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ACCURACY COMPARISON BETWEEN LEICA TOTAL STATION (TC 805 MODEL) AND HI –TARGET V30 GPS ON SOME CONTROL POINTS ESTABLISHED IN FEDERAL POLYTECHNIC IDAH, KOGI STATE

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Abstract

The importance of points location on the earth surface with the use of digital instruments cannot be overemphasised this is because the accurate location of points depends on the quality of the instrument used. Different equipment can perform the same function. For example, total station can be used to coordinates points on the earth surface, likewise the DGPS can still be used for the same purpose, but the accuracy of each result will be different from each other. Hence, the research. This research, aims at comparing data collected from Total Station to that of DGPS on some already established survey points within the study area. The instruments compared were Leica Total Station (TC 805 model) and Hi –Target V30 GPS. The methods used in achieving the desire goal include: reconnaissance survey, test of instrument, data acquisition by running traverse on some control points. Moreso, data collected were processed and analysed. The linear accuracy in Hi–Target V30 GPS and Leica Total Station (TC 805 model) was 1/600,000 and 1/300,000 respectively. Furthermore, statistical analysis was carried out on the results collected. From the analysis, it was concluded that the result from Hi–Target V30 GPS is more accurate compare to Leica Total Station (TC 805 model).

Keywords: Leica Total Station, Hi-Target GPS, Reconnaissance, In-Situ Check and Software.

1.0 INTRODUCTION

In surveying, many different disciplines use geodetic instruments to determine the whereabouts of points of interest. Disciplines such as map production, cadastral surveying, measuring and stakeouts on building sites, machine control, and flooding risk analysis are examples, among others. Conventional instruments used for these are total stations (T.S.s), Global Positioning System, levels, and laser scanners. The measured objects vary widely, such as determining the locations of lampposts and lakeshores, establishing boundaries between neighboring landowners, telling the elevation and slopes of the earth's surface to estimate water flows and rainwater catchments areas or the monitoring of constructions, etc. In each endeavour of determining coordinates, there is the need for absolute accuracy – precise or coarse. The limits of tolerance, concerning the accuracy, in the following task, differ between projects – depending on the motives. However, no matter what the final objective is, there is always a limit of tolerance (Erikkson, 2014).

According to Zeiske, 2018 and Solomon, 2014 a Total Station consists of a theodolite with a built-in Electronic Distance Measurement so that it can measure angles and distances at the same time. The modern electronic total stations have the ability to scan the coded scales of the

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horizontal and vertical circles electronically due to the presence of an opto-electronic distance meter (EDM) and electronic angle scanning from which the angles and distances are displayed digitally. The computation of horizontal distance, height difference, and coordinates are done automatically and record all measurements and additional information. Software package are supplied with the Leica Total Station that enables most survey tasks to be carried out efficiently, rapidly and smartly. The positions and heights of points can easily be determined by Total Stations. The instrument can be used to determine the coordinates of unknown point relative to a known coordinate as long as a line of sight can be established directly between the two points. Total Station requires line of sight to determine an absolute location of an unknown point and can be set up over a known point or with line of sight to two or more points with a known location, called free stationing (Wikipedia, 2013).

Most Total Stations use purpose-built glass prism reflectors for the EDM signal. A typical total station can measure distances with an accuracy of about 1.5 millimetres (0.0049 ft) + 2 parts per million over a distance of up to 1,500 meters (4,900 ft) (Leica Geosystems, 2008).

Differential Global Positioning Systems (DGPS) are enhancements to the Global Positioning System (GPS), which provide improved location accuracy, in the range of operations of each system, from the 15-meter nominal GPS accuracy to about 10 cm in case of the best implementations (Wikipedia, 2018).

Differential corrections are calculated by a reference station for time and locations. Operators can be 370km away from the reference station, though some of the compensated errors differ with space. Example of these errors include; ionospheric and tropospheric distortions and satellite ephemeris errors. As a result, the DGPS accuracy decreases with distance from the reference station. However, if the station lacks "intervisibility" (when the same satellite cannot be seen) the problem will be serious (Wikipedia, 2018).

