Factors Influencing the Cost of Utilizing Unmanned Aerial Systems for Construction Monitoring

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ABSTRACT

Unmanned Aerial Systems (UAS) have emerged as a promising technology for construction monitoring due to their ability to collect data efficiently and provide valuable insights. However, the cost implications associated with the use of UAS in construction monitoring remain a significant concern. This research aims to investigate the factors that influence the cost of utilizing unmanned aerial systems for construction monitoring. By analyzing various cost-related factors such as equipment, training, data processing, and regulatory compliance, this study seeks to provide valuable insights into the financial considerations involved in adopting UAS technology for construction monitoring. The findings of this research can help project stakeholders make informed decisions and optimize cost-efficiency when implementing UAS in construction monitoring practices.

Keywords: Unmanned Aerial Systems, UAS, construction monitoring, cost factors, equipment costs, training expenses, data processing, regulatory compliance

BACKGROUND

Effective monitoring plays a vital role in ensuring the success and efficiency of construction projects. Unmanned Aerial Systems (UAS), commonly known as drones, have shown great potential in enhancing construction monitoring activities by providing aerial data collection, remote sensing capabilities, and real-time monitoring. However, the cost implications associated with UAS implementation are crucial factors to consider for construction stakeholders. This research aims to identify and examine the various factors that influence the cost of utilizing UAS technology for construction monitoring, enabling project managers and decision-makers to make informed choices regarding its adoption.

Factors Affecting the Adoption of UAS Technology for Project Monitoring in The Nigerian Construction Industry

The major barriers and various dimensions are thematically grouped into five categories: technical difficulties, restrictive regulatory environment, site-related problems, weather and organizational barriers.

a) The technical difficulty category deals with the shortcomings associated with the operating system of UASs, as well as the technical flaws UASs in performing specific tasks.

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b) Economic factors – Putting into consideration inflation rate, maintenance & replacement cost, operational cost, flight license, software maintenance cost etc.

c) A restrictive regulatory environment points to the regulations that restrict using and applying UASs for various tasks.

d) Site-related barriers present problems that are specific to the operation of UASs on construction sites, while weather category describes the weather conditions that affect or prevent the operation of UASs and Lastly,

e) Organizational barriers present difficulties that affect the adoption of UASs, stemming from business considerations within construction companies.

Technical-Based Challenges

The effectiveness of monitoring and evaluation of projects is hindered by various technical challenges, as highlighted in the literature. Bamberger, Rao, and Woolcock (2010) and Chaplowe (2008) point out that one of the key challenges is the limited demand for utilizing evaluation findings, which affects the implementation of monitoring and evaluation efforts. Furthermore, the diverse perspectives on monitoring and evaluation, shaped by the specific needs of project stakeholders and donors, have resulted in a lack of comparable definitions, as noted by Patton (2003), leading to different interpretations of effective monitoring and evaluation.

Auriacombe (2013) argues that attempts to classify evaluation methods were intended to simplify the wide range of available methods, but instead, they have contributed to confusion within the evaluation field. The challenge of establishing strong linkages between planning, monitoring, and evaluation is also highlighted by Seasons (2003), emphasizing the importance of integrating these processes seamlessly. Additionally, the weak legal and institutional frameworks surrounding monitoring and evaluation, as discussed by Basheka and Byamugisha (2015), cannot be underestimated as they pose further obstacles to effective implementation.

Overall, these technical challenges pose significant barriers to the proper functioning and utilization of monitoring and evaluation practices in projects. Addressing these challenges requires attention to the demand for evaluation, establishing clear and comparable definitions, clarifying the understanding of evaluation methods, strengthening the linkages between planning and evaluation, and enhancing the legal and institutional frameworks for monitoring and evaluation.

Economic Factors

According to Rahman et al. (2012), several factors contribute to the time and cost performance of construction projects. These factors include design and documentation issues, management of financial resources, project management and contract administration, site management by contractors, effective utilization of information and communication technology, availability of material and machinery resources, skilled labor force, and external influences.

Memon et al. (2010) identified twenty-four factors that influence effective cost control in construction projects. These factors encompass practices like assigning contracts to the lowest bidder, inadequate site management and supervision by contractors, cash flow and financial difficulties faced by contractors, inaccurate planning and scheduling, insufficient contractor experience, shortage of skilled workers, delays in material

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procurement, and the presence of an incompetent project team involving designers and contractors. Additional factors include fluctuating material prices, underestimation of project duration leading to schedule delays, material shortages, construction mistakes, poor communication among stakeholders, labor productivity issues, slow decision-making processes, changes in project scope, subpar technical performance, frequent design changes, delayed payments for completed work, unforeseen ground conditions, equipment availability and failure, necessary work variations, owner interference, and social and cultural impacts.

These factors collectively contribute to the challenges faced in controlling construction costs and project timelines. Addressing these issues requires a comprehensive approach that involves effective project management, improved communication, better planning and scheduling, proper resource allocation, competent site supervision, and proactive risk management.

