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Comparative Analysis of Smartphones and Survey-Grade GNSS Receivers for Parcel Boundary Determination

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Abstract

This paper advances the existing body of knowledge on the suitability of the accuracy derivable from the use of smartphones for cadastral mapping. Zenvus App software was installed on two smartphones of a different make. A set of dual-frequency GPS Promark 3 receivers and two different smartphones of different makes were used for data acquisition. Observations were carried out at the boundaries of ten parcels of land, comprising 46 boundary points. The coordinates of these points were obtained using Differential Global Positioning System (DGPS) observation in static mode and two Android smartphones (the Samsung A70 and the Tecno Spark 3 Pro). Mean score, root mean square error, and one-way analysis of variance were used to show significant differences in the equipment used. Overall, both the accuracy (mean) and precision (RMSE) were lower than those obtained by Differential GPS. A one-way analysis of variance (ANOVA) was calculated on the values of both X and Y. For X, the analysis was not significant; F (1, 45) = 0.88, p = 0.419 and for Y, the analysis was also not significant; F (1, 45) = 0.97, p = 0.383. The total RMSE shows that the coordinates of points as obtained by the Samsung smartphone (3.368) were more precise than those obtained by Tecno (4.041). However, the two smartphones (Tecno and Samsung) were less accurate than differential GPS. This implies that there is a 95% chance that the errors in the estimates are less than 6.993m (for Tecno) and 5.848m (for Samsung), respectively. The variation in the observations obtainable with smartphones affects both linear and polygon estimates. The study concluded that the magnitude of these errors is significant in cadastral survey practices and hence not suitable for use. It is recommended that further studies be carried out on the use of the Zenvus app on centimeter grade smartphones; probably this could yield a better result suitable for cadastral mapping.

Keywords: *Demarcation, Accuracy, Zenvus, GPS*

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I. INTRODUCTION

Parcel demarcation is a worldwide phenomenon necessitated by the numerous activities (transportation, agriculture, etc) taking place on land. Due to the fixed nature of land and increase in population, the world is faced with the choice of managing the limited and fixed land resources for sustainable development. Arising from this need, surveyors, geomaticians, and other stakeholders are saddled with the responsibility of demarcating the limited land resources to guarantee the security of ownership.

The need for real-time information on land parcel is increasing. The daily need for cadastral maps as a basis for decision making cannot be overemphasized. The map as a scientific and sometimes legal document needs to be reliable, accurately and precisely done in order to facilitate well-informed decisions. Various approaches employed at demarcating parcels in the past can no longer meet the realities of today where decisions are to be taken in real-time with the highest precision; hence the era of smartphones and drones.

Smartphones are personal devices equipped with different sensors, connected to the Internet, and, most importantly, charged by their users [1]. The use of diverse Apps on smartphones is gaining recognition in the mapping industry and is gradually changing the tradition in cadastral mapping especially the legal aspect. Some of the known apps include My GPS coordinate, Compass360 PRO, and Map Measure. There are also indoor positioning apps installed on smartphones that detect various walking patterns [2]. The use of a smartphone for mapping activities has made surveying easier and time-efficient [1].

Different smartphones exhibit different capabilities in position capturing due to sensors available on the devices such

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as small inertial measurements units (IMUs), proximity sensors, baro--meter, and GPS/GNSS [3]. However, the capabilities and limitations of these various smartphones are not adequately documented. In addition, these studies have focused on the use of smartphones with different applications (Apps) installed on them.

Recently, an intelligent solution, known as Zenvus Boundary Mobile App, for demarcating properties was developed by Ekekwe [4]. Zenvus Boundary is a web App capable of being installed on an android tablet or phone by downloading and installing it from Google play. The App, which requires Internet access, supports two accounts: the Landowner and Enterprise accounts. The former is an individual account that allows the owner to print or download their reports themselves from the Zenvus portal; the landowners do not need a code during data transfer while the latter, which is a collection of accounts, requires a unique code from Zenvus Admin for the purpose of data transfer into Zenvus web portal after mapping [5]. However, there are little known studies on the novel Zenvus Boundary App to determine its ability for classical surveying purposes. Though there is little statistical evidence on the appropriateness of the Zenvus App for parcel demarcation.

Therefore, there is still the need to answer the question of how best Zenvus Boundary App can help to determine parcel boundary. This type of analysis is particularly important because various other apps are emerging and communities of surveying practitioners are in a quandary on whether it should be adopted for survey or not since accuracy and precision are central to survey activities. The surveyors in Nigeria have been in serious conflict with the developer of the App for various reasons that bother on accuracy, legality, and professionalism of boundary mapping using the App. Section 4(d) of CAP 425, Laws of the Federation of Nigeria 1990 empowers the Surveyors' Council of Nigeria (SURCON) to regulate and control the practice of the profession in all its ramifications. As a result of this proviso, only a person registered by SURCON is eligible to practice the profession of surveying in any part of the Federation. Furthermore, there are established minimum standard and accuracy for parcel boundary demarcation [6]. These specifications were ignored in Zenvus App developed by Ekekwe, which caused a conflict between the App developer and the Surveying professionals.

