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Enhancing Safety Management in the Ghanaian Construction Industry: Evaluating the Role of UAV Implementation and Construction Managers Understanding

Zakari Mustapha[1,*], *Benjamin Boahene Akomah*[1], *Ofosu Emmanuel Kwaku*[1], Chris K. Tieru[1]

[1] *Department of Construction Technology Management, School of Built and Natural Environment Cape Coast Technical University, Ghana, (mustapha.zakari@cctu.edu.gh, benjamin.akomah@cctu.edu.gh, ofosuemmanuel13@gmail.com, tierochris@gmail.com)*
Corresponding Author* *mustapha.zakari@cctu.edu.gh*

Abstract

The integration of unmanned aerial vehicles (UAVs) and other rising technologies has become paramount in construction safety monitoring and management. The study aimed to gain insight into the use of drones in construction safety practices and management in the Ghanaian construction industry. Through a literature review, five key domains (aerial surveillance and real-time monitoring, data analysis and risk assessment, emergency response and search-and-rescue operations, information management and visualisation, and safety training and education) were identified as the areas where UAVs or drones could enhance safety practices and management. The study included construction professionals who had a minimum of ten (10) years of experience in project management across different positions. A convenience sampling technique was used for the selection of participants from construction companies within the city of Accra. A structured questionnaire was designed and distributed to these professionals. The collected data was analysed using descriptive statistics and correlation analysis. The correlation analysis highlights the association among the variables used. The study underscores the pivotal role of UAVs in transforming safety practices and management. The diverse applications and potential benefits of UAV technology provide insights for policymakers, educators, and industry stakeholders to optimise safety management strategies and enhance efficiency on construction sites. In addition, the findings emphasise the importance of education and training initiatives to bridge the knowledge gap among construction professionals, thereby promoting a more sustainable and secure construction environment in Ghana.

Keywords: *Construction Safety Management; Risk Assessment; Real-Time Monitoring; Unmanned Aerial Vehicles (UAVs).*

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I. INTRODUCTION

The hazardous nature of construction activities in Ghana has contributed to a number of work-related injuries and fatalities and its adverse effect on development [1]. Construction industries worldwide actively pursue innovative methods and cutting-edge technologies to enhance health and safety standards at construction sites. [1,2] posited that technology has certainly played a very important role in improving construction procedures and processes for many years, but its application for health and safety monitoring and management has not been fully exploited in the Ghanaian construction industry. [3] concluded in their study that the key barriers to the adoption of these technologies for health and safety in the Ghanaian construction industry are 'the excess costs associated with acquiring new technologies', 'weak innovation culture', 'lack of continuous training of the workforce in adapting to the technologies', 'resistance to change with an aging workforce', and 'little or no governmental support or regulations for the use of the technologies'. [4] asserted that new technologies could potentially lead to improved safety and health practices. Digital techniques and technologies are required to advance construction health and safety practices and management [5,6]. The integration of unmanned aerial vehicles (UAVs), commonly known as drones, has emerged as a transformative force [7]. The application of drones in construction has now become a reality, with tangible benefits being realised across diverse projects. The integration of drones for safety management has paved the way for subsequent investigations and advancements in the construction industry [8,9]. The study considered the existing knowledge base, providing a comprehensive overview of the role of drones in construction site safety management and the practical implications of deploying drones as integral components of safety management strategies. Others were the applications of drones, data analytics, surveillance capabilities, and their impact on risk assessment. The paper aimed to acquire a deeper understanding of the of drones in construction safety practices and management in the Ghanaian construction industry.

II. CONSTRUCTION SAFETY IMPLEMENTATION

There are several common causes of fatalities and injuries in construction, such as falls, being crushed, being struck by falling objects or equipment, accidents involving heavy machinery, and contact with electricity [10]. While accidents are often avoidable, they still occur due to inadequate safety planning. Safety planning is a fundamental requirement in construction projects and is governed by regulations set forth by organisations like the US Occupational Safety and Health Administration (OSHA) [11]. Despite improvements in safety standards, the construction industry still lags in other sectors beind terms of safety performance [12]. [13] posited that safety systems should be developed to address hazardous situations in construction environments to prevent accidents. Effective safety planning involves identifying potential hazards and determining appropriate safety measures [14], and the design team must have a strong understanding of health and safety [15]. Safety implementation occurs during the construction phase, where the safety plan prepared during the design phase is put into action.

