Drone Application for Visual Inspection and Surveying: The Case of High-Rise Residential Buildings in India

Abdussalam Shibani[1], Araz Agha[1], Karthik Ambati[1], Dyaa Hassan[1,2]

[1]School of Energy, Construction and Environment, Coventry University, CV15FB, Coventry, UK.

[2]Civil Eng. Dep., Higher Technological Institute, 10th of Ramadan city, Egypt.

Abstract - An unprecedented growth in the development of high rises is started in Indian metropolitan areas. However, construction projects are delayed due to a lack of technological advancements and accidents because of inadequate safety. Thus, the importance of drones in inspecting high rises is discussed in this study. Drone inspections are better than traditional inspection modes as they deliver more accurate data by utilising digital software. Drone inspection is a cost-effective technique of visual inspection that results in the completion of any construction project on time. Moreover, it allows inspection at a height that is inaccessible or difficult to reach for workers. Thus, it also results in a safe and secure inspection at construction sites. A mixed methodology was adopted by the researcher and the questionnaire survey was conducted to get primary data from the respondents and various sources like journals, articles, and online sources are used to gather the secondary data. Quantitative and qualitative findings are derived by the data analysis methods to get useful information. Through the feedback gathered from the survey, it is found that most of the respondents prefer drone inspection to ensure speedy, accurate and cost-effective visual inspection of high rises in the Indian construction industry. Several technological advancements such as digital cameras, infrared rays, 3D modelling, and graphical data processing are involved with drone technologies that make it more viable in visual inspection in modern days. However, security issues are prevalent in this regard to prevent the captured orthographic data from hacking; certain regulations are released by the Indian government that restricts the fly of drones in specific regions. Hence, the inclusion of suitable software to protect the data is recommended and proper licence-acquiring steps are also mentioned in this study as drones caused some security issues. Time and resource constraints are also mentioned in this study. The future scope includes research in respect of further technological advancements in drone technology and its benefits in the form of ROI in the future construction industry in India.

Keywords: Drones (UAVs), visual inspections, construction industry, high-rise buildings, residential, questionnaire, India.

I. INTRODUCTION

The construction industry plays a major role in enhancing a nation's economic development, particularly in a developing country like India. Thus, a significant amount of employment is generated by the construction industry after the agricultural sector in India. According to the latest Global Construction report, India is expected to be the world's 3rd largest construction market by 2030 after China and the United States of America (Robinson, 2019 and expected to record a CAGR of 15.7% to reach $ 738.5 billion, contributing to 9% of India's GDP by 2022 (Dixit et al. 2017). However, India's construction industry is highly fragmented and unorganized (V.P.C & N., 2020). Therefore, the construction industry needs to follow a scientific approach to ensure its potential growth as compared to the global perspective. The Indian construction industry is the least digitised sector in the country having a workforce of 40 million; 80% of them are unskilled or have minimal knowledge about recent construction technologies (Johari & Neeraj Jha, 2021). As per the report of CSDCI, a wide range of challenges are experienced by the Indian construction industry regarding low labour productivity, cost overruns, project delays and lack of technological adaptation. Thus, modern construction developers strive to adopt innovative technologies to develop establishments with high-quality assurance within the predetermined duration and cost limits (Myneni, 2021).

Major problems occurring in Indian construction sites are due to a lack of safety at work that results in unexpected delays in projects. As per the report of the British Safety Council, 80% of the Indian construction sites are unsafe for workers to work and resulting in 20% more-time inclusion and 80% over the budget of the construction project (Singh & Misra, 2021).

It increases the susceptibility of construction workers to unexpected deaths due to falls, electrocution and striking with components situated in an unorganised manner. It is evident that 38 death cases occur daily in Indian construction sites due to a lack of safety precautions (Times of India, 2019). The Occupational Safety and Health Administration examination data reveals that 39.9% of the deaths occurred due to falls, 8.5% were due to electrocution and 8.4% were struck by objects in construction sites (Andersen et al. 2019). Therefore, the utilisation of drones for inspection purposes ensures a safe monitoring activity without exposing workers to vulnerable positions.

