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Geospatial Information System Based Fibre Optic Cable Infrastructure Management Database for Nairobi West District-Kenya

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Abstract

The high uptake of Fibre Optic Cable (FOC) communication in the developing countries has attracted more and more players and has become one of the critical infrastructures upon which countries rides on for prosperity. In Kenya it forms one of the economic pillars towards the achievement of vision 2030. FOC are laid on the road reserves amongst others but has come with its fare share of challenges as companies sought to connect consumers in the last mile. These includes fixed and controlled road reserves widths, lack of a geo-spatially referenced FOC database, inadequate Computer Aided Design (CAD) routes comparison and verification before approval for digging and ducting is done.

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This research paper describes how the prototype Geospatial Information System (GIS) based FOC infrastructure management database can effectively be used as an alternative tool on data management, integration, mapping, FOC planning designing and verification as opposed to the current hard copy CAD based FOC route design and planning system. The database was created in Postgres and accessibility enabled through phpPgAdmin and a web portal to standardize new route designs and their printout. The research revealed that currently there does not exist any relational database in the sector therefore, the need to develop a centralized database that is used to compare and verify the route designs before permit for excavation and laying down new FOC lines is done. Analysis of current FOC infrastructure revealed areas where up to four companies designed their FOC along the same routes with the same cable laying down specification and highest level of FOC destruction reported along them. The Nairobi City County Government (NCCG) can adopt and maintain the prototype centralized GIS based FOC database created from the study and construct a leased infrastructure through which the CSPs could pass their duct in future.

Keywords: Fibre Optic Cable; Geospatial Information System; Spatial GIS database; Critical services.

1. Introduction

The ever increasing need for people to interact globally and on daily basis over time has been made possible through cable air waves, laid down broadband networks or the overhead Fibre Optic Cables (FOC) according to [1,8]. This is realized through concerted efforts by governments and other private CSP who have taken the initiative of lying down broadband cables for ease of interconnectivity and especially by use of FOC infrastructures. Kenya has not been left out in this interconnectivity as many CSP have been licensed in line with Vision 2030 under the social pillar that gives infrastructure in telecommunication as a key pillar to stimulate economic growth. This has not come without challenges due to the fact that road reserves also holds other critical utilities like Sewer lines, Electricity lines, storm water drainage, piped water ways and pedestrian walking lane that determines which side and extent of the road reserves remains for digging and trenching for the FOC. Due to lack of a comprehensive management program in the management of road reserves, FOC that were initially underground today lay bare in piles after uprooting or termination. This can be resolved by the development of a GIS based database for the FOC route designs prepared by the various CSP.

According to [1] GIS is seen as a powerful set of tools for collecting, storing, retrieval at will, transforming and displaying spatially referenced data from the real world that is geared toward data integration and map production. GIS has been used to create and manage spatially referenced data for maintenance of a water based database [4]. It has also been used by [2] to inform the management to come up with informed decisions on the actual location of a client and even in developing a GIS based tool for the management of spatially referenced data for various fields [6]. A comprehensive GIS based database for the FOC infrastructure leads to a centralized management of the established and future location design and placement of FOC on the road reserves to the benefit of all players in the FOC sector. The foundation for these thought concur with the philosophy of access to information at any time, in any place and in any way which were articulated by [3].

The planning for proper utilization of road reserve is critical due to the many players in the provision of these different services where currently the regulators receives hard copy CAD of the FOC designs from the CSPs and files them in hardcopy analogue filing system. Designs comparison and verification is not feasible and also can be tedious and time consuming. This has made it very difficult to ascertain what each of the CSP has done on the various road reserves within Nairobi West district. It is further complicated by the fact that new designs do not take into consideration previous planning done along the same routes but also covers very small areas with the aim of acquisition of digging and trenching permits from the NCCG. Verification of these designs can only be done through site visit and the resultant paper work produced from this process is enormous. A GIS based database system overcomes the above through its spatial capability afforded by the computer processors, graphical visual output of the data either onscreen or output in a hard copy without necessity for site visit [5].