For any GPS receivers to function well, they must reliant on care of a radio or mobile phone link to a base receiver, quality and metier of satellite reception. Therefore, satellite receivers may not effectively function in some areas, such as in a close building, trees covered areas and valleys with a steep-sided (Sjöberg, 2012). In such environments, the Total Station is the best choice of the survey instrument. Well established procedures exist to adjust and integrate the readings taken from different Total Station positions (called stations) during a survey and position the Survey accurately on existing base mapping. For positioning purposes, it is no doubt useful to integrate between GPS and Total Station. The GPS coordinates are geodetic in the positioning system; the goal is to determine the scale factor between GPS and Total Station using common point measurements. The total station is a combination of electronic theodolite, and EDM and software running on an external computer known as a data collector. The position of a point can be determined anywhere on the globe to a high accuracy with GPS. Since it is a space-based radio navigation system that comprises of 24 satellite and ground supports. Baselines of high accuracy can be measured. It controls points without any line of sight requirement since Total stations work on the principles of the signal.

Accuracy and precision for those in the surveying profession (as well as other technical and scientific fields) are defined in different ways. Accuracy refers to how closely a measurement or observation comes to measure an actual or established value since measurements and observations are always subject to errors. Precision refers to how closely repeated measurements or observations come to duplicate the measured or observed values. Malcolm (1958).

According to Lin, (2004), the accuracy of surveying techniques using instruments such as GPS, and Total station is dependent on several parameters that limit their measurement quality. For instance: multipath, the inherent satellite signal accuracy, signal transmission delay, receiver hardware and software limitations, satellite signal obstruction are some of the problems associated with GPS measurement. On the other hand, limitations stemming from the total station are; computed coordinates are in local or target coordinate system. The reference surface for measuring Height is geoid. Because of the earth's curvature, the accuracy of Total Station measurement can also be affected by distance limit (the accuracy will decrease when increasing the distance).

This research aims at comparing the accuracy of this equipment on some already established survey points within the institution. Statistical criteria/method were used on the data collected.

Table 1 briefly compares the GPS and Total Station. (Solomon, 2014).

Table 1: Comparison of GPS and total station

Total Station	**GPS**
Indirect acquisition of 3D coordinates	Direct acquisition of 3D coordinates
Both horizontal and vertical accuracies are comparable	The horizontal accuracy is better than the vertical accuracy
The accuracy depends on the distance, angle and the used prism	The accuracy depends on the satellite availability, atmospheric effect, satellite geometry, multipath
Less precise than GPS	More precise than total station
Satellite independent	Satellite dependent
Needed inter-visibility between the instrument and the prism	Visibility is not needed

Source: Solomon, 2014.

1.1 PROJECT LOCATION

The project site was located within the Federal Polytechnic Idah Kogi State.

The approximate geographical coordinate of the study area is within the coordinate framework of:

Latitude (Ø) = 7° 08'15'N Longitude (φ) 6°47'' 16 E

Latitude (Ø) = 7° 08'34'N Longitude (φ) 6°47'' 28 E as shown in figure 1.

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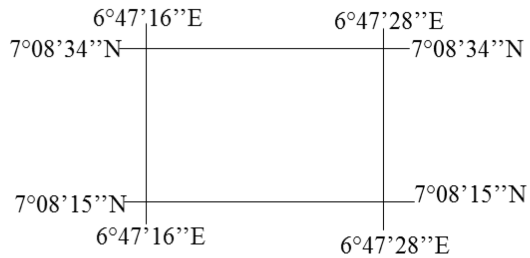

Figure 1: Geographical Coordinates Framework of Study Area.
Source: Google Earth

Furthermore, Figures 2a, b and c are the maps showing the study areas.

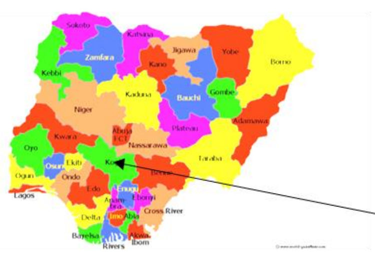

Fig 2a: Map of Nigeria showing Kogi State and the remaining states

Fig 2b: Map of Kogi State showing Idah LGA and the rest LGAs in the State.

