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Drone-Based Technologies for Surveying and Construction Monitoring

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ABSTRACT

The construction industry is changing quickly because of new technology. One important development is the use of unmanned aerial vehicles (UAVs), also called drones. These drones are becoming a powerful tool for surveying land and monitoring construction sites. Traditional methods of surveying sites and tracking construction progress often take a lot of time, require a lot of manual work, and can lead to human errors. In comparison, drones with high-resolution cameras, LiDAR sensors, and photogrammetry software can collect data quickly and accurately, even in large and complex construction areas, while also reducing costs. This technology provides real-time aerial images and 3D models. These help teams make better decisions, plan projects more effectively, and reduce delays. Drones play a varied role in construction site management. For surveying, UAVs can generate contour lines, topographic maps and digital elevation models with high precision, facilitating design verification and earthwork calculations. Drones also help monitor construction sites. They can track construction progress in real time and help managers see how resources and workers are being used. Regular aerial inspections allow teams to spot safety risks, structural problems, or differences from the planned design early, which helps reduce risks and avoid expensive rework. In addition, drones can monitor environmental factors such as dust levels, water runoff, and whether the site is following environmental and sustainability regulations.

Keywords: Drones, UAV, construction surveying, photogrammetry, LiDAR, RTK, progress monitoring, volumetrics, BIM, regulations.

1. INTRODUCTION

Traditional surveying and monitoring (manual surveys, periodic site walks, terrestrial scans) are time-consuming, expensive. In recent years, the construction industry has witnessed a remarkable transformation fueled by technological advancements. Among these innovations, drones have emerged as game-changers, redefining the way construction projects are planned, executed, and maintained. Equipped with sophisticated sensors, cameras, and GPS (global positioning system) technology, drones offer unparalleled capabilities to capture real-time data, generate accurate 3D models, and conduct remote inspections. Drones offer safe, repeatable, and high-resolution remote sensing that can be flown frequently to produce Ortho mosaics, digital surface/terrain models (DSM/DTM), 3D point clouds, and thermal/visual inspection imagery — enabling near real-time situational awareness for project managers, surveyors, and safety officers. Their adoption has accelerated due to improvements in sensor payloads, positioning (RTK/PPK), and processing software. The integration of drones with Geographic Information Systems (GIS), Building Information Modeling (BIM), and cloud-based project management platforms further enhances collaboration among stakeholders. Data collected by drones can be analyzed through artificial intelligence (AI) and machine learning (ML) algorithms to provide predictive insights, enabling proactive decision-making. In addition, drones significantly reduce the need for manual inspections in hazardous or hard-to- reach areas, improving worker safety. Overall, the adoption of drones in surveying and monitoring construction sites improves accuracy, efficiency, and safety while lowering costs and timelines. This transformative in the technology is reshaping construction practices, making project execution more transparent, sustainable, and aligned with the evolving demands of smart construction and digital infrastructure.

Drones have rapidly evolved from being mere novelties to indispensable tools in the construction sector. By utilizing different types of drones, construction professionals can optimize their workflow, improve project coordination, and mitigate risks. Surveying drones, equipped with high-resolution cameras and LiDAR (light detection and ranging) sensors facilitate precise mapping, topographical analysis, and site planning. These drones capture detailed aerial imagery and generate comprehensive 3D models, enabling architects and engineers to make informed decisions about building placement, design optimization, and resource utilization. Inspection drones, on the other hand, provide an unprecedented advantage in assessing hard-to-reach or hazardous areas of construction sites. Equipped with thermal cameras, high-resolution imaging systems, and even artificial intelligence, these drones enable efficient and accurate inspections of infrastructure, buildings, and equipment. By swiftly identifying structural defects, monitoring construction quality, and ensuring compliance with safety regulations, inspection drones contribute to enhanced project transparency, reduced manual labor requirements, and improved overall project outcomes.

1.1 Applications in Construction

Drones rapidly map site topography at high resolution for preconstruction surveys, cut/fill planning, and baseline documentation. They reduce time compared to conventional total station or GNSS roving methods while maintaining acceptable accuracy for many earthwork tasks.

