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Research Article

Spatial Mapping of Polling Units using Open-Source Software

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Abstract

The feasibility for adopting emerging Open-Source software and free mobile GIS data collection tools for Polling Unit mapping (PUs) and inventory was tested. The dynamism of KOBO COLLECT and QGIS Open-Source technologies were used in mapping and analyzing the spatial distribution of polling units in Eket Local Government Area. The study maximized the potentials of Open-Source technologies to provide a geographical inventory of polling units and area coverage for information management in the electioneering process. Spatial analysis tool of QGIS was used for solving shortest path problem centered around emergency response routing scenarios based on travel time and distance impedance from an origin to a destination. It also helped to portray the distribution within the study area in a bid to reveal pattern and accessibility to the populace. Results obtained will allow citizens and electorates access information on the locations of various polling units, which ultimately serve as a decision supporting system that would enhance their participation. The maps are also useful for future distribution of polling booths, security personnel, for solving transportation issues and in service delivery during election periods.

Keywords: Open-Source Software, Polling Units, QGIS, KOBO Toolbox

Introduction

The spatial connectivity of human activities and the need to have a graphical representation of related infrastructure for detail and firsthand comprehension makes geospatial infrastructure of utmost importance in recent times. For geographical data, maps provide clearer view for quick assessments of trends and interrelationships than other presentation format of the same data (Fisher and Myers, 2011; Çelik and Gazioğlu, 2020). Given that maps are created to capture geographical settings and associated variables and infrastructure, specific and detailed features of the real world are usually captured using available mapping geospatial tools. Geospatial tools are used to 'collate and analyze geospatial data and to display the map representation in 2D or 3D format' (Oswal, 2020). They include both hardware and software products.

Of recent, there has been a plethora of proprietary geospatial platforms and software that aid in capturing and building a digital representation of the real world in an effective and efficient way. Such platforms could be commercial or open-source. Open-source Software (OSS) are freely available with no requirement for licensing, with potential for a variety of applications and benefits. Built under the General Public License (GPL), OSS ownership of code is not restricted and is easily obtained and shared (Kesselman, 2014; Satya et al., 2015). Some open-source software includes ArcGIS Collector, Geographic Resources Analysis Support System (GRASS), KoBo Toolbox, Magpi, MapWindow GIS, Open JUMP GIS, Quantum GIS (QGIS), System for Automated Geoscientific Analyses (SAGA), Smap, SurveyCTO, (Sandhya, 2020; UHCL, 2022). Among these, ArcGIS Collector, QGIS, GRASS, etc., are useful for capturing, storing, processing, managing, analyzing, visualizing and producing maps (LWR, No date; UHCL, 2022). Software such as Fulcrum, KoBo Toolbox, Magpi, etc., are for planning, designing and capturing field data (LWR, No date; Kesselman, 2014; UHCL, 2022).

This study had the focus of utilizing the power of OSS-GIS technology for producing and assessing a spatial inventory of polling units in Eket local government area. Among the objectives was to acquire both spatial and attribute data on available polling units using Kobo Collect; comparison of existing and newly created polling units in the context of spatial significance and service oriented. Accessibility of the electoral infrastructure by populace was assessed. The use of Kobo toolbox mobile data collector and QGIS which is a free processing GIS software was adopted. The combination of KoBo Toolbox and QGIS data mapping were chosen to mitigate the challenges of high cost in human resources, mapping technology, licenses, and data integration. Open-source tools also provide a reliable and cost effective means for updating digital inventory of the polling units, secure their enumeration, maintenance and upgrade. The digital inventory allows for a first-hand visualization of the spread, distribution and location of polling unit in the study area.

However, emerging geospatial technologies such as Geographical information system (GIS) have been applied in capturing and managing many geographically related activities and for mapping of environmental

resources. GIS finds application in facility mapping and inventory such as transport infrastructure; health and tourism facilities; telecommunication, electricity, banking and finance utilities; and natural resources management, weather forecasting, research, monitoring, evaluation and social networking, etc. In the electoral sector, GIS tools have been used at several locations and countries for optimal location of polling stations, demarcation of catchment areas, route planning for delivering of electoral materials and conduct of polls (Muslim and Maduekwe, 2017; Sandhya, 2020).

