Quadcopter Drones as a Tool for Monitoring and Reporting Progress in Building Construction Stages. Case Study: Enugu Metropolis Nigeria

Okaka Olisaeloka Patrick[1], Ajaelu C. Henry[2], and Ezeokolie, Fidelis Okechukwu[3]
[1]Physical Planning Unit, Nnamdi Azikiwe University, Awka. Nigeria
[2]Department of Quantity Surveying, Enugu State University of Science and Technology, Agbani Enugu State, Nigeria
[3]Head Department of Building, Nnamdi Azikiwe University Awka, Anambra State, Nigeria

Received: 11 November 2022; Revised: 30 November 2022; Accepted: 02 December 2022; Published: 13 April 2023

ABSTRACT

The digital revolution faced by the construction industries at this time is a shift in the use of technologies, aiming to increase productivity, efficiency, value, quality, sustainability and reduce lifecycle cost. The aim of this study is "to invest in the use of Drones (Quadcopter) as a tool for smart monitoring and reporting building construction stages in Enugu Metropolis Nigeria". In order to actualize this aim, the following objectives were postulated: to ascertain the level of adoption of drones in the digitalization of construction by stakeholders in building project monitoring; the Limitations of adopting digitalization with drones by stakeholders in the building construction industry, and Effect of Drone adoption on project delivery process. The hypothesis was formulated – H_{null}: The use of drones will not fast-trackthe project delivery process. WTC Estate and Devine Hectares Estate in Enugu State Nigeria were used during site observations. The research design adopted a descriptive survey and the population under study was 612 the sample size of 242 was determined using Taro Yamane Formula for the known population. Questionnaires and Drone picture/Video was also used to collect data for observation on site. However, 51(21%) of the professionals used drones while 191 (76%) did not, thereby rating the adoption among Stakeholders low. The hypothesis tested revealed that the significant value (p=0.0019) of the statistic is less than 0.05, the null hypothesis was rejected. However, the use of drones to fast-track the project delivery process was accepted. In conclusion, the adoption of drones in Nigeria is encouraged since data collected from drones could be used to evaluate ongoing construction progress

Keywords: Drones, digital revolution, Stakeholders, Smart monitoring and Reporting

INTRODUCTION

One of the factors facing Nigerian Building Construction in the 21st Century is the timely and efficient delivery of construction projects as in [20]. This has given birth to the incessant collapse of buildings, poor safety monitoring, and lack of material control on the building construction sites. The construction has gone through a series of revolutions from the Middle Ages to the 21st century. New Technologies/tools are making it possible to turn architecture, engineering, and construction into a field that is predictable, timely, and efficient as in [13] Building Information Modeling (BIM), Mobile Technology, Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality have brought a humongous shift together with the internet of things (IoT) and Smart Sensors as in [6]. Due to the covid 19 pandemic that held the world to a standstill, exploitations of new tools/technology to salvage the construction industry came to the limelight. Drones (quadcopters) have transversed from the commercial market to the construction industry for their innumerable benefits [6]. The BIM when combined with drone technology will give a real-time and virtual

streaming of activities in an ongoing building construction project at all stages of construction. However, using drones also gives you a clear view of an ongoing construction project, just like an eagle targeting a kill from the sky [20] Accordingto [7] Nigeria is a well-known latecomer to the adoption of innovations compared to other sectors. The digital revolution faced by the construction industry at this time is a paradigm shift in the use of technologies [20]. The aim of this study is to appraise the use of Drones (Quadcopters) in the digitalization of the Nigerian building construction Industry for effective project monitoring and reporting. In order to actualize this aim the following objectives were postulated: The level of adoption of Drones in the digitalization of construction by stakeholders in project monitoring, Limitations of adopting digitalization with Drones by stakeholders in the building construction industry; and the Effect of Drone adoption on the project delivery process. However, this hypothesis was formulated: H_{null}: The use of drones will not fast-trackthe project delivery process.

LITERATURE REVIEW

Traditional project management was developed in the 1950s, it was a universal practice that includes a set of developed techniques used for planning, estimating, and controlling activities in a sequence without changes. The concept of traditional project management is based on predictable experience and predictable tools, each project as illustrated in Fig1, which follows a life cycle that includes five stages.

