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Research Article

Investigation of the Use of Drones by Construction Professionals in Addressing Built Environment Tasks

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Abstract: An unmanned aerial vehicle (UAV), also called a drone, has been gaining attention globally to solve different tasks. The aim of this study is to assess the awareness and level of adoption of these types of drones by building professionals and the factors limiting their use in the built environment. The study was carried out in Lagos State, in the southwestern part of Nigeria. Data for this research were collected from primary and secondary data sources. Primary data was obtained by administering a questionnaire to the selected building industry professionals, and the collected data were analyzed using both descriptive and inferential statistical techniques. The results showed that structure inspection and photography are the most rated features of drones in addressing built environment tasks, with a mean score (MS) of 4.50, and security surveillance (MS = 3.86) is the least important feature. The level of adoption of drones in addressing built environment tasks was assessed among the professionals, and the results showed that the practice of an emergency response plan and a health and safety plan to reduce the risk of harm and ensure safety on site is considered to be the most important task. The study found that the fixed-wing hybrid drone with an MS of 1.97 is the most commonly used drone type. Lastly, the study showed that lack of public awareness (MS = 4.81) is rated as the most significant factor that limits its use. Few professionals have practically used drones to solve tasks faced in the building industry. Thus, there is a need to further sensitize built environment professionals to the benefits associated with its wider adoption and applications. Also, the importance of drones and their associated managerial and practical implications in solving relevant built environment tasks can be initiated by deepening their relevance in the curriculum of building industry programs at the professional and academic levels.

***Keywords*:** built environment, construction, benefits, drones, innovations, tasks

1. Introduction

Unmanned aerial vehicles (UAVs), also called drones, are a critical part of digital technologies used in the construction industry to ensure efficient delivery and control of construction processes. They also help to complete projects on time, within budget limits, and with precision in their delivery [1]. The use of drones in construction processes is recent; however, their use in other sectors like research and development, remote sensing, security and

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military operations, precision agriculture, and mining has been well documented [2, 3]. Drones have been used in civilian operations like delivering goods and search and rescue operations [4, 5]. In the construction space, drones are used for many purposes, as they have created various opportunities like data gathering by using high and different levels of automation. Drones also help in reaching inaccessible places on construction sites to get the required information [6, 7]. Drones are becoming increasingly applicable in the architecture, engineering, and construction (AEC) industries by making construction phases safer in their operations and execution [8]. Drones also carry out tasks faster and at a reduced cost because they are fitted with high-tech sensors that help collect information [9, 10]. Drones help gather intelligence, inspect, and supervise in order to create a better life for citizens [11, 12]. A drone is a special type of aircraft that is unmanned, used for various operations, and works with the coupling of software and systems with special algorithms by using a range of technologies that enable its smooth operations [6, 13, 14].

The working operations have advanced with a rapid increase in the control, microminiaturization, and computerization of drones. The data captured using drones is taken as images from different points in the cloud, and they are scanned at the construction sites to produce (three dimensional) 3D models using photogrammetric techniques [15]. These models can be likened to what is obtained using Building Information Modelling (BIM) modeling applications at the planning, execution, inspection, and servicing stages of infrastructural and construction project delivery [16]. Drones are also used because of their flexibility, better ability to capture remote data from remote places, capability to maneuver, economical benefits, fewer human errors on construction sites, high mobility, and viable communication during operations. These reasons have made it attract much attention over the years [17]. Jenkins and Vasigh [18] opined that the increasing use of drone applications has led to a boost in economic development in the United States, as it has created more than 70,000 jobs. Thus, the increased utilization of UAV applications has significantly advanced the country's economy. Over the years, the multi-sectoral benefits of drones have increased their potential to address problems in the construction industry by obtaining the required information from buildings and other infrastructural facilities. Due to this, its applications in the built environment practice are increasing in terms of how its potential can help reduce dangers and disasters that building occupants may be exposed to in addressing drone capabilities in humanitarian logistics [19]. This serves as an insight into the motivation to probe into the need to consider drones to solve relevant tasks in the built environment.

