Full paper

International Journal of Real Estate Studies

INTREST

Applications of Drone Technology in the Management of Disaster and Risk Associated with COVID-19 Pandemic in the Built Environment: The Nigerian Experience

Akeem Bolaji Wahab

Department of Building, Obafemi Awolowo University, Ile-Ife, Nigeria

Email: wahabak2002@yahoo.com

Article history: Received: *4 July 2020* Received in revised form: *23 August 2020*
Accepted: *15 October 2020* Published online: *11 November 2020*

Abstract

The world has of recent being faced by the effects and challenges of the COVID-19 pandemic and it has had major tolls on the conditions of living, the live expectancy of building occupants, and thus affecting their expected contributions to the national economy. To provide adequate services and measures to fight the pandemic, various institutional measures are evolving daily across the globe. Amidst the measures initiated by both governmental and non-governmental formations are the provisions of medical services and the decontamination of infected buildings and areas occupied by people in order to fight the pandemic amongst the populace. However, the inability to plan, remoteness, and accessibility challenges of buildings and settlements in major parts of the country has made the delivery of relief materials, fumigation of buildings, and the rendering of other services associated with the management of both disaster and risk linked to the COVID-19 difficult. This paper, therefore, focuses on the emerging intervention initiated by an Imperial Majesty in Nigeria, the Ooni of Ile-Ife, Osun State through the adoption and supply of drones to states across the country to decontaminate likely contaminated or uncontaminated buildings and settlements occupied by people. Given the enormous benefits derivable from the adoption of the use of drone technology in the management of disaster-related issues in the built environment in the country, this paper recommends that its use should be vigorously deepened, being an emerging intervention or device through appropriate institutional supports to complement efforts of stakeholders in making the country's built environment safe and healthy for all.

Keywords: Nigeria, disaster management, COVID-19, drone technology, built environment

1.0 INTRODUCTION

In the recent past, developments in the gathering of information have been made easy through the deployment of the Unmanned Aerial Vehicles (UAVs) otherwise called drones due to their flexibility and a higher chance of the line-of-sight-links to ground users. These potentials have allowed it to attract a very significant level of attention, because of its advantages comprising ubiquitous usability, high manoeuvrability, and low-cost deployment (Handouf & Sabir, 2019). It also has the benefit of high mobility, air location, and good communication channel during its operation. This is because the UAV-ground link can offer have Line-of-Sight (LoS) links (Amorium et al., 2017). A drone can also provide unlimited telecommunications that give information about the surrounding environment. It is also resourceful by providing key technology useful for intelligence, recognition, search, inspection, tasks, surveillance and other associated public needs (Mahmoud et al., 2015; Sharma et al., 2017).

According to Brown (2019), the word 'drone' has two different interpretations; the first one is a low-humming sound that goes continuously, while the other one reflects the male bee that has no work to do based on its mode of operations. Usually, the drone produces a sound like a group of bees that can be directed by humans either from a remote location or works through an automation process like a flying robot. The Unmanned Aerial Vehicles (UAVs) can also be regarded as pointless airborne systems, controlled through ground control systems and operated in a way that it can be exclusively used during military applications (Hallermann & Morgenthal, 2014; Pajares, 2015; Siebert & Teizer, 2014; Zhou & Gheisari, 2018). However, over the years, with the continuing successes identified and recorded in the use of drones, its civilian applications have begun to get recognition (Zhou & Gheisari, 2018). Its uses in the civilian circle range from remote sensing of agriculture practices, to the delivery of goods, supply of medical aids, and search operations in rescue missions (Gonzales-Dugo et al., 2013; Howell et al., 2016; McCormack, 2008). It has also had a major economic impact by generating more than 70,000 job opportunities in the United States of America (Jenkins & Vasigh, 2013).

A drone can also be seen as a flying robot that can be remotely controlled or made to fly autonomously through the incorporation of software-controlled flight plans, embedded in their systems, and with the required algorithm to operate. It has its root of adoption in the

military, by being called the Unmanned Aerial Vehicle (UAVs) or Remotely Piloted Aerial Systems (RPAs). They are now commonly known in the civil environment as drones, and they can be deployed in cases where manned aircraft that has a pilot is considered to be difficult. It is because it can stay up to 17hours at a time, loiter over an area, process and forward real-time imagery for interpretation and analysis. It consists of the aircraft component, sensor, payloads, and a ground control station (Narayanan & Ibe, 2015). The likely use of drones in addressing issues in agriculture, aviation and construction services have been carried out. This has therefore led to the emerging adoption of its use in mitigating the impact of disasters that occupants of buildings could be subjected and thus informed this work. Also, as pointed out by Li and Liu (2019), many fields of interest are increasingly trying to adopt drones in solving their teething problems. The same goes to its potentialities in the course of disaster and risk management that may wreak havoc in the built environment, hence, the need for this study.

Arising from the uses of drones to address environmental issues, studies have been carried out which reveal its potentials in different sectors. However, since its adoption, there has not been a global case of a pandemic like COVID-19 which could further deepen its use. This development becomes an issue of concern that stems the need to look into drone technology in addressing such emergency issue in the built and human environment respectively. Thus, as the interest to adopt drones usage grows globally in the built environment in managing risk and disaster operations, it is therefore important to review the benefits of its adoption to widen the understanding of the researchers, industry practitioners, and policymakers on it. Given this, the main objective of this study is to review the uses of drones sectorally and depict the emerging experience of Nigeria through the intervention measures put in place by a royal head in the country, the Ooni of Ile-Ife. It shows the applications and adoption of a drone as a vital facility needed during the management of disaster or emergency issues like COVID-19. The study adopts a methodology of reviewing selected papers in the body of literature on disasters that affected environmental space that informed the use of drones to mitigate their effects. It further considered the adoption of its technology in combating the COVID-19 pandemic across the globe with the emerging experience of its usage in Nigeria through the intervention scheme of the royal head. The information on the emerging use of drone supplied by the royal father, Ooni of Ile-Ife was gotten from the documented pieces of evidence such as that of Elusogbon (2020) which shows his intervention in using the facility to address COVID-19 pandemic in the country's built environment. The article was structured to show the background to the study, literature base on the origin, operation of the drone, its applications in managing disaster and its adoption in addressing COVID-19 pandemic locally in the country through the interventionistic process.

2.0 METHODOLOGY

The paper is a review type and carried out a systematic review of previous studies on the origin, uses and application of drones. It also considers the review of the occurrence of the forms of a disaster which necessitate the adoption of drones in managing their effects. It went further to look into how nations across the globe have used the unmanned aerial vehicles, drones, during the COVID-19 pandemic and how the Ooni of Ile-Ife in Nigeria, through his intervention scheme has also done so. The information obtained from the available secondary sources on the intervention scheme of the royal head through the donation of drones used in the built environment of states in the country to fumigate buildings and places of the congregation were used.

