Analysis And Comparison Of Volumetric Calculations For Open-Cast Mines Using Two Different Surveying Techniques: Drone-Based Photogrammetry And Traditional Total Station Method

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ABSTRACT

This study presents a comparative analysis of volumetric calculations in open-cast mining using two distinct surveying techniques: drone-based photogrammetry and conventional total station methods. The primary aim is to evaluate the accuracy, efficiency, and practicality of both approaches in estimating stockpile volumes, excavation quantities, and overall site topography within open-pit mining operations.

Drone surveys, leveraging advanced photogrammetric techniques, enable rapid data acquisition and the generation of high-resolution 3D models, offering considerable time savings and reducing the potential for human error. Conversely, total station surveys—renowned for their precision and reliability—deliver accurate ground-based point measurements. While more labor-intensive, they remain a preferred method in the mining industry, particularly for smaller areas where high precision is paramount.

This study outlines the advantages and limitations of both techniques, focusing on parameters such as survey duration, cost-effectiveness, data processing requirements, and the accuracy of volume estimations. The findings indicate that drone surveys provide a faster and more efficient alternative, whereas total station surveys excel in confined or detail-intensive environments.

Ultimately, the study underscores the potential for integrating both methods to optimize volumetric assessments in open-cast mines, combining the strengths of each for more robust and adaptive mine planning.

Keywords: Open-Cast Mine, Volumetric Calculation, Drone Survey, Photogrammetry, Total Station, Surveying Techniques, 3D Modeling, Mining Survey, Volume Estimation, Geospatial Data, Accuracy Comparison, Mine Planning, Remote Sensing, Stockpile Measurement, Survey Efficiency.

2 Introduction

2.1 Study Area Description

The study was conducted in the sanctioned leasehold located at Village Bharla, Tehsil Deoli, District Tonk, Rajasthan. The lease area spans 4.0718 hectares and is primarily exploited for Quartz and Feldspar minerals. The area lies on Toposheet No. 45-O/5 and is defined by the following boundary coordinates:

Pillar	Latitude	Longitude
A	25° 53’ 40.40” N	75° 18’ 06.68” E
B	25° 53’ 41.86” N	75° 18’ 05.90” E
C	25° 53’ 42.62” N	75° 18’ 07.89” E
D	25° 53’ 42.44” N	75° 18’ 11.11” E
E	25° 53’ 35.29” N	75° 18’ 11.09” E
F	25° 53’ 35.30” N	75° 18’ 02.47” E
G	25° 53’ 38.88” N	75° 18’ 02.47” E
H	25° 53’ 38.87” N	75° 18’ 06.68” E

The region is characterized by a semi-arid climate, with flat terrain and sparse vegetation. The topographical elevation ranges from 324 mRL to 345 mRL, making it suitable for drone-based terrain modelling.

2.1.1 Equipment Description Used for Survey

Drone Platform
Model: Surveyaan (H K & Associates)
Weight: Approx 1.9 kg
Flight Time: Up to 40 minutes
Sensor: 23 Mega pixel, Go Pro 10
Navigation System: Real-Time Kinematic (RTK) GNSS for centimeter-level accuracy
Ground Control Equipment
RTK Base Station: D-RTK 2 GNSS Mobile Station
Total Station: Trimble R10 (used for comparative surveying)
DGPS Receiver: Singular Lawrence & Mayo (GCP and checkpoint validation)

Software
Flight Planning: Surveyaan H K & Associates Processing Software
Data Processing: Surveyaan H K & Associates Processing Software
Volume & Contour Analysis: Surveyaan H K & Associates Processing Software and AutoCAD Software
Comparison Analysis: Microsoft Excel

2.1.2 Survey Planning and Data Acquisition

Flight Planning
The area was divided into flight grids for efficient data capture. The following parameters were used:
Altitude: 80 meters above ground level
Image Overlap: 80% front overlap, 70% side overlap
Flight Speed: 5 m/s
Coverage: 41.543 hectares, having mining lease area 4.0718ha.
GCPs Used: 5 well-distributed ground control points were marked using DGPS for georeferencing

2.1.3 Drone Deployment and Data Capture

The drone was flown in autonomous mode following pre-programmed flight paths. Approximately 300 high-resolution geotagged images were captured in a single flight session lasting 25 minutes. All images were stored in RAW and JPEG format for redundancy.

