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VERIFYING THE CONSISTENCY OF PRECISE POINT POSITIONING CONTROLS FOR CADASTRAL SURVEYING

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ABSTRACT

Precise Point Positioning (PPP) is an aspect of Global Navigational Satellite System (GNSS) technique that uses one satellite receiver to determine position, velocity and time of points on the earth's surface. PPP could be used globally for a wide range of applications such as positioning in remote areas and positioning where there are lacks of control networks. In order words, PPP is deployed wherever reference stations are not available for it does not transfer local error about. The aim of this study is to verify the consistency of precise point positioning data in cadastral surveying. Selected points were observed 5 times within the period of 12 months. Each observation lasted 60 minutes for each station. The raw GNSS data were downloaded from the receiver into a computer, and converted to RINEX file which were later uploaded to online post-processing service. The results were subjected to standard deviation and confidence interval computations. The results were in centimeter levels. Therefore, the PPP is recommended for use in static mode for control establishments in areas where there are no controls for surveying and mapping.

Keywords: PPP, GNSS, Control, Accuracy, Rinex

INTRODUCTION

Control, in the surveying profession refers to any monumented point on the surface of the earth whose horizontal and vertical positions are known and from this point, other auxiliary surveys like mining, engineering, topographic, route, photogrammetry and perimeter surveys are referenced to (Najera, 1997 and Dimal, 2020). Control is usually established through different survey operations like astronomical observations, triangulations, trilaterations and Global Navigational Satellite System (GNSS) observations (Hasanuddin *et al.*, 2015, Neenu, 2021,). However, GNSS came into the scene in the 1970s and further developed in the 90s to become very significant in the surveying profession for control establishment (Burch, 2020, Dasgupta, 2016). Rowe (2019) describes a type of GNSS observation which is Precise Point Positioning (PPP) that eliminates or in some cases, models GNSS errors to provide a high level of positioning accuracy from a single receiver. Control established with PPP technique hinges on GNSS satellite clock and orbit corrections to generate positions from a network of global reference stations (Petovello, 2018). Once these corrections are computed, the coordinates of points are delivered to the end users, normally through the Internet.

The salient advantage of PPP technique over the differential GPS positioning in recent times is that, it is cost effective, that is, with just one receiver, high accuracy for mapping and referencing can be achieved (Guma *et al.*, 2023). The PPP allows the establishment of controls according to ITRF 2014 which is also Earth-Centered (Ayhan and Almuslmani, 2021). Seredovich *et al.*, (2012) observed that PPP solutions could be used globally for a wide range of applications ranging from remote sensing to property surveys and can also be deployed where reference stations are not intervisible or existing at all. PPP augmentation services like IGS, uses global networks of sparsely distributed tracking stations to compute precise satellite orbit and clock products which are then made available in real-time or post-mission. Alkan and Ocalan, (2013) inferred that, the PPP technique is a better option to the conventional differential GPS positioning technique in terms of its usability in marine survey too.

What necessitated this study is the need to densify third order controls around the 21 Local Government Areas using PPP technique because in Kogi State there are insufficient distributions of control networks across the State for cadastral works (Yaya, 2020). The handheld GNSS receiver which has positional accuracy challenges of between $\pm 5m$ and $\pm 13m$ (Merry and Bettinger, 2019) respectively have been what most professionals use to carry out survey in the rural areas. This has caused lots of charting or mapping challenges to the Office of the Surveyor General of the State. For this purpose, this study aims at verifying the consistency of PPP controls for usage in cadastral works with the objective of determining their accuracies through standard deviation and confidence intervals assessment. The scope of this study is limited to; reconnaissance survey, monumentation of the points, field observations, conversion from raw GNSS data into Rinex data, uploading and downloading from PPP solutions and carrying out of statistical tests to ascertain the accuracies of each points.

PPP technique and its accuracy

Novatel (2022) observed that, the PPP operates in accuracy of up to 3 centimeters, and the general accuracy of PPP is a function of time of convergence, which should not be less than 30 minutes. From the way it is built and design, the PPP solution needs time to converge to decimeter accuracy level so as to eliminate any local noise like the atmospheric conditions, multipath environment and satellite geometry. More so, accuracy and the convergence time are dependent also on the quality of the corrections performed and how these corrections are applied in the receiver. PPP system provides corrections to a receiver to increase position accuracy (Rowe, 2019). Liao *et al.*, (2021) confirmed that the PPP system allows a single corrections stream to be used worldwide and these corrections enhance PPP results. Andrei (2011) carried out satellite observations with some geodetic receivers placed on some points in Lasi municipal; after analysis was done, the accuracy of the PPP solutions were assessed and calculated to be within the range of 0.003m, 0.007m and 0.015m in the x, y and z coordinates respectively. Andrei (2011) concluded that, the results validated the applicability of the PPP technique for cadastral works.

Kiliszek *et al.*, (2018) in their work, provided analyses of the accuracy and convergence time assessment of the PPP method using different IGS products. So, they did calculations with weighting function of the observations and came up with the accuracy of 3 cm after a convergence time of 44 minutes. Also, the same level of accuracy was obtained with DGPS technique after comparison.