It is thus necessary that an investigation be conducted into the suitability and adequacy of this App for parcel boundary determination. This paper addressed this issue to determine the benefits or dis-benefits of using this App in Nigeria. In achieving this aim, this paper focused on the use of this App installed on two different smartphones and compares their results with a widely acceptable standard of using GNSS receivers on Promark 3.

II. LITERATURE REVIEW

Precise point positioning is core to boundary determination [7]. This can be achieved through diverse approaches such as traversing, trilateration, triangulation, resection, remote sensing, and photogrammetry among others, and also using diverse equipment/devices such as a theodolite, total station, aircraft, laser scanner, satellite scanner, Global Positioning System, drone and smartphone, etc. Due to the availability of Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) coupled with the urgent and high demand for position data, the business of position determination could no longer be left in the hands of trained experts. For instance, rural

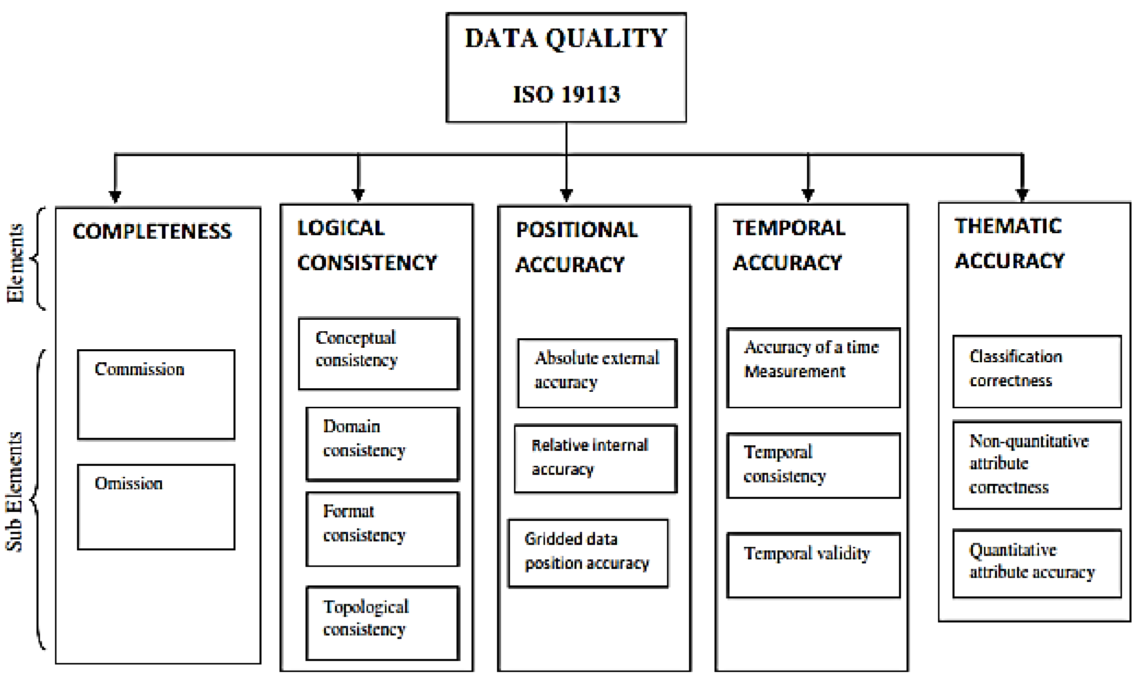

Fig. 1. Data Quality elements and sub elements

Source: (European Standard ISO 19113, 2002) and urban areas are mapped using handheld GPS and innovative techniques [8]. Smartphone apps are also developed to support the need for geographic data.

Smartphones are spatially adapted devices embedded with GNSS which makes them a VGI oriented device and serve as tool to facilitate collection of geometric data which can thereafter be uploaded on spatial database. As concept of VGI and the necessity to build VGI application in land surveying and planning in developing countries is rapidly increasing, land surveyors adopt VGI techniques to various tasks applicable to generating new maps like land cover and transportation in rapidly urbanized areas [9].

Smartphone positioning, being a recent development, has greatly enhanced navigation business and mobile location-based services [10]. In recent times, there is growing awareness in the use of smartphones for location-based solutions and there is constant development of position-based applications compatible with a smartphone. In line with this development, researchers continue to thrive in this direction as well. Smartphone has found applications in several fields such as civil engineering [1], aviation [11] water quality analysis [12], indoor positioning [2], [10], [13], [14], [15] and outdoor positioning [16], [17], [18], [19] (usually coordinates) to the true position.

Accuracy is the closeness of results of observations to the true values or values accepted as being true. This implies that observations of most spatial phenomena are usually only considered to be estimates of the true value. The difference between observed and true (or accepted as being true) values indicates the accuracy of the observations.

