Vol. 12(1), pp. 37-46, July-December 2020
DOI: 10.5897/JETR2020.0695
Article Number: 84C7C5A65235
ISSN: 2006-9790

http://www.academicjournals.org/JETR

ACADEMIC JOURNALS

Journal of Engineering and Technology Research

Full Length Research Paper

Effective use of Quadcopter drones for safety and security monitoring in a building construction sites: Case study Enugu Metropolis Nigeria

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Received 9 May, 2020; Accepted 14 July, 2020

The hazardous nature of the Nigerian building construction industry due to lack of construction data and records of incidents which have led to loss of life, property damage, injuries and loss of materials in an average construction site is alarming. The aim and objective of this study is to know how effective the use of drone to monitor safety and security in Nigerian Building Construction site can improve dangerous site situations. In other to achieve the aim and objective of this study the following were postulated: To examine the level of awareness of drones in Enugu State Nigeria? What is the level of adoption of drones among construction stakeholder in Enugu State Nigeria? To examine the limitations of using drones/UAVs (Quadcopter) for safety and security monitoring within Building Construction sites in Enugu State Nigeria. Genius-idea drones and DJI Phantom 3 Standard Drones were used in this study. The targeted professionals/stakeholder was architects, builders, engineers, quantity surveyors, land surveyors, estate surveyors and clients. However, 242 people responded to the questionnaire. Data collated was analyzed using statistical package for social sciences (SPSS) computer software version 23.0 for windows. However, 66% of respondents were aware of drone concept in construction monitoring while 51% respondents adopted drones in different sectors of construction monitoring. However, in safety and security monitoring 17.6% adoption was indicated as low between stakeholders in the Enugu State Building Construction industry. The use of drones in the developed world namely America, Europe, China, Australia and India have been employed in safety and security monitoring and in construction progress monitoring of both high rising and vast projects with great success. In the Nigerian perspective, drones as a tool for monitoring safety and security of all phases of construction are still at the nascent stage. The effective use of drones in Nigeria is encouraged since reality imagery collected from drones could be used for analyzing and evaluating of ongoing construction activity like planning movement on site and monitoring materials on site and could be stored for future references.

Key words: Quadcopter drone (UAV), reality images, safety and security monitoring, DJI Phantom 3 standard.

INTRODUCTION

The hazardous nature of the Nigerian building construction industry due to lack of construction data and records of incidents which have led to loss of life, property damage, injuries and loss of materials in an average building construction site is alarming. (Grayson, 2015) refers to the aircraft itself or equipment operated

independently of human control. Initial uses for UAVs were primarily for military purposes and military research has been a major driver for advancing UAV technology. Moreover, the advancement of GPS technology has allowed both military and civilian UAVs to be navigated by satellite (Carrison, 2015). Small multi-propeller helicopters called “quadcopters” can be equipped with almost any sensing technology (Snider and Welch, 2015). Drone has improved productivity in agriculture, construction project deliver process, forestry safety and security (Wallace et al., 2014; Andrea et al., 2010). Drone can be used to reach heights that humans can’t reach. While inspecting a leaking roof you can send a drone to take picture and single out the damaged point for further repairs. Drone can be used to inspect high rise buildings without obstruction of work. Unmanned aerial vehicle is capable of capturing numerous photos from various angles and zoom settings in a matter of minutes. The entire operation is conducted without road closures, at greatly lower cost than alternative inspection techniques, and with very little safety risk (Pritchard, 2015). Wind turbine inspections have traditionally been accomplished through the use of binoculars or by technicians that are required to climb to great heights. The introduction of UAVs has provided a much safer option for these inspections and with higher resolution than that offered by binoculars (NAW Staff, 2015). Using drones allows you to have more real-time detailed control over the project, so you can keep track of the progress visually, and achieve closure at perhaps a quicker time than previously estimated (Irina et al., 2018).

According to Ezeokoli et al. (2016), the Nigerian Construction industry is a well-known late comer to the adoption of innovations compared to other sectors. The digital revolution faced by construction industries at this time is a paradigm shift in the use of technologies, aimed at increased productivity, efficiency, value, quality, sustainability and reduced lifecycle costs. The traditional safety monitoring of construction projects lacks a good number of trained staffs and taskforce. However, lots of safety and security incidents have gone undocumented. The indigenous construction professionals and client pay little or no attention to safety and security in an average Nigerian construction site making it risky and accident prone. Government policies and lack of enforcement has made the situation worsen in recent times.