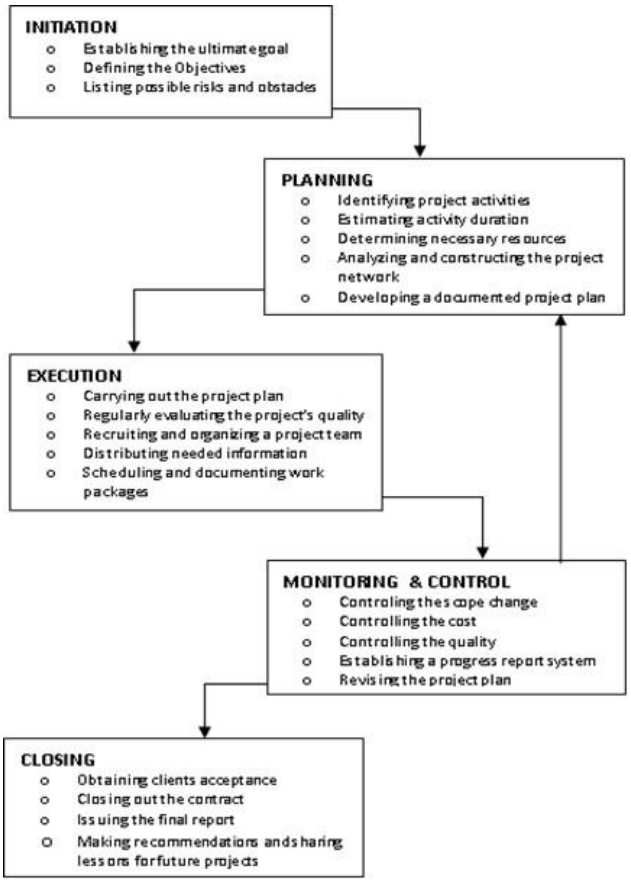

Fig. 1: The life Cycle of a traditional project management model

(Source: [15])

Smart reporting and monitoring are similar, both work hands-on and are required to make clients, investors, and developers satisfied by reporting the day-to-day or week-to-week monthly progress of their investments, using detailed video and photo shots from drones. Table 1 shows key elements of smart construction monitoring systems.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

Table 1: The Key Elements of Smart Construction Monitoring Systems Using Drones/ UAVs.

REAL TIME DATA	ADVANCED DATA PROCESSING	FINE-TUNING OF CONSTRUCTION
GATHERING PRELIMINARY INFORMATION	CONSTRUCTION SITE PREPARATION	PREPARATION OF VISUAL DEMONSTRATION ITEMS FOR INVESTORS AND CLIENTS
WORK PROGRESS CONTROL	3D MAPPING OF THE AREA DETERMINING OF GEOGRAPHICAL PARAMETERS	ADDITIONAL SOURCE OF DATA FOR DECISION MAKING AND IMPROVEMENT MEASURES
PREVENTION OF CONTROL OVER ILLEGAL CONSTRUCTION	CREATI0N OF PANORAMIC 3D VIEWS OF STREET, NEIGHBORHOODS AND BUILDINGS	WORKPLACE SAFETY AND SECURITY CONTROL AND COMPLIANCE SUPERVISION

(Source: Naveed Izhar and Fawad, 2018).

According to [26], the imagery captured by drones gives the safety manager valuable documentation at job site. However, [23] agrees that drones carry out inspections with lower costs than the alternative inspection technique. [17], agrees that Drones have provided much safer inspections. Aerial images produced by drones can be taken daily in order to plan the placement of stored materials, the flow of workers and vehicles, the identity of potential issues with installed construction, or the constructability of planned installations [14].

[16] agree that the use of UAVs has increased in America, Europe, and Asia. However, Kempegowda International Airport in Bangalore India deployed the use of drones to monitor construction progress. Bangalore deployed drones to capture high-resolution videos and photographs of construction activities at various locations. The airport has a terminal 2 (T2) building, a new south parallel runway, Apron Project, and a Forecourt project. The total area of the project is above 1000 acres as in [17]. [27]agrees that Drones in civil infrastructure application can reduce working injury, high inspection costs, and time involved with the conventional inspection. [20] agreed with drones as a tool for building construction monitoring, safety and security are adaptable in Nigeria

Challenges Encountered

[25], Identified motor vibrations and wind can cause disturbance in image quality that results in blurred images.

