless sensor networks (WSNs) and mobile ad-hoc networks (MANETs). - Equipped with sensors to monitor parameters in the environment in order to search for specific items.	Communication modules

Table 1. *Cont.*

Public	Public Security 2/8	Drone-assisted public safety wireless broadband network. Li et al. [43]	2015	Its purpose is to propose a drone-assisted multi-hop device-to-device (D2D) communication program as a way to extend network coverage over areas where it is hard to deploy a land-based relay.	Drone-assisted multi-hop D2D communication	N/A	Communication
Public	Public Security 3/8	A study on auto patrol drone development for safety management. Kwon et al. [44]	2017	This paper wants to see if drones can be used to reduce crime rates.	Fixed-wing, multi-rotor, and hybrid Quadcopter-based auto patrol drone.	LED sensor	Arduino platform based APM board - GPS
Public	Public Security 4/8	Beach safety: can drones provide a platform for sighting sharks? Butcher et al. [45]	2019	The purpose of this study is to determine whether drones can reliably detect shark analogues in the water across a range of environmental conditions on New South Wales beaches.	Standard multirotor drone (DJI Inspire 1)	- Vibration absorbing board and a circular polarising filter (ProMaster Digital HGX CPL–46 mm)	- DJI Zenmuse X5 camera (DJI MFT 15 mm F/1.7 ASPH lens)
Public	Public Security 5/8	Malicious UAV Detection Using Integrated Audio and Visual Features for Public Safety Applications. Jamil et al. [46]	2020	The study researches different ways to detect UAVs that are being used illegally and criminally.	UAV	- Detection sensors - Image sensors	- AlexNet: extracting features for images - Support Vector Machine - Malicious UAV Detection - Mel Frequency Cepstral coefficients

Table 1. *Cont.*

Public	Public Security 6/8	Survey of Drone Usage in Public Safety Agencies. Nguyen et al. [47]	2020	The aim of the study is to understand what first responders who use UAVs, as well as civilians, understand using this technology.	UAV	N/A	N/A
Public	Public Security 7/8	Security analysis of drone's systems: Attacks, limitations, and recommendations. Yaacoub et al. [48]	2020	A comprehensive review of the different aspects of drones' cyber-security is presented in this paper, including two main aspects: drones' security vulnerabilities and the security concerns associated with compromised drones. They discuss countermeasures for securing drone systems and detecting malicious ones.	- Drone-to-Drone (D2D), Drone-to-Ground Station (D2GS), Drone-to-Network (D2N), and Drone-to-Satellite (D2S). - Multi-Rotor Drones - Fixed-Wing Drones - Hybrid-Wing Drones	N/A	- Evading Radar-Detection - Anomaly-Based Detection - Signature-Based Intrusion Detection
Public	Public Security 8/8	Key technologies and system trade-offs for detection and localization of amateur drones. Azari et al. [49]	2018	The study gives a summary on how to detect amateur drones.	Amateur dronesSurveillance Drones	- Passive RF sensing and detection	N/A

Table 1. *Cont.*

Public	Mega & Sporting Events 1/2	Drone ambulance for outdoor sports. Kumar and Jeeva [50]	2017	The purpose of this paper is to provide first aid for injured sportsmen while participating in outdoor activities using drones, in addition to preventing fire accidents during outdoor sporting events. Drones are usually used to accomplish this.	- The fixed wing And Multi rotary wing - The method used a combination of the drones above called HYBRID wing model	- GPS - Thermal and smoke sensors	Thermal camera and GIMBAL camera
Public	Mega & Sporting Events 2/2	The use of drones in organizing the Olympic Games. Nadobnik [51]	2016	This paper explains how modern technology is being used to organize mass sporting events, with a particular focus on Unmanned Aerial Vehicles (drones) during events such as the Olympic Games.	- Quadcopter, hex copter or octocopter - Hermes 900: US-Israeli made drone - Dragan Flyer X4-ES16 - Titan Aerospace	- Infrared light sensor	- Cam recorders and camera - GPS
				(d). Healthcare			
Healthcare	COVID-19 1/3	How drones can help fight the coronavirus. Skorup and Haaland [52]	2020	The aim of the study is to see how drones can be helpful in encouraging social distancing and reduce human to human contact.	N/A	N/A	N/A

Table 1. *Cont.*

Healthcare	COVID-19 2/3	Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems? Euchi [53]	2021	With a pandemic going on, the study wishes to understand if drones can aid its treatment. It provides a detailed summary.	UAV	Thermal sensors	N/A
Healthcare	COVID-19 3/3	Containing the COVID-19 pandemic with Drones-Feasibility of a drone enabled back-up transport system. Kunovjanek and Wankmüller [54]	2021	The aim of the study is seeing if drones are feasible as a way to reduce the risk of infection.	Their approach relied on the retrofitting of drones of private owners and public institutions (e.g., disaster management agencies, non-governmental organizations, etc).	N/A	N/A
Healthcare	Healthcare & Medicine 1/3	Drones in medicine—the rise of the machines. Balasingam [55]	2017	It notes the benefits and limitations of drones in the medical sector.	N/A	- Imaging - GPS	N/A

Table 1. *Cont.*

Healthcare	Healthcare & Medicine 2/3	5G communication: an overview of vehicle-to-everything, drones, and healthcare use-cases. Ullah et al. [56]	2019	This paper examines 3 major use-cases of 5G: V2X communication, drone communication, and healthcare. The aim is to identify which use-case is most challenging for future research. Their discussion of V2X networking was followed by discussions of V2V, V2P, V2I, and IV networking, as well as their applications.	Single UAV Multiple UAV	V2X communication Vehicle-to-infrastructure (V2I)	Vehicle on-board unit (OBU), Roadside Unit (RSU), and a safe communication channel. Radio transceiver Night-time pedestrian detection infrared sensors. GPS, audio and visual entertainment, and on-board internet facilities
Healthcare	Healthcare & Medicine 3/3	Drone transport of microbes in blood and sputum laboratory specimens. Amukele et al. [57]	2016	The aim of the study is to see if microbiological specimens could be transported with unmanned aerial vehicles.	Small fixed-wing aircraft (Aero, 3D Robotics, Berkeley, CA)	N/A	N/A
Healthcare	Disaster Relief 1/4	Humanitarian Drones: A Review and Research Agenda. Rejeb et al. [58]	2021	This study seeks to improve the understanding of current tools and technologies that humanitarian organizations can use to support efficient and effective rescue interventions by systematizing the growing but still limited literature on drones.	UAV	N/A	N/A