2.1.4 GCP Collection

Ground Control Points were identified and physically marked with high-contrast targets. Each point's coordinate was precisely recorded using DGPS to ensure sub-decimeter georeferencing during photogrammetric processing.

2.2 Data Processing Workflow

2.2.1 Photogrammetric Processing

Using H K & Associates, Surveyaan software processing software, the images underwent the following steps:
Image Alignment and key point matching
Point Cloud Generation (Sparse and Dense)
Orthomosaic Creation
DSM/DTM Generation
Contour Map Extraction (with intervals of 1m, 2m, and 5m)

2.2.2 Volume Calculation

Volumetric measurements of identified stockpiles and dumps were computed using:
DSM surface subtraction method
Grid-based interpolation with boundary constraints
Comparison with Total Station-derived volumes

2.2.3 Traditional Survey for Validation

To validate drone results, a parallel ground survey was conducted using: Total Station for contour mapping and benchmark leveling .Cross-sectioning and spot levels collected at 10m intervals. Volume estimation using trapezoidal and cross-section methods
The accuracy comparison was conducted using RMSE and percentage deviation between drone and conventional methods.

2.2.4 Total Station Survey

We have carried out the Total station mining survey of the mines. The schedule is presented in the tabulated form in table 4.1 which shows that the work was completed in seven days for covering 41.453 hectares.

Table 2.1 Total Station

S.No.	Days	Work Completion	Area
1	Day One	Grid marking and survey	15 hectares
2	Day Two	Grid marking and survey	15 hectares
3	Day Three	Grid marking and survey	12 hectares

Fig 2.1 KML of Mining Lease area.

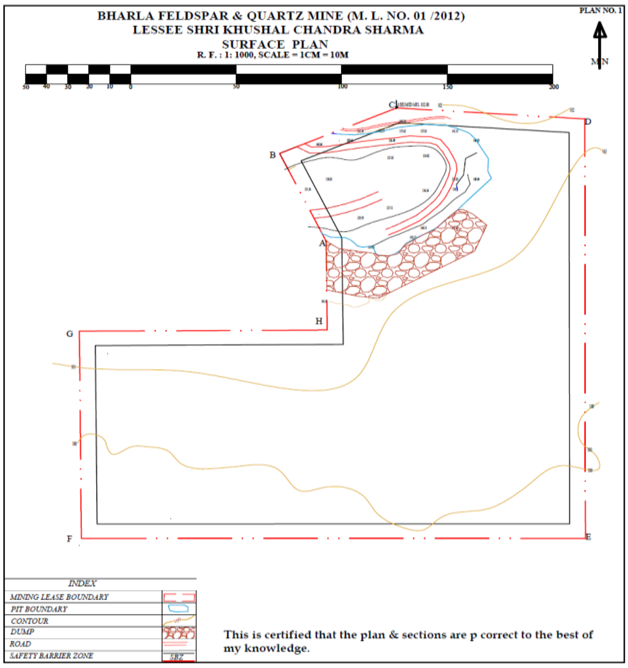

Fig 2.2 Map showing the detail surface plan prepared after Total Station Survey

Table2.2 The below table is showing the volumetric calculation done from conventional method

PIT Excavation Volume			
Level	**Area Sqm**	**Height in m**	**Volume in cum**
101-100	4567.45	1	4567.45
100-96	3656.98	4	14627.92
96-85	1883.01	11	20713.11
	10107.44		**39908.48**
Loose Dump Volume			
103-101	**1611**	**2**	**3222**

Date	**03/05/2025**
Total Area Processed	**41.543 Hectare(s)**
GSD - Orthomosaic	**3.04 cm/px**
GSD - DSM/DTM	**9.1 cm/px**
Total Photos	**490**
Camera Model	**GoPro HERO10 Black**
Photo Resolution	**5568 x 4176 px**
Position Reference	**GPS & GCP**
Photogrammetry Engine	**Surveyaan Proprietary**