These safety challenges are addressed by modern construction developers and can be mitigated by introducing digital techniques such as robotics, UAVs (Drones), Artificial Intelligence and others. Drones are considered the most potential option to resolve a few issues in a significant way along with obtaining real-time data regarding construction sites that are out of reach for workers. Drones are aircraft operated through remote or autonomous control without the assistance of a pilot (Al-Turjman et al. 2020). The utilisation of such systems is lesser in the construction industry as compared to other sectors such as geographical mapping, environment monitoring, forestry, filming, electric power delivery and others. However, the Indian construction industry is gradually becoming conscious of the usage of drones. Indian UAV drone market is estimated to attain a compound annual growth rate of 14.61% to $ 1,810 million by 2026 (Mishra, 2019). Drones have a wide range of use in the construction sites such as area mapping, monitoring work in progress, inspecting built-up structures, identifying construction problems and diagnosing through 3D evaluation. The inspection process in sites that are difficult to access becomes easier by means of drones. For instance, an inspection of high-rise establishments, bridges and highways can be done safely and cost-effectively by drones. The conventional mode of inspection requires developing scaffolds that are less secure for the workers and inspectors. It includes additional overhead costs along with making the situation of workers' falling off workers that leads to accidents. On that note, drones consist of cameras and sensors that act as the eye of an inspector. It captures a huge collection of images and videos of the location as compared to manual inspection by using advanced software such as AIVA (Kapliński, 2018). Images captured by drones are processed and used in later stages of constructional development. International companies such as Vinci construction, Kier, Balfour Betty and others utilise drones in construction projects extensively (Chea et al. 2020). As per the data of the UK Drone Safety register 70 to 85% of the project duration can be saved by utilising drones in regular site inspection (Tsiamis, Efthymiou & Tsagarakis, 2019). Moreover, drones also contribute to improving the quality of safety in the construction industry along with saving money and time for the project. Drones' usage at construction sites showed 55% increased safety, 52% reduction in inspection, 61% measurement accuracy and 65% improved communication (PWC, 2018).

The study will be helpful towards improving the quality of construction along with more effective cost management and safety management in the construction sites for high-rise buildings. High-rise buildings usually carry a small footprint as it has a comparatively smaller roof area along with tall facades. Because of the height, specialization is needed during construction inspections and monitoring processes. The main objective of this study is to explore the impact of advanced drone technology in high-rise residential buildings in India. It would help in evaluating both the positive and negative effects of using drone applications. The objectives of this study are explained as follows: a) explore drone technology and its applications for site management, addressing the pros and cons by i) understanding different drone technologies available and their relevance to the construction industry; ii) Understanding how to capture data and process the data by drones. b) identify the issues with conventional methods used for construction site inspections and project monitoring in high-rise residential buildings. c) explore and develop the proposed method of statement for the visual inspection process within the frame of Indian regulations and d) highlight the various challenges and limitations involved in using drones in India.

II. LITERATURE REVIEW

In India, drones were first used during the 1999 Kargil war, for conducting reconnaissance in a suitable manner (Drones in India, 2014). In the post-world war era, the focus of drone technology has diversified, expanding to civilian applications as well from being only limited to military applications. Later on, the DRDO started to develop UAVs for domestic purposes. Presently UAS is used in Indian railways for inspection and 3D mapping (DRDO, 2021). It is estimated to attain an 18% annual growth in the Indian UAV market within 2023 (Joshi et al. 2020) due to increased demand. In the global field drones are mainly classified into five major categories based on maximum gross take-off weight, normal operating altitude, and airspeed (Geospatial Applications of Unmanned Aerial Systems, (2020). However, the ministry of civil aviation, India, in the report of the Directorate General of Civil Aviation, Government of India (2021), classified drones based on their maximum weight encompassed with payload in India as follows: i) Nano unmanned aircraft, ii) Micro unmanned aircraft, iii) Small unmanned aircraft; iv) Medium unmanned aircraft and v) Large unmanned aircraft. The flying range of drones is also classified based on their weight, such as nano drones being permitted up to the range of 50 feet and micro drones up to 200 feet (Rahman & Robertson, 2019). Special flying conditions are applied for all other small, medium and large drones.

Figure 1. Flying range of nano and micro drones (Directorate General of Civil Aviation, Government of India, 2021)

2.1. Regulations

The DGCA, India has also released mandatory norms regarding the manufacturing of drones that should include 16 main components. It is supported by the statement of Nugraha, Jeyakodi and Mahem (2016) that a GNSS receiver is required to fix the position both horizontally and vertically. An autonomous system is necessary to terminate the flight. Other components include strobe lights to avoid a collision, a geo-sensing sensor, no permit take-off system and a flight controller (Pathak et al. 2019).

o Drones are not permitted to fly within the circumferential range of 5 km of international airports in 7 metropolitan cities in India. In addition, drones are not allowed within a range of 3km of any domestic, private or defence airport (Mehta, Kalra & Prasad, 2021).

o All drones except the nano drone are required to have permission from the Digital Sky online platform, through which all the requests are taken.

o Drone pilots are required to have a minimum education up to the 10th standard and be in the age group of 18 to 65 years for running drones in commercial projects (Heydarian Pashakhanlou, 2019).

o A medical clearance from the DGCA is also required for a drone pilot along with a radio operation certificate for operating medium and large drones.

o A penalty of Rs. 25,000 is charged for operating drones (excluding nano) without a valid licence and INR 50,000 for operating a drone over restricted regions (Viraktamath, 2015).