Table 1. *Cont.*

Healthcare	Disaster Relief 2/4	Towards "drone-borne" disaster management: future application scenarios. Tanzi et al. [59]	2016	Various humanitarian relief scenarios are discussed in the paper. Also, the article examines possible issues that may arise in such scenarios. The authors examine recent experiments to determine whether autonomous flight operations have inherent advantages, both on a lone basis and in formation. After sketching out an embedded security architecture and its specific hardware capabilities, the question of autonomy is discussed.	Sense fly - Blimps - Fixed wing drones - Vertical axis drones	Optical sensors - Tele detection - Light Detection and Ranging (LIDAR) - EM detection	- Conveying messages using a Disruption Tolerant Network (DTN) technique - GPS - Cognitive module, providing basic Artificial Intelligence algorithms
Healthcare	Disaster Relief 3/4	Generating evacuation routes by using drone system and image analysis to track pedestrian and scan the area after disaster occurrence. Maher and Inoue [60]	2016	The purpose of the study is to see if drones can be used to help with disaster events. The study aims to see how a drone will act when tasked with finding humans, such as victims that are hard to find such as being under rubble, or in tracking different people if they are running away from danger and are lost.	AR Drone	- HD Camera. 720p 30 fps and 60 fps vertical QVGA camera - Ultrasonic sensors	Fully reprogrammable motor controller, water resistant motor's electronic controller

Table 1. *Cont.*

Healthcare	Disaster Relief 4/4	A remotely piloted aircraft system in major incident management: concept and pilot, feasibility study. Abrahamsen [61]	2015	In pre-hospital environments, rotor-wing drones can transport tools and audiovisual equipment, and can serve as flying platforms for sensors and audiovisual equipment. This paper introduces the ways a drone can be used in a hospital setting, as well as what it can do in major incidents to reduce injury of the search and rescue teams as well as finding victims quickly. There are many ethical issues.	Remotely controlled multirotor unmanned aerial vehicle Rotor-wing RPA. The RPA was propelled by six standard brushless electric (DC) rotors. The rotor span was 84 cm and maximum take-off weight was 3 kg.	- Flight control was mixed manual (remote control (RC)) and autonomous (autopilot) - Global Positioning Module - Laser, release hook, searchlight	Aerial imagery and remote sensing Video camera Avalanche beacon

3. Findings from SLR

As highlighted in the methodology section for the systematic review findings, in Table 1, essential items were included to enable the achievement of the goal of this study. It starts with identifying the drone application sector, industry of use, study title and authors, year of publication, study goal, type of drone used, type of sensors used, type of software used, and finally, the key outcomes from the study were listed following each.

From Table 1, the key findings from SLR(a) on drones' applications for security and safety within the engineering sector can be summarized as follows:

- Drone technology has a range of applications in different industries, including construction, mining, and urban development. In construction, drones can make managers' safety inspections easier by providing real-time footage and pictures, and by spotting hazards much quicker than human inspectors [17]. Drones can also improve worker safety by performing tasks that are hard for them to do, such as mapping areas and using thermal imagery to ensure site stability, and they can save time and money for those who use them [18].
- However, more work and research are required to use drones on a daily basis and outside of a controlled environment, and the hazards associated with drones have not been thoroughly researched [19,23]. Nevertheless, participants in studies found the benefits of drone usage to be positive and preferred the clear view it provided [22,28].
- In the mining industry, drones can help with the challenges faced by workers [26], but some types of drones and sensors face challenges, which suggests more research on alternative drone usage is needed [27]. In construction, the use of the 4D (3D + Schedule) BIM-based model system can mitigate accidents and fatalities during construction by following regulations and improving safety for all stakeholders [24].
- The proposed system of augmented reality (AR) and drones can provide safety for difficult and dangerous access for humans and modify and perform different operations for the models created by the system [25].
- In urban development, smart cities are turning to technology, including drones, to improve their quality of life, accommodate new residents, and offer benefits such as package delivery, policing, traffic monitoring, and ambulance drones [30].
- Overall, drone technology has a variety of applications in engineering sector, and while more research is needed to address the hazards and improve daily usage, their benefits cannot be overlooked.

From Table 1, key findings from SLR(b) for drones' applications for security and safety within the environment and urban sector can be summarized as follows:

- Drones have proven to be useful in a variety of applications, including environmental monitoring and gas detection. In one study, drones equipped with gas monitors accurately determined the amount of gas released from known sites [31]. However, it is important to consider the potential risks associated with drone usage. While drones can aid in management, it is necessary to determine if their benefits outweigh the risks [32].
- One advantage of using drones for environmental monitoring is the ability to install sensors and software specific to certain tasks, such as monitoring ground movement. This not only provides a more comprehensive view but also increases human safety and reduces the need for physically demanding work [33].
- Drone control systems offer users the ability to manually fly the drone or set waypoints that conform to a desired trajectory. Google Maps can be used to ensure the drone stays on course and does not pose a danger to those on the ground [34].
- While drones have shown promising results in various applications, more research is needed, particularly in active environments such as roads outside of university campuses. Researchers have also identified the potential for drones to identify conflicts [35].

- As the popularity of drones continues to increase, it is necessary to study their long-term impact on infrastructure and transportation. Additionally, achieving unmanned aircraft traffic management within the next five years could enhance economic growth while maintaining privacy for those not involved in drone operations [36].
- One proposed application for drones is a swarm of autonomous drones that can assist first-responders from multiple organizations. Researchers plan to study path selection mechanisms to reduce end-to-end delay using a wireless mesh network [38].

From Table 1, key findings from the systematic literature review on drones' applications for security and safety within the public sector can be summarized as follows:

