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Barriers to the Adoption of Unmanned Aerial Vehicles for Construction Projects in South Africa †

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Abstract: At inception, unmanned aerial vehicles (UAVs) were mostly used for military purposes; however, in today's technology-driven world, they are used for many more applications. In construction, UAVs can be used for pre-planning, proper surveying of the given area, checking or inspecting safety, 3D printing, quality monitoring and other related objectives. Even though UAVs' features and capabilities have been highlighted in various prominent studies, they are not being adopted efficiently in the construction industry, necessitating this study. A quantitative research approach was adopted to achieve the set objective of this study. Data were retrieved using a questionnaire survey distributed to construction professionals randomly in the South African construction industry. The retrieved data were analysed using descriptive and inferential data analysis methods. The findings from the analysis revealed that two significant clusters of barriers to adopting UAVs in the construction industry are related to technicalities and security factors. It was concluded that there is a long way to go in adopting UAVs in the construction industry. This study recommended that construction stakeholders take necessary measures to mitigate the identified barriers. This will assist the industry in improving its efficiency and performance.

Keywords: construction technology; drones; unmanned aerial vehicles

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1. Introduction

Construction is one of the most important industries worldwide [1]. It plays a huge role in the economy of South Africa. Construction comprises different work schedules, including planning, alterations, demolishing, repairs, maintenance, civil engineering, and electrical and mechanical works [2]. Construction is also an entity that comprises different activities [3]. These activities are tagged as high-risk activities that must be diligently managed from the procurement stage, cutting across the design stage, and then to the end of construction. In construction, there are delays because of the project's complexity, which usually leads to cost overrun [4]. Furthermore, the construction industry is divided into three categories: building, infrastructure and special trade construction [5]. Building construction involves the construction of residential, commercial or industrial buildings. Infrastructure involves heavy construction like roads, bridges, dams, railways and sewers. Special trade construction involves plumbing, electrical and mechanical works, paintings and specific fitting [5]. An unmanned aerial vehicle is a technological device that can be adopted in these three categories of the construction industry.

Unmanned aerial vehicles (UAVs) are called "drones" in common terms [6]. It is an aircraft with no pilot on board. It can only be controlled when an individual is on the ground [7]. Unmanned aerial vehicles are operated using remote controls by human operators [6]. UAVs can undergo autopilot stages if no human control is needed. At inception, drones were primarily used for military purposes [8]. They are now used for many more applications including aerial photography, construction uses, surveillance, science, infrastructure inspections, etc. [9]. These UAVs in construction are used for pre-planning; proper surveying of the given area; checking or inspecting if the area is safe to commence work; and things like marketing, 3D printing, quality monitoring and other related objectives [10]. Construction project managers usually inspect the site's progress once a week; the adoption of unmanned aerial vehicles will save more time and bring in more accurate and safe inspections [11]. This will also assist in obtaining a bird-eye-view of the project at hand, which may reveal concerns that would be impossible to trace when performing real-life ground-level inspections [12].

When conducting a building survey, visualising the roof can be difficult or dangerous [13]. The traditional way would be erecting a scaffold or using a cherry picker and a ladder. That takes up so much time, requiring high safety measures [14]. Using drones for this specific reason (building survey) can save time, money and people's lives by preventing them from being injured [15]. A drone is often employed by planners and architects in the construction industry as a real-time tool to observe their progress and if it corresponds with their vision and imagination. As a result of the data acquired, developers and construction site businesses are encouraged to track their inventory [16]. Various drone models can produce high-resolution images and be customised according to topographic support, lens distortion, and camera motion [17]. By using drones, construction industry professionals can display projects in ways that cannot be imagined. The project team gains a bigger picture and makes better decisions. Based on the submissions made thus far, the importance of UAVs in the construction industry cannot be overemphasised. Therefore, this study is set to assess the barriers to adopting UAVs in the construction industry.

2. Barriers to the Adoption of UAVs in Construction

Despite the extensive potential and intense promotion within academic dialogue, unarmed aerial vehicles have not attained wide adoption throughout the construction industry owing to the overabundance of barriers [18]. For instance, recent studies opined that the germane barriers include rigorous aviation policies exacerbated by widespread concerns that aerial vehicles are used ostensibly as surveillance equipment [19]. Likewise, individuals and advocacy corporations have disparaged their commercialised usage around matters concerning informational integrity and secrecy [20,21]. Considering the aforementioned, the impediments to the adoption of UAVs in the construction framework represent a substantial problem. Table 1 summarises the identified barriers to adopting UAVs for construction projects in the construction industry.

Table 1. Barriers to the adoption of UAVs.