Thus, drone manufacturers are required to follow the above-mentioned norms to design and fly drones for practical applications.

2.2. Cost-effectiveness and safety perspectives of drone application at construction sites

Drones are becoming preferable for industrial applications and commercial activities due to their cost-effectiveness. Industrialists prefer to use drones for inspection activities to lower the cost of hardware used in this regard. As opined by Kumar, Balasubramanian & Raj (2016), 57.85% of the time

and 51.67% of the cost can be saved by utilizing drones in the Indian construction industry. Moreover, drones can reach up to a height that is inaccessible or difficult to reach manually. It is evident that a huge amount of investment is required to conduct an inspection at the highest points of high rises through conventional manual methods. By using drones the expense of scaffoldings, elevation platforms, and other developments can be eradicated. Moreover, a safe and secure inspection can be obtained that ensures no harm to workers associated with that project. It is found that the utilisation of drones leads to a decrease in the cost of scaffolding and inspection by 60% as compared to the manual method of inspection in the Indian construction industry (Hassija, Saxena & Chamola, 2020). Moreover, the time for inspection is also reduced by 30 minutes and more accurate visual data is obtained during the survey conducted by Shradha Land surveyor (Shradha Land Surveyor, 2021). It has resulted in the extensive use of drones in construction sites in the UK, USA and other developed nations. It is supported by the report of Balfour Beatty that £8,000 has been saved by using drones in the inspection process of bridges in West Sussex (Balfour Beatty, 2021). In accordance with Fan & Saadeghvaziri (2019), rigorous monitoring of high rises under construction can be done by drones. On the other hand, as argued by Hassan alian & Abdelkefi (2017), the fabrication of a complex control system of a drone includes a significant amount of expenditure. However, it is a one-time investment that ensures a high rate of return through its cost-effective applications in respect of inspection. Microfabrication technology is significant in this regard to produce a large number of micro-drones at a lower cost as shown in fig 2. Therefore, the Indian government is encouraging new startups under the "Make in India" program to manufacture drones in India and a few commercial UAV start-up details are mentioned in Figure 2.

Apart from those drones are effective tools to ensure a reduction in injuries in the construction industry. Drone inspections can be conducted at the highest elevations without any traffic closure and avoid exposing working personnel in that unsafe situation.
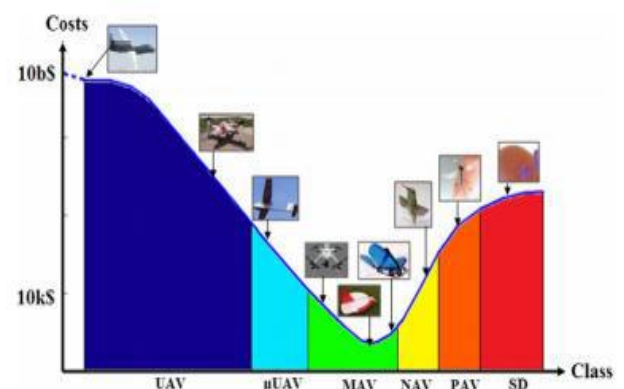
Figure 2. Schematic diagram of the cost required to fabricate different drones *(Hassan alian & Abdelkefi, 2017).*

As stated by Patrick, Nnadi & Ajaelu (2020), safety and security during construction projects are monitored by drones which results in a reduction of the chance of material loss and danger of the construction activity. In support of this Balfour Beatty made a statement that using a UAV reduced disruption and inconvenience to the public and road users and lowered potential health and safety risks at construction sites (COPTRZ, 2021). Therefore, the usage of drones in the construction industry is expected to reach $10 billion within 2026 for monitoring structures and inspections of high rises (Hubbard & Hubbard, 2020).

