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RESEARCH ARTICLE OPEN ACCESS

THE USE OF DRONES IN URBAN CONSTRUCTIONS: LITERATURE REVIW

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ABSTRACT

This work presents how drone technology can be used in a beneficial way of monitoring urban constructions during the construction process or after the conclusion of the construction. The research had the main objective of bringing up which construction areas and activities have been studied the most using drones. The systematic literature review was chosen as a research method, to cover the lack of knowledge on the subject matter discussed in this study, between 2015 and 2020. The investigation was carried out using the systematic literature review approach. The literature review obtained a chronology of existing publications, showing through quantitative analysis, which are the trends of the use of drones in monitoring activities in construction fields. With this study, it was found that the use of drone technology is becoming increasingly common in civil construction, making verifying construction standards easier. It was concluded, that after the systematic literature review, that the use of drones is presenting an increase in the number of researches involving its use in the area of construction and post-disaster monitoring, showing that its use will be a future trend due to its ease of use, accessibility in areas unattainable by man, and low operating costs.

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INTRODUCTION

It is discussed in this research how monitoring of constructions can be done using drones. The systematic literature review carried out from 2015 to 2020 showed that the use of drones in civil construction, environmental monitoring, and post-disasters has, in all of them, the use of drones to support professional activities. This study demonstrated that the use of drones is becoming increasingly common in several areas. It is no different in the construction industry. Drones have been necessary for support in several areas. It is possible through the images obtained by a drone to monitor the built areas and make a comparative study with the property's floor plan, thus showing if there are constructions made irregularly. This monitoring work becomes faster and more productive with the use of drones. According to Arantes (2018), the application of images to update and detect changes in urban properties began to appear in the 1990s. However, remotely piloted aircraft or unmanned aviation systems, also known as drones, gained increasing popularity in remote sensing. Drones provide a system to quickly obtain information, with low costs and flexibility for high spatial resolution data and generating images. Developments related to drones started in the 70s for military purposes and currently represent numerous applications. Vizvári et al. (2019) showed that in monitoring tasks after the first 48 hours of the post-disaster period, the use of drones is of fundamental importance. Traditionally, information is obtained by measuring tapes and electronic distance measurements. These instruments have a high level of precision and performance when surveying points, lines, and objects, yet they are slow. Compared to these traditional survey methods, photogrammetric applications are used to create and update maps or images, especially for larger areas. However, conventional images in the air are limited to their use for the registrational survey (Ezekiel 2014). According to Arantes (2018), Unmanned Aerial Vehicles - UAVs - allow images to be obtained in resolutions equal to or higher than human-crewed flights, even without clouds and at a low cost. According to Dougherty (2019), high-quality aerial images can be acquired using conventional platforms, such as satellites and aircrafts, but their temporal resolution is limited by the restricted availability of aircraft platforms and satellite orbit characteristics. Therefore, this limits its use to update maps, as it will increase the cost and time production. However, UAVs were introduced in monitoring activities and linked to the low-cost production of accurate and high-quality spatial data quickly. Burin (2009) states that in the course of urban construction, several aspects must be considered and discussed in order to be successful. They include the survey of services performed, the logistics on the construction site, the construction within the regulation established in the standards, and demolitions. With the study done by the authors, it is possible to note the applicability of drones in all the construction stages. Steps that previously needed to be done with a worker today can be done with the use of a drone, which brought agility in the collection and obtaining of results and savings for the management of the construction. There is a need to carry out a systematic literature review with the use of drones in the various areas of the construction industry since no similar study has been carried out. Therefore, this research makes a systematic literature review on the monitoring of drones' use in urban constructions, showing sequentially, which areas within the civil construction have benefited from the use of drones in their management. Through the systematic literature review in the last five years, a chronology of publications was obtained, which shows the main areas where the drones were applied in the construction sector.

