

SURVEYING USING DRONE TECHNOLOGY AND DGPS INTEGRATION

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ABSTRACT

Surveying has undergone significant transformation with the adoption of modern geospatial technologies such as Unmanned Aerial Vehicles (UAVs), commonly known as drones, and Differential Global Positioning System (DGPS). Conventional surveying methods, although accurate, are often time-consuming, labor-intensive, and difficult to apply in inaccessible or hazardous terrains. Drone-based surveying offers rapid aerial data acquisition, high-resolution imaging, and efficient generation of topographic maps, orthomosaics, Digital Elevation Models (DEM), and 3D surface models. When integrated with DGPS, the positional accuracy of drone-derived spatial data improves substantially, enabling centimeter-level georeferencing suitable for engineering and cadastral applications. This review paper presents a comprehensive study on surveying using drone technology and DGPS integration by examining the working principles, data acquisition workflow, equipment, accuracy parameters, applications, benefits, and limitations. The study also discusses the role of Ground Control Points (GCPs), Real-Time Kinematic (RTK), and Post-Processed Kinematic (PPK) corrections in improving survey precision. Based on literature and practical developments, the paper concludes that drone surveying integrated with DGPS is

a highly effective, accurate, and economical solution for modern civil engineering, infrastructure planning, land development, and environmental monitoring.

KEYWORDS

Drone Surveying, UAV Photogrammetry, DGPS, GNSS, RTK, PPK, Ground Control Points, Orthomosaic Mapping, DEM, Civil Engineering Surveying

1. INTRODUCTION

Surveying is one of the most essential activities in civil engineering, land development, transportation planning, irrigation, urban planning, and construction management. Traditionally, surveying has been carried out using chain, compass, plane table, total station, dumpy level, and GPS-based methods. Although these methods provide reliable results, they often require considerable field time, manpower, and direct site accessibility.

In recent years, drone technology has emerged as a revolutionary tool in surveying and mapping. Drones equipped with high-resolution cameras, Global Navigation Satellite System (GNSS) receivers, and inertial sensors can quickly capture aerial images of large areas with high overlap, which are then processed using photogrammetric software to generate accurate maps and 3D models. UAV-

based photogrammetry is increasingly being adopted because it offers faster data collection, lower operational cost, improved safety, and high spatial resolution compared with conventional ground methods and even some traditional aerial survey techniques [1], [2]. Recent photogrammetric studies also emphasize that integrating UAVs with GNSS, IMU, and direct georeferencing workflows has significantly improved mapping quality and operational efficiency [3].

However, the accuracy of drone-based surveying depends strongly on the quality of image geotagging and control data. Standard drones without correction often provide only meter-level positioning, which may be insufficient for engineering-grade work. Therefore, DGPS integration is used to enhance positional precision by correcting satellite-based errors through a reference base station and rover or network corrections. Differential positioning methods such as DGPS, RTK, and PPK help reduce errors caused by atmospheric delay, clock drift, and orbital bias, thereby enabling centimeter-level accuracy for orthomosaics, contours, and terrain models [4], [5]. Commercial photogrammetry guidance also notes that RTK/PPK workflows can bring expected absolute accuracy into the centimeter range when properly corrected, while standard non-RTK drone positioning is much lower in accuracy [6].

This review paper aims to provide a detailed and systematic understanding of surveying using drone technology and DGPS integration, including its methodology, equipment, applications, accuracy, and practical significance in modern engineering projects.

2. OBJECTIVES OF THE STUDY

The main objectives of this review paper are:

- To study the concept and importance of drone technology in modern surveying.
- To understand the principles and working of DGPS in improving positional accuracy.
- To analyze the integration of drone surveying with DGPS, RTK, and PPK methods.
- To evaluate the workflow involved in aerial data acquisition and processing.
- To identify the major applications of drone and DGPS integrated surveying in civil engineering.
- To compare the advantages and limitations of drone-based surveying with conventional methods.
- To review recent literature and technological advancements in UAV photogrammetry and precise positioning.

3. RESEARCH METHODOLOG

This study is based on a review of secondary data collected from textbooks, research papers, journal articles, technical manuals, photogrammetry resources, and geospatial practice documents. The methodology follows a descriptive and analytical approach to examine the principles, instrumentation, workflow, and applications of drone-based surveying integrated with DGPS.

The paper includes:

- ❖ Study of conventional and modern surveying concepts
- ❖ Review of UAV photogrammetry principles
- ❖ Analysis of DGPS, RTK, and PPK correction techniques
- ❖ Comparative discussion on accuracy and

efficiency

- ❖ Examination of practical use in civil engineering and land survey applications

Relevant literature from photogrammetry and surveying sources was used to synthesize the findings and prepare a structured review [1], [3], [4], [5].