A. Unmanned aerial vehicles (UAVs)

An unmanned aerial vehicle (UAV) is an aircraft that can fly autonomously or under remote control. The geomatics community uses a variety of names, including remotely piloted vehicle (RPV), remotely operated aircraft (ROA), remote controlled (RC) helicopter, unmanned vehicle systems (UVS), and model helicopter, in addition to the term unmanned aerial system (UAS). Drones are the popular term for these types of aircraft. A smartphone or tablet may be used to manage a lot of unmanned aerial vehicles (UAVs). These drones have cameras and other sensors, such as a GPS system, which enable them to efficiently and correctly collect high-resolution footage from different perspectives. Unmanned Aerial Vehicle (UAV) technology has been applied in a number of civilian fields, including mining, agriculture, forestry, construction, archaeology, and search and rescue missions [7]. They are used for taking pictures and videos of project sites. UAVs could contribute positively to real-time monitoring in building and civil construction projects. These smart devices have been utilised for a variety of tasks, including maintenance inspections of infrastructure and transportation-related duties, including assessing road surface distress, supporting repair and maintenance activities, managing work zones to ensure worker safety, and monitoring and directing traffic on highways during and after emergency occurrences or severe weather conditions. UAVs have the benefit of effectively covering a vast area and flying over work zones when compared to traditional traffic control systems [7,10].

B. Area Surveillance and Real-Time Monitoring

Construction managers use tracking and monitoring systems to monitor changes on construction sites [16]. Through these devices, safety managers get important insights from monitoring construction operations, which helps them control progress [17]. [18] discovered that, in comparison to conventional techniques, immersive technologies greatly enhance on-site project information accessibility and communication. Project teams can collaborate and communicate more easily when they use immersive technologies. Researchers have examined the application of immersive technologies in electrical construction design communication [19]. Electrical construction workers who used immersive technology performed better than those who used traditional paper-based methods, according to a comparison. [20] developed a system for real-time BIM data synchronisation in virtual reality (VR), designed to facilitate group decision-making. Their solution automatically updates BIM model changes in VR headsets by interpreting BIM metadata on the cloud. [21] suggested using a visualised environment—like a BIM table—to encourage cross-disciplinary cooperation and construction talks. Using augmented reality technology, they linked the BIM Table to mobile devices, as well as both public and private data. [22] conducted a study that analysed the application of VR-based processes in real projects, aiming to tackle issues related to team collaboration. In [20], they developed collaborative virtual reality (CoVR), a cloud-based, multi-user VR headset system that enables interpersonal project communication within an interactive VR environment. In general, immersive technologies—such as drones—are essential for enhancing communication and teamwork in building projects.

C. Data Analytics and Risk Assessment

The first important step in a thorough analysis of construction site safety procedures is identifying potential dangers. Next, prioritise safety duties, focusing on resolving the most serious risks. A dangerous workplace has a substantial impact on project time and expense, in addition to jeopardising site safety [23]. Unmanned Aerial Vehicles (UAVs) can help with the immediate implementation of preventative measures and the identification of significant hazards. Safety managers may conduct physical inspections to confirm that safety procedures are being adhered to by employing unmanned aerial vehicles (UAVs) to identify safety hazards during construction.

D. Emergency Response and Search-and-Rescue Operations on construction site

Drones offer numerous advantages in emergency response scenarios within the construction industry, particularly in terms of their rapid deployment capabilities [4,24]. Unlike helicopters, UAVs can be launched swiftly and easily from virtually any location, as they do not require runways or landing fields [25,26]. This agility in deployment ensures that emergency responders within construction sites can quickly mobilise drones to assess the situation and provide assistance in case of accidents or emergencies [27]. The use of drones in construction emergency response operations enhances safety for both responders and victims [28, 27]. Drones reduce the risk to emergency personnel by allowing them to operate remotely from various locations within the site, particularly in hazardous or high-risk environments such as unstable structures or confined spaces.

