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Applications of Drones for Safety Inspection in GCC Construction

Abstract (Structured)

Purpose (mandatory):

Construction Industry in the Gulf Cooperation Council (GCC) member countries is at the peak as the region is in the stage of developing its infrastructures. Apart from some positive sign of this boost, several other issues have also been developed in the region. One of such issues is the safety of workers at the construction sites. This article, based on a variety of applications of drones in other industrial sectors, considers the use of drones for construction safety improvement in the GCC countries. This article aimed to investigate the safety-related applications of drones considering technical features and barriers and enablers for safety-related tasks.

Design/methodology/approach (mandatory):

A mixed research approach using both qualitative and quantitative methods was adopted to achieve the aims and objectives of this research. Data was collected through a systematic literature review, semi-structured interviews, and using a structured questionnaire. A total of 37 relevant research items and 10 interviews were held with construction safety professionals, and 92 responses collected from the safety managers through a structured questionnaire was used to derive the conclusion of this research. The collected data were processed and analyzed using the SPSS program. Descriptive analyses were carried out in which means and importance factors were calculated.

Findings (mandatory):

25.92% of participants confirmed that they or their company had used the drone in different activates. The most common application of drones reported by the respondents was photography for marketing purposes followed by surveying application and quality inspections. The camera movability was the top-rated technical feature required for safety-related inspections. Similarly, 'Working near the corner or edge of unprotected opening' was the top-rated application of drone for safety-related tasks. The safety concerns of using drones at job sites were rated as the most important barrier by the participants. Technical challenges associated with the use of drones for safety improvement was rated as the second most important barrier by the participants.

Research limitations/implications (if applicable):

Although, the research presented in this article is based on the GCC construction industry, however, since the data collected through systematic review and semi-structured interviews are not a regional base, therefore the finding of this research could also be useful in other regions. Further research however, needs to be conducted to reduce the implications of the barriers identified in this paper so that the drone can be effectively used for safety improvement in construction not only in the GCC region but also in other countries.

Practical implications (if applicable):

Once the GCC construction industry will be able to overcome the challenges associated with the application of drones in safety improvement, the safety managers will be able to monitor the site more effectively which could be helpful to improve the safety performance of the construction organization.

Social implications (if applicable):

Improved safety performance in not only in the greater interest of the construction organizations as they can reduce the costs associated with poor safety but can also avoid the delay caused by construction accidents. Similarly, improved safety performance reduces the accidents at construction sites, and thus reduces injuries and disabilities caused by such accidents, making the construction workers a useful part of the society. The application of drones in safety-related tasks is one of the key solutions that can lead us to improved safety performance.

Originality/value (mandatory):

Although, the use of drone technology has revolutionized a number of industrial sectors due to its variety of applications, the application in construction particularly in the GCC region is still very limited. As noted in the results of this research, only 21 participants (25.92%) expressed that they or their company had used the drone in different activates. This means that the industry is not getting the full advantage of the available drone technology. The results of this research will enable construction industry

stakeholders to know the challenges associated with the application of drones for safety improvement and to develop strategies to overcome these challenges.

Keywords: Construction, Construction Planning, Construction Safety, Management Project Management, International Practice.

1. Introduction:

The construction industry in the GCC member countries is one of the major industries providing jobs to millions of local and foreign workers. Currently, the construction projects in the region are at a peak as most of the countries in the region are in the stage of developing their infrastructure (Umar et al., 2019). The GCC economy is heavily reliant on oil and gas revenue and since all the major infrastructure projects in the region are funded by the government, the dip in oil and gas prices also affects the construction industry. It is however anticipated that the construction project's value in the region will be increasing despite the fact the oil and gas prices are still at a low. In this regard, the Middle East Economic Digest (MEED) report for the year 2019 indicates that the value of the planned project in the GCC countries stands at US $ 2,563,966 Million (MEED, 2019). As indicated in figure 1, Saudi Arabia projects alone are valued at the US $ 1,188,432 Million, the highest in the region. These projects (shown in figure 1) don’t count those which have been awarded till July 2019 as shown in table 1 which is worth the US $ 3,459 Million. It is worth mentioning that the contracts awarded in the GCC countries only in March 2018 accounted for the US $ 9,894 billion (Umar et al., 2018). Similarly, different statistics shows that the construction industry of some of the GCC countries such as Oman and Bahrain employed more peoples as compared to the UK construction industry (Statista, 2018; OSC, 2016; LMRA, 2018). More specifically the employment ratio in the Omani construction industry is 4 times more than the employment ratio of the UK construction industry. Similarly, the Bahrain construction industry employment is 3 times more than the UK construction industry. The increased number of projects in the GCC region provides employment and business opportunities at one side, however, on the other hand, it creates several serious issues. One of such issues is the occupational safety and health which is briefly explained in the next section.

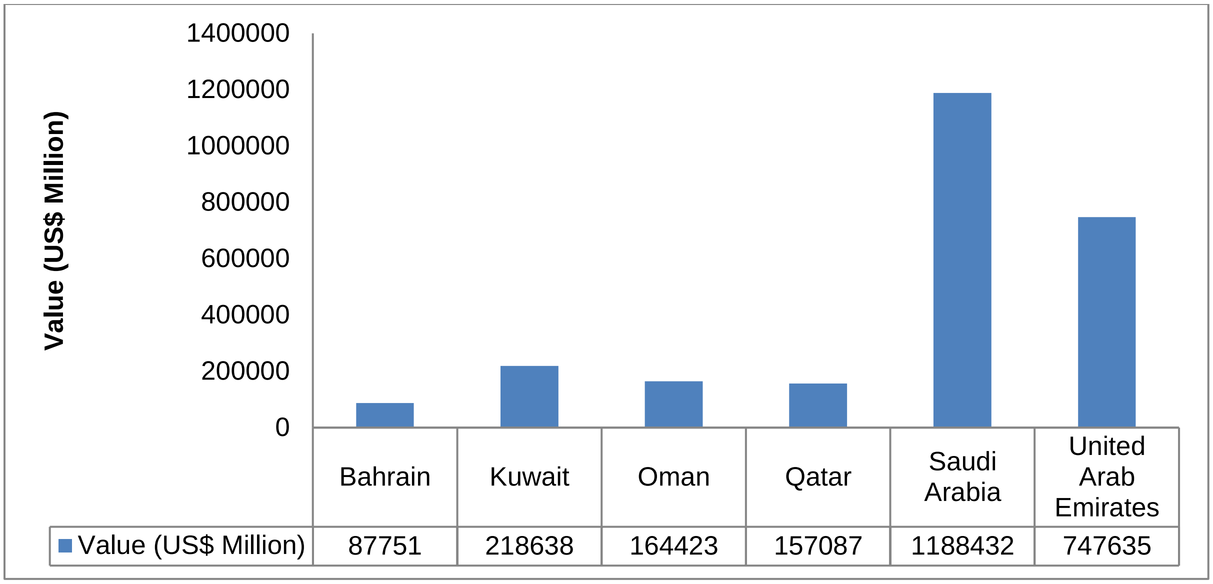

Figure 1: The Values of Planned Projects in the GCC countries

Table 1: Contract Awarded in Different GCC Countries until July 2019

Country	**Contract Awarded (US$ Million)**
United Arab Emirates	768
Saudi Arabia	525
Oman	316
Bahrain	265
Kuwait	76
Other GCC Countries	1509
Total	**3459**