Fig 2c: Satellite Imagery of the study area (Federal Polytechnic Idah).

Figure 2: Showing Map of the Study Area (Google)

1.2 AIM AND OBJECTIVES

1.2.1 AIM

The study aims to compare the level of accuracy between the Leica Total Station (TC 805 model) and High-Target V30 GPS by running a traverse on twenty control points and carrying out analysis on the coordinates obtained.

1.2.2 OBJECTIVE

The following objectives were embarked upon:

a. Reconnaissance survey was carried out on the study site.
b. Points were identified and monumented.
c. In-situ checks were conducted on the existing controls used for the connection.
d. Total Station traversing was carried out on the points established, after which GPS observation was conducted on the same points established.
e. The results collected from the two methods were compared and test for accuracy based on computational and statistical analysis.
f. Forward possible recommendations that can improve the precision and accuracy of the two methods.

2.0 PROJECT PLANNING

2.1 RECONNAISSANCE SURVEY

Reconnaissance survey is the process of taking a general view of the terrain to be familiar with the environment before the actual execution of the job. (Udoh, 2015).

A reconnaissance survey was carried out to know the nature of the terrain and be able to know the best way to achieve the research. It involves two stages: field and office reconnaissance. The control points in table 2 below, was found close to the study area and was used for the connections and also formed part of the boundary for the study. In-situ check was carried out on these controls, and it was discovered that they were still in their proper position.

Table 2: Showing existing Controls

Control IDS	Eastings (m)	Northings (m)	Heights (m)
FPI 001	256424.389	789399.003	132.047
FPI 003	255674.119	789165.454	122.815
FPI 004	255568.563	789405.167	119.622
FPI 011	256473.313	789242.909	130.378

Source: FPI Survey Department Coordinate Register

2.2 INSTRUMENTATION

The following equipment was used for the study:

i. ***Hi-Target V30 RTK GPS and its accessories***
ii. Leica 305 Total Station and its accessories.

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iii. AutoCAD 2019 Software
iv. Microsoft word
v. Microsoft Excel 2016 for plotting of chart
vi. H.P. Laptop Computer
vii. HP. (A3) 9800 Printer

2.3 TEST OF INSTRUMENT

According to Lin (2004), testing of the instrument is essential to ascertain the reliability and effectiveness of the instrument. The Hi-Target GPS and Leica Total Station were tested, and it was confirmed that they were still in order. The tested conducted were GPS receiver and EDM Total Station calibration test.

2.3.1 GPS RECEIVER TEST/VERIFICATION OF CONTROLS (IN-SITU CHECK)

Baseline In-situ check observation was executed for the purpose of testing the GPS receivers as well as verifying the integrity of the existing controls.

The baseline check was carried out using control pillars whose coordinates were given. The check was performed using the differential GPS static mode under a clear sky view. One receiver was set on FPI 001 as the base while the other receiver was used as rover on FPI 011 and FPI 004. The operation was repeated but in reverse order (making FPI 011 the base in turn). See figure 3 below.