Seredovich *et al.,* (2012) while imploring Surveyors to resort to PPP controls for dam and deformation monitoring, observed that, the termination of selective availability has improved the accuracy and latency of Precise Point Positioning operations. It could be observed that observers could achieve on a global scale, positioning of centimeter to decimeter accuracy. Seredovich *et al.,*(2012) worked on dual frequency pseudorange and carrier phase observations along with IGS Precise orbit products to achieve centimeter results. Ovstedal *et al.,* (2006) observed that the PPP technique is a good alternative to differential methods for satellite positioning because the rigours normally experienced using DGPS is never there. Ovstedal *et al.,* (2006) developed software which was used by the Norwegian government for seafloor mapping and this software took care of the major ambiguities that usually affect satellite observations. The result of the PPP was compare with DGPS and at various durations, it showed that they were almost the same with DGPS technique.

Petovello (2018) cited that PPP measurement errors are accounted for using stochastic models and these models are used to produce results that are within centimeter level accuracy. Rowe (2021) observed also that, PPP positioning precision is determined by the uncertainty of the orbit and clock products used in the solution, and not just with the proximity to any base station anywhere. With just observation duration of 15 minutes to an hour, some decimeter to centimeter accuracy can be attained. Angrisano *et al*., (2021) who adopted the open source software RTKLib to make comparison between PPP and DGPS techniques concluded that centimeter accuracy was possible. The Ionospheric-free model was an added advantage in improving every PPP measurements.

Re-establishing the consistency of PPP controls

In re-establishing the consistency of every control network, the use of statistical approach like the confidence interval and the standard deviation of redundant observations made at the point of interest are necessary (Erdogan and Gulhan, 2016: Simundic, 2008).

Confidence Interval

Confidence interval estimates the precision of a sample size and as well as depicts the quality of any research. It is defined by its margin of errors (Simundic, 2008). Menon (2022) explained that confidence interval shows the probability that a parameter would be, between some values around the mean. They are constructed using confidence levels of 95% or 99%.Bevans (2022) explained that, the more accurate the observation data and experiment, the greater the chance that the confidence interval contains the true value of observations. Confidence intervals are useful in determining the variations around the mean or true value. The confidence interval formula for the PPP data observed which follows a standard normal distribution is;

$$CI = \bar{X} \pm t^* \frac{\sigma}{\sqrt{n}} \quad (1)$$

Where CI is the confidence interval, X is the mean of observation, t^* is the critical value of the t distribution, σ is the standard deviation and $\sqrt{n}$ is the square root of the population size when the formula was used on the sets of observations.

Standard Deviation

The standard deviation is used to analyze the accuracy and precision of observation data (Ayeni, 2014). As the standard deviation increases, the variance or dispersion from the mean also increases. More so, low standard deviation shows a very high level of precision in any set of observation. To compute the standard deviation for set of measurements, we have;

$$\sigma = \sqrt{\frac{\sum(x_i-\mu)^2}{N}} \quad (2)$$

Where σ is the Standard deviation, $\sum(x_i - \mu)^2$is the sum of square of the residuals and N is the number of observation times.

This research would use PPP technique to establish controls. The standard deviation and confidence interval assessment would be carried out on the results to establish their consistency.

MATERIALS AND METHOD

Study Area

The study areas for this study include three local government areas of Kogi State and they are Lokoja, Ajaokuta and Adavi. Kogi State is one of the 36 states in Nigeria and is in the North Central part of the country. The State is known as the Confluence State for its capital, Lokoja, is where the Rivers Niger and Benue meet. It is located between latitudes 07º 03' 0" to 07° 05' 5"North of the Equator and longitude 06° 03' 00" to 06° 05' 00"East.

The elevation of the study areas range from 45-125m, meaning that there are hills and mountains that are steep sided and very rough (Nathaniel, 2012). The terrains are mostly allied with granite and limestone complexes that slope around their margins. The valleys around the study area have irregular drains which usually have a mixture of fine and coarse textured sand (Dalil *et al.,* 2017).

These study areas are surrounded by the Savanna which is associated with high temperatures, low humidity and cloudless sky for most period of the year. The climate of the study area tends to be classified under the Koppen's Aw classification as having two different seasons (rainy and dry seasons), (Nathaniel, 2012).Their temperature is generally high with monthly maxima and minima of about 35ºC and 21ºC respectively. This is due to the latitudinal location of the region within the tropics, though some mild modifications are traceable to influences by sea breeze from the Atlantic Ocean and Northern trade wind (harmattan) (Adejoh and Abubakar, 2018)