[12]also identified four risks associated with the use of drones perceived by contractors in most American Construction Companies as

- Risk of crashing
- Risk of causing personal injuries to employees or civilians
- Risk of privacy concerns
- Risk of causing property damage on Jobsite/surrounding properties.

MATERIALS AND METHODS

The drone used for research work was a DJI phantom 3 standard with a maximum tested altitude of 500m, an endurance time of 25 minutes, it has an integrated 3-axis Gimbal stabilization, photo resolution of 12mg, a shutter speed of 8 to 1/1800 seconds, video resolution FHD (1920 x1080) HD (1200 x 720), Package Weight 0.65kg, Recording media: Micro SD 64GB, operational temperature 32 to 40^{o}F and 0 to 40^{o}C respectively.

The DJI Phantom 3 Drone comes with a remote controller that helps to navigate and control the functions of the drone.

Measures Taken in Preparation to Drone Flight on Site

During the flight exercise the flight path was established after considering the power cables and electrical poles and the workspace 10m and 3 meters was established as the height from the takeoff point to monitor a selected construction area both at Devine Hectares and WTC estate. However, 50-100m was established to take aerial photographs and videos.

Study Area

The two Estates used in this research work for observation purposes are Divine Hectares estates and WTC estate. Devine Hectares Estate is new and located at th is 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 Duplexes and a few Bungalows that are prototype residential buildings. The Estate has its own construction team. The Estate is divided into Phases 1,2,3 and 4. Phases 1 and 2 are developed with some built area and about 160 plots while 3 and 4 have not been developed at the point of this research work. However, WTC Estate is located at latitude 6° 25 ’36N _ 7°30’14” E New layout Enugu North close to UBA Bus stop, Ogui, Enugu State Nigeria. The semi-detached bungalow undergoing construction was observed in this research work.

Location and Composition

Enugu State is one of the states in south-eastern Nigeria with its capital in 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, see figure 2 below.

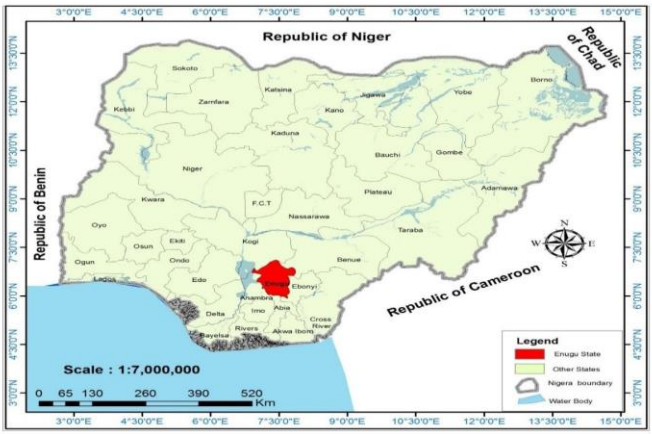

Fig. 2: Map of Nigeria Showing Enugu State.

Source: GIS Mapping, 2018

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

Some of the important towns in the State are Oji, Udi, and Nsukka Urban. The state shares borders with Abia State and Imo State to the south, Ebonyi State to the east, Benue State to the northeast, Kogi State to the northwest, and Anambra State to the west. Enugu State is made up of 17 local government areas.

Enugu Urban which is the study area is made up of Enugu East, Enugu North, and Enugu South. Enugu Urban is located within latitude 06^{o} 24'N and 06^{o} 30'N and longitude 07^{o} 27'E and 07^{o} 32'E (Geo-information, 2018). It is bounded in the north by Igbo-Etiti and Isi-Uzo Local Government Areas, in the west by Udi Local Government Area, in the south by Awgu and part of Nkanu East Local Government Areas and in the east by Nkanu East Local Government Area. See Fig3 below.

There are 18 prominent residential areas in the Urban. These are Abakpa, TransEkulu, Nike, GRA, Ogui, Asata, New Heaven, Obiagu, Ogbete, Iva valley, Independence Layout, Achara Layout, Ugwuaji, Maryland, awkunanaw, Uwani, Agbani, and Coal Camp.

