

Exploring the use of Drones for sustainable construction in developing countries

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Abstract:

Construction is faced with the challenges of economic and environmental ailments in developing countries. Low productivity in construction work, delays in construction, occurrence of accidents, and environmental pollution are experienced. Despite using various strategic measures and technology to plan, design, execute, monitor and control, construction related challenges continue to occur. It is argued that the use of Drone can enable alleviating various construction related challenges and assist in achieving sustainable construction. Using the context of South Africa and India's construction industry, this study explored for what purposes Drones can be used in construction and how they can contribute to the sustainability of construction in developing countries. A survey was conducted among various construction industry stakeholders, such as construction industry professionals and Drones technology experts, to obtain data. The collected data was analysed by using relevant descriptive and inferential statistics. Findings suggested that Drones can be used in several construction activities in developing countries and offer significant advantages such as gathering real-time information and tracking construction activities, virtual accessibility of non-accessible areas, obtaining high-resolution and 3D images. However, lack of knowledge, competency and trained personnel, Government regulations, piloting license requirements etc. are major barriers. The use of Drones can have significant implications on the construction industry, such as reduction in delay and cost and assisting in real-time decision making.

Keywords:

Construction, Developing countries, Drone, Sustainability, Unmanned aerial vehicles

Introduction

Sustainable construction in developing countries is argued to be a challenge. Many developing nations, including South Africa and India, face several social, economic, environmental, infrastructural, legislation, and technical challenges that lead to unsustainability in construction. For example, a significant proportion of construction projects experience cost overruns and delay in project delivery in India and South Africa (Das, 2015; KPMG and PMI, 2012; Watermayer and Philip, 2016). Further, rework, wastage of materials, and poor utilisation of labour and equipment are other major challenges experienced in construction (Aiyetan and Das, 2015; Das and Emuze, 2021; Bon-Gang & Lay Peng, 2013; Han et al., 2013; Love et al., 2011). Furthermore, environmental problems, including air pollution, water pollution and noise, are recurrent phenomena in the vicinity of the construction sites. Consequent to this, loss in productivity in the project, delay in project delivery, environmental

pollution, health ailment among the people in and around the construction projects are experienced.

Different construction companies have adopted several project management and construction management strategies to attain sustainable construction and prevent or mitigate the challenges. For example, project management techniques for the whole project life cycle starting from initiation to closure of the projects are generally adopted in many projects. Similarly, Environmental Impact Assessment (EIA), Total Quality Management (TQM), material, equipment and resource management techniques are also used. Moreover, advanced techniques and software such as BIM are also used to predict various scenarios that would enable implementing strategic measures to either prevent or resolve the construction challenges. However, challenges continue to occur at the construction project sites, which sometimes need information and real-time intervention. For example, construction activities are sometimes carried out in relatively inaccessible or less accessible areas. The gathering of information from such areas by conventional means might be time consuming and expensive. Similarly, there might be a need for real-time monitoring of construction works in the project sites by the project managers and construction engineers and to provide instructions. However, handling such situations is observed to be difficult by the use of conventional methods.

Therefore, there is a need for more advanced information gathering technique to meet such challenges. With the advent of advanced technologies and equipment such as light detection and ranging technology (LiDAR) and unmanned aerial vehicle (Drone) with both photographic and video cameras and the ability to assess information in real-time, it is argued that Drones would enable alleviating various construction related challenges and assist in achieving sustainable construction. Although such techniques are in some way used in developed countries, their use in developing countries, for example, India and South Africa, which are engaged in large scale construction activities, is scarce. Therefore, using the context of the construction industry of South Africa and India, this study explored for what purposes Drone' can be used in construction and how they can contribute to the sustainability of construction in developing countries.

Literature Review

1.4 Drones: The technology, benefits and challenges

Unmanned Aerial Vehicles (UAVs) can be traced back to 1793 and evolved significantly over the years. However, UAVs in the form of 'Drone' technology have been developed and used since 2010 (www.consortiq.com). A Drone is essentially a powered, Aerial vehicle that performs its functions without carrying a human operator on board. It can be expendable, recoverable, and can carry a lethal or nonlethal payload (www.TheFreeDictionary.com). Two types of Drones are observed. One that is fully automated performs all the functions as programmed without any human interventions (Hu & Lanzon, 2018; Sharma, Basnayaka & Jayakody, 2020). On the other hand, another type of Drone is generally operated under remote control by a human operator with various degrees of autonomy (Cary & Coyne, 2012).