1.1 Construction Safety and Health in GCC Countries:

Statistics published by the International Labour Organization (ILO) reveals that construction workers in different developed countries are 3~4 times more likely to die from accidents at the site compared to workers in other industries. In the developing world, There are higher risks (3~6 times more) of death linked with construction work in developing countries (ILO, 2015). Many construction workers suffer and die from work-related diseases developed from past influences to risky materials, such as asbestos and other chemicals. The construction industry is known as one of the world's major industrial sectors, which include sub-sectors such as building, civil engineering, demolition, and maintenance. Although no industry including construction is accident-free so far around the world, the condition in GCC countries particularly in construction is alarming. There is a lack of accurate data related to the number of accidents and fatalities in these countries except the report published in the media or international independent organizations. In recent days, the death of construction workers working the in construction of a stadium for football world cup 2022 has attracted the attention of a large number of media and international organizations. Some of these reports show the number of construction workers died at this project have already reached to 1,200, and further estimates that this number will reach to 4,000 by the end of 2020 when this project will be completed (safety Media, 2018; ITUC, 2014; Ganji, 2016). The Human Rights Watch report indicates that the total workforce in Qatar is approximately two million. 95% of this workforce are expatriates out of which 800,000 (=40%) are employed in the construction sector (Human Rights Watch, 2018). The report further shows that only in 2012, a total of 520 workers from India, Bangladesh, and Nepal died due to different work-related accidents and conditions in Qatar. Such poor occupational safety and health performance of the GCC region has also affected its progress towards the United Nations (UN) Sustainable Development Goals (UN-SDG, 2015). The UN under its goal 8 which is related to decent work and economic growth aims to ensure workers' rights and promote safe and secure workplaces for all workers. The current progress and score of the GCC region of all the UN goals are, however, very low and it seems that the region would not be able to achieve these goals by 2030. For instance, the study carried out by Sachs et al. (2019) on the global progress towards UN SDGs noted that none of the GCC countries is on track to achieve goal 8. The mean score of the GCC region in goal 8 is 71.15 which is far lower than the score of the countries which have already achieve this goal or on track to achieve it by 2030.

Similarly, Umar and Wamuziri (2017) noted that, officially, there are no statistics in Oman as to how many construction workers were injured at work. However, data from ten reputable construction organizations show that in 2014, more than 3,500 construction workers received medical treatment due to work injuries. Due to the severity of injuries, around 10% of these workers were hospitalized. The report further reveals that roughly 18% of these workers, who were hospitalized, later died at their work or in hospital. In comparison to the previous year’s data, the number of injured workers rose by 246. For various reasons including reputation, company owners hesitate to publicize such information. Similarly, Umar and Wamuziri (2016) quoted the analysis of one daily newspaper reports covering six months (from May 2015 to November 2015) and stated that in different accidents 9 construction workers died and 25 were injured in Oman were reported in this newspaper. Apparently, these were accidents taken place in major cities of Oman, therefore, were reported in the newspapers, there may be accidents resulting in injuries and fatalities in a remote area but may not be reported in the newspapers. Thus the actual number of fatalities and injuries may be greater than the one reported in the newspapers.

The statistics published by the General Organization for Social Insurance (GOSI) of Saudi Arabia indicate that in the third quarter of 2018, occupational injuries in construction were 47% of the total occupational injuries in Saudi Arabia (GOSI, 2018). This clearly indicates that the construction industry in Saudi Arabia is the most hazardous sector which almost accumulates half of the injuries (3,625 out of 7,776) that took place in the third quarter of 2018. If the injuries number is estimated at the same rate as of the third quarter of 2018, then the total number of injuries will, therefore, stand at 14,500 (3625 x 4). The statistics further reveal that in the same period, fall from height was the most frequent types of injuries followed by struck and collision, then rubbed and abrasion (figure 2). The most common causes of accidents reported in many studies include poor hazard recognition, unsafe behavior, unsafe condition, training deficiency (Choudhry and Fang, 2008; Fang et al., 2016; Bohm and Harris, 2010; Jeelani et al., 2017; Salas et al., 2020). The General Organization for Social Insurance reports further indicates that the number of death in the third quarter of 2018 from the total injuries (7,776) was 16. This can be translated into the number of death per year which would be roughly equal to 64 (= 16x4). This number, however, appears not to be reliable simply because of the overall safety and health condition in the whole region. For instance, one project, the football world cup stadium, in Qatar resulted in 1,200 death from 2010 to 2017, roughly 171 deaths per year. It is hard to believe that workers' deaths per year in the UK (~144) are more than the deaths of workers in Saudi

Arabia (~64). Similarly, in the United States, there are robust occupational safety and health systems are placed and implemented through the government organization Occupational Safety and Health Administration (OSHA), bust despite these systems there were 991 fatalities (10.10% of the total injuries) in the United States in 2016; much more than the fatalities of Saudi Arabia (~64 or 0.2% of the total injuries). The General Organization for Social Insurance, Saudi Arabia statistics of the third quarter of 2018 further shows that 4002 injuries (51%) out of 7,776 were recovered without disabilities, while 386 injuries (5%) resulted in permanent disabilities. The report further indicates that 3372 injuries (43%) are still under treatment. Overall, the discussion reveals that the construction safety in the GCC countries is not at a satisfactory level and therefore required not only the attention of all the stakeholders but also the need to adopt the technological tool which could be helpful to improve safety at construction sites. One of the key aspects of safety improvement is the safety inspection, which is normally done by the safety supervisor. The safety inspections through safety or site supervisors have a number of problems that tend to reduce the effectiveness of such inspections. These problems of safety inspections were evaluated by a number of studies which indicates that (i) the limited number of safety supervisors to check the safety and environment requirement at the construction site, (ii) overlooking in the data collection due to a large number of safety requirements, (iii) lack of standardized checklist for different site conditions, (iv) time required for data collection and analyzing, (v) loss of information in data collection during inspections, (vi) lack of communication between project staff, execution team, and management team, (vii) and difficulty in real-time action required for a specific site are some of the key issues in the safety inspection at construction sites (Kim et al., 2008; Park et al., 2013). These problems in safety inspection, however, can be reduced and controlled by incorporating technology and machines such as drones (De Melo et al., 2017). There are, however, very few or no studies, particularly in the GCC region which have a look into the application of drones for the safety inspection, the technical requirement of such drones, and the barriers in using drones for such purpose. This article, therefore, aims to investigate all the aspects of drones in the GCC context. The next section, therefore, sheds light on the importance of the safety inspections with a specific reference of using drones for such purposes.