Identified Barriers	References
Technical difficulties	[19]
Lack of trained individuals	[22–24]
Limitation to the UAV device	[25]
UAV and controller link can be easily weakened	[26]
UAV accidents due to system failures	[27]
Possible accidental discharge	[28]
Unable to operate in extremely bad weather	[29]
Over-dependency on technology	[30]
Privacy concerns	[31]
Data security	[32]
Job insecurity	[33–35]
Minimisation of workforce's value	[36,37]
Financial constraint	[38]
Cyber security concerns	[39]

3. Methodology

The rationale behind the current study is to contribute to the body of knowledge on the barriers to adopting UAVs in the construction industry. This study adopted the quantitative research approach to achieve the set objective. A quantitative research survey is a simple self-reporting system that obtains information from a sample of people and reports on the questions posed by the researcher. When conducting a quantitative research study, the numerical measurement of specific aspects of phenomena is imperative and should be precise. This study retrieved data through a well-structured questionnaire distributed to the respondents. This study adopted an e-questionnaire retrieval system through the use of Google Forms, which was sent to respondents via email from October to December 2023. These respondents are construction professionals such as architects, quantity surveyors, engineers, construction managers and project managers in the Gauteng province, South Africa. A 5-point Likert scale questionnaire was developed utilising knowledge obtained from the literature to gather data relevant to the intent of the research. The choice of Gauteng province was because it houses the majority of the professionals within the country. In total, 200 questionnaires were randomly distributed to professionals within the study area, and 177 questionnaires were recovered. All the questionnaires recovered were deemed suitable after being reviewed for completion. The data obtained from the questionnaire were evaluated using the Mean Item Score (MIS), Standard Deviation (SD) and Exploratory Factor Analysis (EFA). Shapiro–Wilk's test was used to determine the normality of the retrieved data, while Cronbach's alpha was adopted to determine the reliability coefficient of the data collection instrument. The adopted cutoff alpha for this study was 0.70, and all measures were above 0.70, making all data retrieved reliable.

4. Findings and Discussion

This study shows that 48.6% of the respondents are quantity surveyors, 5.1% are architects, 29.9% are construction managers, 4.0% are electrical engineers, 2.3% are project managers, and 5.1% are construction managers and construction project managers. Additionally, 31.1% of the respondents have a Diploma as their highest educational qualification, while other respondents show 34.5% Bachelor's Degree qualification, 25.4% Honours Degree qualification, 6.8% Master's Degree qualification and 2.3% Doctoral qualification. Moreover, 23.2% of the respondents have construction-related work experience that ranges from 1 to 5 years, 41.7% have work experience ranging between 6 and 10 years, 31.1% have work experience ranging between 11 and 15 years, while 4.0% have work experience between 16 and 20 years. Furthermore, 15.8% of the respondents currently works in a consultancy firm, while 48.0% work for a contracting firm. A total of 20.9% of the respondents work for the government, while 15.3% work for private organisations; 4.5% have not participated in any construction project, while 2.3% have limited working experience only in 1–2 projects; and 13.0% have been opportune to participate in 3–4 projects, 29.4% have been able to participate in 5 to 6 projects, while 50.8% have participated in any number of construction projects that range between 7 and 8. This is an indication that the group of respondents used for this study possess the necessary background to construction industry activities as well as adequate professional qualifications needed for the study.

In evaluating the barriers to adopting UAVs, Table 2 reveals that the most significant barriers to adopting are 'Accidents with workers due to close proximity' with a mean score (M) of 4.40 and a standard deviation (SD) of 1.220. The other most significant challenges include 'Privacy concerns' (M = 4.26; 1.147), 'Data security' (M = 4.24; SD = 1.111), 'Lack of trained individuals' (M = 4.20; SD = 1.037) and 'Minimisation of workforce's value' (M = 4.10; SD = 1.152). The table also reveals the Shapiro–Wilk test for normality, in which the significant value of all the 14 assessed barriers is well below the 0.05 criteria required for normality. This infers that the information accumulated is non-parametric in nature. The outcome in the table additionally revealed that every one of the assessed factors gave a mean value higher than the average value of 3.0, which suggests that respondents accept that all the identified barriers are substantial.

Table 2. Descriptive analysis of barriers to the adoption of UAVs.

Barriers	Mean	Std. Deviation	Rank	Shapiro–Wilk	
				Statistic	Statistic
Privacy concerns	4.26	1.147	1	0.841	0.000
Lack of trained individuals	4.20	1.037	2	0.841	0.000
Minimisation of workforce's value	4.10	1.152	3	0.798	0.000
UAV accidents due to system failures	4.04	1.123	4	0.813	0.000
Dependency on technology	4.04	0.932	4	0.844	0.000
Financial constraint	3.98	1.189	6	0.776	0.000
UAV and controller link can be easily weakened	3.98	0.994	6	0.831	0.000
Limitation to the UAV device	3.94	1.133	8	0.789	0.000
Technical difficulties	3.88	1.070	9	0.808	0.000
Job insecurity	3.88	1.246	9	0.729	0.000
Unable to operate in extremely bad weather	3.78	1.044	11	0.777	0.000
Data security	3.71	0.882	12	0.811	0.000
Cyber security concerns	3.68	0.917	13	0.863	0.000
Accidents with workers due to close proximity	3.65	1.035	14	0.793	0.000

Table 3 shows the pattern matrix report of the EFA carried out; the eleven (11) variables identified from the literature were factored into two (2) clusters that are thus interpreted based on the observed inherent relationship among the variables in the cluster.