Volumetric calculations and earthworks monitoring frequent drone surveys allow accurate stockpile and earthwork volume estimation and tracking of quantities over time (cut/fill reconciliation). Photogrammetry and LiDAR both provide volumetric outputs; choice depends on required precision and surface complexity. Studies validate UAV-derived volumes against conventional methods showing small errors when adequate control and processing are used. Progress monitoring and schedule control Orthomosaics and 3D models captured periodically enable automated or manual comparison against project schedules and 4D BIM, supporting progress verification, earned-value tracking, and early detection of delays. Regular imagery improves transparency for stakeholders.

As-built verification and quality control High-resolution 3D models allow comparison of as-built conditions to design models (BIM) for clash detection, dimensional checks, and quality control — improving handover documentation and reducing rework.

2. TYPES OF DRONES

Fixed-wing drones offer several advantages for civil engineering applications but also come with a few disadvantages. They have longer flight times compared to rotary-wing drones. Their efficient forward flight allows them to cover larger areas and remain airborne for an extended period, which is beneficial for large-scale surveying and mapping projects. These drones can cover larger distances in a single flight due to their higher speed and endurance. This increased coverage area makes them ideal for large-scale topographic surveys, aerial inspections, and monitoring of construction sites.

Fixed wing drones are generally more stable in windy conditions than multi-rotor drones. Their aerodynamic design and ability to withstand gusts allows them to maintain stability and capture high-quality imagery even in challenging weather. They have a higher payload capacity, enabling them to carry heavier equipment such as high-resolution cameras and LiDAR sensors. This capability allows them to capture detailed aerial data for the precise mapping, 3D modeling, and volumetric analysis of construction sites. However, fixed-wing drones have some disadvantages to consider. They have limited maneuverability and cannot hover or fly in tight spaces like rotary-wing drones. This restricts their ability to inspect vertical structures or perform close-range inspections in congested areas. Furthermore, it requires a relatively longer runway or open area for take-off and landing compared to vertical take-off and landing
(VTOL) drones. This can be a constraint in sites with limited space or challenging terrain
. Operating fixed-wing drones often requires skilled pilots due to their advanced flight characteristics and longer flight distances. Pilots need expertise in planning flight paths, con ducting pre-flight checks, and coordinating with air traffic authorities, if necessary. In general, fixed-wing drones are more expensive than rotary-wing drones due to their sophisticated design and advanced flight capabilities. The initial investment required for a fixed-wing drone system can be a barrier for small-scale civil engineering projects or businesses with limited budgets. While fixed-wing drones offer significant advantages in terms of flight time, coverage area, and stability, their limited maneuverability, longer take-off/landing requirements, complex operation, and higher initial cost should be considered when selecting the appropriate drone for civil engineering applications.

Rotary-Wing Drones Rotary-wing drones, also known as quadcopters and multi-rotor drones, have their ownset of advantages and disadvantages when used in the civil engineering field. Rotary wing drones provide excellent maneuverability and the ability to hover, making them well-suited for close-range inspections of vertical structures and operating in tight spaces. Their agility allows for detailed inspections of construction sites and infrastructure
providing valuable data for engineers and project managers. These drones have shorter take-off and landing requirements compared to fixed- wing drones. They can perform vertical take-offs and landings, eliminating the need for a runway or open area. This makes them more suitable for operating in confined construction sites or areas with limited space. Rotary-wing drones are relatively easier to operate compared to fixed- wing drones. They can be flown bypilots with less training and experience, making them accessible for small-scale civil engineering projects or businesses with limited resources .

The main disadvantage of rotary-wing drones is their limited flight time. They have shorter endurance due to the energy-intensive nature of hovering and maneuvering. This restricts their coverage area and makes them less suitable for large-scale surveys or monitoring projects that require long flight times. Furthermore, it can be