The fundamental issue with respect to data is accuracy. Positional accuracy is analysed in absolute and relative terms. Absolute accuracy concerns the accuracy of data elements with respect to a coordinate scheme, e.g. Universal Traverse Mercator (UTM). Relative accuracy concerns the positioning of map features relative to one another. Often relative accuracy is of greater concern than absolute accuracy.

Various studies have been carried out in the past in order to check data quality. GPS is often preferred over its alternatives such as GSM/WiFi based positioning systems because it is known to be more accurate [20]. Iyiola et al [21] carried out a data quality check of control points established in Osun State, Nigeria. The purpose was to ensure completeness and consistency of data before various users make use of it. The coordinates of points earlier determined independently using dual-frequency GPS were checked using continuously operating reference stations (CORS). It was discovered that control extension carried out with differential GPS was good and safe to use for mapping purposes. Oluwadare [22] studied the use of handheld GPS in conjunction with CORS data for position determination and noted that the accuracy obtainable will not pose any serious threat to boundary conflict in farmland but possible of creating conflict in urban areas where there is high competition for limited spaces. Oluwadare and Oguntade [23] studied position determination using smartphones and GPS and discovered that the Application is not suitable for cadastral mapping needed for title registration. The paper recommended Zenvus Boundary Application for navigation and mapping of boundaries not intended for cadastral purposes. Oluwadare and Oguntade [23] did not give an adequate statistical analysis of variation that existed between the smartphones and GPS. In addition, the methodology was not strictly based on a designed parcel fabric.

Increasing participation of both experts and non-experts in position data acquisition through crowdsourcing, volunteered geographic information (VGI) has cost and time benefits [9], [24]. However, the issue of accurate positioning is mostly compromised. Laarakker and de Vries [16] explored potential perspectives and weaknesses of crowdsourcing in Cadastre. Constant efforts are being made by experts at probing the integrity of positions derived from the use of smartphones and google maps. Numerous attempts have been made at solving problems of inaccurate definition of positions emanating from the use of smartphones, OpenStreetMap and google map [3], [8], [18], [19], [25], [26].

Navratil and Frank, De Vries et al and Basiouka et al investigated the term Neocadastres in an effort to explore the involvement of Volunteered Geographic Information (VGI) within the traditional methods of Cadastre [19], [27], [28]. Basiouka et al [19] attempted the possibility of using OpenStreetMap (OSM) for official mapping projects and weighed the contributions of experts and amateurs in such projects while El-Ashmawy [29] tested the positional accuracy of OpenStreetMap data for mapping applications. Basiouka et al [19] revealed that a significant difference occur in the accuracy of OSM and the commercial software. The results of El-Ashmawy's research show that OpenStreetMap data has positional accuracy of 1.57 m which is suitable for generating planimetric maps of scale 1:5000 or smaller. The obtained results embolden the use of OpenStreetMap maps for general preliminary planning where larger areas are covered but only moderate accuracy is needed. It then suggests that OpenStreetMap data are not reliable and acceptable for cadastral survey. In Nigeria, the cadastral regulations set a linear accuracy at 1/5000. The implication of this is that maximum error of 1metre is expected over a total distance of 5000 metres.

The American Society for Photogrammetry and Remote Sensing (ASPRS) highlights the accuracy requirement for a well-defined point (see Table I). The table shows that small scale map to be produced in 1/20,000 can accommodate Root Mean Square Error of 5metres. Large scale cadastral map can only accommodate RMSE that falls within the range of 0.0125 – 1.25. RMSE greater or outside this range will not be suitable for cadastral survey purpose.

Basiouka et al [19] proposed a semi-hybrid approach which encourages a synergy among experts, volunteers and NGOs participation in and application of Geographic Information. This will provide a wider participation in land tenure and registration [8].

Using Greece example, Basiouka et al [19] proposed online cadastral application via the web or through online processing using installed applications in smartphones. In their methodology, they compared smartphones with the Total station survey. Smartphone observation was carried out at the same location twice at 30 minutes interval to allow independent satellite constellation tracking. The average error between coordinates obtained through conventional Total Station and Smartphone ranges from 1.7m to 8.5m. Their research concluded that GNSS measurements from the mobile phone are very inaccurate and inappropriate for cadastral surveying purposes. They advised that surveyor must not use any equipment without first determining its accuracy.

TABLE I. ASPRS PLANIMETRIC COORDINATE ACCURACY REQUIREMENT FOR WELL-DEFINED POINTS (CLASS I MAPS)

Planimetric (X or y) Accuracy (limiting RMSE in Meters)	Typical Map Scale
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1: 1,000
0.50	1:2,000
1.00	1:4,000
1.25	1:5,000
2.50	1:10,000
5.00	1:20,000

Looking at equipment design as a contributory factor to the issue of accuracy, Pesyna et al [18] hinted that under good multipath conditions, 2-to 3-meter accurate positioning is typical while 10 metres or worse is obtainable in an adverse multipath condition. They however demonstrated the possibility of a centimeter accuracy positioning with a smartphone-quality Global Navigation Satellite System (GNSS) antenna. This is possible where additional effort is made by the manufacturers at equipping phones with such quality grade antenna. Common antenna found in most smartphones is the low-quality consumer-grade type. Where antenna type is not expressly stated as a specification in the adoption of an app, variation is bound to occur and if different smartphones with different specifications are used to acquire data into the same database or web portal, map produced from such arrangement will be misleading and trigger more confusion for the users.

