International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

# Production of Revised Street Map of Uyo Urban Area, Nigeria Using Remote Sensing and GIS Approach

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**Abstract** - ***The use of remote sensing data and geographic information system technique especially with high spatial resolution satellite imagery has great capabilities for mapping and map revision. These techniques have been used in various times and at different stages to study characteristics of Earth features, monitor natural and physical phenomena and also produced street maps of different places. In this study, the GeoEye-1 satellite image of 2011 was used to update and produce the revised Street Map of Uyo Urban Area in Southern Nigeria. The methodology adopted for the research was an integrated and conceptualized approach consisting of digital image processing and cartographic procedures. Data capture was by scanning and digitizing of the old street map while field work was carried out for the purpose of ground truthing/field completion, annotation and for collection of coordinates of selected control points. The acquired data was processed using ArcGIS 9.3. Analysis carried out reveals the total number of roads to be 950 while the total distance of road network in the study area is 433.206km. In addition, the new roads totaling 608 made up a distance of 243.082km while the old roads (432) made up 190.125km of the total length of the road network. The revised map also has 12 roundabouts, 2 flyovers, a pedestrian bridge and a bypass. Paved roads accounted for about 25.2% of the total roads network while unpaved and partially paved roads made up 74.8% of the roads in the study area. From the study, it is recommended among other things that government should create more bypasses and open up new roads to decongest and ease traffic on the streets at the central part of the study area. Provision should also be made for the periodic revision of the street map and production of street maps of major towns in the state.***



## 1. INTRODUCTION

A street map is a graphic portrayal of a town or city, showing the positions and names of all the streets; major/ minor highways and roads, railroads, tracks and other points of interest and the general road network. It is a form of map that details roads and transport links. Street maps are used for locating houses and streets; car navigation; planning of transportation, trips and driving directions; and for planning of movement and provision of facilities, goods and services. In Africa and Nigeria in particular, movement of goods and services, social and economic development of the country are dependent on good road network as road is the major means for transportation. As observed by Igbokwe [4] very few rail lines exist in the country and are mostly unreliable. Besides, aviation is on the developing phase and not readily affordable by majority of the citizens hence continuous mapping and an updating of the county's road maps will give a proper inventory of the road network in a more current state.

Besides, high and accelerating rate of urban changes and township area extensions, that leads to construction of new roads particularly in a developing country such as Nigeria, calls for an efficient and fast technique that will meet mapping standards and accuracy for mapping and regular updating of these changes. In the past, the processes used for mapping and revision of maps had been the classical land surveying method. Later in nineteen century, aerial photographs were used to extract data for producing and revising topographic maps. These methods proved to be time consuming and inefficient for large study areas and limited in the ability to conduct frequent updating and revision. Fortunately, remote sensing a fast means of acquiring data about the environment without physical contact with the features has made significant advances over the past twenty years in providing cost effective data for mapping. New advances in this field led to development of multispectral high-spatial resolution (HSR) and very high resolution imaging (VHR) systems such as QuickBird, Orbview-1, IKONOS, GeoEye-1, etc. Since data from these satellites became available for commercial use, they have served as a useful means of monitoring our environment and the state of our road networks and also provides the tool to constantly map these road networks and even plan for new ones. The availability of the new generation satellite imageries have opened a new era and signaled promising futures for producing and updating digital maps. Satellite remote systems provide a synoptic view of large portions of the earth surface as an entity rather than in small bits. These images allow a view and the analysis of different features of the environment (and even road network) on regional and global scale [4].

With this, remote sensing has become an important tool available for mapping urban changes and infrastructures. This capability is made more versatile with the use of the GIS - a computer based information system that is used to input, store , retrieve, manipulate, analyze and output geographically referenced data (geospatial data), in order to support decision making for planning and management of land use, natural resources, environment, transportation and urban facilities, etc. As a scientific tool, GIS is used to capture, store, create interactive queries, analyze and manage spatial information and edit spatial data and associated attributes. It provides a computer-implemented spatially oriented database for evaluating remote sensing data in conjunction with other spatially formatted data and information acquired from different sources. The objective of this work was to produce the revised Street Map of Uyo Urban area, using Remote Sensing and GIS approaches. The essence of using this integrated approach is for the convenience and economy it offers.