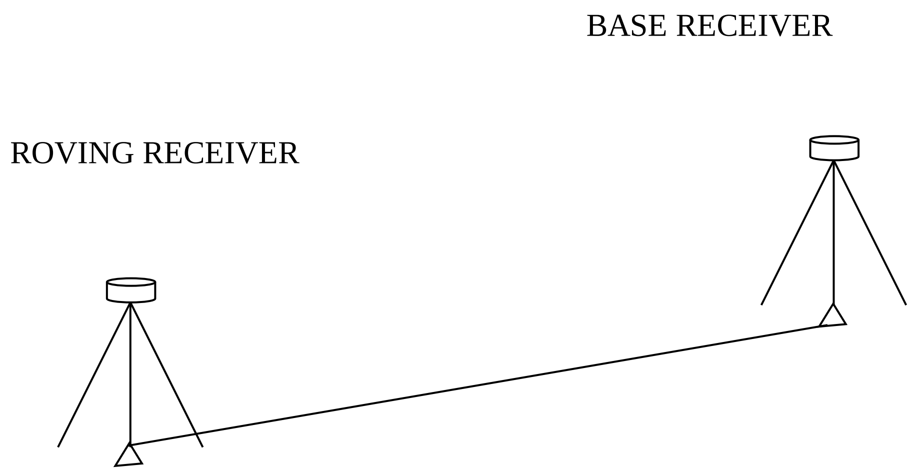

Figure 3: GPS Receiver Test/Baseline check

The Registered/ known coordinates of the control pillars were compared with the observed ones. The differences between the known values and their corresponding observed values indicated that the controls were in good state. The GPS baseline check performed also confirmed that the operation of the GPS receivers and data processing software were in good condition, hence the calibration of the equipment are in good order. See Table 3 below.

Table 3: Comparison Between Registered/ (Known) and Observed Coordinates of Controls									
PILLAR	Known Coordinate			Observed Coordinate			Differences (Obs Coord – Reg Coord.)		
	NORTHING	EASTING	HEIGHT	NORTHING	EASTING	HEIGHT	NORTHING	EASTING	HEIGHT
FPI 001	789399.003	256424.389	132.047	789399.005	256424.309	132.067	0.002	**-0.08**	**0.02**
FPI 011	789242.909	256473.313	130.378	789242.911	256473.310	130.411	0.002	**-0.003**	**0.033**
FPI 004	789405.167	255568.563	119.622	789405.143	255568.478	119.632	-0.024	**-0.085**	**0.01**

2.3.2 TOTAL STATION EDM CALIBRATION TEST

For the purpose of this test, a base of 400m long divided into four segments of 100m long each was used as shown in figure 4 below.

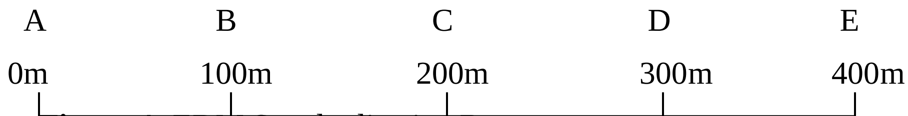

Figure 4: EDM Standardization Base

The total station and target were set up, centred and levelled at points A and E respectively. The target was sighted, bisected and linear measurements made three times and booked. In the same manner the distances AB, BC, CD, DE and EA were measured. The result of the test is shown in table 4 below.

Table 4: Total Station EDM Calibration Test							
SECTION		**AE (1)**	**AB (2)**	**BC (3)**	**CD (4)**	**DE (5)**	**EA (6)**
DISTANCE (m)	1	400.0018	100.002	100.008	99.999	100.003	400.006
	2	400.0017	100.001	99.991	100.001	100.002	400.005
	3	400.0016	100.002	99.997	100.003	100.001	400.005
TOTAL		1200.024	300.006	299.996	300.003	300.006	1200.016
MAEN= Total/ no of obs		**U=400.0080**	**V=100.002**	**W=99.999**	**X=100.001**	**Y=100.002**	**Z=400.0053**

$(U + Z)/2 = V + W + X + Y + Z$ - - - - - equ 1

Ideally, from equ 1,

$\{(U + Z)/2\} - \{V + W + X + Y + Z\} = 0$ - - - - equ 2

But this is normally not the case in real practice. The deviation from zero is the standardization correction.

Therefore, standardization correction = (U + Z)/2 = V + W + X +Y + Z (i.e. equ 1).

Substituting the value of U, V, W, X, Y and Z to equ 1,

= {(400.0080 + 400.0053)/2} – {100.002+ 99.999 + 100.001 + 100.002}

= 400.007 – 400.004

= 0.003m

After the test, the results showed a discrepancy of 0.003m; this discrepancy is negligible for a third order job hence was ignored.

2.4 STATION SELECTION

Twenty control points (20) were selected in the study location, and we ensure they are intervisible from one station to the other. These stations were monumented and numbered serially that is FPI 001, FPI 002, FPI 003, ………….FPI 020.