Dabove [3] Compared iPhone, an older generation phone which is able to track GPS satellites only, and modern Galaxy S5 Samsung which is able to track both GPS and GLONASS satellites. The two phones exhibit different features in terms of their designs and this reflected in the differences in their position determination outputs. Pesyna et al in [18], [25], using signals obtained with smartphones antenna, pointed out that processing of carrier-phase differential GNSS (CDGNSS) is significantly affected by multipath-induced phase errors due to the antenna's poor multipath suppression ability. Dabove [3] also affirmed that the accuracy of smartphone positioning depends mainly on the environment, in terms of obstacles, satellite visibility, and multipath. Counselman et al [30] and Mohiuddin et al [31] suggested the technique of replacing standard code-phase positioning with carrier-phase differential GNSS in order to suppress the multipath error. Dabove [3] attempted to reduce the multipath error by carrying out double observation of a series of points. Beyond this approach, since antennae design determines resistance to multipath error, Geodetic- and survey-grade GNSS antennas are designed to have a highly stable phase center and a

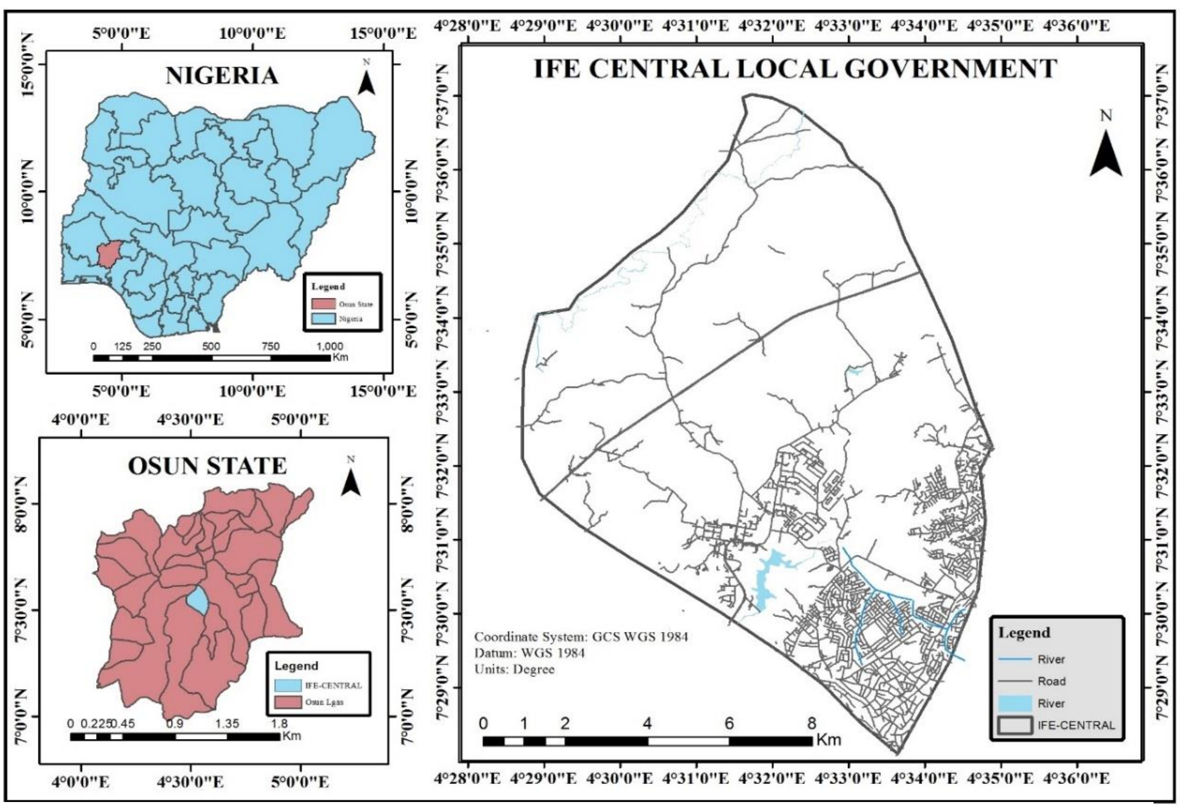

Fig. 2. Map of Ife Central Local Government Area

gain pattern that strongly attenuates multipath-prone low-altitude signals [26].