Although Drones originally used for missions that are very difficult and dangerous for humans (Tice, 1991), the use of Drones have now been expanded to conduct aerial photography, product deliveries, agriculture, policing and surveillance, infrastructure inspections, data collection for scientific research and finding criminals or monitoring smugglers and Drone racing (Lalrochunga, Parida & Choudhury, 2020; Koparan, Koc, Privette & Sawyer, 2020;

Umar, 2020). The advantages of Drones are that they can be used for military, civilian and commercial purposes (Hu & Lanzon, 2018; Lalrochunga, Parida & Choudhury, 2020; Sharma, Basnayaka & Jayakody, 2020). Also, they can carry a payload of 500 kilograms and have a range of up to 300 Kilometres. (Lalrochunga, Parida, & Choudhury, 2020). However, the major disadvantages are that they can create security and privacy challenges and cause safety concerns for the Air Traffic movement, specifically in developing countries that do not have adequate rules and regulations to control the use of Drones (Lalrochunga, Parida & Choudhury, 2020).

1.5 Drone in developed and developing countries

The use of Drones in the developed and developing countries have increased significantly after their acceptance for commercial use. While it is used for a whole range of purposes such as aerial photography, data collection for science, agriculture, healthcare, dropping off packages and so on in the developed countries, it is used mainly for recreation in developing countries (Lalrochunga, Parida, & Choudhury, 2020). Moreover, it is also observed that Drones are not predominantly used in the construction sector. Also, in developed countries such as the USA, UK, Germany, France, Australia and Japan, the policies, rules and regulations relating to the use of Drones have been developed and being implemented (Lalrochunga, Parida & Choudhury, 2020). However, although the developing countries are not far behind, the policy framework and the rules and regulations are not at par with the developed countries (Lalrochunga, Parida & Choudhury, 2020). Furthermore, the operational areas of Drones in developing countries are far smaller than that of the developed countries (Lalrochunga, Parida & Choudhury, 2020).

2.3 Drone in construction

Although it is alleged that the construction industry adopts advanced technology at a slower rate (Holt et al., 2015), an increase in the use of advanced technology such as BIM and Drone has been experienced, specifically in the developed countries (Vacanas, Themistocleous, Agapiou, & Hadjimitsis, 2016). Drones have been used for or proposed to be used in construction for earth-moving operations, health and safety, quality control, material tracking, structural damage assessment, on-site data collection, vehicle detecting and tracking, land surveying, productivity, human performance, equipment planning and damage assessment (Lin, Han, & Golparvar- Fard, 2015; Morgenthal & Hallermann, 2014; Wang, Chen & Yin, 2016; Wen & Kang, 2014). Specifically, it is argued that Drones can assist in help in real-life monitoring of construction projects (McCabe et al., 2017; Hamledari, McCabe & Davari, 2017). They can enable the collection of high-quality visual data in the form of high-resolution images, which can also be transformed into 3D models, that can help in the analysis of different critical aspects of construction (Bang, Kim & Kim, 2017; Fleming et al., 2016; Julge, Ellmann & Köök, 2019; Kim, Park, Cho & Kang, 2019; Mahami, 2019). In other words, Drones can influence every aspect of construction that include surveying, site monitoring, project planning, project execution, monitoring, control, inventory management, equipment management, health and safety and so on (PWC, 2018). Moreover, it can also assist in the post-construction phase to monitor the risk or hazards, stock-taking of resources, including materials and equipment (PWC, 2018).

Research Methodology

The study was conducted by using a survey research method for data collection and descriptive and inferential statistical methods for data analyses. The following subsections present the detailed data collection and data analyses methods used.

3.1 Data

A survey was conducted to collect data among the construction industry stakeholders in South Africa and India. A purposive sampling process was used. Initially, a list of several stakeholders was drawn. These stakeholders who would participate in the survey were selected based on their association, engagement and experience in the construction industry and Drone technology in the respective countries. The stakeholders who are engaged in the construction industry and have significant experience were chosen.

Similarly, experts or users of Drone technology were selected. The respondents were contacted and selected for the survey based on their willingness to participate in the survey. The respondents constitute 54 stakeholders from South Africa and 40 stakeholders from India, totalling a sample size of 94. The respondents include project managers, engineers, consultants and designers, contractors, supervisors, surveyors, safety professionals, lawyers, academics, and Drone technology experts. The respondents selected had at least three years of experience and higher than Diploma qualification in the relevant field.

The survey was conducted using a questionnaire developed by incorporating questions relating to various aspects such as the advantages of Drones, barriers against the use of Drones, construction-related activities that can be performed by using Drones and the plausible impacts of Drones in construction. The respondents were asked to respond to the questions on a five-point Likert scale in which 1 indicates very low, 2 indicates low, 3 indicates average, 4, indicates high and 5 indicates very high. The survey was administered through a digital questionnaire survey platform and also through emails.

