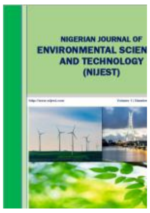
Nigerian Journal of Environmental Sciences and Technology
(NIJEST)
www.nijest.com
ISSN (Print): 2734-259X | ISSN (electronic): 2734-2603
Vol 8, No. 1 March 2024, pp 01 - 12



Accuracy Assessment of Established Controls for Precise Positioning using DGPS and CORS

Alabi A.O[1,2]*, Alademomi A.S[1,2,3], Salami T.J[1,2], Okutubo A.D[1], Oyedokun W.R[1]

[1]Department of Surveying and Geoinformatics, Faculty of Engineering, University of Lagos, Akoka, Lagos State, Nigeria
[2]Geospatial and Environmental Research Group, University of Lagos, Nigeria
[3]Centre for Multidisciplinary Research and Innovation, Suite C59, New Bannex Plaza, Wuse 2, Abuja, Nigeria
Corresponding Author: *aoalabi@unilag.edu.ng

https://doi.org/10.36263/nijest.2024.01.02

ABSTRACT

Over the years, the control network has been used as the framework which serves as the basis for all subsequent mapping and surveying work where the position of points on, beneath and above the earth is precisely determined. The need for controls in surveying and mapping cannot be overemphasised especially in projects that require precise measurements and plotting e.g. engineering and construction projects, land mapping, archaeological surveys, geology, forestry, and hydrology. This study looks at the accuracy assessment of established controls for precise positioning using differential global positioning system (DGPS) and continuous operating reference stations (CORS). The focus of the study is to assess the accuracy of controls established within the University of Lagos, Akoka campus using DGPS. The coordinates of the existing controls within the University of Lagos were obtained and re-coordinated using Stonex S900A (DGPS) referenced to CORS for precise measurements. The data obtained was processed using the Trimble Business Center (TBC) software. The existing coordinates of controls and the newly acquired ones were compared and contrasted. Various statistical analyses were done to assess the accuracy of the controls established within the University of Lagos. Results show that the p-values for existing and new horizontal coordinates of the controls are (E = 0.002768695 and N = 0.00036642) which is less than the 0.01 p-value. Also, the p-value for existing and new vertical coordinates of the controls is 0.069657705 which is greater than the 0.01 p-value. Therefore, there is a significant difference between the existing and the newly acquired horizontal coordinates of controls established within the campus at a 99% confidence level but no significant difference between the existing and the newly acquired vertical coordinates of controls established. The results obtained were presented in the form of tables.

Keywords: Controls, Continuously Operating Reference Station (CORS), Differential Global Positioning System (DGPS), Precise Measurements, Trimble Business Center.

1.0. Introduction

In Geomatics, positional accuracy is one of the major bases of undertaken scientific measurement and it is a matter of improved interest due to competencies offered by the advent of the global positioning system and the need for better spatial communication that can back up spatial data infrastructures (Ariza-López & Atkinson-Gordo, 2008). The accuracy and reliability of the controls at the local level are critical to infrastructural development, a very reliable and accurate control network is needed for different infrastructural progress among which are deformation monitoring, urbanization control, transport infrastructure (Alademomi et al 2020). Infrastructure development is a key driver for progress across all continents and a critical enabler for spatial planning, productivity, and sustainable growth. It contributes significantly to human development, poverty reduction, and the attainment of the Sustainable Development Goals (SDGs). Investment in infrastructure accounts for over half of the recent improvement in economic growth in Africa and has the potential to achieve even more.

Control networks consist of stable, identifiable points with published datum values derived from observations that tie the points on the Earth's surface together (John, 1984). Survey control stations are reference monuments to which other survey works of lower accuracy are connected (John, 2020). The purpose of a control system is to prevent the accumulation of errors, by connecting detailed work to a reliable geometrical network system of points that can assure reliable measurement within allowable tolerance for high-precision engineering projects. Great care is taken to ensure that these controls are sufficiently accurate (Dimal et al. 2009). The significance of the concept of survey controls in point positioning and navigation systems gave birth to the concept of the Global Navigation Satellite System (GNSS) tasked with the primary duty of providing reliable positioning data for precise point positioning and navigation (Dabove & Di Pietra, 2019). While the use of GNSS for point positioning and navigation has advanced beyond reliance on survey controls, even making use of smartphones, the improvement of survey control networks has been carried out with GNSS (Dabove & Di Pietra, 2019). Continuously Operating Reference Stations (CORS), which operate highly dependent on GNSS, help to differentially correct static Global Positioning System (GPS) measurements and are designed to support the broad spectrum of post-processed, relative GPS techniques, and applications (Botsyo et. al, 2019). For tasks involving mapping and geomatics activities, the allowable distance between the CORS and the rover stations can be 70km and beyond (Okorocha Chika et.al, 2023). However, Pham Cong Khai and Nguyen Quoc Long (2019) stated in their work that when the real-time kinematics (RTK) technique is deployed using single CORS technology, the horizontal error of position is directly proportional to the distance from the CORS to the Rover base station. They concluded that applying the RTK technique using single CORS technology the maximum distances from the CORS station to the rover station when producing cadastral maps with scales of 1: 200, 1: 500, 1:1000, 1:2000 and 1:5000 should be 2.2 km, 5.3 km, 10.5 km, 20.8 km, and 51.7 km, respectively.

