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Comparative Evaluation of The Accuracies of Differential GPS and Total Station in Determining the Coordinates of Existing Controls

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ABSTRACT

A Control survey is a survey operation that is carried out in order to establish position of points with a high degree of accuracy in order to support activities like mapping and map revisions, property boundary surveys, construction projects and so on. Control densification is a continuous exercise in the field of geomatics. This forms the basis upon which other geomatics and engineering activities geared toward development are referenced. This study is aimed at determining the coordinates of existing control points network along Ayetoro / Egbeda Atuba road using dual frequency GPS and Total Station with a view to comparing the accuracies of DGPS and Total Station using statistical analysis to determine which one has better accuracy. The Objectives of the study are to locate the existing control points, to collect the information/coordinates of the existing control points, and to carry out the observation using DGPS and Total station and process/compute the final coordinates and compare the results by using statistical analysis. The methodology that are adopted for this project is Satellite Positioning Technology using Differential Global Positioning System (DGPS) and Total Station. And the acquired data was processed and adjusted. The statistical analysis was used to compare the result obtained from DGPS and Total Station with the data collected from the Ministry of Land and Housing. The result of the analysis shows that DGPS has better accuracy. It is recommended that whenever more suitable and accurate method of measurement is to be employed, the DGPS method should be selected as this study has demonstrated and compared the accuracy of the two methods and showed that the DGPS method is better.

Keywords : DGPS, GPS

I. INTRODUCTION

Surveying, which is also interchangeably called Geomatics, has traditionally been defined as the science, art, and technology of determining the relative positions of points above, on, or beneath the Earth's surface, or of establishing such points (Charles and Paul, 2008). In more general sense, however, Surveying (Geomatics) can be regarded as that discipline which encompasses all methods for measuring and collecting information about physical earth and our environment, processing that information, and disseminating a variety of resulting products to a wide range of clients. Surveying has been important since the beginning of civilization. Its earliest applications were in measuring and marking boundaries of property ownership. Throughout the years its importance has steadily increased with the growing demand for a variety of maps and other spatially related types of information and the expanding need for establishing accurate line and grade to guide construction operations (Charles and Paul, 2008).

Surveying, specifically in the area of control extension, deformation monitoring and engineering projects, sophisticated instruments such as Total Station (TS), Laser Scanner and Differential Global Positioning System (DGPS) are employed to improve the efficiency and accuracy of the projects (Borgelt et al, 1996). Different surveying instruments are used in the history of surveying to collect data from field measurements for various applications with different accuracy capabilities and requirements. Thus the knowledge of these factors on any instrument is important in designing any surveying project. The required accuracy depends on the needed deliverable output (Clark, 1998). The total station is a surveying instrument that combines the angle measuring capabilities of theodolite with an electronic distance measurement (EDM) to determine horizontal angle, vertical angle and slope distance between particular points. Or more precisely total station is version of EDM that used infra-red signals to measure the time taken for wave to reached the reflector and return to the instrument and the distance is calculated.

Also, surveying majorly can be classified into two and they are: Plane and Geodetic surveying. The main factor on which these two classes of Surveying are based is that the shape of earth is an approximate oblate ellipsoid of its revolution. In geodetic surveying the curvature of the earth is taken into account. Surveys are conducted with a high degree of accuracy. However, in plane surveying, except for levelling, the reference base for field work and computations is assumed to be a flat horizontal surface. The error caused by assuming the earth to be a plane area is not serious if the area measured is small say, within 250 km^2 (Roy, 2008).

The study is under geodetic surveying which involves high degree of accuracy in the determination of position of points. This type of surveying operation is called “Control Survey”. A control survey is a class of survey that establishes position of points with a high degree of accuracy in order to support activities such as mapping and map revisions, property boundary surveys, construction projects, and so on. In order to facilitate the mapping and map revision requirements, adequate control network is needed, since no accurate mapping and survey work can be carried out in the absence of a good system of control network.