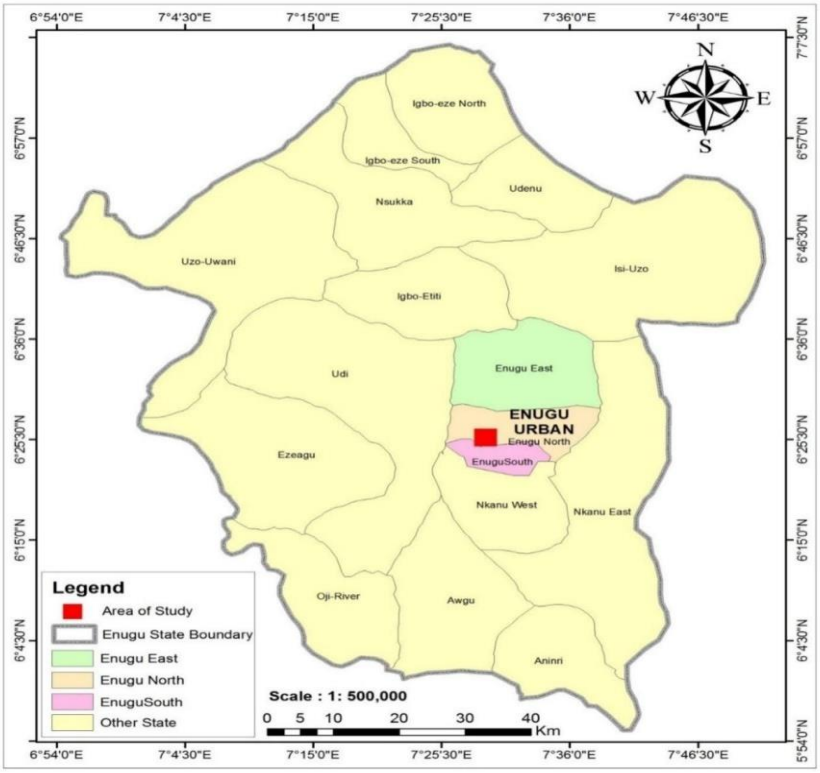

Fig. 3: Map of Enugu State Showing Enugu Urban.

Source: GIS Mapping 2018

Enugu Urban is the most developed urban area in Enugu state. The study area falls within the humid tropical rainforest belt of South-eastern Nigeria. It has two seasons, the rainy season and the dry season. The rainy season which is characterized by heavy thunderstorms lasts from April to October with the South Westerly moisture accompanied by air mass moving northwards into the city. The turbulent runoff results in leaching, sheet erosion, and eventually gullies [1]. The mean temperature varies from about 20.30ºC to about 32.16ºC in the dry season and rainy season respectively, [1] During the dry season, the humidity is lower than in the rainy season. Temperature is most often high during the day and low during the night. This results in a high evaporation rate during the day. Harmattan which occurs between the months of November and February is always accompanied by poor visibility mostly at night and early in the morning. The rivers and streams which flow from the Udi hills dissect the study area into several sections. Thus, there are rivers such as

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

Ekulu, Idaw, Asata, and Nyaba Rivers which separates Enugu South from Nkanu East. These rivers have many tributaries; the study area is generally marked by low land, sloping towards Enugu South Local Government Area and the Southern part of Enugu East Local Government Area. The elevations are between 182.88 meters and 219.45 meters above sea level.

Research Design

The research design adopted was a descriptive Survey. The research population covers a population of respondents who are construction professionals who are categorized as consultants and contractors in the study area. However, it was expected that those capable enough to give the necessary and genuine information needed for this study are the Architects, Builders, Quantity Surveyors, Engineers, and Estate Surveyors who manage construction projects within Enugu State. The population of the study was 612 registered professionals as distributed in table 2 below. A sample size of 242 was determined for the study using the Taro Yamane formula for the known population.