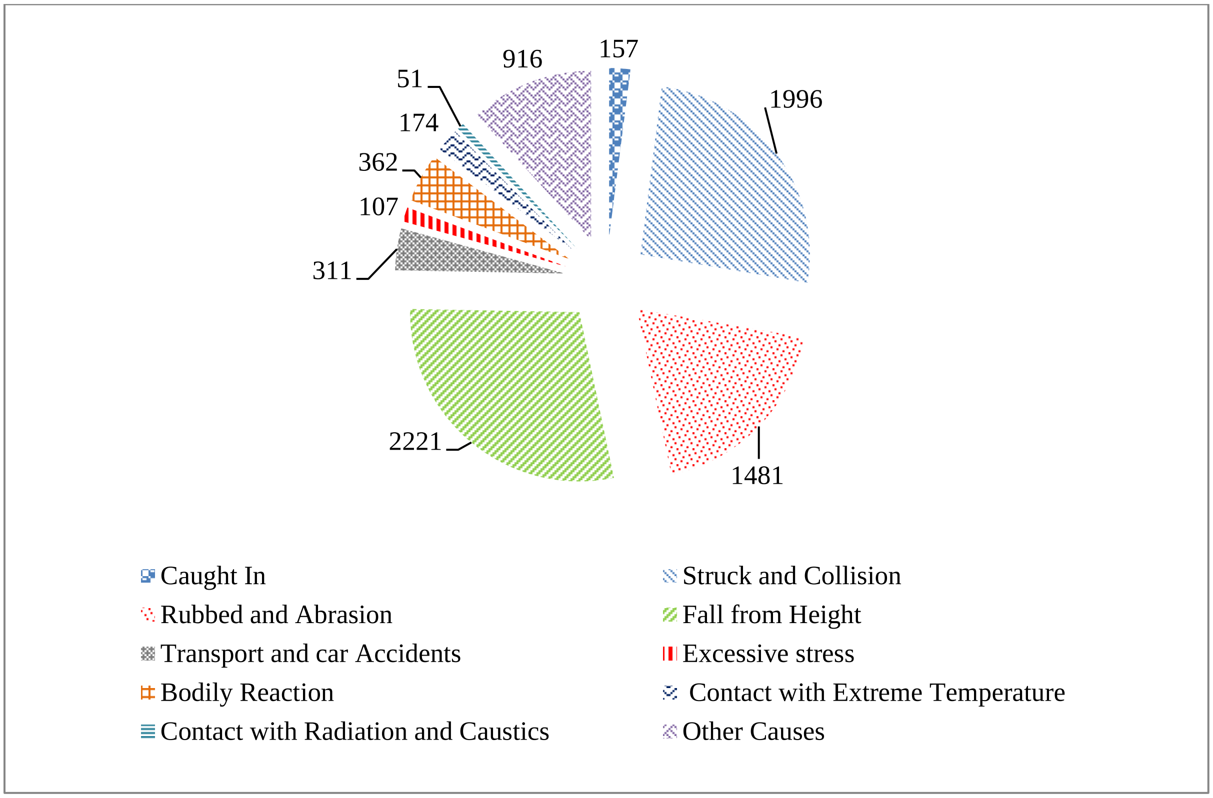

Figure 2: Different Types of Injuries in Saudi Arabia – 3rd Quarter 2018 (GOSI, 2018)

1.2 Improving Construction Safety:

As discussed in the above section, the safety performance in construction in the GCC region is poor, so the question is then how to make construction industry accident free, or reduce the number of accidents? The straight forward answer is to improve the safety performance which needs several factors to be considered. One of the methods to avoid accidents at the construction site has attracted the attention of many researchers in construction management is to identify and control hazards at the construction site (Goetsch and Goetsch, 1996; Holt and Lampl, 2006; Hasanzadeh et al., 2017; Gheisari and Esmaeili, 2019). Safety supervisors normally visit the construction site at different intervals to identify the hazards that could cause accidents. Such inspections allow detecting the problems at an early stage and helping project managers to implement the required safety measures to effectively manage the risk (Woodcock, 2014). Many research studies have established that the frequency and quality of site inspections of the conditions and safety behavior of workers can be used as an indicator of safety performance (Jaselskis et al., 1995; Laitinen et al., 1999; Reese, 2011; Abudayyeh et al., 2006; Umar and Egbu, 2018). One emerging technology that has the potential to affect traditional safety inspections is the drone or unmanned aerial system (UAS), which can be used as a vehicle in a variety of applications (Gheisari et al., 2014; Li, and Liu, 2019). Tatum and Liu (2017) classified the applications of drones in the construction industry into four main categories that include i) Photography/videography, ii) Conducting surveying, iii) Conducting inspections, and iv) Safety inspections. Similarly, monitoring of construction activities using drones at workplaces through was one of the key applications of the drones identified by Mosly (2017) in his study on applications of drones in the construction sector. Similarly, the key benefits of using drones in different construction operations discussed by McCabe et al. (2017) can be summarized as in-flight agility, capacity to hold an array of sensors, and automation potential.

Drones can move faster than humans into hard-to-reach areas of workplaces and can be equipped with devices such as video cameras, sensors, radar, and communication hardware to transfer real-time data to safety managers. Drones can also perform tasks similar to those performed by manned vehicles but more quickly, more safely, and at a lower cost (Irizarry and Johnson, 2014; Gheisari and Irizarry, 2015). The accessibility of such low-cost and easy-to-fly drones has significantly increased their use over the past few years (Liu et al., 2014; Zucchi, 2015; Ham et al., 2016). It is expected that the market for such systems which was US$ 3 billion in 2017 will reach US$10 billion by the year 2026 (Teal Group Corporation, 2018). There is a wide range of evidence that established the use of drone in civil, construction, transportation engineering for the purpose of structures monitoring, traffic surveillance simulation, avalanche control and bridge inspection (Coifman et al., 2004; Frew et al., 2004; Coifman et al., 2006; Chen et al., 2007; Puri et al., 2007; Metni and Hamel, 2007; Rathinam et al., 2008; McCormack and Trepanier, 2008; Ellenberg et al., 2016). Due to a number of applications of drones in the civil and construction industry, some researchers also considered the application of drones in construction safety (Irizarry et al., 2012). In general, the application of drones in the construction industry can be categorized into three main categories that include airborne surveying, safety, and quality inspection, and progress monitoring (Vascik and Jung, 2015; Irizarry and Costa, 2016). Apart from many positive aspects of the drone, there are a number of risks associated with the application of drones in the construction industry. Construction organizations are therefore required to be aware of all regulations, legislations, privacy liability, and risks for construction-related businesses (Buckeridge et al., 2016).

Generally, a consensus exists that the use of drones is useful to improve safety performance, however, there is a lack of understanding of the drone's operations, required technical features, and barriers of using drones for construction safety. For instance, the study conducted by Gheisari and Esmaeili (2016) on the application of drones for safety improvement concluded that real-time video transmission, high-precision outdoor navigation, sense and avoid, durability, actuated video camera are the top five most desirable technical features of drones for safety improvement at the construction sites in the United States. Zhou and Gheisari (2018) however, considered the ability of drones to use various sensor devices and the potential to hover for long periods of time as one of the top leading technical features for safety inspection in construction.

For the technical analysis, a drone was considered to consist of three components: vehicle, control station, and system as described by (Gheisari and Irizarry, 2015). In the vehicle section, airframe hardware requirements commonly known as unmanned aerial vehicles (UAVs) that can be either fixed-wing or rotary were included. Fixed-wing platforms are similar to airplanes and require a runway to take-off or land, while rotary UAVs can take off and land vertically, quite similar to a helicopter (Gheisari and Esmaeili, 2019). A UAV, depending on its task, can carry a variety of sensors including visual cameras, laser scanners, smoke detectors, motion detectors, and temperature sensors (Ham et al., 2016). The ability to use various sensor devices and the potential to hover for long periods of time has made rotary-wing UAVs well-suited platforms for construction safety applications (Zhou and Gheisari, 2018).

The control station comprised the hardware and software requirements used by the UAS operator. The software considered in the control station is related to the graphical user interface (GUI) of the UASs and does not include specific guidance, navigation, and control (GNC) aspects (Agnisarman et al., 2019). The GNC requirements are divided into the system section, which contains the capability features of the reference systems and communication links. The GNC systems vary from fully manual to semiautonomous or fully autonomous (Ge et al., 2019). Several required features of a UAS vehicle, control station, and system were previously identified in a pilot study conducted by Gheisari and Esmaeili (2016) and thus were considered important in this study.