Flight Path

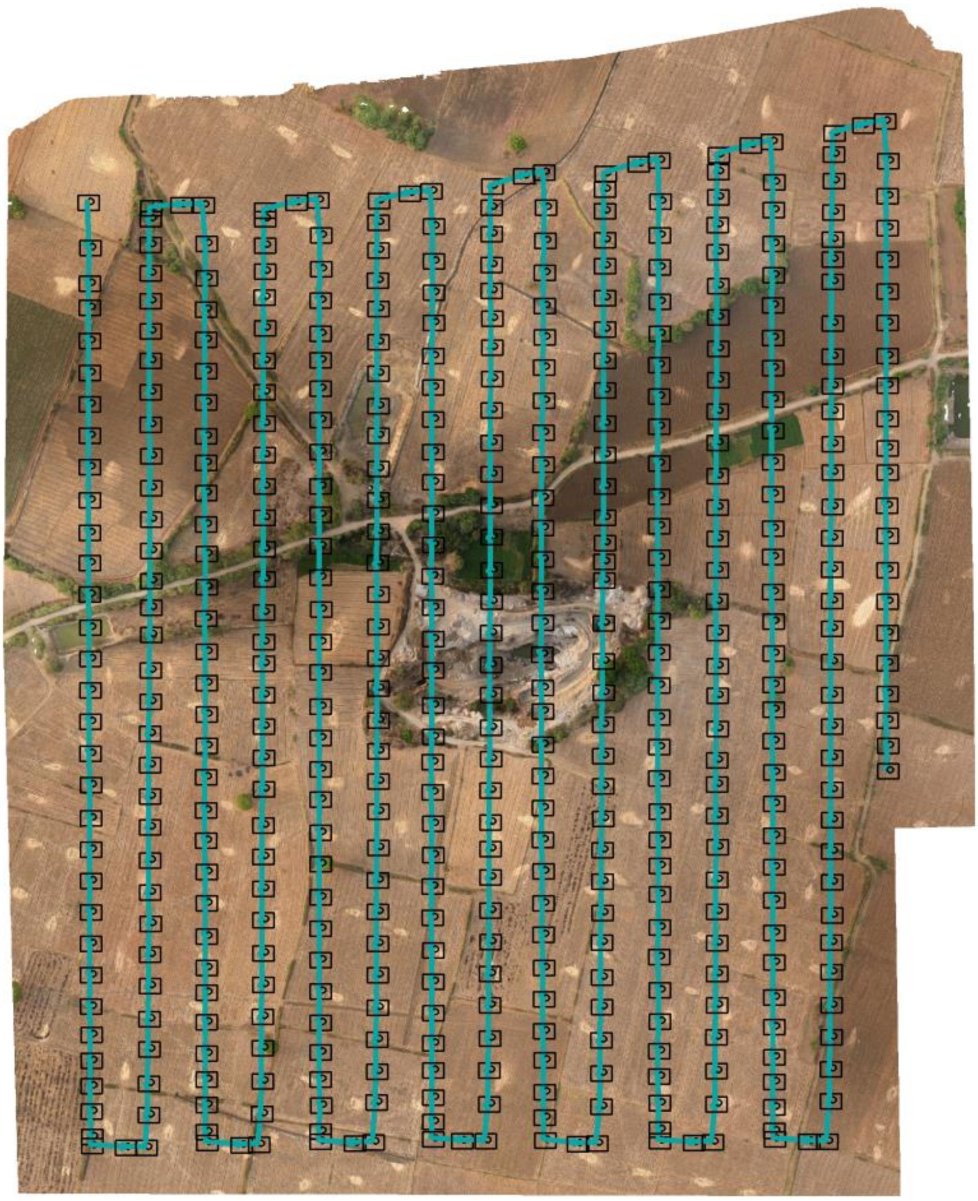

Fig. 2.3 Flight Path during the Drone Survey

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Orthophoto

Fig. 2.5 Ortho Photo generated after Drone Survey

GCP Report

GCP Number	label	X_Error (in m)	Y_Error (in m)	Z_Error (in m)
1	GCP-1	-0.011370	0.006300	0.027130
2	GCP-2	0.016150	-0.002170	-0.015440
3	GCP-3	0.007910	0.001730	-0.012770
4	GCP-4	-0.000910	-0.012400	0.020690
5	GCP-5	-0.011780	0.006540	-0.019610
Total		**0.01088**	**0.00698**	**0.01974**