In Nigeria, GIS software have been used for mapping polling-units' locations, demarcate electoral districts and voting subdivision boundaries (Abubakar and Alhassan, 2017; Moses and Nwoha, 2017; Okosun, 2020; Herbert et al., 2021; Bala et al., 2022). Polling units are important facilities and locations isolated or created to serve as spots where many election activities are carried out such as voters' registrations, voter's accreditation, voting and declaration of election results, etc. (Abubakar and Alhassan, 2017). GIS and GPS integration in the mapping of polling-units have been well documented both in Nigeria, Africa and other parts of the globe. This approach has inherent challenges requiring high cost in man power training, GPS and GIS integration, software licensing (ACE, 2015). In order to minimize these challenges, the choice of KoBo Toolbox data collection platform and QGIS for mapping were adopted. Kesselman (2014) argues that open-source software offers better software design, cheaper implementation, no vendor lock-in and high transparency strength in voting system design. This holds true for mapping and inventorying polling stations.

Fisher and Myers (2011) attempted the use of three open-source GIS tools namely Cybertracker, Open Jump; and AccessMod© for mapping of health facilities in the Nusa Tenggara Timur Province of Eastern Indonesia. The study explored the possibilities of these simple and inexpensive GIS software in the context of increasing data analysis at the local provincial level. Sandhya (2020), tested the capabilities of QGIS Open-Source Software for spatial analysis and web publishing. The effectiveness of the Open-Source GIS software for establishment of GIS system was established in the study as it was used to store, manage, sharing geospatial data, and to solve network and transportation problem. The usefulness of QGIS as an Open-Source Software in modeling noise indicators and producing noise maps of Nocera Inferiore Municipality, in South Italy was carried out by Graziuso *et al.* (2022).

Materials and Methods

Methodology adopted (Figure 1) in the study involved the configuration and utilization of mobile GIS driven tools in data acquisition and use of open-source software for processing and map production. Procedure for the work included mobile GIS data acquisition, geodatabase creation and network analysis using open-source GIS software. Kobo Toolbox (Kobo Collect) installed on GPS-enabled android mobile phone was used for data collection, while QGIS 3.20.1 GIS software was adopted for processing, analysis and graphical visualization. The procedure for installation of "Kobo Collect" on the mobile app used for the data collection and configuration with QGIS adopted are as highlighted in Leh, et al. (2019).

KoBo Toolbox is 'a set of free simple, robust and powerful tools for data collection' (Mtembenuzeni, 2021). Kobo Toolbox provides a good platform to collect data on mobile devices such as tablets and smart phones. It has robust enabling tools such as ODK Collect, KoBo Collect and KoBo Toolbox API. ODK Collect is an intuitive platform with comprehensive data collection, basic mapping and analysis capabilities (LWR, No date; Leh, et al., 2019). KoBo Collect is an offline data collection Android-based application, and for feeding data into a Kobo Toolbox account. According to Mtembenuzeni (2021), KoBo Collect allows for online or offline data entry into any platform. It has special features which include multiple language support, facility for wide and variable data collection, logic for skip patterns, field calculation, validations and integration. KoBo Toolbox has wide application since it is free and easy-to-use comprehensive mobile data collection platform with limited GIS analysis function. Other special functionals include straightforward conditional logic and skip tool, support image, audio, video, scanner and GPS data types, as well as, online/offline functionality which enhances cost effectiveness (LWR, No date).

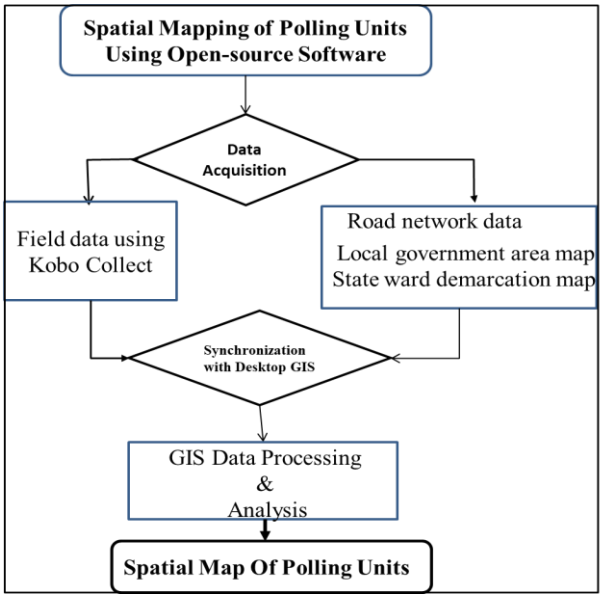

Fig. 1: Flow Chart of Methodology

QGIS is open-source software that runs on Android, Linux, Mac OSX, Unix and Windows operating systems. Key features of QGIS include data capturing, editing and management, overlaying and spatial analysis. QGIS has multiple plug-ins and customizable tools veritable for visualizing, managing and editing data. It is very apt for environmental resource mapping, terrain analysis, feature location and visualization (Oswal, 2020; UHCL, 2022; USC, 2022). Most importantly, QGIS is a cross-platform GIS solution with capacity to integrate other open-source GIS package, such as GRASS, KoBo Toolbox, Map Server, PostGIS, etc., for data exchange processing and for creating series of maps and 'a cross-platform GIS solution' (USC, 2022).