4. LITERATURE REVIEW

The application of drones in surveying and mapping has increased rapidly over the last decade due to advancements in UAV platforms, camera sensors, GNSS technology, and photogrammetric software. UAV photogrammetry has become a practical alternative to conventional topographic surveying because it can generate dense point clouds, digital terrain models, and orthophotos with high spatial resolution in a short period [1], [2]. The literature indicates that drone surveys are especially effective for large, inaccessible, or hazardous areas where conventional field measurements are difficult or risky [1].

Recent research highlights that direct georeferencing in UAV surveys can be achieved using GNSS-assisted positioning and inertial measurements, reducing dependence on extensive ground control [1], [3]. However, many standard UAV systems without correction still produce only meter-level positional accuracy, making Ground Control Points (GCPs) or precise GNSS correction necessary for engineering applications [1]. Studies on UAV-based photogrammetric production confirm that RTK and PPK methods significantly improve horizontal and vertical accuracy compared with uncorrected image geotagging [4], [5].

Technical guidance from photogrammetry platforms further suggests that with properly configured RTK/PPK drones, expected

absolute accuracy can reach around 1–2 cm horizontal and 2–3 cm vertical, depending on baseline distance, correction source, flight conditions, and processing workflow [6]. At the same time, literature also emphasizes that GCPs and check points remain important for validation and quality assurance, especially in projects demanding legal, cadastral, or design-grade precision [6].

The reviewed studies collectively show that the integration of drones with DGPS/GNSS correction methods improves survey productivity, safety, and data richness while maintaining accuracy suitable for topographic mapping, volume estimation, construction monitoring, corridor mapping, and infrastructure inspection [3], [4], [5].

5. PRINCIPLES OF DRONE SURVEYING AND DGPS INTEGRATION

Drone surveying integrated with DGPS is based on the following core principles:

5.1 Principle of Photogrammetry

Photogrammetry is the science of obtaining reliable measurements from photographs. In drone surveying, overlapping aerial images are captured and processed to reconstruct the terrain in 2D and 3D form. By identifying common points in multiple images, software calculates their spatial position and generates a point cloud, surface model, and orthomosaic [2].

5.2 Principle of Differential Positioning

DGPS works on the principle that many GNSS errors are common to two receivers located relatively close to each other. A base station is placed on a known coordinate and calculates correction values by comparing its known position with the satellite-derived position. These corrections are then transmitted or

applied to the rover/drone data to improve accuracy [4]. RTK literature notes that centimeter-level precision is achievable in seconds, though accuracy depends strongly on baseline length and atmospheric conditions [4].

5.3 Principle of Direct Georeferencing

In UAV mapping, each image is assigned geographic coordinates through onboard GNSS and IMU data. This is known as direct georeferencing. When combined with RTK or PPK correction, the photo centers are positioned more accurately, reducing the need for a large number of GCPs [1], [3].

5.4 Principle of Ground Control

Ground Control Points are clearly marked points on the ground whose coordinates are measured accurately using DGPS or total station. These points are used during processing to strengthen the photogrammetric model and improve absolute accuracy [1], [6].

6. EQUIPMENT USED IN DRONE SURVEYING WITH DGPS

The major equipment used in drone surveying integrated with DGPS includes:

- UAV/Drone Platform

Multi-rotor or fixed-wing drones depending on area and mission requirements.

- High-Resolution Camera / Sensor

RGB cameras are commonly used for photogrammetry; LiDAR and multispectral sensors may also be used.

- Onboard GNSS Receiver

Captures image geotags and supports RTK/PPK workflows in advanced drones.

- DGPS / GNSS Base and Rover System

Used to establish accurate ground coordinates and provide differential correction.

- Ground Control Points (GCPs)

Marked targets distributed across the site.

- Check Points (CPs)

Independent surveyed points used to validate final model accuracy.

- Flight Planning Software

Used to define altitude, overlap, flight path, speed, and mission geometry.

- Photogrammetry Software

Used for image alignment, point cloud generation, DEM/DSM creation, orthomosaic generation, and contour extraction.