The aim of this study is to know how effective the use of drone to monitor safety and security in Nigerian Building Construction site can improve dangerous site situations and reduce material loss on site. In other to achieve the aim, the following objectives were raised: To examine the level of awareness of drones in Enugu State Nigeria? What is the level of adoption of drones among construction stakeholder in Enugu State Nigeria? To examine the limitations of using drones/UAVs (Quadcopter) for safety and security monitoring at selected building construction site in Enugu Metropolis.

RESEARCH METHODOLOGY

In this study, investigations were carried out on the use of Quadcopter drones (unmanned aerial vehicles) as a tool for monitoring Safety cultures of workers on the building construction sites through reality images and video streams captured by DJI Phantom 3 and genius-Idea drones. The researcher selected these drones because of the high quality of pictures and availability of drones in the research area. However, DJI enterprise makes drones with features that ease data collection in the construction sites. The genuine Idea drone is a recreational drone that was used as backup flight in the survey.

Genius-idea drones and DJI Phantom 3 standard drones with the following specifications were used in this study: Genius-idea drone taking off weight 275 g, maximum used altitude 3000 m, endurance time 20 min, video resolution ratio 4 K;1080 P and 720P, controlled with an android phone or an iPhone with the help of G-idea app. The requirements for the versions in mobile equipment system is android 4.3 and above or iOS 8.0 and above. While the DJI Phantom 3 standard maximum tested altitude is 500 m, endurance time 25 min, it has an integrated 3-axis Gimbal stabilization with photo resolution 12 mp, Shutter speed 8 to 1/8000 s, video resolution FHD (1920 x 1080), high density (1280 x 720), package weight 0.65kg, recording media: micro SD 64GB, operating temperature 32 to 40°F/ 0 to 40°C. It also comes with a remote controller.

Site location

Enugu State is one of the states in south-eastern Nigeria. Its capital is Enugu. The state was created in 1991 from the old Anambra State. Enugu state is located within latitude 06^{o} 00’N and 07^{o} 00’N and longitude 07^{o} 00’E and 07^{o} 45’E. The state is called the Coal City State because of the discovery of coal in a commercial quantity in Enugu Urban in 1909. Enugu was then the capital of Eastern Nigeria. However, the two estates used in this research work for observation purposes are Devine Hectares estates and WTC estate. Devine hectares estate is new and located with this latitude 6°25’39” N_7°31’13” E inside Centenary City, Enugu State Golf and Lifestyle City. Centenary City is Located at Enugu-South KM7, Enugu, Port-Harcourt Expressway. Devine hectares estate comprises of duplexes and few bungalows that are prototype residential buildings. The estate has its own estate manager and engineers. The estate is divided into Phase 1, 2, 3 and 4. Phase 1 and 2 are developed with some built up area and about 160 plots while 3 and 4 have not been developed at the point of this research work. While WTC estate is located in the center of Enugu State close to Uba Bus stop, Ogui, Enugu State Nigeria. The semidetached bungalow located in this latitude 6°25’36N _ 7°30’14” E was observed in this research work.

Batching of flight timing

The flight dispatch was scheduled into two batches morning and

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Figure 1. Genius-idea drone picture during calibration onsite.
Source: Field survey 2019.

evening to monitor the activities at work during the commencement of work and at the end of work. Work started on site by 8:00 hour and two hours into the work 10:00 hour the first inspection was conducted, and another inspection was conducted to know the last condition and positions of materials on site around 5:00 hour before handing over to the site/estate security.

Questionnaire

Opinion pool were sought and questionnaire was prepared with goggleform (www.googleform.com) for the use of drones for effective monitoring of safety culture in the building construction sites and was distributed to the professionals in the construction industry through SMS, WhatsApp, Facebook messenger and field distribution. The targeted professionals were Architects, Builders, Engineers, Quantity Surveyors, Land Surveyors, Estate Surveyors and clients. However, 242 people responded to the questionnaire. Data collated was analyzed using statistical package for social sciences (SPSS) computer software version 23.0 for windows. Descriptive statistics which includes frequency and percentages were used to summarize categorical variables while means and standard deviations were obtained for continuous variables. The Likert scale was ranked from code 1 = strongly disagree/very difficult/very slow to code 5 = strongly agree/very easy/very fast. Mean greater than the criterion means of 3 was regarded as a positive response and vice-versa.