### 1.1 Integration of Remote Sensing and GIS Techniques in Map Production and Updating

The production and updating of maps using remote sensing data dates back to when data from the first earth remote sensing satellite launched in 1972 were first used for the inventory of natural resources and for monitoring of the human environment. Since then, space remote sensing imagery has facilitated and speeds up the work of producing as well as revising maps at all stages, beginning with the selection, acquisition, analysis and evaluation of the quality of base data. The potential benefits from the repetitive and continuous supply of data afforded by satellites provide the flexibility for change detection and mapping as well as revision and updating of existing maps.

With a computerized GIS, it is possible to combine reference data from several sources, it can be used to extract and process ground survey data and remote sensing data as well as existing analogue and digital data sets. GIS has analysis, interpretive and measurement tools that can be used to extract and present useful information and to produce any type of map. In GIS environment, spatial search and query analysis are possible such that solution to questions such as: where a road is; where it leads to; the distance (length) and type; the best route between points A and B; the shortest route between two points can be obtain by combining spatial and non- spatial data from different sets [1].

GIS and remote sensing in map production allow for the combination of data from different sources as well as the interpretation, manipulation, management, analysis and accurate presentation of map information. This approach also gives optimal benefits as the advantages of both technologies are combined in the mapping process. This however has been ascertained by many scholars and researchers. For instance, Abbas et al [1] concluded that street mapping using remote sensing data and GIS technique is less tasking compared to the traditional map making and is also cost effective and time saving. They posited that remotely sensed data provides repetitive, synoptic view and accurate information that can be used to obtain up-to-date maps.

In their work, Nnam et al [7] demonstrated that the use of satellite imagery together with computer hardware and software technology (GIS) in street map production have tremendously improved both the speed and quality of map making as well as increase the precision, accuracy, quality and productivity. These they posited has met the need for the capability / capacity of producing high precision and quality maps (street map) within a reasonable time frame and at a greatly reduced production cost.

Howbeit, it should be noted that the accuracy of urban street mapping using satellite imageries depends on the image geometric accuracy and extractable map scale based on adopted standards and its information content. Thus for updating and producing road infrastructure map,1-30m resolution imagery could be used in area of minimum tree density but to obtain an accurate, precise and quality street map, a high resolution (0.25 – 0.5m) image must be used [6]. Hence, to produce a quality street map for the study area, a 0.5 meter pan sharpened colour image of GeoEye-1satellite was employed.



### 1.2 Study Area

Uyo Urban Area lies between Longitudes 07$^{o}$ 53’ and 07$^{o}$ 57’E and between Latitudes 04$^{o}$ 59’ and 05$^{o}$ 03’N. It is situated at the north central part of Akwa Ibom State and occupies a model position with road links to all local government areas in the state. It is the entire land mass that lies within the four ring roads (about 42sqm) and is about 60km from the coast of the Atlantic Ocean [3]. The project area is located in Uyo Local Government Area and extends into part of Itu Local Government Area of Akwa Ibom State. It is comprised of several settlements including Aka Offot, Efiat Offot, Eniong Offot, Ewet Offot, Iboko Offot, Afaha Oku, Ikot Udoro Oku, Ikot Ebido Oku, Ikot Ntuen Oku, Afaha Ube Itam, Itiam Etoi, and Uyo (Fig. 1).

Uyo Urban lies within the equatorial rain forest belt and within the lowland plains of Nigeria, along the tropical climatic region. The mean annual and mean monthly rainfall is about 2316mm and 2782mm respectively while the mean temperature is 27$^{O}$C with high relative humidity throughout the year [3]; [5]. Given the status of Uyo as a state capital, the area is inhabited by a vast majority of persons from various nationalities.