Fig. 2.6 GCP report generated during Drone survey

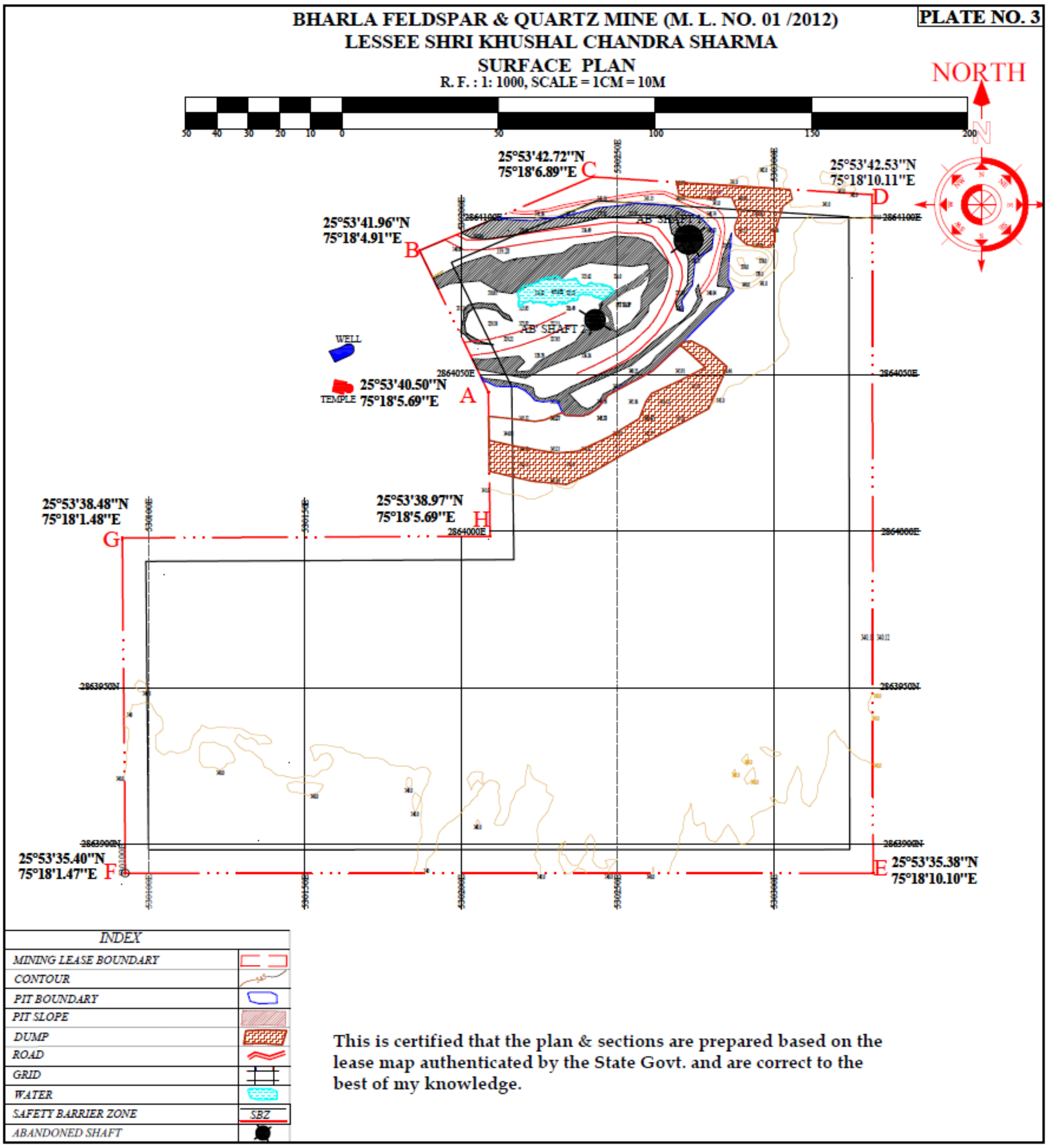

Fig 2.7 Map showing the detail surface plan prepared after Conducting Drone Survey

3. Results and Discussion

Presents the outputs, analyses the data, and compares results with conventional methods.