THEORETICAL FOUNDATION

Drones: For decades, little was heard about drones. The idea was to be a simple flying object used as recreation for adults and children. As time went by, everything changed, and today we have the idea of its use for different purposes, including its use in human tasks. Dougherty (2019) states that drones are used in various areas, such as military, research, or even environmental monitoring. It is necessary to understand what the main types of drones and their definition are to obtain the best result with their use. Aircrafts called drones can be classified basically into three types: autonomous, remotely piloted - which are known as a drone - to sporting or recreational airplanes (Castilho, 2019). The last type of mentioned is intended for leisure, while there are apparent differences between autonomous aircraft and drones, which are piloted remotely. Therefore, traditional radio-controlled aircraft and such devices are not necessarily drones. Several aircraft drones are not the simple fact of being semi-autonomous (Ezekiel, 2014). Despite the three types of classification of drones, the entire systematic review was done based on the type remotely piloted because this type provides greater control in the activities of high precision monitoring. When monitoring urban buildings, it is necessary to have high precision to obtain quality images so that they are processed to obtain a satisfactory result. The monitoring of urban construction using drones is done in three stages: flight planning and data acquisition, post-processing of obtained data, and data delivery (Siebert, 2014). Dougherty (2019) states that the flight planning and data acquisition occurs in 3 (three) steps. First, the collection of aerial images of the area of interest using a UAV remote sensing platform. In the second stage, data acquisition is obtained through images by UAVs. In the third stage, we intend to use the data from the chosen images and compare them with the original floor plan, thus checking if they are being made in the standard. Over time, this monitoring becomes increasingly necessary. It continues to be done in 3 (three) stages, both of which are of paramount importance in research involving monitoring the use of drones. Liu (2018) states that monitoring the progress of the project and detecting temporary objects can also be achieved by using point images from data captured by drones. This monitoring can facilitate and improve the planning of works for managers. Based on this context, Liu (2018), states that the use of drones can be a great ally in managing time and activities developed in urban works. The use of drones in the inspection or monitoring of works, according to the bibliographic survey done, proved to be a strong ally that came to contribute positively, saving time and optimizing tasks. Through its use, it is possible to perform tasks in less time and with greater efficiency.

Drones technologies: Most drones are considered aircraft or aircraft-type devices. When referring to drones, there are two broad categories to divide them: rotary-wing or multi-rotor aircraft and fixed-wing aircraft. The latter type does not necessarily need to be driven by an engine (Dougherty, 2019). According to Dougherty (2019), the vast majority of fixed-wing drones use a propeller to provide the driving force. This force can be activated through an internal combustion engine, widely used only in larger drones. Models with several rotors have advantages over fixed-wing drones, even though they have to provide an engine for each of the rotors and control systems to operate it (Chen AY, 2014). A propeller-powered drone needs an engine to supply power to the rotors. This motor is driven most of the time, electrically. Furthermore, within the drone technology, it should be mentioned that most of them carry at least one type of sensor, that is, a means of obtaining information, and have a communication system to allow them to receive commands or navigation data (McCabe, 2017). According to Dougherty (2019), a drone can use the Global Positioning System - GPS - to navigate. This technology is applied to drones that can capture the satellite signal and orient itself through it. However, there are limitations to GPS guidance. However, signal loss is significant, as drones are equipped with sophisticated data transmission, which eliminates the possibility of accidental interference or signal loss. Most of the drones used in construction have sensor systems (Boccardo, 2015; Besada, 2018; Alwateer, 2019). These sensors are cameras of various types, small and effective in the task of observing or photographing. Equally important, these cameras can store a large number of images (Siebert, 2014). Dougherty (2019) claims that cameras are also handy for security and law enforcement purposes. The cameras can be useful in terms of cost and monitor a large estate or area, safely, conducting overflights of drones and only a few fixed cameras.

Legislation for the use of drones: In Brazil, the regulation of specific aspects of the aerial survey activity is very recent and made by two agencies, linked to different government ministries, and a military department, all at the federal level: Department of Airspace Control - DECEA, National Aviation Agency Civil - ANAC and National Telecommunications Agency - ANATEL (Castilho, 2019). According to the National Civil Aviation Agency - ANAC (2019) legislation for the use of drones, remotely piloted vehicles, over 250 grams, can only fly over distant areas of at least 30 meters from third parties. However, the specified distance is not followed when a protective barrier is required between the equipment and people. Furthermore, operators of drones (up to 250g) are considered licensed, without needing a document issued by ANAC as long as the equipment is not used for flights above 400 feet. ANATEL does not control the flight itself, but only approves the aircraft using a declaration of conformity, based on a request made digitally, to avoid interference in communication caused by radio systems and video transmitters. In a short time of the existence of the registration, ANAC today gathers about 50 thousand registered devices, and this number is increasing more and more. The mandatory registration objective would be to allow liability for any illegal acts practiced from the flight or resulting from it, which is why there is a need for registration, which corresponds to the aircraft registration. Peral & Veiga (2017) also show the regulation of drones' use at an international level. Such standards covering manned and uncrewed aircrafts are established at the United Nations level by the convention on international civil aviation (Chicago Convention), signed in 1944. Peral & Veiga (2017) argue that drones registered in an area are not allowed to fly over another territory of another state without your permission. It also obliges states to ensure that pilotless flights in regions open to civilian aircraft are controlled to eliminate risks to civilian aircraft. These rules allow operations with drones since a national authority will grant a specific authorization or authorize the use of drones in a not segregated airy space, which means operating in the same airspace used by manned traffic.