3.0 LITERATURE REVIEW

3.1 Origin and Operation of Drones

According to Brown (2019), the history of drones can be traced to the first aircraft made in the thirties that had a reusable radio control mechanism and worked as a base model for the new models used nowadays. The military drones came later, had classic sensors and camera. Drones in the present world are used in the film industry and news reportage to source for information from inaccessible locations and this has been observed to be a major opportunity offered by it in its applications. Drones unlike helicopters can fly independently and the multi-propeller system inside makes it highly independent. The operation of drones is linked to the controller that establishes a proper communication channel between the remote unit and radio waves. Most drones work on 2.4 GHz frequency range with help from Wi-Fi networks which assist in making active decisions (Brown, 2019).

The operation of drones has witnessed the adoption of various innovations that exist in the field of technology. According to Pham et al. (2020), in recent years, various innovative transportation data collection technologies have been developed, and it comprised other global positioning satellites, bluetooth detectors, video detectors, lidar detectors, and radar detectors. The use and operation of drones in most countries across the globe are supposed to be in line with the existing regulations and Nigeria is not an exemption. The drone permit was introduced in Nigeria to regulate the use of drones and equally to ensure the safety of the Nigerian airspace. The Nigerian Civil Aviation Authority (NCAA) ordered that no government agency, organization, or an individual should launch Unmanned Aerial Vehicles (UAVs) in the Nigerian airspace for any purpose whatsoever without obtaining requisite approvals/permit from the agency (Sidebrief, 2019). The NCAA rules provide that any person or corporate body that owns a drone and intends to fly the drone outdoors must register the RPAs (Remote Piloted Aircraft) according to their weights being more than 250grams.

Similarly, the technical description of drones can be considered by identifying its composition and the functions of its various types. According to Kardasz et al. (2016), batteries power drones, which are basically, the principal draw-back; because it is always exhausted after fifteen minutes of flight. Given this, it causes a decrease in drone system on the ground. It also has lithium polymer batteries, used basically, for powering it. It has been earlier posited that drones can be of different types because they can be military and civilian types, and the military drones are usually bigger than civilian drones. It is powered by the internal combustion engines while the civilian drones are driven by electric motors (Kardasz et al., 2016). Technical applications of drones can also be considered by assessing its uses in the area of photography, recreation, commercial and military circle respectively. To ensure that drones have effective flight operations, it must have a power source, battery or fuel, rotors, propellers, and a frame. The frame of a drone typically consists of lightweight composite materials meant to principally decrease its weight and enhance any likely manoeuvrability process during flight operations (Rouse et al.,

2019). It has other technological components such as electronic speed controller, flight controller, GPS module, antenna, receiver, cameras, sensors, accelerometer, and altimeter.

3.2 Uses and Applications of Drone Technology

Going down the line, according to (Meier, 2014), the Unmanned Aerial Vehicles (UAVs) or drones have so far being used as viable facilities needed during different response interventions since the occurrence of September 11 Terrorist Attack of 2001. Its use was also deployed in the Philippines after the occurrence of the Typhoon Haiyan in 2013 in Haiti and of recent, after the massive flooding that took place in Balkans and earthquake in China respectively. They were operated by the electronic equipment adapted to it with a Ground Control Station (GCS) or with the use of the Remotely Piloted Vehicle (RPV) (Bravo & Leiras, 2015). Its naming process has witnessed various evolutions, because in some literature, it is termed as Drone, ROA (Remotely Operated Aircraft), UVS (Unmanned Vehicle system), and UAS (Unmanned Aerial System) (Bendea et al., 2008). It has also been documented that different governments across the world spent more than $6.6billion on drone technology in 2012 and the figure is expected to increase in the future years. Unlike satellites, individuals in society can own a drone and use it to respond and mitigate the effects of crises (Meier, 2014). Its applications in the fields of infrastructural development, technological and engineering development, and in other areas like seismic risk assessment, transportation, and disaster response have been documented (Liu et al., 2014).

According to Tkáč and Mésároš (2019), the applications and use of drones, over the last decades, with the rising evolution of digital technologies, have appeared to improve productivity. It has equally helped to decrease significantly the overall time and cost of executing projects. Its use has also had sway in other areas of industry such as agriculture, public safety, military purposes, science and research, monitoring, security, mining, etc. In the construction industry, its use has witnessed about 240% increase in recent years and this has been observed to be far higher than what obtains in any other commercial sector (Zitzman, 2018). He further pointed out that drones can be classified using different criteria, such as drones for photography, aerial mapping, military purposes, surveillance, etc. Hence, because of aerial operations of drones, it can be classified into four major parts; fixed-wing drones, multi-rotor drones, single rotor drones, and fixed-wing hybrid VTOL drones (CircuitsToday, 2017).

According to Ayemba (2018), drone technology has various applications in the built environment and largely in the construction industry. Its use can be seen in the areas of building surveys, topographic mapping and land surveys, construction site inspections, equipment tracking and automating, remote monitoring and progress reports, integration of laser scanning and aerial photogrammetry, and thermal imaging recording. It can also be deployed to address different layers of effects stemming from human involvements and activities comprising disaster response and emergency operations by using data imagery process in getting real information on events that occur aerially and on the land. Ezequiel et al. (2014) concluded that various applications of UAV aerial imagery were used in the post-disaster assessment and recovery processes in the Philippines. Studies of Câmara (2015) and Zhang and Wu (2014) have also shown the use of drones in solving challenges associated with disaster scenarios and mitigation operations. The adoption of drones in this context considerably helped to mitigate the associated effects occasioned by the disasters.

The applications of drones are also diverse based on how industry players have been trying to key into their uses. According to Li and Liu (2019), many sectors are increasingly showing interest in using drones for mapping in mining and surveillance operation activities in the transportation sector. The construction industry has been a slow adopter of this novel technology because it has great potentials to facilitate construction practices in many aspects. The same goes for its potentialities in disaster and risk management by considering the effects, havoc, that their occurrences, may rage in the built environment. Gallacher (2016) noted that drone has its expanding applications in surveillance operations, with the need for better safety and security systems in the urban environment. He also noted that the niche for small drones is difficult when there are few to no people, but this still includes many potential applications in the environmental management field over the years. As advancement becomes more pronounced globally, the use of unmanned aerial vehicles (UAVs) has improved in the past ten years, with its inputs, now being considered as a required piece needed for acquiring data in specific areas of interest through the creation of 3D models. This would further need prior knowledge of data processing and a good drone pilot ability to manage flight processes (Giordan et al., 2020).