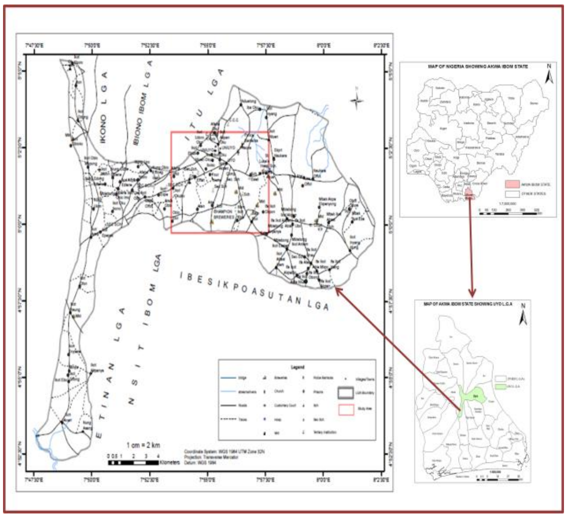

Fig. 1. Location Map of Study Area

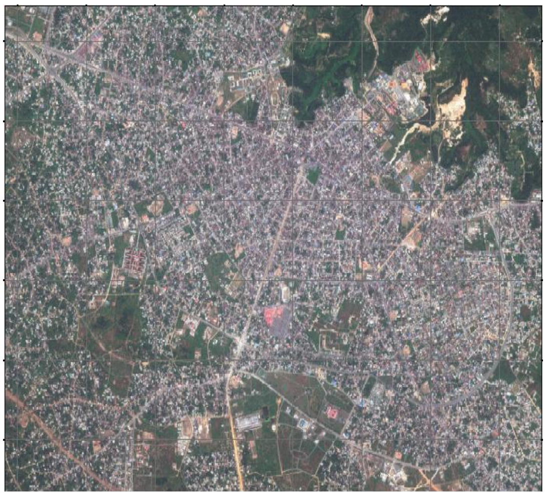

Fig. 2b. GeoEye-1 Image of Study Area

2. Materials and Methods

2.1 Data

The data used for the research consists of both primary and secondary data and included:

- Geographic coordinates of control points used for georeferencing and coordination of the route map and satellite image
- Attribute data of marked features and street annotation
- 1:7,500 Old Analogue Street Guide of Uyo (figure 2a)
- GeoEye-1 0.5 meter colour image of December, 10 2011(Fig. 2b).

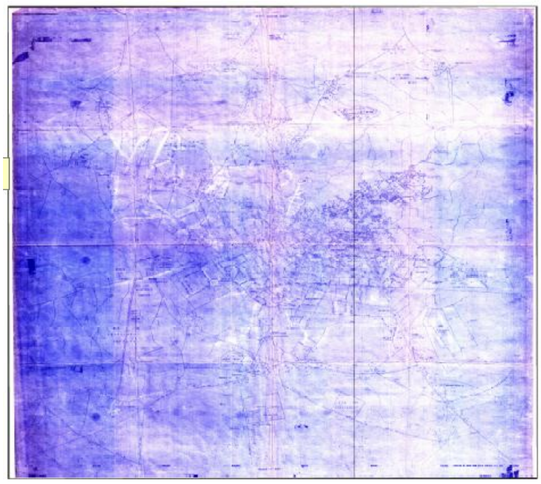

Fig. 2a. Old Street Guide of Uyo Urban Area

*2.2 Methodology*

The mapping of urban road by remote sensing and GIS techniques can be accomplished by either automatically extracting the road network from remote sensing imagery using different approaches or by digitizing the imagery and applying normal cartographic procedures. The methodology adopted for this research involves two major steps of data acquisition and processing as expressed in the procedural flow chart, shown on figure 3.



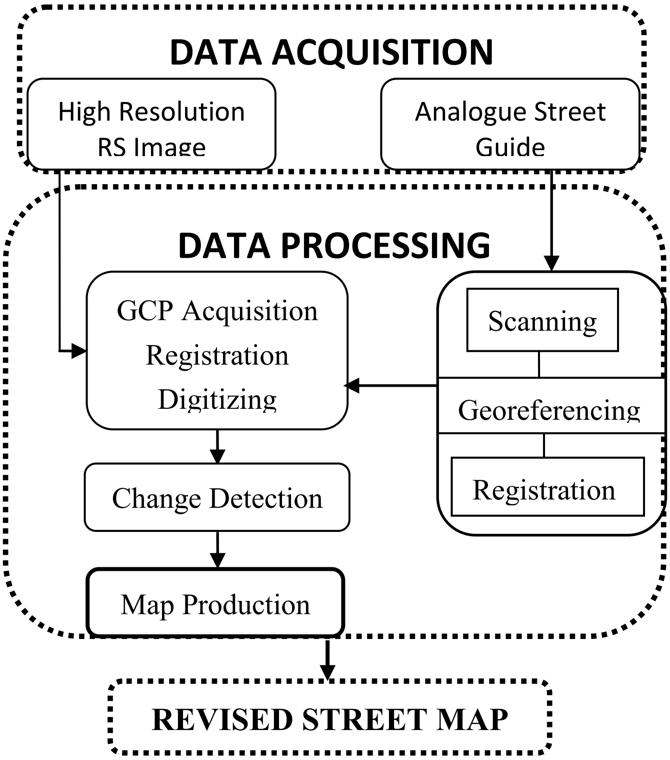


Fig. 3. Procedural Flow Chart (Source: Author)

2.2.1 Data Acquisition

Data acquisition is the first step in the execution of any mapping project after the preliminary stage of planning. It is a very important aspect of GIS as the type of data obtained and the accuracy of the data determines the output of the whole process. In this work, this was taken into consideration.