affected by wind and gusts more than fixed-wing drones. Their small size and lightweight construction make themmoresusceptible to wind disturbances, which can impact flight stability and the quality of captured data. Compared to fixed-wing drones, rotary-wing drones have lower payload capacities. They can carry lighter equipment such as small cameras or sensors, which may limit their capabilities for high- resolution mapping or advanced data collection tasks. In summary, rotary-wing drones offer advantages in terms of maneuverability, close- range inspections, and ease of operation. They
are suitable for small-scale projects and operations in confined spaces. However, their limitations include shorter flight times, susceptibility to wind, and lower payload capacities. 2.3. Hybrid Drones Hybrid drones combine the features and capabilities of both fixed-wing and rotary wing drones. They can take off and land vertically like rotary-wing drones, allowing them to operate in tight spaces and perform close-range inspections. At the same time, they can transition to fixed- wing flight for efficient forward flight, enabling them to cover larger areas and achieve longer flight times. This flexibility makes them suitable for a wide range of civil engineering applications. Hybrid drones offer extended flight times compared to traditional rotary-wing drones. By transitioning to fixed- wing flight, they can conserve energy and cover larger distances in a single flight. This is advantageous for conducting large-scale surveys, mapping, and monitoring projects that require longer f light durations. The combination of vertical take-off and landing capability and f ixed-wing flight allows them to carry larger cameras, LiDAR sensors, or other equipment. This enhances their capacity for detailed data collection, such as in high- resolution mapping or 3D modeling of construction sites. However, hybrid drones have some disadvantages to consider. They are generally more complex to operate compared to single-mode drones. Pilots require specific training and expertise to
handle the transition between vertical and fixed-wing flight modes, as well as understanding the nuances of operating a hybrid system. Furthermore, hybrid drones may have higher initial costs compared to single-mode drones as the integration of both fixed-wing and rotary-wing capabilities requires additional engineering and design, leading to a potentially higher purchase price.This cost factor may limit their accessibility for smaller civil engineering projects or businesses with limited budgets.

According to the flight plan, the on-site team flew the drone at a height of 70/120m autonomously. The drone mounted with a 3-axis gimbal and a 24MP camera captured high- resolution images. It took us 70 flight Minutes to capture the data for the entire section. We used 2 pre-charged batteries in order to make use of the full daylight.

2.1 Data Processing

- Image sorting
- Photogrammetry Software- Agisoft Metashape.
- Align Images
- Generate Dense Cloud
- Generate DEM
- Orthomosaic Generation

2.2 Post Processing

Esurvey Cadd- To generate the Contours & Volume Calculation. An orthomosaic image is a high-resolution, georeferenced aerial or satellite image that has been orthorectified and stitched together from a collection of individual images. The term "orthomosaic" is derived from "ortho," meaning correct or true to scale, and "mosaic," indicating that multiple images have been combined to create a seamless, single image. The file is compatible with ARU, Esri, AutoCAD and Bentley design software, therefore, existing plan can be easily superimposed on Ortho mosaic. It can also be used to better understand the site at the time of survey. Ortho mosaic image is used to properly define the boundaries of the waste and mark them to accurately calculate the area of the waste which will further be multiplied by depth to obtain the volume.

Table 1: Client & Project Details

Client	Greater Noida Industrial Development Authority
Project Area	Lakhnawali Legacy Waste Remediation Site
Property Status	Owned by Greater Noida Industrial Development Authority

A DEM file, or Digital Elevation Model file, is a digital representation of terrain topography that stores elevation data for specific geographic locations. DEMs are widely used in various applications, including geographic information systems (GIS), cartography, land use planning, environmental modeling, and earth sciences.

DEM files store elevation data, representing the height or depth of the terrain at specific locations in Colour coded format. The elevation values are typically measured in meters above/below a reference point, such as sea level.

DEM files was generated from our Aerial survey and levels were obtained using dem file.

DEM Files was loaded in Global Mapper software and a Grid of 5 x 5mtr was marked and elevations for corners of every grid were obtained using DEM Model. This data was further feeded to Esurvey cadd Software along with levels to obtain both the contours.

2.3 Topography of Lakhnawali Legacy Waste Site:

Lakhnawali waste site area is located in Greater Noida in the state of Uttar Pradesh. It is 32 km away from Hindon Airport, Ghaziabad City. We conducted flights across area sprawling over Approx 19.14 Acres.

