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A COMPARATIVE STUDY OF ROAD ALIGNMENT SURVEY DATA MEASURED USING UNMANNED AERIAL VEHICLE AND TOTAL STATION

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ABSTRACT

Ground surface information is required to determine any road alignment as well as earth work volume calculations. As a conventional practice, land surveying and photogrammetric techniques are the most widely used methods to measure and determine original ground level data. However, these methods are time consuming and labour intensive and more over, reduction of these is also requires Office work. Unmanned Aerial Vehicle (UAV) is a new and alternative technology which can be used for acquiring ground levels and the plan details, including the parcels of land falling in any particular survey number. By using UAV, is possible to collect the land information even though the unfavourable environmental conditions, including during sunset, sunrise, cloudy sky. It is also noted that, the UAV data may be less accurate than photogrammetric mapping, however, UAV data can be used for preliminary surveys such as reconnaissance surveys during expiring the possibility of alternative highway routes location and the design drawings.

This paper presents a proposed methodology of usage of UAV in conjunction with total station survey for highway location and design purpose, including cost estimates and the times required for both. The objective of this research is to obtain plan views of the proposed route by using UAV for a site and explore the possibility of determination of accurate earth work volume calculations. A comparison study has been conducted between the data collected by UAV and the Total station. The results indicated that the accuracy of the data is satisfactory with a maximum error of 1.0 cm on with reference to the ground control points (GCP's), and 4 cm for the rest of the land area considered. Earth work volume comparative study reveals that by UAV with scale factor has 3.36 % error when compared with total station data.

1. INTRODUCTION

Direct surveying techniques i.e. Electronic Distance Measurement (EDM) surveys or Total Station (TS) and RTK Global Navigation Satellite System (GNSS) are the most widely used in surveying engineering and volumetric computation at open pit mining due to ability to obtain observations with millimetre accuracy. However, they are cost and time consuming techniques, and in some complex environments, these techniques may be unsafe to workers. Recent technological innovations have provided new alternative techniques for topographic surveying such as Terrestrial Laser Scanning (TLS) and airborne Light Detection and Ranging (LiDAR) or airborne laser scanning (ALS).

Innovation in topography and land surveying is aimed at acquiring more data with higher accuracy. Computer developments were a key change in that regard. Nowadays, utilizing drones could lead to another quantum leap in the surveying profession. With the development of smart cities and BIM technologies, it will probably become easy to create a 3D model of a terrain utilizing UAVs and exporting it to a 3D Geographic Information System (GIS). Up until now, for construction sites, 2D plans have been required to get reliable measurements quickly.

1.1 OBJECTIVES OF THE PRESENT STUDY:

Broad Objective:
To explore the possibility and evaluating the performance of using UAV for conducting road alignment surveys at test Site and field-realistic environments.
Specific objectives:
(i). Compare accuracy of UAV collected data with the survey grade data collected by using Total Station.
(ii).To conduct volumetric analysis and also compare earth work costs based on UAV and Total Station.

2. METHODOLOGY

Actual survey operations have been carried out when the topography survey of construction site was still operating, in order to check volume error difference between UAV and total station of the area. Flight area coverage and times, as well as take-off and landing sites, have been defined in collaboration with works direction to ensure maximum safety. The flight has taken place along the proposed road, covering the overall topography .The flight plan was designed for a restitution scale greater than 1:1000, providing for a coverage of aligned road with a total flight length of about 1000m.

The airborne photogrammetry survey has been carried out by means of a Quadcopter fitted with a Sony NEX 7 digital camera, whose technical features are listed below:

1. Weight: 1380gms (including battery and propeller)
2. Sensor dimensions: 23.5mm x 15.6mm
3. Sensor definition: 6000pixel x 4000 pixel
4. Optics: 18-55mm zoom, set in Wide mode (f#19mm)

Planning of image collection provided for pseudo-nadiral shots, with horizontal strips; flight height was # 60m, with Ground Sampling Distance (GSD)#1.8cm/px, 80% overlap along both axes, and theoretical coverage of about 100m x 65m.
The following flight process was developed: (1) prepare UAV for flight, e.g., check its hardware including frame, motors, propellers, battery, sensors, availability of signal, (2) turn on the (photo) camera, (3) upload the way points for the flight path, (3) check the environmental conditions including surrounding airspace, wind, human hazards, (4) turn quadrocopter on, lift it off the ground manually, and switch to autonomous flight mode. After lift-off, the quadrocopter is following its pre-set tasks autonomously. At each waypoint the quadrocopter takes a photo. In case of an unexpected event, a manual intervention is possible at any time. When the last waypoint is reached, the UAV returns automatically to its lift-off location by switching to the “coming home” mode. The landing can be performed either manually or automatically.