According to a study by Peral & Veiga (2017), national aviation authorities are facing the crucial challenge of ensuring the citizens' safety and privacy, without suppressing innovation and growth. In the United States legislation on the use of drones is made by the Federal Aviation Administration (FAA), which is the national aviation authority of the United States with powers to regulate all aspects of American civil aviation, which includes the operation of all Unmanned Aerial Systems (SANTs), which also includes the use and operations with drones. According to Peral & Veiga (2017), the United States launched its first operational standards for operating and using drones in 2016, where drones weighing less than 55 pounds (25 kg) can perform amateur operations. It came into force in August of the same year and aims to promote the commercial use of drones and support innovation, to maintain safety standards in US airspace, thereby minimizing the risks to other planes. Peral & Veiga (2017) explain that member states of the European Union and the national civil aviation authorities regulate the use of experimental or amateur drones, government flights military or non-military with a moving mass of 150 kg or less, and aeromodelling. In 2015, it published a technical opinion on drones' operation, where its purpose was to lay the groundwork for future work and serve as a guide for the EU Member States on uncrewed aircraft. The professional opinion developed by the states of the European Union was made in parallel with the draft amendments to the basic regulation, necessary to remove the obsolete limit of 150 kg. For this basic regulation, three categories were created, and the types of unmanned flights were divided. The European Union shared the first type of unmanned flights in an 'open' category, where the risk is considered low. In this category, the required rules are minimal, since safety is guaranteed through operational limitations, under industry standards, requirements in certain functionalities and a minimum set of operational rules. According to the map made by the states of the European Union, once the necessary regulation is changed, the rules implemented for low and medium risk operations can be adopted in a short time. Meanwhile, work on higher risk operations only started in 2016, as this category is already the responsibility of federal agencies.

The use of drones in the construction industry: Liu (2018) thoroughly investigated the applications of multi-rotor drones, analyzing their roles, and exploring the potential use in construction engineering. In his research, Liu (2018) investigated the various applications of multi-rotor drones under construction, identifying the topographic survey usage, logistics, analysis of the construction site, maintenance, and demolition. As a result, Liu (2018) found that drones represent an increasingly popular technology under development in society. In this scenario, the author concludes that the drones have the potential to facilitate the construction and management of construction. In this context, through the “type of work”, as it is possible to explore the use of drones comprehensively in many aspects of construction engineering, checking “which works” would be studied. Through the type of work studied, it is possible to define which type of multi-rotor drone to use, as many of them are equipped with cameras and sensors and can be piloted remotely using smartphones, tablets, or computers facilitating construction activities.
Ezekiel (2014) discusses in his article the combinations of aerial surveys, observations on the ground, and collaborative sharing with the domain of specialists in low-cost drones. In his research, Ezekiel (2014) us as means the image analysis obtained by image processing, collected through data acquisition and planning, post-processing of data, and data delivery. As a result, the author found that the aerial images need to be checked with the comparison of the soil in order to produce more accurate information. Arantes (2018) examined the ability to use unmanned aerial vehicles for measuring purposes of the built area of a property with the use of an orthophoto without control points, making the comparison of the area constructed obtained through the aerial image and the real value of the property. As a result, it was possible to measure built-up areas and adjust irregularities in the dimensions of urban properties quickly and at a low cost. Dupont (2016) states that it is possible to obtain information from civil construction and model it using drones to obtain better management. The author argues that few solutions allow the integration of information with a software platform. The construction process itself is still outside the scope of most developments, as it involves a tight schedule, congested environment, and challenges in navigation conditions. Shi (2011) proposed a new method based on objects for the detection of changes using UAV images that can overcome the effect of deformation and fully utilize the feature of high-resolution images. In his research, Shi (2011) presented a method containing five main blocks: pre-processing, image matching, image segmentation, resource extraction, detection of changes, and accuracy evaluation. The proposed method was tested using multi-temporal images acquired by UAV. The results confirm its effectiveness.