RESULTS

Figures 1 and 2 show the picture of drones used in this study. The DJI drone was used more onsite because it is easy to control it gives a stable and high-resolution imagery. The genius-idea drone calibration was not successful due to poor GPS signal onsite.

Location

Divine Hectares Estate is a large estate with about 800,000 m^2 for phases one, which is about 160 plots. The property is being developed by geo-square meter (private developers) it runs into phases 1 to 4. Figures 3 and 4 show an aerial view of Divine Hectares Estate.

Batching of flight time

Flight dispatch was scheduled into two batches morning and evening to monitor the activities at work during the commencement of work and at the end of work. Images captured by the UAV during commencement of work showed that five workers in the foundation were not wearing their Personal Protective Equipment's (PPE) while mixing concrete and laying blocks in the foundation. Figure 5 shows the aerial view of the foundation. Figure 6 also shows workers on a duplex without any safety wears as well.

Figures 7 and 8 show activities covered on site. Data collected through drone inspection during site closure around 17:00 hours showed materials and equipment positioning on site before handing over to the site security.

Questionnaire

The response to the various questions from the questinnaire are peresented in Figures 9. Figure 9 shows

Figure 2. DJI drone Phantom 3 Standard captured onsite with an android phone.
Source: Field survey 2019.

Figure 3. Aerial view of devine hectares estate from entrance.
Source: Field survey 2019.

that 66% of the respondents in the building construction industry are aware of UAV concept. Table 1 shows that out of 51 professionals that use UAVs in project monitoring, only 3 (5.9%) use it often while 30 (58.8%) use it occasionally. The kind of projects they use UAV include: Surveying mapping (29.4%), construction project monitoring (23.5%) and safety and security monitoring (17.6%). The respondents that owned drones more were

Figure 4. Aerial view of devine hectares estate.
Source: Field survey 2019.

Figure 5. Worker in the foundation working without their personal protective equipment and the foundation basket dropped carelessly on the floor, captured by a DJI Phantom 3 Standard drone.
Source: Field survey 2019.

land surveyors, an architect and a builder which added up to 17.6%. The type of drones owned by them includes DJI Phantom 4 Pro (33.3%), Geniusidea drone (33.3%) and Phantom 3 standard (33.3%). The table also reveals that 58.8% of the respondents have been trained on how to fly a drone. Most of the training took place online (40%) and in Nigerian Institute of Surveyors training section (20%).

Table 2 shows that the respondents outlined various UAV adoption limitations. They include: Poor performance of drones in extreme weather conditions (3.67), battery life and limited flight time (3.78), communication loss (3.39), laws and regulations with restrictions (3.57), labour and work distractions (3.08), privacy concerns

Figure 6. Workers in the upper floor were not wearing any Personal Protective captured by DJI drone.
Source: Field survey 2019.

Figure 7. Samples of materials on site captured by a DJI Phantom 3 Standard drone during closing of work.
Source: Field survey 2019.

Figure 8. Aerial reality image of material and equipment onsite during closing hour including offcuts scattered on the floor. captured by a DJI Phantom 3 Standard drone.
Source: Field survey 2019.

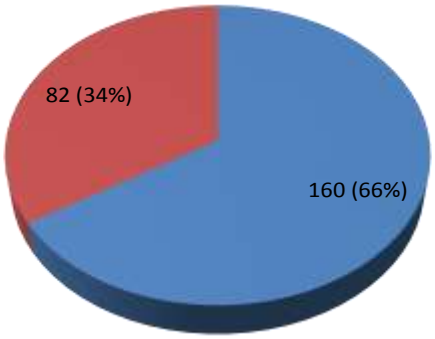

Figure 9. Awareness of UAV concept among stakeholders.
Source: Field survey 2019.

Table 1. Level of adoption of UAVs by stakeholders in building project safety and security monitoring.