RESTRICTIVE REGULATORY ENVIRONMENT

When construction costs spiral out of control, it creates added investment pressure, increases project expenses, and significantly impacts investment decision-making (Rahman et al., 2012). The reality is that most construction projects end up being completed at costs much higher than initially estimated, undermining the reliability of clients' initial cost estimates (Olawale & Sun, 2010). This issue of poor cost and time management, along with consequent cost and schedule overruns, is a significant problem in both developed and developing countries. It demands serious attention to improve construction cost and time performance, as projects rarely stay within budget and schedule. Given the widespread adoption of Unmanned Aircraft Systems (UASs) in the aviation industry, it is crucial to establish aviation traffic regulations to prevent in- flight collisions. Researchers such as Clothier et al. (2015) and Jordan (2015) have highlighted the significant risk of collisions between high-altitude flying RPAs (Remotely Piloted Aircraft) and manned aircraft, which could have catastrophic consequences for passenger safety. The Australian Transport Safety Bureau (ATSB) reported that 48 percent of UAS unsafe flight reports from January 2012 to June 2017 involved close encounters with manned aircraft, while 23 percent were collisions with terrain, and the remaining incidents were related to loss of control (ATSB, 2017). System failures and equipment problems have been identified as the main causes of UAS accidents (Wild et al., 2017), pointing to the lack of a proper collision avoidance system in commercial RPAs (Morgenthal and Hallermann, 2014).

Considering the paramount importance of public safety, UAS operations have been subjected to restrictive regulatory frameworks globally (Morgenthal and Hallermann, 2014; Blinn and Issa, 2016; Herrmann, 2016; Kacunic et al., 2016; Kim et al., 2016). In Australia, amendments to Part 101 of the Civil Aviation Safety Regulations 1998 were implemented on September 29, 2016, restricting commercial flights of UASs under 2 kg to licensed pilots. Operators within this category must notify the Civil Aviation Safety Authority (CASA) at least five working days before the first flight and adhere to standard operating conditions (CASA, 2018). However, these conditions are often too restrictive for typical construction activities, necessitating the employment of licensed operators on construction sites (Blinn and Issa, 2016). This introduces additional costs and concerns related to employing certified operators (Irizarry et al., 2012; Boudreau, 2016; Kim et al., 2016). Opfer and Shields (2014) suggest subcontracting UAS tasks to external firms specializing in RPAs, but this may limit the main contractor's flexibility in performing the tasks when required. Ownership, maintenance, and use of UASs in construction also raise legal liability issues for contractors, necessitating appropriate insurance coverage for risks associated with RPA operations (Herrmann, 2016). However, it is important to note that insurance may not fully cover all damages incurred, and determining liability for UAS flights can be challenging due to pilot anonymity concerns (Boudreau, 2016; Lidynia et al., 2017). Furthermore, the use of UASs for commercial purposes is still relatively new, and many people are unfamiliar with the technology and safety issues associated with it (Clothier et al., 2015). While regulations restrict flying UASs in populated areas, public concerns persist, emphasizing the need for well-established emergency plans and effective communication protocols to address these apprehensions (Kim et al., 2016; Anastasios et al., 2018).

Project-Based Challenges

The effective implementation of monitoring and evaluation (M&E) at the project level relies on the careful planning of M&E activities at the management level. However, limited financial resources at the project level often hinder the M&E process (Badom, L.N., 2016). The methods employed for collecting project information for decision-making purposes often result in poor data quality, which is inadequate for management to base future project decisions on (Tengan, C. et al., 2016). Stockman (2011) recognizes the challenges associated with collecting and analyzing M&E data and emphasizes the importance of generating relevant information through effective data collection and analysis to facilitate sound management judgments in M&E activities for the project.

Communication plays a crucial role in the M&E of projects. According to Diallo, A. and Thuillier, D. (2005), project success is closely linked to effective communication among key stakeholders. However, poor communication is further compounded by insufficient information on project design and the inconsistency of project information, including drawings, specifications, and bill of quantities, which are essential for M&E purposes. This lack of consistent and comprehensive project information poses challenges to effective communication and M&E (Stockman, 2011).

Organizational Level Challenges

The nature and operation of organizations present various challenges to effective monitoring and evaluation (M&E) practices. One major challenge, as discussed by Cameron (1993), is the absence of dedicated M&E units within organizations. Without an M&E unit, the planning and implementation of M&E for projects become ineffective. Strengthening the planning and implementation of M&E is crucial for efficient project delivery (Tengan, C., Aigbavboa, C., 2016).

Weak institutional capacity also significantly influences M&E performance. Tengan, C. and Aigbavboa, C. (2016) found that a lack of technical capacity, skills, and knowledge among M&E staff in the Ghanaian construction industry led to project failures. Continuous training is essential to equip the M&E team and staff with the necessary skills and knowledge for effective M&E.

Furthermore, the integration of monitoring and evaluation plans or systems during planning, budgeting, and infrastructure development is often lacking, as highlighted by Badom (2016). This lack of integration hampers the measurement of progress and impact, making it difficult to hold projects accountable for their performance. Additionally, power struggles between M&E unit staff and the general organizational structure pose challenges in project monitoring and evaluation (Muriithi, N., Crawford, L., 2003).

Another significant challenge is the underutilization of M&E information and reports for decision-making and organizational learning. In the Ghanaian construction industry, Tengan, C. et al. (2016) found that M&E information and reports are poorly utilized in the organizational planning process and the implementation of future projects. In the context of the UK, the adoption of building information modeling (BIM) technology faces challenges such as a lack of investment and low demand from clients (Kim, K.P., Park, B.L., 2013). These challenges hinder the effective implementation and utilization of BIM technology in the construction industry.

Overall, addressing these challenges requires the establishment of dedicated M&E units, enhancing institutional capacity, promoting continuous training, integrating M&E into planning processes, addressing power dynamics, and improving the utilization of M&E information for decision-making and learning.