In Nigeria, there has not been a noticeable increase in interest in using drones to solve different challenges linked to the built environment and the building construction sector in particular. Lagos State is Nigeria's most developed state based on the supporting socio-economic and infrastructural indexes that it has. The state has faced numerous challenges in addressing and mitigating different risks and disasters that occur in the building industry. This has affected the production of buildings and other infrastructure-related services. Thus, the use of drones could bridge this gap by providing information on how to address risks and disasters that building stock could face; hence, this study. The outlook of the research problem in this study is shown in Figure 1.

With the foregoing, drones are being used more often to address environmental issues around the world; hence, the aim of this study is to assess the level of adoption and application of drones by building professionals in addressing areas of need in built-environment-related jobs in Lagos State, Nigeria, with a view to promoting their use. Thus, the objective of the study is to assess the level of awareness of the benefits of drones in addressing built environment issues among construction professionals; examine the level of adoption of drones in addressing built environment tasks among professionals in the built environment; assess the types of drones used in solving built environment-related tasks; and examine the factors limiting the practice and use of drones in addressing built environment-related tasks in the study area.

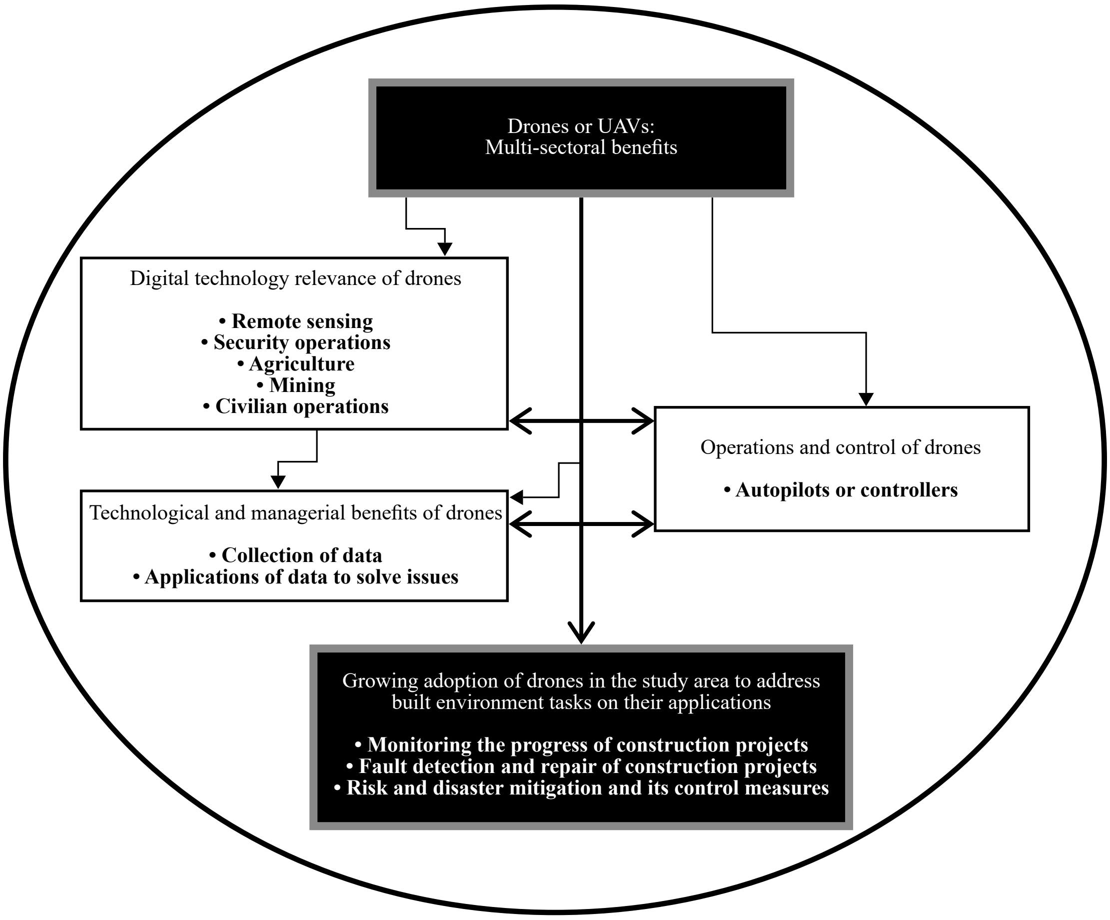

Figure 1. Schematic representation of the research problem

1.1 *Review of literature on the development and use of drones*

Drones are not pilot-driven or pilot-operated; instead, they fly through the air up to a certain height and are managed by ground control centers. It operates in a guided fashion that uses cloud computing, storage, and web services [6, 20]. The use of drones in military, civilian, and other disciplines has advanced over the years [7, 14, 21]. Additionally, it has relevance and applications in the fields of engineering, remote sensing, agriculture, surveillance, disaster management and planning [22]. The utilization of UAV applications has been used in construction businesses, buildings, roads, bridges, project monitoring, inspections for repairs, and other construction-related tasks, which are rapidly gaining importance. According to previous studies [8, 15], it is also employed in surveying, facilities management, architectural engineering, construction management, and monitoring services.

Over the years, the United States of America has produced numerous innovative ideas that have advanced the development of drones. Since companies like Sacramento Bee have employed drones to acquire media information, among other uses, the United States is leading the world in the manufacture of UAVs [23]. In their study, Mátyás and Máté [24] illustrated the technological advancement of drones through their historical evolution. Drones have been utilized in other regions of the world, including Australia, Japan, Australia, and the United Kingdom, for a variety of tasks like surveying, mapping, and contract management. Helicopters cannot fly autonomously, but drones can, and their multi-propeller system gives them a great degree of independence. Drone operation is dependent on the controller, which creates a reliable radio channel of communication with the remote unit. Drones use Wi-Fi networks to operate in the 2.4 GHz frequency band, which helps scientists draw conclusions from the data that they collect. These innovations display the characteristics of UAV-detecting capabilities [25]. Digital technology principles