This Comparative Evaluation of the Accuracies of DGPS and Total Station in Determining the coordinate of Existing Controls will provide the much needed control network for large and small scale mapping, road development and other engineering surveys. This will contribute immensely to the development of Ayetoro and Egbeda Atuba Community.

The use of Total Station and Dual frequency GPS is adopted due to the fact that single frequency receivers have the obvious weakness in that it takes longer to resolve integer ambiguities at the beginning of an observation session and after cycle slip, compared to dual frequency receivers. Typically for L1 data it can take anything up to 30 minutes, whereas for dual frequency receivers this is reduced to under a minute in most cases (Emily, *et al.,* 2003).

1.2 STATEMENT OF THE PROBLEM

a. The accuracy of the geodetic network generally decreases, resulting from the errors inherent in the observation over time, Most often, surveyors are faced with the challenges of choosing the appropriate technique or instrument in acquiring spatial data.

b. Questions are often asked about the best instrument between DGPS and Total Station in determining precise location of geospatial infrastructure. (Ejikeme, *et al,* 2016)

c. Attempt and the experiences of other Researcher toward handling challenges in Comparative Evaluation of the Accuracies of DGPS and Total Station in Determining the Coordinates of Existing Controls are as follows

i. Ejikeme et al, 2016, In their reseach ''Comparative Analysis of the Accuracies of DGPS and Total Station Instrument in Precise Location of Geospatial Infrastructure'' found out that The introduction of DGPS and Total Station, has improved the accuracy of positioning information. But the fact still remains that these methods of acquiring data are highly affected by various factors.

ii. Umar and Usman 2019 in their work ''A Comparative Suitability For Control Extension'' opined that it was very difficult to manage the field measurement alone, specially establishing the reference network has been a big problem.

iii. Solomon, 2014 in his work ''Comparative Study of Surveying with GPS, total station and terresterial laser scaner'' explained that Accuracy refers to how closely a measurement or observation comes to measure a true or established value, since measurements and observations are always subject to errors.

d. The differences in the Survey techniques of using these instruments as well as factors affecting their accuracies necessitated the need for carrying out a Comparative Evaluation of the Accuracies of DGPS and Total Station in Determining the Coordinate of Existing Controls

1.3 AIM OF THE STUDY

The aim of this study is to acquire the coordinate of an existing control point network along Ayetoro / Egbeda Atuba road using dual frequency GPS and Total Station with a view of comparing the accuracies of DGPS and Total Station

1.4 OBJECTIVES OF THE STUDY

To achieve the above mentioned aim, the following objectives were addressed.

(i) To locate the existing control points and collect the information/coordinate of the existing control points;
(ii) To carry out the observations using Dual frequency GPS and Total Station on a static mode;
(iii) To process/compute the final coordinates from the DGPS and Total Station.
(iv) To compare the results obtained from DGPS and Total Station with the existing control value using statistical analysis

1.7 THE STUDY AREA

The study area stretches from Ayetoro to Egbeda Atuba in Ibadan and is located in Oluyole Local Government area of Oyo State, South-Western Nigeria. Oluyole Local Government is bounded by Ona-Ara, Ido and Ibadan South East Local Government area of Oyo State. It has an estimated population of 202,725 according to 2006 population census (National Population Commission, 2006). It is located within latitudes 7º 04′ 41.02"N to 7º 18′ 24.15"N above the Equator and longitudes 3º 43′

37.12" E and 4º 00´ 44.25" E of the Greenwich meridian. In addition, the State is bounded by Ogun, Osun and Kwara States.