Risks Associated with Construction Project Monitoring

Construction accidents have been extensively studied by numerous authors, who have identified various factors contributing to these incidents. In terms of safety plan management, Aksorn and Hadikusumo (2008) have highlighted four dimensions that should be considered: worker involvement, safety prevention and control system, safety arrangement, and management commitment. Bavafa et al. (2018) further emphasized the critical elements in safety programs, including the safety responsibilities of each worker, personnel selection and subcontracts, employee involvement, and safety evaluation. Therefore, organizational management is recognized as a crucial factor in safety management (Li et al., 2018), allowing for better understanding of the company's dynamics and projects and promoting a safety- oriented organizational culture (Asilian-Mahabadi et al., 2018). By implementing efficient information and material management practices, along with the use of technological tools, it is possible to develop a resilient safety culture and reduce accidents in construction projects (Feng and Trinh, 2019).

Several authors have conducted studies in different countries, identifying factors that affect construction safety. Winge et al. (2019) focused on Norway, Memon et al. (2017) and Choi (2020) on Mongolia, Yap and Lee (2019) on Malaysia, Al- Aubaidy et al. (2019) on the United States, and Chen et al. (2020) on Taiwan. These studies have identified factors associated with the worker and the work team, including the company's internal organization and management, safety regulations, workplace conditions, supervisory aspects, worker training, and individual responsibilities.

In addition to the factors mentioned above, there are several risks associated with the implementation of construction works, which include:

Risk of protests from ecologists or the local population

Risk of poorly recognized soil structure, such as quicksand

Risk of a poorly planned work schedule

Risk of equipment failure

Risk of employees' absence due to illness or strikes

Risk of inadequate employee qualifications and performance

Risk of poor management of material resources, supplies, and personnel

Risk of delays in the timely supply of construction materials

Risk of poor quality construction materials

Risk of failing to maintain standards

Risk of insufficient control measures

Risk of expanding the scope of work beyond the original plan

Risk of poor work organization.

Understanding and effectively addressing these risks are crucial for ensuring the successful and safe implementation of construction projects. By proactively managing these risks, organizations can mitigate potential accidents and create a safer working environment.

CONSTRUCTION SITE ACCIDENTS

Every year, the construction sector witnesses a staggering number of fatal accidents worldwide, with approximately 60,000 reported cases. Shockingly, this means that a worker loses their life due to an occupational accident every 10 minutes. The inherent nature of the construction industry, characterized by labor-intensive processes and high risks, contributes to this alarming statistic. Occupational accidents not only lead to human tragedies but also result in significant financial losses for the sector on a large scale. Moreover, these accidents have far-reaching implications for enterprise sustainability, considering the associated costs and environmental impacts they bring. Industrial accidents, particularly those of a substantial magnitude, pose significant risks not only to public health but also to the environment (Takala, 1999; International Labour Office, 2004; Rubio, Martinez, Rubio & Ordoñez, 2008).

The construction industry relies on a diverse range of manufactured components, in addition to basic construction materials, throughout its operations. Managing production within construction sites involves a substantial workforce exposed to challenging working conditions, hazardous materials, and machinery. The production process in construction entails various occupational accident risks, including falls from heights, equipment and machinery-related incidents, crane accidents, electric shocks, explosions, and fires. Additionally, the welding process exposes workers to hazards such as burrs, toxic fumes, and clouds of dust, leading to injuries or accidents that result in lost working days (International Labour Office, 1992; Sorock, Smith & Goldoft, 1993; Ikpe, Felix & David, 2012).

The construction industry must address these occupational risks comprehensively to prioritize worker safety and minimize the occurrence of accidents. By implementing effective safety measures and providing appropriate training, organizations can work towards creating a safer working environment and reducing the devastating impact of accidents in the construction sector.

To address the research gaps and achieve a comprehensive understanding of the topic, this study aims to accomplish the following objectives:

Research Objectives:

To identify the cost-related factors involved in utilizing unmanned aerial systems for construction monitoring.

To investigate the cost implications of data processing, storage, and management in the context of UAS-based construction monitoring.

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To assess the influence of regulatory compliance and licensing requirements on the overall cost of UAS utilization in construction monitoring.

Hypotheses:

H_O1: The cost of using unmanned aerial system (UAS) in construction monitoring is influenced by various factors.

METHODOLOGY

This research employed a combination of quantitative and qualitative methods to investigate the factors affecting the cost of utilizing unmanned aerial systems for construction monitoring. Quantitative data were collected through surveys distributed to construction professionals. The survey covered aspects such as equipment costs, training expenses, data processing costs, and regulatory compliance. Additionally, qualitative data was obtained through interviews and case studies to gain a deeper understanding of the financial considerations associated with UAS implementation.

Research Design

For this study, a quantitative research approach was adopted, utilizing the survey research method. The chosen method of data collection was a questionnaire, specifically designed to employ the survey research method. The questionnaire consisted of Likert Scale questions, which aligns with Baridam's (1995) observation that Likert Scale questions are easily comprehensible and facilitate the drawing of conclusions, generating reports, results, and graphs from the collected quantitative data.