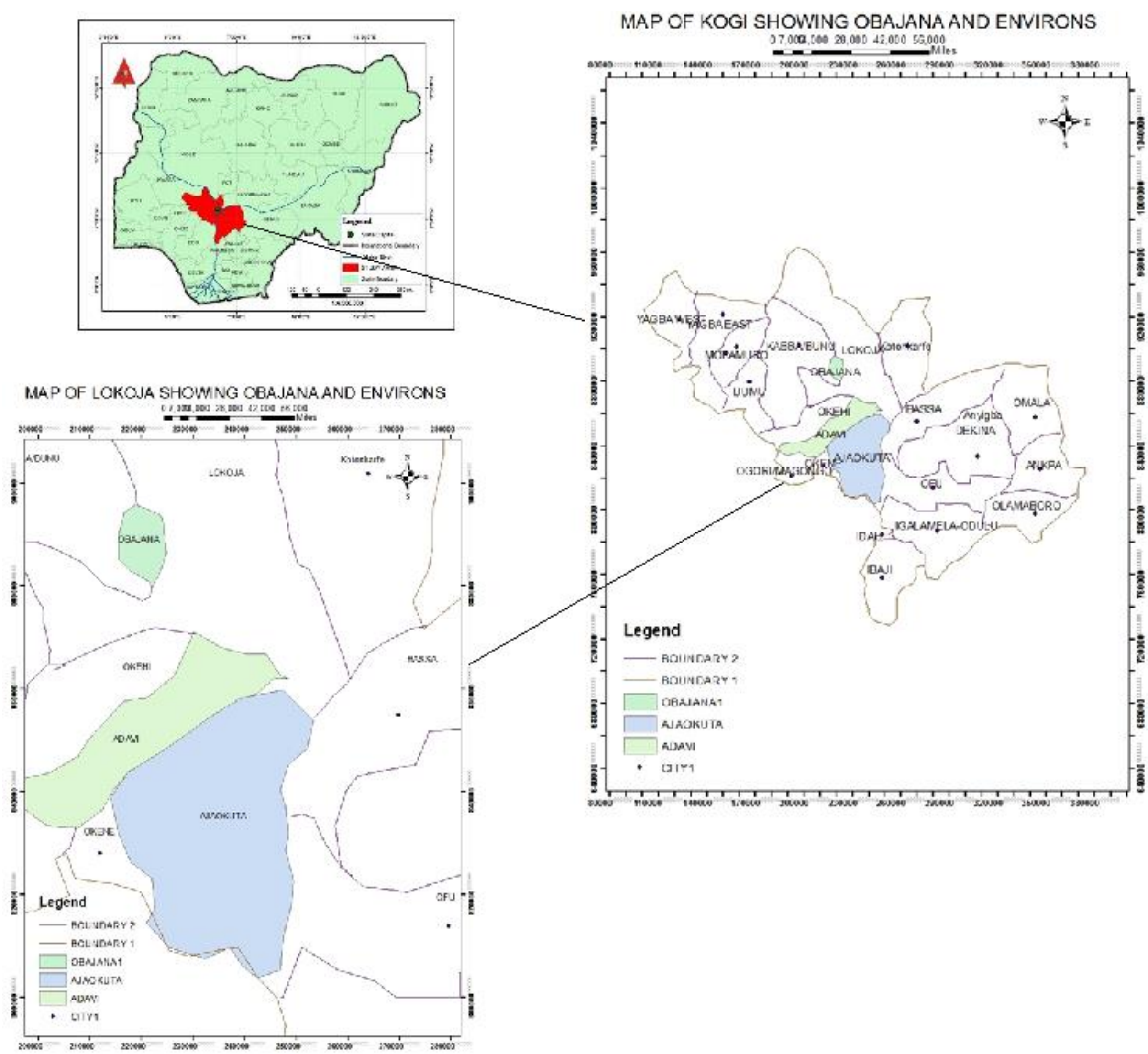

Figure 1: Map of Kogi State showing Lokoja and Map of Lokoja showing points of observations.
Source: Guma, 2022.

Instrument Requirement
The Hardware instrument used in this study includes; Hi-Target V30 single receiver and accessories, Hp Laptop Computer, downloading USB cable. The software used for this research include; Hi-Target Geomatics Office, MS-Excel 2007 and Canadian Spatial Reference System (CSRS) online solution. The data that were used were secondary data and they are Eastings and Northings of the various points of interest in ITRF 14 or WGS 84 Coordinates of points.

Method of Data Acquisition
The secondary data that were used were results of points observed at interval of 3 months for a total period of 12 months by Guma *et al.,* (2021). Observations were carried out on control points for averagely 60 minutes respectively. The V30 Hi-Target Receiver was used on static mode and the acquired raw GNSS data were downloaded to a laptop computer using a USB downloading cable; the data obtained were processed into RINEX format using the Hi-Target Geomatics office software. The RINEX data were further uploaded to the Canadian spatial Reference System (CSRS) online Post Processing solution.

RESULTS AND DISCUSSION
The results were transmitted back through internet. Tables 1 to 5 show the returned results.

Table 1: The PPP results for First observation

STN ID	EASTING (m)	NORTHING (m)	ELLIP HGT
PTT 001A	*252506.448*	*872471.814*	*74.902*
PTT 006A	*252670.394*	*868382.856*	*79.449*
PTT 007A	*249303.245*	*862100.665*	*81.823*
PTT 008A	*251812.304*	*864381.901*	*66.794*
PTT 011A	*241153.682*	*843998.099*	*87.632*
PTT 016A	*217416.604*	*881042.205*	*232.363*
PTT 017A	*218015.872*	*883422.256*	*268.713*

PTT 018A	*217698.872*	*882087.851*	*249.117*
PTT 021A	*246109.945*	*864605.587*	*114.687*
PTT 023A	***240464.990***	***863692.444***	***151.738***

Source: Guma *et al.*, (2021).