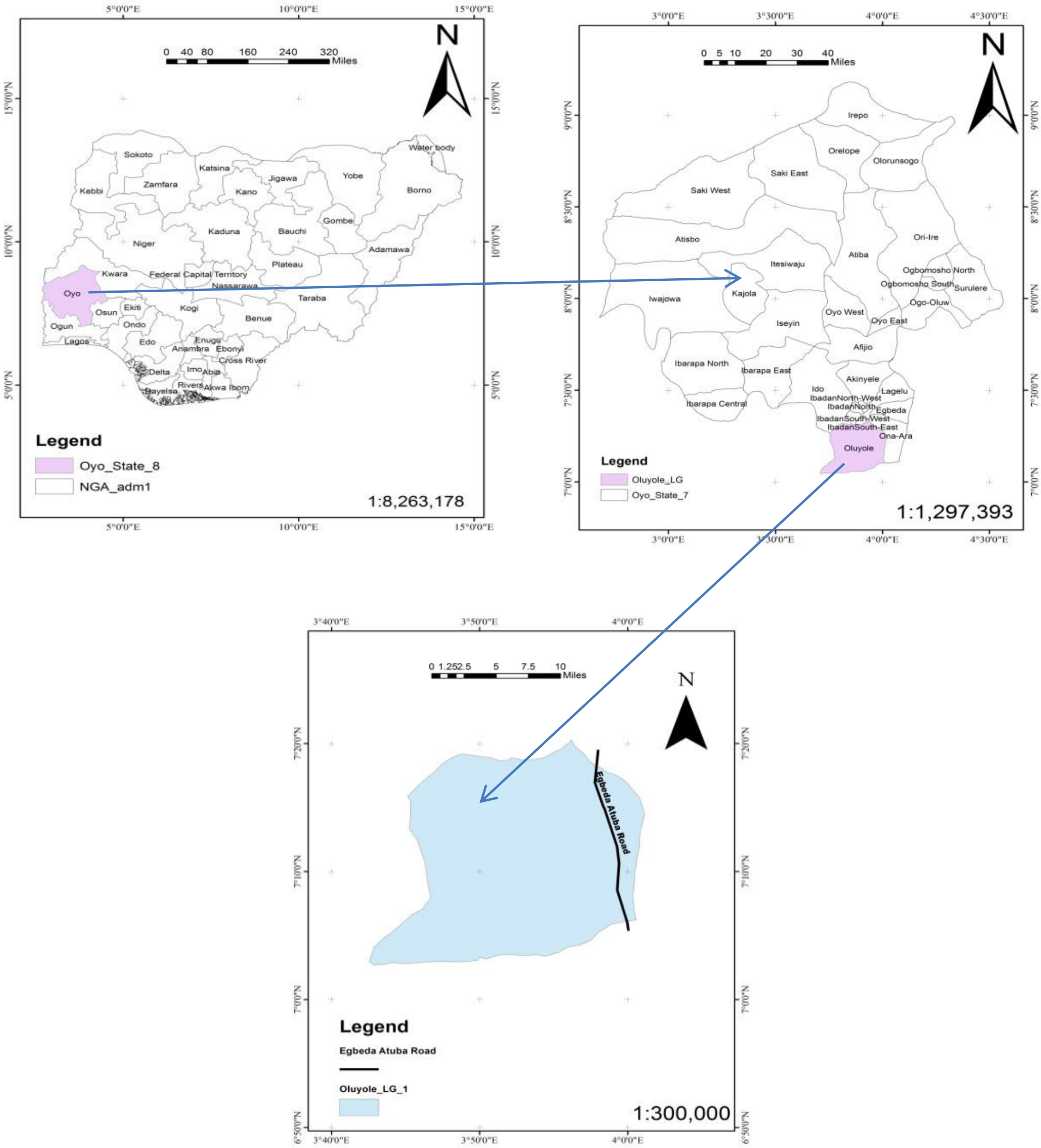

Fig. 1a Map of Nigeria showing Oyo State. Fig. 1b Map of Oyo State, showing Oluyolr Local Govt. Fig. 1a. Map of Oluyole Local Government, the Study Area

Source: Department of GIS, Ministry of Land and Surveys, Lagos State.