A centralized GIS based database that holds all the FOCs from all players enables creation of a centralized/distributed database system that can be used to detect areas where FOC can be uprooted from the new designs, planning for digging a new standardized routes easily, faster and in a timely manner while preserving current investments. The FOC output maps can be widely used for various mapping and surface analysis by different organizations that uses the same area of the road reserve rendering thorough route mapping, analysis, maintenance and management possible.

1.1 The objectives

The objective of the study was to develop a prototype GIS based Fibre Optic Cable infrastructure management database for the existing infrastructure for Nairobi West District. To realize this the following specific objectives were identified; to gather data and understand the status, operations and interaction of players in the FOC sector, to create a spatial GIS based database for the Fibre Optic Cable Infrastructure and to create database accessibility, querying and standardized FOC designs output.

1.2 The study area

The study area selected for purposes of this research was Nairobi West District in NCCG and covers Lavington, Kileleshwa, Kilimani, Parklands and Westlands shopping centre. It lies between 9868492N, 254177E and 9856952N, 257467E in the north south direction and covers approximately 100.35 KM^2. The study area is home to residential middle and upper income class of the community with large houses, bungalows and several existing and upcoming modern apartments. Majority of these houses and apartments use has been converted to commercial purpose that holds office blocks for those running away for the traffic jams experienced in Nairobi Central Business District (CBD) making it a major pull for internet connectivity for personal use and office work. Its' proximity to the CBD as well as good roads interconnectivity with some of the major roads like Waiyaki way, Forest road, Limuru road, James Gichuru, Dennis Pritt and Kenyatta Avenue has pulled high end business population with internet connectivity needs to the area. Westlands district is a major pull for FOC interconnections companies whereby nearly all the internet CSP have a considerable number of customers linked to their network in this vicinity (Figure 1). The area under consideration is also expansive and majority of feeder roads to these parcels are 9M wide. The construction layout of these road reserves allows for road construction at 5M and 2M on each shoulder of the road for the pedestrian walk while the other side holds sewer line and other infrastructures.