E. Information management and Visualization.

UAVs provide architects and engineers with new ways to see and analyse structural needs from the ground up. These devices are becoming an increasingly important part of virtual design and construction (VDC). [9] presented a framework that integrates the surrounding environment of Google Earth, geometric models, and unordered photos. This framework consists of two main parts: an image and 3D model-management system based on Keyhole Markup Language (KML) and UAV-centric picture alignment and processing. The system's goal is to give construction engineers an accessible and affordable means of managing, integrating, and visualising data on dynamic building sites. [29] developed three-dimensional models that focus on material performance, utilising UAV-based photogrammetry investigations to assess the structural health of buildings. Unmanned aerial vehicles equipped with visual-range cameras collected a variety of picture data sets relating to the condition of infrastructure assets. The health of the structures was then visualised and examined using the 3D models that were made using this data. In order to enhance the precision and calibre of digital elevation models (DEMs) produced by unmanned aerial vehicles, [29] developed a technique that combined additive median filtering and weighted averaging methods. According to their investigation, the accuracy of the merged DEM increased by an impressive 88%. In [21], researchers presented enhanced neural networks for extracting road information from remote-sensing images captured by UAV-mounted camera sensors. [30] introduced a robotic UAV-assisted approach that aimed to reduce human intervention and time for data collection and processing. This approach enabled continuous monitoring, updating, and analysis of cluttered environments, thereby supporting timely decision-making. [31] proposed an innovative way to automatically retrieve frames containing construction-related content from consecutive images or collected video footage. This way, practitioners can effectively evaluate the current state of construction sites using selected visual data, promoting data-driven decision-making.

F. Safety Training and Education

The integration of virtual simulations facilitated by drones creates immersive safety training experiences for construction workers, enhancing their awareness and preparedness [32]. Various industries, including aviation, widely use VR-based training simulators to train operators and professionals in a safe environment [31]. [33] emphasised that immersive technologies enable construction workers to receive direct instructions and practice operating machinery, leading to enhanced skill development. Researchers have developed immersion technology-based methods to provide construction workers and students with safe and practical experiences [21,7]. [17] emphasized that, because of its shooting techniques, 360-degree VR delivers great degrees of realism, easy-to-produce simulations, and quick digital job-site development. Immersion technologies allow remote specialists to virtually present themselves, increasing training speed and quality.

Authors of [4,34] demonstrated how VR and MR mock-ups can simulate accessibility design reviews and assessments for construction projects, involving both student novices and professional experts. [35] emphasised the use of AR technology and simulated visualisations to bridge the knowledge gap between experts and new employees, thereby improving their spatial and temporal comprehension of complex construction processes. Immersion technologies could potentially integrate with drones to provide realistic training simulations for drone operations and safety protocols, enabling workers to familiarise themselves with drone usage in construction projects in a safe and controlled environment.

III. METHODOLOGY.

The research began with an extensive review of the existing literature to explore the role of drones in construction health and safety. This review aimed to identify specific studies and knowledge gaps within the domain. This process identified five key domains where unmanned aerial vehicles (UAVs) or drones have the potential to enhance safety practices and management in the construction industry:

1. Aerial surveillance and real-time monitoring.
2. Data analysis and risk assessment.
3. Emergency response and search-and-rescue operations.
4. Information management and visualisation.
5. Safety training and education.

A convenience sampling method was employed to select 150 participants from various construction companies in Accra, and questionnaires were given to them to express their opinions about the issues highlighted. Out of this number, 130 responses were collected during the survey period from June to August 2023. The researchers personally distributed structured questionnaires to a diverse group of respondents, including project managers, quantity surveyors, civil engineers, site supervisors, architects, and safety officers. The criteria for inclusion were that all participants must have served in various roles or positions and have a minimum of ten years of work experience.