II. METHODOLOGY

Methodology means the methods and principles used for doing a particular kind of work, especially scientific or academic research. Conventional or classical methods for establishing geodetic control points are expensive, tedious and limited to inter-visibility between beacons. Satellite Positioning Technologies have been proven to be fast, simple, accurate and cheaper alternative to classical or conventional methods. Based on the above development, the methodology that shall be adopted for this project is Satellite Positioning Technology using Differential Global Positioning System (DGPS) and also the uses of Total Station.

III. RESEARCH STUDY DIRECTION

Having gone through various researches carried out by various people on the densification of control points and various methods adopted, and by considering the gaps identified, this study shall be carried out to yield a better result.

The methodology that will be adopted is as stated below:

i. Location of the existing control point to be used for the traversing
ii. Inter-visibility between the points
iii. Government agencies in any selected government properties will be enlightened about the importance of control points and about their duty in the protection of the control points located in their office premises.
iv. Redundancy observations will be incorporated in to the observations for quality control and to guard against gross errors.
v. Dual frequency GPS and Total Station will be used for the observations.
vi. The acquired data will be processed and adjusted.
vii. Finally, Comparing the results of DGPS and Total Station using statistical analysis
viii. Presentation of final results

Ten control points were selected for the exercise and the uses of DGPS and Total station to obtain the Northing, Easting and Height coordinates

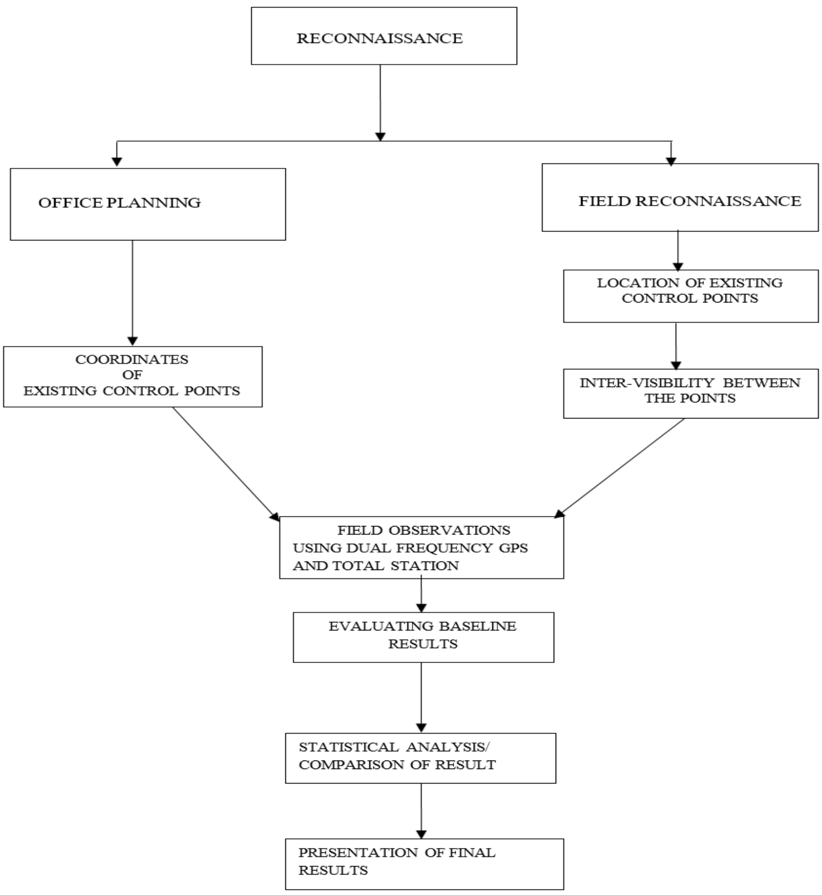

Fig. 3.0 Methodology Flowchart

3.1 DATA REQUIREMENTS

This has to do with the activities and materials that were used for the execution of the project. The primary data required for this research work are the field data acquired using Dual Frequency Global Positioning System (GPS) and Total Station. And the activities involved are as stated below starting from reconnaissance.