Sankarasrinivasana (2015) presented an innovative protocol for monitoring large civilian structures that involve the effective use of drones to allow structural monitoring of the health of structures in real-time. The author aimed to work with image processing obtained by drones to identify cracks and imperfections in large civil structures. In his research, Sankarasrinivasana (2015) used as a methodology a graphical interface of the mathematical software developed to analyze real-time images and get the result expected by comparing images in grayscale. The results obtained were satisfactory and showed that the image algorithms are developed to determine primary structural defects, such as cracks and degradation surfaces. Daniel (2010) states that the civilian operations using drones that monitor environmental disasters are increasingly common. In this sense, the use of skills in handling drones in areas of environmental incidents is, in general, a proper technique used for remote sensing and reconnaissance for surveillance and communication purposes. Police, security departments, firefighters, and other bodies will have easier access to their use, which will be a future trend for use in environmental disasters. McCabe (2017) examines the potential of using uncrewed aerial vehicles and unmanned aerial systems to monitor construction sites. According to the author, the drones have become ubiquitous due to their commercialization as a tool. Falorca (2018) used the drones to carry out an approach to its use as an emerging technological tool to the field of inspection of buildings. The author used the analysis of images obtained in the inspection of building structures using drones. Through this analysis, Falorca (2018) realized the potential use in the inspection of facades of buildings with many floors, which will be a facilitator when using drone technology.

Lisboa (2018) reports using drones to inspect work in the capital of the state of Pará, located in the north region of Brazil. To that end, the author used procedures for safety inspection in works by capturing (photos and videos) with drones in the work of an extension of an avenue located in the metropolitan region of Belém. According to the author, the objectives of the investigation were achieved and demonstrated efficiency in the use of daily inspections in the progress of the work. Wongi (2016) addresses the use of drones in remote sensing technologies for structural monitoring of civil construction. The research aims to use a new concept to allow drones to identify damage at an earlier stage or detect internal damage, such as thickness or loss due to corrosion. The visual inspection method with image processing is a universal concept when using drones to find cracks, rust, or other damage types that can be identified visually. Siebert (2014) addresses the use of drones as a data acquisition platform and as a measurement instrument to become an attractive method for the many survey applications in civil engineering. Its objective was to use a new program for photogrammetric flight planning and its execution for the generation of 3D point clouds from digital mobile devices where the images are explained. The test results show that it is possible to monitor the use of drones in excavation-type works, facilitating the work of measuring the work. Liu et al. (2014) discuss the challenge faced by civil engineers and the uncertainty in the planning, construction, and maintenance of infrastructure. According to the authors, the main advantage of using drones is the low cost and high mobility. As a disadvantage, Liu et al. (2014) recorded low flight stability. As conclusions, the authors presented a summary of drones' possible applications in the assessment of seismic risks, transport, disaster response, construction management, survey and monitoring, and flood assessment. Liu (2014) concludes that the use of drones in construction management will soon be a traditional tool in civil engineering and construction management.

Alwateer (2019) argues that the use of drones is taking mobile computing into a new era. With the technology improvement, soon they may be ubiquitous and may be used in providing civil engineering services, either through the applications with the use of drones, data management for drones, data services using drones, highlighting specific concerns in data management and computing the internet of things. The internet of things will connect to drones forming a cloud and widely used in the image processing and construction sectors. Lynch, Greenwood & Zekkos (2019) maintain that drones have become popular tools for professionals and researchers. In their research, the authors aimed to provide a summary of the systematic literature review on efforts related to the development of drones with a focus on civil infrastructure applications, showing the advantages and disadvantages between different types of drones and their performance characteristics, with emphasis on the progress in civil construction.

Hausamann, Zirnig & Schreier (2014) say that it is possible to design monitoring natural gas pipeline systems with remote sensors and drone-oriented image processing software, which will be useful for preventive monitoring of disasters and post- environmental disasters. The recent development in drone technology shows its suitability as a platform for such missions directed to the customer. The results showed drones have great potential for improving the public's quality of life. Also, they can be performed where manned flights are hazardous, expensive, or monotonous. Therefore, it is clear that the use of droes will require improvements regarding the regulation of use. Agatz et al. (2018) state that the use of drones can lead to substantial cost savings, such as in infrastructure monitoring, spray fields, and surveillance in precision agriculture, as well as in deliveries of packages. In some applications, such as disaster management, transporting medical supplies, or environmental monitoring, aerial drones can help save lives. In their research, Agatz et al. (2018) described the most likely aerial drones' applications and delineated the relevant characteristics of such equipment to operational planning. Therefore, it is not surprising that planning for drone operations has recently attracted considerable interest and research.