Table 2: Registered Population Distribution

Professional bodies	**Registered population**
Nigerian Institute of Quantity Surveyors (NIQS)	63
Nigerian Society of Engineers (NSE)	200
Nigerian Institute of Builders (NIOB)	25
Nigerian Institute of Estate Surveyors and Valuers (NIESV)	105
Nigerian Institute of Surveyors (NIS)	105
Nigerian Institute of Architects (NIA)	114
TOTAL	612

Source: Directory of Regulatory Bodies in Nigeria (2020)

Sample Size:

$n = N/1 + N(e)2$

where

n = Sample size

N = Total population

e = Tolerable error (0.05)

$n = 612/1 + 612(0.05)^2$

n = 242

Data Collection Method

Primary Data was collected using constructive questionnaires, obtained life pictures/video streams from DJI Phantom 3 Drones on building construction sites, supplemented interviews and observations. Secondary data was derived from published materials such as journals, web, and books with content-related materials. A questionnaire was formulated in google-form with close-ended multiple-choice questions which were mailed to the correspondent and followed up with calls.

In order to ensure the reliability of data collection instruments, drones were flown to capture ongoing activities on site and were carefully observed.

Data collected was analyzed using Statistical Package for Social Sciences (SPSS) computer software version 23.0 for windows. Frequency and percentage were used to summarize categorical variables while means and Standard Deviations were obtained for continuous variables. The Likert Scale was ranked from:1-strongly disagree/very difficult/very slow to code 5= Strongly agree/very easy/very fast. A mean greater than the criterion means of 3 was regarded as a positive response.

Association between categorical variables was done using chi-square, while means of continuous variables were compared using student's t-test. A p-value less than 0.05 was considered Statistically significant. Results were presented in tables.

RESULTS AND DISCUSSION OF THE SIGNIFICANT STUDY ANALYSIS IN THE STUDY OF DRONES FOR BUILDING CONSTRUCTION IN NIGERIA.

Site Observation

Figure 4, shows a picture observing the lintels being prepared on the upper floor, clear views of window openings positions and form works.This also shows a clear view of the project.

Fig. 4: Lintels being prepared on the upper floor; window openings and block work is visible for counting.

Source: Field Survey, 2020

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

Aerial view of the WTC semi-detached duplex under construction was captured showing the partitioned rooms, and form works for lintel beams (Figure 5)

Fig. 5: Aerial View of an ongoing semi-detached duplex at WTC Estate. Captured by a DJI Phantom 3 Standard Drone.

(Source: Field Survey, 2020)

Figure 6 shows an aerial self-descriptive image of the semi-detached duplex under construction at WTC Estate Enugu State Nigeria

Fig. 6: WTC Estate Aerial view captured by a DJI Drone Phantom 3 Standard.

(Source: Field Survey, 2020)

Data Analysis From The Questionnaire

Table 3 shows that out of 51 (21%) professionals that use UAVs in project monitoring, only 3 (5.9%) use them often while 30 (58.8%) use them occasionally. The kind of projects they use UAVs includes Surveying Mapping 15 (29.4%), Construction project monitoring 12 (23.5%), and Aerial photography 9 (17.6%). The proportion of building professionals who own drones is very low 9 (17.6%). The types of drones owned by them include DJI Phantom 4 Pro 3 (33.3%), Genius idea drone 3 (33.3%), and Phantom 3 standard (33.3%). The table also reveals that 30 (58.8%) of the respondents have been trained on how to fly a drone. Most of the training took place online 12 (40%) and in NIS training section 6 (20%).

Table 3: Level Of Adoption Of Uavs In Digitalization Of Construction By Stakeholders In Project 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 UAV use for?		
Aerial Photograph	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
Genius idea 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: Okaka et al, 2020)

Fig 7 shows that 21% of the building professionals use UAVs in project monitoring while 79% don't.

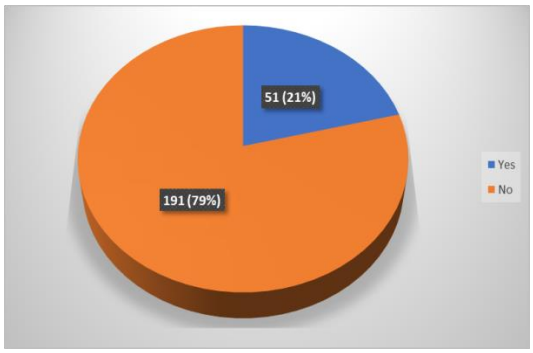

Fig. 7: Use of UAVs in digitalization of construction by stakeholders in project monitoring.