7. WORKFLOW OF SURVEYING USING DRONE TECHNOLOGY AND DGPS INTEGRATION

The general workflow is as follows:

7.1 Reconnaissance and Planning

- Study the site boundary and terrain
- Identify obstacles, no-fly zones, and control locations
- Decide flight altitude and image overlap

7.2 Establishment of Ground Control

- Select GCP and check point locations
- Measure coordinates using DGPS (base-rover or CORS-based system)
- Ensure good spatial distribution across the project area

7.3 Flight Mission Planning

- Set flight path in grid or double-grid pattern

- Choose front overlap (typically 70–85%)
- Choose side overlap (typically 60–80%)
- Set flying height based on required Ground Sampling Distance (GSD)

7.4 Aerial Data Acquisition

- Fly the drone automatically
- Capture overlapping images with geotagging
- Maintain stable lighting and proper shutter speed

7.5 DGPS / RTK / PPK Correction

- Apply real-time corrections (RTK) during flight
or
- Apply post-processing corrections (PPK) after the mission using base station logs

7.6 Data Processing

- Import images into photogrammetry software
- Align images and generate sparse point cloud
- Insert GCPs and optimize bundle adjustment
- Generate dense point cloud, DEM/DSM, contours, and orthomosaic

7.7 Accuracy Assessment

- Compare model coordinates with check points
- Compute horizontal and vertical RMSE
- Verify suitability for design or planning use.

8. METHODS OF DGPS INTEGRATION IN DRONE SURVEYING

8.1 DGPS with Ground Control Points (Indirect Georeferencing)

In this method, the drone captures standard images while GCPs are established using DGPS. During processing, the GCP coordinates are used to accurately georeference the project. This is widely used and provides strong accuracy when GCPs are well distributed [1], [6].

8.2 RTK-Based Drone Surveying

In Real-Time Kinematic (RTK) mode, the drone receives correction data from a base station or network (NTRIP/CORS) during the flight. This improves image geotag accuracy in real time and reduces the number of required GCPs. RTK is fast and efficient for field operations, but depends on continuous communication and reliable correction signals [4], [5].

8.3 PPK-Based Drone Surveying

In Post-Processed Kinematic (PPK) mode, the drone and base station both log raw GNSS data. Corrections are applied after the flight during data processing. PPK is useful where mobile network coverage is poor or unstable and often provides highly reliable results [5].

8.4 Hybrid Method (RTK/PPK + GCPs)

This is the most robust method for engineering-grade work. RTK or PPK provides accurate image positions, while a smaller number of GCPs and check points are used for validation and model strengthening. This method is often preferred for high-accuracy projects [4], [6].

9. FACTORS AFFECTING ACCURACY

The accuracy of drone surveying integrated with DGPS depends on several factors:

- Quality of DGPS / GNSS Correction Source

Base station accuracy, CORS quality, and baseline length directly affect results [4], [6].

- Distribution and Number of GCPs

Poorly distributed GCPs can reduce model stability and increase distortion [1], [4].

- Flight Altitude and GSD

Lower altitude generally improves resolution but reduces coverage area.

- Image Overlap

Adequate forward and side overlap is essential for strong photogrammetric reconstruction [1].

- Camera Calibration and Image Quality

Blur, rolling shutter effects, or poor exposure can degrade results.

- Terrain and Vegetation

Dense vegetation, steep slopes, and reflective surfaces affect accuracy.

- Weather Conditions

Wind, shadows, and poor lighting can impact image quality and flight stability.

- Coordinate System and Vertical Datum Handling

Errors may occur if ellipsoidal heights and orthometric heights are mixed improperly.

10. APPLICATIONS OF DRONE SURVEYING WITH DGPS IN CIVIL ENGINEERING

Drone surveying integrated with DGPS has wide applications in civil engineering:

10.1 Topographic Survey

Used to generate contour maps, spot levels, DEMs, and terrain models for planning and design.

10.2 Land Development and Plotting

Useful for site layout, land subdivision, boundary visualization, and pre-construction planning.

10.3 Road and Highway Corridor Survey

Suitable for route alignment studies, earthwork estimation, and progress monitoring.

10.4 Earthwork and Volume Calculation

Stockpile measurement, cut-and-fill analysis, quarry volume estimation, and excavation monitoring.

10.5 Construction Progress Monitoring

Frequent aerial surveys help compare planned vs actual work.

10.6 Irrigation and Canal Projects

Useful for embankment inspection, command area mapping, and watercourse planning.

10.7 River and Watershed Survey

Can be used for floodplain mapping, erosion monitoring, and drainage analysis.

10.8 Bridge, Dam, and Infrastructure Inspection

Provides safe access to difficult or hazardous structures and supports deformation or condition monitoring.

11. ADVANTAGES OF DRONE TECHNOLOGY AND DGPS INTEGRATION

The major advantages are:

- High Speed of Data Collection

Large areas can be surveyed in a short time compared with conventional methods.