Maza et al. (2010) described a distributed architecture decision, developed under a set of tests using drones. With this study, the authors show that it is possible to monitor the use of drones as robots with divided tasks, for disaster monitoring and civil security. In their work, Maza et al. (2010) developed a research method using drones to perform various tasks to maximize the team's efficiency and ensure adequate coordination among its members to complete a mission. His experiments showed that the developed architecture allows the use of drones in several areas, such as surveillance, especially in the monitoring of disasters, enabling the integration of the project and with little development effort. Vizvári et al. (2019) focused on monitoring with the use of drones in tasks after the first 48 hours of the post-disaster period, showing that the monitoring platform and transport with these devices help in post-environmental disasters such as earthquakes. In their work, the authors had the main objective of discussing the different modes of transport for the distribution of post-disaster aid. Popescu et al. (2019) developed one systematic approach for structuring the main aspects of implementation using drones. According to these authors, the advantage of these systems was emphasized by large-scale monitoring, increasing mobility, accessibility, and reaction time in an emergency. As a result, the authors concluded that the use of drones made systems cheaper, friendly and accurate in monitoring in various areas such as environmental monitoring, agriculture, smart cities, security, search and rescue missions. Labib et al. (2019) found that the rapid adoption of the Internet of Things (IoT) encouraged the integration of new connected devices and drones into the ubiquitous network. The drones promise a pragmatic solution to the limitations of existing terrestrial infrastructure to bring new ways of providing services through a wide variety of applications. According to these authors, there is an expectation that drones will soon dominate low-altitude airspace overpopulated cities, proposing a new way to structure open and low-altitude areas in the airspace, in order to address the complex traffic management problem abstractly. The authors concluded that the Internet of Things connected to drones facilitated the development of new devices able to interact with our physical world, generating a large amount of information.

Máthé & Busoniu (2015) showed that drones had gained significant attention in recent years. The research conducted by these authors had as an objective to address an overview, for detection and tracking capabilities, using, for that, a drone list with the most popular and inexpensive. In their research, Máthé & Busoniu (2015) developed the use of drones for railway inspection using the processing of images obtained by this equipment. This research showed that even with the computer challenges generated by image recognition obtained by drones, this would be a future trend for visual inspection because the processed images have a low cost to obtain it. Alvear et al. (2017) found that air pollution monitoring has recently become an issue of extreme importance in our society. Because of its importance, the deployment of a drone fleet for this monitoring can be considered an acceptable alternative. Adopting this approach proposes the use of drones equipped with sensors ready to perform air pollution monitoring tasks. The authors used an algorithm based on a chemotaxis metaheuristic and a local particle swarm optimization strategy. Together, they allow monitoring an area automatically. The experimental results show that it is possible to quickly obtain accurate maps compared to other strategies, thus achieving a better performance. In particular, the project was able to find the most polluted areas with more precision, offering greater aerial coverage. Besada et al. (2018) developed an automated flight process that allows the implementation of measurement plans for discrete inspections of infrastructure using aerial platforms and drones explicitly with multiple rotors. In this research, the authors compared the system with the existing tools and showed that it is possible to carry out detailed inspections using multi-rotor drones. The images obtained are processed and used for infrastructure inspection showing the accuracy of the flight tool in real operations using automated flight control.

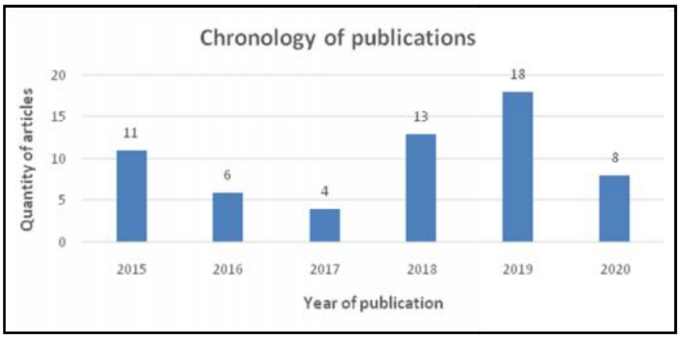
Boccardo et al. (2015) explored the reduction of costs related to drone technology in different fields, including the monitoring of disasters and gathering information, community empowerment, and logistics to transport goods. It was carried out together to evaluate operational procedures for monitoring and usability of data acquired in an emergency response context. The results demonstrate the efficiency of using drones for post-disaster monitoring, proving to be a trend in this type of monitoring. Castellanos et al. (2019) used the internet of things supported by drones use to monitor a city. The authors presented a tool capable of designing an auxiliary network to be used by drones to monitor and evaluate the performance of the return of drone images in a realistic scenario. The results obtained in the research showed that a flight with an ideal drone would be at height (80 m) could satisfy the access and return networks; however, full coverage has not been achieved. Given all the tests, the use of drones to monitor cities using the internet will also be a future trend. Chamoso et al. (2018) developed a platform with different modes designed to control and monitor the status of drones, showing the advantages that make the use of a drone safer, such as the use to control restricted areas in cities or even to avoid collisions between vehicles. Their use is becoming more frequent, and they can perform a wide range of tasks. Authors also showed that drones have many advantages over other operating aerial systems, mainly when used in the professional or commercial fields, in addition to having a lower cost. It is expected that all cities will use drones for small control tasks in cities, aiming at the low cost of operation and the ease of connection to the internet in large cities.