Several studies have shown the existence of considerable discrepancies in data reports of all the previous attempts made to coordinate and re-coordinate Survey Control stations within the University of Lagos campus in Lagos, Nigeria. Iyoyojie (2014); and Owodunni (2015) both re-coordinated XST347 presumed to be a first-order control and ended up producing two coordinate values (Table 1) with a significant difference. This then prompts the question, "How accurate or precisely determined are all these controls?” Hyun Choi and Kyu Cheol Kim (2012) investigated the accuracy of cadastral control points using a Virtual Reference Station (VRS). The VRS gives high reliability and mobility by generating the imaginary point near the mobile station from several observatory datum of GPS and sets the accurate location of the mobile station (Choi et.al, 2012). The VRS improves the accuracy of GPS Real Time Kinematics methods which always need two base stations and has a fault of the accuracy decreasing as the distance between a mobile station and a receiver is increasing (Choi et.al, 2012). Choi et.al, (2012) carried out a comparative analysis of the cadastral datum through the VRS method by Continuously Operating Reference Station. The results of their comparison between surveyed result with the repetition method through total station observed Cadastral Control Points and surveyed result with VRS-RTK show that the average error of the x-axis is -0.08m, the average error of the y-axis, +0.07m and average distance error is +0.11m.

Given the foregoing, this study assesses the accuracy of control points within the University of Lagos using DGPS linked with the Continuous Operating Reference Station (CORS). The spatial and non-spatial data of existing established controls within the University of Lagos was obtained from the Department of Surveying and Geoinformatics, University of Lagos. Some of the existing established controls within the University of Lagos were selected based on their current status and the standard of their monumentation and a review of these controls was done based on establishment methodology, inherent discrepancy, values, and order. The existing controls were re-coordinated to obtain new coordinates (horizontal and vertical) of the controls. Both the new and existing coordinates of the controls established were compared and contrasted and statistical analysis was done to assess their accuracy. Table 1 below shows the coordinates of some of the existing controls obtained from the Department of Surveying and Geoinformatics, University of Lagos.

2.0 Methodology

2.1. Study Site

Field reconnaissance revealed the control beacons are physically present on the ground with some in bad states. The office inspections further validated the need for the research due to inconsistencies within the sourced existing data leading to a conceptual comprehensive plan devised for instrumentation, data acquisition, and processing. Figure 1 presents the methodology workflow for this study. Furthermore, Trimble GNSS planning online software helped the planning process.