2.3. Advantages and disadvantages of drone application

Technological convergence has paved the way for business entities operating in different industrial sectors including the construction industry to utilise advanced technologies for maximising performance outcomes. Following the specific case of the construction sector, the use of drones as a visual inspection tool will revolutionise the construction work management process in India. Now, in the case of assessing the applicability or usage of done in construction projects for high-rise buildings, the main advantage lies in easy accessibility to inspect construction sites that are risky or difficult to reach (Mairaj et al. 2019). For example, an inspection of construction sites including high-rise buildings, bridges and highways can be easily managed using drones. Besides, it can result in reduced time for data insights for conducting build-up structure inspections of these projects, especially in the case of high-rise buildings (Boukoberine et al. 2019). For instance, the use of drones in Microsoft's Redmond campus renovation project has helped to feed data into 3 million 3D building components for over 100 models (Goodman, 2020). In the case of India, drone usage can help to uplift the process of construction project quality assessment while improving project monitoring and surveillance. Following the case of inspecting pre-construction sites, drone usage can help to track the terrain conditions while ensuring the pre-verification of sites and preparing blueprints (PWC, 2018).

In addition, considering the infrastructure industry of India with a drone-powered solutions addressable value of $45.2 billion, it can be benefited by using drones through ensuring effective collaboration and communication (PWC, 2018). Similarly, it can help to improve safety management due to less engagement of on-field workers while reducing the risk of fast-moving traffic contributing to serious hazards for onsite workers and is useful for regular site monitoring and quality inspections. Besides, in the case of using drones in post-construction management, the combined use of a drone with a digital device can result in generating 100 times more observations for ensuring effective safety plans (PWC, 2018) as shown in Figure 3.
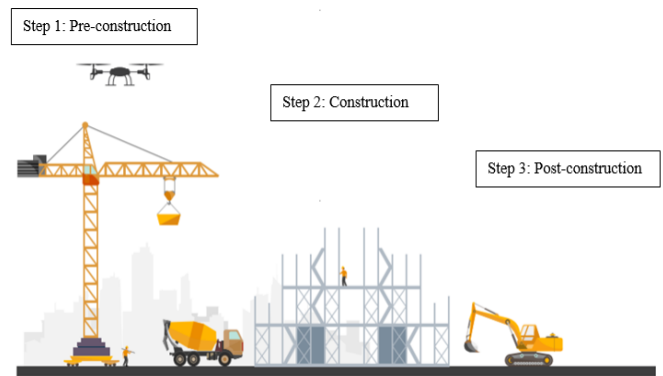

Figure 3. Use of Drones in Different Stages of Construction Projects, Developed from (PWC, 2018)

2.4. Difference between drone technology with conventional visual inspection methods

Traditional inspection methods include the closure of regular construction works and leading the technicians to climb more heights to conduct the inspection. As opined by Seo et al., (2018), a lack of expertise in monitoring construction activities is found in conventional methods along with a lot of undocumented cases regarding safety protocols. On that note, drones can capture photos of areas under inspection along with store documents in the hardware associated with them. For inspecting a large-size construction site or high rises more expenses are included in employing expert safety officers. It also leads to unexpected delays regarding the completion of the construction project. On the other hand, the inclusion of drones in inspection activities results in gathering more accuracy within the least amount of time and money along with the desired level of safety. It is supported by the data that the DJI Phantom 3 standard can cover a huge range of 8,00,000 sq metres area in less than 30 minutes (Zefri et al. 2018). Self-explanatory images of the site are obtained by the safety officer through this technology that helps them to prepare appropriate site documentation. Thus, displacing traditional methods of inspection with software-based technologies ensure both safety and quality of the project. As supported by Inzerillo, Di Mino & Roberts (2018), lightweight fibre drones can be used to reach the maximum heights of a building to conduct inspection activities appropriately.

The latest technology of phantom is used in drones to avoid collision with objects associated with areas under inspection (Salamh, Mirza & Karabiyik, 2021). Infrared cameras, laser technology and GPS are also equipped with drones to capture high-resolution images of components in a project. This kind of technology is extensively used in developed countries such as the UK, Australia and New Zealand to inspect defects in high rises to maintain the safety of the establishment. It is supported by the statement of Chen, Zhang & Min (2019), that laser scanners with LiDAR are used in modern drones. This is used for attaining a high level of accuracy in capturing images during the inspection and

survey. On the contrary negative information shown by Kumar (2019), by mentioning that a lack of technological development results in an overrun of 40% of construction projects in India. Thus, an appropriate drone inspection process is required to cope with the fast-growing demand for residential construction projects. Visual inspection by drones can be done in three steps, initially, pre-flight path design for drones is done by the FLIR tools programme and it determines the flight path (Zefri et al. 2018).