The data gathered aimed to capture respondents' perspectives and insights on the understanding of different aspects of UAV application in construction safety management and areas where UAVs could be utilised in the construction sector. Descriptive statistics, including frequencies and percentages, were used for the demographic data, while mean scores and standard deviations were used for the variables under observation to evaluate the understanding of various aspects of UAV applications. A correlation analysis was also conducted to examine the relationship between construction workers' understanding of drone implementation and the various aspects of safety management within the Ghanaian construction industry.

IV. FINDINGS

Table 1 shows that the majority, 58 (44.6%), were within the age group of 26–30 years. The age group of 31–40 years followed with 48 (36.9%). The age group of 46–50 years had the lowest number of respondents, accounting for 8 (6.2%). Quantity surveyors were the highest 32 (24.6%) among the construction professionals. Civil engineers (30) accounted for 23.1%, followed by project managers (17.7%) and safety officers (17.7%). The least number of construction professionals (6.2%) were site supervisors. Safety officers (20%) had served more years within their respective companies than other professionals. Civil engineers ranked second at 13.8%, while site supervisors made up the least number of professionals at 9.2%.

TABLE 1: DEMOGRAPHIC DATA OF RESPONDENTS

Age Group (years)	**Frequency**	**Percent (%)**
26 - 30	58	44.6
31 - 40	48	36.9
41 - 45	16	12.3
46 – 50	8	6.2
Construction Professionals		
Project managers	23	17.7
Quantity surveyors	32	24.6
Civil engineers	30	23.1
Site supervisors	8	6.2
Architects	14	10.8
Safety officers	23	17.7
Years of Service in the Company		
Project managers	12	9.2
Quantity surveyors	16	12.3
Civil engineers	18	13.8
Site supervisors	10	7.7
Architects	16	12.3
Safety officers	26	20
	130	100

A. *Understanding of different aspects of UAV application in construction safety management*

Table 2 provides insights into Ghana's construction workers' knowledge levels regarding the use of unmanned aerial vehicles (UAVs) for construction health and safety practices. Aerial surveillance and real-time monitoring emerge as the most comprehensively understood aspects, with construction workers demonstrating a strong understanding of their applications, as indicated by the highest mean score of 4.1538 and relatively low standard deviation of 0.86680. This suggests a consensus among respondents regarding this area of knowledge, positioning it as the top-ranked variable. Following closely, data analysis and risk assessment also exhibited a significant level of understanding among respondents, with a mean score of 3.7692 and a standard deviation of 0.99252. Emergency response, search, and rescue operations show a comparatively lower level of comprehension, with a mean of 3.0538 and a standard deviation of 1.24085, suggesting potential areas for further education and training initiatives to enhance workers' understanding and utilisation of UAVs in construction safety practices.

While studies such as [36] have highlighted various applications and findings related to unmanned aerial systems (UAS) in construction, Ghanaian construction professionals have not yet fully realised the potential of UAVs. Research from [37] indicates that although these professionals are open to adopting new construction technologies, there is a low likelihood of fully integrating such technologies into the industry. This reluctance stems from a perception among professionals that key technologies such as the Internet of Things, robotics, human-computer interaction, and cyber-physical systems are not crucial for creating smart construction sites. A similar study identified that important technologies for health and safety in the Ghanaian construction sector include wearable safety devices, geographic information systems, sensing technologies, virtual reality, and Building Information Modelling (BIM) [3]. Ghanaian construction professionals use these technologies only moderately, despite their recognition of their importance. Key barriers to adoption include high costs of new technologies, a weak innovation culture, a lack of continuous workforce training, resistance to change, especially among older workers, and inadequate government support or regulations.

TABLE 2: UNDERSTANDING OF DIFFERENT ASPECTS OF UAV APPLICATION IN CONSTRUCTION SAFETY MANAGEMENT

	N	*Mean*	*Std. Deviation*	*Rank*
Aerial surveillance and real-time monitoring	130	4.1538	0.86680	**1st**
Data analysis and risk assessment	130	3.7692	0.99252	**2nd**
Information management and visualization	130	3.4231	1.36322	**3rd**
Safety training and education	130	3.2538	1.29586	**4th**
Emergency response, search and rescue operation	130	3.0538	1.24085	**5th**

Fig. 1. gives a graphical representation of the level of understanding of UAVs in the Ghanaian Construction Industry, the chart shows construction workers comprehension of the various uses of UAVs.