For Volumetric analysis we require two levels, one top and one bottom. Area is marked on ortho mosaic image and divided into parts in a 5 x 5 m grid pattern. Average of differences of bottom and top level of corners of Grid are multiplied by area of the grid to get the volume of waste. 9 no of pits were dug to obtain bottom levels of waste in dumping yard. Top levels are obtained using drone survey. All the work calculations for volume are done in ESurvey-Cadd software to get accurate results.

Table 2: UAV Specifications

UAV Details	
Weight (Battery & Propellers Included)	< 2 Kg
Maximum Speed	10 m/s
Maximum Service Ceiling Above Sea Level	400 m above take off point
Maximum Flight Time	40 minutes
Operating Temperature Range	-10° C to 50 °C
Drone Category	Micro
Type of Drone	PPK Based Survey grade Drone
Camera Resolution	24 MP Sony Camera
Satellite Systems	GPS/ GLONASS/SBAS

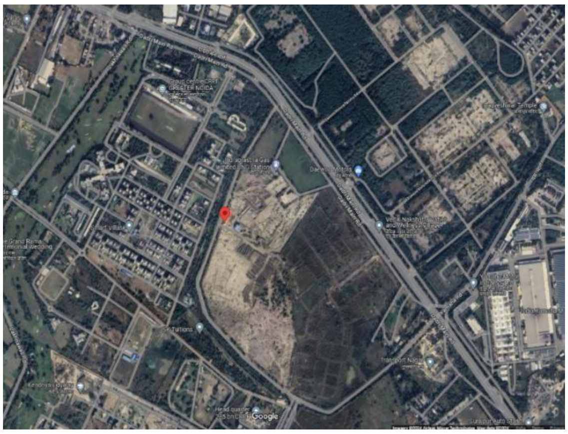

Fig. 1 : Satellite Image of the area

3. RESULTS AND DISCUSSION

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Fig 2: Orthomosaic of Study Area

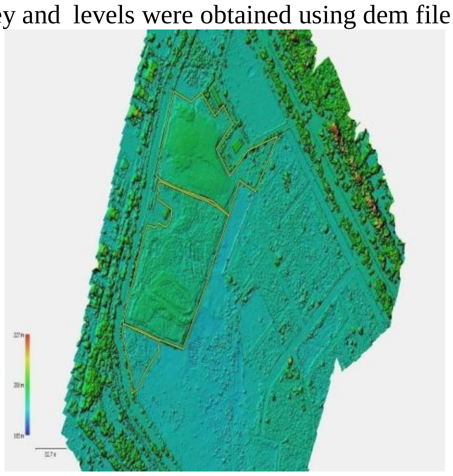

Fig 3: Orthomosaic of Study Area

DEM Files was loaded in Global Mapper software and a Grid of 5 x 5mtr was marked and elevations for corners of every grid were obtained using DEM Model. This data was further feeded to Esurvey cadd Software along with levels to obtain both the contours

Table 3: Area & Volume report

Name of Area	Area	Volume
Part 1 Left Side Waste Area	30216.04 Sq mtr	2,47,913.806 Cum
Part 2 Center Waste Area	41568.40 Sq mtr	3,16,091.947 Cum
Fresh Food Waste Area	5691.50 Sq mtr	19,108.058 Cum
Total	**77475.961 Sq mtr**	**5,83,113.811 Cum**

4. CONCLUSION

This study demonstrates the practical effectiveness of UAV-based surveying through a case study conducted at the Lakhnawali Legacy Waste Remediation Site in Greater Noida, covering an area of approximately 19.14 acres. High-resolution orthomosaic images and DEMs generated using a PPK-enabled drone and photogrammetry techniques enabled accurate contouring and volumetric analysis. The site was divided into 5 × 5 m grids, and drone-derived top levels combined with ground-observed bottom levels allowed precise estimation of waste volume, which was found to be about 5.83 lakh cubic meters.

The case study confirms that UAV-based surveying significantly reduces survey time, manpower, and safety risks while delivering reliable data for large and complex sites. Integration of drone outputs with Global Mapper and ESurvey-CADD software further improved accuracy and usability for engineering analysis. Overall, UAV technology proves to be a fast, safe, and cost-effective solution for construction surveying, volumetric assessment, and planning of remediation and earthwork projects.

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