Next, IR cameras are utilized to capture images of the inspection site. Approximately 1000 to 1300 photos are captured by the cameras during the flight of drones (Rakha & Gorodetsky, 2018). Then Pix 4D programme is utilised to generate 3D cloud points from 2D images. Cad software such as Rhino 3D is used in this regard to generate 3D modelling for better analysis (Tsanakas, Ha & Al Shakarchi, 2017). In addition, as mentioned by Anwar, Izhar & Najam (2018), photogrammetric software is used by drones to analyse the project data captured through cameras and further processed to create a 3-D orientation by coupling all the images. Processing of images is performed using suitable algorithms such as geometric modelling to identify defects in the portion of a high rise under inspection (Boersma et al. 2019).

A 3-D reconstruction technique is used to convert the drone data into a 3D model for observing the portion minutely as shown in Figure 4. Also as stated by Buffi et al. (2017), overlapping between two different mages results in obtaining more accuracy in 3D reconstruction. Thus, inspectors can track the amount of material, quality of concrete pours and dimensional accuracy in structures accurately through these documents.
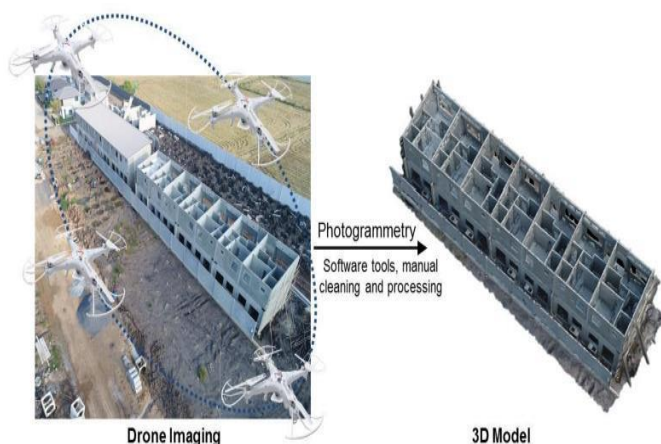
Figure 4. Conversion of drone image into the 3D model *(*Anwar, Izhar & Najam, 2018)

III. METHODOLOGY

The advanced research methodologies are divided into three categories to guide the research from its broad beginnings to a more focused and in-depth demonstration. They are qualitative, quantitative, and mixed methodology (Wiki How, 2020). By Rutberg & Bouikidis, (2018), the

quantitative method differs from the qualitative method in respect of the technique followed to analyse the data. The quantitative technique is based on the collecting of statistics and figures to evaluate theoretical goals, which can then be examined and presented in statistical and graphical formats. Whereas the qualitative method is based on linguistic wording, and the data collected by this method is usually the answers to questions such as why, where, and how, among others. However, this study is looking at both these details, so a mixed methodology is used in this research. The mixed methodology is regarded as a superior research strategy since it includes an integrated self-correcting element that boosts the research's academic reputation (Tesfaye haile & Hartono, 2017) (Shibani et al., 2022)(Hassan et al., 2021). In this study, an exploratory research design has been adopted to illustrate further research and to obtain information and data about drone application and its use in India. As opposed to Shen et al. (2021), especially in correcting the research problem, the research design is considered an effective master stroke for the researcher. Exploratory research design is capable of serving a theoretical or hypothetical idea for reducing the research problem. In this scenario, the researcher has adopted this research design to gain more informative data regarding drone usage in construction sites.

3.1. Data Collection Methods

Collecting relevant and appropriate data helps the research process to maintain its quality as well as its reliability. In the words of Rahmatizadeh et al. (2018), there are two types of data collection methods such as primary data collection method and secondary data collection method. In this study, both primary and secondary data collection methods have been applied by the researcher to lead the further process of the research positively. the current study, a close-ended questionnaire-based survey method is used, keeping in mind the objectives of the study at all times (Abdussalam et al., 2020; Dyaa etal, 2020). The data received from this survey was used to get quantitative data for this research. The survey data is collected by using Bristol online survey tool and the survey link is sent out via emails and social media. All the primary data collected in this study is collected from 101 respondents with first-hand experience people in the Indian construction industry and the survey responses summary can be found in appendix 3. The data from the survey is analysed by descriptive analysis, where raw information is interpreted in a meaningful way. The survey consists of well-structured questions that encouraged and motivated the participants.

There are mainly two sampling methods, such as probability and non-probability methods. The probability method is again classified into Simple random, Systematic, Stratified, and Clustered sampling and the non-probability method is divided into Convenience, Quota, Judgment (or Purposive), and Snowball sampling Mathers, Fox, & Hunn, 2009). However, the stratified random sampling method is used in this survey as the sample is divided into subgroups

with similar industry experience in this method. The respondents are professionals with experience in the construction industry like quantity surveyors, surveyors, planning engineers, safety engineers, site engineers, cost engineers etc have contributed to accumulating valid data regarding the research topic (Araz et al., 2021).