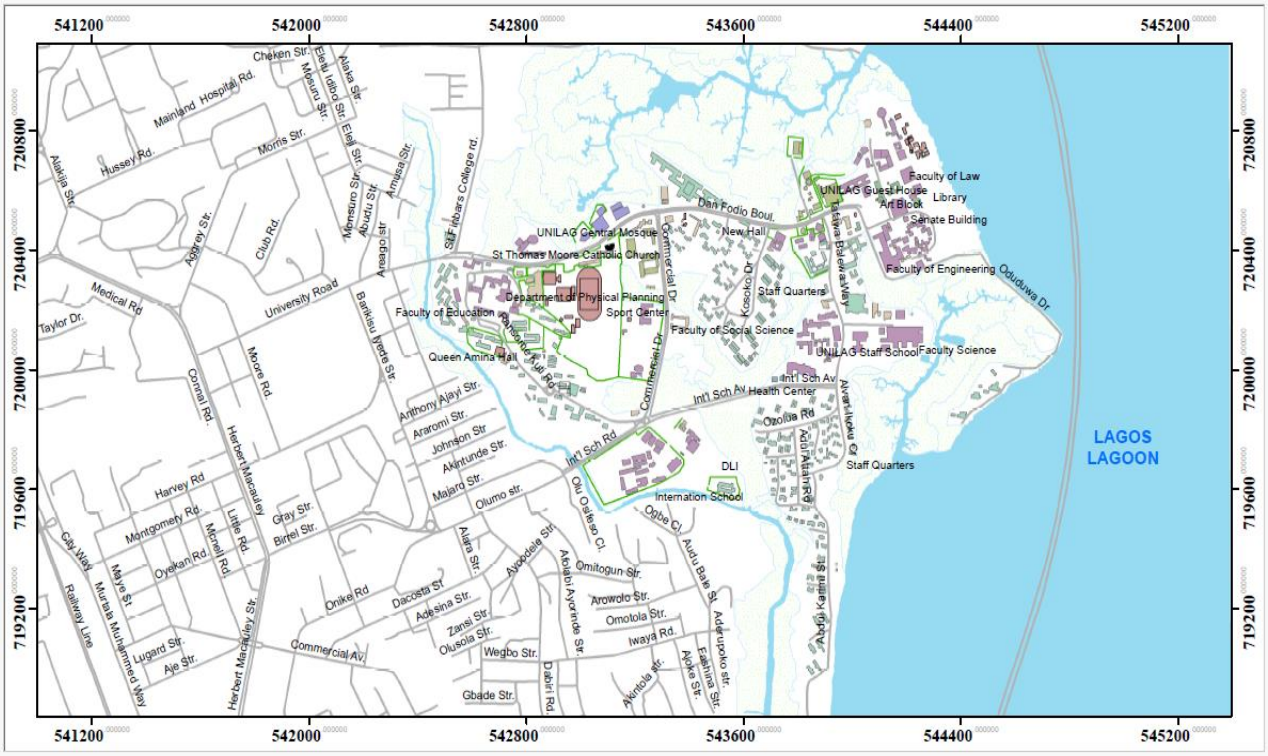


Figure 1: Map of Study Area

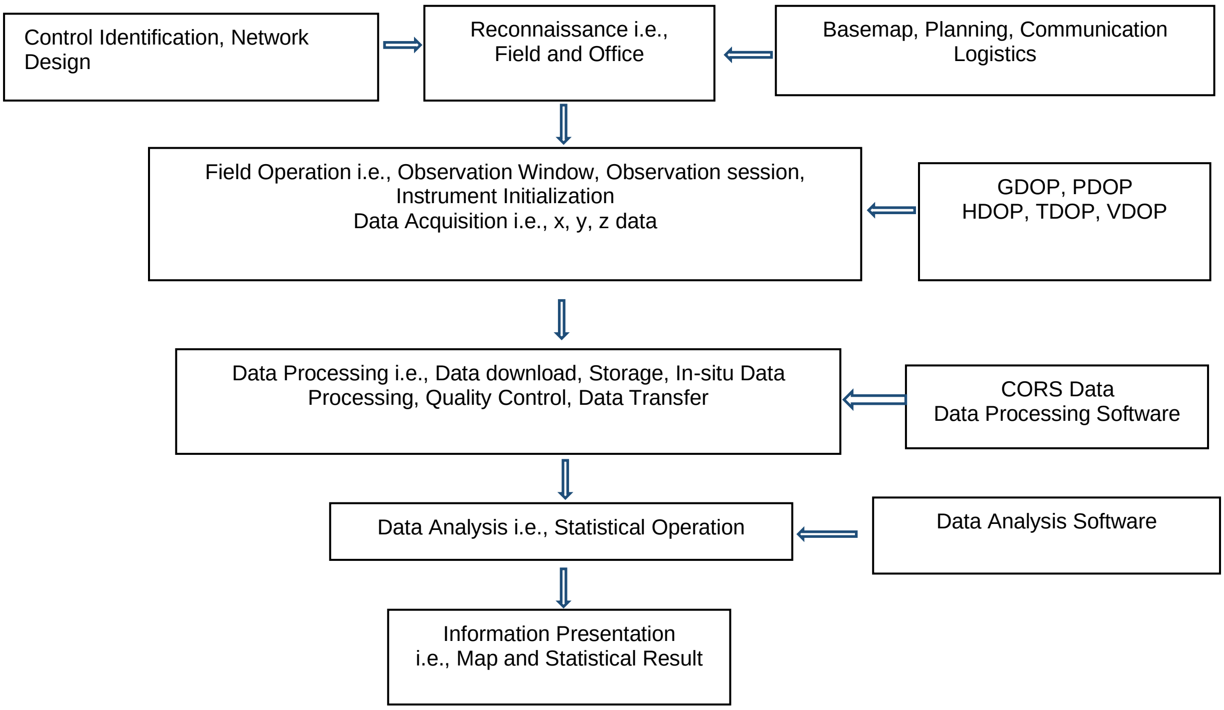


Figure 2: Methodology Workflow

2.2. Instrumentation

Stonex S900A GNSS Receivers (See Figure 2 and Figure 3), with known records to acquire GNSS data even in a forested area (Brach, 2022), were deployed to re-coordinate the selected survey controls. Two CORS stations were used; the Nigerian Permanent GNSS Reference Network (NIGNET) CORS code-named LGLA (situated within the University of Lagos) and the Nigerian Institution of Surveyors (NIS) CORS (See Figures 4 and 5), were used as reference stations which process and transmit GNSS data to the GNSS receivers, the reason for using two CORS was to have a loop of repeated baseline for finer adjustment of each observed

survey controls. However, the use of two CORS stations can incur errors if there is an inconsistency between the two CORS stations. These errors can be reduced using a baseline distance less than 13km and CORS stations operating in the same datum and stability of the CORS stations.
Trimble Business Centre (TBC) Software was used for Baseline processing of the GNSS data while ArcGIS 10X was used in the visualizing location of the selected survey controls and the production of maps showing the location of the survey controls. Global Mapper software was used in converting geographical coordinates to projected coordinates and finally, statistical analyses were carried out on the various data acquired from the project site.