METHODOLOGICAL PROCEDURE

This article presents a systematic literature review (SLR) addressing the use of drones in the construction sector in the last five years. The research was carried out based on the web of science and Scopus platforms journals, using the keywords construction, drones, construction management, and mapping, considering only publications in English. With this approach, it was made an article acquis search, using as a filter the last five (5) years of publications, since it includes the latest results, as the research involves the use of a device that receives enough technological innovation. In this sense, research carried out before the period considered, could be very out of date regarding the current context. Therefore, the decision to search for articles in the last five years is because the drone is equipment in constant evolution, and that is increasingly being inserted in everyday tasks. In each article found, it was analyzed the abstract in order to obtain the first filter of research related to the use of the drones, involving the use or monitoring of any construction task. In order to verify each article's content, a detailed analysis was conducted. At this stage, information was derived about the gap of knowledge, the overall goal, the research method, the results, and the conclusions obtained in the analyzed work. With the second filter, it was possible to separate each article published by the year of publication and the subject that was treated within the area of civil construction, allowing to determine a chronological evolution of publications, expressed graphically, showing which area of construction has the most significant emphasis on the study of the use of drones in civil construction. In the investigation, 150 (one hundred and fifty) articles were obtained presenting in their abstract the use of drones. When considering only the jobs using drones in the construction sector, in urban real estate, in the monitoring of cities and internet of things, in environmental monitoring and post-disaster environmental monitoring, image processing and use of drones in the safety of cities, the sample was reduced to 60 (sixty) articles, since some works were not focused on this sector. An investigation searching considering the type of research was made in each article. A categorization of drone use by area was also made, to determine which area represents the trend of study in the coming years. It was shown in the survey that countries have the respective quantities of publications, and lastly, a study was made by the type of drone used in the research. After obtaining sixty articles, it was possible to carry out an SLR and define the use of drones in urban constructions as a theme.

RESULTS AND DISCUSSIONS

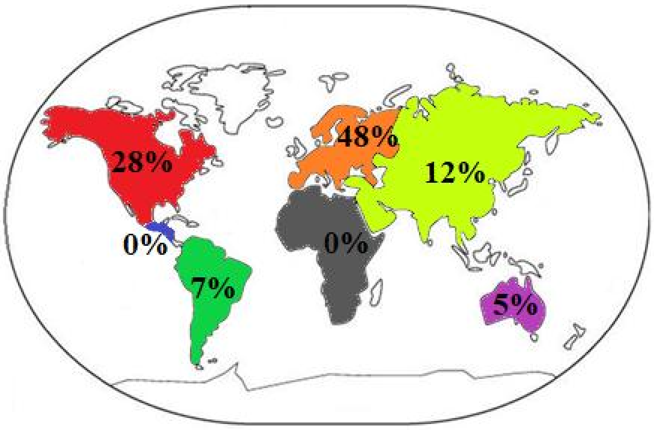
The various authors referenced through the systematic literature review showed through this study that the use of drones in construction is increasingly studied. It is noticed that its use is applied in several areas within the construction sector. Based on this survey, Graph 1 was obtained, which shows the publications obtained in the last five years that address the use of drones as a theme.



Source: Elaborated by the author (2020)