IV. RESULTS AND DISCUSSION

Bristol online survey tool is used to conduct the questionnaire survey on 101 participants by using the stratified random sampling method, appendix 4 contains the survey created for this study. This primary data will be analysed by descriptive analysis to evaluate the responses received from people to the survey and data is used for the quantitative findings. Descriptive analysis is the first stage of analysis, which assists researchers in determining absolute numbers, summarising individual variables and identifying trends (Calzon, 2021). A few examples are mean, median, percentages, ranges etc. In this particular scenario, the research decided to use percentages, to show the statistics of the responses in absolute numbers in a ratio of a fraction of 100. Also, this analysis method is used because the sample size is limited, and the analysis keeps the data organized so that it can be useful for further analysis.

Q 1. More safety measures are needed in the construction projects

The question tried to understand the mindset of the sample towards the existing safety standards of the construction industry.
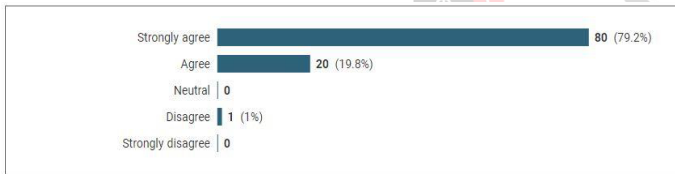

Figure 4. Safety needs in construction projects, (JISC Online Surveys, 2021)

The responses are shown in the bar chart, most of the participants agreed with the statement, as they think that more safety is needed in the construction segment. A total of 79.20% of the participants strongly agreed and 19.80% agreed with the statement. The responses convey that the chances of accidents are much higher in high-rise construction projects. More safety is essential as working in such conditions is always a risk for lives, especially in the Indian construction industry where the labour will hardly have any PPE while working at heights.

Q 2. Are you familiar with drones in construction?

The participants were asked about drones to check their level of knowledge about the latest advancements in the industry and their awareness of drones in construction. Overall, 52.50 % of the participants mentioned that they are very familiar and familiar with drones, which shows that the remaining half of

the participants were totally unfamiliar as they have never heard of drones before or their application in the construction industry. This shows the importance of this study to understand how drones improve safety standards, optimize cost savings and also increase awareness of the latest technologies available in the market as shown in Figure 5.
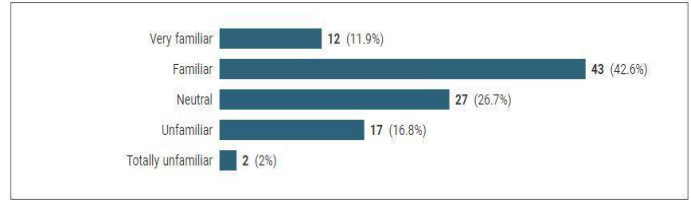

Figure 5. Familiarity with drones in construction projects, (JISC Online Surveys, 2021)

Q 3. Drones support enhancing the safety standards in high-rise buildings

This question focuses on the first objective and tried to understand the implication of drone technology towards construction site management.
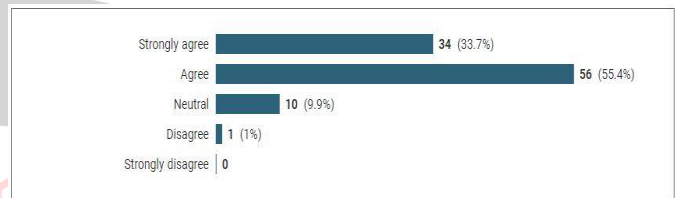

Figure 6. Safety standards with drones in construction projects, (JISC Online Surveys, 2021)

The responses are shown in Figure 6, Nearly 34 % of the participants strongly agreed that they think drones can be helpful towards enhancing the safety standard. This is supported by 57.1% of the participants who mentioned that there is a need to improve the safety standards at the construction sites. This indicates a positive response from the participants about the drones and also shows the determination in the participants about the safety enhancement in the industry.

