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RISE OF DRONES IN INDIAN CONSTRUCTION INDUSTRY

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Abstract - *Construction Industry accounts to 13% of the global GDP. Indian construction industry may grow at 10.7% in Financial Year 2022 as per government financial report [1]. This growth is expected owing to the government's increased focus on infrastructure projects and smart recovery of demand expected for residential as well as commercial segments. And yet, for the last two decades, productivity growth in construction has been very slow. According to 2016 McKinsey study, large construction projects typically take 20% longer than expected to complete and are up to 80% over budget [2]. Every other industry is moving towards new technologies like robotics and automation which benefits the growth of that sector. So, the need of the hour is a new monitoring technology which can make construction faster, save money and resources. Unmanned Aerial Vehicle (UAV) or Drone technology is the most effective among those technologies which helps in efficient project management by addressing the challenges in a construction project like surveying, monitoring activities, safety of labors, quality and cost control and getting timely on-site progress reports. Due to its remarkable improvement in software and hardware components, Drone technology acts as a visual inspection tool which provides high-resolution images and videos of the site. The Indian drone market has seen an increase of 18% CAGR (Compounded Annual Growth Rate) from 2017-2022, because of major usage in other disciplines like military and agriculture [3]. Still majority of the Indian construction industry is lagging behind in the usage of Drones. The main goal of this study is to understand the awareness level, advantages & barriers of using Drones in Indian construction industry and its cost, time & resource savings through case studies and questionnaire survey among various stakeholders of Indian construction industry. The outcome of the research illustrates Drones are a valuable replacement for conventional project management monitoring tools and a biggest boon to project managers to successfully handle large scale construction projects with considerable saving.*

Key Words: Drones, UAV (Unmanned Aerial Vehicle), construction monitoring, construction project management, surveying, Indian construction industry

1.INTRODUCTION

An Unmanned Aerial Vehicle (UAVs) or Drone is a small aircraft without a human pilot aboard. Drones consists of a control system, rotor, motor, cameras, landing gear, altimeter and communication system. Initially Drones were used only for military purposes. But in recent times, due to its remarkable improvement in software and hardware components like increased battery life for longer flights, carrying heavier payloads to hold more sensors and improved signal ranges, this new technology is finding a predominant place in construction industry making the work faster in low cost.

In 2018, the global construction sector saw a 239% increase in the adoption of Drone technology according to 'Flying High' PwC report [4]. The report states that drones help a construction project by providing increased efficiency and accuracy of a project, and eliminates the miscommunication in a project at a given point of time.

In a construction project, Drones acts as an important project management tool. Drone aids in visual inspection process such as area mapping, surveying, monitoring construction work progress, equipment & material tracking on site, inspection of buildings, identifying construction defects and 3D modelling by capturing high resolution images and videos. Drone technology can be used throughout the lifecycle of a project (pre-construction, during construction & post construction) to record and document valuable information and progress. The emerging new Drones inspection technologies like LIDAR (Light Detection and Ranging), SLAM (Simultaneous Localization and Mapping), Laser scanning, photogrammetry and Thermography along with processing software provides precise real-time scenarios [5]. Since drone maps are geotagged, it's even possible to take basic area measurements and instantly estimate stockpile volumes for real-time decision making. Drone data integration with BIM (Building Information Modelling) assists in critical analysis of a project by comparing as-built vs as-designed. Recent studies show incorporation of RFID (Radio Frequency Identification) technology along with Drones which aids in identifying equipment and material in construction site [6]. Digital tools and processes are required in construction to increase quality of work, reduce cost & time and reduce safety risks and improve project scheduling. Flight assembled architecture is the most futuristic technology envisioned, for which a 6m high tower was constructed by drones which carried 1500 polystyrene bricks in FRAC center Orleans, France [7].