2.2.2 Data Processing

As depicted in the procedural flow chart, data processing was of three basic phases; the processing of the acquired data, change detection and map production. Generally, studies have shown that most digital images are not usually aligned with the same geographic coordinate system of the base data used and in some instances may contain geometric distortions that result from the image acquisition. As a result the images do not have a simple “map-like” geometry, and accurate map relationships cannot be derived from them. Processing of satellite images and the base data prior to data capture is essential and this was carried out in this work.

Image/Map Registration

The old analogue street map was scanned and georeferenced in ArcGIS using coordinates found on the map. This was followed with map registration. In this study, the map was registered to the Clarke 1880 NTM datum on which it was based using the observed values of the grid lines on the map. After this, the coordinate system of the street guide was later transformed to the WGS84 and Universal Transverse Mercator (UTM) system zone 32 north. The essence of this process was to have the two major data sets on the same coordinate and projection system.

In using remote sensing images to update maps research has shown that accurate registration of the base maps and remote sensing imagery is the key issue for ensuring result accuracy in the update map. For this study, conspicuous points found on the satellite imagery were selected as control points for used in the registration of the image with the base (existing) map. Georeferencing and geocoding of the image were done using the GCP data with ArcGIS.

Data Capture/ Change Detection

Data capture refers to the digitizing process by which new data required to produce or revise a map is transformed into digital format for storage and further processing where necessary. Although manual on-screen digitizing method process is slower than the automatic digitizing, this approach according to researches has proved that the results are usually close and as real as the real feature forms [2] and as such was employed in this study. Upon registration, the different features found on the scanned streets guide were captured using the heads up digitizing method of raster data vectorization in layers. The different layers identified were roads, rivers, facilities, electric transmission line and footpaths.

Following this, the two data sets were overlaid in ArcGIS using the overlay module so as to identify and extract new roads for updating and producing the street map of the study area. Roads (new) found on the GeoEye-1 imagery were digitized for the purpose of change detection and updating. However, other features found on the image were also digitized in the process and different layers created. The various layers created included: road, bridge, roundabouts and public facilities (land marks).

Map Production/Editing

One of the major capabilities and the usefulness of GIS operations is its overlay function. With this, the result of change detection and data extraction was utilized for producing the street map. This was followed with topology building and editing. Topology building is the process by which spatial relationships between connecting and adjacent geographical elements are established. Here, it was carried out to join the various roads and also establish a geographical relationship amongst the different road classes. This also ensures that the roads were connected to form a network and also correct for dangling node errors. Editing was further undertaken to check dangling nodes – overshoots, undershoots and other errors. This was followed with the creation of a database, attribute editing and annotation.



3. Database Creation and Data Presentation

Database design and creation is one of the fundamental process in every GIS work executed. For this work, the vector conceptual scheme whereby roads and bridges were classified as linear (line) features, landmarks (facilities) and roundabouts as polygon was adopted. For the logical design stage, the relational data model by which data are separated into tables was adopted for each of the entity types. That of the road network is as depicted below.

Table 1. Table Showing Fields, Description and Attributes for Roads

| FIELD | DESCRIPTION |
|---|---|
| RD_ID | Road Identification Number |
| RD_NAME | Road Name |
| RD_TYPE | Road Type |
| RD_CONDITION | Road Condition |
| RD_STATUS | Road Status |
| RD_DESIGNATION | Road Class |
| RD_LENGTH(KM) | Road Length in Kilometers |

(Source: Author)

The logical design was followed with the physical design. Here, the data structure was represented in a format of the implementation software. Line and polygon layers were created respectively for bridge and roads, roundabout and landmarks. Following the processing and manipulation of the data and the populating of the database, the results were produced as tables; graphs and map (see section 5).

## 4. SPATIAL SEARCH AND ACCURACY TEST

The importance of spatial analysis and accuracy test in any GIS work is dependent on the use of the data and the geographical location and features portrayed. To enhance the quality and trustworthiness of any data set generated or information presented, these procedures are usually undertaken. Spatial analysis is the process of applying analytical techniques to geographically referenced data sets to extract or generate new geographical information. Although the overall analytical technique may be complex, it is usually a combination of simple techniques applied in the appropriate order. GIS query/ spatial search combines spatial and non-spatial data from different data sets for spatial analysis operation. Spatial analysis may be used to model simple or complex geographical interactions. It is useful for investigating site suitability, location of features of interest, determining best and shortest routes between two points and determining the distance and type of roads. Spatial analysis and spatial search (query) carried out in the research were both single and multi-criteria and network analysis.