Study Population

The study's target population will consist of registered Architects, Quantity Surveyors, Project Managers, Land Surveyors, Civil and Structural Engineers, Mechanical and Electrical Engineers, and Builders in South-Eastern Nigeria. These professionals have significant involvement and responsibilities in Project Monitoring, making them the primary participants. Other construction professionals will be excluded from the study as they do not typically play a coordinating role in the development of information models in Construction Projects. Table 3 provides a breakdown of the population as follows:

Table 3: Registered Member of Construction professionals in South-East

S/N	Professionals	Population	Registration Bodies
1	Architects	604	Architects Registration Council of Nigeria (AFCON)
2	Builders	410	Council of Registered Builders of Nigeria (CORBON)
3	Quantity Surveyors	764	Quantity Surveying Registration Board of Nigeria (QSRBN)
4	Project Managers	255	Chartered Institute Of Project Managers Of Nigeria (CIPMN)

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5	Civil and Structural Engineers	613	Council for the Regulation of Engineering in Nigeria (COREN)
6	Mechanical/Electrical Engineers	1477	Council for the Regulation of Engineering in Nigeria (COREN)
7	Land Surveyors	738	Estate Surveyors and Valuers Registration Board of Nigeria (ESVARBON)
TOTAL		5117	

The above figures was generated from the list of licensed registered members as of 2022 operating in the (5) south-Eastman states of Nigeria namely Abia, Anambra, Enugu, Ebonyi and Imo State.

Sampling Size

The Taro Yamane formula will be used to determine the sample size for the study. $n= N/ 1 + N(e)^2$

Where: n = Sample size

N = Population size (5117)

e = Level of precision or error margin (set at 5%) 1 = Constant

$n = \frac{5117}{1 + 5117 (0.05)^2}$

$n = 371$

Adding 10% attrition will bring the sample size to 408.

Sample Technique

The study employed the random sampling technique, specifically Stratified Random Sampling, to select samples based on the availability and willingness of individuals to participate in the study. The sample size will be determined using proportionate allocation, ensuring an appropriate representation from each stratum. The distribution of participants is as follows:

Table 4: Sample Size Allocation

S/N	Professional Bodies	population	Sample size Allocation
1	Architects	604	51
2	Builders	410	34
3	Quantity Surveyors	764	64

4	Civil and Structural Engineers	255	21
5	Project Managers	613	51
6	Mechanical/Electrical Engineers	1477	125
7	Land Surveyors	738	62
TOTAL		5117	408

Table 5: Stratified Random Sampling allocation by States

S/N	Professional Bodies	Abia	Anambra	Enugu	Ebonyi	Imo	Total
1	Architects	10	10	11	10	10	51
2	Builders	7	7	7	6	7	34
3	Quantity Surveyors	13	13	13	12	13	64
4	Civil and Structural Engineers	4	4	5	4	4	21
5	Project Managers	10	10	11	10	10	51
6	Mechanical/Electrical Engineers	25	25	25	25	25	125
7	Land Surveyors	12	12	13	12	13	62
TOTAL		81	81	85	79	82	408

Administration Of Questionnaire.

To ensure data reliability and acceptance, a total of 408 prepared questionnaires were randomly distributed among construction professionals and experts, aiming to obtain a sample that accurately represents the population. The questionnaires were formulated in a clear and concise manner to enhance clarity, based on the identified research questions. Multiple-choice formats were used to provide alternative sets of answers that best represent the actual perceptions and on-the-ground situations. These alternative answers were presented using a Likert scale consisting of five grade points (1-5), as shown below:

Table 6: Likert five grade scales

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Views	Grade points
Strongly disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly agree	5

However, the questionnaires will be personally delivered by hand to various selected respondents, while some will be sent via electronic mail and Google questionnaire to reach relevant respondents not within proximity.

Inferential Statistics

For hypothesis testing, inferential statistics were employed, specifically Factor Analysis (PCA).

DATA AND FINDINGS

Table 1.8 outlines the factors that influence the cost of utilizing unmanned aerial systems (UAS) in construction project monitoring.

Table 1: Factors affecting the cost of using UAS in construction projects monitoring.

s/n		Very low n (%)	Low n (%)	Moderate n (%)	High n (%)	Very high n (%)	Mean ± SD
1	Large volume of the generated data generated from UAS	40 (10.1)	92 (23.3)	4 (1.0)	213 (53.9)	46 (11.6)	3.34 ± 1.24
2	Lack of efficient GPS signals	24 (6.1)	157 (39.7)	16 (4.1)	133 (33.7)	65 (16.5)	3.15 ± 1.27
3	UAS Flight paths	12 (3.0)	116 (29.4)	12 (3.0)	210 (53.2)	45 (11.4)	3.41 ± 1.11
4	Communication with human objects	45 (11.4)	132 (33.4)	0 (0.0)	186 (47.1)	32 (8.1)	3.07 ± 1.23
5	Flight duration	24 (6.1)	149 (37.7)	8 (2.0)	178 (45.1)	36 (9.1)	3.13 ± 1.19
6	Amount of payload	17 (4.3)	153 (38.7)	8 (2.0)	165 (41.8)	52 (13.2)	3.21 ± 1.21