2. LITERATURE REVIEW

2.1 Drones or Unmanned Aerial Vehicle (UAV)

The term Drones refers to an aircraft that is not manned physically by a pilot but works through human involvement [8]. Drones are made of lightweight composite materials. It helps in reducing the weight and increasing the manoeuvrability making it easy to fly. Drones can capture from high altitudes. The drones are controlled from the ground. Drones can be controlled remotely, often from a smartphone, tablet or a joy stick and GPS system. Wireless connectivity helps drone to capture different views. These are designed to absorb vibrations in air. A drone depends on rotors for its vertical motion. Drones have built-in cameras onboard that allows to capture images and videos where the drone is flying without having a direct line of sight to the device. Landing Gear allow Drones to set down like birds [9]. Different types of drones are multi-rotor drones, single rotor drones, fixed wing drones and hybrid drones [10, 11]. Drones can be selected depending on the usage and its pay-load capacity.

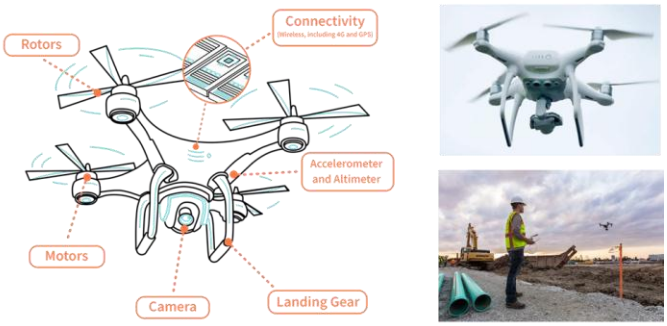


Fig 1 : Parts of Drone [9]

2.2 Potential Drone Application areas in Construction Industry

2.2.1 Site surveying

For many years, the construction industry relied heavily on professional land surveyors to perform topographical surveys which are highly time consuming and expensive as it requires bulky tools, such as tripods, total stations and GSP equipment [10]. In recent years, drone technology has entered this space to perform topographical surveys [12]. By using drones 80% is the time saving and approximately around 30% is the cost saving compared to traditional survey methods [13] . The information extracted from a drone survey is also near accurate with a satisfactory error of between 1cm for ground control points and 4cm for other parts of the survey [14]. High resolution visual cameras are the most popular one used in the industry. LIDAR (Light Detection and Ranging), SLAM (Simultaneous Localisation and Mapping), Laser scanning, photogrammetry and Thermography helps in surveying [5]. For a drone to survey and collect photogrammetry information, photos, and videos of a 20 acres site, it would take approximately 2 to 4 hours and to process the data it requires 1 hour for every one hour of flying time [15].

2.2.2 Volumetric calculation (cut and fill)

Volumetrics is one of the most popular use cases for drones on any construction site. Since the entire site can be captured in a couple of hours or less, drone data serves as an affordable source of timely and accurate information [16]. Drones helps in calculating stockpile measurements and comparing it to a final grade design file to calculate how much material needed either for cut or fill [17].

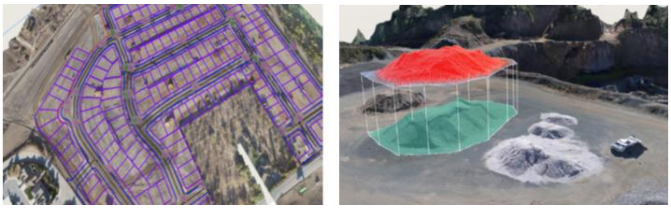


Fig 3a (left): Drone image of Site Surveying and mapping & **Fig 3b (right)**: Drones used for Volumetric calculation

(Source: DJI & Propellor – The drones in Construction Guidebook) [16]

2.2.3 Construction Project Monitoring

The conventional methods of building inspections require teams to walk across potentially dangerous rooftops and scaffolding [16]. Construction project monitoring is the key in a project to avoid cost and time over-runs and loss of resources. Drones are becoming the key tool for monitoring sites as it provides real-time data. Frequent drone inspection of construction sites helps in checking the safety of works (whether they are wearing helmets & PPE suits etc.) [18], monitoring the material storage area, preventing theft of materials, inspecting the quality of construction work done, identifying the defects and mitigating it in early stages [10]. Drones give multiple high-resolution aerial images and high-quality videos, which helps project managers getting a better overview of project progress at daily, weekly or monthly intervals aiding in the preparation of progress reports for stakeholders [19].