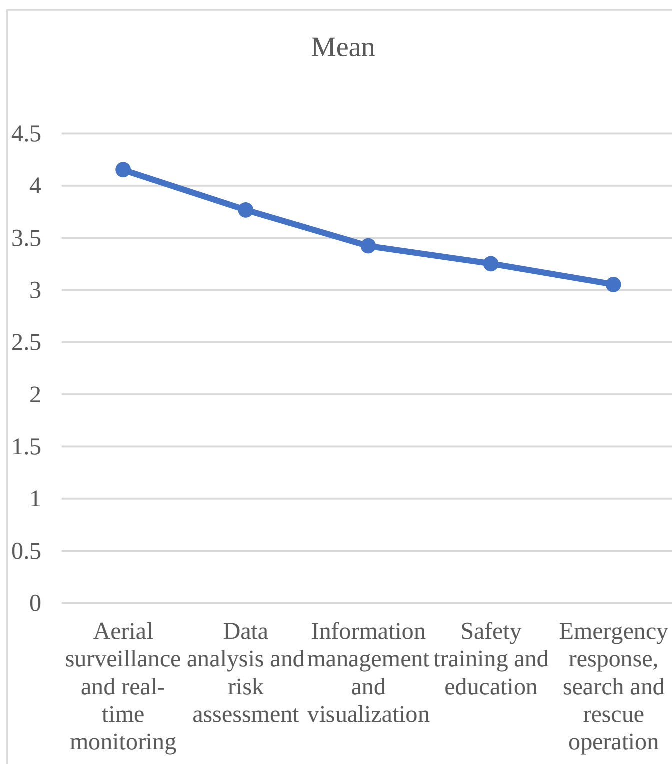

Fig. 1. level of understanding of UAVs in the Ghanaian Construction Industry

B. Areas where UAVs could be used in the construction sector

The dataset presented in Table 3 provides valuable insights into the varied applications of drones within the construction sector. The use of drones for remote monitoring is at the forefront of priorities, as evidenced by their highest mean score of 5.3385 with a standard deviation of 6.18269 and top ranking. This indicates a widespread recognition of the value drones bring to overseeing construction sites from a distance, potentially improving project oversight and management efficiency. Additionally, the emphasis on topographic mapping and measurement underscores the critical role drones play in providing accurate spatial data for construction projects, aiding in site planning and design, with mean scores of 4.1462 and 4.0538 and standard deviations of 0.79837 and 1.02912, respectively. Furthermore, the data highlights the significance of drones in facilitating inspections and enhancing security measures on construction sites, with mean scores of 4.0538 and 4.0077 and standard deviations of 1.02912 and 1.00769, respectively.

These applications, while ranking slightly lower than remote monitoring and topographic mapping, still receive considerable attention, indicating their perceived importance in ensuring construction site safety and integrity. Moreover, the focus on efficiency and improved planning implies that drones serve as tools to enhance project workflows and decision-making processes, potentially resulting in more efficient and cost-effective construction operations. While certain areas like data management and communication rank lower in priority, they nevertheless underscore the importance of effective information handling and dissemination in drone-assisted construction projects. Lastly, the recognition of drones' potential for enhancing safety protocols and providing surveillance highlights their multifaceted role in promoting a secure and controlled construction environment. Research by [38] reveals that software development for the drone era has transformed the leisure industry, offering several advantages such as enhanced productivity and safer, more environmentally friendly operations. A variety of tasks, including development tracking, online site surveys, environmental tracking, and inspections, employ drones. However, [39] also identified UAV technological developments that promote automation and digitisation, including real-time video streaming, automated UAV inspection planning, automated progress tracking, and parametric model development for historic structures.