Study area

Eket Local Government Area occupies the south central territorial part of Akwa Ibom State Spanning Northwards between Latitude 4°32'N to 5°33'N and Eastwards between Longitude 7°25'E to 8°25'E and occupies an area of approximately 176,000 square Km. The region is characterized by uniformly hot and wet tropical climate with average annual temperature of 25.9 °C and annual rainfall is 3675 mm. As at 2015, Eket Local Government Area had 11 political wards and 98 polling units. The number of polling-units increased to 203 in 2021 when the Independent National Electoral Commission (INEC) created 105 new polling units in the area. However, this study was limited to 8 wards namely Urban 1, Urban 2, Urban 3, Urban 4, Central 2, Central 3, Central 4 and Okon ward 2. Figure 2 is the map of the study location.

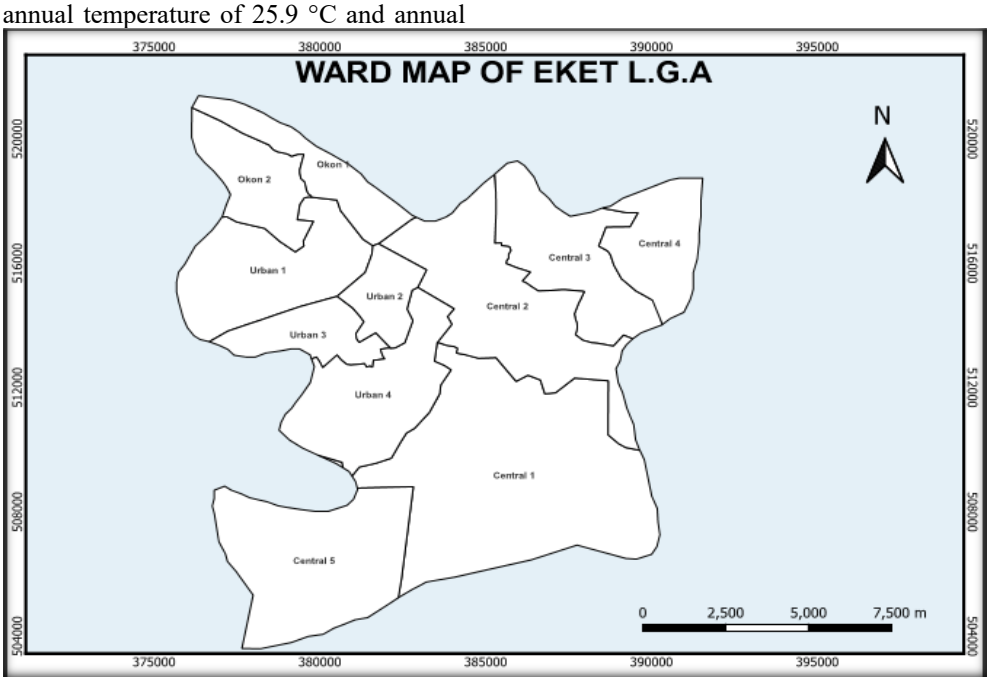

Fig. 2: Map of Study Area (Eket LGA.)

Dataset

Data requirement for the study included Polling-Unit information, population data, base map of study area, spatial data of existing polling unit locations and election related features such as political ward, INEC Office, police station, hospital, significant land marks and attribute data of the polling units. Polling-Unit information and population data (total number of registered voters for each ward) were obtained from Independent INEC office, Uyo. Spatial map details namely road network data, local government and ward boundary shape-files were obtained from the Department of Geoinformatics and Surveying, University of Uyo. Coordinates and attributes of polling units and other related facilities were obtained in the field using Kobo toolbox open-source software.

Application of KOBO Toolbox involved online registration, online form design, installation of 'Kobo Collect' on the mobile phone and Synchronization with QGIS. To access Kobo Toolbox, a new account was first created online via the Kobo Toolbox. The was configuration and activated through the email address used during registration and subsequently, 'Survey Question Form' which was to be used for data acquisition was created (Figure 3). The "build from scratch" utility of the Kobo Toolbox was accessed for the purpose. Appropriate title and questions were filled. Information contained in the form included; location of polling unit, location of electoral offices, location of police station and hospitals, location of telecommunication mast as well as their associated attributes (the name of the polling unit, polling unit code, ward name, ward code, street name). 159 polling units and 1 INEC office were mapped besides other points of interest.