2.2.4 Drone images + BIM Integration (as-built vs as-designed)

Drones are capable of capturing highly-accurate georeferenced data. These Drone data can be used to create 3D models with accurate positioning information that can be readily fitted into the BIM models to visualize designs to check the as-built vs as-designed [16]. This helps in checking the project time schedules and avoid time over-runs and mitigate the risks before occurrence. A lot of researches have been conducted on Drone photogrammetry for 3D mapping

and modelling [20]. The 3D model reconstruction is performed using a regular camera, and later combining the photos from different angles. This process is known as monocular photogrammetry [5].

2.2.5 Equipment and material tracking

In a bigger construction site, different equipment will be involved and various materials in huge quantities will be put up in site. Monitoring the equipment and materials is a bigger task. This is usually a problem with a large number of different tables and documents, which are often difficult and time-consuming to keep [19]. Drones along with RFID (Radio Frequency Identification) technology helps in easy tracking of materials and equipment on site [6].

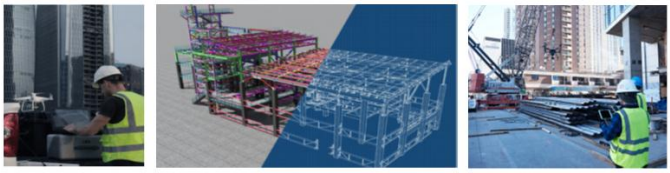


Fig 3c (left): Construction monitoring using drones, **Fig 3d (middle)** Drone images +BIM Integration to check as-built vs as-designed & **Fig 3e (right)** Asset monitoring and tracking

(Source: DJI & Propellor – The drones in Construction Guidebook) [16]

2.2.6 Damage Assessment

Assessment of damaged construction site after a flood or an earthquake is important to plan the first response, rescue and recovery [21]. Drones can help in giving High-Definition images and videos of the damaged site immediately after the disaster which otherwise would take more time if in-person assessment has to be made delaying the rescue plans [22].

2.3 Barriers in Drone Technology

There are few barriers involved in Drone technology like security and privacy issues, legal considerations, drone crashes due to bad weather or technical glitch, lack of technical knowledge to operate drones, large capital investment and air traffic [5, 23-25].

2.4 Case Examples of Drone technology saving cost, time and resources

2.4.1 Example 1

Civil contractor Grade Tech has regularly flown Drones once a week for every active project over the last year. The company estimates that in one year alone, it has saved $250,000 in operational costs and made $1.5 million in additional revenue. Savings in trucking costs, accurate volumetric calculations, or saving in crew days because a drone survey in construction site has helped in enhanced productivity and better scheduling [16].

2.4.2 Example 2

California-headquartered Sukut Construction decided to use Drones after traditional aerial surveying proved too costly and too slow for their fast-moving project needs. They were able to save $20,000 and also 3 weeks time using Drones. The contour map was prepared within two days using the drone technology [16].

2.4.3 Example 3

Established in 1937, Hensel Phelps is one of the largest general contractors and construction managers in the US is an early adopter of Drones in construction. For an exterior inspection of a 15-storey building, they used to spend a lot of money in hiring workers to set up scaffolding, and then the inspection crew would do their job; which would take weeks. But, using Drones, it took them only 4 hours to complete the flying, 8 hours to process the data, and another 4 hours to analyse it. Achieving 8x times more efficiency [16].

2.4.4 Example 4

Andhra Pradesh Real Estate Regulatory Authority (APRERA) and CIDC used drones Real time monitoring of 2,950 construction projects across Andhra Pradesh resulting in the employment of 8,850 drone operators in the state. Extrapolating these numbers for Pan-India, translates into a demand for 1,68,000 drone operators for monitoring alone [4].

2.4.5 Example 5

American Surveying (AAS) surveyed 90 acres of land which took only 3 days using drone technology which was 6x times faster than conventional method (generally would have taken 18-22 days with traditional surveying methods) [4].

2.4.6 Example 6

The Indian government is already leveraging the power of drone technology in various development programmes. Under the SVAMITVA Scheme (Survey of Villages and Mapping with Improvised Technology in Village Areas) which was launched in April 2020 to help Indian rural residents establish clear ownership of their properties. This was done using Drone technology by mapping land parcels which was done within a month. The scheme benefitted more than 6.62 lakh villages, granting financial stability to the rural population and enabling them to use their land to complete transactions/avail loans [26].