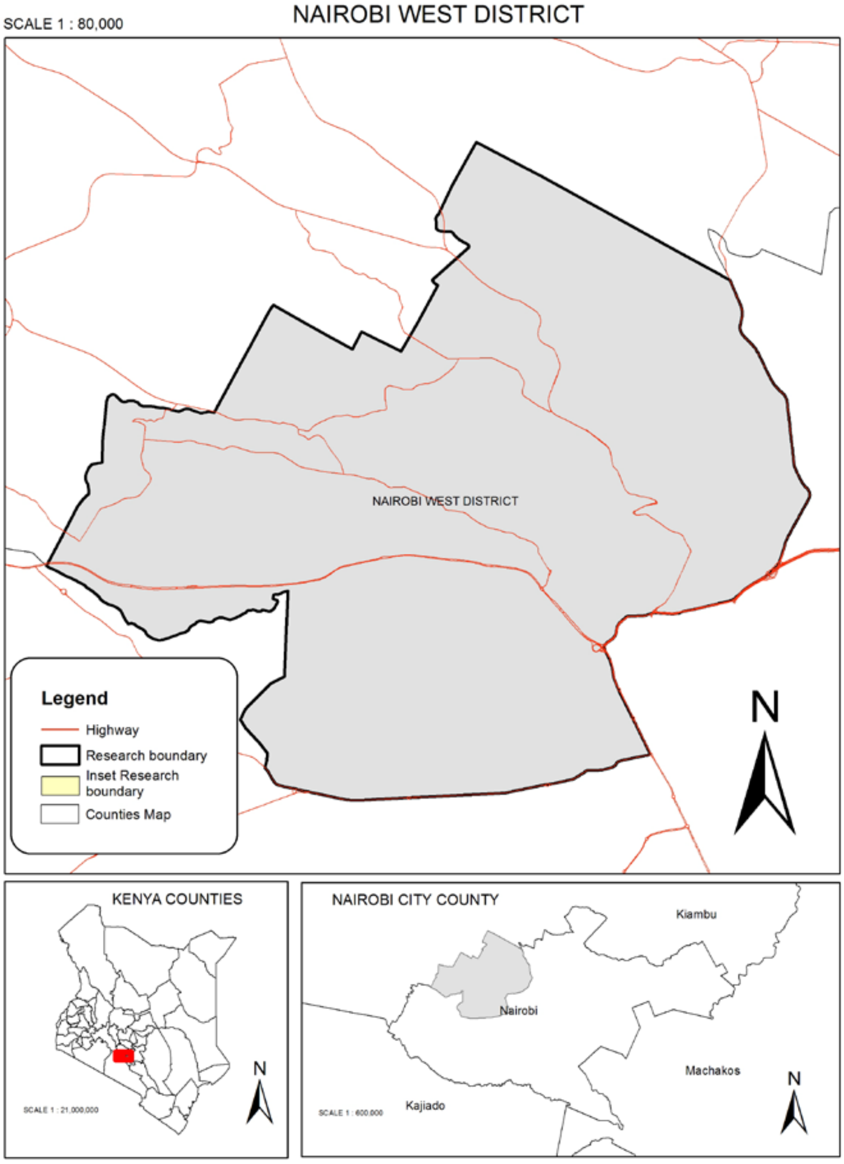

Figure 1: Nairobi West District

1.3 Fibre optic cable links

According to the Communication Authority of Kenya (CAK) regulations, FOC are supposed to be laid 2m from the edge of the road reserves, 1.5M deep and any new design for laying another FOC on the same route must me at least 1M away from the previous path. The CAK as a regulator controls and supervises installation of boosters that are fixed on building or whose height can be hazardous for those using the Kenyan airspace. Road reserves are under the custody of NCCG, other government departments and road authorities whose land the FOC will be passed through. CSP who wants to do a single FOC may need to requests for permit to use the road reserves from various departments that controls different roads or in whose land the FOC in question will traverse through. This makes the acquisition of digging, trenching and ducting process for the FOC a very lengthy one yet not homogeneous. The routes upon which these structures are done are informed of two issues which are customer location or future business prospective. Due to the fact that customers do not show up at the same time, then FOC designs, digging and ducting of new routes becomes a frequent occurrence.

2. Materials and method

The quantity of data required for this exercise was enormous and it included the roads network data got from Kenya National Highways Authority and Kenya Urban Roads Authority, orthophotomaps and topographical maps from Survey of Kenya. The FOC layout CAD design maps from the different CSP, the NCCG city engineer's offices, Communication Authority of Kenya (CAK) and other stakeholders in the sector and scanned at 300dpi (dots per inch). Attribute data and other aspatial data was collected using questionnaires and oral interviews administered to the stakeholders, control points taken in the field and the Kenya Counties map, place names were from the Independent Electoral and Boundaries Commission and keyed into the database through postgres SQL. Data collection method adopted for this research involved field study through field study, oral interviews and expert questionnaires subjected only to the personnel in the industry who are in the management, planning, design, maintenance, FOC interconnection personnel's and sales departments/section in the ICT industry.

Other secondary data collected from the CSP included current FOC infrastructure maintenance costs and schedules, interconnection designs and tertiary data held by other stakeholders that was relevant to the creation of the prototype database for the case study. It proved necessary to establish the best datum to be adopted for the case study upon which all the above data after scanning was projected to UTM Arc 1960 Zone 37 South to create a spatial reference frame for the project. Vector data was extracted using onscreen digitization with a lot of keenness on details and road widths which informed web server configuration.