- A total of nine (9) variables were loaded onto cluster 1, as shown in Table 2. These variables include 'Technical Difficulties' (89.1%), 'Unable to operate in extremely bad weather' (88.0%), 'Limitation to the UAV device' (87.5%), 'Accidents with workers due to close proximity' (87.1%), 'UAV accidents due to system failures' (85.1%), 'Privacy concerns' (84.3%), 'Dependency on technology' (82.7%), 'Lack of trained individuals' (74.8%) and 'UAV and controller link can be easily weakened' (74.7%). All these can be observed to relate to technical issues. Therefore, this factor cluster can be termed 'Technicalities' with a variance of 57.445%, making it a major factor serving as a barrier to the adoption of unmanned aerial vehicle.
- In cluster 2, there are five (5) variables loaded onto it. These variables include 'Data Insecurity' (90.0%), 'Job Security' (89.3%), 'Cyber security concerns' (87.2%), 'Minimisation of workforce's value' (83.0%) and 'Financial constraint' (82.7%). The common factor to the variables in this cluster is security issues. The cluster is therefore labelled 'Security', with a total variance of 14.505%. This cluster is ranked as a factor serving as a barrier to the adoption of UAVs behind the variables in cluster 1.

Tables 2 and 3 provide a detailed insight into the challenges hindering the widespread adoption of UAVs in construction monitoring. These tables categorise the barriers into different groups, emphasising technical complexities and security concerns. The technical barriers are primarily associated with the operation and maintenance of UAVs. These include issues related to integrating UAV technology into existing construction processes, the need for specialised skills to operate these aerial vehicles, and data management and analysis challenges. The security concerns, conversely, are predominantly centred around the vulnerability of UAVs to cyber-attacks and the risk of unauthorised data access.

Table 3. Factor loading of barriers to the adoption of UAVs.

Cluster Factor Groupings	Eigenvalues	Variance	Pattern Matrix Factor	
			1	2
FACTOR 1—Technicalities	*8.042*	*57.445*		
Technical Difficulties			0.891	
Unable to operate in extremely bad weather			0.880	
Limitation to the UAV device			0.875	
Accidents with workers due to close proximity			0.871	
UAV accidents due to system failures			0.851	
Privacy concerns			0.843	
Dependency on technology			0.827	
Lack of trained individuals			0.748	
UAV and controller link can be easily weakened			0.747	
FACTOR 2—Security	*2.031*	*14.505*		
Data insecurity				0.900
Job security				0.893
Cyber security concerns				0.872
Minimisation of workforce's value				0.830
Financial constraint				0.827
Total Variance Explained		71.95		

The concerns highlighted in these tables resonate with the findings and opinions of several authors cited in the study. For instance, the author of [10] discussed the risks associated with the digitalisation of construction activities, particularly how it opens up avenues for cybercriminals to access and exploit critical project information. This vulnerability to cyber-attacks is a significant deterrent to adopting UAVs in construction monitoring, as it threatens the confidentiality and integrity of sensitive project data. Similarly, the author of [23] delves into the implications of relying heavily on technology in construction. This reliance is seen as a double-edged sword; while it enhances efficiency and accuracy, it also leads to structural unemployment. The adoption of UAVs and other digital tools in construction can potentially reduce the demand for human labour, leading to job losses and a devaluation of human resources in the industry.

The author of [28] further elaborates on these themes, highlighting the challenges in integrating UAV technology with the current workforce and processes in construction. The need for specialised training and the potential resistance from the existing workforce are identified as key barriers. The authors of [33,37] contributed to this discourse by emphasising the need for robust cybersecurity measures and workforce training to mitigate these barriers. They argue that while UAVs offer numerous benefits for construction monitoring, such as real-time data collection and enhanced project oversight, addressing the technical and security challenges is crucial for their successful adoption.

5. Conclusions and Recommendations

This study has evaluated the barriers to adopting UAVs for construction monitoring activities in the South African construction industry. This study shows that the adoption of digitisation is on the rise, with different factors influencing its adoption and usage. The barriers to adopting UAVs range from technical difficulties to security concerns. However, it was revealed that organisations in the construction industry are most likely to be faced with data privacy concerns and data insecurity as factors that serve as barriers to the adoption of unmanned aerial vehicles. Based on these findings, it can be concluded that there is still a long way to go in ensuring that UAVs are adopted for use in the construction industry. It is, therefore, recommended that construction stakeholders put in place necessary measures to ensure that the identified barriers are mitigated to assist the industry in adopting this technology, which will improve the industry's performance. This study was limited to Gauteng province of South Africa due to accessibility, time and cost constraints. Also, the study did not focus specifically on a particular application of UAVs in the construction industry. Further studies can be carried out using a larger population sample, while another study can be carried out on the benefits of adopting UAVs in the construction industry. In addition, further study can be carried out to focus on specific applications of UAVs in the construction industry.

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