2.5 Drones in Indian Construction Industry

Productivity in the Indian construction sector is 58% higher than agricultural productivity but it lags behind

other sectors. Construction sector is one of the major employments generating sector in India that has seen a decline in its productivity over the past few years because of not adopting new technology like other disciplines. Since it is a labor-intensive industry, adopting drone technology can increase its productivity by saving cost, time and resources [22].

According to the recent 'Flying High' 2018 report by the ECI-PwC, the construction sector is expected to employ around 2.5 lakh drone operators to be implemented for various activities [4]. India has one of the fastest growing Drone markets. India imports nearly 22.5% of the world's drones. Indian Drone marked is expected to grow at 18% CAGR (Compound Annual Growth Rate) during 2017 to 2023 in terms of revenue and is estimated to reach USD 885.7 million [3, 4, 27]. In India on 15th September 2021, under 'Made in India' scheme, Union cabinet has announced Production Linked Incentive (PLI) for drone manufacturers to make India a drone hub by 2030. The PLI scheme will provide up to 20% incentive to manufacturers of drones and drone components in India as 90% of the drones are imported as of now. This scheme reinforces that drone technology will play an inevitable role in Indian construction industry in future [26, 28] [29] if there is proper awareness and understanding of this Drone applications.

3. MATERIALS & METHODS

3.1 Stage 1: Review of Secondary data

The study involves extensive and critical review of secondary data which includes books, journals, reports, case examples, government policies and news articles focusing on drones and its various applications in the Indian construction industry which is detailed in the above topic.

3.2 Stage 2: Data Collection & Analysis (Primary data)

This study involves detailed questionnaire survey to understand the awareness, application and barriers of drones in Indian Construction Industry. The study population included employees of L&T, STUP Consultants, few government officials, few Independent Architectural and construction firms in Chennai, Mumbai & Bangalore & Free-lancers. Respondents would be Architects, Civil Engineers, Consultants (MEP/Energy/Financial), Contractors, Clients & Project Managers. Access to the Sampling Frame is through Google forms & Telephonic Interviews.

3.2.1 Data Collection

Two questionnaire sets were circulated. The first questionnaire had questions pertaining to awareness and understanding of Drone technology. As part of the first survey, a sample size of 155 people was identified from the study population with more than 3 years of work experience in Indian construction industry. Out of which 146 valid responses were taken for the final analysis. The second questionnaire was circulated to the identified 56 respondents who had used drones in Indian Construction industry from the 146 valid responses. This survey helped in ranking the applications and barriers of Drone technology in terms of cost, time and resource saving in construction industry with research tool like Relative Importance Index (RII). SPSS software was used to arrive at the final results.

Table 1*:* Respondents Demographics (146 responses)

Parameters	Description	Number	Percentage
Career Position	Architects	66	45.7%
	Project Managers	13	8.7 %
	Civil Engineers	28	19.6 %
	Consultants (MEP/Energy/ Others)	26	17.4 %
	Contractor	10	6.5 %
	Client	3	2.2 %
Experience in Construction Industry	3 to 10 years	114	78.3 %
	> 10 years	32	21.7 %

Table 2: Responses to the questions (146 responses) – First questionnaire survey

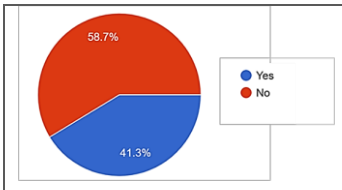


Figure 4: Awareness on the PLI scheme (Production Linked Incentive) for manufacturers of drone, launched by Central Government on 15th September 2021 in the aim of making India, a Drone hub by 2030.

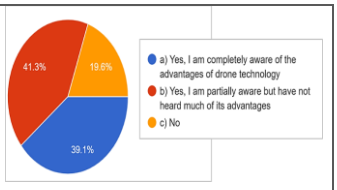
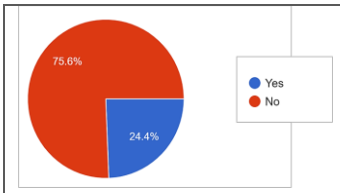
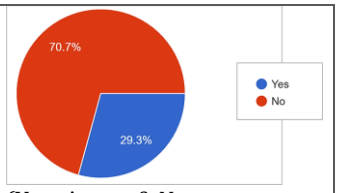


Figure 5: Awareness of drone technology in construction in Indian construction industry



(Yes- Aware & No Unaware)

Figure 6: Awareness on the capital investment of drones, its annual maintenance charges and pay-back period



(Yes- Aware & No – Unaware)

Figure 7: Awareness on the registration and licensing process of drones in India?