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7	Resolution of the captured images	24 (6.1)	129 (32.7)	8 (2.0)	185 (46.8)	49 (12.4)	3.27 ± 1.21
8	Positioning system	28 (7.1)	153 (38.7)	8 (2.0)	165 (41.8)	41 (10.4)	3.10 ± 1.22
9	Lack of user-friendliness	44 (11.1)	150 (38.0)	16 (4.1)	137 (34.7)	48 (12.2)	2.99 ± 1.29
10	Lack of professional understanding of technologies	32 (8.1)	109 (27.6)	5 (1.3)	149 (37.7)	100 (25.3)	3.45 ± 1.34
11	Lack of accessible technologies and know-how	16 (4.1)	110 (27.8)	0 (0.0)	181 (45.8)	88 (22.3)	3.54 ± 1.22
12	Poor planning	32 (8.1)	147 (37.2)	12 (3.0)	176 (44.6)	28 (7.1)	3.05 ± 1.19
13	Operational inefficiency and component failure	45 (11.4)	104 (26.3)	0 (0.0)	202 (51.1)	44 (11.1)	3.24 ± 1.27
14	Lack of research	46 (11.6)	112 (28.4)	16 (4.1)	165 (41.8)	56 (14.2)	3.18 ± 1.31
15	Scarcity of local competencies	16 (4.1)	64 (16.2)	8 (2.0)	197 (49.9)	110 (27.8)	3.81 ± 1.13
16	Construction monitoring period	37 (9.4)	162 (41.0)	16 (4.1)	164 (41.5)	16 (4.1)	2.90 ± 1.16
17	Durability and adaptability of technologies	28 (7.1)	137 (34.7)	0 (0.0)	169 (42.8)	61 (15.4)	3.25 ± 1.27
18	Technological gap and operational challenges	16 (4.1)	85 (21.5)	4 (1.0)	206 (52.2)	84 (21.3)	3.65 ± 1.15
19	Lack of affordability	21 (5.3)	77 (19.5)	4 (1.0)	160 (40.5)	133 (33.7)	3.78 ± 1.25
20	Cost of Purchase	8 (2.0)	24 (6.1)	8 (2.0)	180 (45.6)	175 (44.3)	4.24 ± 0.91
21	Cost of maintenance & replacement	4 (1.0)	69 (17.5)	0 (0.0)	217 (54.9)	105 (26.6)	3.89 ± 1.02
22	Presumed cost ease of the traditional systems	12 (3.0)	125 (31.6)	8 (2.0)	210 (53.2)	40 (10.1)	3.36 ± 1.12

23	Cost of operator training	16 (4.1)	92 (23.3)	8 (2.0)	246 (62.3)	33 (8.4)	3.48 ± 1.06
24	Cost of flight license	24 (6.1)	121 (30.6)	4 (1.0)	193 (48.9)	53 (13.4)	3.33 ± 1.21
25	Software license	32 (8.1)	97 (24.6)	8 (2.0)	192 (48.6)	66 (16.7)	3.41 ± 1.25
26	Cost of monitoring report collaboration	8 (2.0)	117 (29.6)	8 (2.0)	246 (62.3)	16 (4.1)	3.37 ± 1.01
27	Cost of programs interoperability	17 (4.3)	106 (26.8)	16 (4.1)	232 (58.7)	24 (6.1)	3.35 ± 1.07
28	Insurance	32 (8.1)	130 (32.9)	16 (4.1)	177 (44.8)	40 (10.1)	3.16 ± 1.22
29	Restrictive national regulations	40 (10.1)	152 (38.5)	8 (2.0)	167 (42.3)	28 (7.1)	2.98 ± 1.23
30	Certifications for pilot and flight	40 (10.1)	128 (32.4)	17 (4.3)	153 (38.7)	57 (14.4)	3.15 ± 1.29
31	Insurance issues	24 (6.1)	126 (31.9)	12 (3.0)	209 (52.9)	24 (6.1)	3.21 ± 1.14
32	Privacy issues	24 (6.1)	142 (35.9)	16 (4.1)	197 (49.9)	16 (4.1)	3.10 ± 1.12
33	Public safety	57 (14.4)	136 (34.4)	28 (7.1)	126 (31.9)	48 (12.2)	2.93 ± 1.31
34	Accidents	97 (24.6)	152 (38.5)	8 (2.0)	101 (25.6)	37 (9.4)	2.52 ± 1.29
35	Interferences with project activities	93 (23.5)	162 (41.0)	8 (2.0)	104 (26.3)	28 (7.1)	2.52 ± 1.29
36	Obstacles on construction sites	85 (21.5)	178 (45.1)	8 (2.0)	100 (25.3)	24 (6.1)	2.49 ± 1.25
37	Sensitive to weather	41 (10.4)	133 (33.7)	4 (1.0)	168 (42.5)	49 (12.4)	3.13 ± 1.29
38	Acquisition, setup, operating, and maintenance costs	8 (2.0)	80 (20.3)	4 (1.0)	190 (48.1)	113 (28.6)	3.81 ± 1.12
39	Management and owner support	28 (7.1)	162 (41.0)	4 (1.0)	177 (44.8)	24 (6.1)	3.02 ± 1.18

Table 8 shows that the technical factors affecting the cost of UAV in construction project monitoring to a high

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extent includes: Large volume of the generated data generated from UAS (3.34 ± 1.24), Lack of efficient GPS signals (3.41 ± 1.11), UAS Flight paths (3.41 ± 1.11), Communication with human objects (3.07 ± 1.23), Flight duration (3.13 ± 1.19), Amount of payload (3.21 ± 1.21), Resolution of the captured images (3.27 ± 1.21), Positioning system (3.10 ± 1.22), Lack of professional understanding of technologies (3.45 ± 1.34), Lack of accessible technologies and know-how (3.54 ± 1.22), Poor planning (3.05 ± 1.19), Operational inefficiency and component failure (3.24 ± 1.27), Lack of research (3.18 ± 1.31), Scarcity of local competencies (3.81 ± 1.13), Durability and adaptability of technologies (3.25 ± 1.27), Technological gap and operational challenges (3.65 ± 1.15) and Lack of affordability (3.78 ± 1.25). These were indicated by mean response values greater than the criterion mean of 3.

The economic factors affecting the cost of UAV in construction project monitoring to a very high extent includes: Cost of Purchase (4.24 ± 0.91), Cost of maintenance & replacement (3.89 ± 1.02), Presumed cost ease of the traditional systems (3.36 ±1.12), Cost of operator training (3.48 ± 1.06), Cost of flight license (3.33 ± 1.21),

Software license (3.41 ± 1.25), Cost of monitoring report collaboration (3.37 ± 1.01), Cost of programs interoperability (3.35 ± 1.07) and Insurance (3.16 ± 1.22).