Accuracy test in a mapping project include positional (absolute) accuracy, relative accuracy and attribute accuracy. In this study, the relative accuracy of the revised map was tested by comparing the measured length of roads in the field with their corresponding lengths measured on the map using the “Calculate Geometry” tool of ArcGIS package. Some of the roads measured included Bennet Bassey Street and Prince O. U. Utuk Avenue. For Prince O. U. Utuk Avenue, the measured length on ground was 481.490m while the length of Bennet Bassey Street was 400.807m. From the calculated results obtained from the revised map, the lengths of these streets were 481.425m and 400.578m respectively. These gave a difference of 0.065m and 0.237m respectively.

To ascertain the absolute accuracy which is the relationship between a geographic position on a map and its real-world position measured on the ground, the position of some features/buildings were measured and compared to their position on the image. Features taken included major bulwarks on some streets and an academic block in the University of Uyo Annex. The attribute accuracy which is the closeness or precision of attribute value of features on the map to their true value was also checked. Attributes of the streets and other features portrayed on the map were verified through field completion.



## 5. RESULT AND ANALYSIS

Based on the study and the map produced, different road classes and types were identified. Amongst the total roads obtained in the study area, paved roads accounted for 25.2% while unpaved road accounted for 74.8% of the total roads. The total distance of road network in the study area is 433.086km while the total number of roads is 950. By comparism, it was discovered that the total number of roads on the revised map was 950 while that on the existing street guide including footpaths was 515 implying that there is an additional 435 roads between 1989 and 2013. Also, the percentage of dual carriage roads, single lane and other roads show a considerably increase. For other features, the existing street guide had only one roundabout whereas the produced street map has 12 roundabouts, 2 flyovers, a pedestrian bridge and a bypass. Summary of the road coverage for both road types and designation (class) is presented in the tables 2 and 3 while the graphical portrayal of the road coverage for 1989 and 2013 and the comparison between the road coverage types and designation for the two years are shown in fig. 4 and 5, 6, 7, 8 and 9 respectively. The revised street map of the study area is given in fig. 10.

Table 2. Identified Road Types in 1989 and 2013

| Road Type | Coverage (%) - 1989 | Coverage (%) - 2013 |
|---|---|---|
| Major Roads | 1.95 | 2.42 |
| Minor Road | 3.70 | 6.95 |
| Street | 39.49 | 39.68 |
| Lane | 32.68 | 44.95 |
| Access | 2.14 | 3.68 |
| Footpath | 20.04 | 2.32 |
| Total | 100 | 100 |
| | | |

Source: GIS Analysis

Table 3. Identified Road Classes in 1989 and 2013

| Road Designation | Coverage (%) - 1989 | Coverage (%) - 2003 |
|---|---|---|
| 4-lane Express Way | 0.00 | 0.10 |
| Dual Carriage Way | 0.39 | 2.95 |
| Single Lane | 49.61 | 42.42 |
| Other Roads | 50.00 | 54.53 |
| Total | 100 | 100 |

Source: GIS Analysis

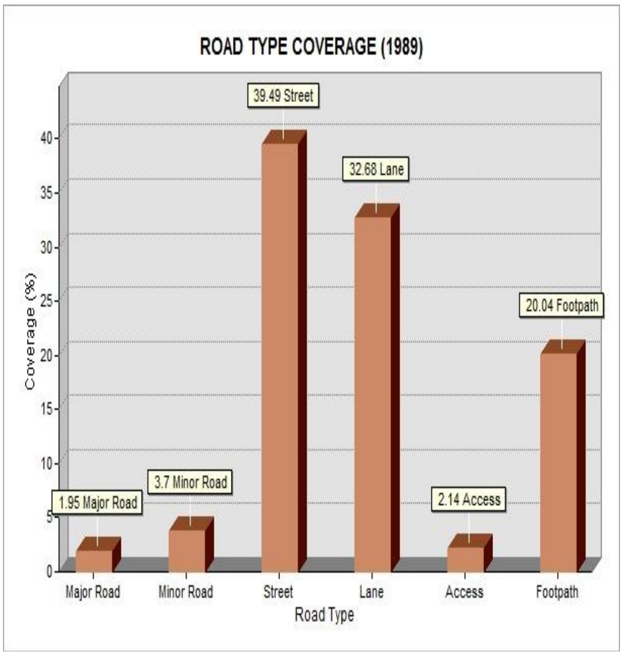


Fig. 4. Graph Showing Percentage (%) Coverage of Road Type in 1989 (Source: GIS Analysis)