The pillars were of dimension 18cm x 18cm x 75cm. The concrete mix was in the ratio of 1:2:3 of cement, gravel, and sand, respectively. The beacons were cast such that 67.5cm of the entire length was buried underground, with 7.5cm of the length above the ground surface. A steel rod of 10mm diameter and 100cm length was used to define the center of each beacon, as shown in figure 5.

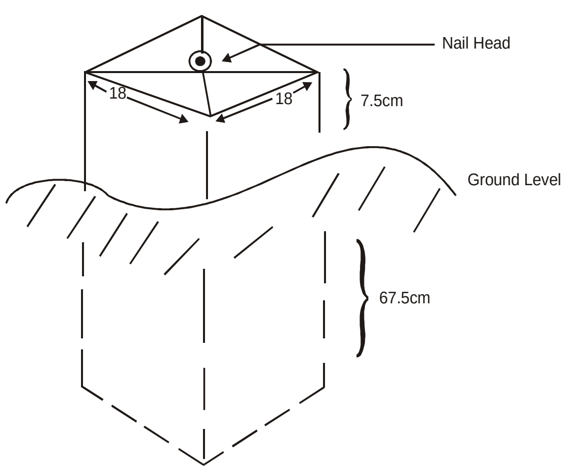

Figure 5: Control Beacon Specification.

3.0. METHODOLOGY/DATA ACQUISITION

The data were acquired by via Hi-Target GPS V30 and Leica TC 805 Total Station. The general survey procedures of observation were used for the data acquisition using the instrument one after the other. At each stage of observation, temporary (centring, focusing, and levelling) and permanent adjustment were perform on each of the instruments. The observation commenced

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from the control points and closed back on the control points, which give room for adjustment of data.

4.0. DATA PROCESSING, INFORMATION PRESENTATION AND ANALYSIS

The data collected from Leica TC 405 Total Station and Hi-Target V30 GPS were downloaded and processed using Leica Total Station and Hi-Target GPS downloading software respectively then the analysis was carried out.

4.1 ANALYSIS OF RESULT

The data collected from both Leica Total Station and Hi-Target GPS were compared with the existing control points (Known Coordinates). Table 5 shows the difference between the Northings and eastings of Leica Total Station and the Known Coordinates.

Table 5: Showing the error in Northings and eastings between the existing controls and the coordinates from the LEICA Instrument.

	The difference in Northing Coordinates (Leica Instrument)			The difference in Easting Coordinates (Leica Instrument)		
STN	Existing Northing (m)	New Leica Northing (m)	ΔN (m)	Existing Easting (m)	New Leica Easting (m)	ΔE (m)
FPI 001	789399.003	789399.039	-0.036	256424.389	256424.304	0.085
FPI 003	789165.454	789165.526	0.072	255674.119	255674.200	-0.081
FPI 004	789405.167	789405.229	0.132	255568.563	255568.640	-0.077
FPI 011	789242.909	789242.898	0.011	256473.313	256473.318	-0.005

Source: Author

Furthermore, Table 6, also explain the differences between Northings and eastings of Hi-Target GPS and the Known Coordinates.

Table 6: Showing the error in northings and eastings between the existing controls and the coordinates from Hi-Target GPS.

STN	The difference in Northing Coordinates (GPS Instrument)			The difference in Easting Coordinates (GPS Instrument)		
	Existing Northing (m)	New GPS Northing (m)	ΔN (m)	Existing Easting (m)	New GPS Easting (m)	ΔE (m)
FPI 001	789399.003	789399.005	-0.02	256424.389	256424.309	0.080
FPI 003	789165.454	789165.442	0.012	255674.119	255674.200	-0.081
FPI 004	789405.167	789405.143	0.022	255568.563	255568.478	-0.085
FPI 011	789242.909	789242.911	-0.002	256473.313	256473.310	0.003