- With the rise of police drones, the radical asymmetry between the techniques of the hunters and the hunted becomes more apparent, bringing this relationship of dominance even more to the forefront, in a similar but even more dramatic fashion than SWAT teams and armored vehicles. This unmanning of the police manhunt is but the newest symbol of the pacification project that the poor and oppressed have been living and dying under. Pacification, however, always assumes populations that resist and is, therefore, never a completed project [39].
- For homeland security missions, UAV requirements and preliminaries are largely different from those for military operations. UAVs transmit telemetry and payload data using frequencies that are not owned by homeland security agencies. As fire and police departments have limited funding, cost is also a major concern for them. On the other hand, the requirements for payload weight, operating conditions, and ranges are relatively lax. Work on getting past these issues is needed [40].
- Firefighters support the use of drones due to their benefits, and future work should consider using drones in a real fire situation to see if they are still functional or beneficial [41]. UAVs will be beneficial for the network, but more research on how to solve issues is needed [42]. One study notes how useful or strong the communication capability of the drone is. The study proposes that the D2D drone's communication be extended to the wireless coverage of the public safety network [43]. Another study found that the drone was useful in tracking targeted people and worked well in the field. However, some issues came up that would need to be studied further to ensure they do not happen again in the field [44].
- Drones are shown to be a valuable tool for detecting sharks in one study, meeting increasing demands for better protection while remaining minimally destructive to marine life. Drones are useful in notifying staff and lifeguards when a shark has been spotted, making evacuation quicker [45]. It is important to understand people's perception of this technology. Many of the people using this technology were pilots, army members, and first responders such as firefighters [47].
- Drones provide users with a bird's eye view that can be used almost anywhere and at any time. In recent years, however, criminals and cybercriminals have begun to use drones maliciously [48]. Using surveillance drones is one way to detect amateur drones and is cost effective. More research on how to maximize the time and energy of the drone is needed [49].
- In sports, typically 80% of injuries are sprains, cramps, and abrasions. Drones equipped with Elide-brand fire extinguishable balls are used to stop fires during such accidents as soon as possible. Organizers of sports events can provide athletes with medical support with the aid of the solution presented here as quickly as possible. This is due to how effective drone usage is in ensuring the safety of athletes should an emergency occur [50].
- While humans could be replaced by robots and computers in jobs requiring physical exertion in hazardous conditions, automation can negatively impact the job market and can change people's behavior, such as how they spend their free time. Technology during sports is viewed negatively when it engages in unacceptable, unjudged behavior defined as abusing modern technological solutions, commonly known as

"technology doping." A German competitor's bicycle was found to have an electric engine in its frame in Heusden-Zolder in 2016 [51].

From Table 1, key findings from SLR(d), for drones' applications for security and safety within healthcare sector can be summarised as followed:

- The United States faces a major challenge with drone companies. FAA regulations are causing limitations on drone operators, whether large or small. It is not possible to access some airspace. If cities and states released their aerial easements, that would be helpful. Medical innovation is encouraged by drones, which enhance supply logistical efficiency. Switzerland, Rwanda, and China all have drone delivery networks in place. In many hard-to-reach areas of the United States, there are several companies and organizations that can provide medical care and mail. Due to their top speed of 60 to 100 mph, drones can shorten supply chains since they don't need to navigate through traffic. Since drones deliver goods directly to rural homes instead of distribution centres, they could also in-crease social distance. By downloading an app, you can have the grocery store employee's load up your items and send them back to you [52].
- Drones are useful in aid of the healthcare sector. However, as this may be the first-time drones have been used during a pandemic, more research is needed [53]. Drone use will reduce human contact. This will reduce rates of infection and those who die from COVID 19. Nurses and doctors as well as patients will be safer [54]. Despite regulation issues, drones are a useful technology to use [55].
- By utilizing surgical robots to maintain high quality care, the healthcare system in Europe will operate at a much higher performance and cost-effectiveness. The operator should be close to the remote site in order to reduce performance degradation caused by large latencies. 5G technology would reduce latency issues, making mobile robotic surgery more accessible. This paper also presents a data sharing mechanism and personalized data analysis model for 5G-Smart Diabetes. A cyber-physical healthcare system allows the recognition of a patient's condition at the first step of a fully digitized remote healthcare system. ML is used in a multi-layer framework that consists of many low-cost lightweight devices. 5G technology makes it possible to establish virtual hospitals via a communication channel, offering a variety of services [56].
- Researchers found that the drone transportation system tested in this study had no negative effects on the growth times of sample types or microbes. All microbes studied showed similar recovery times, colony counts, and morphologies [57]. These findings contribute to the development of future research directions for humanitarian drones, their performance outcomes, and their respective barriers. In this study, we analyze potential humanitarian applications of drones, and we present a comprehensive agenda to structure and guide future research on this topic [58].
- Drone usage in disaster areas is beneficial as it keeps people safe. In conclusion, they provide an example of how UAVs can be used to aid rescue teams in detecting and observing. This approach is nonetheless promising, both technically and operationally, in enhancing disaster management efforts. Search and rescue can benefit from drone use in a variety of ways. They are more likely to become a burden if they cannot function autonomously and independently [59]. Drones are capable of tracking people after implementing software and training them to move left or right to follow the person. Their durability makes them effective against falling debris or shaking of the ground. They are not perfect as their durability does need more work, as well as there being a need to implement programs where the drone, once it detects trouble, immediately moves out of the way to stay safe and keep tracking people. Overall, the use of drones in a disaster area is beneficial [60].
- Despite its limited payload capacity, wind speed, and flight endurance, small, remotely piloted aircraft can be used as effective tool carriers. A major incident scene can be assessed, and information exchanged using remote sensing using RPA technology already in use in pre-hospital settings. Future work on real-time video footage from

an incident is important as it will allow decision-makers and situational analysts to assess [61].

4. Findings from Meta-Analysis

Figure 2 demonstrates the numbers of papers that have been taken place in the safety applications of drones to each theme—Engineering, Environment & Urban, Public, and Healthcare—during the last 10 years from 2011 to 2021. We considered the safety applications of drones of each theme—Engineering, Environment & Urban, Public, and Healthcare—during the last 10 years from 2011 to 2021. As the diagram shows, most of the selected papers to this research have been published just from the last 5 years of this study, while in the first 5 years are just a few papers from different themes.