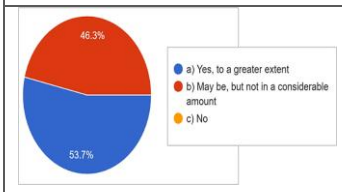


Figure 8: By using drone technology in construction projects, can we save considerable amount of cost, time & resources (man and material)?

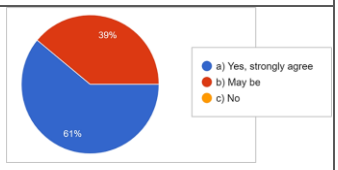


Figure 9: Will drone be the futuristic technology that would improve the quality of construction projects by bridging the gap between all inefficiencies in a project lifecycle?

3.2.2.1 Ranking the Application of drones (56 responses) – Second questionnaire survey

The second questionnaire survey helped in ranking the six major applications of Drones in construction industry in terms of cost, time and resource savings like Site surveying, Volumetric calculation, Construction monitoring, Drone images + BIM Integration, Equipment and material tracking on site and Damage assessment after a disaster at the site.

RII (Relative Importance Index) = €W/A*N *A is the highest score (3 in this case)* *N is the Total number of Respondents (56)* *€W is the Total score of the 56 Respondents*	Scoring Criteria: *3 (Most Efficient Application),* *2 (Efficient Application),* *1 (Not very Impactful*).

Table 3: Ranking the most efficient application of drones in-terms of cost, time and resource saving using SPSS software

APPLICATIONS of DRONES	Total Score (€W) (From 56 respondents)	RII (Relative Importance Index)	Ranking
Site Surveying	164	0.97	1
Volumetric Calculations (cut & fill)	136	0.80	4
Construction Monitoring	160	0.95	2
Drone Images + BIM Integration (to check as-designed vs as-built)	144	0.85	3
Equipment & Material tracking onsite	120	0.71	5
Damage assessment after a disaster	112	0.66	6

3.2.2.1 Ranking the Application of drones (56 responses) – Second questionnaire survey

The second questionnaire survey further helped in ranking the six major barriers of Drones in construction industry from highest risk to lowest risk. The six identified main barriers are Privacy, Safety issues while operation, Weather, Legal considerations, Lack of technical knowledge, large Capital investment.

RII (Relative Importance Index) = €W/A*N *A is the highest score (4 in this case)* *N is the Total number of Respondents (56)* *€W is the Total score of the 56 Respondents*	*Scoring Criteria:* *4 (High Risk),* *3 (Medium Risk),* *2 (Low Risk),* *1 (No Risk)*

Table 4: *Ranking the Barriers of drones in-terms of cost, time and resource saving (Highest risk to Lowest risk) using SPSS software*

BARRIERS of DRONES	Total Score (€W) (From 56 respondents)	RII (Relative Importance Index)	Ranking
Privacy	180	0.80	2
Safety Issues while operation	172	0.76	3
Weather	148	0.66	4
Legal Considerations	196	0.87	1
Lack of Technical knowledge	120	0.53	5
Large Capital Investment	92	0.41	6

4. RESULTS AND FINDINGS

The results of the first questionnaire survey helped in understanding the awareness level of Drone technology in Indian construction industry. 58.7% respondents (Figure 4) were aware of the PLI scheme launched by the Government of India on 15th September 2021. Around 49.3% (Figure 5) respondents were completely aware of Drone technology, 39.1% were partially aware and 19.6% were not aware. Around 75% (Figure 6) respondents were unaware of the capital investment, its maintenance cost and pay-back period of drones. Only 29.3% (Figure 7) were aware of the registration and licensing process of drones in India. 53.7% (Figure 8) respondents agreed drone will save cost, time and resources in a construction project and 61% (Figure 9) respondents opted that drone will be the futuristic technology in bridging the in-efficiencies in a construction project.