Table 2: PPP results for second observation

STN ID	EASTING (m)	NORTHING (m)	ELLIP HGT
PTT 001B	*252506.500*	*872471.818*	*74.841*
PTT 006B	*252670.429*	*868382.900*	*79.548*
PTT 007B	*249303.341*	*862100.666*	*81.931*
PTT 008B	*251812.355*	*864381.902*	*66.803*
PTT 011B	*241153.697*	*843998.110*	*87.602*
PTT 016B	*217416.595*	*881042.204*	*232.207*
PTT 017B	*218015.895*	*883422.271*	*268.665*
PTT 018B	*217698.913*	*882087.849*	*249.181*
PTT 021B	*246110.011*	*864605.575*	*114.827*
PTT 023B	***240464.954***	***863692.458***	***151.678***

Source: Guma *et al.*, (2021).

Table 3: PPP results for third observation

STN ID	EASTING (m)	NORTHING (m)	ELLIP HGT
PTT 001C	*252506.427*	*872471.801*	*74.817*
PTT 006C	*252670.474*	*868382.868*	*79.381*
PTT 007C	*249303.389*	*862100.641*	*81.825*
PTT 008C	*251812.36*	*864381.924*	*66.768*
PTT 011C	*241153.692*	*843998.096*	*87.615*
PTT 016C	*217416.572*	*881042.209*	*232.304*
PTT 017C	*218015.821*	*883422.243*	*268.682*
PTT 018C	*217698.854*	*882087.861*	*249.125*
PTT 021C	*246109.978*	*864605.597*	*114.733*
PTT 023C	***240464.769***	***863692.356***	***151.439***

Source: Guma *et al.*, (2021).

Table 4: Results for fourth observation

STN ID	EASTING (m)	NORTHING (m)	ELLIP HGT
PTT 001D	*252506.472*	*872471.807*	*74.865*
PTT 006D	*252670.543*	*868382.914*	*79.393*
PTT 007D	*249303.395*	*862100.631*	*81.893*
PTT 008D	*251812.385*	*864381.919*	*66.796*
PTT 011D	*241153.684*	*843998.102*	*87.609*
PTT 016D	*217416.643*	*881042.211*	*232.291*
PTT 017D	*218015.938*	*883422.253*	*268.699*
PTT 018D	*217698.88*	*882087.882*	*249.133*
PTT 021D	*246109.958*	*864605.592*	*114.735*
PTT 023D	***240464.93***	***863692.447***	***151.654***

Source: Guma *et al.*, (2021).

Table 5: PPP result for Fifth, Observations.

STN ID	EASTING (m)	NORTHING (m)	ELLIP HGT
PTT 001E	*252506.491*	*872471.823*	*74.842*
PTT 006E	*252670.505*	*868382.891*	*79.384*
PTT 007E	*249303.325*	*862100.626*	*81.883*
PTT 008E	*251812.334*	*864381.899*	*66.761*
PTT 011E	*241153.662*	*843998.130*	*87.725*
PTT 016E	*217416.606*	*881042.204*	*232.336*
PTT 017E	*218015.899*	*883422.248*	*268.714*
PTT 018E	*217698.895*	*882087.844*	*249.143*
PTT 021E	*246109.949*	*864605.568*	*114.703*
PTT 023E	***240464.918***	***863692.439***	***151.789***

Source: Guma *et al.*, (2021).

PPP accuracy computation

Standard deviation of PPP result

The PPP results for all the observation times were collated and tabulated as seen in tables1 to 5. The mean was first computed for each point data and then followed by the computation of the standard deviation of the point. The mean of the various observation conducted on each station was determined using the following formula;

$$\bar{X} = \frac{\sum x}{N} \quad (3)$$

The standard deviations of the various phases of the observations were determined using;

$$\sigma = \sqrt{\frac{\sum (x_i) - \mu)^2}{N}} \quad (4)$$

The online standard deviation calculator was used to obtain the results displayed in Table 6. This was sourced from https://www.calculator.net/math/standard-deviation.