The data acquisition is now complete. If the size of the survey area is too large for one flight, additional flights can be performed. Photogrammetric processing of the collected images was carried out by means of software. PhotoScan implements SfM and MVS photogrammetric algorithms, and its potential in generating 3D models from point clouds are well documented. Depending on the computer processor’s size and its graphical performances, the mentioned3D terrain representation can be obtained after a relatively short processing time in form of a

Point cloud or orthophoto map. The point cloud and orthophoto map, which are fully measurable, can be used to define cross sections and calculate volumes that can be transferred to CAD programs, which are readily used in most professions conducting mapping and design activities. After transfer to the CAD or GIS program, surfaces can be generated very simply from point clouds using the TN (triangulated irregular network) algorithm, and contour lines can be generated at equidistance as desired by the user.
In this case, the software has been used to generate a Dense Digital Surface Model (DDSM) and an ortho photograph of the object area. Control Points (CPs) have been uniformly spread across the area and signalized; their coordinates have been surveyed by RTK GPS. These points have been used for the definition of external and internal orientation parameters of the images, by means of a self-calibration procedure built into the bundle block adjustment, in order to scale and georeference the photogrammetric survey.

3. STUDY AREA AND DATA COLLECTION

Project Data has been source collected from Jadcherla-Kalwakurthy road. First Total Station has been used for topography after with Unmanned Aerial Vehicle (UAV) for source collection of data for this project. The collected data has been compared and verified with precision so has to represent the report without any discrepancies. The view of both survey data is represented with adequate details and pictorial representation in the form of drawings and values.

Fig. Google Map of study area

4. ANALYSIS OF DATA

The study length is subdivided in to four parts viz.
Part-1 as in between chainage 0.00m to 250.00m,
Part-2 as in between chainage 250m to 500.00m,
Part-3 as in between chainage 500.00m to 750.00m,
Part-4 as in between chainage 750.00m to 1000.00m,

4.1 Volume Estimation: In order to estimate the volumes two methodologies were performed, one for the data obtained with the Total Station, and one methodology with data obtained by the UAV.

4.2 Volume Estimation with Total Station Data:For estimate the volume we use a software methodology to calculate the volume with the data obtained by the TST. After obtaining the field data with the TST, the data was downloaded to the computer with the TST software and saved in .shp format, in this format point cloud is readable by ArcGIS.

4.3Volume Estimation with UAV Data:For estimate the volume, we adjust the image first with the GCP, these points was the same geo-referenced points (with GNSS) around the road alignment that we use to set up the TST, after that, we use Pix4D software to generate cad drawing to estimate the volume.