The regulatory factors affecting the cost of UAV in construction project monitoring to a high extent includes: Certifications for pilot and flight (3.15 ± 1.29), Insurance issues (3.21 ± 1.14) and Privacy issues (3.10 ± 1.12).

Other organizational factors include Acquisition, setup, operating, and maintenance costs (3.81 ± 1.12) and Management and owner support (3.02 ± 1.18).

Hypothesis Testing

H_O1: The cost of using unmanned aerial system (UAS) in construction monitoring is influenced by various factors.

Table 4.6: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.768
Bartlett's Test of Sphericity	Approx. Chi-Square	6847.447
	df	741
	Sig.	.000

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is a statistic that indicates the proportion of variance in the variables that might be caused by underlying factors. A value of 0.768 generally indicates that a factor analysis is appropriate for the data. Bartlett's test of sphericity indicates that the correlation matrix is not an identity matrix ($P < 0.001$), which means that the variables are related and therefore suitable for structure detection.

Table 4.7: Communalities for hypothesis one

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Large volume of the generated data generated from UAS	1.000	.670
Lack of efficient GPS signals	1.000	.699
UAS Flight paths	1.000	.622
Communication with human objects	1.000	.652
Flight duration	1.000	.799
Amount of payload	1.000	.729
Resolution of the captured images	1.000	.766
Positioning system	1.000	.653
Lack of user-friendliness	1.000	.739
Lack of professional understanding of technologies	1.000	.727
Lack of accessible technologies and know-how	1.000	.686
Poor planning	1.000	.689
Operational inefficiency and component failure	1.000	.739
Lack of research	1.000	.711
Scarcity of local competencies	1.000	.707
Construction monitoring period	1.000	.718
Durability and adaptability of technologies	1.000	.637
Technological gap and operational challenges	1.000	.643
Lack of affordability	1.000	.651
Cost of Purchase	1.000	.775
Cost of maintenance & replacement	1.000	.741
Presumed cost ease of the traditional systems	1.000	.766
Cost of operator's training	1.000	.710
Cost of flight license	1.000	.788

Software license	1.000	.702
Cost of monitoring report collaboration	1.000	.722
Cost of programs inter-operability	1.000	.791
Insurance	1.000	.727
Restrictive national regulations	1.000	.621
Certifications for pilot and flight	1.000	.573
Insurance issues	1.000	.567
Privacy issues	1.000	.713
Public safety	1.000	.660
Accidents	1.000	.587
Interference with project activities	1.000	.674
Obstacles on construction sites	1.000	.757
Sensitive to weather	1.000	.801
Acquisition, setup, operating, and maintenance costs	1.000	.665
Management and owner support	1.000	.663

Extraction Method: Principal Component Analysis.

Communalities indicate the amount of variance in each variable that is accounted for. Initial communalities are estimates of the variance in each variable accounted for by all components or factors. For principal components extraction, this is always equal to 1.0 for correlation analyses. Extraction communalities are estimates of the variance in each variable accounted for by the components. The communalities in this table are all high (greater than 0.5), which indicates that the extracted components represent the variables well.

Table 4.8: Total Variance Explained for hypothesis one

Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	% of Variance	Cumulative	Total	% of Variance	Cumulative	Total	% of Variance	Cumulative

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Component Total			%			%			%
1	5.532	14.186	14.186	5.532	14.186	14.186	3.768	9.661	9.661
2	3.556	9.117	23.303	3.556	9.117	23.303	2.791	7.157	16.817
3	3.110	7.975	31.279	3.110	7.975	31.279	2.328	5.970	22.787
4	2.494	6.395	37.674	2.494	6.395	37.674	2.157	5.531	28.318
5	1.909	4.896	42.569	1.909	4.896	42.569	2.134	5.471	33.790
6	1.755	4.501	47.070	1.755	4.501	47.070	2.039	5.229	39.019
7	1.510	3.873	50.943	1.510	3.873	50.943	1.975	5.064	44.082
8	1.450	3.719	54.662	1.450	3.719	54.662	1.893	4.854	48.936
9	1.336	3.425	58.087	1.336	3.425	58.087	1.803	4.624	53.560
10	1.211	3.105	61.192	1.211	3.105	61.192	1.775	4.552	58.112
11	1.180	3.026	64.218	1.180	3.026	64.218	1.541	3.952	62.063
12	1.142	2.927	67.145	1.142	2.927	67.145	1.534	3.933	65.996
13	1.053	2.699	69.844	1.053	2.699	69.844	1.500	3.847	69.844
14	.983	2.521	72.365						
15	.874	2.240	74.605						
16	.846	2.168	76.773						
17	.795	2.040	78.813						
18	.773	1.982	80.794						
19	.716	1.836	82.631						
20	.680	1.742	84.373						
21	.589	1.511	85.884						
22	.559	1.435	87.319						
23	.535	1.373	88.692						

24	.511	1.309	90.001						
25	.478	1.226	91.227						
26	.456	1.170	92.397						
27	.381	.977	93.374						
28	.360	.923	94.296						
29	.333	.853	95.149						
30	.306	.784	95.933						
31	.264	.677	96.611						
32	.248	.635	97.246						
33	.212	.545	97.791						
34	.191	.491	98.282						
35	.182	.466	98.748						
36	.162	.415	99.163						
37	.128	.328	99.491						
38	.106	.271	99.762						
39	.093	.238	100.000						

Extraction Method: Principal Component Analysis.