Source: Field Survey, 2020)

Table 5 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 (3.44), Must be operated by a competent person (4.02), Water resistance (3.08) and distraction in working environment/construction site (3.24).

Table 5: Limitations Of Adopting Digitalization With Uavs By Stakeholders In The Building Construction Industry.

	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
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: Okaka et al, 2020)

Hypothesis Testing

H_0: The use of a drone will not fast-trackthe project delivery process

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

Decision rule:

Since the significant value (p = 0.019) of the t statistic is less than 0.05, the null hypothesis is hereby rejected and the alternative accepted. Therefore, the use of dronesfast-tracks project delivery processes. Table 5 shows that respondents who use Drones reported that the Project Delivery process is faster (3.53) compared to those who don't use UAVs (3.26) as shown in table 5.

Table 5: Effect OfUav Adoption On Project Delivery Process

	Use of UAV			
	Yes n (%)	No n (%)	t	P value
Project Delivery process ranking on a scale of 1-5	3.53 ± 0.61	3.26 ± 0.74	2.366	0.019

(Source: Field Survey, 2020)

DISCUSSION

During the flight exercise the flight path was established after considering the power cables and electrical poles, 10m and 3 meters was established as the height from the takeoff point to monitor a selected construction area both at Devine Hectares and WTC estates. However, 50-100m was established to take the aerial photographs and videos captured in figure 4-6. Fig 5 shows a complete aerial view of the Semi-detached superstructure at the WTC estate. However, there is a clear view of the partitions, stairs, and work progress on the lintel formwork. Fig 6 shows stacked materials and their locations onsite at the close of work at 17:00 hrs for security purposes. In agreement with [26], the imagery captured by drones gives the safety manager valuable documentation at Jobsite. Aerial images produced by drones can be taken daily in order to plan the placement of stored materials, the flow of workers and vehicles, the identity of potential issues with installed construction, or the constructability of planned installations

[12] reported that the use of UAVs in the construction industry fits into four categories: photographs/videography, surveying, inspection, health, and safety monitoring.

Level of Adoption by Stakeholders

This study shows drones as a tool for monitoring project delivery process and smart reporting can be adoptable in Nigeria. Data obtained from a field survey indicated that activities monitored on site were safety habits of workers, construction progress, and security of materials on site. This was achieved through aerial pictures with a well-defined flight path, which this study agrees with ([12], [16]). However, [16] also indicated that drone data gives room for better operation, planning, and adjustments.

The traditional project management system bequests the roles of the principal on the architects and engineers and depending on the type of construction projects (building or civil engineering). This, however, limits innovation which the involvement of the clients brings to the project. The client involvement exposes the project to changing requirements which traditional project management systems cannot respond to and adapt swiftly [3]. Drone smart monitoring promotes client satisfaction and reports of its adoption in many countries demonstrate client involvement through regular inspection, and reports of activities using aerial photographs/videography captured by drones before progressing to another phase of project delivery objectives. Drone monitoring and reporting save inspection time and early corrections which also saves costs.

Limitations of Adopting UAVs by Stakeholders in the Building Construction Industry

The study's results under these objectives show that drones do not function well in extreme weather conditions, with limited battery life and flight time, communication loss, and privacy concerns. Risk of privacy concerns, risk of causing personal injuries and property damage as in [12]. [25] also identified that the impact on motor vibrations can cause blurred images. According to a 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 a flight path was established considering these limitations mentioned in the literature. The vibration on the motor did not blur the images. Drone companies have improved from recreational to commercial drones which carry various types of sensors to suit clients' specifications. [16] drones can be flown in batches four times to achieve the desired reports thereby complimenting the short flight timing. Flying a drone is legal in Nigeria provided being aware and compliant with the regulations. The 6 threats to the adoption of drones for smart building construction monitoring are Extreme weather conditions, communication loss, laws and regulations, accidents and property damage, privacy concerns, and lack of trained pilots. However, mapping out flight paths while considering obstacles and working areas in your flight mapping will help avert most of the listed limitations. Also, the new technology sensors included in drones for obstacle detection have made them smarter, safer, and easy to handle.