The first dual-frequency Global Navigation Satellite System (GNSS) Smartphone (Xiaomi Mi 8 Android), equipped with a Broadcom BCM47755 chip, was launched in 2018 by Xiaomi. The smartphone is capable of receiving signals from GPS, Galileo, Beidou, and GLONASS (GLObal Navigation Satellite System) satellites [31]. Robustelli et al [32] determined position using multi-constellation, dual-frequency pseudorange, and carrier phase raw data collected from Xiaomi Mi 8 Android smartphone. Furthermore, the availability of dual frequency raw data allows the multipath performance of the device to be assessed. The smartphone's performance was conducted under two different multipath conditions and compared with that of a geodetic receiver. Smartphone measurements showed a lower carrier-to-noise density C/No and higher multipath compared with those of the geodetic receiver.

Availability of raw carrier and code phase observables from smartphone GNSS allows it to be written to a file in standard RINEX format for CDGNSS processing [26]. In addition, Rinex On app produced in 2018, provides directly both observation and navigation files in RINEX 3.0.3 format and this made the smartphone data to be processed further using post-processing GNSS software [32].

Previous research has linked errors obtainable from smartphones with multipath, antenna type, and sensors. This study investigates and analyses the significance and variability of the errors in measurements and observations carried out with the selected smartphones. To test if there are significant differences in data output generated using the same application on two different smartphones. What purpose at its best can Zenvus App serve when installed on heterogeneous smartphones? Should the App be adopted for high accurate survey work or any less accurate survey work? How can the use of the app be improved upon if it has to be adopted for survey-grade work? With a focus on specific parcels of land in a layout within the Obafemi Awolowo University Ile Ife campus, this paper provides answers to this question and extends Oluwadare and Oguntade [23] by testing the statistical significance of the Zenvus App for parcel demarcation.

III. Research Methodology

Fieldwork was carried out on parcels of land allocated to religious associations at the religious centre of Obafemi Awolowo University (OAU), Ile-Ife. OAU campus is situated in Ife Central Local Government Area (see Fig. 2 and Fig. 3). A set of dual-frequency GPS Promark 3 receivers and two different smartphones (See Table II) were used for data acquisition. Coordinates of 46 boundary points were obtained using Differential Global Positioning System (DGPS) observation in static mode. The Zenvus Boundary Application was installed on two android smartphones (Samsung A70 and Tecno Spark 3 Pro). The accuracy of the two phones was compared and the differences were compared with those obtained through DGPS. A reference station was established near the site while observations were carried out in static mode. A minimum of 15 minutes was spent on each point in the course of observing with the DGPS. Zenvus App observes in geographical coordinates and was converted to universal traverse Mercator (UTM Zone 31) projected on Minna Datum.

ArcGIS 10.4 software was used in carrying out the following activities: processing of the downloaded Google Earth imagery of the study area (Obafemi Awolowo University, Ile-Ife), extraction of the shapefile from the digitized map of the study area, plotting of the observed points, performing of spatial queries and production of the final map. Microsoft Office Excel was used to deduce the differences between the baseline points and the Zenvus App points. It was also used to determine the Root Mean Square Error. The field data and the baseline data were used for the assessment of positional accuracy of the equipment used.

One of the most widely used statistics in GIS for positional accuracy determination is the Root Mean Square Error (RMSE) expressed as follows (Kerle, et al, 2004):

$$RMSE\ (\delta x) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\mathcal{X}_i - \bar{\mathcal{X}}_i)^2} \quad (1)$$

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

$$RMSE_{Total} = \sqrt{(\delta x)^2 + (\delta y)^2} \quad (3)$$

Where

RMSE = Root Mean Square Error
N = the number of observations
$\mathcal{X}_i$, y_i = predicted values
$\bar{\mathcal{X}}_i$, $\bar{y}_i$ = observed values
δx =RMSE along x-axis
δy =RMSE along y-axis
$RMSE_{Total}$ = Total RMSE

RMSE measures how much error exists between two datasets. RMSE usually compares a predicted value and an observed value. For instance, coordinates obtained through Zenvus Boundary Application (observed values) were compared with Differential GPS coordinates (predicted value).

Table II: Devices and their Principal Characteristics

Name	Samsung Galaxy A70	Tecno Spark 3
Operating System	Android 9.0 (Pie) Upgradable to Android 10.0	Android 9.0 (Pie), HIOS 5.0
CPU	Octa-core (2x2.0GHz Krp 460 Gold)	Quad-core 2.0 GHz Cortex A53
GPU	Adreno 612	Power VR GE 8320
Digital Camera Resolution	32Mpx	13Mpx
A-GPS	Yes	Yes
GNSS Constellation	GPS+GLONASS	GPS+GLONASS
Inertial Platform	Yes (Accelerometer, gyro proximity, compass)	Yes Accelerometer No Gyro proximity and Compass
Internal Memory	128GB, 6GB RAM	32GB, 2GB RAM

IV. Data Presentation and Discussion of Findings

The results of observations using three different devices (DGPS, Tecno and Samsung) are presented in Table III. In order to have a more complete analysis from statistical point of view, the most significant statistical parameters are summarized in Table IV. The two smartphones exhibit different capabilities of incurring error behavior as a result of their characteristics (see Table II). In both devices, the accuracy (mean) and precision (RMSE) obtained are lower than those obtained using Differential GPS. Accuracy refers to the closeness to the true value whereas precision refers to the spread/dispersion of the results regardless of whether the solution is near the true solution or not.