The Total column gives the eigenvalue, or amount of variance in the original variables accounted for by each component. The % of Variance column gives the ratio, expressed as a percentage, of the variance accounted for by each component to the total variance in all of the variables. The first factor explains larger amount of variance whereas the rest of the factors explain smaller amounts of variance. According to Kaiser's criterion, retain all factors with eigenvalues above 1 and 0.6 average communality. Therefore, all factors with eigenvalues greater than 1 were retained. The eigenvalues associated with these factors are again displayed and the percentage of variance explained in the columns labeled Extraction Sums of Squared Loadings. The cumulative percentage for the 13 components extracted is 70%. They explain 70% of the variability in the original 39 variables, so we can considerably reduce the complexity of the data set by using these components, with only a 30% loss of information. In the final part of the table (labeled Rotation Sums of Squared Loadings), the eigenvalues of the factors after rotation are displayed. Rotation has the effect of optimizing the factor structure; however, some changes occurred after the rotation. The rotation maintains the cumulative percentage of variation explained by the extracted components, but that variation is now spread more evenly

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over the components. The changes in the individual totals suggest that the rotated component matrix will be easier to interpret than the unrotated matrix.

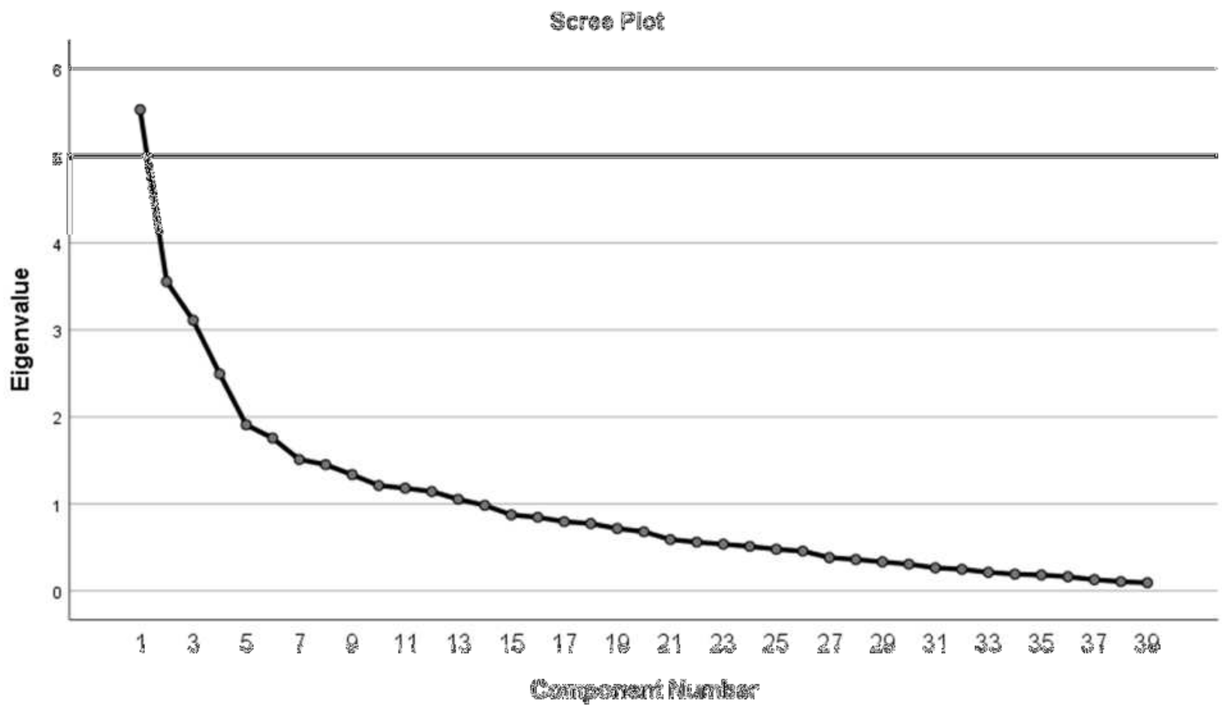

Figure 4.4: Scree plot for hypothesis one

The scree plot helps to determine the optimal number of components. The eigenvalue of each component in the initial solution is plotted. Generally, the first thirteen (13) components on the steep slope were extracted. The components on the shallow slope contribute little to the solution.

Table 4.9: Rotated Component Matrix[a] for hypothesis one Component

1		2	3	4	5	6	7	8	9	10	11	12	13
Poor planning	.749												
Lack of accessible technologies and know-how	.724												
Lack of research	.705												
Lack of professional understanding of technologies	.697												

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Operational inefficiency and component failure	.638												
Technological gap and operational challenges	.618												
Cost of Purchase		.853											
Cost of maintenance & replacement		.721											
Acquisition, setup, operating, and maintenance costs		.598											
Lack of affordability		.548											
Cost of operator's training		.525											
Scarcity of local competencies													
Restrictive national regulations			.764										
Certifications for pilot and flight			.616										
Insurance issues			.568										
Insurance			.513										
Interference with project activities				.752									
Accidents				.600									
Amount of payload					.760								
Flight duration					.738								

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Privacy issues					.644								
Resolution of the captured images						.820							
Positioning system						.602							
Cost of programs inter-operability													
Software license							.756						
Cost of monitoring report collaboration							.699						
Cost of flight license							.543						
Construction monitoring period								.728					
Durability and adaptability of technologies								.574					
Sensitive to weather									.816				
Obstacles on construction sites									.563				
Management and owner support													
UAS Flight paths													
Communication with human objects										.762			
Lack of efficient GPS signals										.752			
Presumed cost ease of the traditional systems											.832		

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Public safety													
Large volume of the generated data generated from UAS												.750	
Lack of user-friendliness													.502

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 22 iterations.

