

ANALYSIS OF THE VOLUME COMPARATION OF 3'S (TS, GNSS and TLS)

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Abstract. Recently, technological developments in the field of surveys and mapping are growing very rapidly such as total station, navigation satellite (Global Navigation Satellite System), drones and laser scanners. One application of this technology is to measure a stockpile area quickly and accurately. This research will measure two stockpiles (coal warehouses) using total station (TS), GNSS and terrestrial laser scanner (TLS). This research will compare the results of volume calculations with the data generated by 3'S (TS, GNSS and TLS). Research is conducted at Coal Yard PT. Barkalin Surabaya in Benowo District, Surabaya, East City with geographically located at 112°39'11" E and 7°07'13" S. The first step is to make 3D model of Laser Scanner data by TLS Faro 3D 120 and to do regristration and filtering using Faro Scene. After that the data export to be 3D model from Faro Scene format to Recap 2016 (.rcp) to present and get coordinates. The next step is to compare the coordinates from TLS, TS and GNSS RTK. Finally, the accuracy of volume calculation from TS and GNSS RTK can be compared to TLS. The volume differences between TS and TLS data are -7.31 m³ (-0.45%) for the 1st location and -6.89 m³ (-0.24%) for the 2nd location. While the volume differences between GNSS RTK and TLS are -10.34 m³ (-0.63%) and -9.05 m³ (-0.31%) for the 1st location and the 2nd location respectively. Generally, the volume differences between TLS, TS and GNSS RTK are not significant. Therefore, 3'S can be used to measure a volume of stockpile.

1 Introduction

Surveying or land surveying is a science that aims to determine the relative positions of points above, on, or beneath the Earth's surface. Surveying has a very important role in measuring and marking boundaries of property ownership since the beginning of civilization [1]. The last few decades its importance has steadily increased with the growing demand for many applications, not only making a map but also other spatially related types of information.

Volume of earthwork is an important matter in many type of engineering project such as to determine the capacities of bins, tanks, reservoirs and buildings, to check stockpile of coal, gravel and other materials, to compute cut and fill landfill and landclearing for road and drainage engineering and construction. There are several methods for estimate the stockpile of coal volumes [1]. In the traditional method the data is obtained from a theodolite or a digital theodolite or a total station (TS).

The survey technique using total station provides horizontal and vertical coordinates, and three-dimensional coordinates (x,y,z). This technique has been widely used for volume determination due to its high accuracy result [2][3]. In this method you need to hold a staff, a prism pole and occupy areas of a large pile of material, this method can be time consuming and

dangerous in some cases. To overcome this problem, we can use the reflectorless (without prism) total station. However, the range (distance) is limited and if the field is open pit and during the day, the laser beam is not visible

There are other methods for obtain data to estimate the stockpile volumes with different technologies like GNSS RTK and Lidar (Terrestrial Laser Scanner). GNSS RTK survey technique requires at least two receivers. One was located on the precisely known ground coordinate, as Base Station and another receiver moves between position to be determined, as Rover Station [4]. Moreover, both receivers must receive navigation satellite signals from at least four mutual satellites and be able to connect with radio link or internet to provide a coordinate correction.

Terrestrial Laser scanning called TLS [5] is a new method to obtain geometric data easily and quickly from detail situation such as buildings, trees, roads, objects etc. Each point is determined by the position (x, y, z) and the intensity (i) of the returning signal. Thus this method can also be used to measure coal stockpile volume very fast, very detail and very accurate [6].

This research aims to compare the results of the calculation of the volume of coal raw materials using the 3's (TS, TLS and GNSS RTK) in two different locations. In addition, this research also aims to find out the

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efficiency of survey time and costs by using 3'S for stockpile volume calculation.

2 Data and Method

2.1. Data

Locating a suitable area for conducting this study is the coal stockpile yard of PT. Barkalin, Benowo, Surabaya, East Java with geographically located at 112°39'11" E and 7°07'13" S



Figure 1. Survey Location

2.2 Instruments

The study used Total Station Topcon GTS 235, TLS Faro Focus 3D 120, and Topcon HiperPro to measure the surface area for volume determination. The instrument specifications are shown in Table 1 to Table 3 respectively.