and advancements are included in the creation, use, and upgrading of drones. It includes contemporary developments like global positioning satellites, radar, Light Detection and Ranging (LiDAR), and Bluetooth detectors, as well as its emerging uses in transportation data collection technology. A multi-sensor drone-detection system with a fish-eye camera and detecting technologies, as shown in the output of [26], can gather data that helps in its interpretation. Remote-controlled aircraft systems and totally autonomous vehicles were the two technology branches that were combined to create drones whose applications were explored in their production.

Different types of drones that are frequently employed in various industries have been produced to perform different tasks, and they are enjoying innovations in technology. With laser scanning devices, it can capture data in several dimensions for applications across a variety of industries [27, 28]. Multi-rotor drones, fixed-wing drones, single-rotor drones, and fixed-wing hybrid drones are the four main types of drones, and they have all been adapted to modern culture and ways of life [29, 30]. The most popular drones are multi-rotor models, which are utilized for aerial mapping jobs as well as for recreational purposes. Aerial photography, video recording, and aerial surveying are typical uses of multi-rotor drones. They are employed in several contexts in environmental management. According to Gallacher [31], fixed-wing drones function substantially on the same principle as commercial airplanes.

Instead of employing vertical rotors to provide thrust, these drones use fixed wings to produce lift. These drones do not require energy to maintain flight; they simply need it to fly forward. Because of this, they are a far more effective alternative for topographic mapping of huge areas and can travel farther than multi-rotor drones. Compared to multi-rotor drones, it has the potential to fly for a longer period of time [32]. Drones in the built environment, particularly in the construction business, have a variety of applications [33]. It can be applied to a variety of tasks, including building surveys, topographic mapping and land surveys, site inspections, equipment tracking and automation, remote monitoring and progress reports, integration of laser scanning, aerial photogrammetry, and thermal imaging recording, as well as remote monitoring and progress reporting. It can also be used to examine certain human behaviors in order to process and gather accurate data on events that take place from the air. It can be used for mapping both before and after disasters, as well as for the opportunity to identify disaster victims [34].

When airborne surveillance is required for crowded rallies and sizable athletic events, its use has also been found to be helpful in law enforcement [35]. Drones are utilized in the construction sector for a variety of tasks, including documenting, monitoring, tracking equipment, inspecting buildings and coordinating projects. Drones are employed in the construction industry to provide a 3D bird's-eye perspective of the site, allowing for surface and volume measurements [31]. Drones can be used for transportation projects like landslide monitoring and mapping, earthwork and traffic surveillance, cultural heritage and conservation projects like historic preservation, monitoring historic monuments, 3D modeling of heritage buildings, and landscape preservation. According to Albeaino et al. [36], drones also have a place in the construction industry. A post-disaster assessment of structural damages to buildings and other infrastructural facilities is also found to be done through the use of drones. It is also proven to be useful for monitoring construction project progress [25, 28].

