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Benefits of Unmanned Aerial Vehicles in the South African Construction Industry: Exploratory Factor Analysis

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Abstract

Construction is a toxic industry with numerous difficulties such as time and budget overspending to mention a few. Despite these challenges, the construction industry (CI) is at the centre of the development of any economy. Thus, it is crucial to identify and understand the different technologies that are available to assist in growing the sector. Unmanned aerial vehicles (UAVs) are among the novel innovations that can lessen the difficulties encountered in the CI. Thus, the purpose of this study is to assess and emphasis the significance of UAVs. The study uses a survey methodology, and a standardized questionnaire was used to evaluate South African built environment experts. SPSS was used for the questionnaire's analysis, and the data was presented using principal component, t-test, and mean score for statistics testing. The results revealed that the application of UAVs on construction projects is beneficial to construction professionals. The application of UAVs for high-quality image capture, offering real-time information prevents injuries and accidents on site. It is anticipated that the findings will inform the many stakeholders involved in construction about the advantages of implementing the usage of UAVs for CI. Additionally, it will enhance the current body of knowledge in the CI and the research field. It is anticipated that this investigation will contribute to the CI's adoption and application of innovation technologies.

1. Introduction

Since construction serves as the core of any economy's development, it has become essential to comprehend the various technologies that might support such growth. However, according to [1] the building business has been viewed as archaic and dormant due to its lack of inventive ways to stay ahead of the competition. Although South Africa's economy was named the best in Africa, [2] said that the country's construction sector had adopted advanced technologies since winning the authorisation to hold the FIFA World Cup tournament in 2010. The South African economy also gained access to the global economy following the 2010 FIFA World Cup, which introduced novel innovations [3]. South Africa's construction industry showcased a commitment to utilising various modern tools to improve the building sector.

Modern machines are said to be exceptionally beneficial to many industries including the construction industry. One of the advanced technologies includes unmanned aerial vehicles (UAVs). Unmanned aerial vehicles

(UAVs) are devices that operate or look similar to an aircraft but differ because of less weight and can be operated without a specialised pilot, affirmed by [4]. An unmanned aerial system (UAS) is a system that consists of UAVs which are the most important part of the system, the ground control station, and the communication link [5]. Therefore, all these components of UAS work hand-in-hand, meaning they all depend on each other to successfully perform activities or tasks.

The use of UAVs, commonly referred to as drones, has significantly increased. According to [6], the terms drones and UAVs are used interchangeably. Additionally, [7] separated the use of UAVs in construction into four groups: surveying, safety and security monitoring, shooting images from UAVs, and site inspections from the developing site or viewed in the office.

It is claimed by [8], that the digital model which was used to organise the inspection tracking performance and authorisation for the building project provided access to the fundamental details. As a result, employing UAV applications has shown to be a simpler method of data or information storage than the traditional methods. The primary uses of UAVs by the construction business, are mostly for surveying the construction site and capturing high-definition (HD) images and videos for generating progress reports [9]. Consequently, the use of UAVs or drones has made it easier to monitor the site and survey the activities taking place in the building area. Despite UAVs utilisation getting extensively reported in the building sector internationally, in South Africa, very few investigations have been conducted to examine the advantages offered by UAVs in the building sector due to inadequate resources for conducting in the area. Furthermore, it has been determined that there are fewer UAV drivers and customers in the South African building sector, and this has impeded the industry's adoption of the latest technology.

The potential benefits of using unmanned aerial vehicles in the South African building sector were assessed in this study. additionally, by examining the advantages of implementing this modern technology, this study sought to bridge the gap within the construction sector and add to the current body of knowledge.