Table 1. Total Station GTS 235 [7] Specification

Accuracy Horizontal and Vertical Angle	5"
Distance Measurement	3000 m with 1 prism
Distance Accuracy	$\pm (2\text{mm} + 2\text{ppm} \times D)$
Measuring Time	0.3 s

Total Station GTS 235 has 5" for horizontal and angle accuracy and $\pm 2 \text{ mm} + 2\text{ppm} \times D$ for distance accuracy. In addition, the measuring time is 0.3 s.

From Table 2, it can be seen that GNSS RTK Topcon HiPer Pro has 10 mm + 1.0 ppm for horizontal accuracy and 15 mm + 1.0 ppm for vertical accuracy. These accuracies are very enough to conduct volume measurement of coal stockpile.

Table 2. GNSS RTK Topcon HiPer Pro [8] Specification

Static Accuracy of Horizontal	3mm + 0.5 ppm
Static Accuracy of Vertical	5mm + 0.5 ppm
RTK Accuracy of Horizontal	10 mm + 1.0 ppm
RTK Accuracy of Vertical	15 mm + 1.0 ppm

Table 3. TLS Faro 3D 120 [9] Specification

Integrated digital camera	70 megapixel color
Maximum range	120 m
Minimum range	0.6 m
Range accuracy	2mm

Finally, TLS Faro 3D 120 has range between 0.6 m and 120 m and its range accuracy is 2mm. This TLS is enough to conduct measurement coal stockpile in these locations where these areas are less than 1 ha.

2.3 Method

The first procedure of this research is to measure the coal stockpile surface using 3'S (TS, TLS and GNSS RTK). To get x, y and z coordinates of coal stockpile surface, TS measurements used tachymetric method as follow [7]:

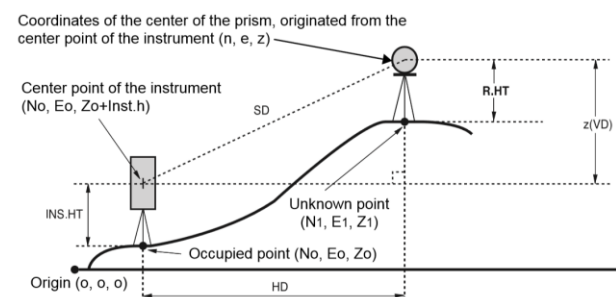


Figure 2. Tachymetric Method [7]

$$N_1 = N_0 + n \quad (1)$$

$$E_1 = E_0 + e \quad (2)$$

$$Z_1 = Z_0 + \text{Ins.HT} + z - \text{R.HT} \quad (3)$$

where:

N_1 = northing coordinate of object

E_1 = easting coordinate of object

Z_1	= elevation of object
N_0	= northing coordinate of origin
E_0	= easting coordinate of origin
Z_0	= elevation of origin
SD	= slope distance
VD	= vertical Distance
Inst.h	= height of instrument
R.HT	= height of reflector (prism height)
n	= $HD \sin Az$
e	= $HD \cos Az$
z	= $HD \tan VA$
HD	= horizontal distance
Az	= azimuth
VA	= vertical angle

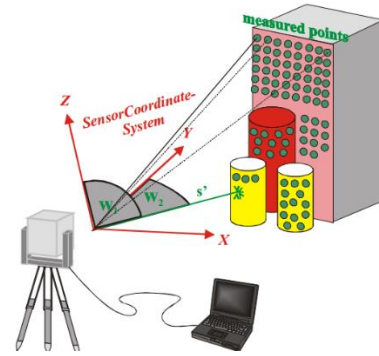


Figure 4. Principle of Terrestrial Laser Scanning [5]

Basically, TS is an equipment used to measure distance (slope distance) and angle (horizontal and vertical). From slope distance and vertical angle can be used to compute horizontal distance and vertical distance. In addition, horizontal angle and horizontal distance can be used to compute abscissa and ordinate difference (dx,dy). Finally, these data can be processed to get x, y, z coordinates.