Figure 3: Sets of Stonex DGPS Receivers

Figure 4: Stonex S900A Setup on GME 17/5

Figure 5: NIS CORS

Figure 6: UNILAG CORS

2.3. Data Acquisition

Static DGNSS observation technique was adopted with an hour-long observation in a bid to achieve a second-order level of accuracy, wherein noisy data and unhealthy satellites can be accounted for during processing (Pindinga & Zakari, 2020; Rizos et al., 2012). Having set up and initialised the receiver, the data was acquired for each control station. precautions observed included a minimum angle of elevation of 15°, PDOP (Position Dilution of Precision) not less than 4 (four), avoidance of power lines, metallic objects, canopy trees where possible and availability of spare batteries for DGNSS receivers, all in line with safety requirements while carrying out a DGNSS observation (Ghilani & Wolf, 2010). While occupying a survey control, the control ID, the observation start and end time, the instrument heights and the name of the observer were logged into a field book. The DGNSS observation was carried out on the survey controls, the NIS CORS, to be used for the post-processing of DGNSS data, was monitored to be in operation and continuous streaming data to avoid a data gap (Pindinga & Zakari, 2020).

2.4. Data Processing

Receiver INdependent Exchange (RINEX) Format raw data from NIGNET CORS and the NIS CORS both corresponding to the observation epoch and the DGPS receiver were imported into the TBC (Trimble Business Center). The NIGNET CORS and the NISCORS coordinate values given in the geographical coordinate system were converted to their UTM equivalent using Global Mapper. The raw data were processed and adjusted using the CORS as baseline controls. The TBC uses the Chi-square test to adjust the data until the initial a priori error estimates agree with the adjusted errors for the network vectors. The CORS assigns standard estimated error values to each control point based on its quality. The TBC also determines the root mean square error which evaluates the quality of predictions.

2.5. Accuracy Assessment

The Root Mean Square Error (RMSE) of the points concerning the referenced CORS was determined within the TBC software environment. This evaluates the quality of predictions (how far the predicted values fall short from measured true values using Euclidean distance). Equation 1 shows how RMSE was computed for the study (Ayodele et al., 2017).

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(y_i - \underline{y}_i)^2}{n}} \quad (1)$$

Where y_i= measured (predicted) value
$\underline{y}_i$= the average of the measured (actual) value
n= number of non-missing data points
i= variables

In computing the horizontal displacement (S) for each control under consideration, equation 2 was applied. (Ayodele et al., 2017).

$$S = \sqrt{\Delta E^2 + \Delta N^2} \quad (2)$$

where;
ΔE - Change in the Eastings Coordinate
ΔN - Change in the Northings Coordinate
S - Vector Deviation Distance

2.6. Statistical Analysis

Ninety-one per cent (91%) of the observed controls were used for statistical analysis based on the criteria that there exist values for the coordinate points and the survey control is in stable condition. To access the correlation coefficient (r) between the existing variables x (X_1, Y_1, Z_1) and the newly acquired variables y (X_o, Y_o, Z_o), equation 3 was applied (Iyoyojie, 2014).

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{\{n\Sigma x^2 - (\Sigma x)^2\}\{n\Sigma y^2 - (\Sigma y)^2\}}} \quad (3)$$

where;
r - correlation coefficient
x - existing coordinates variables
y - newly acquired coordinates variables

With a two-sample t-test for means of (X_o, X_1), (Y_o, Y_1) and (Z_o, Z_1), equation 4 was used to produce the $p - value$ based on the $t - distribution$ (Ayodele et al., 2017).

$$T - Statistic = \frac{(\underline{x}_i - \underline{y}_i) - Hypothesised\ difference}{SE_{\underline{x}_i - \underline{y}_i}} \quad (4)$$

where;
$\underline{x}_i - \underline{y}_i$ - the mean difference between the sample means

$SE_{\underline{x}_i - \underline{y}_i}$ - standard error of the difference

The standard error of the difference in the Aspin-Welch t-test or unequal-variance t-test for the unequal variance case is expressed in equation 5.

$$SE_{\underline{x}_1 - \underline{x}_2} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \tag{5}$$

n_1 *and* n_2 are the assumed sample sizes for groups *x* and *y*.

H_0: $\underline{x}_i - \underline{y}_i$ = Hypothesised difference

Since the Hypothesised difference is zero, the t-statistic formula reduces to equation 6:

$$T - Statistic = \frac{x_i - y_i}{SE_{\underline{x}_i - \underline{y}_i}} \tag{6}$$

For the unequal variance case equation

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{\left(\frac{S_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{S_2^2}{n_2}\right)^2}{n_2 - 1}} \tag{7}$$

3.0 Result and Discussion

3.1. Accuracy Assessment

Here, the results collected during the research were presented, discussed and compared with existing results. Some of the coordinates of the existing controls within the University of Lagos, Akoka Campus are shown below.

Table 1. Coordinates of some of the Existing Controls

Station	Eastings (X_o)	Northings (Y_o)	Height (Z_o)
CR 7	543302.33	720161.975	3.193
CR 8	543242.733	719910.413	4.318
GME 02	543978.166	720210.922	7.173
GME 03	543944.970	720410.697	7.418
XST 347	543235.430 (543245.510)	719894.220 (719884.330)	4.701 (4.735)

Source: Department of Surveying & Geoinformatics, University of Lagos

The results are outlined correctly and concisely. The overview of the results is detailed and also expressed in Table 2 below.