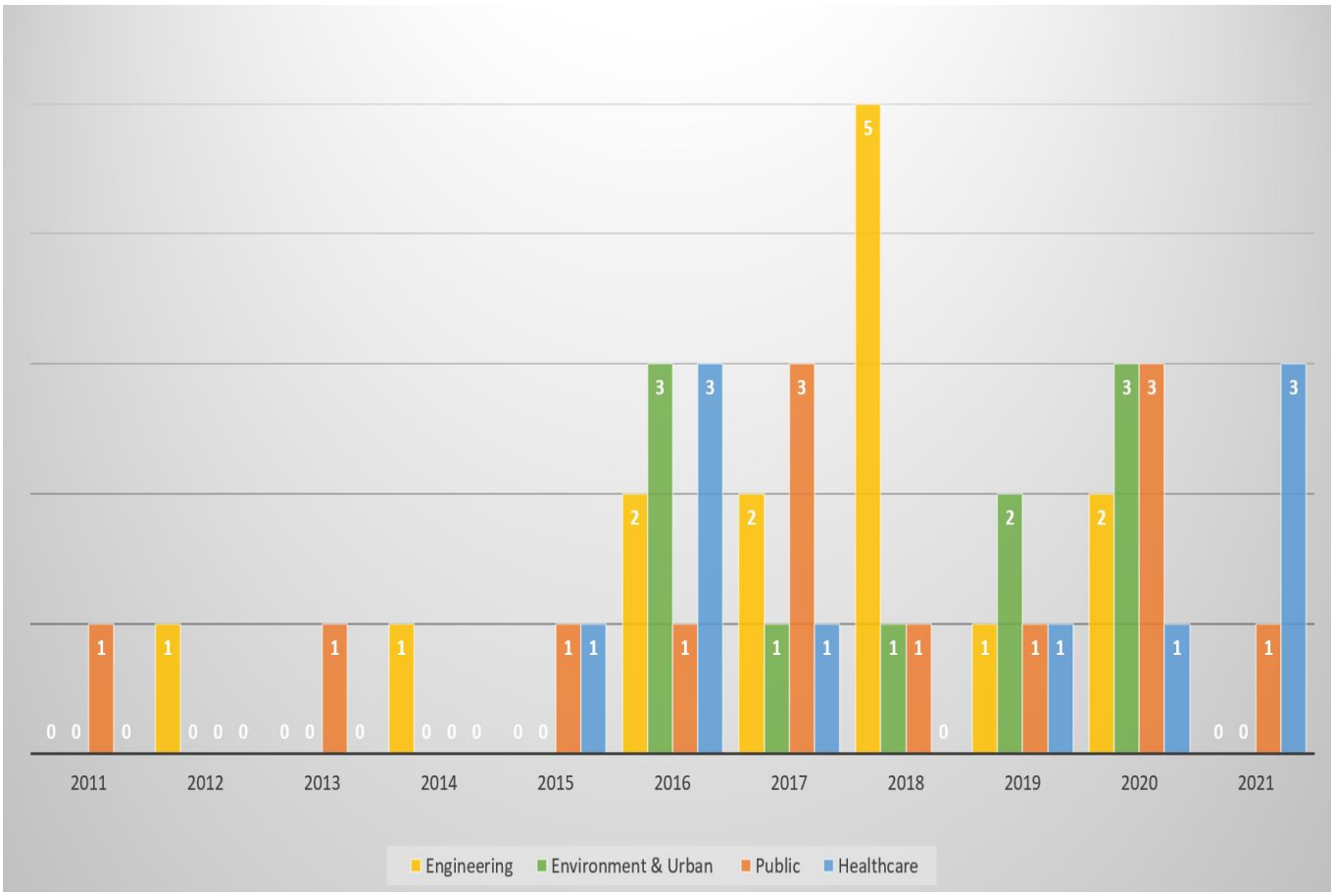

Figure 2. Number of Papers to Each Theme from 2011 to 2021.

Figure 3 illustrates the percentage of each theme that has taken place in the safety applications of drones. The table on the right-hand side is an illustration showing the percentage of each industry in each theme, where the colours refer to each theme. The Engineering and Public themes have more focus on this research in comparison with the Environment & Urban and Healthcare themes.

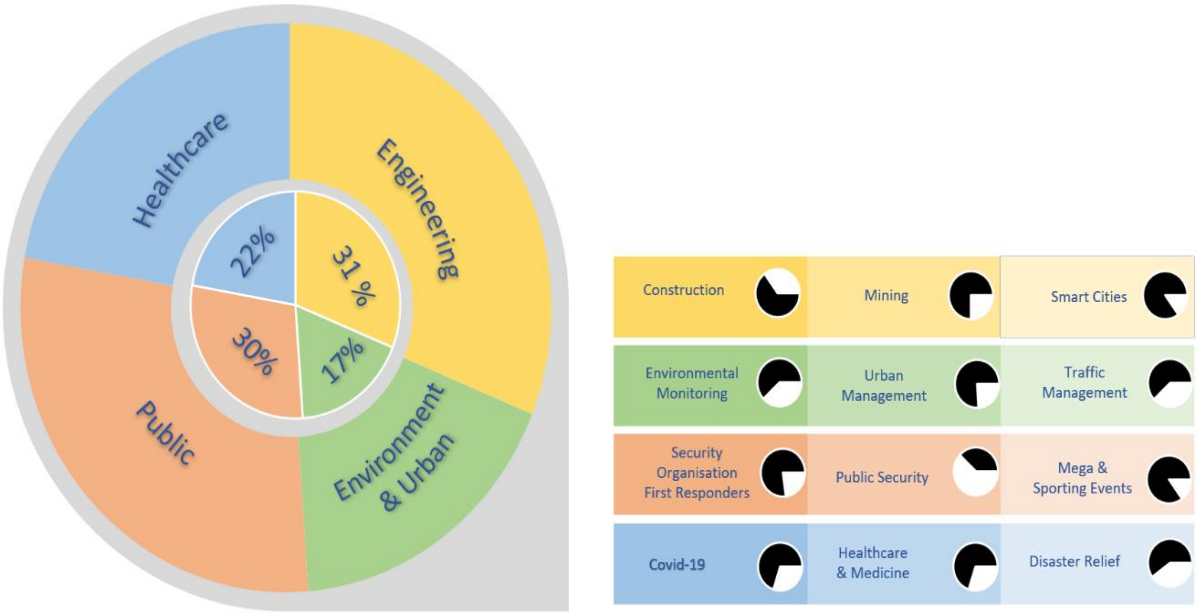

Figure 3. Percentage of Each Drones Application Theme.

The pie charts in Figure 4, generated from Appendix A (Table A1). present the proportion of papers or studies that used drones with Basic Sensor GPS/Camera, Advance Sensor, and Advance Software in their research. As the diagrams show 71% of the involved studies in this research used the Basic Sensor as GPS and 64% of them used the Basic Sensor as a Camera. 51% of the involved studies used Advanced Sensors and 56% used Advance Software.