- High Accuracy

DGPS, RTK, and PPK can provide centimeter-level accuracy when properly implemented [4], [6].

- Reduced Manpower Fewer survey personnel are needed in the field.
- Improved Safety Hazardous, steep, or inaccessible areas can be mapped without direct human exposure.
- High-Resolution Outputs Produces orthomosaics, point clouds, DEMs, and 3D models.
- Cost Effective for Medium and Large Areas Repeated surveys become economical over time.
- Better Documentation Provides permanent digital records for future comparison.

12. LIMITATIONS AND CHALLENGES

Despite its advantages, several limitations remain:

- Dependence on Weather Conditions

Strong wind, rain, or poor visibility can affect mission quality.

- Battery Limitations

Flight time is limited, especially for large projects.

- Regulatory Restrictions

Drone flights must comply with aviation rules and permissions.

- Need for Skilled Processing

Accurate photogrammetric processing requires technical knowledge.

- Vegetation Interference

Dense tree cover can prevent accurate ground surface extraction.

- Signal Issues in Urban or Remote Areas

Multipath, GNSS blockage, or poor network coverage can affect RTK performance [4].

- Datum / Projection Errors

Incorrect coordinate system setup may cause horizontal or vertical shifts.

- Initial Equipment Cost

Professional RTK drones and DGPS systems can be expensive.

13. RESULTS AND DISCUSSION

The review indicates that drone surveying integrated with DGPS is a powerful and practical alternative to conventional survey methods for many civil engineering applications. UAV photogrammetry significantly reduces field time and improves area coverage, while DGPS-based control ensures that the spatial outputs are accurate enough for design, planning, and monitoring purposes.

Key Survey Results

Total Area Surveyed: 8.66 hectares

Survey Dimensions: 303 m × 286 m

Elevation Range:

Minimum: 560.0 m

Maximum: 578.5 m

Total Relief: 18.5 m

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Generated Outputs

Orthomosaic (high-resolution image)

Digital Surface Model (DSM)

Contour Map

Contour Details:

Interval: 0.5 m

Total Contours: 149

Elevation Labels: 70

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Accuracy Results

DGPS Accuracy:

Horizontal: $\pm 8 \text{ mm} + 1 \text{ ppm}$

Vertical: $\pm 15 \text{ mm} + 1 \text{ ppm}$

Achieved centimeter-level accuracy

Suitable for engineering design and DPR

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Terrain Analysis

1. Siltation Zone

Elevation: 560–563 m

Indicates sediment deposition and reduced depth

2. Lake Basin

Central depression observed

Uneven contour spacing → irregular bed

3. Bund Condition

Uneven elevation along bund

Shows erosion and weak sections

4. Catchment Area

Higher elevations (575–578 m)

Natural slope towards lake

Engineering Use of Results

Desilting quantity estimation

Lake capacity calculation

Bund design and strengthening

Drainage and inlet planning

DPR preparation

Discussion (Key Points)

Drone + DGPS provides high accuracy (cm-level)

Much better than normal GPS (3–10 m error)

Survey is:

Faster

Requires less manpower

Safer in difficult areas

The literature suggests that:

- Standard drone geotagging alone may be insufficient for engineering-grade work.
- DGPS-surveyed GCPs greatly improve absolute model accuracy
- RTK/PPK drones reduce field effort and can achieve high precision when corrections are reliable.
- A hybrid approach (RTK/PPK + limited GCPs + check points) often provides the best balance of speed, reliability, and accuracy [4], [5], [6].

Thus, the integration of drone technology and DGPS is highly suitable for topographic surveys, road projects, site development, stockpile analysis, and infrastructure monitoring in civil engineering.

14. CONCLUSION

This review paper concludes that surveying using drone technology and DGPS integration represents a major advancement in the field of modern surveying. Drone-based photogrammetry offers rapid, safe, and high-resolution spatial data acquisition, while DGPS provides the positional correction necessary to achieve accurate and dependable geospatial outputs. The combined system is capable of producing orthomosaics, digital elevation models, contours, and 3D models with accuracy suitable for a wide range of civil engineering applications.

Compared with traditional methods, this integrated approach reduces survey time, minimizes manpower requirements, improves safety in difficult terrain, and provides richer digital deliverables. Although limitations such as weather dependency, regulatory constraints, battery life, and processing complexity remain, the overall benefits strongly support the adoption of this technology in modern engineering practice.

Therefore, drone surveying with DGPS, especially when supported by RTK/PPK workflows and proper ground control, can be considered an efficient, accurate, and future-ready solution for topographic and infrastructure surveying.

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