2.1 Method

The development of the GIS based FOC infrastructure management database involved collection of both spatial and aspatial data both from the CSP and key stakeholders in the ICT industry. The research was implemented four major steps which included project planning and data gathering, processing, analysis and presentation of the information to the management to aid in decision making (Figure 2). The planning process involved tasks necessary in understanding the FOC infrastructure of the ICT sector and data evaluation and gathering and later on keyed in the database created.

The researcher was to carry out oral interviews and administer questionnaires to the experts and other stakeholders in the ICT industry to gather relevant and useful data concerning the FOC industry and database specification. Investments and losses incurred due to vandalism and poor road reserves management was necessary that formed the attribute data for the database to enable closing up of the loop holes in the interaction of the various players which informed the decision making mechanisms based on the database. The researcher gathered critical areas of these organization in which adoption of GIS based FOC technology could be employed to guide infrastructure designs and their management.

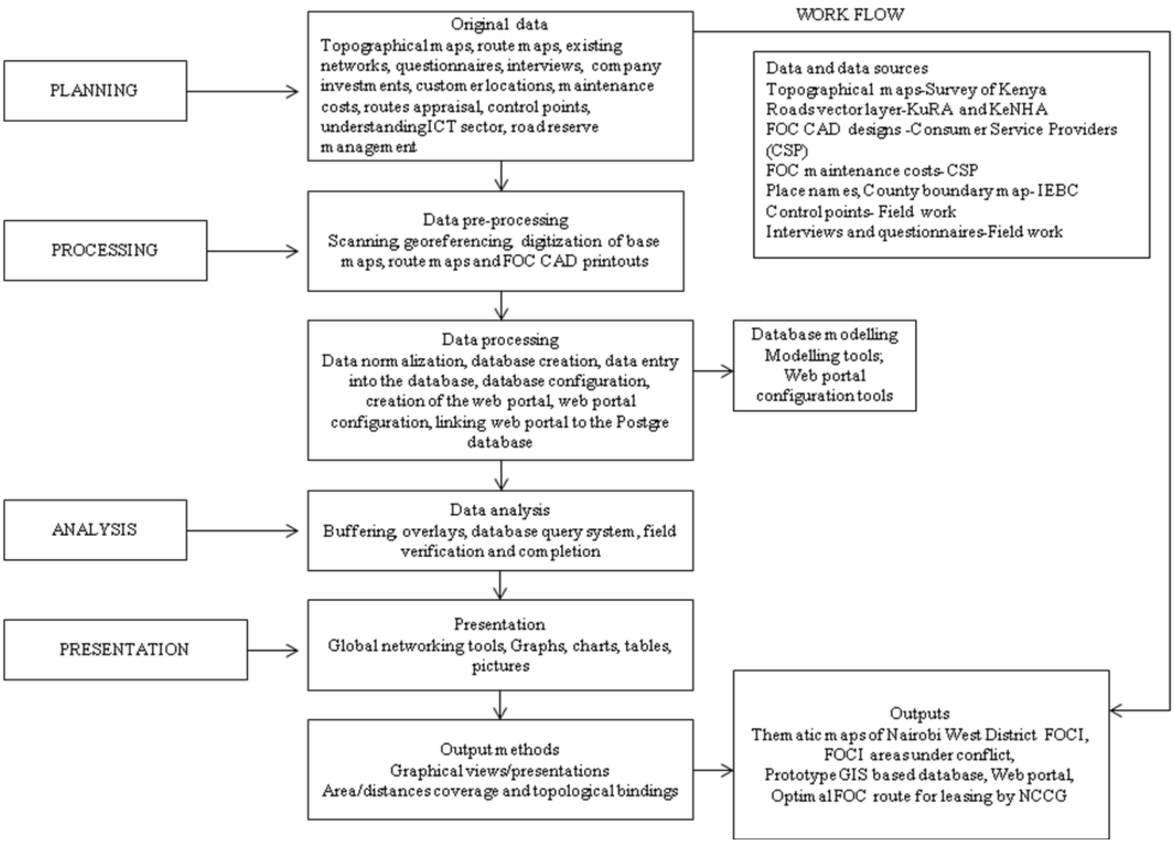

Figure 2: research methodology

The ICT industry in Kenya is regulated under two main levels. The first is the regulator who is in charge of licensing the firms for operation in the ICT sector in the country which lies with the CAK and also regulation with regard to the use to which the road reserves are put. The NCCG is the custodian of the road reserves in the city and regulates digging, ducting and trenching for laying down FOCs (Figure 3). Where the FOC has to cross a road the permit has to be applied to the respective authority that manages that road class.