Further studies have also had sway across the globe on the myriad of uses that drones, unmanned aerial vehicles can be used for. Vergouw et al. (2016) relayed typical examples of drones with their various behaviours, characteristics, how they can be used with their autonomous potentials and also made more affordable with reduced sizes opportunities. Its place in the construction industry was supported in the work of Fan and Saadeghvaziri (2019) by depicting how it can be resourceful in the areas of planning, designing, construction and maintenance of facilities respectively. The various ways through which any bottlenecks faced can be addressed were also depicted in their study. In the same Architecture, Engineering and Construction (AEC) field, Albeaino et al. (2019) explained the various uses of drones during the tasks of inspecting buildings and bridges, and progress monitoring of urban space activities respectively. Its further use in the post-disaster assessment processes and construction safety practices were also given due consideration. In the urban transportation area, Kellermann et al. (2020) maintained that drones are very important when there is need to increase the mobility of people by assessing technological and regulatory problems that can affect their adoption. Their study also suggested ways through which any encumbrances faced during the process can be resolved.

The applications and adoption of drone technology are being experienced in the use of robotics and artificial intelligence lately. In this respect, it is used to interpret events in real-time by depending on appropriate software, that would communicate with each other, create cross-references and interface with 3D models needed to produce photogrammetry effects (Auer et al., 2018). Similarly, drone technology is having its place in different civil applications. According to Shakhatreh et al. (2019), the drone is used to ensure the reduction of risks and cost of construction projects by exploring the opportunities of solving the associated problems during the life cycle of construction projects. Its diverse applications are also captured in environmental management through the need to increase its awareness among researchers and other stakeholders. Ader and Axelsson (2017) noted that cases of variation were found in the need, tasks and methods used by the stakeholders in the adoption of drone technology. They also sought for ways through wich the need to adopt situation-based drones can be deepened.

3.3 Disaster Occurrence and Response Processes in the Environment

Disasters that ravage human beings have been regarded as phenomena that cause imbalances to the landscape and there is a need for appropriate measures to be taken to mitigate their associated impact. According to the International Federation of the Red Cross and Red Crescent Societies (IFRC), disasters are sudden, calamitous events that create an impact in the environment. They can cause imbalances to the activities of a community and lead to human, material, economic or environmental losses. The losses may be more than the established coping and recovery capacities of the concerned society by considering the deployment of its available resources and logistics (Natarajarathinam et al., 2009). Disaster is seen as a natural or man-made (or technological) hazard resulting in a substantial event causing significant physical damage or destruction, loss of life, or drastic change to the environment. It is also an extension of a tragic event stemming from events such as earthquakes, floods, accidents, fires, or explosions. It is also regarded as a phenomenon that has the potentials to cause wanton damages to either life, property, economic, social, or cultural formations in a society (Restas, 2015).

Disasters as a phenomenon have been categorized differently in the body of literature based on its causal factors. The causal factors are specifically based on their points of origin which give them various characteristics and varying degree of impacts that they can cause. Van Wassenhove (2006) gave a classification of both natural and man-made types of disasters that the human environment can face. Typical examples in these categories are famine, drought, political and refugee crises, earthquakes, hurricanes, technological failures, terrorist attacks, and pandemics that cover the global scape. In the wake of the occurrence of disasters, human and built environment stakeholders should be able to evolve appropriate disaster response mechanisms that comprise mitigation, preparedness, response, and recovery. These mechanisms should be carried out to ensure that the final operations and activities of the populace in the built environment can be restored given the impact that the disasters might have caused (Natarajarathinam et al., 2009). The unravelling of the human-induced climate change crisis has emphasized the ability of the human race to adapt and counterweigh the environmental change to ensure balance and sustainability drive. Such a cosy society puts an increasing amount of pressure on hazards assessors, emergency and disaster managers, to get it right, not only to save the majority but all. To achieve this feat, there is dire need to depend on the use of high-quality, and high-resolution geospatial data with the use of UAV (Unmanned Autonomous Vehicles) drones, both on the ground and airborne (Gomez & Purdie, 2016).

Previous works have been carried out on how to apply drone technology in assisting people to overcome disasters. Restas (2015) noted that drones have been useful not only in military and commercial applications, they are also needed in responding to emergency disaster management issues. They use time-scaled separation of the applications involved during the process. This involves taking note of the pre-disaster activity, activity immediately, after the occurrence of a disaster and the activity, after the primary disaster elimination. Estrada and Ndoma (2017) in their study depicted the important roles of drones in cases of natural disasters from a technical response and relief humanitarian aid; and institutional implementation point of view respectively. They maintained that drones can be employed to play crucial roles during possible cases of earthquakes, tsunami, flooding and other natural disasters. Equally, the need to respond to disasters has been maintained to be a crucial role for the first responders to disasters and emergency management community which would depend on the use of drones (Price, 2016). Further to this, with the increasing advancement globally, there have been escalating production of drones used in monitoring and mapping the effects of natural hazards and disasters respectively. This has proved to be lesser and more effective than the conventional remote-sensing techniques. They also stand as viable options in the acquisition of imagery and other physical parameters, before, during and after the occurrence of disasters (Giordan et al., 2017).

Zwęgliński (2020) noted that drones can be regarded as important facilities needed by disaster managers in the course of the discharge of their duties. Hence, there is that need to equip them with more accurate damage assessment know-how through the use of three-dimensional modelling and orthophoto mapping to add values to the aerial assessments of flood-related needs and damages. In their study, de Oliveira Silva et al. (2017) posited that unmanned aerial vehicles (drones) are useful in post-disaster operations by facilitating the speed that the information is generated and made available to the coordination teams. It will thereby highlight the local assessment, detect blocked areas and ensure possible identification of any secondary disaster scenarios. This will make it possible to address any fallouts of natural disasters and chart ways on how to solve them. Equally, Gomez and Purdie (2016) showed that to attain emergency relief for the society due to pressures emanating from human-induced climate change which causes disasters, there is a need to partly consider the use of drones, both on the ground and in the air. Cases of using drones as robotics to address cases of humanitarian needs such as disasters in relief and social cases in health care delivery have also been documented (Pathak et al., 2019). In furtherance of addressing security challenges during disaster management operations, Woodhams (2018) reflected on the need for state officials to be alive to the present trend in the use of drones because of the vast potentials that it has. This has to be done through proper identification of the gaps that exist and how to ensure that security surveillance in the environment is adequately carried out.