Source: Author

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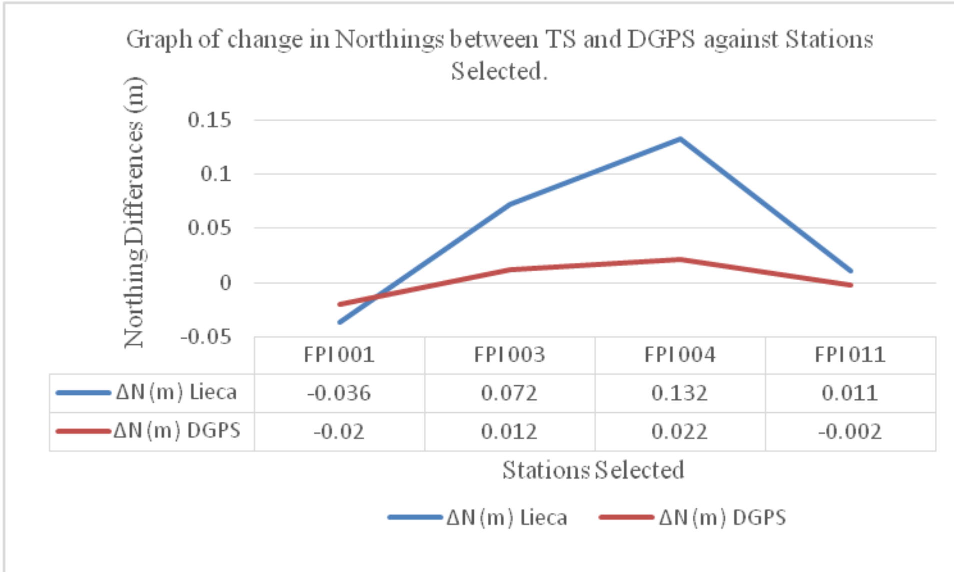

Figure 6: Graph of Change in Northings between TS and DGPS against Stations Selected

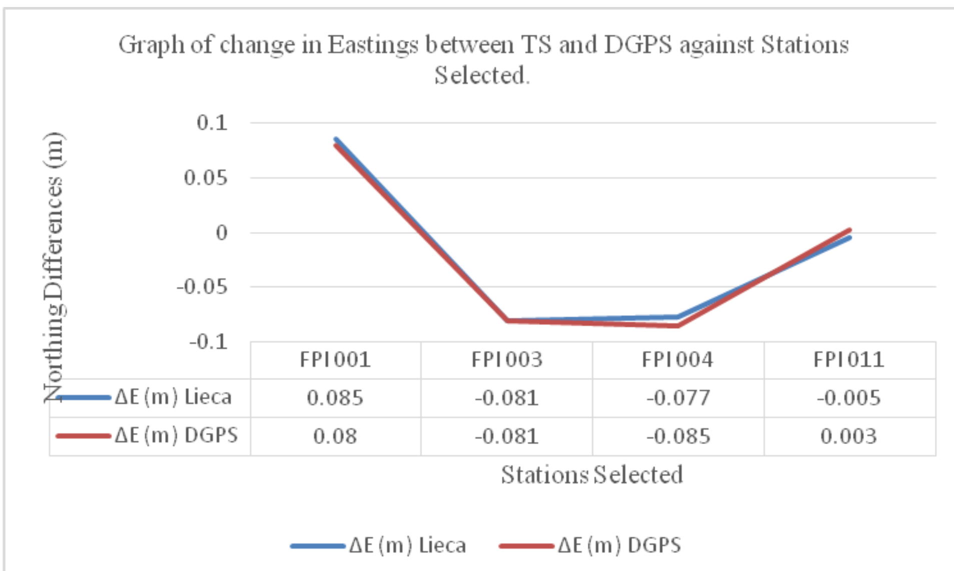

Figure 7: Graph of Change in Eastings between TS and DGPS against Stations Selected

The graph in figure 6 above shows the comparison between the change in Northings of Leica Total Stations to that of Hi-Target GPS, while the comparison between the change in Eastings of Leica Total Station to that of Hi-Target GPS is shown in figure 7.

Moreso, table 7 shows the height difference between the Known Coordinates and Leica Total Station to that of Hi-Target GPS and the Known Coordinates.

Table 7: showing the change in Height between existing control and coordinate from Leica Total Station and Hi-Target GPS.