Similarly, the top five barriers of drones in safety application enlisted by Gheisari and Esmaeili (2019) include (i) liability and legal concerns, (ii) safety concerns, (iii) technical challenges, (iv) requirement for a certified pilot or operator, and (v) extensive training requirements. There is also a possibility that using such machines may result in a reduction in the morality of the workers as they may feel that their company is spying them. This can negatively impact their safety performance as their trust in the company would lose (Conchie et al., 2006). The enablers of drones for safety inspection are that it allows safety supervisors to reach difficult areas where humans can't reach or there are possible hazards that do not allow safety inspectors to reach (Gheisari and Esmaeili, 2019; (Karakhan and Alsaffar 2019). Apart from the reduction in the price of drones, they can be effectively used safety inspections for steel erection in high elevations (Okpala et al., 2020). In this regard, it is worth mentioning that the Department of Transportation in the United States uses drones to monitor the conditions and the structural integrity of steel and concrete bridges as such inspections are quite hazardous (Xu and Turkan, 2019). There are, however, no studies that evaluated these factors associated with the application of drones for safety inspection in the GCC construction industry. This article, therefore, attempts to investigate these factors in the context of the GCC construction industry. The research methodology adopted to achieve these aims and objectives is underlined in the next section.

2. Research Methodology:

The aims and objectives of this study were accomplished using a mixed research method that includes qualitative and quantitative research methods described by (Umar et al., 2019; Cooper et al., 2006; Opdenakker, 2006; Bryman, 2012; Bryman, 2016). In the first stage, a detailed review of the existing literature related to the application of drones for safety in construction was carried out using different keywords and databases. The time frame selected for this systematic review was the past 10 years (January 2010 to January 2020). The time frame selected for the systematic literature review was considered appropriate as this is the period where drones applications in the construction sector have attracted the attention of a large number of researchers and practitioners (Thompson Tractor Company, 2020). Four main databases including Web of Science, Scopus, Proquest, and Science direct were used to extract relevant data. The keywords and phrases used in this search were "safety-related applications of drones in construction", "technical features of drones for safety applications in construction", "barriers in applications of drones for safety improvement in construction" and "benefits of using drones for safety improvement in construction". The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were adhered to during this systematic review (Moher et al., 2009). Proper inclusion and exclusion criteria were adopted to screen the record identified from different databases. The key inclusion criteria for considering a study in this research were i) the study should be in the English language, ii) the keywords/phrases selected for this study should appear in the keywords or in the abstract of the paper and iii) the paper or the study should deal with the application of drones in the construction. During this systemic review, a total of 152 articles were downloaded from the selected databases. After imposing the screening process and removing the duplicate items, a total of 37 items were selected for the final review. The majority of the final selected items (13 ~ 35%) were from the Web of Science, followed by Scopus (11 ~ 29%), Science Direct (7 ~18%), and Proquest (6 ~ 16%). Similarly, the majority of the items selected for the final review were from 2018 and 2019, representing 8 items (21.62%) and 7 items (19.92%) respectively. There was only one, one item (2.70%) from 2010 and 2014 selected for the final review. Similarly, no item was selected for the review from the year 2020.

Likewise, 3 items (8.11%) were selected for the final review from the year 2011. Two (5.41%), two (5.41%) items were from 2012 and 2015. A total of 8 items, four (10.81%) from 2013, and four (10.81%) from 2017 passed the final screening process and thus included in the final review list. The number of final selected items from the year 2016 stood at 5 (13.51%). A total of 15 items related to different situations and safety activities that could be improved using drones were identified from this systematic review. Similarly, a total of 13 items related to the technical characteristics of drones were identified from the existing literature.

In the next stage of the research, expert opinions related to the use of drones in construction safety, the required features, challenges, and opportunities were sought out through semi-structured interviews. Interviewees were identified from different parts of the world using an internet search. In this regard, some common keywords such as “drone expert”, “drone researcher” “using drones for safety inspection” and construction researchers/ practitioners interested in the use of drones” were used in the search engine (Google Chrome). The items displayed on the first screen using each keyword were only considered for further screening. The criteria for the selection of the interviewees was that the respondents should have at least a Bachelor's degree in a close field to the construction industry and should have at least 15 years’ experience with safety management responsibilities. The interviewees may be working in industry or academia. Safety in construction should be one of the research interests for the interviewees from academia. A total of 25 potential participants were identified through the internet search. The sample size for the semi-structured interview was selected based on the sample size used in some similar studies. For instance, Mason (2010) also in his research entitled “Sample Size and Saturation in Ph.D. Studies Using Qualitative Interviews” reported the result of five hundred and sixty studies and noted that the most common size of the sample in these studies was 20. There are, however, some studies that have used a much smaller sample size. Since the purpose of this interview was to collect some additional information related to the application, features, challenges, and opportunities, an overall sample size of 25 was deemed fit for this study. The respondents identified through internet search were contacted to participate in the study through emails with the aims and objectives of the research. A reminder after 15 days was sent to those participants who did not reply. At the end of the prescribed period a total of 10 participants agreed to participate in the study. Interviews were conducted using an online meeting platform Zoom. Based on the results and analysis of the interviews, three additional safety-related activities that could be improved through drones were added to the items identified in stage one of the research (systematic review), making the total items in this category equal to 18. Similarly, two additional items were added to the technical features after the expert opinions were taken making the total items in this category equal to 15.

In the third stage of the research, a structured questionnaire consisting of six sections was developed to collect the data from industry professionals in the GCC region. Section 1 of the questionnaire included basic information about the study, confidentiality, and consent statements. Section two of the questionnaire was related to the professional background of the respondents which includes items related to their age, qualification, company role, position, and experience in the construction industry. The participants also required to indicate their construction sector, nature and size of their current project (s), and the percentage of the new construction. In the third section of the questionnaire, there were some questions which aimed to know the participant's familiarity with drones and previous implementations. In case their organization has used the drone previously, they were asked to mention the purpose. In a situation where the participants' organization has not used the drone so far, they were requested to mention the reasons. In the fourth section of the questionnaire, there were questions about the frequency and effectiveness of using drones to improve safety practices. Several required features of a UAS vehicle, control station, and system were previously identified in a pilot study conducted by Gheisari and Esmaeili (2016) and thus were considered in the questionnaire. There were also a few questions related to the importance of using drones at different distances, heights, time limits, and locations to collect different information associated with the workplace.

In the last part of the questionnaire, respondents were asked about the enablers and barriers to using drones to improve safety at construction projects. The participants were asked to rate their responses on a Likert scale of 1 to 5 (1 = low, 5 = high). The statistical analyses were carried out using SPSS programs. Descriptive analyses were carried out on the collected data to measure the means and ratios. The internal consistency of the collected data was checked through Cronbach's alpha (α). One way ANOVA was applied to establish the significance between different variables considered in the research. One-way analysis of variance (ANOVA) is a simple method to find out if survey or experiment results are significant or not. It is a useful tool to establish to accept or reject the null hypothesis or accept the alternative hypothesis. In simple words one way ANOVA is used to compare means between three or more distinct/independent groups. Similarly, two way ANOVA is used to compares the mean differences between groups that have been split on two independent variables (factors). To know the significance of the age, experience, qualifications, and project value of the respondents on applications of drones, a T-test was performed. Briefly T-test is a statistical test that compares two averages (means) and suggests if they are different from each other. The T-test also informs the significance of the differences. To be more simple and straight forward, one sample T-Test compare two quantitative measurements taken from the same individual and two samples T-Test (independent) - Compare means between two distinct/independent groups. An independent sample T-test (two-tailed) was conducted to see if there is any notable variation among two independent groups. In this research, a probability value (p-value) less than 0.05 from a two-tailed T-test was considered statistically significant for all tests. The normality of the data was checked through the ratio between skewness and its standard error, and the ratio between kurtosis and its standard error. The data was considered normal if the ratio was between –1.96 to +1.96. Briefly, Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. Similarly, Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. That is, data sets with high kurtosis tend to have heavy tails or outliers.