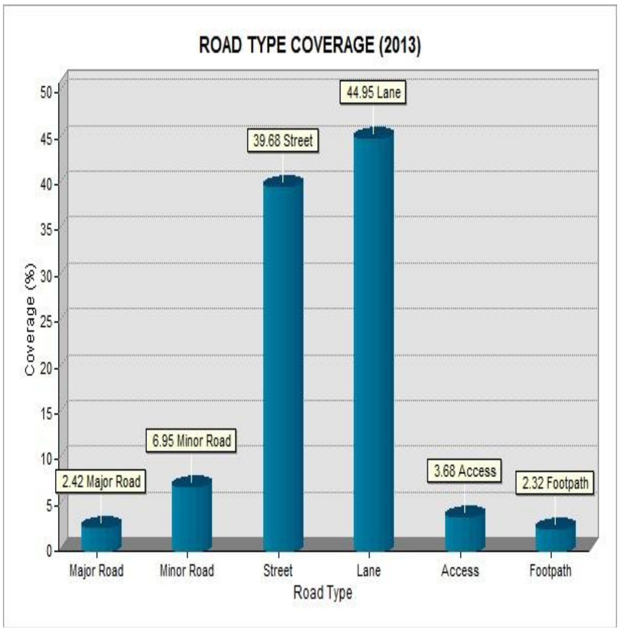


Fig.6. Graph Showing Percentage (%) Coverage of Road Type in 2013 (Source: GIS Analysis)

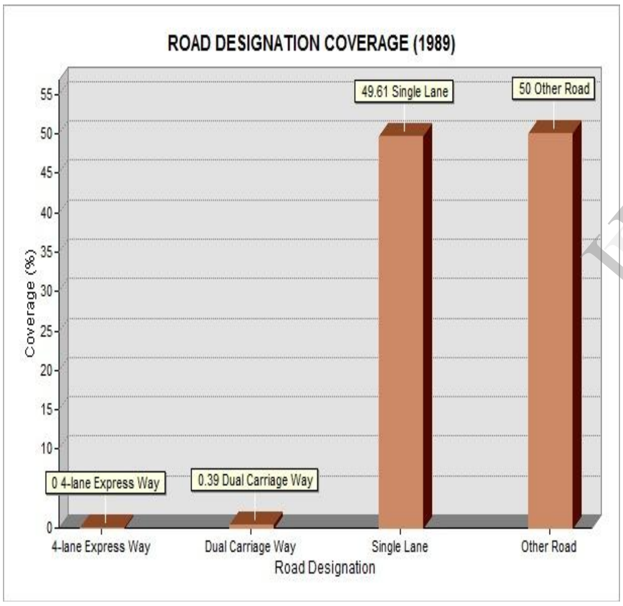


Fig. 5. Graph Showing Percentage (%) Coverage of Road Designation in 1989 (Source: GIS Analysis)

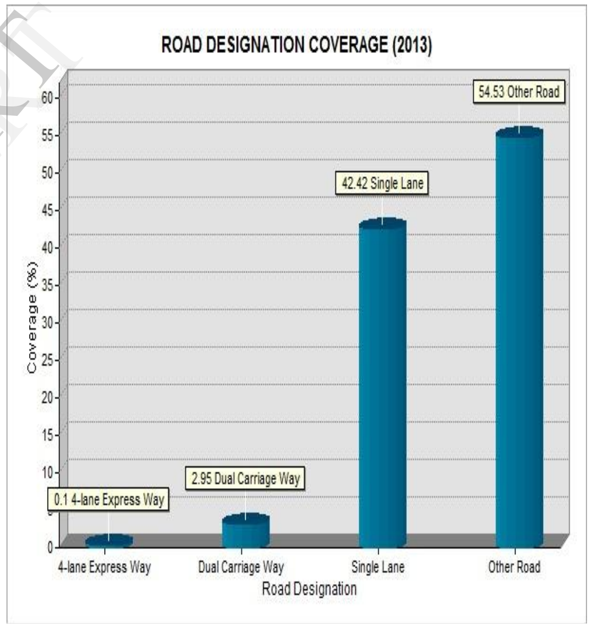


Fig. 7. Graph Showing Percentage (%) Coverage of Road Designation in 2013 (Source: GIS Analysis)