Furthermore, at the same time with TS measurements, GNSS RTK measures points that are the same point measured by TS. One receiver as a base station that sends corrections by radio link and another receiver as a rover that measures the surface points of coal stockpile. The principles used in RTK GNSS [10] is as follows:

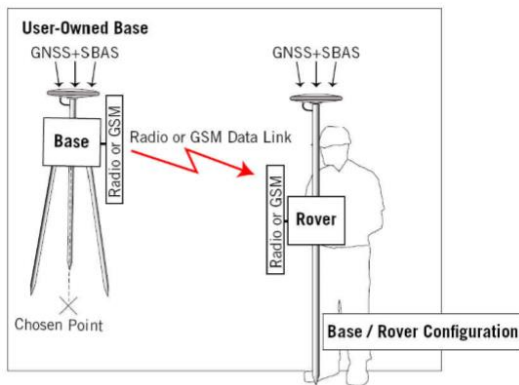


Figure 3. GNSS RTK Principle [10]

GNSS RTK measurement takes 5s - 10s to get fix coordinates. The advantage of GNSS RTK compared to TS and TLS is that there is no need for post processing to obtain x, y, and z coordinates.

The next step is Terrestrial Laser Scanning (TLS) can be defined as the scanning of a surface by the means of Electromagnetic pulses of energy and then creates three dimensional (3D) points of data. Data is achieved by remotely sensing horizontal & vertical angles and reflected distances [11]. This data can then be used to represent the real world in the form of coordinates for the analysis of information and design on a computer display. The TLS principle can be seen Figure 4 as follow:

Each TLS measurement will generate thousands of data points in 10 minutes. Therefore TLS measurement will record point cloud at the location. The amount of data points is very dense and massive.

The next step is comparing of some points elevation of TS and GNSS RTK to TLS. Because the TLS data points are very massive and dense, we can assume that the TLS elevations are true value. Furthermore we can calculate the accuracy of TS and GNSS RTK elevations to TLS elevations by formula as follow [12] :

$$RMS = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - a_i)^2} \quad (4)$$

where a_i refers to accepted elevations value from TLS, x_i refers to TS and GNSS RTK elevations and n is number of point elevations.

The results of the 3'S measurement are in the x, y and z coordinates in the same coordinate system. When creating a stockpile object, the user draws the base surface of the stockpile. This base surface is computed by applying a constrained Delaunay Triangulation on its vertices. Volume is calculated from surface 3D models formed from the Triangulated Irregular Network (TIN). TIN forms a prism geometry from two surfaces. These two surfaces are design surface and base surface. Design surface (actual surface) is the surface whose volume is calculated while the base surface (existing surface) is the surface that is used as a base. The calculation of the volume method is visualized in Figure 5 [13] and volume of a prism is determined using the Equation (5).

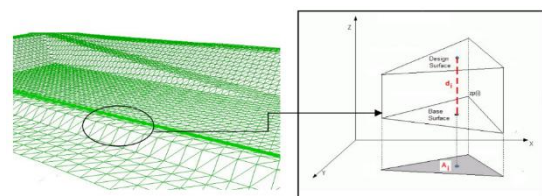


Figure 5. Illustration of TIN and Triangular prism

$$V_i = P \frac{\sum_{i=1}^3 H_i}{3} \quad (5)$$

where V is volume, H_i is elevation and P is area of triangle prism.

Then the volume of TS and GNSS RTK is compared with the volume of TLS. Since TLS data is very dense and massive, the TLS volume calculation results are assumed to be the most accurate (true value).

This study will also compare the measurement time of each measuring instrument ie TS, GNSS RTK and TLS. We will observe that which instrument will produce an effective and efficient measurement time in these cases.