The errors quantified by Root Mean Square Error (RMSE) for the x and y coordinates for Tecno and Samsung lie between 2.3 and 2.8 metres. An allowable linear error of closure for a traverse of 5000 metre is 1metre while the expected corresponding angular closure is 410. The total RMSE in Table IV shows that coordinates of points as obtained by the Samsung smartphone (3.368) are more precise than Tecno (4.041). However, the two smartphones (Tecno and Samsung) are less accurate than differential GPS. According to the national standard for spatial data, accuracy at 95% confidence level is expressed as 1.7308*RMSE. This implies that there is a 95% chance that the errors in the estimates are less than 6.993m (for Tecno) and 5.848m (for Samsung) respectively. The magnitude of these errors is significant in cadastral survey practice. These findings validate Oluwadare and Oguntade [23] on related research. Furthermore, Tecno appears to be fairly good in absolute value determination (for instance x and y coordinates, see Table IV. However, in area determination using the installed App on Tecno and Samsung smartphones, for every hectare of a parcel of land so measured, there is a possibility of committing an error that will lead to gain or loss of 0.0415ha and 0.0554ha respectively in land transaction.

TABLE III: COORDINATES OBTAINED THROUGH DIVERSE DEVICES

	DIFFERENTIAL GPS A		ZEN TECNO SPARK 3 B		ZEN SAMSUNG C	
POINT _Id	**X(m)**	**Y(m)**	**X(m)**	**Y(m)**	**X(m)**	**Y(m)**
BCN01	667292.098	830276.402	667293.976	830275.283	667292.407	830275.897
BCNO2	667325.807	830190.361	667324.459	830189.624	667326.539	830190.247
BCN03	667364.566	830109.361	667367.938	830110.95	667364.797	830108.263
BCN04	667382.442	830069.070	667381.322	830070.444	667382.353	830072.449
BCN05	667423.088	830088.358	667417.358	830089.258	667423.678	830090.419
BCN06	667404.552	830128.167	667409.129	830126.558	667404.547	830130.684
BCN07	667386.399	830166.753	667393.838	830166.179	667393.86	830166.633
BCN08	667366.108	830209.768	667369.980	830213.064	667366.622	830210.504
BCN09	667325.303	830290.514	667328.147	830286.754	667329.043	830290.157
BCN10	667371.281	830311.651	667374.818	830313.991	667374.997	830310.222
BCN11	667402.745	830227.007	667403.042	830227.013	667404.432	830227.057
BCN12	667423.582	830182.221	667424.909	830181.183	667426.593	830182.638
BCN13	667421.597	830217.665	667420.323	830218.082	667419.952	830217.535
BCN14	667407.891	830246.458	667406.843	830244.709	667407.36	830246.09
BCN15	667379.82	830315.462	667381.033	830316.561	667382.94	830314.186
BCN16	667395.491	830322.337	667397.748	830321.536	667395.506	830327.824
BCN17	667428.628	830256.498	667433.264	830258.562	667433.692	830255.153
BCN18	667448.467	830266.184	667448.157	830256.052	667451.596	830266.78
BCN19	667464.219	830256.362	667464.032	830260.406	667464.808	830254.041
BCN20	667486.219	830246.362	667483.732	830245.716	667486.383	830243.059
BCN21	667473.903	830276.918	667472.767	830275.902	667477.699	830279.524
BCN22	667439.411	830340.136	667440.725	830340.673	667435.978	830340.769
BCN23	667415.716	830328.691	667418.891	830330.798	667420.820	830329.557
BCN24	667557.028	830387.774	667559.540	830389.202	667555.636	830389.011
BCN25	667588.885	830403.286	667590.421	830402.38	667591.896	830406.665
BCN26	667625.339	830418.668	667626.428	830416.881	667624.451	830426.750
BCN27	667632.241	830421.633	667634.035	830420.963	667632.162	830424.035
BCN28	667661.715	830435.459	667657.826	830433.026	667658.735	830441.268
BCN29	667662.885	830352.518	667663.986	830357.87	667662.607	830356.361
BCN30	667691.911	830364.19	667693.396	830369.879	667695.674	830365.395
BCN31	667653.310	830347.856	667653.999	830345.551	667654.257	830346.190
BCN32	667710.863	830326.294	667712.462	830326.497	667711.272	830325.984
BCN33	667734.283	830285.928	667739.474	830280.519	667734.556	830288.785
BCN34	667701.254	830270.552	667704.201	830267.679	667699.97	830268.859
BCN35	667695.730	830267.963	667698.501	830264.813	667697.562	830269.459
BCN36	667686.003	830288.066	667688.327	830284.578	667686.431	830288.263
BCN37	667653.188	830272.915	667656.630	830272.07	667651.021	830272.306
BCN38	667662.451	830252.569	667667.921	830251.327	667665.316	830252.482
BCN39	667653.486	830272.788	667652.545	830268.207	667654.603	830272.133
BCN40	667652.269	830198.081	667653.281	830200.383	667652.619	830196.37
BCN41	667678.160	830201.639	667681.758	830205.595	667678.352	830202.45
BCN42	667677.405	830307.395	667681.250	830307.578	667678.722	830307.679
BCN43	667642.902	830294.351	667645.615	830294.018	667642.835	830294.333
BCN44	667611.667	830279.732	667610.506	830276.801	667609.764	830279.122
BCN45	667592.616	830316.215	667594.475	830315.516	667596.583	830316.161
BCN46	667624.211	830333.076	667623.403	830334.117	667624.423	830330.257