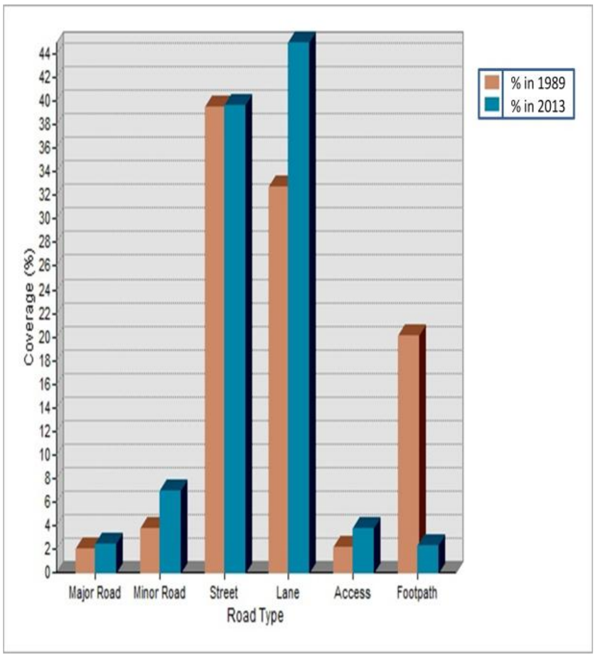


Fig. 8. Graph Showing Percentage (%) Coverage of Road Type in 1989 and 2013 (Source: GIS Analysis)

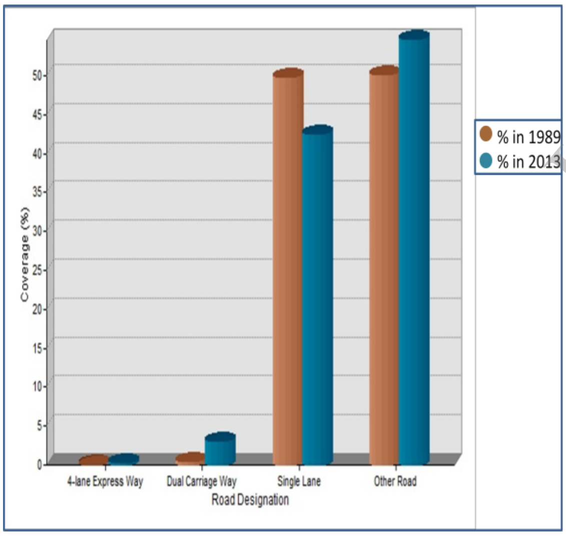


Fig. 9. Graph Showing Percentage (%) coverage of Road Designation in 1989 and 2013 (Source: GIS Analysis)

NB: The dual carriage ways were two lanes of paved roads with median running through the centre. The single lane roads were route that had one lane running, while other roads where those of dwindling nature. The 4 lane express way is a higher capacity highway with median which consists of four paved single lanes running concurrently. The major roads were roads that linked major parts of the city, other parts of the Uyo Local Government Area as well as other Local Government Area of the State. These roads usually link up to the dual carriage roads and other major roads. The roads subtype as minor roads in the study area were offshoot of both the dual carriage and major roads; streets were medium capacity highways that link both the major roads, minor roads and other streets as well. The lane subtypes were those streets of a much lower capacity that connect streets, alleys, lanes and streets that were close; access roads were streets that lead to premises while footpath were unmotorable roads; other roads were unpaved roads both named and unnamed.

Besides the coverage and number of roads identified within the study area, it is also identified from the map and during ground truthing that, the general road network of Uyo urban is radial creating a radiocentric network with Ibom Connection (Circus) the city centre. The roads are also arranged on a series of rings based on the structural design of the city

## 6.0 CONCLUSION AND RECOMMENDATIONS

This study has demonstrated the effectiveness of the integrated use of remotely sensed data and GIS tools in the production of urban street maps. The use of satellite data for the exercise not only gives accurate information on the features located within the study area but was also acquired within a short time. Time and cost for the collection and processing of the data are saved as compared to other methods. The GeoEye-1 satellite image is particularly very excellent for use in map revision and updating as well as for mapping of urban facilities and phenomena given its high resolution which allow for identification and delineating of features in a crowded urban setting.

The results obtained show that Uyo Urban has gone through a tremendous development in the past 24 years. Footpath has been developed into motorable roads and proposed roads corridors constructed. It is however expected that the result of this study will be an instrument for decision makers in making appraisal of the current state of the road network in the study area. The map is also produced to play essential role in mail distribution services, revenue and refuse collection services, in tourism and transport industries as well as in policing for combating crime and in the effective surveillance of the area.