In this literature review section, different pieces of literature have been considered. In order to present the most related literature review, Table 1 shows the highlights of the selected ones.

Table 1. Highlights of the most related literature in the literature section

No.	Literature	Highlights of the literature
1	Hallermann and Morgenthal, 2013 [6]	Indicates the operation of drones by moving up in the air to a certain height and controlling the ground centers
2	Tran and Nguyen, 2022 [20]	Depicts the operation and control of a drone
3	Choi et al., 2022 [8]; Wahab, 2020 [22]	Shows relevance and application in the fields of engineering, remote sensing, agriculture, surveillance, disaster management and planning
4	Yousaf et al., 2022 [25]	Depicts the use of Wi-Fi networks and the 2.4 GHz frequency band in the operation of drones in the bid to collect the needed data
5	Odigie et al., 2021 [30]	Highlights the various types of drones used in different applications
6	Syed Mohd Daud et al., 2022 [34]	Shows the use of drones to examine human behaviors to get information or data from the air in order to identify disaster victims
7	Edulakanti and Ganguly, 2023 [28]	Shows the usefulness of drones to monitor the progress of construction projects

The operation of drones can also be shown through the mathematical form of the model, which shows its movement pattern. According to Sarwar et al. [37], a mathematical model that completes degree of freedom (Df) equations of motion in a non-linear form with its probable simulation model parameters for the use or control of drones is needed to understand its movement. This shows the dynamic characteristics of both the longitudinal and lateral models of the movement patterns of drones, highlighting the need to get realistic simulations of the controllers and autopilots. The use of drones must be grounded in an understanding of the mathematical model of the operation and behavior of UAVs based on the coordinate system to depict relationships between parameters defined in the earth coordinate system and in the body coordinate system [38].

2. Research methodology

The study was carried out in Lagos State, Nigeria; assessed the level of awareness of the benefits of drones in addressing built environment issues by construction professionals; examined the level of adoption of drones in addressing built environment tasks among professionals in the built environment; assessed the types of drones used in solving built environment-related tasks; and examined the factors limiting the practice and use of drones in addressing built environment-related tasks in the study area. The study area, Lagos State, is one of the 36 states that constitute the Federal Republic of Nigeria. The study area had a population of about 15.8 million in 2021 [39]. It is situated in the southwestern part of Nigeria with a landmass of about 3,456 km2, which makes it the smallest state, but it is the most populated state in the country, and the annual population growth rate of Lagos is 2.91% [40]. The study area is situated in a low-lying coastal area surrounded by tropical rainforests and bodies of water with a seasonal tropical wet and dry climate. The geographic location of Lagos State makes it vulnerable to hazards such as sea level rise and flooding [40].

According to Patel and Patel [41], research is a systematic search for pertinent and useful information on a particular topic, and the data needed can be collected with the aid of field study, experiment, observation, analysis, comparison, and reasoning. The research design charts the plan, the framework of the research methods, and the techniques suitable for the study based on how to solve a logical problem by adopting either an experimental or survey research design [42]. For this study, a survey research design was adopted in order to get the positions of the respondents in the construction industry in Lagos State, Nigeria, on the need to assess the level of adoption and application of drones by the building industry professionals in addressing built environment-related tasks with a view to promoting their use. According to Levy and Lemeshow [43], sampling is the process of choosing the number of observations needed to be considered in a statistical sample.

The sample size can be obtained from the whole population to draw inferences about the population under consideration [44]. The target population of this study comprised the list of registered construction professionals in Lagos State, Nigeria, which consisted of architects, builders, engineers, estate surveyors and valuers, quantity surveyors, and urban planners obtained during the pilot study. From the directory of professional bodies on the list of registered professionals, the target population of 410 builders, 764 quantity surveyors, 604 architects, 275 estate surveyors and valuers, 400 surveyors, 321 urban planners, 613 structural engineers, and 2,216 electrical and mechanical engineers in the study area was found. Thus, a 5% sample size was taken from all the professionals except 1%, which was used as the sample frame for the electrical and mechanical engineers. This is due to the large population of electrical and mechanical engineers, as shown in Table 2.