3.2 Data Analyses

The data was analysed using both descriptive and inferential statistics. First, the data collected was checked for consistency and reliability. Cronbach alpha test was conducted to check the reliability of the data. Further Standard Deviation (SD) was calculated to find the consistency of the data. The influence or impact of the various variables or attributes under each aspect was evaluated using the perception index. The Likert mean scores of the responses assigned by the respondents were used as the Perception indices (PI) on the various attributes. Further, the Z-test was conducted for each variable to observe the statistical significance for a confidence level of 95%. A p-value of ≤ 0.05 for $\alpha \leq 0.05$ was considered statistically significant. The influence of the variable was assessed based on the concurrent analyses of perception index value and its statistical significance. A perception index of more than three and less than four with $p \leq 0.05$ was considered fairly influential or influential to a certain extent. Similarly, a perception index value ≥ 4 with $p \leq 0.05$ was considered highly influential. However, if the perception index is less than three or $p > 0.05$, the variable was considered as not influential. The evaluations were first made separately country wise and then on an aggregate basis.

Findings and Discussion

The results based on the respondents' perceptions on the plausible advantages of the use of the Drones, barriers against their use, construction activities that can be facilitated and the impact of the Drones in construction are presented and discussed in the following sections. The responses from the respondents from South Africa and India were analysed separately. Furthermore, aggregate analyses were conducted as the results obtained from South Africa and India show similar trends. A Cronbach α value of 0.792 (>0.74) indicates the reliability, and low SD values ranging between 0.61 and 0.99 indicate consistency of the data set, and thus was used for further analyses.

1.6 Plausible advantages of the use of Drones in construction

The plausible advantages of the use of Drones in construction are presented in Table 1. It was found that respondents from South Africa and India provided similar responses on various advantages of the use of Drone. So, the aggregate result is presented and discussed. According to the respondents, the most important advantages are gathering real-time information and tracking construction activities, easy but virtual accessibility of non-accessible areas and obtaining high-resolution images through mapping. These findings corroborated the findings of previous studies, specifically in the context of developed countries (McCabe et al., 2017; Hamledari, McCabe, & Davari, 2017). Also, Drones can assist in getting three-dimensional images and photos and providing virtual accessibility to underground information without excavation if integrated with LiDAR. However, resolving site related bottlenecks and challenges, monitoring hazards, health and safety, and performing inspections of construction work were statistically insignificant with the use of the Drones. Therefore, it may not be advantageous, which is also in alignment with previous studies in the context of Gulf Cooperation Council construction (Umar, 2020).

Table 1. Plausible advantages of the use of Drones in construction

Advantages	South Africa		India		Overall	
	PI	Z test p values	PI	Z test p values	PI	Z test p values
Easy accessibility of non-accessible areas	4.33	0.000	4.25	0.000	4.20	0.000
Real-time information and tracking of construction activities	4.51	0.000	4.40	0.000	4.47	0.000
High-resolution images	4.05	0.000	3.90	0.000	3.98	0.000
Three-dimensional images and photos	3.79		3.95		3.87	0.000
Accessibility to underground information without excavation if integrated with LiDAR	3.42	0.000	3.45	0.000	3.44	0.000
Resolution of site-related bottlenecks and challenges	3.17	0.061*	3.05	0.387*	3.11	0.113*
Monitoring health and safety, and hazards	3.01	0.426*	3.11	0.192*	3.06	0.223*

Performing inspections	2.70	0.995*	2.86	0.848*	2.77	0.995*
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4.2 Barriers in the use of Drones in construction

The barriers to the use of Drones in construction are presented in Table 2. Scrutiny of the results revealed that the response provided by both South African and Indian respondents are similar with very marginal variations; therefore, the aggregate results were considered. According to the respondents, the two most important barriers include lack of knowledge, competency and trained personnel, and piloting license requirement. The other essential barriers are government regulations, risks of accidents and weather conditions. However, resistance to change and threat to human labour were statistically insignificant, so these aspects are not likely to become obstacles in the use of Drones in construction in developing countries.

Table 2. Barriers in the use of Drone Technology

Barriers	South Africa		India		Overall	
	PI	Z test p values	PI	Z test p values	PI	Z test (p values)
Weather conditions	3.31	0.008	3.43	0.0016	3.37	0.000
High cost	3.44	0.000	3.45	0.000	3.44	0.000
Lack of knowledge, competency and trained personnel	4.31	0.000	4.47	0.000	4.40	0.000
Requirement of piloting license	4.09	0.000	4.20	0.000	4.14	0.000
Government regulations	3.70	0.000	3.84	0.000	3.77	0.000
Risks of Accidents	3.33	0.000	3.18	0.055	3.26	0.000
Resistance to change	2.94	0.703	2.86	0.855	2.91	0.871
Threat to human labour	3.03	0.351	3.09	0.241	3.06	0.291