Following the online survey form creation, the Kobo Collect was installed on 'REDMI Note 9'mobile phone. After installation, the URL of the server was revised to get the question created in the kobo toolbox account via kobo collect. At the field, the Kobo Collect was opened on the phone and data collected based on the content of the form. After collecting the data and at each point, the field question form was reviewed and edited in an "Edit Saved Form". The finalized form was then be sent to the kobo toolbox account which was later downloaded for processing in QGIS software.

Synchronization of field data with QGIS was carried out by exporting data in a .csv format into Excel spreadsheet for editing and then finally imported as a delimited text layer into QGIS through 'Data Source manager' tool (Figure 4). In QGIS, the filed data was automatically transformed into a layer with an already populated attribute.

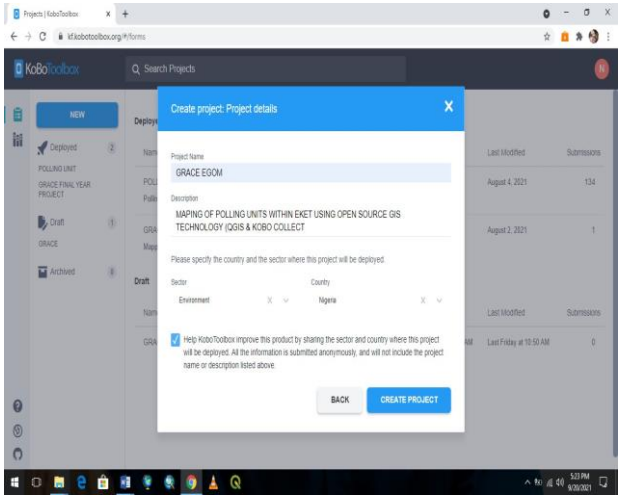

Fig. 3: Screenshot of Kobo toolbox Online Form Creator

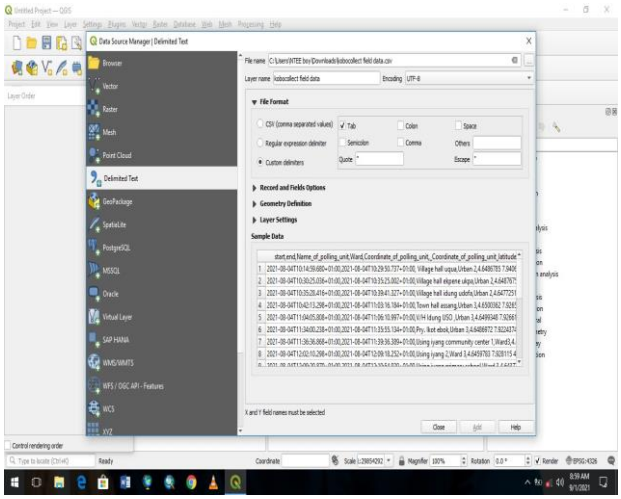

Fig.4 'Data Source manager' tool

Data Processing and Analysis

All datasets were imported into QGIS work environment as data layers and projected into WGS1984 UTM Zone 32N coordinate system. Geodatabase of all acquired features were created and network dataset developed by integrating all data and incorporating speed limit and topological rules to the road dataset. Several analyses were carried out to examine the suitability of polling units' location in respect to associated facilities and infrastructures. Service area analysis was used to determine all accessible routes that could be used to access particular locations of interest within a specified time frame. Shortest route from INEC office to specific polling-units within the study area, closest facility from several facilities and route analysis scenario was executed to determine the shortest route from accident incident point to hospital facility. Spatial analysis of polling units' sites was also undertaken to determine location-allocation priority of one over the other and suitability based on INEC's criteria.

Result and Discussion

Evaluation of Spatial Distribution of Polling Units and Location Site

INEC created more polling units termed polling points in the country to checkmate the challenges of overcrowded polling units and long commuting distance for voters during election days (Sobechi and Omolaoye, 2021). A total of eight four (84) polling units newly created points and seventy-five (75) were old/ existing polling units mapped in the study (Figure 5).

Given that polling units should be located in places devoid of any form of intervention, private interest, hindrance or restriction to accessibility of all stakeholders to the election and voting process, an assessment of ownership of the polling unit premises mapped within the study area was carried out. This analysis was to check INEC's policy that polling units should be centrally located at accessible locations which are non-partisan, non-sectarian and in public places (e.g. public schools) (INEC, 2021). Figures 6 and 7 are graphical display of the analysis result.