TABLE 3: AREAS WHERE UAVS COULD BE USED IN THE CONSTRUCTION SECTOR

	N	*Mean*	*Std. Deviation*	*Ranking*
Remote monitoring	130	5.3385	6.18269	1st
Topographic mapping	130	4.1462	0.79837	2nd
Measurement	130	4.0538	1.02912	3rd
Inspections	130	4.0538	1.02912	4th
Efficiency	130	4.0462	0.74565	5th
Security	130	4.0077	1.00769	6th
Site surveys	130	4.0077	0.94415	7th
Better planning	130	4.0077	1.08189	8th
Data management	130	4.0077	0.94415	9th
Safety	130	3.9615	0.91841	10th
Equipment tracking	130	3.9538	0.74565	11th
Communication	130	3.9231	1.21754	12th
Monitoring	130	3.9077	0.88437	13th
Surveillance	130	3.8615	1.11198	14th
Savings	130	3.8538	1.02004	15th
Construction	130	3.8000	0.75123	16th

V. CORRELATION ANALYSIS

There is a significant positive correlation between aerial surveillance and real-time monitoring, data analysis and risk assessment, emergency response and search and rescue operations, information management and visualisation, as well as safety training and education. This suggests that a strong understanding of one aspect tends to be associated with a strong understanding of the other aspects, indicating a holistic comprehension of drone implementation across different safety management areas among construction workers. Specifically, the strongest correlations are observed between emergency response and search and rescue operations with information management and visualisation, as well as safety training and education. This implies that construction workers who possess a good understanding of emergency response and search and rescue operations are likely to have a better grasp of information management, visualisation techniques, safety training, and education initiatives related to drone implementation. Table 4 presents the correlations.

TABLE 4: CORRELATIONS AMONG DRONE IMPLEMENTATION ASPECTS IN SAFETY MANAGEMENT FOR CONSTRUCTION WORKERS

		Aerial surveillance and real time monitoring	Data analysis and risk assessment	Emergency response and search and rescue operation	Information management and visualization	safety training and education
Aerial surveillance and real-time monitoring	Pearson Correlation	1	.132	.338**	.371**	.345**
	Sig. (2-tailed)		.135	.000	.000	.000
	N	130	130	130	130	130
Data analysis and risk assessment	Pearson Correlation	.132	1	.413**	.101	.438**
	Sig. (2-tailed)	.135		.000	.251	.000
	N	130	130	130	130	130
Emergency response and search and rescue operation	Pearson Correlation	.338**	.413**	1	.504**	.647**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	130	130	130	130	130
Information manageme	Pearson Correlation	.371**	.101	.504**	1	.321**

nt and visualization	Sig. (2-tailed)	.000	.251	.000		.000
	N	130	130	130	130	130
safety training and education	Pearson Correlation	.345**	.438**	.647**	.321**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	130	130	130	130	130

**. Correlation is significant at the 0.01 level (2-tailed).

VI. Conclusion

In the last ten years, researchers have utilised unmanned aerial systems (UASs) in the construction industry for a range of purposes, including site inspections, safety monitoring, and building maintenance [36]. This study aimed to gain insight into the use of UAVs in construction safety practices and management in the Ghanaian construction industry. Construction professionals identified aerial surveillance and real-time monitoring as the most comprehensively understood aspects, indicating a strong foundation for leveraging drones for monitoring and oversight purposes. Areas of lesser comprehension, such as information management and visualisation, safety training, and emergency response, were revealed, indicating potential gaps in knowledge that could be addressed through targeted education and training initiatives. The correlation analysis highlighted the interconnectedness of different aspects of safety management, emphasising the importance of a holistic understanding of drone implementation for maximising safety outcomes on construction sites. The diverse applications of drones in the construction sector range from remote monitoring and topographic mapping to inspections, security enhancement, and efficiency improvement. These findings not only reinforce the importance of leveraging drone technology for enhancing construction safety but also emphasise its potential for optimising project workflows and decision-making processes. By identifying areas where drones can make significant contributions and understanding the level of comprehension among construction workers, stakeholders can better strategise and implement initiatives aimed at harnessing the full potential of drones for promoting safety and efficiency in construction projects. The study provides valuable insights that can inform policy-making, education, and industry practices to foster a safer and more sustainable construction environment in Ghana.

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