2. Literature Review

2.1 Overview of Construction Industry

One of the most important areas of the global economy is the building sector. Its drawbacks, nevertheless, include low output, schedule, expense overruns, and a lack of dialogue [10]. Every nation's and the world's economy is greatly influenced by the building sector. This is because the sector has produced jobs for several employees, it is imperative that it works effectively and improves the contribution it makes to the GDP. The building sector has grown increasingly complex in recent years due to the administrative and technical practices that have been introduced and it has negatively impacted infrastructure development because of the challenges within the management of construction [11]. There have been many innovative technologies in the last years that have been introduced in the building sector to minimize some challenges within the building sector. However, the implementation of these innovative technologies requires a change of conventional methods within the building sector. [17] addressed how the building sector's conventional methods are ineffective, time-consuming, and prone to mistakes, all of which could have a detrimental effect on the project's performance. Novel technology has been used in construction to enhance the industry, while some developing nations are lagging in implementing technological advances.

After the FIFA World Cup for the year 2010 is over, the South African building sector cannot be left behind [3]. It is commonly known that the South African construction industry has been growing, if slowly, following the end of the apartheid in 1994. However, it gained recognition both domestically and globally following the World Cup. Even after incorporating advanced technologies into its construction projects, the South African building sector continues to face difficulties despite being chosen to host the tournament. [12] spoke about how the same technology has been used in both large-scale (ZAR 1.5-3 billion) and small-scale (ZAR 1-2 billion) projects in the South African building sector. Additionally, the South African building sector has been recognised as one of the nations that lag in implementing advanced technologies, and it is necessary to enhance the value chain of their projects to generate a market for construction-related industries, according to [1]. It will take the combined efforts of the government, construction stakeholders, and other construction workers to adopt new technologies in the construction industry. Hence, this study adopted stakeholders and construction workers as respondents.

2.2 Origin of Unmanned Aerial Vehicles

In 425 BC, Archayta's pigeon was used to understand how birds operate, and it was the first unmanned aircraft to be recorded, affirmed by [13]. There was a big debate regarding the first implementation of the aircraft. [14]; [15] argued that the UAS originated in 1849 when the initial version had unmanned hot air balloons being used to drop bombs in a military war in a country called Italy, in the city of Venice. However, during the Italian War, it was so difficult to stop the war, hence unmanned hot air balloons were introduced to put an end to the war. In addition, [16] also mentioned that between the years 1998 and 1999, UAVs were being used to investigate the exploitation

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of combat aircraft and it allowed the spread use of UAVs. Moreover, in the 2000s the UAVs were upgraded with the 2.4GHz spread spectrum technology which allowed many industries such as manufacturing, mining, construction, etc. to use the UAVs [9].

2.3 Overview of Unmanned Aerial System

Unmanned aerial systems is a system that consists of different components including UAVs, a control ground station, and a communication link [5]. Furthermore, [8] further stated that the components of an unmanned aerial system other than the above-mentioned include air traffic control, recovery system, control remote, and communication links. All the mentioned components are essential because every part of the structure is essential, and cannot function without the other components.

2.4 Overview of Unmanned Aerial Vehicles

According to [17] - [18] UAVs are also known as less-weight tools that can be used to collect information fast and the information collected would be of good quality or reliable, and it can fly and land vertically. UAVs are lightweight equipment, can operate without the pilot in them, and can be used to collect the information fastest way possible, which is accurate and of good quality that can be used to prepare documentation. The unmanned aerial vehicles consist of the following components, namely: skeleton (main body of the uavs/ frame), battery, control board, wing(s), motor, motor drive, propeller, electronic and other various sensors, cameras, and communication electronics, affirmed by [19].

Unmanned Aerial Vehicles come in various varieties, namely: Rotary-wing]20], Blimps [14], Fixed-wing [22], Flapping-wing [4], and Vertical Take-Off and Landing [4]. Figure 1 shows components found in unmanned aerial vehicles. Moreover, [23] stated that different types of drones are classified by their measurements, mass, altitude, turbine forms, travel capacity, and distance.