3.1.1 RECONNANSSANCE

Reconnaissance survey is very important in any survey work. This involved:

a. Project planning, that is the pre-analysis of the project for the determination of the methodology that adopted for the project,
b. Visiting the site in order to have a good picture of the site and the terrain condition,
c. Determining the suitable mode of transportation and the available facilities
d. Identification of the nearest control points,
e. The drawing of reconnaissance diagram,
f. The collection of every necessary data about the project site,
g. Determination and establishment of project components. This means the various distinct aspects or activities involved in the project from the beginning to the end of the project.

All the above operations are carried out to acquire necessary information concerning the project site for proper planning and execution of the project.
This reconnaissance survey featured in two forms:
(i) Office planning and
(ii) Field reconnaissance

3.1.2 Office Planning

Planning is the process of deciding how something is going to be done before it is done. That is to say planning is the process of decision making in respect of circumstances that surrounds the project that is to be carried out. It involves development of a work plan showing how goals and objectives are to be accomplished. Hence, planning is one of the essential factors for effective project execution and management. Proper planning was taken for the execution of this project and this included:

a. The choice of the most appropriate techniques for the execution of the project are Satellite Positioning Technology using Differential Global Positioning System (DGPS) and also using Total Station;
b. Selection and the acquisition of equipment that are used for the project that is Dual Frequency Global Positioning System and Total Station
c. Test of instruments
d. Collection of coordinates of the existing controls point from Ministry of Land and Housing Secretariat Ibadan Oyo State.

Table 3.1 DATA COLLECTED FROM THE MINISTRY

STATION ID	NORTHING (METRES)	EASTING (METRES)	ORTHOMETRIC HEIGHT (METRES)
YZN2651	808683.376	605844.204	207.647
YZN2652	808316.522	605894.645	218.485
YZN2653	808171.268	605988.940	220.570
YZN2654	808076.898	606165.755	220.463
YZN2655	807708.000	606428.167	220.974
YZN2656	807454.548	606586.730	212.332
YZN2657	807367.664	606652.452	206.172
YZN2658	807238.648	606636.413	202.193
YZN2659	807040.198	606626.957	193.250
YZN2660	806737.635	606709.323	200.984

3.1.3 Field Reconnaissance

The field reconnaissance is carried out first before the actual field operations begin.

This reconnaissance survey were carried out as follows:

1. Inspection of the whole project area.
2. Location of existing control points that shall be used.
3. Inter visibility between the point

IV. DATA PROCESSING, RESULTS AND DISCUSSION

The field data processing will involve basically the evaluation and computation of the DGPS and Total station derived coordinates. The respective steps to be followed in carrying out these computations are explained thus:

4.1 DATA PROCESSING:

4.1.1 DGPS DATA DOWNLOADING AND PROCESSING

At the end of the field exercise, the DGPS receivers are taken to the GIS laboratory and using a cable interface, the receivers are linked to a computer system with the Spectrum Software installed and the downloading, processing and coordinate transformation from WGS-84 to Minna datum-Nigeria

The Earth Gravitational Model (EGM) 96 in the DGPS processing software was used to convert Ellipsoidal height (h) to Orthometric height (H).

The coordinates (Northing, Easting and Height) of ten points obtained using DGPS are shown in table 4.1

Table 4.1: Data Acquired from DGPS

Station ID	NORTHING (METRES)	EASTING (METRES)	ORTHOMETRIC HEIGHT (METRES)
YZN2651	808683.380	605844.200	207.346
YZN2652	808316.501	605894.629	218.210
YZN2653	808171.253	605988.938	220.284
YZN2654	808076.835	606165.784	220.186
YZN2655	807708.008	606428.222	220.459
YZN2656	807454.541	606586.709	212.254
YZN2657	807367.587	606652.531	205.942
YZN2658	807238.614	606636.392	201.875
YZN2659	807040.141	606626.990	192.996
YZN2660	806737.576	606709.340	200.707