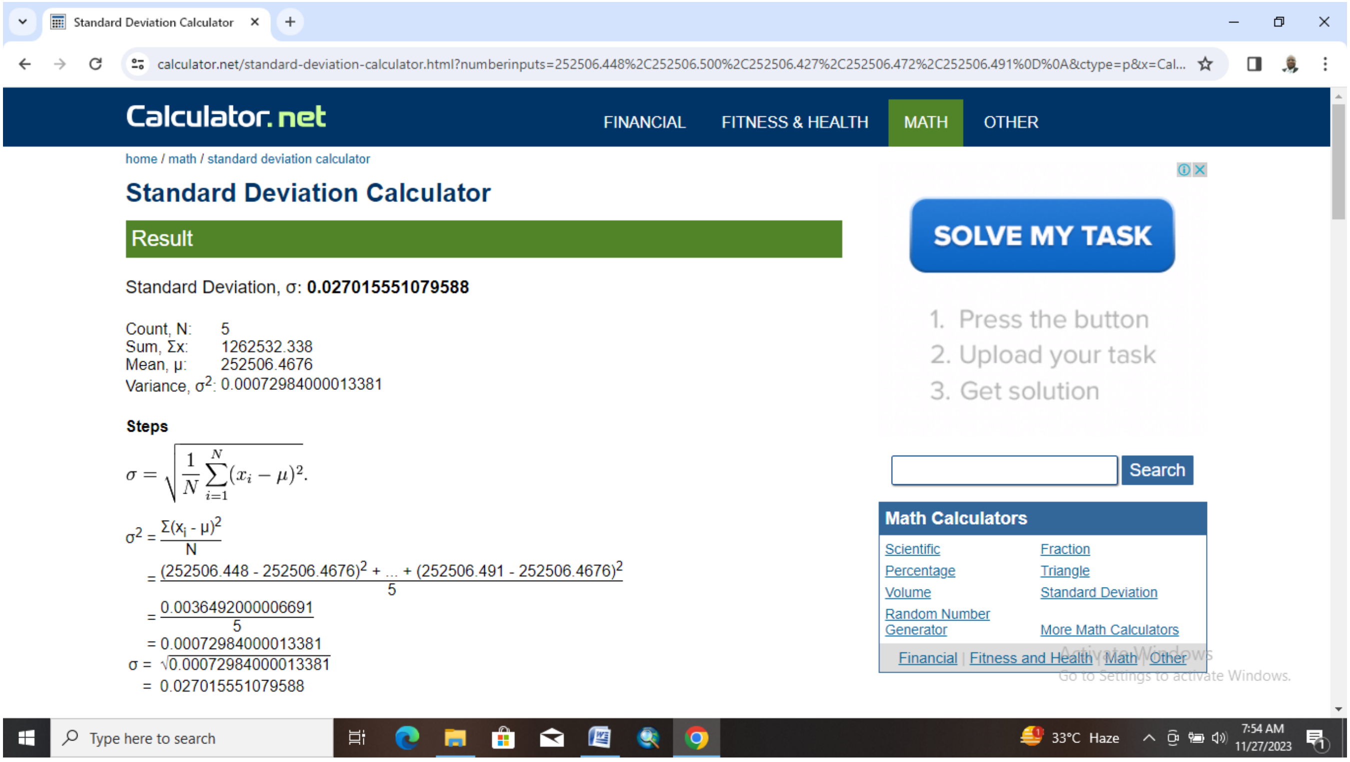

Figure 2: Online standard deviation calculator

Sourced: https://www.calculator.net/math/standard-deviation.

Table 6: Standard Deviation of PPP stations.

POINT ID	STANDARD DEVIATION	
	EASTING (m)	**NORTHING (m)**
PTT 001	*0.027015551*	*0.007812809*
PTT 006	*0.052956589*	*0.020832666*
PTT 007	*0.054170102*	*0.016707618*
PTT 008	*0.02717793*	*0.01037304*
PTT 011	*0.01199333*	*0.01222456*
PTT 016	*0.00287054*	*0.00320936*
PTT 017	*0.03839270*	*0.00949526*
PTT 018	*0.01348480*	*0.01507647*
PTT 021	*0.02424376*	*0.01075918*
PTT 023	*0.07570574*	*0.03692912*
Average	***0.032801104***	***0.014342008***

Source: Author's field book.

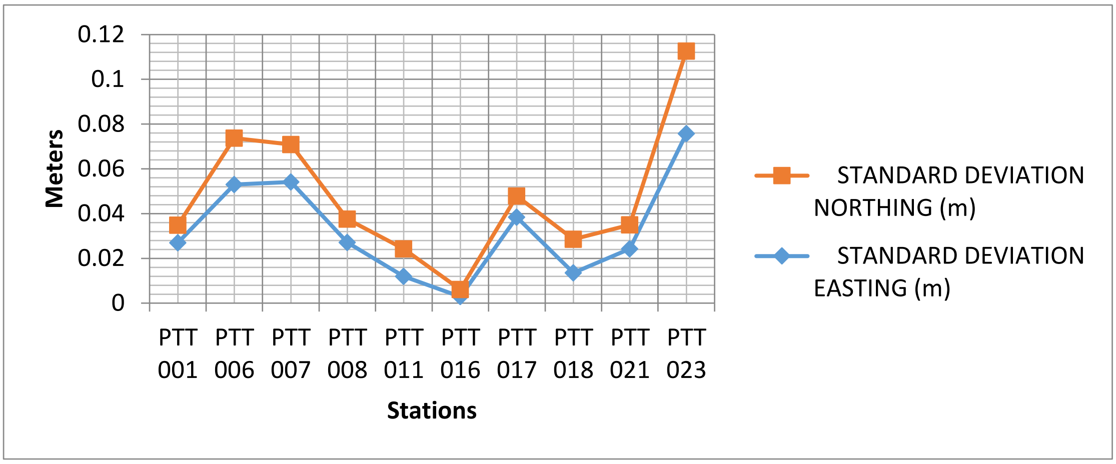

Figure 3: The standard deviation distributions

Confidence interval of PPP results

The margin of error which gives an estimate of the 95% confidence intervalof the PPP data observed that follows a standard normal distribution is;

$$CI = \bar{X} \pm t^* \frac{\sigma}{\sqrt{n}} \quad (5)$$

The table 7 displays the margin of errors both at 95% and 99% confidence level and these are computed from https://www.calculator.net/math/confidence-interval.