3.1 Technical Summary of Drone-Based Survey and Volumetric Evaluation

- The implementation of drone-based photogrammetry in the surveyed open-cast mine has yielded high-resolution spatial datasets, including Orthomosaic imagery, Digital Terrain Models (DTMs), Digital Surface Models (DSMs), volumetric data, and detailed contour maps. UAVs enabled rapid and safe data acquisition across the 4-hectare lease area, particularly beneficial in semi-mechanized, uneven terrains. Compared to traditional total station surveys, drone surveys significantly reduced field time and human effort while enhancing spatial coverage and accuracy.
- These datasets formed the basis for accurate mine planning, geotechnical evaluation, and digital modeling, contributing to improved operational efficiency and safety. Geo-referencing was achieved through DGPS-established Ground Control Points (GCPs), ensuring spatial accuracy of outputs.

3.2 Geological Observations

- The lease area is predominantly covered with 1–2 meters of overburden and alluvium, masking much of the surface lithology. Field validation revealed the presence of medium-hard granite gneiss hosting mineralized pegmatite veins containing Quartz and Feldspar. The mineralization is evenly distributed, with an estimated recovery ratio of 50:50 for Quartz and Feldspar. Field sampling and laboratory analysis confirmed the suitability of these minerals for glass, ceramics, electrodes, abrasives, and refractory applications.

3.3 Volumetric Calculation and Reserve Estimation

- Drone-derived outputs, integrated with field geological data, were used to delineate the mineralized zones and estimate reserves using the area–depth–volume method. Cross-sectional profiles were generated and validated through ground truthing.
- The reserve classification, based on the United Nations Framework Classification (UNFC), is as follows:
- Proved Mineral Reserve (Code 111): 394,546 tonnes
- Feasibility Mineral Resource (Code 211): 123,590 tonnes
- Total Mineral Resource: 518,136 tonnes

3.4 Volume Measurement Results

- **Volumetric calculations from drone-processed data were cross-verified with production, dispatch, and stock records at the mine. The table below presents the measured volumes:**

S. No.	Label	Cut Volume (m^3)	Fill Volume (m^3)
1	**Overburden Yard 1**	**2140.52**	**98.73**
2	**Overburden Yard 2**	**162.53**	**6.24**
3	**Overburden Yard 3**	**106.22**	**6.24**
4	**Mineral Stack 1**	**50.53**	**98.73**
5	**Mine Excavation Pit 1**	**1307.14**	**32,014.89**

These results validate the accuracy and practicality of UAV-based volumetric assessments in open-pit operations.

The results of the study confirmed the following:
The outcomes of this study clearly establish the effectiveness and reliability of drone-based photogrammetry for volumetric assessment and mine planning in open-cast mining operations. Key findings are summarized as follows:

1. Volume Estimation Accuracy
Drone-derived volumetric calculations for overburden dumps and ore stockpiles demonstrated a high degree of accuracy and consistency when compared with conventional methods such as Total Station. The observed deviations remained well within industry-accepted tolerances, thereby validating the reliability and repeatability of UAV-based data for volumetric assessments.

2. Contour Mapping Flexibility and Precision
The UAV-based survey successfully generated contour maps at various user-defined intervals (e.g., 0.5 m, 1.0 m), showcasing the method's adaptability to detailed slope analysis, pit layout design, and surface drainage planning. The resolution and clarity of the contour outputs surpassed those typically achieved with ground-based methods.

3. High-Resolution Spatial Outputs
Photogrammetric processing yielded Orthomosaic, Digital Surface Models (DSMs), and Digital Terrain Models (DTMs) of exceptional resolution. These outputs enabled enhanced visualization of terrain morphology, improved accuracy in geotechnical analysis, and supported effective short-term and long-term mine planning initiatives.

4. Comparative Superiority Over Conventional Methods
When benchmarked against traditional surveying approaches—including Total Station and DGPS-only methods—UAV-based photogrammetry was found to be significantly more efficient in terms of time, cost, and manpower requirements. Notably, this was achieved without compromising precision, making the technique especially advantageous for remote, rugged, or large-scale mining areas.

5. Technological Integration and Survey Effectiveness
The combined use of UAVs and DGPS provided a geospatially accurate, high-resolution dataset that fulfilled all stated research objectives. The integrated methodology proved not only to be a technically viable alternative to conventional survey methods but also to offer a scalable solution for modern digital mining workflows.

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