3 Result and Discussion

3.1 3D Model

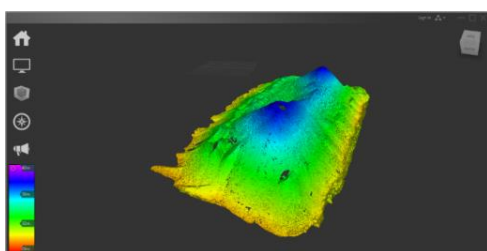
The number of data points for each TS, GNSS RTK and TLS measurement can be seen on Table 4 below.

Table 4. Amount of Points Data 3'S Survey

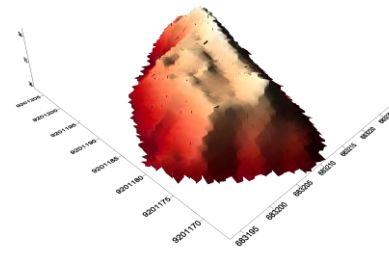
Equipment	Amount of Points	
	1 st Location	2 nd Location
TS	253	218
GNSS RTK	253	218
TLS	22,770,961	24,541,952

TS and GNSS RTK have the same points in both of locations 253 and 218 points respectively. TLS has 22 millions points in the 1st location and 24 million points in the 2nd location. However TLS data points must be filtered with the aim of removing spikes and the outside of area. After filtering the amount of TLS data in the first location is 2.2 millions of points andn the 2nd points is 2.8 millions of points.

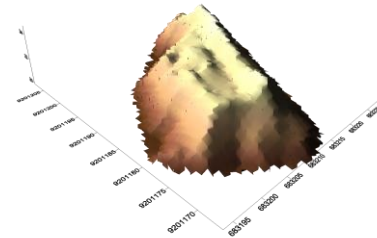
Each TS, GNSS RTK and TLS points of coordinate data can be presented in 3D models as in the following Figure 5 and Figure 6.



(a)

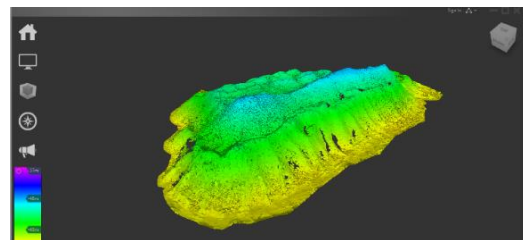


(b)

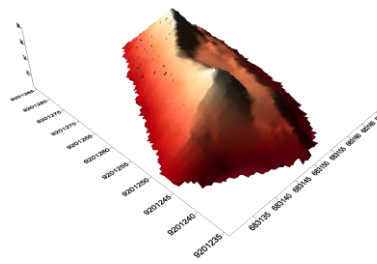


(c)

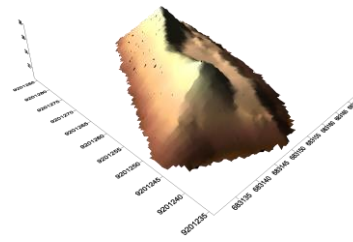
Figure 5. 3D model TLS (a), TS (b) and GNSS RTK (c) for the 1st location



(a)



(b)



(c)

Figure 6. 3D model TLS (a), TS (b) and GNSS RTK (c) for the 2nd location

Both of locations show that 3D model of TLS are the finest and TS and GNSS RTK have similar 3D models. These are caused by the amount of data where TLS have millions data compared TS and GNSS have only hundreds of data. Therefore data interpolation in TS and GNSS RTK will produce rough data models.

3.2 Accuracy Elevation

Position measurement using TS, GNSS RTK and TLS in this study was carried out in two places with each location area is 822.04 m² and 1289.91 m². The conditions of the measured location (coal stockpile) are open space and there are no significant obstacles. Therefore it was easy to conduct measurements with TS, GNSS RTK and TLS.