	Frequency	Percent
If yes in what frequency		
Occasionally	30	58.8
Often	3	5.9
Rarely	15	29.4
Very often	3	5.9
What kind of project does use UAV for?		
Safety and security monitoring	9	17.6
Construction project monitoring	12	23.5
Event coverage	15	29.4
Surveying/mapping	15	29.4
Do you own a drone?		
Yes	9	17.6
No	42	82.4
If yes specify the type		
DJI Phantom 4 Pro	3	33.3
Geniusidea drone	3	33.3
Phantom 3 standard	3	33.3
What is the cost range of owning a drone?		
1000-2000$	3	33.3
2000-3000$	3	33.3
50-1000$	3	33.3
Have you undergone any training on flying a drone both formal and informal?		
Yes	30	58.8
No	21	41.2
If yes specify where u had the training		
Enugu State	3	10.0
Nigerian Aviation School Zaria	3	10.0
NIS training section	6	20.0
NIS workshop	3	10.0
Online/YouTube	12	40.0
Private training	3	10.0

Source: Data adopted from Field survey 2019.

Table 2. Limitations of adopting effective use of Quadcopter drones in safety and security monitoring in building construction sites.

	Strongly disagree n (%)	Disagree n (%)	Moderate n (%)	Agree n (%)	Strongly agree n (%)	Mean ± SD
Drones do not function well in extreme weather conditions	0 (0.0)	18 (7.4)	83 (34.3)	101 (41.7)	40 (16.5)	3.67 ± 0.84
Battery life and limited flight time	3 (1.2)	6 (2.5)	83 (34.3)	99 (40.9)	51 (21.1)	3.78 ± 0.85
Communication loss	3 (1.2)	27 (11.2)	111 (45.9)	75 (31.0)	26 (10.7)	3.39 ± 0.87
Laws and regulations with restrictions	3 (1.2)	32 (13.2)	67 (27.7)	105 (43.4)	35 (14.5)	3.57 ± 0.94
Accident and property damage	12 (5.0)	59 (24.4)	116 (47.9)	32 (13.2)	23 (9.5)	2.98 ± 0.98
Loss of Life	44 (18.2)	120 (49.6)	59 (24.4)	17 (7.0)	2 (0.8)	2.23 ± 0.86
Labour and work distractions	3 (1.2)	67 (27.7)	98 (40.5)	55 (22.7)	19 (7.9)	3.08 ± 0.93
Privacy concerns	3 (1.2)	37 (15.3)	84 (34.7)	87 (36.0)	31 (12.8)	3.44 ± 0.94
Low quality images	18 (7.4)	97 (40.1)	73 (30.2)	45 (18.6)	9 (3.7)	2.71 ± 0.98
Must be operated by a competent person	3 (1.2)	18 (7.4)	58 (24.0)	56 (23.1)	107 (44.2)	4.02 ± 1.05
Blurring images	6 (2.5)	50 (20.7)	132 (54.5)	51 (21.1)	3 (1.2)	2.98 ± 0.75
Water resistance	0 (0.0)	46 (19.0)	133 (55.0)	60 (24.8)	3 (1.2)	3.08 ± 0.69
Causes distraction in working environment /construction site	9 (3.7)	46 (19.0)	92 (38.0)	69 (28.5)	26 (10.7)	3.24 ± 1.00

*Means greater than criterion mean of 3 indicates Agreement and vice-versa.
Source: Data Adapted from Field survey 2019.

(3.44), must be operated by a competent person (4.02), water resistance (3.08) and causes distraction in working environment/construction site (3.24).

DISCUSSION

This study adopted and agreed with the modalities reported by Naveed et al. (2018) for successful drone operation. The inspection of UAV is necessary before site activities are commenced. Monitoring of the environments or locating hazard free zones for flight should be done on site. Special attention should be paid to safety requirements of the environment (people nearby, surrounding buildings, trees, weather conditions, especially wind and humidity, etc.) and the UAV status (GPS reception, condition of components, status of batteries, motors). From our pilot studies, it is important to make a flight plan based on gathered information obtained at the site visit, to ensure that the pilot and the camera operator become familiar with predefined flight path, camera sequence and locations of image capturing, which are necessary for successful work completion. Take-off point should be on a flat surface to avoid and reduce chances of crash. Before flight, all vital components of the UAV must be checked in order to minimize chances of failures. The pilot can then initiate the flight of the drone to the required inspection point and the camera operator may start capturing high-resolution images via remote control. After the inspection process is finished, the pilot can fly the UAV back fully automatically to the starting point (Rok et al., 2016). Irina et al. (2018) agreed that ensuring compliance with the requirements of the Federal civil aviation administration is required before the use of drone on site. Also, there is need to think about tasks in advance as there are no two identical construction sites so also difficulties encountered, it is important to have a clear idea of what you will do with the information before you collect it, as this will allow you to select the level of detail required to perform the task. Finally, there is need for training of staff or resort to the help of licensed pilots (Naveed et al., 2018). Rok et al. (2016) agreed that traditional monitoring is based on visual examination which is time consuming and technically difficult depending on the size of the site. In large projects it is more expensive to employ safety officers that will monitor workers and provide a platform to secure materials on-site. The process of fuelling the transport system and gathering the workers for inspection might lead to distractions and delay in