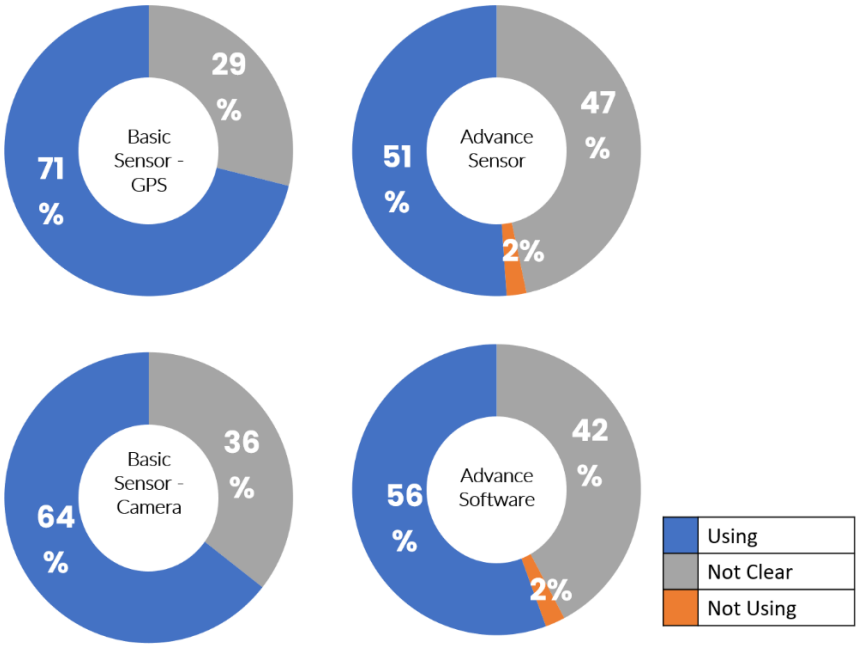

Figure 4. Percentage of Papers that are using Advanced/Basic Sensors and Software.

5. Discussion

The outcomes of this systematic review clearly revealed that drones have great potential within the safety and security applications in different industries, as appears from the great increase in number of publications within the last 5 years of this study. Moreover, the analysis revealed that the majority of applications have used the global positioning

system as the means of location sensor and camera in their system. Meanwhile, over 50% of the applications have extended to include advanced sensors and software to enable advanced applications. Furthermore, the systematic analysis revealed that there are two key areas which still have a limited number of publications or research papers, which are smart cities and mega sporting events. Figure 5 shows the comprehensive applications of drones in safety and security matters in Healthcare, Engineering, Public and Environment, and Urban units. In the field of drone technology, it is important to remember that drone technology is still evolving. Despite the endless opportunities they offer, challenges are still to be met to ensure the safe, secure, and effective deployment of drone applications in real life [62]. This includes various important aspects, such as privacy and security concerns [63,64] and energy restrictions of the battery on board [65]. Moreover. to ensure the safe and effective integration of unmanned aerial vehicles (UAVs) into global airspace, it is necessary to establish civilian UAV deployment frameworks in accordance with the global efforts endorsed by the International Civil Aviation Organization (ICAO) [66].

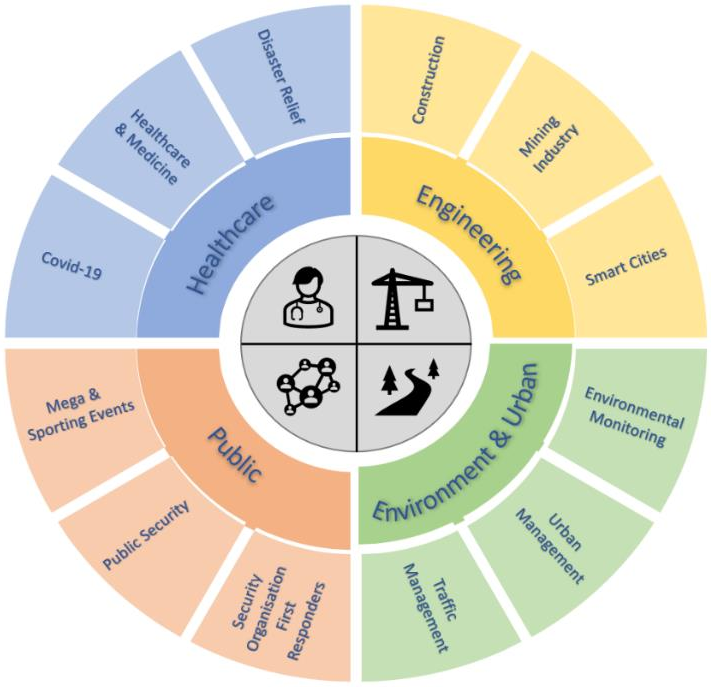

Figure 5. Drones Themes in Safety and Security Applications.

6. Conclusions

The main goal of this study was to conduct a systematic review of published papers from 2011 to 2021 in order to identify possible applications for drones in the areas of safety and security. It was clear from the systematic review that there is great potential for drone applications starting to emerge, mainly during the past five years, in these two domains across a wide range of sectors and industries. The study also revealed that drones need to be equipped with specific sensors and software to achieve such applications. Hence, further research is required to focus is needed to establish standards for safety and security a drones-based applications. The outcomes from this paper will be very useful in different ways, such as supporting further research and enabling stakeholders to use one paper as an index for 45 documents, allowing them to explore those applications further. The search was limited within the scope of the pre-identified systematic review criteria. It would be useful for future research to expand and identify key requirements for drone applications in safety and security in each sector.

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

Appendix A

Table A1. Industry-Based Sensors.

Sector	Industry	Study	Basic Sensor						Advanced Sensor			Advanced Software		
			GPS			Camera								
			Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear
Engineering	Construction 1/9	Usability assessment of drone technology as safety inspection tools.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		
Engineering	Construction 2/9	Utilizing drone technology in civil engineering.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Engineering	Construction 3/9	Site inspection drone: A solution for inspecting and regulating construction sites.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Engineering	Construction 4/9	A review on potential applications of unmanned aerial vehicles for the construction industry.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		
Engineering	Construction 5/9	Utilization of Drone Technology to Improve Tower Worker Safety and Productivity.	GPS **Yes**			Camera **Yes**			Ad-Software **No**			Ad-Software **No**		
Engineering	Construction 6/9	UAS4SAFETY: The potential of unmanned aerial systems for construction safety applications.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Engineering	Construction 7/9	Unmanned aerial vehicles in construction and worker safety.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Engineering	Construction 8/9	UAS-BIM based real-time hazard identification and safety monitoring of construction projects.	GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		