■4.0 CONCEPTUAL ISSUES ON COVID-19

4.1 COVID-19 as a Pandemic

According to Sharma (2020), the COVID-19 is regarded as a global pandemic that has caused more than 164,000 deaths and infected more than 2 million people globally. It has called for the adoption of innovative and established disaster-response mechanisms to mitigate its impact and safeguard the lives of people in the built environment. It has affected the policy trust of government and stakeholders on how to address burning issues in the society. It has obviously made governments, organizations, and societies across the globe to rethink work models and interaction patterns to adopt; either in the workplaces, buildings or in other places of gathering in the built environment. In the light of this, the manpower forces comprising frontline warriors are at the centre stage to ensure effective management of the pandemic. Equally, technologies like Artificial Intelligence (AI), Big Data, GIS and Mapping, Location Technology, and autonomous machines are also integrated into its management framework. The drone is also being used as a modest technological component globally to address the further spread of the coronavirus outbreak (Estrada, 2020). Tiels et al. (2015) have shown in their study that drone technology has had its place in the health sector to ensure the delivery of medical products to health facilities that are in the crucial need of relief materials. Meszaros (2020) opined that as the world struggles to contain the spread of the deadly virus, diagnose and treat not less than a million of

people that have contracted COVID-19, quite forward-thinking leaders are looking at the use of facilities like drones that can be very resourceful to support the health care professionals in combating the virus.

An important policy adopted by authorities globally is to prevent the spread of the virus, to reduce people-to-people contact, ensure closure of non-essential public places, ban on mass gathering, and ensuring social distancing to limit physical contact. However, in areas where individuals are not complying with the restrictions willingly or unwillingly, across the globe, drones are being used to monitor people's movement and their mobility (Estrada, 2020). It is also used to monitor the movement of people and equally break up social gatherings that could pose risk to societies. This has shown the surveillance, monitoring, and managing prospects of the drone in the management of COVID-19 (Sharma, 2020). In addition to street surveillance, authorities are also using drones to propagate messages and information about lockdown measures especially in the rural areas that do not have open communication platforms for health information through the loudspeakers that are attached to them.

4.2 Review of Cases Across the Globe on the Use of Drone in Managing COVID-19 Pandemic

Since the emergence of COVID-19 in Wuhan, China, and its spread to different parts of the world, the deployment of drones to manage the pandemic in human settlements has had no bound. A Global Times video on Twitter shows a drone hovering a village in Inner Mongolia warning building occupants not to go out without wearing facemasks. Agriculture spray drones have been successfully deployed in countries like China, India, Indonesia, Philippines, Colombia, Chile, and the UAE to disinfect buildings and places where people converge in numbers. It was also documented that in Europe, Spain was the first country that harnessed the use of agricultural drones and deployed it to disinfect public places (Sharma, 2020). In Wuhan, the epicentre of the pandemic, a drone was used to deliver medical supplies in the hospital and its usage helped to speed up the delivery of essential medical supplies to hospital buildings and places of need. According to Estrada (2020), drones were used to fight the massive impact of the novel COVID-19 in Wuhan, China. It assisted in the process of quarantine of people in the built environment, and to ease the monitoring and distribution of relief materials to the inhabitants. This helped considerably to mitigate the effects of the virus on the inhabitants.

To assess the body reactions, drones were used to take temperature levels of people indoor, in buildings because of the need to ensure physical and social distancing to prevent the rate at which people contract the virus, during the peak of the pandemic in China. The authorities engaged drones to carry out remote temperature measurement in most apartment complexes through the drones that were equipped with infrared cameras. The drones were controlled to rise to the levels of windows of buildings, take measurements of the building occupants when they opened their windows (Figure 1). Equally, in Wuhan, China, drones were used as a light source in the construction site of a temporary hospital building by hovering 50 metres above the ground, covering an area up to 6,000 square metres and illuminated for 10 hours on a single charge (Sharma, 2020) (Figure 2).

Figure 1 The use of a drone in taking temperature measurement of building occupants in China
(Source: Sharma, 2020)

Figure 2 The use of drones hovering around 50metres above ground as a light source during the construction of hospital buildings in Wuhan, China
(Source: Sharma, 2020)

In other parts of the world, drones have been deployed to buildings, epicentres, and human settlements at large, to harness its potentials in managing the COVID-19 virus. According to Meszaros (2020), the pandemic drone developed in Australia that remotely detects and monitors individuals with any possible infectious respiratory was used in the management of COVID-19. It has features like a computer vision system that monitors temperatures, heart rates, respiratory rates as well as sneezing and coughing levels in crowds. These features help in the mechanism to fight COVID-19 to prevent its spread. In Ireland, drone technology has been used to make urgent deliveries of diabetes medications to remote locations. Equally, the United States uses drone technology with recourse to guidelines of the Federation Aviation Administration (FAA) to use it in this kind of pandemic to carry supplies needed in both rural and metropolitan areas. Also, the Drone Responders Public Safety Alliance in the United States, a non-profit public safety programme, established a task force to plan and ensure how drones can be used to meet the challenges occasioned by the COVID-19 pandemic (Meszaros, 2020).

4.3 The Context and Emerging Experience of Nigeria in the Use of Drone During COVID-19 Pandemic

According to Abiodun (2020), Nigeria as a geographical entity has been noted to be vulnerable to a high level of insecurity challenges, which has hitherto, assumed a fearful dimension. It has subjected the country to national insecurity and has forced the government not to rely on the conventional approaches, comprising intelligence gathering and mounting security check-points alone in addressing the challenge. Attention has now been diverted to the possibility of harnessing the potentials and benefits of drones to foster effective surveillance of the landscape. In another fold in the country, the emerging use of drones in addressing societal needs has also gotten boost through then use of drones in the quest to enhance optimization of the country's vaccine supply chain (Michael et al., 2019). They showed in their study, that the use of drones is effective based on the cost-saving benefits, security, preservation of lives, and their core ability to reach very remote areas and gather data conveniently and effectively. Because of the emerging increasing awareness of the uses of drones in the country, the Nigerian government has also instituted a framework. The framework posited provided a guide on its mode of operations, whereby any drones that weigh between 250 grams and 25 kilograms must be registered by the approval authority (Herrmann & Markert, 2020). The framework also stipulated that foreign drone pilots must receive recognition of ownership during all drone flights and the commercial pilots must equally get permits from the country's aviation authority.