4.1.2 TOTAL STATION GENERATED COORDINATE

The data acquired from the Total Station are downloaded to computer and processed.The coordinates (Northing, Easting and Height) of ten points obtained using Total Station is shown in table 4.2,

Table 4.2 : Data Acquire from TOTAL STATION

Station ID	NORTHING (METRES)	EASTING (METRES)	ORTHOMETRIC HEIGHT (METRES)
YZN2651	808683.366	605844.110	206.966
YZN2652	808316.473	605894.664	217.901
YZN2653	808170.248	605988.952	220.054
YZN2654	808076.830	606165.760	219.723
YZN2655	807707.946	606428.241	220.206
YZN2656	807454.524	606586.763	212.225
YZN2657	807367.581	606652.538	205.269
YZN2658	807238.597	606636.447	201.986
YZN2659	807040.136	606626.993	192.949
YZN2660	806737.568	606709.345	200.480

4.2 PROCEDURE: On launching the software, the map unit and the distance unit will be set to centimeter and meters respectively. By making use of the relational "Table" on the project content, the appropriate "field" (column) for the northing and easting of each control points observed on the field are created. Also created will be records (rows) equal to the total number of points observed on the field. All station codes/number and their respective coordinates (N, E) will be entered into the table via the keyboard to form database. Checking on the table menu "start/stop" Editing on the drop down dialogue box will be clicked to start or stop editing as appropriate. On clicking to "start" or "stop" editing, as appropriate. On clicking the "stop editing button", the table will be saved in the desired folder.

The "view" on the project content and menu bar will be clicked to select a view and "add event theme" respectively. On the dialogue box, the appropriate X-axis as the easting and Y-axis as the northing coordinate will be selected. On clicking the "ok" button the dialogue box, the points will be plotted on view 1. This "theme" will convert to "shape file" on the drop down men. By making use of the "X-tool" extension, the control points were joined with straight lines and plans of the control position plotted. Features of interest will be plotted using the same procedure. The necessary map embellishments were carried out in lay out.

4.3 COMPARISON OF RESULTS USING STATISTICAL ANALYSIS

At the end of the observations, the data acquired from the receivers are linked to a computer and downloaded and processed. Also the data acquired from the Total Station are downloaded to computer and processed. The statistical analysis that was used is "Statistical Package for the Social Sciences" SPSS to compare the result obtained from DGPS and Total Station to know which one has more accuracy. The table 4.3 below shows the distribution of each data, from the Ministry, DGPS and Total Station. (N_Corr., E_Corr. and H_Corr. stand for Northing, Easting and Height of corrected value from the Ministry, N_DGPS, E_DGPS and H_DGPS for Northing, Easting and Height of DGPS observed and N_TS, E_TS, H_TS for Northing, Easting and Height of Total Station observed.

Table 4.3 : Frequencies statistical analysis of each data

Statistics

		N_Corr.	E_Corr.	H_Corr.	N_DGPS	E_DGPS	H_DGPS	N_TS	E_TS	H_TS
N	Valid	10	10	10	10	10	10	10	10	10
	Missing	0	0	0	0	0	0	0	0	0
Mean		807679.47570	606353.35860	210.30700	807679.44360	606353.37350	210.02590	807679.32690	606353.38130	209.77590
Std. Error of Mean		195.849986	108.977801	3.093199	195.855151	108.981537	3.084741	195.826468	108.988007	3.062016
Median		807581.27400	606507.44850	209.98950	807581.27450	606507.46550	209.80000	807581.23500	606507.50200	209.59550
Std. Deviation		619.332036	344.618066	9.781554	619.348368	344.629881	9.754807	619.257664	344.650341	9.682946
Range		1945.741	865.119	27.724	1945.804	865.140	27.463	1945.798	865.235	27.257