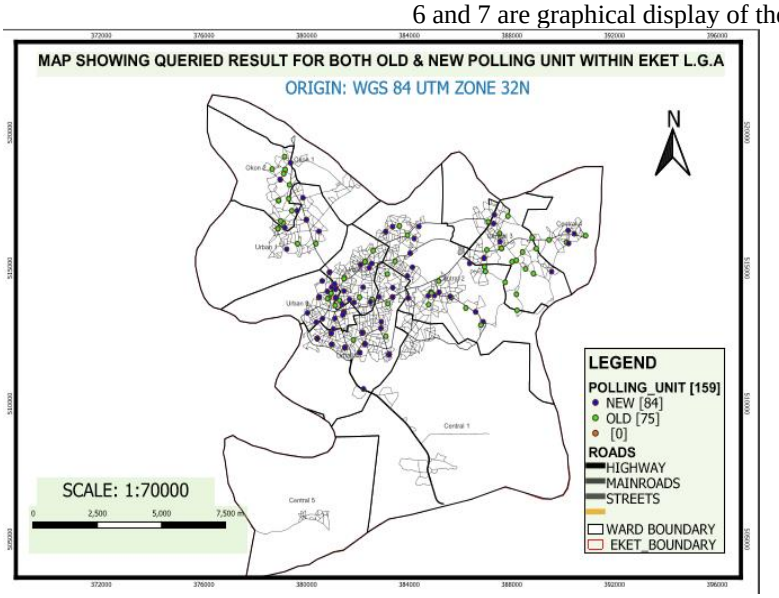

Fig. 5: New and Old Polling-Units Mapped within the Study Area

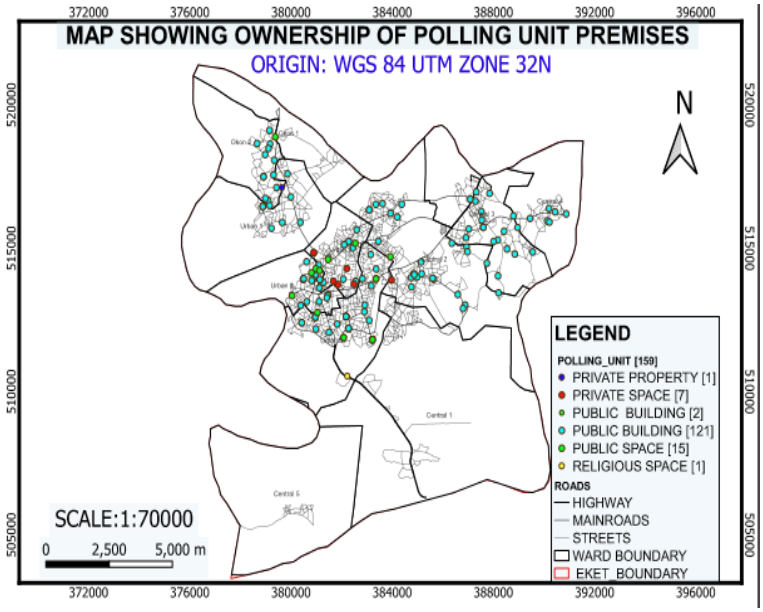

Fig. 6: Map Showing Sites of Polling Units by Ownership

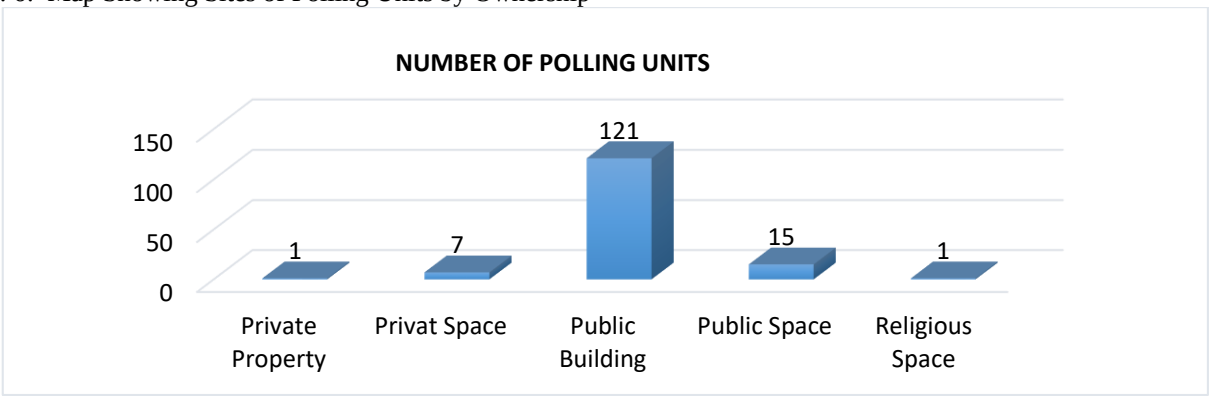

Fig. 7: Graph showing Polling-Unit Site by Ownership.