The results of second questionnaire survey helped in ranking the major applications and barriers of drones in construction industry. Surveying and Construction monitoring being the two top rated applications in terms of cost, time and resource savings and Legal considerations and Privacy being the two top rated barriers of drones.

5. CONCLUSIONS

Efficient project delivery has been a key challenge in construction industry. With rising project management issues like cost over-runs, time over-runs and shortage of skilled labor, it is important for innovative monitoring solutions like drone technology (UAV) implemented as a project management tool to solve all in-efficiencies in a construction project. The main aim of this comprehensive study is to show how drone technology can save cost, time and resources in a construction project with case examples and through questionnaire surveys have attempted to study the awareness, application and barriers of drone technology in Indian Construction industry.

Among the samples studied, it has been observed that there is a good level of awareness of drones in Indian Construction industry but less interest shown to use the same technology. The lack of awareness in initial capital investment, registration process and legal considerations are the main reason for low level of usage in Indian construction industry. Drone technology can be used throughout the construction project lifecycle. Drone data have perfect accuracy and can be recorded for future use. Drone inspection of site during construction helps in identifying the risks earlier and mitigating it with proper plan. Because of regular monitoring, re-work cost and time is considerably reduced or avoided. Project report can be made easily with every day project progress high quality photos from drone trips and check as-designed vs as-built with the BIM model. By proper equipment tracking and monitoring of equipment and materials on site, theft and site congestion can be prevented. Drones engaged safety monitoring helps preventing fatal accidents in site. Hence drone is an inevitable need in large-scale construction projects.

Central Government projects have already started using Drone technology (eg. Statue of Unity, Light House Projects etc.) [30, 31]. Private construction companies and firms should involve this drone technology which would cost approximately 8-12 lakhs Indian Rupees including hardware, software and licensing fee with an annual maintenance of 2-3 lakhs Indian Rupees [15] but has a good pay-back period resulting in more of tangible and intangible benefits. NHAI (National Highway Authority of India) in July 2021 had made Drone monitoring mandatory for all future highway projects for monitoring different stages of development, construction, operation and maintenance. The collected drone videos of each highway project will be saved on NHAI's portal "Data Lake" to assess the progress made on the projects [32]. Awareness on the PLI scheme should be created among the Indian Construction Industry stakeholders so they understand the Return on Investment (ROI) of drones which is more beneficial at the end of a project. Still more training and awareness needed on the licensing of drones, technical knowledge to operate and its safety norms among the stakeholders to appreciate its

advantages. It can be concluded that Drones are going to be the much-needed technology which will bridge all the inefficiencies in a construction project and act as an effective project management tool.

5. RECOMMENDATIONS

Few seminars and workshops can be conducted by government and private sectors on Drone applications & India's drone-related policies which includes the PLI schemes, licensing process of drones, DGCA (Directorate General of Civil Aviation) approvals, legal considerations and obtaining drone operators permit [4, 23, 33]. This will help in increasing the usage of drones in Indian construction industry as still the stakeholders are concerned about the safety and legal issues of using drones which is inferred from the samples studied.

REFERENCES

1. *Indian construction GDP*. 2022; Available from: https://www.moneycontrol.com/news/business/real-estate/construction-sector-expected-to-witness-double-digit-growth-of-10-7-in-fy22-govt-7912591.html.

2. *Mckinsey Report 2016*. Available from: https://www.mckinsey.com/business-functions/operations/our-insights/imagining-constructions-digital-future

3. *Indian Drone market*. Available from: https://www.6wresearch.com/industry-report/india-unmanned-aerial-vehicle-uav-market-2017-2023-forecast-by-types-by-uav-range-applications-regions-competitive-landscape#.

4. Report, P., *Flying High.* 2018.

5. Israr, A., et al., *Internet of Things (IoT)-Enabled Unmanned Aerial Vehicles for the Inspection of Construction Sites: A Vision and Future Directions.* Mathematical Problems in Engineering, 2021. **2021**: p. 9931112.