Again, studies have shown that the use of remotely sensed image with GIS tools has yielded good results in the past and with the use of very high resolution satellite image such as GeoEye-1, the result is splendid. From the result of the study, it is recommended that:

- GeoEye-1 data which is currently the highest resolution satellite image be used for map production as this satellite data are usually radiometrically corrected and geo-rectified and also good for cartographic applications and mapping.
- Provision should also be made for the periodic revision of the street map as well as the production of the street map of major towns in the state.
- It is expected that the street map would play vital roles in the named areas and as such individuals, researchers, tourists, investors as well as public and

private establishments should take advantage of the map by accessing it.

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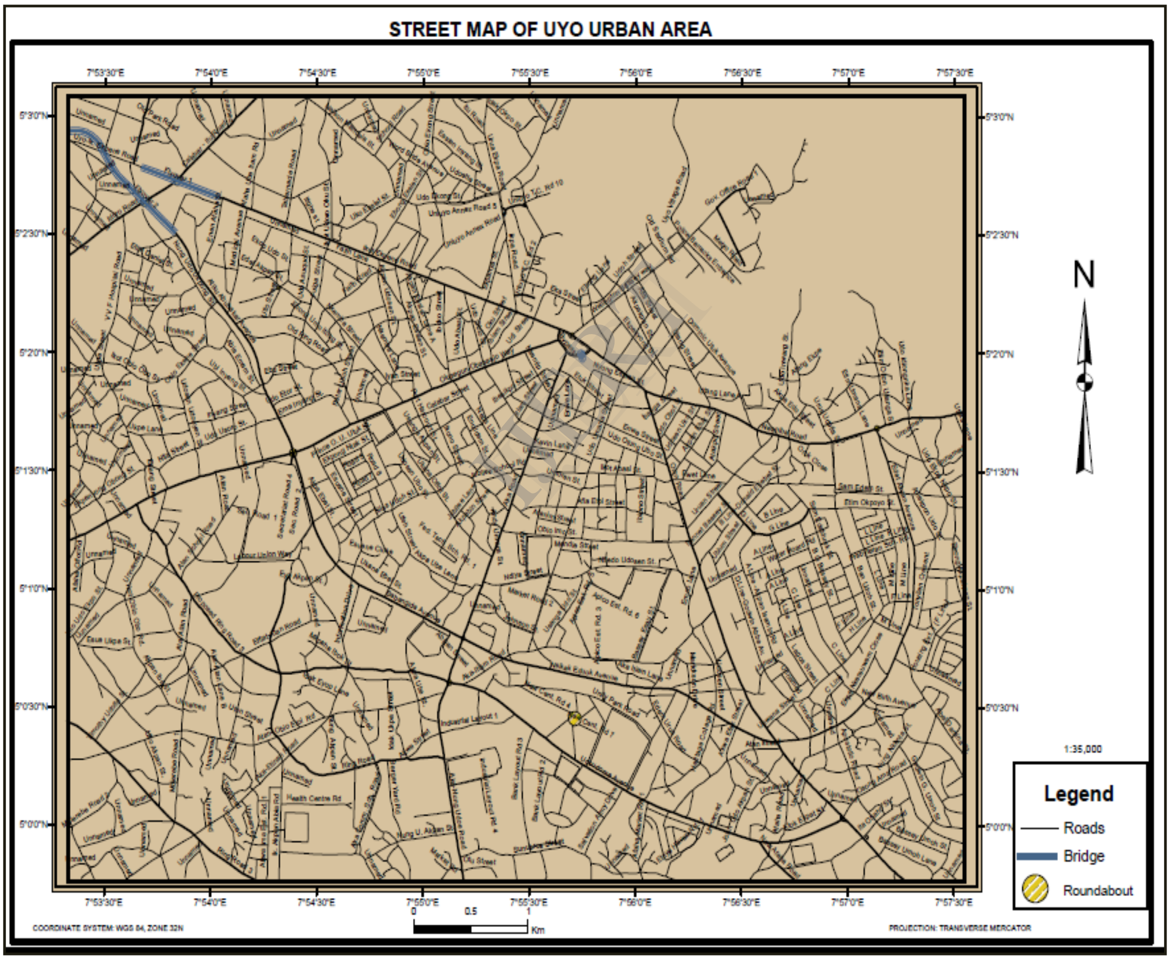


Fig. 10. Revised Street Map of Uyo Urban Area