Table 7: Confidence level of PPP results

POINT ID	values of error margin for 95% confidence level ±		values of error margin for 99% confidence level ±	
	EASTING (Em)	***NORTHING***	***EASTING (m)***	***NORTHING (m)***
PTT 001	*0.0237*	*0.00685*	*0.0311*	*0.009*
PTT 006	*0.0464*	*0.0183*	*0.061*	*0.024*
PTT 007	*0.0399*	*0.0124*	*0.0624*	*0.0194*
PTT 008	*0.02*	*0.00909*	*0.0313*	*0.0119*
PTT 011	*0.0105*	*0.0107*	*0.0138*	*0.0141*
PTT 016	*0.0201*	*0.00252*	*0.0264*	*0.00331*
PTT 017	*0.0337*	*0.00832*	*0.0442*	*0.0109*
PTT 018	*0.0176*	*0.0118*	*0.0231*	*0.0155*
PTT 021	*0.0213*	*0.00943*	*0.0279*	*0.0124*
PTT 023	*0.0664*	*0.0324*	*0.0872*	*0.0425*
Average	***0.02996***	***0.012181***	***0.04084***	***0.016301***

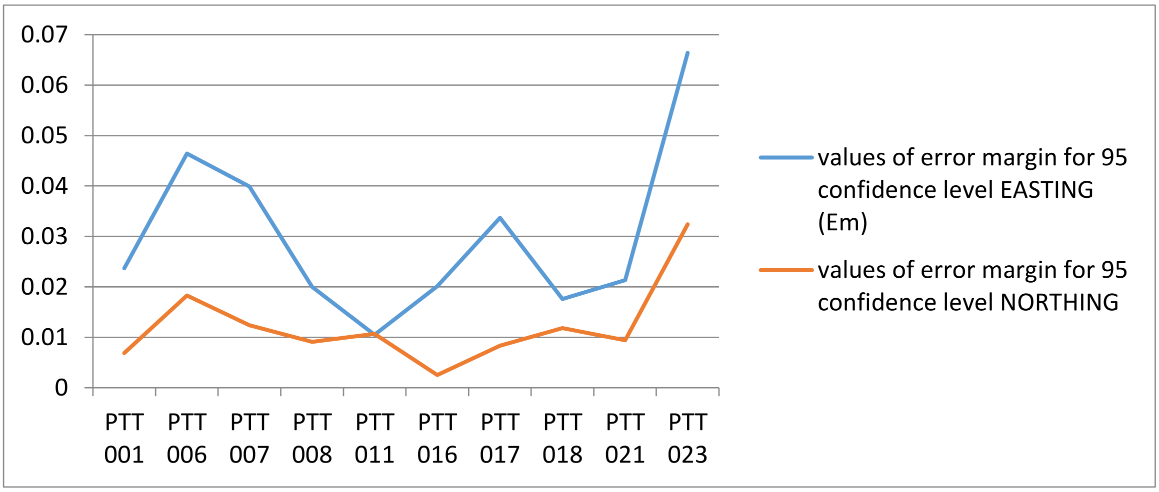

Figure 4: the 95% confidence interval

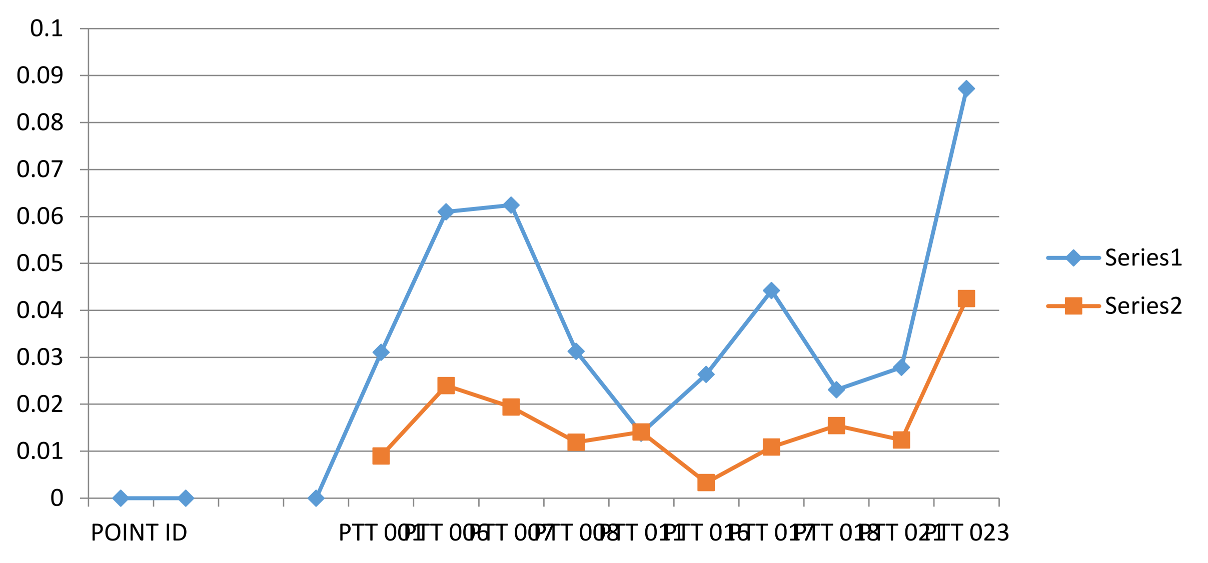

Figure 5: the 99% confidence interval

When the results of the 95% confidence level were applied to the mean, the ranges at which the true value may occur are thereby displayed in table 2.3.