The data collection process is explained in the next section.

2.1 Data Collection and Screening:

The data collection process adopted in this research was guided by the methods adopted in some similar studies (Bernstein et al., 2012; Gholizadeh et al., 2017; Gheisari and Esmaeili, 2019). The questionnaire developed was first tested on a small group of respondents and where found necessary, some required changes were made to the questionnaire before the final distribution. The questionnaire was distributed to the respondents through their emails. The email addresses of the safety managers were collected from their organization website. The construction companies were identified through the contactor association in each GCC country. The top 40 construction companies from each country were selected making total respondents of 200. The main research philosophy behind the selection of top-ranked 40 companies in each GCC country is to make the results of the study more acceptable and reliable in the entire GCC region. There have been some studies that used a qualitative approach and interviewed only six respondents (Umar and Egbu, 2018; Umar et al., 2017). A recent study in the area of renewable energy conducted by Filho et al., (2019) was based on a sample size of only 50. Similarly, Umar et al. (2018) in their study which aimed to assess the construction worker's productivity and safety performance used a quantitative approach selecting a total of 30 respondents only. The total population (construction workers) in their study was, however, stood at 700,000. Some researchers, however, recommend that the sample size or the response rate needs to be calculated based on the population size (Kotrlik and Higgins, 2001). In some cases, the sample size calculated based on the population size could not be helpful or even not adoptable. For instance, if the population is the ‘population of China’; then the sample size calculated through this principle will be very large and thus could not be achieved. A recent study on the challenges associated with renewable energy in the Arabian Gulf region also used a sample size of 87 respondents from five different countries (Umar et al., 2020). Similarly, Dawson in his research investigated the perspective of university teachers on climate change considering a sample of 39 participants (Dawson, 2012). The questionnaire link along with the research brief description was sent to the safety managers of these companies. The respondents were requested to complete the survey in one month's time. The participants were served two reminders during that period if they have not yet completed the survey. After the survey period was completed, the data screening was conducted considering descriptive analysis.

3. Results and Discussion:

A total of 92 responses were received showing a response rate of 46%. In the screening process, a total of 11 questionnaires were rejected due to the fact the less than 50% of the questions were answered. Thus the valid response rate was recorded at 81 (40.50%) participants and was used in further analysis. To justify the response rate and valid sample size used in the analysis of this study some relevant studies were reviewed and it has been found that a response rate of 50.48% with valid questionnaires of 96 is acceptable in such studies. For instance, a study carried out by Shih and Xitao (2008) analyzed a total of 39 different papers published from 1998 to 2006 which have used the data collection tool administrated through web and paper-based. Overall, the existing review of different research reveals that a response rate of 40.50% with a valid questionnaire of 81 is good to draw a conclusion on drones' applications for safety in the GCC region". The results show that the average response rate of the web survey was 33.87% while the paper-based response rate was 44.56%. Since the questionnaire used in this research was a web base and was distributed through email, thus the response rate received (= 40.5%) is considered satisfactory. The majority of the respondents (30.86%) were from the United Arab Emirates, followed by Qatar (21%). The participant's distributions among different GCC countries are shown in figure 3. The mean total experience of the respondents was 18 ± 4.5 years while the mean experience in safety was 9 ± 5.3 years. A total of 21 participants (25.92%) expressed that they or their company had used the drone in different activates.

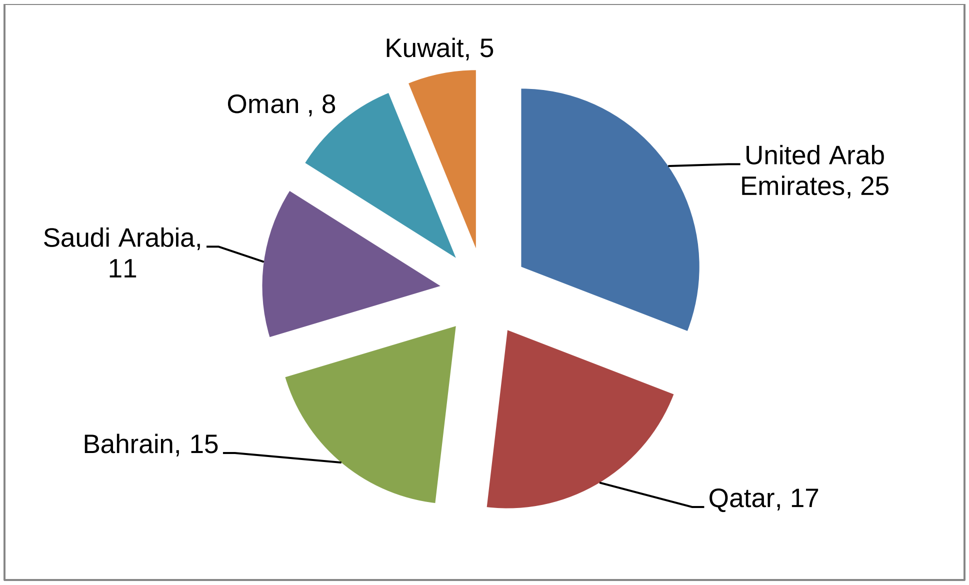

Figure 3: Participants Distribution among GCC Countries

A total of 15 respondents (18.51%) reported that they have a certificate in safety. 53% of the respondents (43) stated that they are registered a Professional Engineer/ Chartered Engineer in a local or international engineering organization. Similarly, 21 participants (25.92%) were having an academic qualification at the Master level, 51 participants (62.96%) were having an academic qualification at Bachelor level and the 9 remaining participants (11.11%) were having an academic qualification at Diploma level. All the respondents who participated in the study were male and foreigners from different countries as mentioned in figure 4.

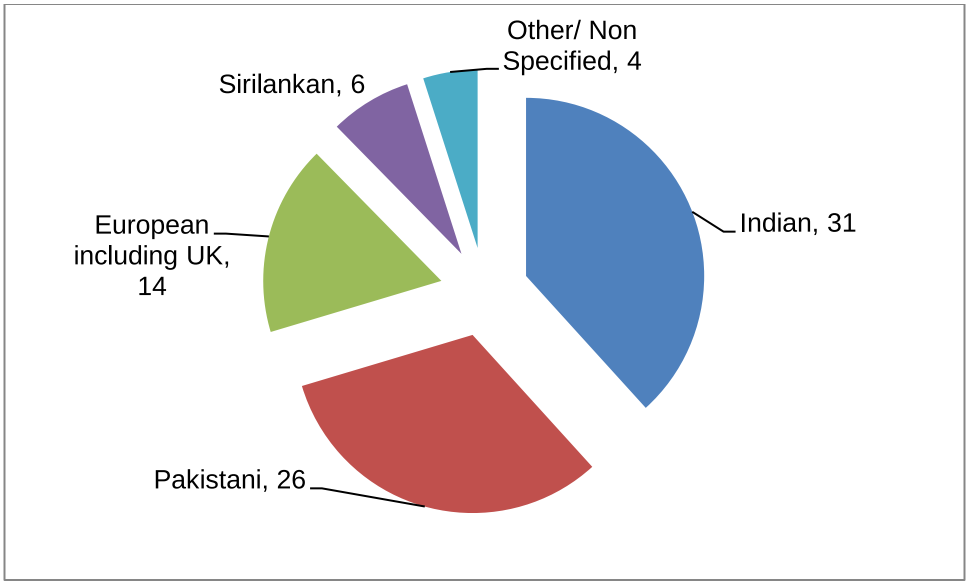

Figure 4: Participants Ethnicity

The majority of the respondents (45 out of 81) stated that they are currently working on a kind of infrastructure project. 30 participants classified their current project as a building project while the remaining 6 participants indicated their response as ‘other’ which means their current project cannot be classified as infrastructure or building. 65 of the participants (80.24%) noted their current project as new construction. The project value in which the respondents are currently working is indicated in table 2.