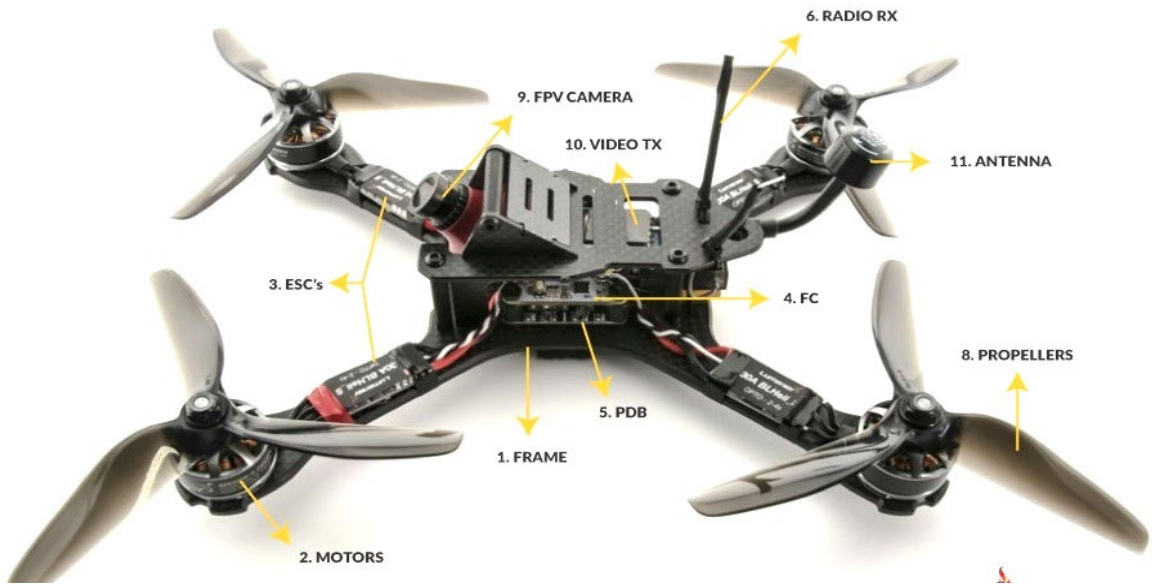

Fig. 1 *Components of unmanned aerial vehicles*

2.5 Benefits of Unmanned Aerial Vehicles

This study reviewed the benefits of implementing UAVs in building projects. [14] stated the market of UAV applications had been increasing fast and in a large number in different industries such as construction. Furthermore, there was a daily rise of UAV use in building activities because it was easy to use, very reliable, simple to access, low-cost, and able to adapt to different activities when merged with different sensors (red, green, blue) and infrared cameras [7]. Hence, it allows different organizations from small firms to large firms to adopt the UAV technology because of its cost and is simple to apply in construction projects. Moreover, construction stakeholders will be able to afford such technology because of its low cost and the benefits brought upon by the UAVs. In addition, [18] state that UAV applications are the quickest, safest, and not expensive way to obtain virtual data about occupying space regarding hazardous geographical locations. Consequently, these are further benefits

that will convince the construction stakeholders to adopt such technology given that its cost is very low and there are no or few risks involved in the implementation of this technology.

Many researchers have discussed that there is a range of benefits of implementing UAVs in the construction project, which include but are not limited to capturing high-quality images, prevention of accidents on construction sites, improved safety control, providing live information to the construction professionals, and reduction of cost and time overruns. Furthermore, [24], affirmed that other benefits of UAVs are the ability to access large structures or hard-to-reach places, places with high facilities, or places that are complex that human beings cannot access without risking their lives. It has been noticed that the application of UAVs in the construction project will assist consultant teams and contractors to enhance safety by being aware of the hazards on the construction sites [25]. Construction in other countries has used UAVs in the execution of construction projects and enjoyed its advantages, and other scholars show that the South African building sector has a comparatively low acceptance rate for UAVs. Other works in the South African building sector pointed up the advantages of UAVs in some study conclusions.