The data for the study were collected from both primary and secondary data sources. The collection of primary data was done by administering a questionnaire to the selected professionals in the construction industry, complemented by conducting field observation to assess the mode of use of drones during the execution of built environment-related activities. Secondary data were sourced from the relevant published outlets on information relevant to the adoption and use of drones by the respondents. As shown in Table 2, a total of 191 questionnaires were administered to the selected building industry professionals. The data obtained from both primary and secondary sources stated above were processed and analyzed with the use of descriptive and inferential statistical methods such as frequency distribution, mean score (MS) analysis, correlation analysis, and analysis of variance.

Table 2. Sample frame of the respondents selected for the study

No.	Group of respondents	Population	Percentage of selection (%)	Sample size
1	Builders	410	5	20
2	Architects	764	5	30
3	Quantity surveyors	604	5	38
4	Estate surveyors and valuers	275	5	14
5	Surveyors	400	5	20
6	Urban planners	321	5	16
7	Structural engineers	613	5	31
8	Engineers (mechanical and electrical engineers)	2,216	1	22
	Total	5,603	36	191

3. Results and discussions

The results of the study showed that out of the total of 191 questionnaires administered to the respondents in the study area, 144 were retrieved. This indicates a response rate of 75.39%, which shows a sizeable number of questionnaires used for data analysis. The information gathered on the profiles of the respondents indicated that out of 144 respondents who returned the questionnaire, 115 were males and 29 were females. The professional affiliation of the respondents shows that 20 are builders, 17 are architects, 22 are quantity surveyors, 12 are estate surveyors and valuers, 31 are structural engineers, 18 are mechanical and electrical engineers, 14 are surveyors, and 10 are urban planners. This indicates the distribution of the selected built environment professionals, which would give the required information on the use of drones in addressing built environment-related tasks. About 33% of the respondents had Higher National Diploma (H.N.D.) qualification, and all the respondents (144) have heard about drones through different outlets, as shown in Table 3. Table 3 shows that 68.1% learned about the applications of drones in building-related projects during their academic training.

Table 3. Profile of the respondents

Respondents	Frequency	Percentage
Gender of respondents		
Male	115	79.9
Female	29	20.1
Total	**144**	**100**
Respondents' years of practice		
1 to 5 years	17	11.8
6 to 10 years	61	42.4
11 to 15 years	28	19.4
16 to 20 years	22	15.3
21 and above	16	11.1
Total	**144**	**100**

Table 3. *Continued*

Respondents	Frequency	Percentage
Education qualification		
Ordinary National Diploma (O.N.D.)	8	5.6
H.N.D.	46	31.9
Bachelor of Science (B.Sc.)	48	33.3
Master of Science (M.Sc.)	33	22.9
Master of Business Administration (MBA)	7	4.9
Doctor of Philosophy (Ph.D.)	2	1.4
Total	**144**	**100**
Areas of professionalism		
Builder	20	13.9
Architect	17	11.8
Quantity surveyor	22	15.3
Estate surveyors and valuers	12	8.3
Structural engineers	31	21.5
Engineers (mechanical and electrical engineers)	18	12.5
Surveyors	14	9.7
Urban planners	10	6.9
Total	**144**	**100**
Projects handled in the last five years		
1 to 5	17	11.8
6 to 10	61	42.4
11 to 15	28	19.4
16 to 20	22	15.3
Above 20	16	11.1
Total	**144**	**100**
Have you heard of a drone?		
Yes	144	100
No	0	0
Total	144	100
How did you first learn about drones?		
Workshops, conferences and/or seminars	65	45.1
Television and radio	14	9.7
Newspapers and magazines	7	4.9
Internet	18	12.5
Other professionals	40	27.8
Total	**144**	**100**

Table 3. *Continued*

Respondents	Frequency	Percentage
During your academic training, did you hear or learn about the use of drones in building construction?		
Yes	98	68.1
No	46	31.9
Total	**144**	**100**
Have you attended any workshops or seminars on the use of drones in building construction?		
Yes	97	67.4
No	47	32.6
Total	**144**	**100**
Range of time (for those who have heard about the use of drones in workshops or seminars)		
0 to 2	20	13.9
3 to 5	6	4.2
6 to 8	3	2.1
9 to 11	6	4.2
12 and above	62	43.1
Total	**97**	**67.4**

3.1 *Awareness of the use and benefits of drones in the built environment*

This section provides results on the level of awareness of respondents in addressing built environment tasks, drone features, and benefits in construction practice. Table 4 shows the MS analysis results. It was indicated that a large proportion of the respondents are aware of the drone features in building projects, with the structure inspection and photography feature having an MS of 4.50, followed by remote monitoring and progress reports with an MS of 4.45, while security surveillance was rated least with an MS of 3.86. This indicated a significant difference in the awareness of the built environment professionals of the varying features of drones in the handling of built environment tasks.