The ratio between skewness and its standards error for age was +0.52. Similarly, the ratio between kurtosis and its standard error for age was +1.42. Both the ratios were found to be less than +1.96, which reflect the normality of data. The correlation between age, experience, and qualifications of the respondents was found to be significant at the 0.05 level (2 tailed). The internal reliability of all the Likert items along with age, experience, and qualifications of the respondents was checked by calculating Cronbach's Alpha (α) using SPSS and was found to be 0.636. A generally accepted rule is that α of 0.6-0.7 indicates an acceptable level of reliability, and 0.8 or greater a very good level. However, values higher than 0.95 are not necessarily good, since they might be an indication of redundancy (Hulin et al., 2001; Ursachi et al., 2015).

Table 2: Average value of Respondents Projects

Average Project Value	Responses (%)
Greater than US$ 20 Million	31
US$ 10 Million to 20 Million	26
US$ 5 Million to 10 Million	15
US$ 1 Million to 5 Million	12
Less than US$ 1 Million	11
Other	5

Considering the number of parameters used in the questionnaire, the results, and the discussion section is further divided into four sections. Each section is therefore presented separately.

3.1 General Application of Drones:

In the questionnaire, the participants were asked to rate their familiarity with the drone on a Likert scale of 1 to 5 (1 = low, 5 = high). The mean value of the responses received was 2.60, which means that the respondents were somehow familiar with the drone and its usage. Similarly, 21 participants responded that their companies are using or have used drones for different applications in construction as described in table 3. A significant relationship ($p = 0.04$) was observed between the participants' responses and the project values in which they are working. The most common application of drones reported by the respondents was photography for marketing purposes followed by surveying application and quality inspections. Participants (~74%) who responded that they are not using the drone in their projects provided some reasons for not using this technology. These reasons can be divided into four main categories. The first main reason reported by the respondents was that they have not yet identified a specific area for which a drone could be used. The second reason reported was the cost of the drone. The participants considered that the drones are very costly and their budget doesn’t allow its use. The third reason reported by some of the respondents reflects their views that the use of drones in construction is too early. In other words, they were in view that for what purpose the drone could be used in construction, they have already the systems and processes for such purpose. These respondents also viewed drone technology as a very new technology for the construction industry which still has a lack of expertise and such technology is particularly affected by the economic condition of the region which is highly influenced by the oil and gas prices. The fourth reason reported by the respondents was that there are alternative tools available that could be used instead of drones. The particular example mentioned by a few respondents was the topographic survey for which google earth, google map and Geographic Information System (GIS) application can be easily and economically used.

Table 3: Application of Drone in Construction Projects

Application of Drones	**Respondents (%)**
Arial Photography - Marketing	44
Surveying - Topography	40
Quality Inspection	35
Safety Inspection	31
Measurement	24
Progress Monitoring	19
Site Monitoring	17
Other	15

The next section presents the results and discussion of the safety-related application of drones in construction.

3.2 Safety-related Application of Drones:

In one of the sections of the questionnaire, the participants were asked to report how frequently the drone was used by the respondents to improve the safety at workstations and how much these drones were effective. The participants have to rate their responses on a Likert scale of 1 to 5 (1 = low, 5 = high). A total of 16 items identified through the literature review and semi-structured interviews were included in this section of the questionnaire. The mean values of each item used and rated by the respondents were calculated. The results show that item No. 1, 3, 4, 7, and 9 (working near the corner or edge of the unprotected opening, inspecting fall protection system, housekeeping inspection, working with the hazardious materials, and using boom vehicles or cranes overhead power line) - (table 4) were significant ($p = 0.05$) when the positions and qualifications of the respondents were considered. A negative relationship was however observed between respondents' positions with item No. 2 “Accident Investigation” (- 0.24) and 4 (- 0.199) at a significance level of 0.05 (two-tailed). Similarly, the statistical results show that there is however no significance when the age groups of the respondents were compared with most of the safety-related activities shown in table 4 ($p > 0.05$) using one way ANOVA test. A significant relationship ($p < 0.05$) was however observed between the experience, qualification groups of the respondents, and the safety-related activities shown in table 4 using one way ANOVA. Similarly, a significant relationship ($p < 0.05$) using one way ANOVA was also observed using age, experience, qualification groups, and items 1(camera movability), 3 (sense and avoid capability), and 5 (high-precision outdoor navigation) of table 5. Likewise, Wilcoxon test was conducted to test the equality of the respondents' opinions with respect to their age, experience, and considering the items in tables 4 and 5. There was, however, no equality in the response of the participants using the above said variables.

To effectively understand the results, an important factor was calculated by multiplying the mean score of effectiveness and frequency. The results are summarized in table 4. The results show that “working near the corner or edge of unprotected opening” with an effective mean of 3.35, frequency mean of 3.16, and importance factor of 10.59 was the most effective and frequent function of the drone to improve the safety at the workplace. This function was followed by “accident investigation” with an effective mean of 3.31, a frequency mean of 3.14, and an importance factor of 10.39. The function of “inspecting fall protection systems” through drones was ranked as the third most effective (mean score = 3.28), most frequent (mean score = 3.08), and most important (importance factor = 10.39) function that could improve safety at worksites. Furthermore, the respondents considered the function of “Inspecting ergonomics condition” as the least effective and frequent function of the drones for improving the safety of workplaces. The calculation of the importance factor mentioned in table 4 could be helpful to understand the significance of the drones to improve the safety of each item and related activities. Clearly, the results show that the most important activity which can be improved using drones is the monitoring near the corner or edge of the unprotected opening. There have been few studies that considered the application of drones for power line inspection and maintenance, however other areas of safety were seldom in focus (Golightly and Jones, 2005; Deng et al., 2014). It is therefore anticipated that the results of this research will open doors for researchers to consider these areas, particularly in GCC contexts.