Nigeria has had a historical base that influenced the possible deployment of drones to the urban environment to manage the COVID-19 pandemic. Laws had also been framed to pave way for the ownership and use of drone in the airspaces for end uses. According to Ahmadu-Suka (2018), the Nigerian Government unveiled the Nigeria-made drone, produced by the country's Air Force Institute of Technology in Kaduna in 2015, addressed the increasing rate of insecurity in the country. The development has been given institutional framework support, to allow private individuals, to also harness its potentials through the ownership of drone permit to be issued by the country's Civil Aviation Authority (Sidebrief, 2019). Since necessity is the mother of invention, the country through personal or corporate social responsibility has not lagged in the quest to equally join the committee of nations across the world in using drones to manage and fight COVID-19 pandemic. The country has distinctively characterized spatial patterns, land use types, different buildings and road networks constructed with inherent challenges, which have over the years, been sources of concern in the planning sphere, and in-service delivery to locations in the either urban or rural environment in most states in Nigeria (Elusogbon, 2020). While trying to partake in the fight against the COVID-19, the Ooni of Ile-Ife, Osun State, Nigeria, Ooni Adeyeye Enitan Ogunwusi Ojaja II engaged local scientists and technologists on how to use drones, made available by the manufacturers, to be used as fumigators, and to disinfect the landscape of the country appreciably. In his position, Ooni Ogunwusi described the current moment of COVID-19 across the world, as one, that inevitably necessitates the deployment of creativities and inventions, as seen in the use of Volkswagen created by the Germans during the Second World War. This intervention has shown the emerging adoption of the use of the Unmanned Aerial Vehicles (UAVs) as opined by (Gomez & Purdie, 2016; Zitzman, 2018) of its applications in surveillance operations as devices useful to the emergency and disaster managers in the urban environment. This is made possible by the high-resolution geospatial data collected during its manoeuvrability in the space that is useful in further predictive processes.

4.4 Ooni of Ile-Ife and His Kingdom in Context

According to Cunningham (2006), Ooni is the spiritual head of the Yoruba in the southwestern part of Nigeria, with his town of the domain being Ile-Ife. It is considered by the Yoruba to be a holy city and the legendary birthplace of humankind and was held to have been founded by a son of the deity, Oduduwa. It was also certainly the capital of a well-established kingdom (probably named for Ifa, the god of divination), in the early 11th century (Cunningham, 2006). Ife was regarded as the epicentre of the major religious centre of the Yoruba people and kingdom. It is also regarded as the actual place of creation of the globe, where the gods descended from heaven to create the world (Cartwright, 2019). Ile-Ife is an ancient town in the current Osun State, located in the South-western part of Nigeria. It is located between latitudes $7^0 28^1$N and $7^0 45^1$N and longitudes $4^0 30^1$E and $4^0 34^1$E. The time zone used in Ile-Ife is Africa/Lagos, and the evidence of its settlement is dated back as far as 500 BC (Adebayo et al., 2014). The town is surrounded by rural settlements where agriculture is the primary occupation. However, Ile-Ife itself is a highly commercialized city and it has the Obafemi Awolowo University (formerly the University of Ife) which was founded in 1961, is located in the town. Ile-Ife is about 218 kilometres (135 miles) Northeast of Lagos and the city has an undulating terrain, characterized by rocky formations and also over-laid by metamorphic rocks (Ajala & Olayiwola, 2013). Ancestrally, the Ooni of Ile-Ife has a major influence on the control of the city and in determining dictate of orders among the Yoruba people in Nigeria.

In the history of the Yoruba people, colonial development of the country and despite the policy in the general functioning of local political systems, the early British administrators chose the institution of Oba (King) as one aspect that deserved attention. The Ooni of Ile-Ife was one of such Obas (Kings) who benefited from the various attempts of the British administration on their political administration in the southwestern part of the country (Oyediran, 1973). The dynasty of Ooni exited before the reign and historians had put up positions that it occurred between the 7th and 9th centuries. Ooni of Ile-Ife remains the spiritual head of the Yoruba people who has custody of the sacred staff of Oranmiyan, which is an 18-foot (5.5 metres) granite monolith that has the shape of an elephant's tusk. The palace compound of the Ooni is also the site of the Ife Museum which contains a collection of cire-perdue bronze castings and terra-cotta sculptures that were partly acquired by the German archaeologist, Leo Frobenius in 1910. This was subsequently expanded through excavations at the

Wunmonije Compound and the nearby, Ita Yemoo (Cunningham, 2006). Beyond his kingdom, Yoruba area in the southwestern part of Nigeria, the Ooni of Ile-Ife is regarded as one of the first-class traditional rulers in the country that tiers of government give due reverence to. The Ooni also plays prominent roles in improving the lives of people in the region. All the Oonis in history are always traced back to Oduduwa who is regarded as the ancestral leader of the Yoruba People. The present Ooni of Ile-Ife, Ooni Adeyeye Enitan Ogunwusi, Ojaja II emerged as the ruler in 2015 and has since been overseeing the control and rulership as due (Folabalogun, 2017).

Arising from the various effects that the COVID-19 has had on the Yoruba kingdom and people in the entire country at large, the Ooni of Ile-Ife carried out an intervention scheme through the adoption of the benefits of using the technology of drone during disaster events. While explaining the advantages of the specially made drones, to be used as fumigators, the Ooni of Ile-Ife posited that it was specially designed with equal fumigation capacity as industrial fumigation trucks used in China, Pakistan and some Western countries with wide fumigation coverage of about 20ft to 30ft in radius. The drone equally has assemblage convenience and cost-effectiveness advantages. Given the benefits that it stands to offer in ensuring safe and hygienic human settlements in the built environment, the supplied drones were initially used within the Ile-Ife town to fumigate settlements and buildings (Figure 3). In a bid to ensure that the country at large, can take a cue from the initiative, 36 further drones were procured by the Imperial Majesty, Ooni of Ife, and each was supplied to every state government in the country to ensure easier fumigation of the landscape to fight the COVID-19 pandemic.

Figure 3 Sections of drones supplied and used to fumigate the built environment and environs of Ile-Ife
(Source: Elusogbon, 2020)

As depicted in the afore discussion on the benefits accruable from the use of the drones to fumigate built environment landscape and buildings in different parts of the country, this has been shown on its relatedness to previous works of Zitzman (2018) which captures its applications in surveillance operations; and Ayemba (2018) which shows its established uses in the field of infrastructure and construction practices, while several other works (Meszaros, 2020; Natarajarathinam et al., 2009; Restas, 2015; Sharma, 2020; Zhang & Wu, 2014) have also shown in the body of existing literature, the wide applications of drones in responding to disasters and emergency operations in the human environment. Also, arising from the use of a drone as an emerging initiative to combat COVID-19 pandemic, it shows its applications and interrelatedness to the existing body of literature to its use in different response interventions like the September 11 Terrorist Attack of 2001 as opined by Meier (2014), and its diverse applications sectorally in the areas of risk assessment and disaster response (Liu et al., 2014).