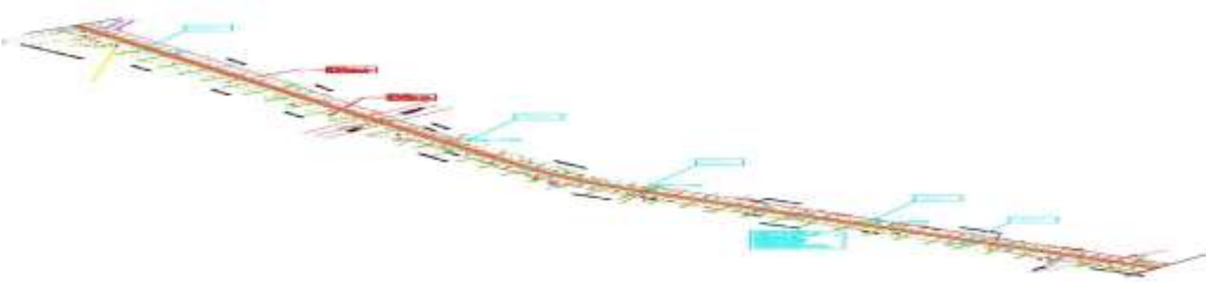

Fig 4.2 AutoCAD drawing for Analysis

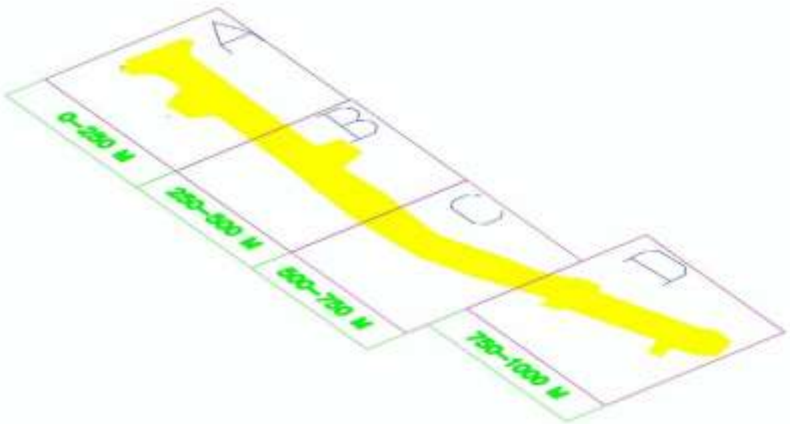

Fig 4.3U.A.V drawing for Analysis

5. ANALYSIS OF DATA

The following paragraphs detail the analysis of the measured data:

Average value of RL obtained from Total Station Data : 523.083 m

Average value RL obtained from UAV Data : 523.610 m

Difference in RL obtained from TS and UAV Values : <u>000.527 m</u>

An Average of 500mm earth filling is taken for 0-1000 m data collected road. This filling value is added to above average levels for cost evaluation of project.

Average value of Total Station Data from survey : 523.083 m

Adding 500mm for earth work : +000.500 m

Total value : <u>523.583 m</u>

Average Depth of Embankment(523.700-523.583) : 000.117 m

Quantity Of Earth Work : 1000m × 15 m × 0.117 m = 1755.0 m^3

Total cost of earth work : 1755 × 300 = Rs. 5, 26,500.00

Average value of UAV Data from survey : 523.610 m

Adding 500mm for earth work : +000.500 m

Total value : <u>524.110 m</u>

AverageDepth of Embankment(523.700-524.110) : 000.410 m

Quantity Of Earth Work : 1000m ×15 m × 0.410 m = 6150.0 m^3

Total cost of earth work : 6150 × 300 = Rs. 18, 45,000.00

The following paragraphs detail the analysis of the measured data for 0-250m **A**:

Road composition levels at **0-250 m**:

	F.R.L. 528.553
Surface course (BC) 50 mm	
Binder Course (DBM) 50 mm	
Base course (WMM) 250 mm	**R.L. 528.003**
Sub base course (GSB) 200 mm	
Soil sub grade(BORROWED SOIL)	
Embankment (NGL)	

Average value of Total Station Data from survey 0-250 m : 527.670 m

Average value of UAV Data from survey 0-250m : 527.780 m

An Average of 500mm earth filling is taken for 0-250 m data collected road. This filling value is added to above average levels for cost evaluation of project.

Average value of Total Station Data from survey A : 527.670 m

Adding 500mm for earth work : +000.500 m

Total value : 528.170 m

Average Depth of Embankment (528.003-528.170) : 000.167 m

Quantity Of Earth Work : 250 m × 15 m × 0.167 m = 626.25 m^3

Total cost of earth work : 626.25 × 300 =Rs. 1, 87,875.00

Average value of UAV Data from survey A : 527.780 m

Adding 500mm for earth work : +000.500 m

Total value : 528.280 m

AverageDepth of Embankment(528.003-528.280) : 000.277 m

Quantity Of Earth Work :250m × 15 m × 0.277 m = 1038.75 m^3

Total cost of earth work : 1038.75 × 300 = Rs. 3, 11,625.00

The following paragraphs detail the analysis of the measured data for 250-500m **B:**

Road composition levels at **250-500 m**

Surface course (BC) 50 mm	**F.R.L. 526.280**
Binder Course (DBM) 50 mm	
Base course (WMM) 250 mm	**R.L. 525.73**
Sub base course (GSB) 200 mm	
Soil sub grade(BORROWED SOIL)	
Embankment (NGL)	

Average value of Total Station Data from survey : 525.980 m

Average value of UAV Data from survey : 525.845 m

An Average of 500mm earth filling is taken for 250-500 m data collected road. This filling value is added to above average levels for cost evaluation of project.