Table 4.4 : Paired Samples Test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	N_Corr - N_DGPS	.032100	.030322	.009589	.010409	.053791	3.348	9	.009
Pair 2	N_Corr - N_TS	.148800	.306852	.097035	-.070709	.368309	1.533	9	.160
Pair 3	E_Corr - E_DGPS	-.014900	.034031	.010762	-.039244	.009444	-1.385	9	.200
Pair 4	E_Corr - E_TS	-.022700	.048431	.015315	-.057345	.011945	-1.482	9	.172
Pair 5	H_Corr - H_DGPS	.281100	.106017	.033526	.205260	.356940	8.385	9	.000
Pair 6	H_Corr - H_TS	.531100	.258661	.081796	.346065	.716135	6.493	9	.000

Table 4.5 : Shows the ANOVA of Northing of DGPS and Total Station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
N_DGPS	Between Groups	3452331.607	9	383592.401	.	.
	Within Groups	.000	0	.		
	Total	3452331.607	9			
N_TS	Between Groups	3451320.488	9	383480.054	.	.
	Within Groups	.000	0	.		
	Total	3451320.488	9			

Table 4.6 : Table 4.4: Paired Samples Test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	N_Corr - N_DGPS	.032100	.030322	.009589	.010409	.053791	3.348	9	.009
Pair 2	N_Corr - N_TS	.148800	.306852	.097035	-.070709	.368309	1.533	9	.160
Pair 3	E_Corr - E_DGPS	-.014900	.034031	.010762	-.039244	.009444	-1.385	9	.200
Pair 4	E_Corr - E_TS	-.022700	.048431	.015315	-.057345	.011945	-1.482	9	.172
Pair 5	H_Corr - H_DGPS	.281100	.106017	.033526	.205260	.356940	8.385	9	.000
Pair 6	H_Corr - H_TS	.531100	.258661	.081796	.346065	.716135	6.493	9	.000

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ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
N_DGPS	Between Groups	3452331.607	9	383592.401	.	.
	Within Groups	.000	0	.		
	Total	3452331.607	9			
N_TS	Between Groups	3451320.488	9	383480.054	.	.
	Within Groups	.000	0	.		
	Total	3451320.488	9			

Table 4.6 : Shows the ANOVA of Easting of DGPS and Total Station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
E_DGPS	Between Groups	1068927.796	9	118769.755	.	.
	Within Groups	.000	0	.		
	Total	1068927.796	9			
E_TS	Between Groups	1069054.718	9	118783.858	.	.
	Within Groups	.000	0	.		
	Total	1069054.718	9			

Table 4.7 : Shows the ANOVA of Height of DGPS and Total Station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
H_DGPS	Between Groups	856.406	9	95.156	.	.
	Within Groups	.000	0	.		
	Total	856.406	9			
H_TS	Between Groups	843.835	9	93.759	.	.
	Within Groups	.000	0	.		
	Total	843.835	9			

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
E_DGPS	Between Groups	1068927.796	9	118769.755	.	.
	Within Groups	.000	0	.		
	Total	1068927.796	9			
E_TS	Between Groups	1069054.718	9	118783.858	.	.
	Within Groups	.000	0	.		
	Total	1069054.718	9			

Table 4.8 : Shows the ANOVA of Height of DGPS and Total Station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
H_DGPS	Between Groups	856.406	9	95.156	.	.
	Within Groups	.000	0	.		
	Total	856.406	9			
H_TS	Between Groups	843.835	9	93.759	.	.
	Within Groups	.000	0	.		
	Total	843.835	9			

V. DISCUSSION OF RESULTS

The result of the statistical analysis revealed that the linear accuracy of DGPS is higher than that of Total Station. The area covered using DGPS and Total Station is 2.247 kilometres.