3. Research Methodological Framework

Innovative technologies were introduced to the construction business, which significantly affected how well construction workers performed. One of these technologies, UAVs, is crucial for evaluating the effects of technological advancement in the construction industry. Thus, the drive of this study is to add to the body of knowledge and emphasis the value of UAV technology in buildings. Data was collected from building experts using a questionnaire to emphasis the significance of this type of technology. In addition, the approach used for gathering data was quantitative. [25] referred to the quantitative approach as a method used by researchers to conduct research, by applying mathematical formulas or methods to analyse the data that have been gathered through questionnaires. In addition, [26] asserted that the quantitative approach contains the arithmetical and statistical approaches or methods to research design. Consequently, this methodology was preferred for the study

Convenience sampling, a non-probability sampling technique, was used in this investigation. Convenience sampling is defined as ‘‘a type of non-probability or non-random sampling where members of the target population meet certain practical criteria, such as easy accessibility, geographical proximity, availability at a given time, or willingness to participate in the study’’ [27]. This selection technique was implemented to involve building experts quickly. The two-section, closed-ended questionnaire was the tool utilised to gather information from the experts. The variables in the questionnaire were derived from the literature search on UAVs. The ‘‘background information’’ of the participants was included in the first portion of the questionnaire, while the ‘‘benefits of UAVs’’ were included in the second. The respondents were asked to describe their occupation, years of experience, greatest qualification, a project they are working on, and, finally, how many years they have worked with UAVs in the first section. The second part of the questionnaire employed a 5-point Likert scale with 1 denoting ‘‘extremely disagree’’, 2 ‘‘disagree’’, 3 ‘‘moderate’’, 4 ‘‘agree’’, and 5 ‘‘extremely agree’’ for analysing the benefits of using UAVs.

This research study had two sources of information, which were the questionnaire being the primary source of data and the literature review as the secondary source of information. The questionnaires were distributed to the targeted population which included architects, health and safety officers, civil engineers, electrical engineers, project managers, quantity surveyors, construction managers, and town and regional planners. The questionnaires were distributed to the construction professionals in the City of Johannesburg (Gauteng Province, South Africa) since it had many professionals undertaking the project and projects involving the applications of UAVs [28]. A total of hundred and fifty (150) questionnaires were circulated to construction professionals and only 93 of the questionnaires were responded to by the construction professionals. In addition, it represented 62% of the response rate. Google form was used to distribute the questionnaire that had been gathered for approximately one and a half months. Additionally, the statistics was computed using the Statistical Package for Social Sciences (SPSS v24) coupled with a Practical Component Analysis (PCA). The PCA displayed the correlation matrix, scree plot, variances, and rotated components. With regards to the limitation, the participants without experience in UAV might lack knowledge of the operation of the innovative technology, which it is believed might be biased as the response may be incomplete. As such, participants with no experience in the construction industry were excluded as they might have not been exposed to the application of UAVs in building developments.

4. Results and Discussion

The study’s findings and discussion were reported in this part. The first part of this section evaluates the ‘‘background of the respondents’’ and the final part assesses the advantages of UAVs in the context of construction.

4.1 Background of Respondents

This segment evaluated the respondents’ backgrounds. Results indicated that from the construction professions, highest qualifications, sector working in, the project involved in, and a project involving UAVs. The results revealed

out of 93 respondents about 21.50 percent were quantity surveyors, 19.40 percent were health and safety officers, 12.90 percent were civil engineers, 11.80 percent were project managers, town and urban planners 9.70 percent, electrical engineering, and architectures had 8.6 percent, and lastly, 7.50 percent were construction managers. The results indicated that the respondents had a minimum qualification of the technical certificate, which implied that the respondents would be able to undertake the questionnaire. Table 1. Revealed that 2 respondents held a technical certificate, fifteen (15) possessed a diploma, forty-four (44) a bachelor's degree, a master's degree nine (9) respondents, and lastly, a doctorate was only two (2) respondents. Moreover, results indicated that 38.7 percent of the respondents worked in the public sector, 40.9 percent of respondents employed in the private sector, and 20.4 percent worked in the private and public domains.