Discussion of Results

Discussion on Standard Deviation

Just like the standard error, the standard deviation shows how spread from the true value the obtained results are and which in turn serves as the accuracy of the work done. The values obtained for instance in table 2.1 for station PTT 001, the standard deviation in the easting and northing is 0.027015551m and 0.007812809m respectively. At the easting, that value means 0.027015551m away from the mean. Of course that is approximately 2cm away from the mean of the redundant values of station PTT 001. The same applies for all other points. If the values are in centimeters, it means the mean value is just centimeters away from the result (standard deviation) obtained. Looking at the table 2.1 again, the values of the standard deviation on the Easting coordinate seem to be a bit higher than those in the Northing coordinates, though they are in centimeter range. With this, it can be deduced that the standard deviations in the Northing are more precise than in the Easting coordinates that is, if we want to compare them. Apart from station PTT 016 whose standard deviation at the Northing and Easting are in millimeter level, every other observation point value is in centimeter range. The average as obtained from the Eastings of the observation is 0.03 m (3 cm). From this result, it can be established that with PPP observation of 1 hour duration, an accuracy of 3cm is certain. However, this result obtained agrees with the works of other recent scholars like Alkan *et al.*, (2020), Nie *et al.*, (2021) and Luo *et al.*, (2021).

Then, on the average all the standard deviations of the northing coordinates of the observed points is in 0.01 m (1 cm) accuracy level. Even when they are in centimeter level, they are very low compared to the standard deviation of the easting coordinates. In general the results of the standard deviation are in centimeter level and that makes the observation very precise as it agrees with recent works on the accuracy and quality of PPP observations made for 1 hour if compared to the earlier cited authors in the preceding paragraph.

The figure 1 presented a pictorial diagram of the standard deviation values. The movement of the graph is a clear indication that they are in centimeter range. The vertical axis represents the metres and while the horizontal axis shows the corresponding points of observation.

Discussions on Confidence Intervals (CI)

The values of the margin of errors which are in centimeter and millimeter range as displayed in table 2.2 are indications that the observations were done with high precision (Bevans, 2022). The error margins definitely showed how close the true value is from the mean. When these results are applied to the mean, the confidence ranges are just in centimeters and milimeters. Table 2.2 displayed 95% and 99% confidence intervals in the Eastings and Northings respectively.

On the average for 95% confidence level for the easting coordinate is, let us say, 0.03 m and the Northing coordinate is 0.01 m. What these values mean is that at 95 out of 100 times of carrying out these observations under 1 hour, there will always be 0.03m and 0.04m accuracies in the easting and northing coordinates. The second row shows results for 99% confidence interval which are 0.04m and 0.01m respectively in the easting and northing coordinates. That is at 99 out of 100 observations; those are the values of accuracies to expect.

The figure 2 and figure 3 show the trend of the 95% and 99% confidence intervals of the observations. A closer look shows that both follow the same pattern. Therefore, the standard deviation and the confidence interval are reliable tools to ascertain the accuracy of observational data.

CONCLUSION

Redundant observations at every 3 months for 12 months were carried out. The processed results underwent statistical processing as standard deviation and error margin to establish the PPP reliability. Actually, the precision for the data obtained was computed and discovered to be in centimeter level, which makes the technique’s result reliable when it comes to using it to establish or densify controls for cadastral survey work. As a result of the usage of this PPP technique, it can be inferred that, the results are accurate and agrees with those obtained from similar works by Kiliszek*et al,* (2018), Alkan *et al.*, (2020), Nie *et al.*, (2021) and Luo *et al.*, (2021) and Novatel (2022) who had centimeter accuracy ranges after 44 minutes and 1 hour observations of with the PPP technique.

When the two accuracy determination formulas were compared, it could be seen that, the results are almost the same. What it therefore proves is that, control networks established through PPP techniques can stand in as references for cadastral surveying projects. Since Kogi State have deficiencies in control networks for cadastral works, the PPP technique which uses a single receiver could best fit in for the control densifications in the state. The high cost of DGPS can never hinder the pursuit for high accuracy survey using a single receiver. The PPP techniques indeed could be used in establishing control stations for cadastral surveying purpose. It is therefore recommended that, the PPP technique be encouraged in the rurals and suburbs instead of the usual over dependency on handheld GNSS obtained coordinates for surveying works.

REFERENCES

Adebanji, W. A. (2014). Empirics of Standard Deviation. Obtained from https://www.doi.org/10.13140/2.1.1444.6729 on 12th November, 2022.

Alkan, R.M., Erol, S., Ozulu, M and Ilci, V. (2020). A comparative study for accuracy assessment of PPP technique using GPS and GLONASS in urban areas. Geomatics, Natural Hazards and risk 11 (1), 178-190, 2020.

Ayhan, M.E. and Almuslmani, B. (2021). Positional accuracy and convergence time assessment of GPS precise point positioning in static mode. *Arabian Journal of Geosciences 14 (13), 1263, 2021*. Obtained from https://www.link.springer.com on 20th Novemebr, 2023.