Finally, the rotated component matrix (also called the rotated factor matrix in factor analysis) which is a matrix of the factor loadings for each variable onto each factor shows factor loadings greater than 0.5 and sorted by order of size. The result reveals thirteen factors (components). The variables that loaded highly are factor; 1. Operational challenges, 2. UAS costs, 3. Regulatory factors, 4. Risk/accident factors, 5. Operational factor, 6. Technological gaps, 7. Licensing, 8. Adaptability, 9. Environmental factors, 10. Internet and connectivity factor, 11. Conventional factors, 12. Big data and 13. User-friendliness.

Decision rule:

The null hypothesis is hereby accepted and the alternative rejected. Therefore, cost of using unmanned aerial system (UAS) in construction monitoring is influenced by various factors.

FINDINGS

The research findings reveal the significant technical, economic, regulatory, and organizational factors that affect the cost of utilizing Unmanned Aerial Systems (UAS) in construction project monitoring. The study collected data from complex construction projects in South-East Nigeria and analyzed the mean response values, which were compared to a criterion mean of 3 to determine the extent of impact.

Technical Factors: The technical factors were found to have a high extent of influence on the cost of UAS in construction project monitoring. These factors include:

1. Large volume of generated data from UAS (3.34 ± 1.24)
2. Lack of efficient GPS signals (3.41 ± 1.11)
3. UAS flight paths (3.41 ± 1.11)
4. Communication with human objects (3.07 ± 1.23)
5. Flight duration (3.13 ± 1.19)
6. Amount of payload (3.21 ± 1.21)
7. Resolution of captured images (3.27 ± 1.21)

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8. Positioning system (3.10 ± 1.22)
9. Lack of professional understanding of technologies (3.45 ± 1.34)
10. Lack of accessible technologies and know-how (3.54 ± 1.22)
11. Poor planning (3.05 ± 1.19)
12. Operational inefficiency and component failure (3.24 ± 1.27)
13. Lack of research (3.18 ± 1.31)
14. Scarcity of local competencies (3.81 ± 1.13)
15. Durability and adaptability of technologies (3.25 ± 1.27)
16. Technological gap and operational challenges (3.65 ± 1.15)
17. Lack of affordability (3.78 ± 1.25)

Economic Factors: The economic factors were found to have a very high extent of influence on the cost of UAS in construction project monitoring. These factors include:

1. Cost of purchase (4.24 ± 0.91)
2. Cost of maintenance and replacement (3.89 ± 1.02)
3. Presumed cost ease of traditional systems (3.36 ± 1.12)
4. Cost of operator training (3.48 ± 1.06)
5. Cost of flight license (3.33 ± 1.21)
6. Software license (3.41 ± 1.25)
7. Cost of monitoring report collaboration (3.37 ± 1.01)
8. Cost of programs interoperability (3.35 ± 1.07) 9. Insurance (3.16 ± 1.22)

Regulatory Factors: The regulatory factors were found to have a high extent of influence on the cost of UAS in construction project monitoring. These factors include:

1. Certifications for pilot and flight (3.15 ± 1.29)
2. Insurance issues (3.21 ± 1.14)

3. Privacy issues (3.10 ± 1.12)

Organizational Factors: Other organizational factors that affect the cost of UAS in construction project monitoring include:

1. Acquisition, setup, operating, and maintenance costs (3.81 ± 1.12)

2. Management and owner support (3.02 ± 1.18)

These findings highlight the multifaceted nature of cost considerations when implementing UAS for construction project monitoring in South-East Nigeria. Understanding and addressing these factors are crucial for effective planning, decision-making, and successful integration of UAS technology in complex construction projects.

CONCLUSIONS

In conclusion, the research also suggests potential for growth and expansion in the use of UAVs within the construction industry. As professionals become more familiar with the benefits and capabilities of UAV technology, there is an opportunity for increased adoption and integration of UAVs into construction projects. The findings highlight the need for further education and awareness campaigns to promote the benefits of UAV technology in construction and address professionals' concerns regarding regulatory compliance, data management, and training requirements.

Furthermore, the research findings emphasize the complex nature of cost considerations when adopting UAVs for construction project monitoring. Technical, economic, regulatory, and organizational factors were identified as influential aspects affecting the cost of UAV implementation. Understanding and addressing these factors are essential for effective planning, informed decision-making, and successful integration of UAV technology in construction projects.

Additionally, the research findings reveal the limitations of UAV technology in directly mitigating risks and accidents in construction project monitoring. While UAVs can provide valuable data and insights, additional measures and safety protocols are necessary to effectively manage and mitigate specific risks. It is crucial for construction stakeholders to implement comprehensive safety strategies that combine UAV technology with other risk management practices to ensure worker safety and mitigate potential accidents and hazards on construction sites.

Moreover, the research findings highlight the impact of cost optimization on construction monitoring through the use of UAVs. By considering various factors such as real-time information, virtual inventory management, quality assurance, and efficient data processing, construction projects can achieve improved efficiency, reduced costs, and enhanced project outcomes.

Lastly, the research sheds light on the significant cost factors that influence the application of UAVs in construction monitoring, including design and documentation issues, financial resource management, project management, labor resources, and external influences. Understanding and addressing these factors are crucial for cost optimization and successful implementation of UAV technology in construction projects.

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