Effect of UAV Adoption on Project Delivery Process

This study compared the variables of those that use drones for construction survey/ monitoring and indicated that the use of drones fast-tracks the project delivery process. According to Schwartz, (2014) drone prices range from 100$-100,000 dollars. However, due to the enabling china market, drones now come in smaller sizes and are cheaper. The long-run use of drones will compensate for the price of the drones. [16] report that data obtained from drones gives room for better operation, planning, and adjustments of building construction projects. UAVs have the ability to monitor ongoing building construction projects in all phasesby capturing activities onsite through photographs/video recording and reporting to various stakeholders for decision-making. ([25], [16], [24], [12]and [20]). However, the effect of drone adoption on project delivery will improve costs, timing, and delivery process to achieve optimum project performance.

CONCLUSION AND RECOMMENDATION

The effective ways of applying effective project smart reporting and monitoring: First and foremost, the site engineer/builder must know what he or she wants to achieve, however, it could be safety and security on site, it could be monitoring and reporting construction progress, it could also be the maintenance of the building envelope. Secondly, trained pilots or personnel should handle the flight and take instructions from the site engineer/builder in collaboration with the architect and quantity surveyor on the precautions and areas to capture (the flight mapped out path) for harmonization and delivery. Photography/videography captured on site will be analyzed and communicated to stakeholders for further analysis and corrective measures if necessary. However, the communication could be done through the following media: WhatsApp, E-mail, Skype, and other application software agreed upon by the stakeholders. The format of the reports should be in MS-word format, pdf, MS-project, or in CAD format if need be.

The use of drones in the developed world namely America, Europe, China, Australia, and India have been employed in safety and security monitoring, and construction progress monitoring in both high-rising and vast projects with great success. In the Nigerian perception, drones as a tool for smart monitoring and reporting fast-tracking project delivery process at all phases of construction is still at the nascent stage. The effective adoption of drones in Nigeria is encouraged since data collected from drones could be used for analysis and evaluation of ongoing construction activity, and planning movement on site and could be stored for feature 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 lifespan. In

recommendation, DJI Mavic 2 pro has accessories that will outbalance most of the limitations mentioned in this work. Finally, a safe flight path, the purpose of monitoring, and a trained drone pilot with basic control techniques will guarantee a great monitoring outputin the building construction stages.

ACKNOWLEDGEMENT

In the blessed memory of my Late Father Professor James. C. Okaka (FNIFST) and Emerita Professor Antoinette N. C. Okaka for her immense contributions to this study.

REFERENCE

1. Akabuike, B. O. (1990) A short text on Geography Pegant Ventures, Enug
2. Alfred Swenson and Poa-Chi Chang. (2019). Construction Building. Retrieved from britannica.com: http://www.britannica.com/technology/building-construction/Bronze-Age-and-early-urban-cultures
3. Ametepey, S.O., Ansah, S.K. and Aigbavboa, C. (2014). A project control process in pre construction phase. Awarness and prospects of agile project management in Ghananian Construction Industry Proceeding 8th Construction Development Board (CIDB) postgraduate conference (pp. 165-178) University of Witwatersrand, Johannesburg, South Africa.
4. Barnes, J. (2018). Establishing a Drone Business with Part 107 in Construction. Retrieved from Commercial UAV News: expouav.com/news/latest/establishing-a-drone-business-with-part-107-in-construction/ on 2018, October 24
5. Burns N, and Grove S. K. (2003). Understanding Nursing Research 3rd Edition. Philadelphia: Saunders Company.
6. Dashore, A. (2019). Embracing Digitalization in the Construction Industry. Retrieved from The Constructor: https://theconstructor.org/digital-tools/digitalization-construction-industry/26291/
7. Ezeokoli F.O, Okoye P.U. and Nkeleme E. (2016). Factors Affecting the Adaptability of Building Construction Modelling (BIM) for Construction Projects in Anambra State. Journal of Scientific Research and Report,11(5): 1-10, 2016; Article no. JSRR.26563 ISSN: 2320-0227
8. Federal Aviation Administration (2016). Small UAS Notice of Proposed Rulemaking (NPRM). Retrieved from https://www.faa.gov/uas/nprm/ 5 4 on 2016, August 25
9. Federal Republic of Nigeria, (2006). National Building Code 1 st Edition. Butterworths, South Africa: LexisNexis.
10. Hazim Shakhatreh, Ahmad Sawalmeh, Ala Al-Fuqaha, Zuochao Dou, Eyad Almaita, Issa Khalil, Noor Shamsiah Othman, Abdallah Khreishah, Mohsen Guizani. (2018). Unmanned Aerial Vehicles: A Survey on Civil Applications and Key Research Challenges. Retrieved from arxiv.org: https://arxiv.org/abs/1805.00881, on 2018, April 19
11. Wallace, A. Lucieer C. S., Watson and Turner D. (2012). Development of a UAV LiDAR system with Application to Forest Inventory. Remote Sensing. 4(6),1519-1543
12. Mark C. Tatum and Junshan Liu (2017). Unmanned Aerial Vehicles in the Construction Industry. 53rd ASC Annual International Conference Proceedings, 383-393.
13. Molitch-Hou, M. (2019, 04 08). BIM-Made Construction kits lay the foundation for the 21st century. Retrieved from Engineering.com: http://www.Engineering.com/amp/18815.html on 2019, April 7
14. Molla, D. Drones for AEC: How every stage of a building project can benefit from drone technology | Building Design + Construction. Building Design & Construction. Retrieved from http://www.bdcnetwork.com/blog/drones-aec-how-every-stage-building-project-can-benefit-drone-technology on 2015, March 23
15. Mrsic, M. (2017). Traditional Project Management. Retrieved from Active Collab: https://activecollab.com/blog/project-management/traditional-project-management on 2017, May 17.