Figure 7 revealed that the newly created polling units were more than existing points by nine (9) units. Among these, assessment based on INEC's criterion for creating a new polling unit where polling units with more than 600 registered voters are to be subdivided into 'Voting Points' revealed that 98% of the newly created polling units were "Voting Points" as they shared same location with some of the existing polling units. Social survey during field data acquisition indicated low exposure and awareness of electorates to the existing of these voting points as only 3 out of 10 persons interviewed within selected areas show knowledge of the new created points.

Figure 6 and Figure 7 above portray the total number of polling units sited within different premises across the eight political wards mapped. The result shows that eight polling units were sited on privately owned locations against INEC's criteria (INEC, 2021).

The implication of this scenario on the election process is that citizens' franchise and full participation may not be achieved as some people may not be allowed access to the private locations while freedom of voting their candidate of choice maybe compromised. This indirectly robs off on the general integrity of the election process in the wards and in the local government area. However, INEC will have to relocate polling units which were wrongly so as to meet its criteria for citing polling units and also promote citizen's full participation in the election process.

Proximity and Service Area Analyses of INEC Office to Polling Units

Proximity analysis was carried out to determine the closeness of polling units (in ward basis) and some facilities (Police station and hospital) to INEC Office. This was analyzed in 5 segments from 2km to 10km (Figure 8). Figure 9 is the result of service area analysis carried out to determine all accessible locations within the study area that lies within specified impedance from INEC office. Distance tolerance was set to 1000m and an impedance of 3 to 5 minutes' drive time from the facility.

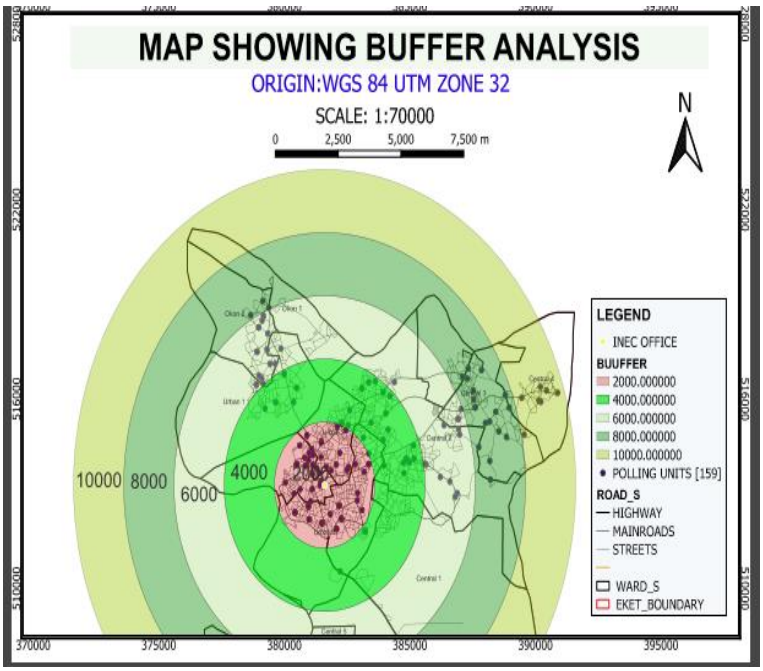

Fig. 8: Map showing Proximity of Polling Units to INEC Office

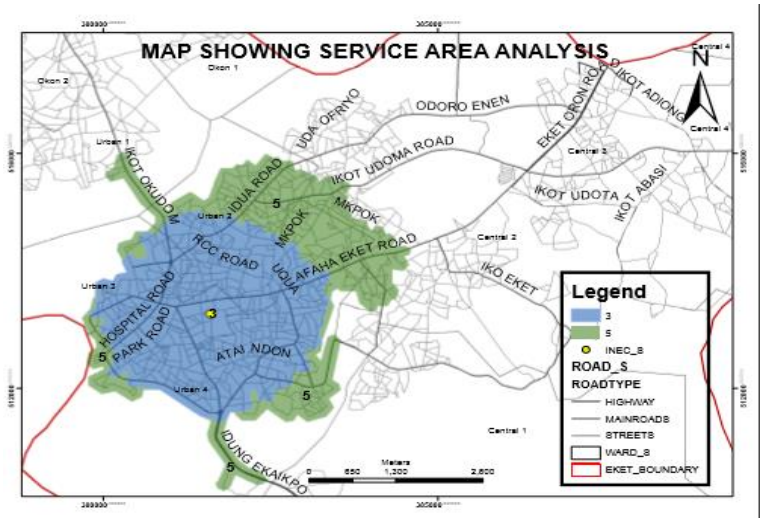

Fig. 9: Service Area Analysis at an Impedance of 3-5 Minutes.