Table 2: Adjustment Statistics

Operation	Result
Number of Iterations for Successful Adjustment:	3
Network Reference Factor:	1.00
Chi-Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	368
Post-Processed Vector Statistics	
Reference Factor:	1.00
Redundancy Number:	368.00
A Priori Scalar:	2.62
Fixed	0.000001(Meter)

Table 2 shows the chi-square test performed on the data at a 95% confidence level was successful and the fixed result obtained surpassed the expected second-order accuracy standard (1: 50,000) for the control survey. The full processed adjustment result summary can be found in Table 3.

Table 3: Processing summary for points from part of the baselines

Observation	Solution Type	H. Prec. (95%)	V. Prec. (95%)	RMS	Distance (m)
LGLA --- GM06	Fixed	0.0099	0.0193	0.0096	207.264
LGLA --- U001	Fixed	0.0078	0.0313	0.0113	514.911
LGLA --- GM05	Fixed	0.0174	0.0449	0.0178	226.642
LGLA --- GM17	Fixed	0.0127	0.0672	0.021	179.156
LGLA --- G174	Fixed	0.0137	0.0285	0.0138	157.001
LGLA --- G172	Fixed	0.0141	0.0647	0.0152	283.771
LGLA --- GM04	Fixed	0.0049	0.0204	0.0083	190.052
LGLA --- GM03	Fixed	0.0074	0.012	0.0066	25.645
LGLA --- GM02	Fixed	0.0219	0.0307	0.0191	200.622
LGLA --- ME03	Fixed	0.0133	0.0351	0.0108	398.865
LGLA --- ME04	Fixed	0.0116	0.0249	0.012	200.912
LGLA --- G176	Fixed	0.0523	0.1172	0.0237	359.290
LGLA --- G175	Fixed	0.0162	0.0434	0.011	321.818
LGLA --- P842	Fixed	0.0053	0.0199	0.0092	215.645
LGLA --- ME07	Fixed	0.0114	0.0207	0.0261	301.619
LGLA --- P132	Fixed	0.0044	0.0231	0.0076	445.656
LGLA --- P201	Fixed	0.0163	0.0824	0.0148	817.961
LGLA --- DOS0	Fixed	0.0188	0.0316	0.0108	869.974
LGLA --- ME10	Fixed	0.0086	0.0536	0.0096	890.020
LGLA --- P191	Fixed	0.0184	0.1272	0.0221	954.611
LGLA --- P181	Fixed	0.0058	0.0318	0.0095	1219.865
LGLA --- Y186	Fixed	0.0138	0.0945	0.0094	1340.267
LGLA --- P171	Fixed	0.0082	0.0473	0.0055	1367.844
LGLA --- DOSS	Fixed	0.0062	0.0364	0.0112	1305.829
LGLA --- P161	Fixed	0.0055	0.026	0.0069	1162.884
LGLA --- CR30	Fixed	0.0075	0.0639	0.0158	662.054
LGLA --- CR50	Fixed	0.0101	0.066	0.0153	673.541
LGLA --- CR60	Fixed	0.0205	0.0417	0.0164	687.126
LGLA --- CR70	Fixed	0.0089	0.0401	0.015	704.437
LGLA --- P151	Fixed	0.0077	0.0573	0.0135	757.060
LGLA --- CR80	Fixed	0.0133	0.0302	0.015	877.004
LGLA --- X347	Fixed	0.0059	0.0265	0.0107	889.657
NIS_CORS --- GM06	Fixed	0.0223	0.0289	0.014	11987.800
NIS_CORS --- U001	Fixed	0.0132	0.0754	0.023	12224.600
NIS_CORS --- GM05	Fixed	0.0322	0.0503	0.025	11884.400
NIS_CORS --- GM17	Fixed	0.0407	0.0653	0.034	12188.300
NIS_CORS --- G172	Fixed	0.0274	0.0418	0.022	12192.200
NIS_CORS --- GM04	Fixed	0.0087	0.0176	0.015	11870.600
NIS_CORS --- GM03	Fixed	0.0206	0.0287	0.014	12051.800
NIS_CORS --- GM02	Fixed	0.016	0.0213	0.021	12249.000
NIS_CORS --- ME03	Fixed	0.0137	0.0238	0.018	12415.500
NIS_CORS--- ME04	Fixed	0.0119	0.0302	0.018	12247.200
NIS_CORS --- G175	Fixed	0.007	0.0181	0.016	11863.200
NIS_CORS--- P842	Fixed	0.0127	0.0444	0.028	11863.100
NIS_CORS --- G176	Fixed	0.02	0.037	0.023	11787.800
NIS_CORS --- P132	Fixed	0.0091	0.0194	0.017	11758.200