Table A1. *Cont.*

Sector	Industry	Study	Basic Sensor						Advanced Sensor			Advanced Software		
			GPS			Camera								
			Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear
Engineering	Construction 9/9	Virtual Design Review and Planning Using Augmented Reality and Drones	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		
Engineering	Mining Industry 1/3	Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Engineering	Mining Industry 2/3	A comprehensive review of applications of drone technology in the mining industry.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Engineering	Mining Industry 3/3	A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Engineering	Smart Cities 1/2	The drone-following models in smart cities.	GPS **Not Clear**			Camera **Not Clear**			**Not Clear**			Ad-Software **Not Clear**		
Engineering	Smart Cities 2/2	Drones for good in smart cities: a review.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Environment & Urban	Environmental Monitoring 1/3	Fast and safe gas detection from underground coal fire by drone fly over.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Environment & Urban	Environmental Monitoring 2/3	Drone applications for environmental management in urban spaces: A review.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Environment & Urban	Environmental Monitoring 3/3	UAV for surveillance and environmental monitoring.	GPS **Yes**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Environment & Urban	Urban Management 1/2	Drone flight planning for safe urban operations.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Environment & Urban	Urban Management 2/2	Pedestrian and bicycle volume data collection using drone technology.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		

Table A1. *Cont.*

Sector	Industry	Study	Basic Sensor						Advanced Sensor			Advanced Software		
			GPS			Camera								
			Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear
Environment & Urban	Traffic Management 1/3	Applications of unmanned aerial vehicles (UAV) in road safety, traffic, and highway infrastructure management: Recent advances and challenges.			GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**
Environment & Urban	Traffic Management 2/3	Unmanned Aircraft System traffic management: Concept of operation and system architecture.			GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Yes**
Environment & Urban	Traffic Management 3/3	Drone-assisted multi-purpose roadside units for intelligent transportation systems.			GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Yes**
Public	Security Organization/ First Responders 1/3	Unmanning the police manhunt: Vertical security as pacification.			GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Not Clear**
Public	Security Organisation/ First Responders 2/3	Using public network infrastructures for UAV remote sensing in civilian security operations.			GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Yes**
Public	Security Organisation/ First Responders 3/3	A Survey on Robotic Technologies for Forest Firefighting: Applying Drone Swarms to Improve Firefighters' Efficiency and Safety.			GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Yes**
Public	Public Security 1/8	Drone-assisted public safety networks: The security aspect.			GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Yes**
Public	Public Security 2/8	Drone-assisted public safety wireless broadband network.			GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**
Public	Public Security 3/8	A study on auto patrol drone development for safety management.			GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Yes**

Table A1. *Cont.*

Sector	Industry	Study	Basic Sensor						Advanced Sensor			Advanced Software		
			GPS			Camera								
			Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear
Public	Public Security 4/8	Beach safety: can drones provide a platform for sighting sharks?	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Public	Public Security 5/8	Malicious UAV Detection Using Integrated Audio and Visual Features for Public Safety Applications.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Public	Public Security 6/8	Survey of Drone Usage in Public Safety Agencies.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Public	Public Security 7/8	Security analysis of drone's systems: Attacks, limitations, and recommendations.	GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		
Public	Public Security 8/8	Key technologies and system trade-offs for detection and localization of amateur drones.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Public	Mega & Sporting Events 1/2	Drone ambulance for outdoor sports.	GPS **Yes**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Public	Mega & Sporting Events 2/2	The use of drones in organizing the Olympic Games.	GPS **Yes**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Healthcare	COVID-19 1/3	How drones can help fight the coronavirus.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Healthcare	COVID-19 2/3	Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems?	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Healthcare	COVID-19 3/3	Containing the COVID-19 pandemic with drones-Feasibility of a drone enabled back-up transport system.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Healthcare	Healthcare & Medicine 1/3	Drones in medicine—the rise of the machines.	GPS **Yes**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		

Table A1. *Cont.*

Sector	Industry	Study	Basic Sensor						Advanced Sensor			Advanced Software		
			GPS			Camera								
			Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear
Healthcare	Healthcare & Medicine 2/3	5G communication: an overview of vehicle-to-everything, drones, and healthcare use-cases.	GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Healthcare	Healthcare & Medicine 3/3	Drone transport of microbes in blood and sputum laboratory specimens.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Healthcare	Disaster Relief 1/4	Humanitarian Drones: A Review and Research Agenda.	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		
Healthcare	Disaster Relief 2/4	Towards" drone-borne" disaster management: future application scenarios.	GPS **Yes**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Healthcare	Disaster Relief 3/4	Generating evacuation routes by using drone system and image analysis to track pedestrian and scan the area after disaster occurrence.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Yes**		
Healthcare	Disaster Relief 4/4	A remotely piloted aircraft system in major incident management: concept and pilot, feasibility study.	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		

References

1. Gertler, J. *US Unmanned Aerial Systems*; Library of Congress Washington DC Congressional Research Service: Washington, DC, USA, 2012.
2. Colomina, I.; Molina, P. Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS J. Photogramm. Remote Sens.* **2014**, *92*, 79–97. [CrossRef]
3. Anderson, K.; Gaston, K.J. Lightweight unmanned aerial vehicles will revolutionize spatial ecology. *Front. Ecol. Environ.* **2013**, *11*, 138–146. [CrossRef]
4. Enemark, C. *Armed Drones and the Ethics of War: Military Virtue in a Post-Heroic Age*; Routledge: Milton Park, UK, 2017.
5. Kardasz, P.; Doskocz, J.; Hejduk, M.; Wiejkut, P.; Zarzycki, H. Drones and possibilities of their using. *J. Civ. Environ. Eng.* **2018**, *6*, 3. [CrossRef]
6. NLD. NLD MOD Client. 2019. Available online: https://nolimitdronez.com/ (accessed on 5 August 2019).
7. Huang, J. *Aviation Safety Through the Rule of Law: ICAO's Mechanisms and Practices*; Kluwer Law International: Alphen aan den Rijn, The Netherlands, 2009.
8. Cai, X.; Nithyanand, R.; Wang, T.; Johnson, R.; Goldberg, I. A systematic approach to developing and evaluating website fingerprinting defenses. In Proceedings of the 2014 ACM SIGSAC Conference on Computer and Communications Security, Scottsdale, AZ, USA, 3–7 November 2014; pp. 227–238.
9. Huttunen, M. Civil unmanned aircraft systems and security: The European approach. *J. Transp. Secur.* **2019**, *12*, 83–101. [CrossRef]
10. 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]
11. Onwuegbuzie, A.J.; Leech, N.L.; Collins, K.M. Qualitative analysis techniques for the review of the literature. *Qual. Rep.* **2012**, *17*, 56. [CrossRef]