Under Kenya Information and Communication (Amendment) Act 2013 the regulating authority controls how the various CSP use their air and cable waves and well as tariffs application between and amongst the various players in the market.

The issue of where and how these CSP lay down their FOC is left at the control of the individual CSP and the circumstances in the field to guide them. The custody of 90% road reserves upon which the CSP are to lay down their infrastructures is solely under the care of the NCCG. Permission is also sought for land under the Kenya

Railways, gazetted forests to the Kenya Forest Service and the Kenya pipeline way leaves. As a result any single operation of extension of the FOC could see the CSP seek several permits and pay levies to various government departments and parastatals so as to serve a single client (Figure 4).

The operation of digging and ducting the FOC infrastructures routes is highly controlled since land in Kenya is owned in a democratic manner. The road reserves are managed by difference bodies which control the different road categories. This makes the acquisition of digging, trenching and ducting process for the FOC a very lengthy one.

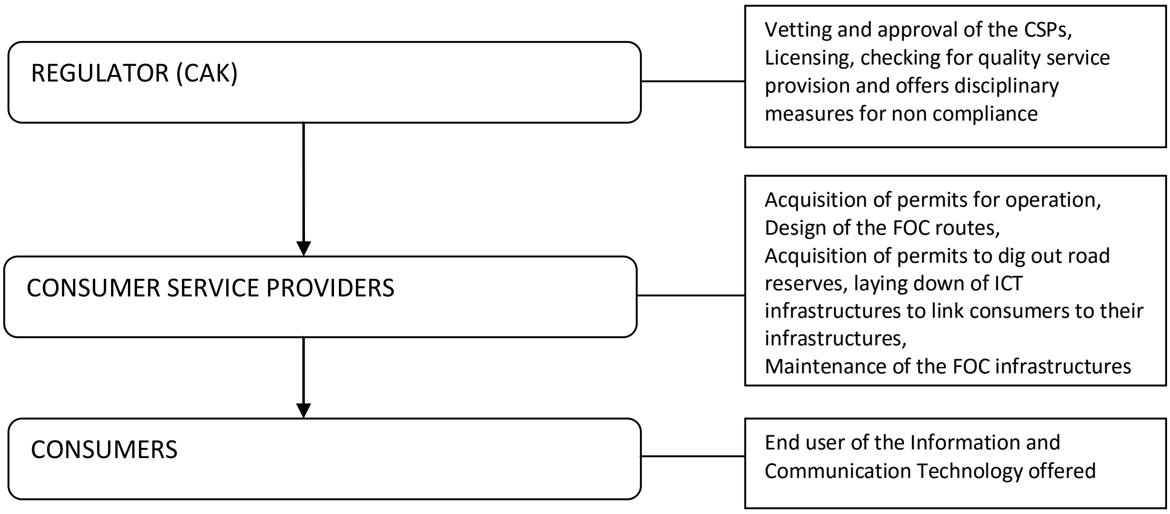

Figure 3: regulators in the ICT sector

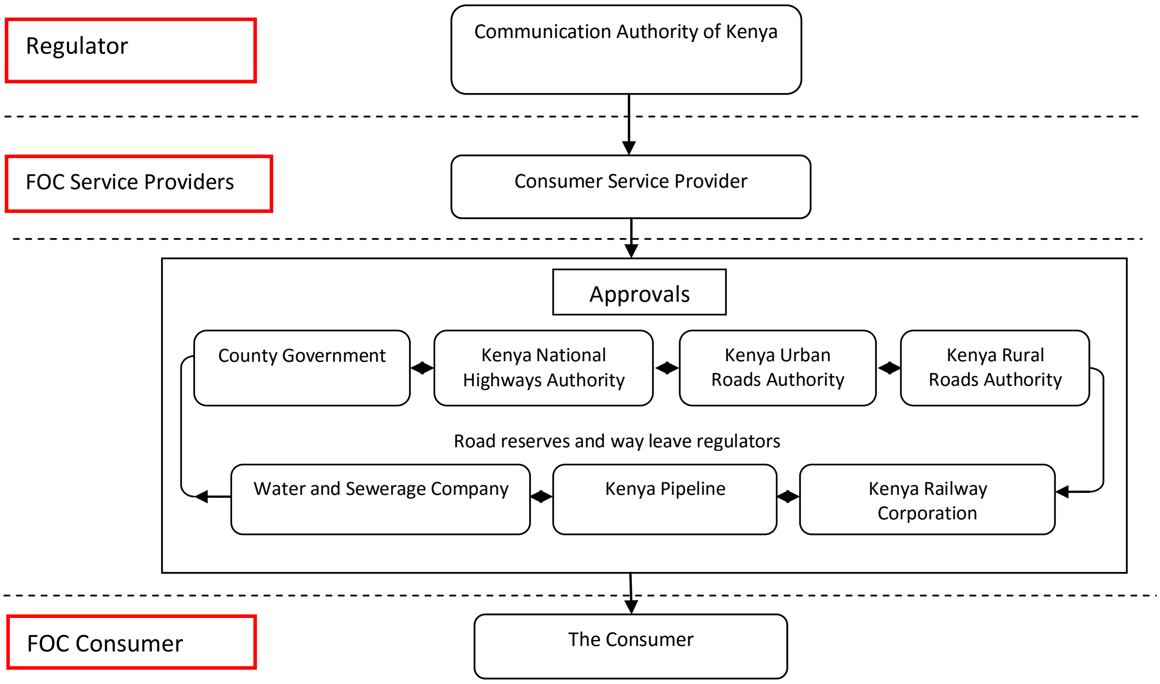

Figure 4: sectors controlling road reserves

The CAK also comes in as a regulator for masks that are fixed on building or whose height can be hazardous for those using the Kenyan airspace therefore, a CSP who is doing a single FOC can end up requesting for several permit from various department that controls different roads or in whose land the FOC will traverse through.