NISCORS --- ME07	Fixed	0.0156	0.0361	0.02	11821.900
NIS_CORS --- DOS0	Fixed	0.0109	0.0309	0.013	11638.000
NIS_CORS --- P201	Fixed	0.0203	0.0343	0.031	11620.700
NIS_CORS --- ME10	Fixed	0.0107	0.0186	0.014	11648.700
NIS_CORS --- P191	Fixed	0.01	0.061	0.02	11689.800
NIS_CORS --- ME10	Fixed	0.0089	0.0197	0.019	11648.600
NIS_CORS --- P181	Fixed	0.0086	0.0514	0.015	11641.000
NIS_CORS --- Y186	Fixed	0.0096	0.0157	0.015	11631.400
NIS_CORS --- DOSS	Fixed	0.0103	0.064	0.018	11811.100
NIS_CORS --- P171	Fixed	0.0096	0.0226	0.013	11642.800
NIS_CORS --- CR30	Fixed	0.0088	0.0212	0.019	11911.800
NIS_CORS --- P161	Fixed	0.0121	0.0272	0.017	12077.000
NIS_CORS --- CR50	Fixed	0.017	0.0373	0.022	11992.300
NIS_CORS --- CR60	Fixed	0.0124	0.0237	0.036	12025.200
NIS_CORS --- CR70	Fixed	0.0174	0.0288	0.028	12054.700
NIS_CORS --- P151	Fixed	0.0153	0.0353	0.028	12127.800
NIS_CORS --- CR80	Fixed	0.0098	0.0285	0.013	12271.400
NIS_CORS --- X347	Fixed	0.0142	0.028	0.029	12283.600
NIS_CORS --- CGGL	Fixed	0.0109	0.0784	0.025	12282.400
NIS_CORS --- P101	Fixed	0.0129	0.0193	0.021	12340.600
NIS_CORS --- YTT1	Fixed	0.0116	0.0215	0.019	12006.800
NIS_CORS --- Y414	Fixed	0.0093	0.0219	0.016	11740.300
NIS_CORS --- CGGL	Fixed	0.0075	0.0162	0.028	12282.400

Table 3 above shows the horizontal, and vertical precision, root mean square error and distances of the controls for points from part of the baselines. It gives information on the accuracy and precision of the control points to the part of the baselines.

3.2 Data comparison

This section compares the coordinates of the existing and the newly acquired control points and shows the horizontal displacement between the existing and newly observed control points as seen in Tables 4 and 5.

Table 4: The existing and newly acquired coordinates

S/N	Station ID	New Easting	Existing Easting	New Northing	Existing Northing	New Elevation	Existing Elevation
1	CGG/SP LAG007	543204.086	543203.050	719885.311	719886.120	4.495	4.431
2	CR 3	543307.351	543306.210	720313.309	720314.270	4.046	4.135
3	CR 5	543313.170	543312.040	720229.869	720230.800	3.665	3.521
4	CR 6	543309.910	543308.810	720193.823	720194.750	3.534	3.251
5	CR 7	543303.422	543302.330	720160.247	720161.975	3.394	3.193
6	CR 8	543241.647	543242.733	719909.645	719910.413	4.380	4.318

7	DOS 03 S	543101.116	543106.081	720530.669	720531.591	6.718	6.704
8	DOS 12S	542672.107	542678.379	720210.441	720213.596	6.025	5.974
9	GME17/02	544243.975	544243.051	720387.283	720386.950	1.758	1.609
10	GME17/04	544062.907	544061.911	720527.947	720527.595	5.971	5.851
11	GME17/05	544116.563	544115.517	720690.446	720690.177	7.203	7.082
12	GME17/06	544068.386	544067.299	720751.478	720751.192	8.214	8.031
13	GME 02	543972.796	543978.166	720209.055	720210.922	7.336	7.173
14	GME 03	543939.765	543944.970	720408.731	720410.697	7.525	7.418
15	GME 04	543886.356	543891.529	720582.688	720584.236	8.235	8.130
16	GME 05	544023.633	544028.926	720626.365	720627.896	8.041	7.946
17	GME 06	544111.108	544116.378	720551.794	720553.334	6.971	6.876
18	GME17/03	544125.843	544124.927	720339.681	720339.302	1.190	1.165
19	MEGA 03	543929.811	543935.205	720011.740	720012.803	7.115	7.126
20	MEGA 04	543967.018	543972.364	720208.528	720209.665	7.348	7.402
21	MEGA 07	543700.858	543713.950	720559.058	720540.706	7.073	6.960
22	MEGA 10	543078.460	543083.070	720511.569	720512.676	6.324	6.345
23	PGD10/13	543756.785	543757.277	720023.714	720023.291	5.047	5.231
24	PGD21/13	543545.370	543545.288	720566.017	720566.007	6.355	6.455
25	PGD15/13	543282.838	N/A	720075.590	N/A	3.195	N/A
26	PGD16/13	542876.047	542875.944	719994.854	719994.774	5.606	5.722
27	PGD17/13	542595.727	542595.566	720363.180	720363.461	6.130	6.242
28	PGD18/13	542742.857	542742.858	720409.693	720409.974	6.295	6.348
29	PGD19/13	543008.628	543008.474	720444.347	720444.129	4.917	5.092
30	PGD20/13	543160.527	543160.877	720569.743	720569.922	6.751	6.885
31	PGD 84/2	543806.487	543819.606	720557.603	720539.176	7.308	7.202
32	UNILAG 001	544473.831	544479.214	720456.669	720458.060	1.519	1.429
33	X347	543236.440	543235.430	719895.006	719894.220	4.770	4.701
34	YTT 28/186	542622.778	542627.672	720383.121	720382.824	6.405	6.252
35	YTT 28/414	540939.495	540935.922	719902.723	719908.560	8.369	N/A
36	YTT 28/413	541039.355	N/A	719648.103	N/A	8.662	N/A

Table 4 above shows the new and existing coordinates (Easting, Northing and Elevation) of control points. Control points whose existing values could not be obtained were designated as N/A.