6. Hubbard, B., et al. *Feasibility Study of UAV use for RFID Material Tracking on Construction Sites*. 2015.

7. Fan, J. and M. Saadeghvaziri, *Applications of Drones in Infrastructures: Challenges and Opportunities*. 2019.

8. Irizarry, J., M. Gheisari, and B.N. Walker, *Usability Assessment of Drone Technology as Safety Inspection Tools.* Electronic Journal of Information Technology in Construction, 2012. **17**: p. 194-212.

9. *Working Principles of drones*. Available from: https://www.re-thinkingthefuture.com/technology-architecture/a2327-how-can-drones-help-architects-in-the-future/.

10. Li, Y. and C. Liu, *Applications of multirotor drone technologies in construction management.* International Journal of Construction Management, 2018. **19**: p. 1-12.

11. *Types of drones*. Available from: https://electricalfundablog.com/drones-unmanned-aerial-vehicles-uavs/.

12. Musonda, I. and N. Pillay, *Using UAV's and BIM integration to improve infrastructure delivery – A case of Gauteng Department of Infrastructure Development, South Africa*. 2019.

13. *Dronedeploy*. Available from: https://www.dronedeploy.com/resources/stories/top-enr-firm-brasfield-and-gorrie-evolved-their-drone-program/.

14. El Meouche, R., et al., *UAV PHOTOGRAMMETRY IMPLEMENTATION TO ENHANCE LAND SURVEYING, COMPARISONS AND POSSIBILITIES*. Vol. XLII-2/W2. 2016.

15. Tal, D.a. and J.a. Altschuld, *Drone technology in architecture, engineering and construction : a strategic guide to unmanned aerial vehicle operation and implementation*. 1st ed.

16. DJI, P., *The Drones in Construction Guidebook.* 2020.

17. *Volumetric calculation*. Available from: https://www.propelleraero.com/blog/how-stockpile-volume-measurement-works-in-drone-surveying-with-propeller/.

18. Gheisari, M., J. Irizarry, and B. Walker, *UAS4SAFETY: The Potential of Unmanned Aerial Systems for Construction Safety Applications*. 2014. 1801-1810.

19. Tkáč, M. and P. Mesároš, *Utilizing drone technology in the civil engineering.* Selected Scientific Papers - Journal of Civil Engineering, 2019. **14**: p. 27-37.

20. Kaamin, M., et al., *The Application Of Micro UAV In Construction Project.* Malaysian Construction Research Journal, 2018. **2**.

21. Ye, S., et al., *Automated Detection of Damaged Areas after Hurricane Sandy using Aerial Color Images*. 2014. 1796-1803.

22. Dastgheibifard[1], S. and M. Asnafi, *A Review on Potential Applications of Unmanned Aerial Vehicle for Construction Industry.* 2018.

23. Charlesraj, V.P. and R. Nijalingamurthy, *Stakeholder Perspectives on the Adoption of Drones in Construction Projects*. 2020.

24. Tatum, M.C. and J. Liu, *Unmanned Aircraft System Applications in Construction.* Procedia Engineering, 2017. **196**: p. 167-175.

25. Albeaino, G. and M. Gheisari, *Trends, Benefits, and Barriers of Unmanned Aerial Systems in the Construction Industry: A Survey Study in the United States.* Journal of Information Technology in Construction, 2021. **26**: p. 84-111.

26. *India Brand Equity Foundation*. Available from: https://www.ibef.org/blogs/indian-drone-industry-reaching-the-skies.

27. *Indian Drone market - need*. Available from: https://info.cecr.in/drones-in-indian-construction-industry/.

28. *India Brand Equity Foundation.*

29. *PLI Scheme*. Available from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1755157.

30. *Statue of Unity*.

31. *Light House Project*. Available from: https://timesofindia.indiatimes.com/india/drones-used-for-live-review-of-new-tech-housing-projects-by-pm-companies-commit-to-complete-them-before-time/articleshow/84102584.cms.

32. *NHAI Drone monitoring*. Available from: https://www.thehindu.com/news/national/use-of-drones-mandatory-for-nhai-projects/article34831893.ece.

33. *UIN*. Available from: https://www.pwc.in/industries/financial-services/fintech/fintech-insights/data-on-wings-a-close-look-at-drones-in-india.html.