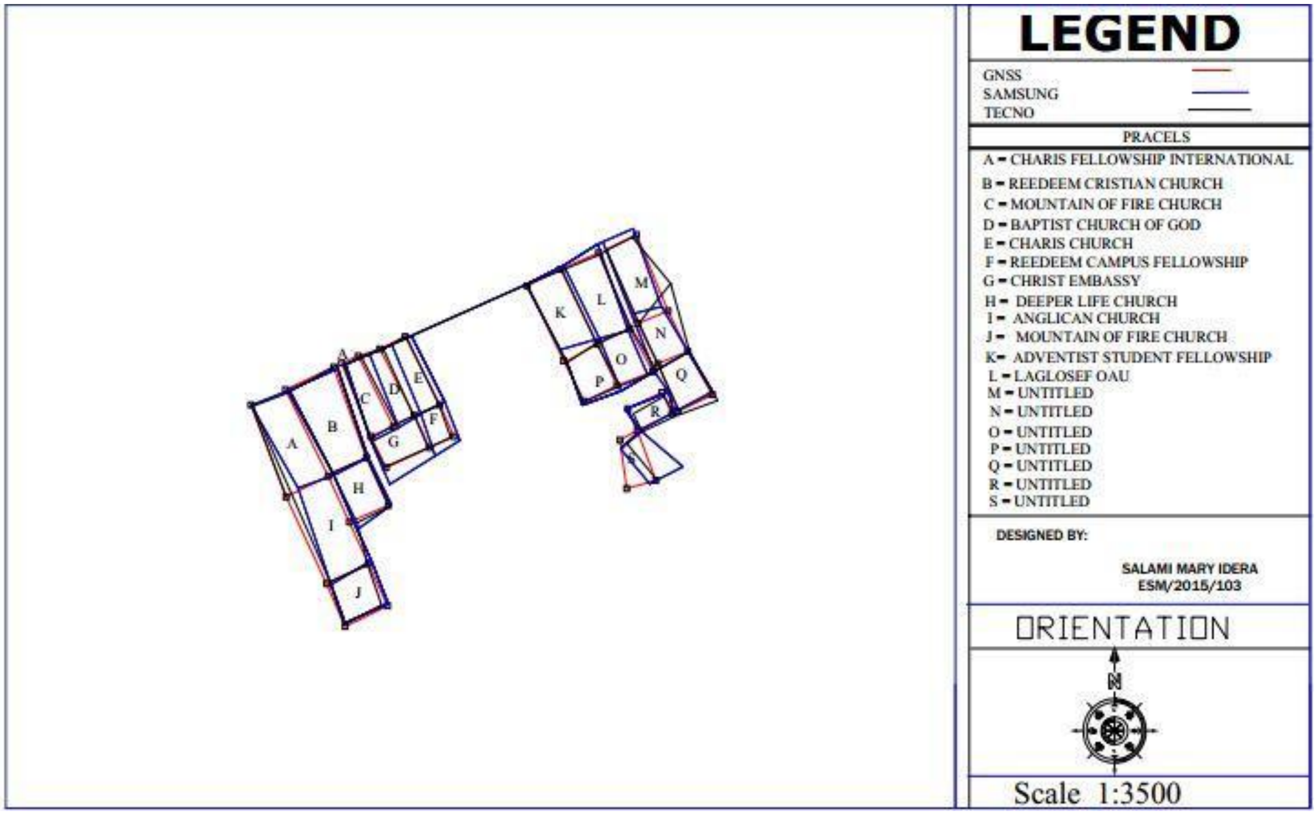

Fig. 3. Overlay of Plots as obtained from DGPS, Samsung and Tecno, Source: Authors' work (2020)

TABLE IV: ERROR ANALYSIS IN COORDINATES AND AREA OBTAINED FROM DIVERSE DEVICES

Data Source	Coordinates of Parcel corners					Area of Parcels		
	Mean Error		*RMSE*		*RMSE Total*	*Mean Error*	*RMSE*	*% Error*
	X	Y	X	Y		M^2	Ha	
ZEN TECNO	8.311	8.020	2.883	2.832	4.041	0.001	0.024	0.04574
ZEN SAMSUNG	5.960	5.384	2.441	2.320	3.368	0.001	0.032	0.03436

Fig. 4 compares the areas of 10 parcels of land as determined using three different devices. It is observed that the areas of parcels do not follow a specific pattern and there are differences in the area of the parcels as shown in Fig 3 and Fig. 4.