STN	Height Data from Leica Total Station			Height Data from Hi-Target GPS		
	Existing Height (m)	New Leica TS Height (m)	ΔH(m)	Existing Height (m)	New GPS Height (m)	ΔH(m)
FPI 001	132.047	132.077	-0.03	132.047	132.067	-0.020
FPI 003	112.815	112.849	-0.034	112.815	112.810	-0.005
FPI 004	119.622	119.599	0.023	119.622	119.632	-0.010
FPI 011	130.378	130.420	-0.042	130.378	130.411	-0.033

Source: Author

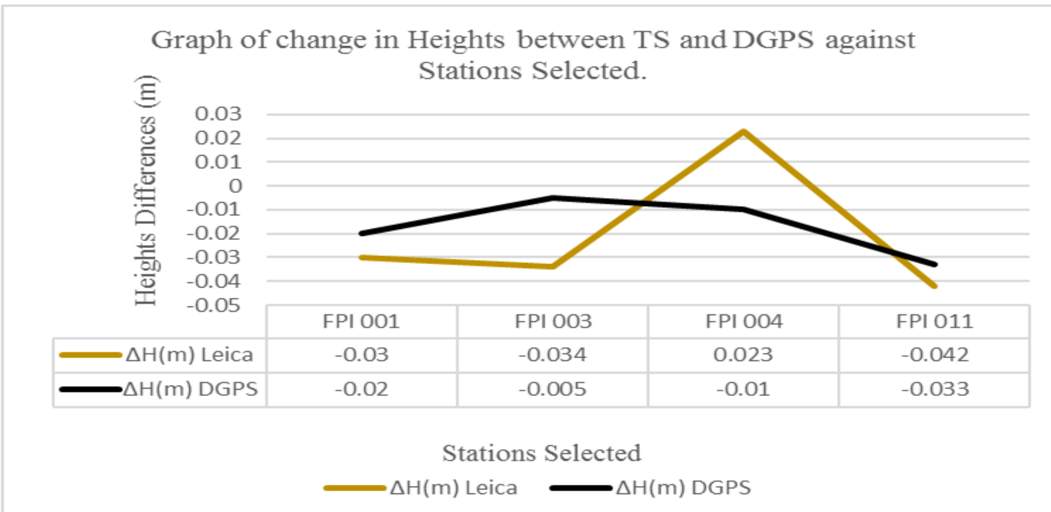

Figure 8: Graph of Change in Heights between TS and DGPS against Stations Selected.

The graph in figure 8, present the comparison between the change in heights of Leica Total Station to that of Hi-Target GPS.

4.2 LINEAR MISCLOSURE OF HIGH-TARGET GPS AND LEICA TOTAL STATION.

The linear accuracy in both methods (Leica Total Station and Hi-Target GPS) was computed for by using the formula shown below.

$$LinearAccuracy = \frac{1}{\frac{\sqrt{(\Delta N)^2 + (\Delta E)^2}}{\text{Total distance}}}$$

The computation of linear accuracy of the Hi-Target GPS traverse is shown below computed using the above formula, as shown below.

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Misclosure in Northing (ΔN) = 0.006

Misclosure in Easting (ΔE) = - 0.005

Misclosure in Height (ΔH) = -0.03

Total distance = 4432.905 m

$$LinearAccuracy = \frac{1}{\frac{\sqrt{(-0.005)^2 + (0.006)^2}}{4432.905m}}$$

Linear accuracy (GPS) = 1/567,575.3252 = 1/600,000

Also, the linear accuracy of the Leica Total Station traverse was computed as shown below:

Misclosure in Northing (ΔN) = 0.014

Misclosure in Easting (ΔE) = - 0.011

Misclosure in Height (ΔH) = -0.03

Total distance = 4432.905m

$$LinearAccuracy = \frac{1}{\frac{\sqrt{(0.014)^2 + (-0.011)^2}}{4432.905}}$$

Linear accuracy (TS) = 248976.7496 = 1/300,000

Table 8 below shows the comparison in the error analysis between the two methods (that is, Leica Total Station and Hi-Target GPS) used.