The emerging adopting of the applications of drone technology in Nigeria has also been substantiated in few other studies, which have also supported the intervention scheme of the Ooni of Ife in using it to fight COVID-19 in the country. Abiodun (2020) showed that drone technology is being used to address security challenges in the face of increasing cases of armed banditry, robbery, herdsmen killings, ritual killings, kidnapping, Boko Haram attacks and Niger Delta militancy. Michael et al. (2019) also carried out a study to determine the opportunities of using drones on how to optimize the country's Vaccine Supply Chain (VSC) among the health and development professionals. They found out that a paltry 27% of the respondents were aware of the opportunities of using drones in Nigeria's VSC. This also substantiates its emerging use in the country. Similarly, Patrick et al. (2020) in their study stated that because of the hazardous effects of most building sites, drones have emerging relevance of being used to monitor safety and security of personnel on-site. It was found out that the level of awareness among the key building professionals on the use of drones for safety and security operations on sites was still at the lowest ebb. A study to assess the geometric quality of the unmanned aerial photography using drones in Nigeria was carried out by Daramola et al. (2017). Their research work established that the accuracy obtained in the horizontal and vertical axes were suitable for cadastral map compilations.

5.0 CONCLUSION

Across the globe and over the years, the myriad applications and utilization of a drone in addressing challenges in the areas of military, mining, agriculture, aviation, surveillance, and construction have been documented (Ayemba, 2018; Hallermann & Morgenthal, 2014; Li & Liu, 2019; Tkáč & Mésároš, 2019). Researchers have also been making further efforts on how drones can be deployed to solve and mitigate risks and disasters that occur in the human environment (Câmara, 2015; Zhang & Wu, 2014). This paper shows that the disasters and risk that pervade built environment, affect comfort and performance of building occupants has been traced to the occurrence of different types and nature of occurrences that equally affect the sustainability of the entire global scape. Given this, the emergence of COVID-19 in Wuhan, China signalled a new order globally, with recourse to the adoption of relevance and applications of technological innovations of the drone in addressing such societal problem that has become pandemic based on its coverage. It also shows that across the globe, the use of drones in different nations in solving environmental challenges is gaining more attention and adoption particularly when the issues of accessibility are of dire importance. In order not to be left behind in harnessing the vast potentials of drone technology in addressing and managing disasters, the Imperial Majesty of Ile-Ife, Ooni of Ile-Ife, Osun State, Nigeria contributed to the emerging adoption of the use of drones in Nigeria, by kick-starting its applications in fumigating and decontaminating urban settlements in Ile-Ife and its environs. This gesture was further extended to other states of the country to address associated challenges of the planning of settlements, which affect remoteness and accessibility of neighbourhood and buildings in the country's built environment. Thus, by leveraging on the advantages accruable from the use of drones in ensuring service delivery and management of disasters as currently experienced in the on-going fight against COVID-19 in the country, its use should be vigorously deepened through appropriate institutional supports to complement efforts of stakeholders in making the country's built environment safe and healthy for all.

References

Abiodun, T. F. (2020). Usage of drones or unmanned aerial vehicles (UAVs) for effective aerial surveillance: Mapping system and intelligence gathering in combating security in Nigeria. *African Journal of Social Sciences and Human Research*, *3*(2), 29-44.

Adebayo, W. O., Jegede, A. O., & Eniafe, D. F. (2014). The economic impact of tourism development in Ile-Ife, Osun State, Nigeria. *Journal of Tourism, Hospitality and Sports*, *2*, 28-33.

Ader, M., & Axelsson, D. (2017). *Drones in arctic environment* (Master's thesis). KTH Royal Institute of Technology, Stockholm, Sweden.

Ajala, O. A., & Olayiwola, A. M. (2013). An assessment of the growth of Ile-Ife, Osun State Nigeria, using multi-temporal imageries. *Journal of Geography and Geology*, *5*(2), 43-54.

Ahmadu-Suka, M. (2018, February 15). Buhari unveils Nigeria-made drone in Kaduna. *Daily Trust*. Retrieved on 18 June 2020 from https://dailytrust.com/buhari-unveils-nigeria-made-drone-in-kaduna.

Albeaino, G., Gheisari, M., & Franz, B. W. (2019). A systematic review of unmanned aerial vehicle application areas and technologies in the AEC domain. *Journal of Information Technology in Construction (ITcon)*, *24*, 381-405.

Amorium, R., Nguyen, H., Mogensen P., Kovács, I. Z., Wigard, J., & Sørensen, T. B. (2017). Radio channel modeling for UAV communication over cellular networks. *IEE Wireless Communication Letters*, *6*(4), 514-517.

Auer, L., Feichtner, A., Steinhäusler, F., Delleske, R. & Keuschnig, M. (2018). Swarm-technology for large-area photogrammetry survey and spatially complex 3D modelling. *International Journal of Latest Research in Engineering and Technology*, *4*(9), 33-39.

Ayemba, D. (2018). Utilizing drone technology in construction. *Construction Review Online*. Retrieved on 14 June 2020 from https://constructionreviewonline.com/2018/03/drones-in-construction.

Bendea, H., Boccardo, P., Dequal, S., Tonolo, F. G., Marenchino, D., & Piras, M. (2008). Low-cost UAV for post-disaster assessment. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *37*, 1373-1379.

Bravo, R. Z. B., & Leiras, A. (2015, October). *Literature review of the applications of UAVs in humanitarian relief*. Paper presented at the XXXV Encontro Nacional de Engenharia de Producao: Perspectivas Globais para a Engenharia de Produção, Fortaleza, Brazil. Retrieved from https://www.researchgate.net/profile/Adriana_Leiras/publication/303938866_LITERATURE_REVIEW_OF_THE_APPLICATIONS_OF_UAVS_IN_HUMANITARIAN_RELIEF_XXXV_ENCONTRO_NACIONAL_DE_ENGENHARIA_DE_PRODUCAO/links/575f2c4108ae9a9c955fb2ed.pdf.

Brown, L. (2019). What is a drone and how does it work? *Wondershare*. Retrieved on 8 May 2020 from https://filmora.wondershare.com/ drones/what-is-drone-how - does-it-work.

Câmara, D. (2015). Calvary to the rescue: Drones fleet to help rescuers operations over disaster scenarios. In *Proceedings of IEEE conference on antenna measurements applications (CAMA) (2014)*. Antibes, France: IEEE.