16. Naveed A., M. A. Izhar and Fawad A. N. (2018). Construction Monitoring and Reporting using Drones and Unmanned Aerial Vehicles (UAVs). The Tenth International Conference on Construction in the 21st Century (CITC-10), 10.
17. NAW Staff. North American Wind power: Report: UAVs for Wind Turbine Inspections to Hit $6 Billion By 2024. Retrieved September 21, 2015, from http://www.nawindpower.com/e107_plugins/content/content.php?content.14613
18. Nnadi E.O.E. and Ugwu O.O. (2014). Managing construction risk in Nigeria through capitalization of construction firms. International conference on artificial intelligence, energy and manufacturing engineering (ICAEME 2014), June 9-10, 2014 Kuala Lumpur. 70-74. http://dx.doi.org/10.15242/IIE.E0614010
19. Okaka, O. P. (2020). Appraisal Of Unmanned Aerial Vehicle For Smart Monitoring of Building Construction Project in Enugu Metropolis, Nigeria. Enugu State University of Science And Technology, Agbani , Submitted to the Department of Quantity Surveying. Enugu: Unpublished.
20. Okaka O. Patrick, Ezekiel O. E. Nnadi and Henry C. Ajaelu. (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 (Academic Journals) AJ., 37-46.
21. Okunbor, K. O. (2016). THE NATIONS. Retrieved from NCAA to sanction illegal drone operators for airspace violation: https://thenationonlineng.net/ncaa-sanction-illegal-drone-operators-airspace-violation/
22. Patterson, J. (2018). An Aerial View of the Future – Drones in Construction. Retrieved from www.geospatialworld.net: https://www.geospatialworld.net/blogs/anaerialviewofthefuturedronesinconstruction/
23. Pritchard, L. Pointer Avionics SkyHunter406 – Main. Retrieved from http://www.skyhunter406.com/news.php?action=display&news=48
24. Rai, A. (2019). Drones for development: This is how India is doing it. Retrieved from nextbigwhat.com: https://nextbigwhat.com/drones-india-usage/
25. Rok Cajzek, Gicgradnje D. O. O. and Uros Klansek. (2016). An Unmanned Aerial Vehicle for Multi-Purpose Tasks in the Construction Industry. Journal of Applied Engineering Science, 2, 341-327.
26. Schriener, J., & Doherty, P. Drones Show Potential to Aid Jobsite Safety and Efficiency | Tech Trends. Retrieved August 9, 2015, from http://enewsletters.constructionexec.com/techtrends/2013/07/drones-show-potential-to-aid-jobsite-safety-and-efficiency/