12. Dixon-Woods, M.; Bonas, S.; Booth, A.; Jones, D.R.; Miller, T.; Sutton, A.J.; Shaw, R.L.; Smith, J.A.; Young, B. How can systematic reviews incorporate qualitative research? A critical perspective. *Qual. Res.* **2006**, *6*, 27–44. [CrossRef]
13. Dixon-Woods, M.; Agarwal, S.; Jones, D.; Young, B.; Sutton, A. Synthesising qualitative and quantitative evidence: A review of possible methods. *J. Health Serv. Res. Policy* **2005**, *10*, 45–53. [CrossRef]
14. Denyer, D.; Tranfield, D. Producing a systematic review. In *The Sage Handbook of Organizational Research Methods*; Buchanan, D.A., Bryman, A., Eds.; Sage Publications Ltd.: London, UK, 2009; pp. 671–689.
15. Rother, E.T. Systematic literature review X narrative review. *Acta Paul. Enferm.* **2007**, *20*, 5–6. [CrossRef]
16. Field, A.P.; Gillett, R. How to do a meta-analysis. *Br. J. Math. Stat. Psychol.* **2010**, *63*, 665–694. [CrossRef]
17. Irizarry, J.; Gheisari, M.; Walker, B.N. Usability assessment of drone technology as safety inspection tools. *J. Inf. Technol. Constr.* **2012**, *17*, 194–212.
18. Tkáč, M.; Mésároš, P. Utilizing drone technology in the civil engineering. *Sel. Sci. Pap. J. Civ. Eng.* **2019**, *14*, 27–37. [CrossRef]
19. Ashour, R.; Taha, T.; Mohamed, F.; Hableel, E.; Kheil, Y.A.; Elsalamouny, M.; Kadadha, M.; Rangan, K.; Dias, J.; Seneviratne, L.; et al. Site inspection drone: A solution for inspecting and regulating construction sites. In Proceedings of the 2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS), Abu Dhabi, United Arab Emirates, 16–19 October 2016; pp. 1–4.
20. Dastgheibifard, S.; Asnafi, M. A review on potential applications of unmanned aerial vehicle for construction industry. *Sustain. Struct. Mater.* **2018**, *1*, 44–53.
21. Ciarletta, L.; Fejoz, L.; Guenard, A.; Navet, N. Development of a safe CPS component: The hybrid parachute, a remote termination add-on improving safety of UAS. In Proceedings of the ERTS 2016-8th European Congress on Embedded Real Time Software and Systems, Toulous, France, 27 January 2016; p. 10.
22. Gheisari, M.; Irizarry, J.; Walker, B.N. UAS4SAFETY: The Potential of Unmanned Aerial Systems for Construction Safety Applications. In *Construction Research Congress 2014: Construction in a Global Network*; HAL Open Science: Lyon, France, 2014; pp. 1801–1810. [CrossRef]
23. Howard, J.; Murashov, V.; Branche, C.M. Unmanned aerial vehicles in construction and worker safety. *Am. J. Ind. Med.* **2017**, *61*, 3–10. [CrossRef]
24. Alizadehsalehi, S.; Asnafi, M.; Yitmen, I.; Celik, T. UAS-BIM based real-time hazard identification and safety monitoring of construction projects. In Proceedings of the 9th Nordic Conference on Construction Economics and Organization, Göteborg, Sweden, 13–14 June 2017; Volume 13, p. 22.
25. Sreeram, S.; Nisha, K.K.; Jayakrishnan, R. Virtual design review and planning using augmented reality and drones. In Proceedings of the 2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 14–15 June 2018; pp. 915–918.
26. Lee, S.; Choi, Y. Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry. *Geosyst. Eng.* **2016**, *19*, 197–204. [CrossRef]
27. Shahmoradi, J.; Talebi, E.; Roghanchi, P.; Hassanalian, M. A Comprehensive Review of Applications of Drone Technology in the Mining Industry. *Drones* **2020**, *4*, 34. [CrossRef]
28. Stroud, D.; Weinel, M. A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry. *New Technol. Work Employ.* **2020**, *35*, 297–313. [CrossRef]
29. Dung, N.D.; Rohacs, J. The drone-following models in smart cities. In Proceedings of the 2018 IEEE 59th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Riga, Latvia, 12–14 November 2018; pp. 1–6.
30. Khan, M.A.; Alvi, B.A.; Safi, A.; Khan, I.U. Drones for good in smart cities: A review. In Proceedings of the 2018 International Conference on Electrical, Electronics, Computers, Communication, Mechanical and Computing (EECCMC), Vellore, India, 28–29 January 2018; pp. 1–6.
31. Dunnington, L.; Nakagawa, M. Fast and safe gas detection from underground coal fire by drone fly over. *Environ. Pollut.* **2017**, *229*, 139–145. [CrossRef]
32. Gallacher, D. Drone Applications for Environmental Management in Urban Spaces: A Review. *Int. J. Sustain. Land Use Urban Plan.* **2016**, *3*, 1–14. [CrossRef]
33. Sharma, S.; Muley, A.; Singh, R.; Gehlot, A. UAV for Surveillance and Environmental Monitoring. *Indian J. Sci. Technol.* **2016**, *9*, 43. [CrossRef]
34. Besada, J.; Campaña, I.; Bergesio, L.; Bernardos, A.; de Miguel, G. Drone flight planning for safe urban operations. Personal and Ubiquitous Computing. In Proceedings of the 2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), Kyoto, Japan, 11–15 March 2019; pp. 1–20.
35. Kim, D. Pedestrian and Bicycle Volume Data Collection Using Drone Technology. *J. Urban Technol.* **2020**, *27*, 45–60. [CrossRef]
36. Outay, F.; Mengash, H.A.; Adnan, M. Applications of unmanned aerial vehicle (UAV) in road safety, traffic and highway infrastructure management: Recent advances and challenges. *Transp. Res. Part A Policy Pract.* **2020**, *141*, 116–129. [CrossRef] [PubMed]
37. Jiang, T.; Geller, J.; Ni, D.; Collura, J. Unmanned Aircraft System traffic management: Concept of operation and system architecture. *Int. J. Transp. Sci. Technol.* **2016**, *5*, 123–135. [CrossRef]