The survey conducted on the construction project revealed that 8 respondents had not participated in any construction projects. Additionally, 23 respondents had been involved in 1 to 2 projects, 37 respondents in 3 to 4 projects, 14 respondents in 5 to 6 projects, 6 respondents in 7 to 8 projects, and 5 respondents in more than 8 projects. Respondents were also asked to indicate the number of projects they had completed that included unmanned aerial vehicles (UAVs) to assess their familiarity with this technology. Table 1 shows that 33.3 percent of respondents had never been involved in a UAV project, while 22.6 percent had participated in 1 to 2 UAV projects, 31.2 percent in 3 to 4 UAV projects, 9.7 percent in 5 to 6 UAV projects, 2.2 percent in 7 to 8 UAV projects, and lastly, 1.1 percent had been involved in more than 8 UAV projects. The minority of participants 33.3% who have never been involved in UAVs projects might struggle to understand technical aspects. Their lack of hands-on experience could mean that these participants may be less capable of operating UAVs or understanding their functionality. It demonstrates that South Africa's construction sector's awareness and usage of UAVs is comparatively low. The group of 33.3% without experience might skew the outcomes or responses if the UAV-related tasks are critical to the study. They were offered tutorials on UAV technology to ensure that all participants had the same level of understanding. Providing additional resources or support for those who are less experienced, ensures that the lack of prior knowledge does not hinder their performance. The results on working experience indicated that 52 respondents had 1 -5 years of experience, 22 had 6 -10 years of experience, 10 had 11 - 15 years of experience, 6 had 16 -20 years of experience, and lastly, 3 had more than 20 years of experience.

Table 1 *Respondents background*

Respondents Background	
Highest Educational Qualification	*Frequency*
Technical certificate	2
Diploma	15
Bachelor's degree	44
Honour's degree	21
Master's degree	9
Doctorate	2
Projects involving UAVs	*Percentage*
None	33.3
1 – 2 projects	22.6
3 – 4 projects	31.2
5 – 6 projects	9.7
7 - 8 projects	2.2
More than 8 projects	1.1
Working Experience	*Frequency*
1 – 5 years	52
6 – 10 years	22
11 – 15 years	10
16 – 20 years	6
More than 20 years	3

4.2 Benefits of UAVs

Principal component analysis (PCA) was used in this study to evaluate the degree of unmanned aerial vehicles (UAVs) adoption. PCA is a statistical technique used to reduce data complexity while preserving the most significant variations in the information [29]. The adequacy of the gathered data was assessed using the Kaiser-Meyer-Olkin (KMO) test. With a KMO value between 0.8 and 0.1, acceptable sampling is indicated; middling sampling is suggested by values between 0.7 and 0.9; ordinary sampling is indicated by values between 0.6 and 0.69; and inadequate sampling is indicated by values below 0.6 [30]. According to Table 2, the KMO value for this investigation was 0.876, suggesting that the sampling was appropriate. After calculating the chi-square value using 66 degrees of freedom or more years of experience, the result was 445.350. The significant figure was less than 0.001, which, according to previous research by [30], indicates that a significance level below 0.005 shows that the analysis conducted on the collected data is valid and worthwhile.