With respect to the awareness of the respondents on the associated benefits of drones in built environments, the study showed that the ability to inspect difficult and hazardous areas of projects was ranked most with an MS of 4.75. Meanwhile, its ability to offer accurate and comprehensive data was ranked next with an MS of 4.28, and its ability to offer cost- and time-saving benefits was ranked least with an MS of 3.57. Table 4 further shows that the respondents are aware of the benefits of drones in the areas of structural and infrastructure inspection, transportation, culture and heritage conservation, city and urban planning, progress monitoring of projects, post-disaster assessment, and construction safety, with the respective rankings of the MS of the sub-activities involved in each category. These findings indicated that a very large number of the respondents are significantly aware of the benefits of the use of drones in addressing built environment-related tasks. These findings underscore why much importance should be given to the adoption of drones in solving built environment tasks based on the awareness of professionals about their multifarious uses.

Table 4. Awareness of the use and benefits of drones in the built environment

Awareness		Benefits	Mean	Rank
Awareness of the drone features in building projects	Drone features in building	Structure inspection and photography	4.50	1st
		Remote monitoring and progress reports	4.45	2nd
		Equipment tracking and automating	4.28	3rd
		Topography mapping and land surveys	4.25	4th
		Personnel safety	3.99	5th
		Security surveillance	3.86	7th
Awareness of the benefits of drones in built environment activities	Drone in building-related activities	Ability to inspect difficult-to-reach and hazardous areas	4.75	1st
		Accurate and comprehensive data	4.28	2nd
		Better documentation	4.14	3rd
		Flexibility to suit the majority of inspections	4.12	4th
		Remote access to the current status of the site	4.08	5th
		Faster reconciliation with subcontractors	3.81	6th
		Increased safety	3.60	7th
		Cost- and time-saving	3.57	8th
Awareness of the application areas of drones	Structural and infrastructure inspection	Building inspection	4.49	1st
		Bridge inspection	4.42	3rd
		Road inspection	3.98	8th
	Transportation	Landslide monitoring and mapping	3.85	10th
		Earthwork	3.96	9th
		Traffic surveillance	3.56	18th
	Cultural heritage conservation	Historic preservation and reconstruction	3.78	13th
		Monitoring historic monuments	3.85	10th
		3D modeling of heritage buildings	3.78	13th
		Landscape preservation	3.67	16th
		Land policy monitoring	3.81	12th
		Cadastral surveying	3.58	17th
		City and building modeling	3.69	15th
	Progress monitoring	Construction progress monitoring	4.26	6th
		Tracking material on complex job sites	4.49	1st
	Post-disaster assessment	Assessing damages (including structural damage) to cities and buildings after disastrous events	4.39	4th
	Construction safety	Construction safety inspection	4.31	5th
		Monitoring the safety hazards of equipment on construction sites	4.24	7th

3.2 *Level of adoption of drones in addressing built environment tasks*

This section provides the results of the study on the level of adoption of drones by professionals in addressing built environment tasks and the associated types commonly used in their respective execution. This depicts different real-life examples of the applications and uses of drones to solve related built environment and construction tasks, construction risks and disaster assessment, landslide movement and management, and tracking of materials used on site, amongst other associated applications that they can be used for. The streams of applications of drones are in the areas of monitoring the progress rate of construction services, obtaining data on fault detection and repairs of infrastructure projects, and city and urban space planning. The results obtained are contained in Table 5, with the indication that professionals in the building industry used drones most significantly to address activities related to the practice of emergency response plans and health and safety plans to reduce the risk of exposure to harm and ensure safety on sites, with an MS of 3.02. It also indicated that, based on the importance of activities, it was closely followed by its use for tracking materials on-site and the requirements for city and urban planning, with MSs of 2.63 and 2.59, respectively. It further showed that its adoption to minimize the impacts of transportation in the built environment was rated the least with an MS of 1.62. The study is also premised on the fact that different types of drones are being sourced and procured by building professionals to perform different tasks; thus, Table 5 shows the fixed-wing hybrid drone was most significantly adopted based on the ease of its applications with an MS of 1.97, while the small type drone was least adopted with an MS of 1.11 based on the features that it has. This result upholds the position established in the literature that different types and versions of drones are used based on their scope of applications and tasks that they can perform. A section of the types of drones used on construction sites visited in Lagos State during the study is shown in Figures 2 and 3 to depict the applications and uses of drones in addressing associated and relevant tasks in construction practice.