Table 5: Horizontal Displacement between the Existing and Newly Observed Controls

S/N	**Station ID**	**Difference in Easting (m) ∆E**	**Difference in Northing (m) ∆N**	**Difference in Elevation (m) ∆H**	**Horizontal Distance Shift – S (m)**
1	CGG/SP LAG007	1.036	-0.809	0.064	1.3146
2	CR 3	1.141	-0.961	-0.089	1.4919
3	CR 5	1.130	-0.931	0.143	1.4641
4	CR 6	1.100	-0.927	0.283	1.4383
5	CR 7	1.092	-1.728	0.201	2.0443
6	CR 8	-1.086	-0.768	0.062	1.3302
7	DOS 03 S	-4.965	-0.922	0.014	5.0503
8	DOS 12S	-6.272	-3.155	0.051	7.0203
9	GME17/02	0.924	0.333	0.149	0.9821
10	GME17/04	0.996	0.352	0.120	1.0562
11	GME17/05	1.046	0.269	0.121	1.0798
12	GME17/06	1.087	0.286	0.183	1.1238
13	GME 02	-5.370	-1.867	0.163	5.6855
14	GME 03	-5.205	-1.966	0.107	5.5635
15	GME 04	-5.173	-1.548	0.105	5.4001
16	GME 05	-5.293	-1.531	0.095	5.5104

17	GME 06	-5.270	-1.540	0.095	5.4908
18	GME17/03	0.916	0.379	0.025	0.9911
19	MEGA 03	-5.394	-1.063	-0.011	5.4974
20	MEGA 04	-5.346	-1.137	-0.054	5.4653
21	MEGA 07	-13.092	18.352	0.113	22.5434
22	MEGA 10	-4.610	-1.107	-0.021	4.7409
23	PGD10/13	-0.492	0.423	-0.184	0.6487
24	PGD21/13	0.082	0.010	-0.100	0.0825
25	PGD15/13	N/A	N/A	N/A	N/A
26	PGD16/13	0.103	0.080	-0.116	0.1311
27	PGD17/13	0.161	-0.281	-0.112	0.3244
28	PGD18/13	-0.001	-0.281	-0.053	0.2808
29	PGD19/13	0.154	0.218	-0.175	0.267
30	PGD20/13	-0.350	-0.179	-0.134	0.3929
31	PGD 84/2	-13.119	18.427	0.106	22.6201
32	UNILAG 001	-5.383	-1.391	0.090	5.5597
33	X347	1.010	0.786	0.069	1.2802
34	YTT 28/186	-4.894	0.297	0.153	4.9033
35	YTT 28/414	3.573	-5.837	N/A	6.8435
36	YTT 28/413	N/A	N/A	N/A	N/A

From Table 5 above, it is clear that the more precise control points in existence are most of the PGD series; followed by the GME17 and CR series. Having plotted the discrepancies, the existing values of points which do not correlate with newly observed values were discarded to avoid statistical analysis errors. The accuracy of geodetic measurements depends on various factors, including the observation method deployed, the type of instrument used, environmental conditions and time of day, the processing software employed, as well as the potential for the observer's mistakes or blunders.

It could be deduced that there exists less deviation in the Eastings of the PGD series; followed by the CRs and the GME17 series. Also, the less deviated in the Northings existed in the PGD series; followed by the CRs and the GME17 series while in elevation, the lowest deviation occurs at MEGA03 and the maximum deviation at CR6.

Therefore, the existing heights (elevations) data and the newly acquired one have no significant difference while there is a significant difference between the existing and newly acquired Eastings and Northings.

3.3. Statistical Analysis

This section examined the relationship that exists between the existing and newly acquired Eastings, Northings and Elevation coordinates of control points. Also, the summary of the Aspin-Welch t-test results was examined.

The correlation matrices between the existing and newly acquired Eastings, Northings and Elevation coordinates of control points are shown below.

Table 6: The Correlation Coefficient between Existing and Newly Coordinates of Controls Points

	New Easting	**Existing Easting**
New Easting	1	
Existing Easting	0.999985879	1
	New Northing	Existing Northing
New Northing	1	
Existing Northing	0.999993	1
	New Elevation	Existing Elevation
New Elevation	1	
Existing Elevation	0.998153	1

Table 6 above shows a strong correlation between the newly acquired Easting and existing Easting, newly acquired Northing and existing Northing, and newly acquired Elevation and existing Elevation.