Cartwright, M. (2019, March 26). Ife. *Ancient History Encyclopedia*. Retrieved on 9 Octoer 2020 from https://www.ancient.eu/ife.

CircuitsToday. (2017). *Types of drone - Explore the different models of UAV's*. Retrieved on 8 June 2020 from https://www.circuitstoday.com/types- of-drones.

Cunningham, J. M. (Ed.) (2006). The world cities: History of Ile-Ife. *Encyclopaedia Britannica*. Retrieved on 3 October 2020 from https://www.britannica.com/place/Ile-Ife.

Daramola, O., Olaleye, J., Ajayi, O. G., & Olawumi, O. (2017). Assessing the geometric accuracy of UAV-based orthophotos. *South African Journal of Geomatics*, *6*(3), 395-406.

de Oliveira Silva, L., de Mello Bandeira, R. A., & Campos, V. B. G. (2017). The use of UAV and geographic information systems for facility location in a post-disaster scenario. *Transportation Research Procedia*, *27*, 1137-1145.

Elusogbon, D. (2020, April 21). COVID-19: Ooni fumigates Ile-Ife, moves to donate fumigators to 36 states. Retrieved on 27 June 2020 from https://nnn.ng/covid-19-ooni-fumigates-ile-ife-moves-to-donate-fumigators-to-36-states/.

Estrada, M. A. R. (2020, March 4). The uses of drones in cases of massive epidemics contagious diseases relief humanitarian aid: Wuhan-COVID-19 crisis. Retrieved on 9 October 2020 from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3546547.

Estrada, M. A. R., & Ndoma, I. (2017). How unmanned aerial vehicles- UAV's - (or Drones) can help in case of natural disasters response and humanitarian relief aid. Retrieved on 1 October 2020 from https://papers.ssrn.com/Sol3/papers.cfm?abstract_id=2961576.

Ezequiel, C. A. F., Cua, M., Libatique, N. C., Tangonan, G. L., Alampay, R., Labuguen, R. T., Favila, C. M., Honrado, J. L. E., Caños, V., Devaney, C., Loreto, A. B., Bacusmo, J., & Palma, B. (2014). UAV aerial imaging applications for post-disaster assessment, environmental management and infrastructure development. In *ICUAS 2014. Proceeding of 2014 international conference on unmanned aircraft systems* (pp. 274-283). Orlando, FL: IEEE.

Fan, J., & Saadeghvaziri, M. A. (2019). Applications of drones in infrastructures: Challenges and opportunities. *International Journal of Mechanical and Mechatronics Engineering*, *13*(10), 649-655.

Folabalogun, M. (2017). Art, symbol and royalty: A case study of the Yoruba speakers in Nigeria. *International Journal of Arts and Humanities*, *6*(1), 162-175.

Gallacher, D. (2016). Drone applications for environmental management in urban spaces: A review. *International Journal of Sustainable Land Use and Urban Planning*, *3*(4), 1-14.

Giordan, D., Manconi, A., Remondino, F., & Nex, F. (2017). Use of unmanned aerial vehicles in monitoring application and management of natural hazards. *Geomatics, Natural Hazards and Risk*, *8*(1), 1-4.

Giordan, D., Adams, M. S., Aicardi, I., Alicandro, M., Allasia, P., Baldo, M., De Berardinis, P., Dominici, D., Godone, D., Hobbs, P., Lechner, V., Niedzielski, T., Piras, M., Rotilio, M., Salvini, R., Segor, V., Sotier, B., & Troilo, F. (2020). The use of unmanned aerial vehicles (UAVs) for engineering geology applications. *Bulletin of Engineering Geology and the Environment, 79*, 3437-3481.

Gomez, C., & Purdie, H. (2016). UAV-based photogrammetry and geocomputing for hazards and disaster risk monitoring - A review. *Geoenvironmental Disasters*, *3*, 26-46.

Gonzales-Dugo, V., Zarco-Tejada, P., Nicolás, E., Nortes, P. A., Alarcón, J. J., Intrigliolo, D. S., & Fereres, E. (2013). Using high resolution UAV thermal imagery to assess the variability in the water status of five fruit tree species within a commercial orchard. *Precision Agriculture, 14*, 660-678.

Hallermann, N., & Morgenthal, G. (2014, July). Visual inspection strategies for large bridges using unarmed aerial vehicles (UAV). In A. Chen, D. M. Frangopol & X. Ruan (Eds.), *IABMAS 2014. Proceedings of the 7th International Conference on Bridge Maintenance, Safety and Management (IABMAS 2014)* (pp. 661-667). Boca Raton, FL : CRC Press.

Handouf, S., & Sabir, E. (2019). Strategic availability and cost-effective UAV-based flying access networks: S-modular game analysis. *Mobile Information Systems, 2019*, 1-11.

Herrmann, S., & Markert, F. (2020). Drone laws in Nigeria. *Drone Traveller*. Retrieved on 12 August 2020 from https://www.drone-traveller.com.

Howell, C. T., III, Jones, F., Thorson, T., Grube, R., Mellanson, C., Joyce, L., Coggin, J., & Kennedy, J. (2016, May). *The first government sanctioned delivery of medical supplies by remotely controlled unmanned aerial system (UAS).* Paper presented at XPONENTIAL 2016, New Orleans, LA.

Jenkins, D., & Vasigh, B. (2013). *The economic impact of unmanned aircraft systems integration in the United States*. Arlington, VA: Association of Unmanned Vehicle Systems International. Retrieved from https://robohub.org/_uploads/AUVSI_New_Economic_Report_2013_Full.pdf.

Kardasz, P., Doskocz, J., Hejduk, M., Wiejkut, P., & Zarzycki, H. (2016). Drones and possibilities of their using. *Journal of Civil and Environmental Engineering, 6*(3), 1-7.

Kellermann, R., Biehle, T., & Fischer, L. (2020). Drones for parcel and passenger transportation: A literature review. *Transportation Research Interdisciplinary Perspectives, 4*, 100088.

Liu, P., Chen, A. Y., Huang, Y.-N., Han, J.-Y., Lai, J.-S., Kang, S.-C., Wu, T.-H., Wen, M.-C. & Tsai, M.-H. (2014). A review of rotorcraft unmanned aerial vehicle (UAV) developments and applications in civil engineering. *Smart Structures and Systems*, *13*(6), 1065-1094.

Li, Y., & Liu, C. (2019). Applications of multirotor drone technologies in construction management. *International Journal of Construction Management, 19*(5), 401-412.

Mahmoud, S., Mohamed, N., & Al-Jaroodi, J. (2015). Integrating UAVs into the Cloud using the concept of the Web of Things. *Journal of Robotics, 2015*, 1-10.