From Figure 8A total number of three wards (Urban Ward 2, 3 and 4), a police station and some health facilities fell within the 2km buffer zone. This implies that within 2km buffer zone electoral officers will not have to travel beyond 2km to get to polling-units for discharge of duties and residents within the 2km buffer zone will also cover less distance and short travel time to get INEC office. Polling-Units in Urban Ward 1, Central Ward 2, Ward 4 and parts of Urban Ward 2 were within 4km from INEC office. Okon Ward 2, parts of Central Ward 2 and Ward 3 polling units were within 6km buffer zone. Polling units in parts of Central Ward 3 were cited within 8km from INEC office and Central Ward 4 lies within the 10km buffered zone. This result revealed a tendency where late delivery of materials particularly to Central Ward 4 which lies 10km away from the INEC office is imminent and subsequent delay in the franchise of the citizens except precautionary measures are taken to forestall such occurrence.

Figure 9 revealed the locations and polling wards that could be serviced between 3 to 5 minutes' drive time. The yellow mark indicates the location of INEC office. The blue region indicated the extent of all the streets and locations that can be reached within 3 minutes at 80km/hr. time vehicular travel while the green region showed the extent within 5 minutes from the facility. The result shows that within the wards mapped, travel time was optimum. Thus, delivery of materials to the centers and services by the INEC official may be prompt if other variables are well taken care.

Best Route Analysis for Election Incidence to Health Facility:

Analysis of result for finding the best route for an emergency response vehicle from hospital facility to incident and back to the hospital with a victim during an election mishap based on its specialization and facilities are depicted in figure 10. The database was queried for specialist hospitals for immediate response activity from

an outstanding polling unit (Primary School Ikot Okudom), which usually have records of high number of electorates. Both the 'DIST' and the 'Drive Time' cost attributes were applied as impedances in order to obtain the shortest and fastest route.

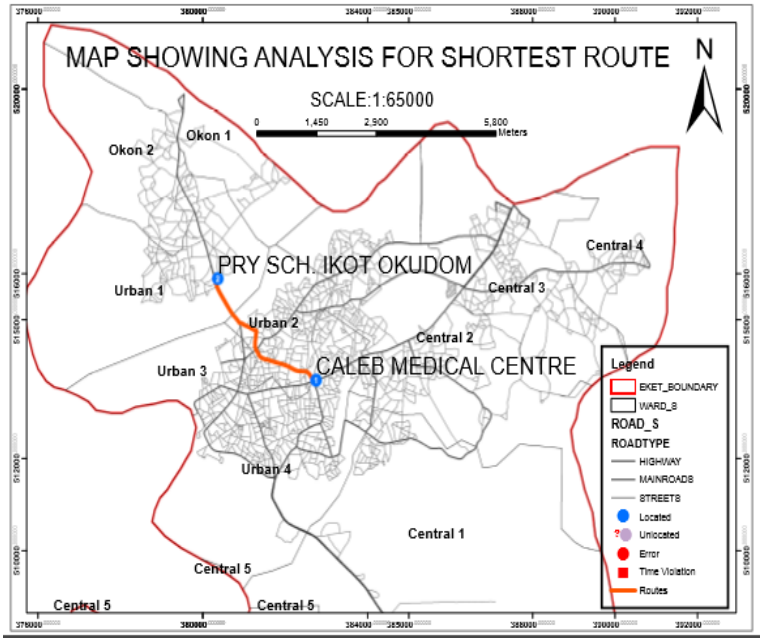

Fig. 10: Map showing Shortest Route Analysis from the Point of Incident (Primary School Ikot Okudom) to the Facility (Caleb Medical Centre).

Table 1: Results of Best Route Analysis

Route Description	Origin- Destination	DIST (m)	Drive/Time (mins)
Shortest route	Caleb Medical Centre to Primary School Ikot Okudom	3803.2	6

Considering the number of results obtained, the output presented in Figure 10 and table 1 had the least travel time and distance and was marked as the best for an emergency response. Route marked with orange color indicted the best route of travel from the medical facility (Caleb Medical Centre) to the incident point (Primary School Ikot Okudom).