Graph 1. Applications using drones

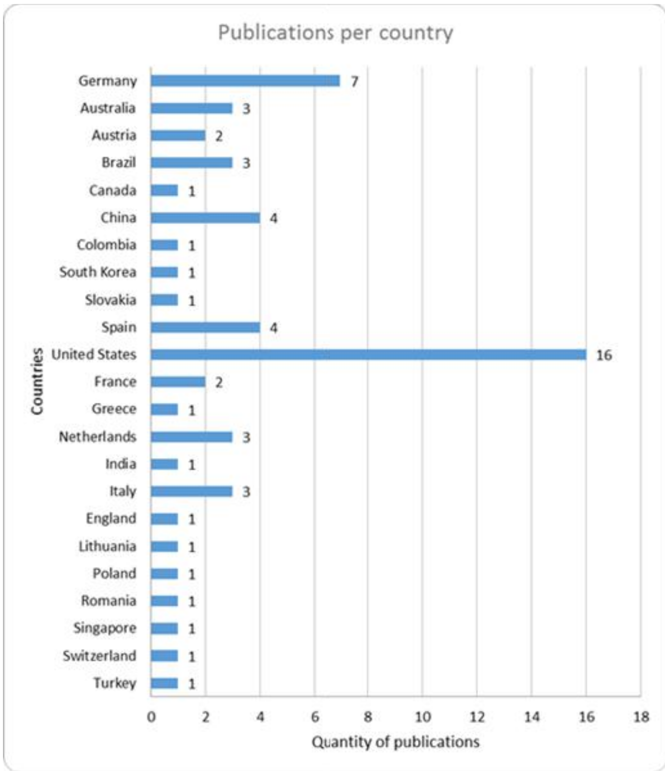
According to the analysis of the chronology of publications, it is noted a growing demand for drones in 2020. This increase is due to several factors: the ease of using drones in various tasks that can be done with greater time optimization and resource savings. The use of drones has been researched on several continents. Image 1 shows the percentage of publications obtained between 2015 and 2020 with the respective percentage of publications on sampling 60 articles.



Source: Elaborated by the author (2020)

Image 1. Percentage of publications by continents

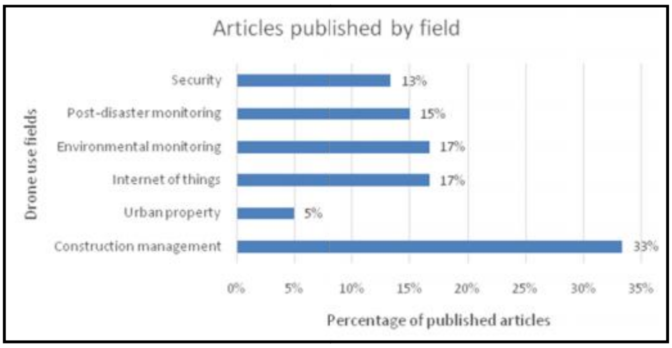
Just as each continent had its number of articles published, there are countries responsible for carrying out numerous studies using drones. Graph 2 shows the number of publications obtained by each country:



Source: Elaborated by the author (2020)

Graph 2. Publications per country

After performing an analysis between image 1 and graphic 2, it is clear that the European continent has the largest number of published articles since it has a larger number of countries and a greater university concentration. Graph 2 shows that North America is responsible for most publications if we analyze by country of publication. The United States and Canada are responsible for publishing 17 articles among the 60 studied in the sample. With this study, a survey was made of the use of drones by area of applicability. Graph 3 was obtained from it, which shows different areas that allow the use of drones:

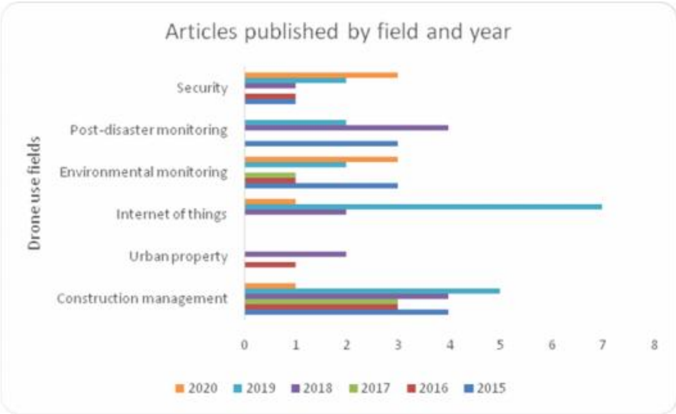


Source: Elaborated by the author (2020)

Graph 3. Articles published by area

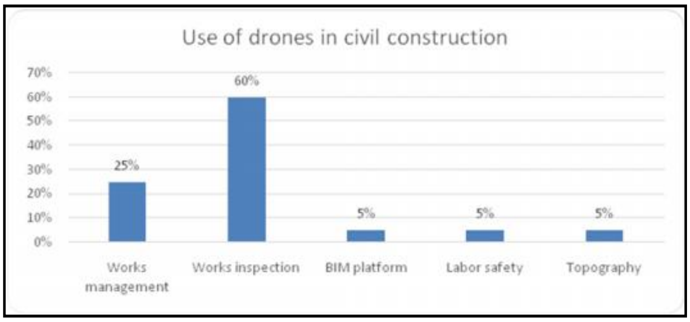
The analysis of graph 3 shows that the use of drones in the urban real estate sector had a lower percentage in its activities in the period from 2015 to 2020. In contrast, the construction management sector had a greater number of articles published, thus showing, according to graph 4 that the use of drones, if it continues with this evolution, indicates an increase in the use of the tasks of a work. The use of drones in the urban real-estate sector had a lower percentage in its activities in the period of 2015 to 2020. In contrast, the construction management sector had a more significant number of published articles, showing that the use of drones, if it continues with this evolution, will be a future trend in the day-to-day work.