Table 2 *KMO and Bartlett's test*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.876
Bartlett's Test of Sphericity:		
	Approx. Chi-Square	445.350
	Degree of Freedom	66
	Significant level	<0,001

Table 3. shows the Eigenvalues of the components, with the Eigenvalues of 5.364, 1.189, and 1.035 for each of the first three parts, in that order. The first component's percentage variance was 44.700, while the last component was 8.624, according to Table 3's second column. Lastly, Table 3's final column displays the commutative percentage of the variance of the three extracted components,

Table 3 *Eigenvalue of components*

Component	*Eigenvalue*	*Percentage variance*	*Cumulative percentage of variance*
1	5.364	44.700	44.700
2	1.189	9.912	54.612
3	1.035	8.624	63.236

Table 4. shows the rotating factors that were established from the Eigenvalue component table (Table 2). Since this study adopted the PCA, the principle of naming the extracted component was applied. The variables that were extracted for the first components included 'project assessment', 'reduce exposure to risks', 'reduce construction project delays', 'reduces construction project overruns', and 'lessen interference by owner(s)'. The variables in the first component were related to the benefits that organisations would adopt the UAVs for and minimise some of the challenges faced by different organisations. Consequently, this component was named 'Organisational-based benefits. Furthermore, four variables were extracted for the second component, which consisted of 'offers real-time information', 'enhance safety control', 'prevents accidents on-site', and 'promotes health and safety on-site'. The four variables were noticed to enhance the building site conditions, which led to the component being named 'Construction-site enhancement'.

Table 4 *Benefits of unmanned aerial vehicles*

Variables	Components		
	1	2	3
High-quality image capture			0.845
Enhances efficient project monitoring			0.775
Supports wireless communication on the project site			0.757
Offers real-time information		0.685	
Enhances safety control		0.760	
Prevents accidents on site		0.774	
Promotes health and safety on-site		0.690	
Provides effective project assessment	0.679		
Reduce exposure to risks	0.639		
Reduces construction project delays	0.657		
Reduces construction project cost overruns	0.797		
Lessen interference by owner(s)	0.610		
Extraction Method: Principal Component Analysis			
a. Rotation converged in 5 iterations.			

Lastly, on the third component, only three variables were extracted using the PCA. Three variables comprised of 'High-quality capture', 'enhance efficient project monitoring', and 'support wireless communication on the project site'. These variables were related to the characteristics of improvement of the advanced technology within the built environment. Hence, this component was named 'Project Technology Progress' due to the improvement brought about by technology in the execution of building activities. The results of all three components are similar to the study conducted by [9]; [13]; [20]; and [31] that revealed the improvement of the construction site that has caused growth in the adoption of the UAVs.

5. Conclusion

Innovative technologies have dominated the building sector and changed the procedures of executing construction projects. In addition, Unmanned Aerial Vehicles being one of the innovative technologies resulted in this study evaluating the benefits of this innovation used in the field of construction. The goal of the study was to explore the benefits of implementing UAVs in South Africa's built environment.

The study's conclusions demonstrated how important innovative equipment is to the building sector and how it has significantly improved the industry. Unmanned aerial vehicles adoption is therefore by improving the standards of project tracking and decreasing obstacles encountered during the development process. Nonetheless, the study also showed that construction experts had a comparatively low acceptance rate for this technology. Furthermore, the study's goal has been achieved based on its findings.

In the construction sector, the use of UAVs has opened up a gap of UAVs operators and analyst to fully utilise this innovative technology. Additionally, the UAVs technology produces a high volume of data which if it can be accurately analysed, will assist in making informed decisions and improve the parameters of the construction industry such as better planning, tracking of the progress, and diminishing cost and time of the construction project. This study recommends that the adoption of the Unmanned Aerial Vehicles technology is emphasized as there are many benefits that the built environment will achieve by the use of this technology in their building projects. Furthermore, this study recommends that there should be more awareness creation of this technology within the South African building sector and assist the local organisation in the adoption of this technology. The implementation strategies of UAVs in the South African construction industry require further investigation.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

Unarine Ronaldo Phuriwa contributed to ***draft preparation, conceptualization, methodology analysis, software analysis, validation, and manuscript editing****. Murendeni Liphadzi contributed to* ***conceptualization, manuscript editing, project administration, and visualization.*** *Olusegun Aanuoluwapo Oguntona contributed to* ***conceptualization, methodology analysis, and manuscript.*** *Clinton Aigbavboa contributed to* ***validation and project administration.***

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