Closest Facility Analysis for Election Security Incidence:

To forestall fatal incidence and ensure law and order, it is imperative that polling units be located at safe locations. In this study, analysis to scenarios where emergency situations could require the interference of a quick respond squad from the closest police station was modeled. Polling units were selected at random from each ward and nearest facility solver executed. Figure 11a was the analysis result for nearest police station with time impedance while figure 11b was analysis output for DIST impedance from the selected location to the security outfit (police station). The distance and drive time from selected polling-units to the nearest police station location Table 2. For each of the figures (11a and 11b), the route to the security outfit from each polling unit was depicted by blue link. Police stations are marked with red while polling units are marked green.

Table 2: Distance and Drive Time from Selected Locations to closest Police Stations.

S/N	Location (Polling Ward)	Security Outfit	Distance (M)	Drive-Time (Mins)
1	Okon 2	P. S. - Area Command Eket Oron Road	5512.51	8.266879
2	Urban 3	P. S.- Area Command Eket Oron Road	2554.56	3.830938
3	Urban 4	P. S.- Area Command Eket Oron Road	2112.61	3.16818
4	Central 2	P. S.- Area Command Eket Oron Road	3644.21	5.464958
5	Central 3	P. S.- Area Command Eket Oron Road	2443.92	3.664971

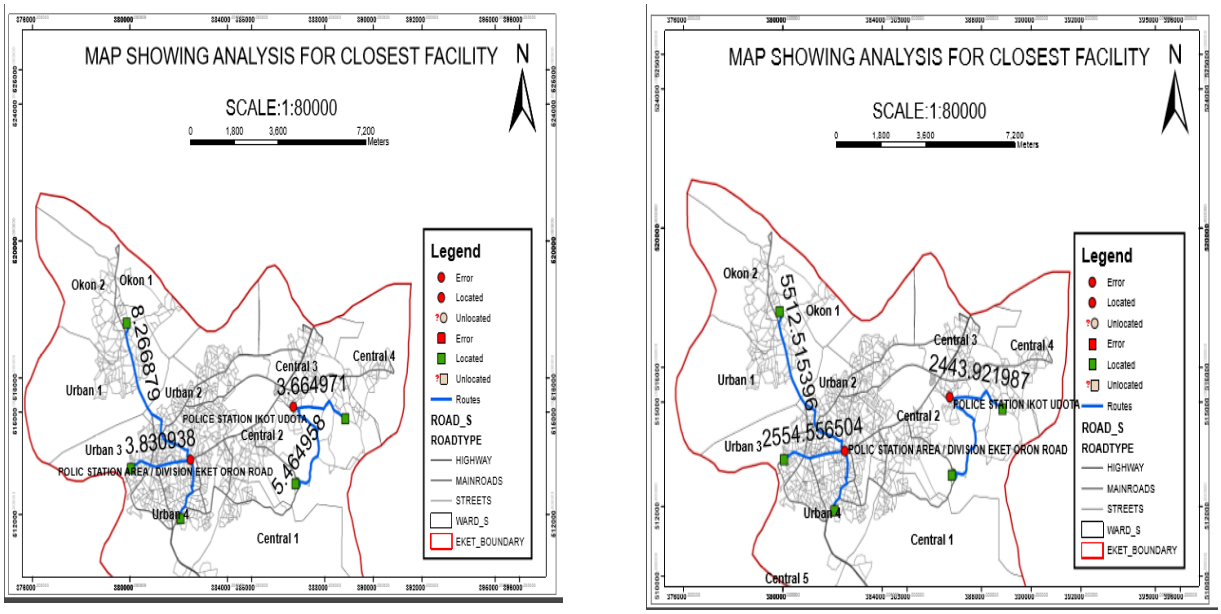

Fig. 11: Map Showing Analysis for Closest Security Facility to Polling Units

The result revealed optimum travel times and distances from security outfit to polling unit and promote prompt response to security issues. Generally, proximity of major facilities and services that sustain the election process to polling units/points were will enhance effective election process and efficient service delivery and general satisfaction.

Conclusion

The location and spread of polling units as well as the spatial location of police stations and INEC office within the study area were spatially depicted. The study shows that 93.8% were located at publicly owned sites, 5.5% within private premises and 0.7% on religious centers. This indicated that INEC may have to relocate 6.2% of the polling facility points as the locations were unsuitable based on INEC's criteria, to cater for proper accessibility and security of electorates. Besides, the study also shows that 52.8% polling units (98% being "Voting Points") were newly created to enhance citizens accessibility and participation in the election process.

The capabilities of open-source tools (QGIS and Kobo collect) for collecting, analyzing, modelling and visual presentation of polling unit information was harnessed. Integration of open-source tools in combination with other media enabled effective manipulation management and visualization of geographic information, thus making polling unit information readily available where traditional maps fail to serve the purpose. This implies that open-source GIS tools are viable and cost-effective tools for mapping and could be harnessed for other applications.

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