A one-way analysis of variance (ANOVA) was calculated on the values of both X and Y. For X, the analysis was not significant, $F(1, 45) = 0.88$, $p = 0.419$ and for Y, the analysis was also not significant, $F(1,45) = 0.97$, $p = 0.383$ (see Table V). The same ANOVA test was also repeated using other approaches: Kruskal-Wallis and Jonckheere-Terpstra as summarized in Table VI. In both cases, the results showed that the values are not statistically significant at a 5% risk level (see Table VI). It is evident from the ANOVA results (Tables V and VI) that the mean of the data captured with the three devices were related but the RMSE as earlier pointed out in Table IV were different. This could be as a result of disparities in the characteristics of the smartphones as shown in Table II.

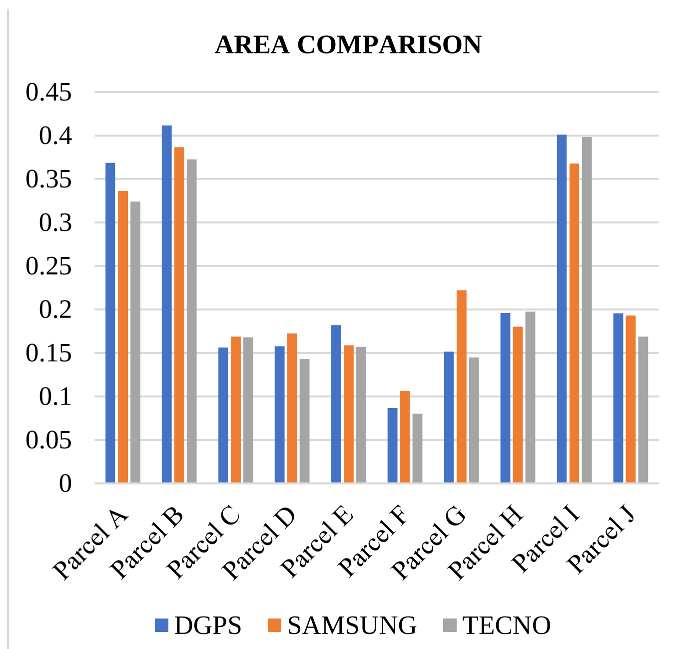

Fig. 4. Comparison of individual parcels using coordinates obtained from DGPS, Samsung, and Tecno

TABLE V: ONE-WAY ANOVA BETWEEN THE ZENVUS BOUNDARY APP ON THE TWO ANDROID PHONES AND DGPS

		Sum of Squares	F	Sig.
X	Between Groups	48690.926	.875	0.419
	Within Groups	3869026.958		
	Total	3917717.884		
Y	Between Groups	1109011.624	.967	0.383
	Within Groups	79700255.691		
	Total	80809267.315		

Source: Author's Field Data Analysis (2020)

TABLE VI: KRUSKAL-WALLIS TEST AND JONCKHEERE-TERPSTRA ANOVA TEST

Test	X	Y
Krusai-wallis test	0.914	0.961
Jonckheere Terpstra Test	0.940	0.776

Source: Author's Field Data Analysis (2020)

V. CONCLUDING REMARKS

This research investigates the reliability of Zenvus App installed on smartphones for cadastral survey purpose using the religious centre layout of Obafemi Awolowo University Ile Ife as a case study. The positional accuracy of smartphones for cadastral mapping was tested using Root Mean Square Error (RMSE) and other statistical comparative approaches. The position determined with DGPS was used as the baseline data and basis for comparison.

The variances in the data obtained on the two different smartphones, though installed with the same Zenvus Boundary App, were attributed to different sensor abilities of the smartphones. The Zenvus Boundary App requires the user to place the device on safe, stable and accessible areas and there will always be a variation in the coordinates obtained during observation. The accuracy of data acquired with smartphone also depends on the signal strength of the in-built antennae of the device; and its ability to track satellites. In addition, the study revealed that the use of the Zenvus Boundary App on smartphones for area determination of a large expanse of land is not advisable. It gives an inaccurate estimate of the actual size of land. This can result in a serious and undue gain or loss in land transactions.

Though, different devices produce different results, users might ignore them due to variations in smartphone sensors. User should adhere to a specific smartphone for data acquisition. A mixture of two different phone for a particular project might result into serious data conflict. Considering the possibility of centimeter accuracy positioning with quality antennae type as proposed by Pesyna et al (2014), it is suggested that further studies be carried out on the use of Zenvus App on centimeter grade smartphones probably this could yield a better result suitable for cadastral mapping

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