Bevans, R. (2022). Understanding Confidence Intervals: Easy Examples & Formulas. Scribbr. Obtained from https://www.scribbr.com/statistics/confidenceinterval/ on 16th November, 2022.

Najera, C. (1997). Control Surveys. The Surveying Handbook. Second Edition. CBS Publishers & Distributors Pvt. Ltd., New Delhi, India. Pages 563-623.

Kiliszek, D., Szołucha, M. andKroszczynski, K. (2018). Accuracy of Precise Point Positioning (PPP) with the use of different International GNSS Service (IGS) products and stochastic modelling. *GEODESY AND CARTOGRAPHY, Polish Academy of Sciences, Vol. 67, No. 2, 2018, pp. 207–238*. Obtained from https://doi.org/10.24425/gac.2018.125472 on the 1st January, 2023.

Dalil, M., Omeiza, O.A., Yahaya, A.A., and Husaini, A. (2017). Effect of cement factory on land use-land cover in ObajanaLokoja Local Government Area, Kogi State, Nigeria. *African Journal of Environmental Science and Technology*, pp 384-392. Obtained from https://doi.org/10.5897/AJEST2017.2327 on 19 December, 2020.

Dasgupta, A., (2016). Evolution of the Global Navigational Satellite System (GNSS). Obtained from https://www.geospatialworld.net/article on 20th of November, 2023.

Dimal M. (2020). Introduction to Control Surveying. Obtained from www.academia.edu/10750910/introduction-to-Control Surveying on 21th November, 2022.

Guma, E.P., Ono, M.N., Yaya, A.L., and Aremu, R. (2021). Analysis of the Displacement Patterns of Obajana and environs using Precise Point Positioning Solution. *International Journal of Academic Multidisciplinary Research (IJAMR). Vol.5 Issue 7, July 2021, pages:110-136*.

Guma, E.P., Babatunde, I., Bello, A.E., Haruna, A.A., Aremu, R., Yakubu, O.M. and Abraham, S.S. (2023). Exploring the use of GNSS data in the identification of activity areas for census enumeration exercise. *FUDMA Journal of sciences (FJS) Vol. 7 No. 3, June, 2023, pp 64 – 70.*

Hassanuddin, Z.A., Haroen, T.S., Adiyanto, F.H. and Soemarto, I. (2015). On the establishment and implementation of GPS CORS for cadastral surveying and mapping in Indonesia. Survey review. Obtained from https://www.doi.org/10.1179/1752270614Y.0000000094 on 20th of November, 2023.

Kartik Menon (2022). Understanding the Fundamentals of Confidence Interval In Statistics. Accessed from https://www.simplilearn.com/tutorials/data-analytics-tutorial/confidence-intervals-in-statistics on 18th November, 2022.

Luo, X., Schaufler, S., Branzanti, M. and Chen, J. (2021). Assessing the benefits of Galileo to high precision GNSS positioning-RTK, PPP and post processing. *Advance in space Research 68 (12), 4916-4931, 2021*. Obtained from https://www.scholar.google.com on 20th November, 2023.

Nathaniel, O. A. (2012). Spatio-Temporal Analysis of Land Use/Cover of Lokoja – *A Confluence Town Journal of Geography and Geology* ,41(1). Obtained from https://www.doi.org/10.5539/jgg.v4n4p40 on 30 December, 2020.

Neenu, (2021). Trilateration Surveying: Working, Applications and Advantages. Obtained from https://www.prodyogi.com/2021/08/trilateration on 20th of November, 2023.

Nie, Z., Xu., X., Wang, Z. and Du, J. (2021). Initial assessment of BDS -3 B1C/B2b service: precision of orbit and clock corrections and PPP performance. *Remote sensing 13 (11), 2050, 2021*. Obtained from www.https://www.scholar.google.com on 21st of November, 2023.

Merry, K. and Bettinger, P. (2019). Smartphone GPS accuracy study in an urban environment. PIoS one 14 (7), e0219890, 2019. Obtained from https://www.scholar.google.com on 20th November, 2023.

Octavian Andrei (2011). Precise Point Positioning applicability for the implementation of a cadastral system in Lasi municipal. Proceedings of the Geo PrevVi 2011 conference, pages 65 – 78, May 12 – 13, 2011, Bucharest, Romania. Accessed from www.academia.edu on 12th November, 2022.

Ola Ovstedal, NarveSchipperKjorsvik and Jon Glenn (2006). Surveying using Precise Point Positioning. Obtained from https://www.researchgate.net/publication/242050475 on 1st February, 2022.

Sarah Rowe (2019). Introducing TerraStar-X: PPP corrections with fast convergence and integrity. Obtained from https://www.blog.novatel.com/terrastar-x on 1st February, 2022.

Simundic, A.M. (2008). Confidence Interval. Biochemia Medica 18 (2), 154-161, 2008. Obtained from https://www.biochemia-medica.com on 20th December, 2023.

Tim Burch (2020). 30 years of GNSS and the Surveyor. Obtained from www.gpsworld.com/30-years-ofgnss-and-the-surveyor on 29th November, 2022.

Yaya A.L (2019). A technical report on Perimeter survey submitted to the Office of the Surveyor General, Kogi State.