Average value of Total Station Data from survey B : 525.980 m

Adding 500mm for earth work : +000.500 m

Total value : 526.480 m

AverageDepth of Embankment (525.73-526.480) : 000.750 m

Quantity Of Earth Work : 250m ×15 m × 0.750 m = 2812.50 m^3

Total cost of earth work : 2812.50 × 300 = Rs 8, 43,750.00

Average value of UAV Data from survey B : 525.845 m

Adding 500mm for earth work : +000.500 m

Total value : 526.345 m

Average Depth of Embankment (525.73-526.345) : 000.615 m

Quantity Of Earth Work : 250m × 15 m × 0.615 m =2306.25 m^3

Total cost of earth work : 2306.25 × 300 = Rs. 6, 91,875.00

The following paragraphs detail the analysis of the measured data for 500-750m **C:**

Road composition levels at **500-750 m**

	R.L. 522.060
Surface course (BC)50 mm	
Binder Course (DBM) 100 mm	
Base course (WMM) 150 mm	**R.L. 521.660**
Sub base course (GSB) 250 mm	
Soil sub grade(BORROWED SOIL)	
Embankment (NGL)	

Average value of Total Station Data from survey : 522.456 m

Average value of UAV Data from survey : 522.613 m

An Average of 500mm earth filling is taken for 500-750 m data collected road. This filling value is added to above average levels for cost evaluation of project.

Average value of Total Station Data from survey C : 522.456 m

Adding 500mm for earth work : +000.500 m

Total value : 522.956 m

Average Depth of Embankment (522.060-522.956) : 000.896 m

Quantity Of Earth Work : 250 m × 15 m × 0.896m = 3360.0 m^3

Total cost of earth work : 3360.0 × 300 = Rs 10, 08,000.00

Average value of UAV Data from survey C : 522.613m

Adding 500mm for earth work : +000.500 m

Total value : 523.113 m

Average Depth of Embankment(522.060-523.113) : 001.053 m

Quantity Of Earth Work : 250 m × 15 m × 1.053 m = 3948.75 m^3

Total cost of earth work : 3948.75 × 300 = Rs. 11, 84,625.00

The following paragraphs detail the analysis of the measured data for 750-1000m **D**:

Road composition levels at 750-1000 m

	R.L. 518.382
Surface course (BC) 50 mm	
Binder Course (DBM) 100 mm	
Base course (WMM) 100 mm	R.L. 517.832
Sub base course (GSB) 250 mm	
Soil sub grade (BORROWED SOIL)	
Embankment (NGL)	

Average value of Total Station Data from survey : 517.564 m

Average value of UAV Data from survey : 518.169 m

An Average of 500mm earth filling is taken for 750-1000 m data collected road. This filling value is added to above average levels for cost evaluation of project.

Average value of Total Station Data from survey D : 517.564 m

Adding 500mm for earth work : +000.500 m

Total value : 518.064 m

Average Depth of Embankment (517.832-518.064) : 00.2320 m

Quantity Of Earth Work : 250 m × 15 m × 00.232 =870 m^3

Total cost of earth work : 870 × 300 = Rs. 2, 61,000.00

Average value of UAV Data from survey D : 518.169 m

Adding 500mm for earth work : +000.500 m

Total value : 518.669 m

AverageDepth of Embankment (517.832-518.669) : 000.837 m

Quantity Of Earth Work : 250 m × 15 m × 0.837 m = 3138.75 m^3

Total cost of earth work : 1076.25 × 300 = Rs. 9, 41,625.00

5.1 Percent difference in Elevation:

	Total Station (m)	UAV (m)
A. 0-250 m	527.670	527.780
B. 250-500 m	525.980	525.845
C. 500-750 m	522.456	522.613
D. 750-1000 m	517.564	518.169
Total average:	523.417	523.601

Difference in Average-Elevation %

$$= \frac{(\text{Avg.Elev. by total station} - \text{Avg. Elev.By drone}) \times 100}{\text{Avg. Elev. Total station}}$$

$$= \frac{(523.417 - 523.601) \times 100}{523.417}$$

$$= 0.035\ \%$$

5.2 Percent difference in volume of Earth Work (m^3):

	Total Station	UAV
A. 0-250 m	626.25	1038.75
B. 250-500 m	2812.50	2306.75
C. 500-750 m	3360.00	3948.75
D. 750-1000 m	870.00	3138.75
Total Volume Average (m^3):	1917.18	2608.12