Table 5. Adoption of types of drones used in addressing built environment tasks

Adoption of drones in built environment		Mean	Rank
Practice of emergency response plans and health and safety plans to reduce the risk of harm and ensure safety on site		3.02	1st
Used for tracking materials on site		2.63	2nd
Used for city and urban planning		2.59	3rd
Used in performing structural and infrastructure inspections. The assessments cover buildings, bridges, as well as several other structures (e.g., retaining walls, roads, windmills, and dams)		2.53	4th
Drone for progress monitoring on site		2.44	5th
Evaluation based on benchmark datasets and exhibited a highly accurate model comparable to the LiDAR surveying method		2.32	6th
Used for virtual reality in post-disaster assessment		2.20	7th
Earthwork: Comparing earthwork volume calculations retrieved from UAVs with the ones generated by conventional techniques		2.13	8th
Landslide monitoring and mapping: Examined UAV usage in landslide monitoring and mapping		2.10	9th
Autonomous manual to enable environmental complexity and improved flexibility		1.67	10th
UAVs are offered by reconstructing a digital 3D building model using UAV visualizations		1.67	10th
Careful site selection to minimize the impacts of transportation options		1.62	12th
Adoption of drone types used in solving built environment-related tasks	Fixed-wing hybrid	1.97	1st
	Tactical	1.95	2nd
	Large combat	1.72	3rd
	Reconnaissance	1.68	4th
	Multi-roter	1.65	5th
	Fixed-wing	1.63	6th
	Photography	1.57	7th
	GPS	1.50	8th
	Single-roter	1.19	9th
	Small	1.11	10th

Figure 2. A typical multi-rotor drone used on a construction site in Lekki Phase 1, Lagos State, Nigeria

Figure 3. Construction of the Ikeja Bus Rapid Transit (BRT) Terminal with the adoption of drones on a construction site in Ikeja, Lagos State

The section further shows, via one-way analysis of variance (ANOVA) analysis, the relationship between the tasks performed by drones in the built environment and the probable areas in which they are implemented by the diverse built environment professionals. This is shown in Table 6, which indicates that there is a fair level of relationship between the various types of tasks that drones can be put to by building professionals.

The findings from the respondents provide managerial insights into the utilization of drones. These insights highlight the digital innovations that can be achieved through the implementation of drones, which can facilitate the execution of construction projects, including repairs, in a manner that optimizes quality, cost, and time. It will also help construction professionals learn how to obtain data or information on defects that can't be easily accessed and will affect the performance of construction projects. Such benefits from drones would also let the citizenry derive value from the provision of construction services and the achievement of overall sustainability benefits.

Table 6. Relationship between the tasks that drones are used for by professionals in the built environment

Source of variation		Sum of squares	Df	Mean square	F	P-value
Topography mapping and land surveys	Between groups	18.928	7	2.704	8.344	0.000
	Within groups	44.072	136	0.324		
	Total	63.000	143			
Equipment tracking and automating	Between groups	18.222	7	2.603	9.655	0.000
	Within groups	36.667	136	0.270		
	Total	54.889	143			
Remote monitoring and progress reports	Between groups	4.927	7	0.704	1.749	0.103
	Within groups	54.733	136	0.402		
	Total	59.660	143			
Security surveillance	Between groups	3.554	7	0.508	1.157	0.331
	Within groups	59.668	136	0.439		
	Total	69.222	143			
Personnel safety	Between groups	18.552	7	2.650	3.451	0.002
	Within groups	104.441	136	0.768		
	Total	122.993	143			
Structure inspection and photography	Between groups	7.173	7	1.025	4.002	0.001
	Within groups	34.827	136	0.256		
	Total	42.000	143			

The practical applications of the adoption and use of drones as obtained from the study are evident in the automation benefits through the integration of high-tech sensors in their architecture, which helps to gather intelligence, inspect, and supervise construction projects so as to create a better life for the citizenry that will depend on them.