Several articles published within the civil construction field were created, which demonstrates its applicability in various areas of civil construction. Graph 5 shows the values found.



Source: Elaborated by the author (2020)

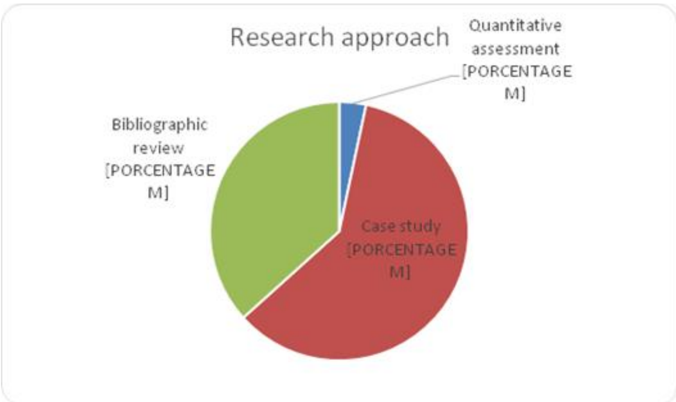
Graph 4. Articles published by área and year



Source: Elaborated by the author (2020)

Graph 5. Use of drones in civil construction

To arrive at the results presented, each author used different research methodologies. Graph 6 was created in this study, which shows that the case study and the literature review are applied in greater quantity. The main reason would be the applicability of using drones in real situations.



Source: Elaborated by the author (2020)

Graph 6. Research approach

In general, drones represent an increasingly popular technology in the construction sector. Multi-rotor drones have many advantages, such as high maneuverability and low cost. Drones can be equipped with various sensors, such as video or cameras, and infrared sensors, based on radar or laser and specialized communication devices. Also, multi-rotor drones can be piloted remotely using smartphones, tablets, or computers. The drones can facilitate activities in the construction sector, such as structural observations and inspections, work safety management (being used to monitor the use of personal protective equipment), but are still in an exploratory phase, not being widely used in the construction industry. Researchers initially explored the use of drones in many aspects of construction engineering. However, it is expected that current researches will increase awareness about the use of multi-rotor drones and its potential in the civil construction sector. It is noted through this study that, during the last 5 (five) years, the use of drones, although not very common, was already the object of study among researchers. It is clear that in 2015, publications maintained a percentage of 20 % of articles published concerning the sample of 60 articles. There was an 8% increase in research publications in 2019. This fact leads to the understanding that the use of drones in civil construction has been a growing trend since the use of drones in the field of civil construction has come to facilitate and assist in tasks where human access is considered severe. Moreover, this trend will be more significant in 2020, as we already have 17% of the publications made until May 2020. This shows that following this trend, we will have more articles published at the end of 2020 than in previous years. In civil construction, drones were more used in the inspection and management of civil works due to the ease of use and the precision that they can provide with their maneuvers.

Final Considerations

Regarding the studied fields, it was noted that drones have applicability in several areas within the construction, whether in construction management, in the safety of cities, disaster monitoring, or environmental monitoring or even in the capture and management of aerial images obtained by drones. The use of drones in construction will benefit managers who will use the results obtained for better awareness of the use of this technology in managing the work. Through the bibliometric study carried out with a sample of 60 articles, it is clear that the field of drone use to manage civil works has been of more interest to the researchers. However, further studies are needed in other areas of civil construction. Among them, the identification of construction pathologies or even the use of drones in the management of work safety. The need to carry out new studies in the areas of civil construction is perceived through the chronology of this systematic literature review. It is expected that over time, the use of drones in construction will be shared in all types of works, but before that, it is necessary to address new studies that deal with the areas of civil construction that were not addressed in this study. Therefore, further studies using drones are recommended to diagnose external pathologies in vertical urban residential buildings. It is also recommended studies to detect the use of PPE in small and medium-sized projects. With the graphs and results obtained in this systematic literature review, it is concluded that the use of drones is experiencing an increase in the number of publications involving the area of construction and post-disaster monitoring, showing that its use will be a healthy future in the management and inspection of civil work. This fact is justified by the ease of use, easy access to areas inaccessible by man, and the low cost of operation. All of these factors have aroused interest in the topic by researchers.

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