McCormack, E. D. (2008, June). *The use of small unmanned aircraft by the Washington State Department of Transportation* (Report No. WA-RD 703.1). Retrieved from https://rosap.ntl.bts.gov/view/dot/16515.

Meier, P. (2014). *Humanitarians in the sky: Using UAVs for disaster response*. Retrieved on 17 May 2020 from https://irevolutions.org/2014/06/25/humanitarians-in-the-sky/.

Meszaros, L. (2020, April 9). *Drone technology: A new ally in the fight against COVID-19*. Retrieved on 21 June 2020 from https://www.mdlinx.com/article/drone-technology-a-new-ally-in-the-fight-against-covid-19/61gQW7xmBCg6LyGy43925Z.

Michael, O. T., Olusegun, A., Paul, O. A., Felix, S. O., Kaniki, F. R., Ayosanmi, O. S., Wade, D., Faith, A. O., Terna, G. Z., Musa, A., Afelumo, O. L., Aiden, J., & Adeiye, A. L. (2019). The use of UAV/Drones in the optimization of Nigeria vaccine supply chain. *International Journal of Scientific & Engineering Research*, *10*(10), 1273-1279.

Narayanan, R. G. L., & Ibe, C. O. (2015). Joint network for disaster relief and search and rescue network operations. In D. Câmara & N. Nikaein (Eds.), *Wireless public safety networks, volume one: overview and challenges* (pp. 163-193). London: ISTE Press - Elsevier.

Natarajarathinam, M., Capar, I., & Narayanan, A. (2009). Managing supply chains in times of crisis: A review of literature and insights. *International Journal of Physical Distribution & Logistics Management*, *39*(7), 535-573.

Oyediran, O. (1973). The position of the Ooni in the changing political system of Ile-Ife. *Journal of the Historical Society of Nigeria, 6*(4), 373-386. Retrieved on 3 October 2020 from https://www.jstor.org/stable/41856970.

Pajares, G. (2015). Overview and current status of remote sensing applications based on Unmanned Aerial Vehicles (UAVs). *Photogrammetric Engineering & Remote Sensing, 81*(4), 281-329.

Pathak, P., Damle, M., Pal, P. R., & Yadav, V. (2019). Humanitarian impact of drones in healthcare and disaster management. *International Journal of Recent Technology and Engineering, 7*(5), 201-205.

Patrick, O. O., Nnadi, E. O. E., & Ajaelu, H. C. (2020). Effective use of Quadcopter drones for safety and security monitoring in a building construction site: Case study Enugu Metropolis Nigeria. *Journal of Engineering and Technology Research, 12*(1), 37-46.

Pham, H. Q., Camey, M., Pham, K. D., Pham, K. V., & Rilett, L. R. (2020). Review of unmanned aerial vehicles (UAVs) operation and data collection for driving behavior analysis. In H.-M. Chuong, V. D. Dong, F. Benboudjema, S. Derrible & V. K. H. Dat (Eds.), *CIGOS 2019, Innovation for sustainable infrastructure* (Vol. 54, pp. 1111-1116). Singapore: Springer.

Price, D. E. (2016). *Unmanned aircraft systems for emergency management: A guide for policy makers and practitioners* (Master's thesis). Naval Postgraduate School, Monterey, CA.

Restas, A. (2015). Drone applications for supporting disaster management. *World Journal of Engineering and Technology, 3*(3), 316-321.

Rouse, M., Shiao, D., Earls, A., Shea, S., & Wigmore, I. (2019). Drone (UAV). Retrieved on 11 August 2020 from www.internetofthingsagenda.techtarget.com.

Shakhatreh, H., Sawalmeh, A. H., Al-Fuqaha, A., Dou, Z., Almaita, E., Khalil, I., Othman, N. S., Khreishah, A., & Guizani, M. (2019). Unmanned aerial vehicles (UAVs): A survey on civil applications and key research challenges. *IEEE Access, 7*, 48572-48634.

Sharma, V., Lim, J. D., Kim, J. N., & You, I. (2017). SACA: Self-aware communication architecture for IoT using mobile fog servers. *Mobile Information Systems, 2017*, 1-17.

Sharma, M. (2020, April 20). How drones are being used to combat COVID-19. *Geospatial Media and Communications*. Retrieved on 28 June 2020 from https://www.geospatialworld.net/blogs/how-drones-are-being-used-to-combat-covid-19/.

Sidebrief. (2019, June 27). *You absolutely need a drone permit to fly a drone within the Nigerian airspace*. Retrieved on 7 May 2020 from https://sidebrief.com.

Siebert, S., & Teizer, J. (2014). Mobile 3D mapping for surveying earthwork projects using an unmanned aerial vehicle (UAV) system. *Automation in Construction, 41*, 1-14.

Tiels, C. A., Aho, J. M., Zietlow, S. P., & Jenkins, D. H. (2015). Use of unmanned aerial vehicles for medical product transport. *Air Medical Journal*, *34*(2), 104-108.

Tkáč, M., & Mésároš, P. (2019). Utilizing drone technology in the civil engineering. *SSP - Journal of Civil Engineering*, *14*(1), 27-37.

Van Wassenhove, L. N. (2006). Humanitarian aid logistics: Supply chain management in high gear. *Journal of the Operational Research Society*, *57*(5), 475-489.

Vergouw, B., Nagel, H., Bondt, G., & Custers, B. (2016). Drone technology: Types, payloads, applications, frequency spectrum issues and future developments. In B. Custers (Ed.), *The future of drone use* (Vol. 27, pp. 21-45). The Hague: T.M.C. Asser Press.

Woodhams, G. (2018). Weapons of choice? The expanding development, transfer and use of armed UAVs. United Nations Institute for Disarmament Research (UNIDR). Retrieved on 4 October 2020 from https://unidir.org/publication/weapons-choice-expanding-development-transfer-and-use-armed-uavs.

Zitzman, L. (2018). *Drones in construction: How they're transforming the industry*. Retrieved on 15 May 2020 from https://www.grentz.com/blog/drone-construction.

Zhang, W., & Wu, J. (2014). To explore the UAV application in disaster prevention and reduction. *Applied Mechanics and Materials*, *590*, 609-612.

Zhou, S., & Gheisari, M. (2018). Unmanned aerial system applications in construction: A systematic review. *Construction Innovation, 18*(4), 453-468.

Zwęgliński, T. (2020). The use of drones in disaster aerial needs reconnaissance and drainage assessment - Three-dimensional modeling and orthophoto map study. *Sustainability, 12*(15), 6080.