4.3 Activities facilitated by Drones

Various activities which can be facilitated or performed by the Drones were categorised under pre-construction, during construction and post-construction phases. The aggregate evaluation of the responses revealed that Drones could perform surveys (Aerial) significantly in the pre-construction phase. Also, it can assist in planning and design to a certain extent as the data gathered from the survey by Drones can provide useful information to be considered in planning and design (Table 3). During the construction phase, Drones can perform monitoring of the construction activities significantly. Moreover, monitoring of delay, hazards and safety can be performed, and the deployment of materials and equipment and labour can be facilitated to a certain extent. Besides, they can help in the communication of decisions to a certain extent too. These findings are in line with the findings of previous studies in the context of developed nations (Lin, Han & Golparvar- Fard, 2015; Morgenthal & Hallermann, 2014; Wang, Chen & Yin, 2016; Wen & Kang, 2014). However, monitoring of defects may not be possible by the use of Drones (Table 3). Finally, in the post-construction phase, Drones are likely to assist in the stock-taking of resources and making surveillance and monitoring of criminal activities such as vandalism or theft to a certain extent (Table 3). Therefore, it is revealed that Drones can assist in most construction activities throughout the life cycle of the projects.

Table 3. Activities facilitated by Drones

Activities	South Africa	India	Overall
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	PI	Z test p values	PI	Z test p values	PI	Z test p values
Pre-construction						
Survey	4.25	0.000	4.16	0.000	4.21	0.000
Planning and Design	3.20	0.084	3.13	0.155	3.17	0.042
During construction						
Monitoring of construction activities	4.20	0.000	4.11	0.000	4.16	0.000
Deployment of materials and equipment	3.61	0.000	3.75	0.000	3.67	0.000
Deployment of labour	3.55	0.000	3.61	0.000	3.59	0.000
Monitoring of defects	3.05	0.289	3.02	0.438	3.04	0.316
Monitoring of delay	3.77	0.000	3.75	0.000	3.77	0.000
Monitoring of hazards and safety	3.61	0.000	3.5	0.000	3.56	0.000
Communication of decisions	3.29	0.001	3.43	0.000	3.36	0.000
Post-construction						
Stock-taking of resources	3.38	0.000	3.29	0.016	3.34	0.000
Monitoring of safety	2.66	0.999	2.79	0.938	2.72	0.999
Surveillance and monitoring of criminal activities such as vandalism or theft	3.83	0.000	3.95	0.000	3.89	

4.4 Impact of the use of Drones in construction

The impacts of the use of Drones in construction were evaluated from the responses of the respondents. The results of the evaluation are presented in Table 4. It is found that the impacts of the use of Drones in South Africa and India are similar. The aggregate evaluation showed that Drones could significantly assist in reducing delay, saving the cost of projects and real-time decision making. Furthermore, they can, to a certain extent, help in real-time communication, appropriate deployment of material and equipment, and adequate and timely deployment of labour. Also, hazards can be avoided by the use of the information gathered from Drones. Therefore, Drones can have significant positive impacts and contribute to the sustainability of construction in developing countries.

Table 4. Impact of the use of Drones in construction

Impact	South Africa		India		Overall	
	PI	Z test p values	PI	Z test p values	PI	Z test p values
Saving in cost	4.24	0.000	4.13	0.000	4.19	0.000
Reduction in delay	4.44	0.000	4.36	0.000	4.41	0.000
Real-time communication	3.85	0.000	3.81	0.000	3.83	0.000
Real-time decision making	4.07	0.000	4.20	0.000	4.13	0.000
Appropriate deployment of material and equipment	3.27	0.000	3.40	0.000	3.34	0.000
Adequate and timely deployment of labour	3.62	0.000	3.72	0.000	3.67	0.000
Avoiding hazard	3.33	0.000	3.40	0.000	3.37	0.000

Conclusions

Drones are argued to play an important role in construction and assist in the automation of construction activities. The study's objective was to explore how Drones can be used in

construction, what advantages they can bring, what barriers would be faced, and how they would impact the construction industry in developing countries. Findings revealed that the major advantages of using Drones in construction are gathering real-time information and tracking construction activities, virtual accessibility of non-accessible areas, and obtaining high-resolution images, including 3D images. The major barriers to using Drones in developing countries include lack of knowledge, competency and trained personnel, and requirement of piloting licenses, Government regulations, risks of accidents and weather conditions. They can be utilised in pre-construction, construction and post-construction phases. For example, surveys can be done in the pre-construction phase, monitoring construction activities during construction and surveillance, monitoring and stock-taking after the construction. They can assist in reducing the delay, cost of construction and real-time decision making. The study contributes to the opportunities and challenges of Drones in construction in developing countries, which could assist in decision-making for their use in the pursuit of attaining sustainability in construction. The limitation of the study is that it was conducted based on limited perception survey data. Also, cost-benefit analysis and comparative analysis of the use of Drones in construction between developed and developing countries were not included in the scope of the study and are considered further scope of research.

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