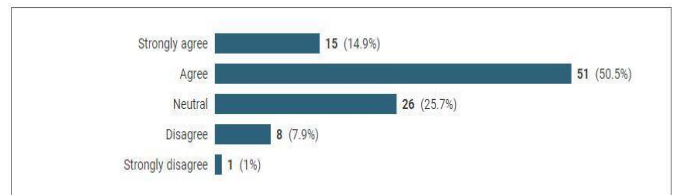**Q 4. Drones usage in construction helps in reducing project costs**

Figure 7. Reduction in project costs with drones, (JISC Online Surveys, 2021)

This question focuses on the implication of drone usage on the overall cost of the project. The responses show that participants felt that drones are viable for the effective use of resources and to reduce project costs. As shown in Figure 7. Almost 15 % of the participants mentioned that they strongly

agree using drones helps to reduce the overall project costs. Their views are supported by 50.50 % of the participants as who agreed with the statement. However, it felt that nearly 35 % of the participants think that drones can increase the overall cost. This could be because drone usage is associated with a number of additional costs and participants might have thought that these costs combined can increase the overall cost of the segment. However, most of the companies across the globe clearly stated that they were able to save money after the use of drones for inspections and in also in other activities.

## Q 5. Drones can improve the quality of inspections at construction sites

This question helps to understand the perception of the industry on the applications of drones in construction, particularly about the applicability of using drones for inspections in high-rise projects. 36.60 % of the total participants strongly agreed that they think drones will improve the quality of the inspection. This statement is agreed by 51.50 % of the participants as they agreed with the statement. Nearly 9 % of the participants provided a neutral response and 3 % disagreed, as they think the orthodox methods of inspection are working fine and they are not susceptible to change as illustrated in Figure 8.
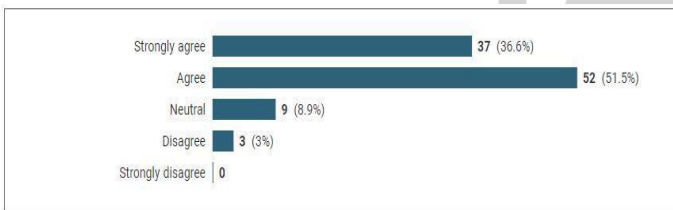
**Figure 8.** Quality inspections with drones, (JISC Online Surveys, 2021)

Q 6. Drones will identify the issues quickly during the construction process and eventually helps to make decisions immediately.

The question tries to meet the objectives of the study by understanding the importance of using drones during the construction phase of high-rise buildings and even after the construction during their maintenance stage. Figure 9 explains that More than two-thirds of the respondents agreed with the statement as they thought it would be a good option to launch drones to identify the issues quickly as everyone in the construction industry was aware that delays are directly related to cost escalations. However, 4 % of participants were not happy as they might felt that the manual and convection methods are still preferred by them.
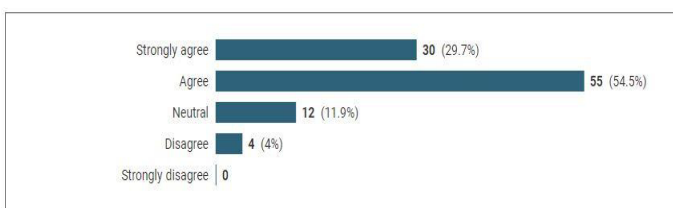
Figure 9. Drones in decision making, (JISC Online Surveys, 2021)

Q 7. Drones will make construction activities more complicated
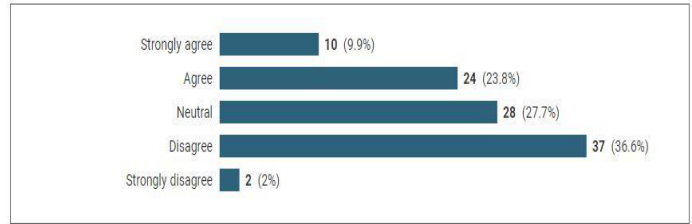

Figure 10. Complications with drones in construction projects, (JISC Online Surveys, 2021)

This question tried to understand the willingness of the industry people to incorporate new technologies without using conventional methods of practice. The data in Figure 10 illustrated that only 10 % of participants felt that, drones would make their job even more difficult for them. This statement is supported by 23.80 % of the people as they also mentioned that using drones would make the overall job more complicated. This shows the fact that the construction industry is one of those industries that do not adapt to the latest technologies. On a contradictory note, 38.60 % of people disagreed with the statement, who understands the technology and working smart with efficiency.