Table 4: Effectiveness, Frequency and Importance factors of Using Drone to Improve Safety at Workplaces

S.No.	Safety-Related Activity	Effectiveness - Mean	Frequency - Mean	Importance Factor (Effectiveness x Frequency)
1	Working near the corner or edge of unprotected opening	3.35	3.16	10.59
2	Accident Investigation	3.31	3.14	10.39
3	Inspecting fall protection system	3.28	3.08	10.10
4	Housekeeping inspection	3.16	3.02	9.54
5	Inspecting ladders or scaffolds	3.11	2.99	9.30
6	working in a trench	3.08	2.92	8.99
7	Working with the hazardious materials	3	2.87	8.61
8	Inspecting of Personal protective equipment (PPE)	2.91	2.75	8.00
9	Using boom vehicles or cranes (overhead power line)	2.89	2.7	7.80
10	Working with boom vehicles or cranes	2.74	2.67	7.32
11	Working near the blind spot of heavy vehicles/ equipment	2.64	2.61	6.89
12	Inspecting rigging operation	2.59	2.53	6.55
13	Inspecting confined area entries	2.55	2.41	6.15
14	Sending safety messages to workers	2.51	2.24	5.62
15	Inspecting guarding for machinery	2.45	2.19	5.37
16	Inspecting ergonomics conditions	2.41	2.14	5.16

3.3 Technical Requirements and Features:

A total of 14 items were used in this part of the questionnaire the respondents were asked to rate their responses on a Likert scale of 1 to 5 (1 = low, 5 = high). The top three rated features to improve workplace safety monitoring and control as shown in table 5 include camera movability (4.45), autopilot (4.41), and sense and avoid capability (4.32). The results show that all these items were significant ($p = 0.03$, 0.017, and $p = 0.04$) when positions, experience, and value of the projects of the respondents were considered. The drone camera movability refers to the drone's ability to tilt and pan the video sensor. Camera movability in all three axes allows safety managers to obtain the maximum visible angle of the work area to conduct an enhanced safety inspection. The drone system normally consists of four main components including the onboard processor, on-board sensors, the autopilot system, and the drone’s hardware. The on-board processor in the drones will receive the location information of the scheduled inspection visit. Then, it will send this information to the autopilot system via ”Mavlink” (Ashour et al., 2016). Autopilots provide critical functionality for the efficient and dependable operation of drone platforms (Bregu et al., 2016). A drone on autopilot can fly a programmed route, called waypoints, and take aerial photos or videos much better than any pilot can. This is especially true in difficult weather conditions. A drone flying in autopilot mode is monitoring and adjusting its position thousands of times per second. The third top-rated feature is Sense-and-avoid capability. This feature can help to detect cooperative and non-cooperative objects including machinery, humans, and structures near the drone, and conduct evasive maneuvers if a collision might occur. A collision avoidance feature should also be considered a proactive safety measure and should, therefore, be incorporated in drones.

The fourth top rated feature of the drone is real-time video communications. Drones might play the role of safety officer assistants that can fly over large or remote areas and help the safety officer to be more efficient and to conduct site inspections more frequently and potentially at a lower cost than that of traditional site inspection approaches. Since the majority of inspection sites are outdoors, the drone system should be able to precisely navigating in an outdoor environment (mean = 4.19). Such high-precision outdoor navigation should be considered another proactive safety measure for drone applications in the workplace. Participants also considered the compatibility of drones with other portable devices such as mobile phone, iPad, and laptop as one of the top-rated features (mean = 4.09). This may be because such devices are normally used at workplaces and have become an integral part of our life. Thus integrating these devices with the drones was expected to well conceive. The response of participants in relation to portability (mean = 4.01) also reflect that drone and control station should have the flexibility to be easily transported to different locations. The next top-rated feature was the durability of the drone (mean = 3.78. This finding implies that the drone's components should be able to withstand the typical environment of a construction project, with overall sturdiness and lasting quality to protect against drops, dust, and water. Simple user interface (mean = 3.61), high-resolution mapping capability (mean = 3.54), real-time audio communications (mean = 3.44), motion detector (mean = 3.26), thermographic/infrared camera/sensor (mean = 3.17) and high-precision indoor navigation (mean = 3.11) were the least some of the least important features based on the rating from the respondents.

Table 5: Important Technical Features Required to Improve Site Safety

S.No.	Drone Technical Feature	Mean Score
1	Camera movability	4.45
2	Autopilot	4.41
3	Sense and avoid capability	4.32
4	Real-time video communications	4.23
5	High-precision outdoor navigation	4.19
6	Compatibility with mobile devices/ computer	4.09
7	Portability	4.01
8	Durability	3.78
9	Simple user interface	3.61
10	High-resolution mapping capability	3.54
11	Real-time audio communications	3.44
12	Motion detector	3.26
13	Thermographic/infrared camera/sensor	3.17
14	High-precision indoor navigation	3.11

Similarly, the most rated average height for which the respondents would need to fly the drone for safety-related inspection was 50 m (mean = 4.06). Some of the respondents, however, also mentioned the height of 100 m to fly the drone for safety inspection (mean = 3.74). The respondents rated the unreachable area as the most frequent area for which they indicated that they would need to use a drone for safety inspection (mean

= 4.10). Similarly, the most frequent distance for which the participants would like to use the drone was noted as 150 m (mean = 4.26). The respondents were also asked to rate the location for which they would like to use a drone for safety inspections. The outdoor location (mean = 4.14) followed by indoor location (mean = 3.96) were the top-rated locations for which the respondents would use the drone for a safety inspection. The participants noted that they would need to use the drone for at least 1 hour to complete the safety-related inspections (mean = 4.20). Some of the respondents also mentioned 30 minutes are enough for such inspections (mean = 3.84). Some researchers reported that the drone cost significantly increases if the drone is required to be used for a continuous long-flight-time (1 to 2 hours) (Eiris and Gheisari, 2017). The respondents rated videos (mean = 3.98) and pictures (mean = 3.74) provided by drones as the most important data they would use to execute safety-related tasks.

The next section describes the barriers to use the drone for safety applications in the GCC region.

3.4 Barriers to Use Drones for Safety-related Tasks in GCC Construction:

Typical barriers to use drones for safety-related tasks were identified through a review of existing literature. These identified barriers were social, legal, financial, and logistic in nature. A total of 15 items were used in this part of the questionnaire. Respondents were asked to rate them on a Likert scale of 1 to 5 (1 = low, 5 = high). These items and their mean scores are presented in table 6. The safety concerns of using drones at job sites were rated as the most important barrier (mean = 4.15) by the participants. This item was rated as a top significant item ($p = 0.011$) when the experience of the participants was considered. Such safety concerns and unsafe circumstances are normally associated with the use of drones that might be occurred from the collision and falling to the distraction of other construction workers. In other words, the respondents considered the use of drones at the construction site as a safety hazard. In this regard, the findings of the study conducted by Namian et al. (2018) also suggest that workplace distractions can adversely affect hazard recognition, safety risk perception, and safety performance. They also classified the use of drones in the construction as one of the distractors which can possibly affect the safety performance of the workers. This open new door for further research and investigation that how this new safety hazard created by the use of drones on construction sites can be managed by developing appropriate safety measures. Technical challenges associated with the use of drones for safety improvement was rated as the second most important barrier by the participants (mean = 4.11). Gheisari and Esmaeili (2019) noted that the battery life, payload, radio interference, and sensor types mounted on drones are examples of some complex technical issues for safety managers that should be clarified before using a drone on a construction site. The third top-rated barrier as rated by the respondents is associated with liability and legal concerns (mean = 4.04). Such liability and legal concerns could be ranged from personal injury and property damage that could be caused by drone driver error to issues such as violation of privacy, trespassing, property rights, or insurance issues. Obtaining a license from the concerned aviation authority and several conditions to this effect to use the drones at construction sites was among the legal concern noted by the respondents. The next two important items rated by the respondents were an operator requirement (mean = 3.98) and a training requirement (mean = 3.81). in many countries, it is a legal requirement that a drone operator should be certified by the local or international organization. For instance in Oman, such information related to drone operators is required before a license is granted to use a drone (PACA, 2015). Similarly, Safety officers and other authorized persons who will need to operate a drone may require extensive training to obtain the pilot certification. The next top-rated barrier concluded from the participant's responses was the weather conditions (mean = 3.76). Different weather conditions including wind, rain hot climatic conditions, rain, and snow can affect the use of drones for safety inspections. The GCC region is commonly known for its hot climatic condition and fast-moving wind (Umar and Egbu, 2020). In such a situation the performance of the drone in relation to safety inspection could be limited as compared with other regions with mild climatic conditions.