project delivery time. McClintock (2019) agrees that drones can execute work with complete accuracy, saving time, effort and money, DJI Phantom 3 standard covered 800,000 m^2 in less than 30 min and provided clearly self-explanatory aerial pictures that can be interpreted by a safety officer and communicated to the site engineers for effective correction during working hours (Figure 3 and 4). Images and video captured by the UAV gives the safety manager valuable documentation of jobsite conditions in cases where accidents do occur, and the UAV provides a tool to cover a larger area of the construction site in a shorter amount of time (Schriener and Doherty, 2015). Figure 5 shows the activities of the number of workers in the foundation, the light circle in the figure indicates that the workers were being monitored and when zoomed it was seen that they were not wearing PPE and also the foundation basket dropped on the working area can cause injury to workers (unsafe act). In Figure 6, workers were captured at an elevated height which is hard to access normally. It also shows that the safety culture in the workplace is below standards thereby putting the workers at risk. Materials and equipment were captured in Figure 7 and 8 at the closing of work as a security picture to mark the state in which the site was, before handing over to the estate security. The disposition of the site implies that materials and machines were in safe conditions. Ingenious (2015) agreed that using a quadcopter drone could enhance security of a construction site. The stream/reality videos used for this research identified movements of workers and their activities during the drone monitoring exercise.

Results from questionnaire shown in Figure 9 shows 66% of respondents were aware of drone concept in construction monitoring. However, Table 1 indicated that 51 respondents adopted drones in different sectors of construction monitoring but safety and security monitoring 17.6% adopting was indicated between stakeholders in the Enugu State Building Construction industry.

The results of this study under these objectives showed that drones do not function well in harsh weather conditions, limited battery life and flight time, communication loss and privacy concern. Mark and Junshan (2017) indicated that there is risk of privacy concern, risk of causing personal injuries and property damage. Rok et al. (2016) also identified that impact on motor vibrations can cause blured images. According to field observation report the DJI phantom 3 standard drone did not crash land nor hit stationed objects, it also did not cause injury to workers because flight path was established considering this limitations metioned. The vibration on the motor did not blurr the images. Drone companies have improved from recreational to commercial drones which carry various types of sensors to suit clients specifications. Drones can be flown in batches like four times to achieve the desired reports thereby complimenting the short flight timing (Naveed et al., 2018). The Nigerian Civil Aviation Authority (NCAA) has put in place Regulations/Advisory Circular to guide the certification and operations of civil RPA in the Nigerian airspace (Nig.CARs 2015 Part 8.8.1.33) and implementing standards (Nig.CARs 2015 Part IS.8.8.1.33); No government agency, organization or an individual will launch an RPA/UAV in the Nigerian airspace for any purpose whatsoever without obtaining requisite approvals/permit from the Nigerian Civil Aviation Authority (NCAA) and Office of National Security Adviser (NSA), in compliance with Irine et al. (2018). Currently in January 2020, legal ristrictions on drones was lifted by the Nigerian Civil Aviation Authority (NCAA), flying a drone is legal in Nigeria provided there is awareness and compliance with the regulations. However, this gives a fair play ground for more drone innovations in the Nigerian Construction Industry.

Conclusion

The effective use of drones in Nigeria is encouraged since data collected from drones could be used for analyzing and evaluating of ongoing construction activity like planning movement on site and monitoring materials on site and could be stored for future references. The use of drones will reduce the rate of building collapse, wastage of materials, inadequate monitoring, and unsafe working environment. Job satisfaction will improve because the client will be carried along in the decision making from any location during the project life-span. Drone/quadcopter as a tool for building construction monitoring, safety and security is adoptable in Nigeria. During the construction activity video streams/pictures showed unsafe conditions on the site and these were communicated to the construction team/workers, and unsafe conditions were averted. The use of Quadcopter is a possible panacea for the effective monitoring of building construction sites. This research proposes use of unmanned aerial vehicles as a viable alternative to the traditional safety and security monitoring in the Nigerian building construction site.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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