3.3 *Factors limiting the adoption of drones in addressing built environment tasks*

This section provides information on the associated factors that may affect the adoption of drones in addressing built environment-related tasks by professionals in the building industry. Table 7 shows that amongst the identified factors in the literature, lack of public awareness was found to contribute most significantly as a limiting factor to the adoption and use of drones by professionals in the built environment practice, with an MS of 4.81. Lack of government support and a lack of demand for drones came in second and third place, respectively, with MSs of 4.70 and 4.43, while a lack of environmentally friendly technology to support its use received the lowest rating, with an MS of 3.79. This indicated the strength of the contributions of the various identified factors to their propensity to limit the adoption of drones in solving relevant tasks in the building industry. This implies that the identified factors need to be looked into in order to seek ways to deepen the awareness, adoption, and use of drones in performing various tasks by building professionals.

Table 7. Factors limiting the adoption of drones in addressing built environment tasks

Limiting factors	Mean	Rank
Lack of public awareness	4.81	1st
Lack of government support	4.70	2nd
Lack of demand for drones	4.43	3rd
Ethical procurement and partnerships	4.38	4th
Legal issues	4.32	5th
Transparency, informed consent and community engagement	4.26	6th
Lack of incentive	4.18	7th
Privacy and data protection	4.07	8th
Higher investment costs	3.85	9th
Lack of informed design and use	3.83	10th
Lack of sustainable technology	3.79	11th

4. Conclusion and recommendations

Drones are regarded as an important technological asset in the built environment. Its use in the construction industry will continue to increase with its ability to collect data that will be useful to analyze the features of existing and ongoing projects. It has been observed that construction companies adopt drones much faster than ever because of their immeasurable benefits. Whether drones are used by construction companies for topographic terrain mapping, building surveys, land surveys, construction site inspections, remote monitoring, progress reports, thermal imaging recording, or integration with laser scanners, they have proven to be invaluable tools throughout the life cycle of a construction project. The capabilities of drones enable them to save costs, time, risk, and labor, which automatically makes built environment professionals, contractors, investors, and customers more confident in achieving certainty when working on construction projects.

In this study, an attempt was made to examine the level of awareness of building professionals about the use of drones in addressing built environment issues in the construction industry in Lagos State. Firstly, an assessment of the profile and characteristics of the respondents in relation to the use of drones in building project execution was assessed, and the result showed that all 144 respondents were aware of the use of drones in addressing the built environment. The awareness of drones features and benefits in addressing built environments was assessed among professionals. The result from the study shows the assessment of drone features in buildings, with structure inspection and photography being the most important drone features, while security surveillance was the least rated drone feature by the professionals. It also shows the assessment of drone benefits in a built environment, with the ability to inspect difficult-to-reach and hazardous areas (MS = 4.75) being the most important benefit, followed by accurate and comprehensive data (MS = 4.28) and cost and time savings being the least important.

Also, an examination of the level of adoption of drones in addressing built environment tasks was assessed, and it was shown that the practice of emergency response plans and health and safety plans to reduce the risk of harm and ensure safety on site (MS = 3.02) is considered the most important task for the adoption of drones, while careful site selection to minimize the impacts of transportation options (MS = 1.62) is considered the least important of the rating tasks. Lastly, the examination of factors limiting the practice of drones in addressing built environment-related tasks by construction professionals was assessed, and the study shows that the most rated limitation affecting the practice of drones is lack of public awareness (MS = 4.81), and the lack of technology and sustainability (MS = 3.79) factor has the least importance.

Given the findings of this study, which depict that few professionals have practically used drones to solve tasks faced in the building industry, there is a need to further sensitize built environment professionals on the benefits associated with their adoption. Also, the importance of drones and their associated managerial and practical implications in solving relevant built environment tasks can be initiated by deepening their relevance in the curriculum of building industry programs at the professional and academic levels.

Conflict of interest

There is no conflict of interest in this study.

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