Q 8. The usage of drones will make the overall construction process better

The question shows the outcome of using drones to expedite projects by saving time, cost and improving safety during the construction process. The responses from the participant proved that nearly 88 % believed that drones will of great use in the construction process. This can be achieved by eliminating numerous dangers and safety hazards. Also, drones provide construction stakeholders with expansive, accurate, and precise data which will help in better planning of the projects, as shown in Figure 11.
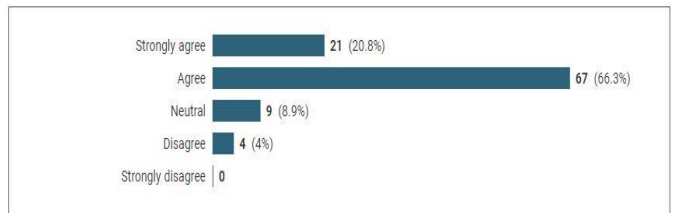
Figure 11. Drones in the overall construction process, (JISC Online Surveys, 2021)

Q 9. The government should support and/or provide free drone training to promote its usage in the Indian construction industry

This question answers the research question, the ways to overcome the challenges, and barriers to using drone technology in the Indian construction industry. The data in Figure 12 explained that nearly 34 % of the participants

mentioned that they strongly agree about the training by the government and nearly 52% of the participants supported this because the Indian government is one of the biggest barriers that is stopping the use of drones. It has got its own reasons, but the government is forgetting the positive sides of the coin and this response clearly depicts that government should support drone applications in various fields. There are few participants who disagreed with the statement as they might felt that this may cause some security issues.
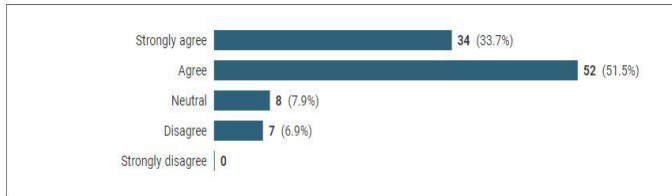

Figure 12. Government support for free drone training, (JISC Online Surveys, 2021)

Q 10. Developers should provide real-life case studies to show the effectiveness of drone usage during the construction process.

The section helps drone technology to penetrate deeper sections of the construction industry. An outstanding 94 % positive response from the participants shows that people are interested in the technology and since the government is not encouraging the respondents felt that individual construction companies should come forward and take the step forward to incorporate the drone technology.
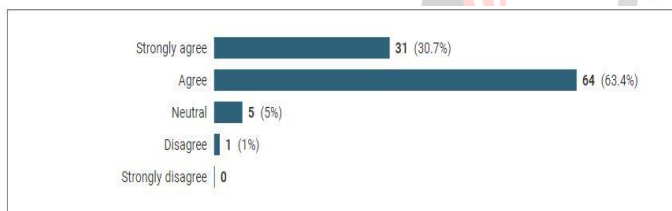

Figure 13. Developers' support for real-life case studies, (JISC Online Surveys, 2021)

V. CONCLUSION

The Indian construction industry plays an important role in the country's GDP and it is one of the major sectors of employment in India. Also, the construction sector in India is going to be the largest in the world in the coming future. However, the industry faces many challenges, and this study helps to address a few of those challenges by introducing drones into construction site management to conduct visual inspections of projects. This study has addressed the fact of cost-effectiveness, safety improvement and time consumption of drones during visual inspection processes. The mixed methodology is considered where the quantitative analysis is done by the data collected from the primary source, through a questionnaire survey conducted on 101 respondents from first-hand experience people in the construction industry. The primary data gave good results from the survey that helped the researcher to understand the present issue in construction and

the perspective of the industry toward drone technology. Also, the responses from the primary data proved the theme from secondary data and support the idea of drones for visual inspection in high-rise residential buildings in India.

Research questions are generated to address three key aspects regarding the research topic. The first question is framed to identify the extent of drone usage in the Indian construction industry and the quantitative data showed that only 52% of the participants are aware of this technology. The second question is about cost-effectiveness, safety concerns and quality enhancement of project inspections by using drones. This aspect is addressed in a comprehensive manner in the thematic study of the secondary data and primary data responses also show that 65 % agreed that drones can reduce cost and almost 90 % said that drones will improve safety at sites. To address the third question a wide range of advantages of drone inspections have been mentioned in this study and providing free training and employing an expert to control the flight of drones are the best ways to overcome the barriers to drone implication in the Indian construction industry. All the above said statements from different people from various construction companies around the globe supported and proved the results of a survey conducted in this research, where 65% of the participants agreed that drones will reduce construction costs,90 % responded that drones increase the safety at sites and 88 % greed that drones will make overall construction proves better. Also, the thematic analysis from secondary data showed evidence about the drones. finally, it can be concluded by saying that, the idea of using drones for visual inspections in high-rise buildings can save money and improve the safety standards at construction sites.

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