Table 7: Summary of two-sample t-test for means X and Y

	mean	**variance**	**t-stat**	**t-critical two-tail**
X_o	543517.792	296791.317		
X_1	543516.078	296318.464	3.2606253	2.74999565
Y_o	720334.439	58484.4529		
Y_1	720333.773	58499.9592	4.0149979	2.74999565
Z_1	5.54964097	3.78898635		
Z_o	5.58976516	3.73290145	-1.8813701	2.74999565

Table 7 presents the result summary of the hypothesis calculations. There was a statistically significant difference at 99% confidence level in the horizontal control coordinates but no significant difference between the height data. For the Eastings and Northings, the p-values were smaller (E = 0.002768695 and N = 0.00036642) than the 0.01 p-value. For the Height, the p-value (0.069657705) is greater than the specified 0.01 p-value.

4.0. Conclusions

Since there is evidence of significant difference at a 99% confidence level for the Eastings and Northings and no significant difference for the height, we infer the rejection of the existing Eastings/Northings, keep the newly acquired Eastings/Northings and fail to reject the existing height of control coordinates of the University of Lagos The deviation between the old and new coordinates may have originated from environmental factors on the instruments of observation and on the control platform itself; as well as improvements made on survey instruments thereby improving their accuracies; multipath, atmospheric refraction, solar interference, outdated satellite ephemeris; and observational technical skills.

Acknowledgements
The authors are grateful for the contributions of the Nigerian Institution of Surveyors (NIS), Lagos Chapter, and Olalekan Jimoh in providing the CORS Data used. Special thanks to Chukwuma John Okolie for his reviews and helpful feedback which has contributed greatly to improving the quality of this research. Appreciation to Adegbite Usman Olalekan for making his DGPS equipment available for spatial data acquisition.

References

Alademomi, A. S., Omeiza, M. A., Emmanuel, D. O., Julius, S. T., and Bolarinwa, O. J. (2020). Establishment of Deformation and Subsidence Monitoring Baseline in the Coastal Environment: A Case Study of University of Lagos. *South African Journal of Geomatics*, *9*(1), pp. 13-30.

Ariza López, F. J., and Atkinson Gordo, A. D. (2008). Analysis of some positional accuracy assessment methodologies. *Journal of Surveying Engineering*, *134*(2), pp. 45-54.

Ayodele, E. G. Okolie, C. J. Ezeigbo, C. U. and Fajemirokun, F. A. (2017). Evaluating the Stability and Adequacy of NIGNET for the Definition of Nigerian Geodetic Reference Frame. Department of Surveying and Geoinformatics, University of Lagos; Global Geodetic Solution Limited, *UNILAG Consult, University of Lagos, Vol. 17, No. 1.*

Choi, H., & Kim, K. C. (2012). Accuracy analysis of cadastral control points surveying using VRS case by Jinju city parts. *Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography*, 30(4), 413-422.

Brach, M. (2022). Rapid Static Positioning Using a Four System GNSS Receivers in the Forest Environment. *Forests*, *13*(1), p. 45.

Botsyo, S., Bortei, B.B. and Ayer, J. (2020). CORS Usage for GPS Survey in the Greater Accra Region: Advantages, Limitation, and Suggested Remedies. *J geovis spat anal 4* https://doi.org/10.1007/s41651-020-00061-8. (Accessed 16 Mar. 2020)

Dabove, P., & Di Pietra, V. (2019). Towards high accuracy GNSS real-time positioning with smartphones. *Advances in Space Research, 63(1).* Pp. 94-102.

Dimal, M. O. Dimal, R. L. and Balicanta L. (2009). Comparative Analysis of GPS Azimuth and Derived Azimuth for the Establishment of Project Controls. 7th FIG Regional Conference. Hanoi, Vietnam.

Ghilani, C. D., & Wolf, P. R. (2010). *Elementary surveying*. Prentice hall.

Iyoyojie, H. A. (2014). 'Re-coordination of Survey Controls within the University of Lagos using total station and digital level'.

John A. Dulton (2020). The Nature of Geographic Information. *e-education Institute, College of Earth and Natural Science*, Pennsylvania University.

John, D. B. (1984). Standards and Specifications for Geodetic Control Networks. *Federal Geodetic Control Committee*; Rockville, Maryland

Okorocha, C., Olushola, O. and Ehigiator Irughe, R. (2023). Regression Modelling of the Accuracy of GNSS Real Time Kinematic Observations Referenced to Sacredion Tersus Geobee30 Cors. 10.26480/pjg.01.2023.11.20. pp 11-20.

Owodunni, O. A. (2015). Re-coordination of Survey Controls using Total Station and Digital level within the University of Lagos.

Pham, C.K and Nguyen, Q.L (2019). Accuracy assessment of the single CORS technology for establishing the large-scale cadastral map. International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019 1ISSN 2229-5518

Rizos, C., Janssen, V., Roberts, C., & Grinter, T. (2012). Precise Point Positioning: Is the era of differential GNSS positioning drawing to an end?

Cite this article as:

Alabi A.O., Alademomi A.S., Salami T.J., Okutubo A.D. & Oyedokun W.R., 2024. Accuracy Assessment of Established Controls for Precise Positioning using DGPS and CORS. *Nigerian Journal of Environmental Sciences and Technology*, 8(1), pp. 1-12. https://doi.org/10.36263/nijest.2024.01.02