From the Table 4.3 shows the mean of each observations where the mean of Corrected value are: Northing = 807679.4757, Easting = 606353.3586 and Height = 210.307, the mean of the DGPS are: Northing = 807679.4436, Easting = 606353.3735 and Height = 210.0259 and the mean of Total Station are: Northing = 807679.3269, Easting = 606353.3813 and Height = 209.7759.

The mean differences are shown in Table 4.4 where DGPS: N=0.0321, E= -0149 and H= 0.2811 AND Total Station: N=0.1488, E= -0.0227 and H= 0.5311. The standard deviation, standard error and 95percent Confidence Interval of the Differences with the T-Test carried out in table 4.6, shows that DGPS is closer to the corrected value.

The Analysis of Variance (ANOVA) was carried out, the differences of Northing, Easting and Height of DGPS and Total Station shows that DGPS is more accurate.

Therefore the result of comparing the two instruments shows that both DGPS and Total Staion are good but DGPS has better accuracy.

VI. SUMMARY

In summary, the densification of an existing control point network along Ayetoro / Egbeda Atuba road using DGPS and Total Station was carried out to determine and compare the accuracy of the two horizontal methods so as to determine which of them is better in terms of accuracy which in turn will enable users (Surveyors, Geodesist, Engineers, etc.) to decide on the method to employ as regards the purpose of measurement, the magnitudes and direction of the expected displacements of any engineering structures. Ten control points were used. The DGPS observations are processed using Spectrum Software installed in a computer and downloading, processing and coordinate transformation from geocentric to geodetic. The coordinates (Northing, Easting and Height) was obtained and the data acquired from the Total Station are downloaded to computer and processed.The coordinates (Northing, Easting and Height) was also obtained.

The reliability of the observations was determined by carrying out some statistical evaluations. The adjusted observations were accepted as the results of the statistical evaluations and analysis showed that none of the ten observations of the two methods was rejected and as the precision and accuracy of each of the adjusted observations and those of the adjusted coordinates were very high. The adjusted ten observations (coordinates) of each of the two methods were compared by finding the differences between the first and the subsequent coordinates. The computed mean differences in coordinates were used to evaluate the measurement

The two methods were also compared to determine which of them is better in terms of accuracy. The results showed that the DGPS method is better as the posteriori standard errors and the traces of the variance of ten control point of DGPS observations were all less than those of the total station. The results of this study have shown that the DGPS method is better than the total station method in terms of accuracy for control densification, deformation monitoring of engineering structures. This will assist users to decide on the method to apply as the selection of method depends upon the accuracy requirements which in turn are determined by the purpose of measurements and by the magnitude and direction of the expected measurement.

VII. CONCLUSION

There have been rapid and tremendous advancement in surveying instruments, sophisticated instruments are being introduced for collection of accurate data in precise location of points. The introduction of DGPS and Total Station, has improved the accuracy of positioning information. But the fact still remains that these methods of acquiring data are highly affected by various factors. The mean variations in the coordinates of DGPS with reference to Total station may look insignificant but could be a subject of land in dispute. The correlations between the mean plots of the various coordinates of control points are strong and the regression equations are linear.

DGPS and Total Station instrument are good for precise location of spatial infrastructure depending on the order of survey accuracy. Under ideal environmental and atmospheric condition for both instruments. DGPS may be preferred for high accurate job, larger area coverage and reduced labour cost.

5.3 Recommendations

Having densified the control point and compared the accuracy of the two methods, based on the result obtained from this study, the following recommendations were made:

1. That Surveyors, Geodesists, Engineers, etc should employ the most suitable method of measurement by considering the purpose of the survey and the expected accuracy requirements.
2. That whenever more suitable and accurate method of measurement is to be employed between the DGPS and the Total station methods, the DGPS method should be selected as this study has shown that the DGPS method is better.
3. That other geodetic methods of monitoring such as InSAR, etc should be compared with any of the two traditional (DGPS and Total Station) methods of monitoring of engineering structures to determine which is better in terms of accuracy.

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