Difference in volume Earth Work % $= \frac{(\text{volume total station - volume drone}) \times 100}{\text{Volume total station}}$

$$= \frac{(1917.18 - 2608.12) \times 100}{1917.18}$$

$$= 36.04\ \%$$

5.3 Scale Factors

In the field of measurements, the scale factor of an instrument is sometimes referred to as sensitivity. The ratio of any two corresponding lengths in two similar geometric figures is called as Scale Factor.

$$\text{Scale Factor } A\ (0 - 250\ M) = \frac{\text{Average value of RL obtained by Total Station}}{\text{Average value of RL obtained by UAV}}$$

$$= \frac{527.670}{527.780} = 0.999$$

$$\text{Scale Factor } B\ (250M - 500\ M) = \frac{\text{Average value of RL obtained by Total Station}}{\text{Average value of RL obtained by UAV}}$$

$$= \frac{525.980}{525.845} = 1.002$$

$$\text{Scale Factor } C\ (500M - 750M) = \frac{\text{Average value of RL obtained by Total Station}}{\text{Average value of RL obtained by UAV}}$$

$$= \frac{522.456}{522.613} = 0.999$$

$$\text{Scale Factor } D\ (750M - 1000M) = \frac{\text{Average value of RL obtained by Total Station}}{\text{Average value of RL obtained by UAV}}$$

$$= \frac{517.564}{518.169} = 0.998$$

6. Volumetric Analysis of Earth Work by UAV Data

Value of Unmanned Aerial Vehicle:

Chainage	RL's
A. 0-250 m	527.780 m
B. 250-500 m	525.845 m
C. 500-750 m	522.613 m
D. 750-1000 m	518.169 m
Total average: 523.601 m	

Average Scale factor = (0.999+1.002+0.999+0.998) ÷ 4 = 0.999

Equivalent RL by Scale factor = 523.601 × 0.999 = 523.077 m

Average value of UAV Data from survey : 523.077 m

Adding 500mm for earth work : 000.500 m

Total value : 523.577 m

Average equivalent depth of embankment (523.700-523.577) : 000.123 m

Equivalent Quantity of Earth Work by scale factor : 1000m×15 m × 0.123 m = 1845 m^3

Total cost of earth work : 1845 × 300 = Rs. 5, 53,500.00

6.1 Difference in earth work cost:

Total cost of earth work total station : (A+B+C+D)/4= Rs.5, 75,156.25

Total cost of earth work UAV : (A+B+C+D)/4 =Rs.7, 82,437.50

Total cost amount difference = Rs. 2, 07,281.25

6.2 Difference in earth work cost with scale factor:

Total cost of earth work total station : A+B+C+D = Rs.5, 75,156.25

Total cost of earth work UAV by scale factor : = Rs.5, 53,500.00

Total cost amount difference = Rs. 21,656.25

6.3 Difference in volume Earth Work with scale factor %

$$= \frac{(\text{volume total station - volume drone})}{\text{Volume total station}} \times 100$$

$$= \frac{(1917.18 - 1845)}{1917.18} \times 100$$

$$= 3.76\ \%$$

6.4 Summary of Analysis:

Description	Total Station v/s UAV (volume in % difference)	Total Station v/s UAV (scale factor in % difference)
Volume of Embankment	36.04 %	3.76 %
Cost	Rs. 2,07,281.25	Rs. 21,656.25

7.0 CONCLUSIONS

In this study, the traditional method with TST to estimate volumes of stockpile were compared with UAVs, data from the same site were taken and the post processing was done in ArcGIS with a TIN model from the point cloud data obtained with TST and in Pix4D from data obtained by the UAV.

After comparing the results it was found that, there was a 0.035 % difference in elevation obtained by comparing the data measured by using TST and UAV; and 36.04 % difference in volume of earth work obtained by comparing between the TST data and UAV data. After addition of scale factor the volume of earth work obtained is 3.76 % Therefore, based on the above calculations, it is concluding that the estimated volume with UAV data is comparable which is less than 10% and the procedure adopted in the present study can be used for conducting reconnaissance surveys of road and railway embankment works.

On addition of scale factor the percentage difference is marginal with this the surveyors shall add this for analysis of UAV in further projects.

Additionally, we compare the time taken to get the data for the both methods, in this comparison, it was concluded that the UAV is about 6 times faster than the TST.

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