Generally, the adaptation and implementation of new technology required some investment. Such investment could be of different forms including hardware, software, and system integration (Baumers et al., 2016). In this study, two items were used related to investment and economic conditions. The large investment (mean = 3.54) for the use of drones for safety improvement was rated as a more important barrier than the overall economic condition of the region (mean = 3.49). The current economic condition of the GCC region was well reported in the research conducted by Umar et al. (2018) in which a comparison of the contracts awarded in 2017 and 2018 was made. The next two items which were closely rated by the respondents are technology awareness (mean = 3.28) and different nature construction projects (mean = 3.23). In this regard, it should be noted that the majority of the construction workers in the GCC region are foreigners who came to work in GCC countries from different Asian countries (NCSI, 2017). Most of these workers have a low level of educational level and are classified as illiterate (OSC, 2016). In a situation when the drones will be flying over the workers who have a low educational or technological background, it may create some uncertainty or safety hazards. This factor, however, needs to be further investigated considering the specific GCC working environment. Similarly, the application of drones for safety inspection could only be limited to some specific projects. The application of drones for safety inspection could be more appropriate for the projects that are in the form of tall buildings and large infrastructure projects.

Apart from the above-discussed items which were considered as important barriers, there have been some other items which were somehow the least important barriers as mentioned in table 6. These items (barriers) include regulations related to a safe distance of a drone, dynamic of construction projects, confined and congested areas, using the drone at night, and communication with the craft.

Table 6: Rating of Barriers to Use Drones to Improve Construction Safety in GCC Construction

S.No.	Item	Mean Score
1	Safety Concerns	4.15
2	Technical Challenges	4.11
3	Liability and legal concerns	4.04
4	Requirement for operator	3.98
5	Training requirement	3.81
6	Weather conditions	3.76
7	Large Investment	3.54
8	Uncertain economic situation of the region	3.49
9	Awareness of Technology	3.28

10	Limitation of application due to different nature projects	3.23
11	Regulations related to safe distance of a drone	3.19
12	Dynamic of construction projects	3.15
13	Confined and congested area	3.08
14	Using the drone at night	2.96
15	Communication with the craft	2.87

In the same section of the questionnaire, participants were asked to provide specific items that could be enablers of the drone for safety improvement. This was asked through an open-end question. The reported strengths and advantages of drones in safety-related applications were particularly related to inspection hard-to-reach areas and reduce safety hazards. One of the respondents noted that the drone can allow to easily inspect the tall communication tower. Fast and easy inspection of safety compliance trough drones was another enabler mentioned by two respondents. One of the respondents mentioned the monitoring of safe work behavior through the drones as an important advantage of using the drone for safety improvement. Similarly, another respondent highlighted the assistance of the drone images and videos for the effective investigation of the accidents at the construction site. Overall, the strength and advantages of using drones for safety inspections at construction sites are one of the important elements that might convince construction organizations GCC region to use drones in their projects. The findings of this research could be useful for the construction organizations in general and for the GCC region in specific to understand different parameters of drones applications for the safety-related task including desirable technical features, the key issues involved in the adaptation and implementation of drones in safety inspections, and the strength and advantages that construction organizations could gain. One of the main limitations of this study is that only 26% of the participants reported that their organizations are using drones for different activities in their projects. The results, however, could be more robust once more participants have the experience of using drones at their construction sites. This study, however, still presents some interesting results that could lead the construction organizations and the decision-makers to adopt drones for safety-related tasks.

Conducting a similar study at a later stage, once sufficient construction organizations in the GCC region will have used drones in safety inspection; will provide more accurate and reliable results to understand different parameters of drones for safety improvement.

The next section provides a conclusion of the whole study.

4. Conclusion:

Accidents resulting in injuries and fatalities not only in construction but also in other sectors have a huge financial implication and negatively all the stakeholders and the society. The main effort to reduce the number of accidents is to improve safety performance by identifying and controlling the hazards at workplaces. For this an effective mechanism of inspection is mandatory. Technological advancement has revolutionized our industrial sectors by different means. The use of UAVs such as drones for different operations is one of the best examples of such technological advancement which has not only reduced the manpower requirement but also the cost. This article attempted to investigate the applications of drones for the improvement of safety performance in the GCC context. The construction industry in the GCC region is one of the main industrial sectors based on investment and employment. The value of different planned development projects in GCC for the year 2019-2020 is the US $ 2,563,966 Million. A large number of development projects in the region may result a number of issues and concerns. Safety is to remains one of the concerns. This study was therefore conducted to examine the effectiveness of using drones to improve safety-related activities particularly identifying hazardous situations, identify the ideal technical features of such drones, and find out the barriers and enablers of using drones for safety improvement in the region. A mixed research method that included both quantitative and qualitative approaches was used. The initial data was collected through a qualitative method in which the existing relevant literature was reviewed and semi-structured interviews with 10 industry professionals were conducted. A structured questionnaire was developed and distributed through emails and the data was collected from 92 participants working in the construction industry of different GCC countries. the results show that working near the corner or edge of the unprotected opening, accident investigation, inspecting fall protection system, housekeeping inspection, inspecting ladders or scaffolds, working in a trench, working with the hazardous materials, inspecting of PPE compliance, using boom vehicles or cranes (overhead power line), and working with boom vehicles or cranes are some of the most important safety-related tasks which could be benefited from using drones on a construction site. Similarly, the results show that camera movability, autopilot, sense and avoid capability, real-time video communications, high-precision outdoor navigation, compatibility with mobile devices/ computer, portability, durability, simple user interface, and high-resolution mapping capability are some of the top-rated technical features required by the safety managers to effectively use drones for construction safety improvement. The top 10 barriers of using drones for safety-related work in construction reported by the participants in this study were safety concerns, technical challenges, liability and legal concerns, the requirement for operator, training requirement, weather conditions, large investment, the uncertain economic situation of the region, awareness of technology, and limitation of application due to different nature projects. All the identified barriers associated with the use of drones for safety improvement which are social, legal financial, and logistics need to be further investigated to reduce its implications, and the drone can be effectively used for safety improvement in construction. The common enablers of the drone for safety improvement reported by the respondents were the inspection hard-to-reach areas, reduce safety hazards, an inspection of the tall communication tower, fast and easy inspection of safety compliance, and monitoring of safe work behavior. The main limitation of this study is that the sample is statistically significant however it is still small to generalize the findings. The main reason for not achieving a larger number of respondents is that the use of drones in the construction industry particularly in the GCC region is at a very early stage. Thus it is very challenging to find out the safety managers using drones for safety applications. With this limitation, the outcome of this research is expected to be fruitful for both industry professionals and academicians. The findings of this research will help the readers to know the applications of drones for safety improvement in construction, the technical requirement for such drones, and the challenges associated with its applications. Similar research after a span of 5 years or when there is evidence that more construction organizations are using drones in their projects is recommended so that to get a more clear picture and requirement of drones for safety inspection in the GCC construction industry can be obtained.

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