Figure 7. Condition of the area during the survey

In this case study, we assume that TLS elevations data are the true value, because the amount of data in TLS are millions of points. Thus we can calculate the TS and RTK elevations accuracies to TLS elevations. The accuracy of TS and GNSS RTK elevations to TLS elevations can be seen on Table 5. Based on the Equation 4, the accuracy of TS to TLS elevation is 0.46 and 0.71 cm for GNSS RTK in the 1st location. In addition, the 2nd location, the accuracy of TS elevations is 0.36 cm and GNSS RTK elevation is 0.51 cm. These accuracies are very small and less than 1 cm. It means that TS, GNSS RTK and TLS data have the same elevation accuracy, therefore their data can be used to compute volume of coal stockpile.

Table 5. RMSE of TS and GNSS RTK point elevations to TLS elevations

Equipment	RMSE	
	1 st Location	2 nd Location
TS	0.46 cm	0.36 cm
GNSS RTK	0.71 cm	0.51 cm

3.3 Volume Comparison

Coordinate points (x,y,z) of 3'S measurement is computed by composite method to get volume of coal stockpile in both locations. From the calculation of the volume below (Table 6), the difference between volume of TS and TLS is -7.31 m³ (-0.45%) and GNSS RTK and

TLS is -10.34 m³ (-0.63%) for the 1st location. In the 2nd location, the volume difference of TS and TLS is -6.89 m³ (-0.24%) and GNSS RTK and TLS is -9.05 m³ (-0.31%). In general, it can be concluded that the difference of TS, GNSS RTK and TLS can be ignored. In other word, the volume calculation of TS, GNSS RTK and TLS has the same results.

Table 6. Volume Computation Results of 3'S elevations

Equipment	Volume (m ³)	
	1 st Location	2 nd Location
TS	1632.55	2904.74
GNSS RTK	1629.52	2902.58
TLS	1639.86	2911.63

3.4 Time Measurements

In this research, there are two places of coal stockpile to data measurement using TS, GNSS RTK and TLS equipment. Field measurements at the 1st location need time 5.15 hours for TS, 4.20 hours for GNSS RTK and 1.25 hours for TLS. In the 2nd location, the field measurement of TS, GNSS RTK and TLS need time 5.45 hours, 4.50 hours and 1.45 hours respectively. Measurement with TLS is 4.12 times faster than TS and 3.36 times faster than GNSS RTK for the 1st location. For 2nd location, TLS measurement is 3.75 times faster than TS and 3.10 times faster than GNSS RTK.

Table 7. Time of 3'S Measurement

Equipment	Time (hours)	
	1 st Location	2 nd Location
TS	5.15	5.45
GNSS RTK	4.20	4.50
TLS	1.25	1.45

Although TLS is the fastest measurement, TLS data processing will take a long time compared to TS. GNSS RTK does not need data processing to produce x, y and z coordinates because this method can directly get coordinates within 5s – 10s. TS processing requires a little time to convert distance and angle x, y, and z coordinates.

4 Conclusion

In this research, the measurement method with TS and GNSS RTK to estimate volumes of stockpile were compared with TLS from the same site were taken and the

post processing was done with a TIN model. After comparing the results, it was found that there was -7.31 m^3 (-0.45%) difference between the volume calculated with the TS and the TLS volume in the 1st location and -10.34 m^3 (-0.63%) and -6.89 m^3 (-0.24%) and -9.05 m^3 (-0.31%) for the 2nd location. The volume difference between TS, RTK GNSS and TLS are not significant, therefore they have the same accuracy for two locations with 0.8 ha in the 1st location and 1.3 ha in the 2nd location. Additionally, we compare the time taken to get the data for the three methods, in this comparison, it was concluded that the TLS is the fastest measurement with four times faster than TS and three times faster than GNSS RTK.

5 Acknowledgment

We wish to acknowledge PT. Berkalin for the contributions of the locations and PT. Geosolution Pratama Nusantara and Geodesy and Surveying Laboratory, Geomatic Department ITS Surabaya, for the Total Station GTS 235, GNSS RTK HiPer Pro and TLS Faro 3D 120, thus we can complete this research quickly and accurately

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