Table 8: showing the analysis of result at the closing station (FPI 001)

	LEICATOTAL STATION	HI-TARGET V30 GPS
Closing misclosure in Northing	0.014	0.006
Closing misclosure in Easting	-0.011	-0.005
Closing misclosure in Height	-0.03	-0.03
Linear Accuracy	1/300,000	1/600,000

Source: Author

5.0 COMPARISON OF MEAN, STANDARD DEVIATION, AND VARIANCE OF EXISTING CONTROLS AND THAT OF TOTAL STATION AND GPS

Statistical analysis was conducted on the differences in reading to be able to check the accuracy of the instruments used, which helped to come to a conclusion on which of the instrument is accurate. The statistical analysis carried out were: Mean, Standard Deviation, and Variance. Via Microsoft Excel 2016 as shown in table 9.

Table 9: shows the comparative analysis results for mean, variance and standard deviation calculated for Existing control points and that of Leica Total Station and GPS

	Easting Leica (m)	Easting GPS (m)	Northing Leica (m)	Nothing GPS (m)	Height Leica (m)	Height GPS (m)
Mean	-0.0195	`-0.02225	0.04475	0.0075	-0.02075	-0.017
Variance	0.006073	0.006072	0.005338	0.000137	0.000876	0.000153
Standard Deviation	0.077929455	0.077923038	0.073061617	0.011704699	0.029597297	0.012369316

Source: Author

5.1 SUMMARY

From the statistical analysis on table 9 above, it can be deduced that the Hi-Target V30 GPS used was more accurate compare to that of the Leica total station. This accuracy is based on the fact that the Hi-Target V30 GPS was free from ionospheric and tropospheric distortions when used and at the same time free from satellite ephemeris errors. Furthermore, the quality and strength of satellite reception on the GPS receivers were highly maintained. In addition, the mean value of in easting, northing and Height of GPS tends to zero whereas the reverse is the case in that of mean value of Leica Total Station. The same observations applicable to the value of variance and standard deviation of GPS to that of Leica Total Station.

5.2 CONCLUSION

Based on the statistical analysis on table 9, the research has shown that the accuracy in Hi-Target V30 GPS is better than that of the Leica Total Station, but this not to say that Leica Total Station is not accurate. The choice of instrument to be used depend on the accuracy to be attained. The nature of the Survey, the location of the Survey, and many more. In conclusion, the various analysis carried out shows that the Hi-target V30 is more precise than the Leica total station when the minimum number of four satellite needed to acquire data are obtained and maintained during observation of data.

REFERENCES

Dr. Joseph C. Udoh, 2015: ESM 421- ELEMENTS OF SURVEYING. Department of Geography and Regional Planning, University of Uyo, Uyo, Akwa Ibom State. Retrieved on May 5, 2015 from Google Search Engine.

Karl Zeiske (2018): Surveying Made Easy, Pp 1. Leica Geosystems AG. CH-9435 Herebrugg (Swizerland). www.leica-geosystems.com.

Leica Geosystems (2014). Americas. http://www.leicageosystems.us/commom/shared/downloass/inc/downloader.asp?id=14376

Lin Bannister, A. S (2004). Surveying (5th ed), London; W.C 2 Constable & co 1974, Pp1.

Malcolm, D.H (1958): Surveying and Levelling (8th ed.) Delhi: Tat McGraw Hill Publishing Company, pp. 439-444.

Malin Hagglund Erikkson (2014), Accuracy and Precision Analysis of Total Station Measurements Pp. 188-189

Sjöberg, L.E. (2012). Lecture notes on the course AH2923 Global Navigation Satellite System (GNSS), Division of Geodesy, KTH, Stockholm, Sweden.

Solomon D. C, 2014: Surveying with GPS, Total Station and Terresterial Laser Scaner: a comparative study. Master of Science Thesis in Geodesy No. 3131 TRITA-GIT EX 14-001. School of Architecture and the Built Environment, Royal Institute of Technology (KTH) Stockholm, Sweden.

Wikipedia (2018), Total Station and Differential Global Positioning System. Retrieved from http://en.wikipedia/total_station/DGPS. Accessed on 15th July, 2018.

Wikipedia (2013), Total Station. Retrieved from http://en.wikipedia.org/wiki/Total_station. Accessed on 18th March, 2013.