38. Saputro, N.; Akkaya, K.; Algin, R.; Uluagac, S. Drone-Assisted Multi-Purpose Roadside Units for Intelligent Transportation Systems. In Proceedings of the 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall), Chicago, IL, USA, 27–30 August 2018; pp. 1–5. [CrossRef]
39. Wall, T. Unmanning the Police Manhunt: Vertical Security as Pacification. *Social. Stud. Études Social.* **2013**, *9*, 32–56. [CrossRef]
40. Daniel, K.; Wietfeld, C. *Using Public Network Infrastructures for UAV Remote Sensing in Civilian Security Operations*; Technical University Dortmund: Dortmund, Germany, 2011.
41. Roldán-Gómez, J.; González-Gironda, E.; Barrientos, A. A Survey on Robotic Technologies for Forest Firefighting: Applying Drone Swarms to Improve Firefighters' Efficiency and Safety. *Appl. Sci.* **2021**, *11*, 363. [CrossRef]
42. He, D.; Chan, S.; Guizani, M. Drone-Assisted Public Safety Networks: The Security Aspect. *IEEE Commun. Mag.* **2017**, *55*, 218–223. [CrossRef]
43. Li, X.; Guo, D.; Yin, H.; Wei, G. Drone-assisted public safety wireless broadband network. In Proceedings of the 2015 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), New Orleans, LA, USA, 9–12 March 2015; pp. 323–328.
44. Kwon, D.; Yoon, G.; Kim, S.Y.; Kwon, Y. A study on auto patrol drone development for safety management. In Proceedings of the International Conference on Compute and Data Analysis, Lakeland, FL, USA, 19–23 May 2017; pp. 293–297.
45. Butcher, P.A.; Piddocke, T.P.; Colefax, A.P.; Hoade, B.; Peddemors, V.M.; Borg, L.; Cullis, B.R. Beach safety: Can drones provide a platform for sighting sharks? *Wildl. Res.* **2019**, *46*, 701–712. [CrossRef]
46. Jamil, S.; Fawad; Rahman, M.; Ullah, A.; Badnava, S.; Forsat, M.; Mirjavadi, S.S. Malicious UAV Detection Using Integrated Audio and Visual Features for Public Safety Applications. *Sensors* **2020**, *20*, 3923. [CrossRef]
47. Nguyen, H.V.; Manley, T.W.; Saidi, K.S. *Survey of Drone Usage in Public Safety Agencies*; US Department of Commerce, National Institute of Standards and Technology: Gaithersburg, MD, USA, 2020. [CrossRef]
48. Yaacoub, J.-P.; Noura, H.; Salman, O.; Chehab, A. Security analysis of drones systems: Attacks, limitations, and recommendations. *Internet Things* **2020**, *11*, 100218. [CrossRef]
49. Azari, M.M.; Sallouha, H.; Chiumento, A.; Rajendran, S.; Vinogradov, E.; Pollin, S. Key Technologies and System Trade-offs for Detection and Localization of Amateur Drones. *IEEE Commun. Mag.* **2018**, *56*, 51–57. [CrossRef]
50. Kumar, G.D.; Jeeva, B. Drone ambulance for outdoor sports. *Asian J. Appl. Sci. Technol.* **2017**, *1*, 44–49.
51. Nadobnik, J. The use of drones in organizing the Olympic Games. *Handel Wewn.* **2016**, *365*, 288–299.
52. Skorup, B.; Haaland, C. *How Drones Can Help Fight the Coronavirus*; Mercatus Center Research Paper Series; Special Edition Policy Brief: Fairfax, VA, USA, 2020.
53. Euchi, J. Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems? Chin. *J. Aeronaut.* **2021**, *34*, 182–190. [CrossRef]
54. Kunovjanek, M.; Wankmüller, C. Containing the COVID-19 pandemic with drones—Feasibility of a drone enabled back-up transport system. *Transp. Policy* **2021**, *106*, 141–152. [CrossRef] [PubMed]
55. Balasingam, M. Drones in medicine—The rise of the machines. *Int. J. Clin. Pract.* **2017**, *71*, e12989. [CrossRef]
56. Ullah, H.; Nair, N.G.; Moore, A.; Nugent, C.; Muschamp, P.; Cuevas, M. 5G Communication: An Overview of Vehicle-to-Everything, Drones, and Healthcare Use-Cases. *IEEE Access* **2019**, *7*, 37251–37268. [CrossRef]
57. Amukele, T.K.; Street, J.; Carroll, K.; Miller, H.; Zhang, S.X. Drone Transport of Microbes in Blood and Sputum Laboratory Specimens. *J. Clin. Microbiol.* **2016**, *54*, 2622–2625. [CrossRef]
58. Rejeb, A.; Rejeb, K.; Simske, S.; Treiblmaier, H. Humanitarian Drones: A Review and Research Agenda. *Internet Things* **2021**, *16*, 100434. [CrossRef]
59. Tanzi, T.J.; Chandra, M.; Isnard, J.; Camara, D.; Sébastien, O.; Harivelo, F. Towards "drone-borne" disaster management: Future application scenarios. In Proceedings of the XXIII ISPRS Congress, Commission VIII (Volume III-8), Copernicus GmbH, Prague, Czech, 12–19 July 2016; Volume 3, pp. 181–189.
60. Maher, A.; Inoue, M. Generating evacuation routes by using drone system and image analysis to track pedestrian and scan the area after disaster occurrence. In Proceedings of the 10th SEATUC (South East Asian Technical University Consortium) Conference, Tokyo, Japan, 22–24 February 2016; pp. 22–24.
61. Abrahamsen, H.B. A remotely piloted aircraft system in major incident management: Concept and pilot, feasibility study. *BMC Emerg. Med.* **2015**, *15*, 12. [CrossRef]
62. Al-Dosari, K.; Hunaiti, Z.; Balachandran, W. A review of civilian drones' systems, applications, benefits, safety, and security challenges. In *The Effect of Information Technology on Business and Marketing Intelligence Systems*; Alshurideh, M., Al Kurdi, B., Masa'deh, R., Salloum, S.A., Eds.; Springer International Publishing: Cham, Switzerland, 2023.
63. Abro, G.E.M.; Zulkifli, S.A.B.M.; Masood, R.J.; Asirvadam, V.S.; Laouti, A. Comprehensive Review of UAV Detection, Security, and Communication Advancements to Prevent Threats. *Drones* **2022**, *6*, 284. [CrossRef]
64. Ko, Y.; Kim, J.; Duguma, D.G.; Astillo, P.V.; You, I.; Pau, G. Drone Secure Communication Protocol for Future Sensitive Applications in Military Zone. *Sensors* **2021**, *21*, 2057. [CrossRef] [PubMed]

65. Citroni, R.; Di Paolo, F.; Livreri, P. A Novel Energy Harvester for Powering Small UAVs: Performance Analysis, Model Validation and Flight Results. *Sensors* **2019**, *19*, 1771. [CrossRef] [PubMed]
66. AL-Dosari, K.; Hunaiti, Z.; Balachandran, W. Civilian UAV Deployment Framework in Qatar. *Drones* **2023**, *7*, 46. [CrossRef]