The routes upon which these structures are done are informed of two issues which are customer location or future business prospective. Due to the fact that customers do not show up at the same time, then digging and ducting of new routes becomes a frequent occurrence. The level of permits that each company needs to submit for issuance is also based on the needs at hand.

The second step was processing, in which data that was collected from the CSPs in CAD formats and other hard copies was scanned, georeferenced and projected to UTM Arc 1960 Zone 37 South datum in preparation for vector data extraction using onscreen digitization. The available roads vector layers were also projected to the same datum to ensure spatial data compatibility in the database. The data was normalized in preparation for its entry into the database which also involved GIS database creation where database modeling was necessary. Data abstraction levels were establishment in proportional to the map objects for visual representation and output of the final maps. Both spatial and aspatial data was then entered into the database. A geodatabase for the shapefiles was initially created in ArcGIS desktop in which datasets were grouped with regard feature classes of the CSPs name and then imported into PostGIS relational database using SPIT (Shapefile to PostGIS Import Tool) which has capability to handle and manipulate large amount of spatially referenced data. Other attribute data collected during the oral interviews and the questionnaires was keyed into the Postgres database using PostgreSQL in a structured manner that could allow analysis, querying and output of the results.

The database content required a dotmap file which required the database to be imported into QGIS environment where dotmap files could be created for operation and configuration for use in the web server. PostgreSQL and PostGIS software were used by the researcher in the design and creation of the spatial database for this project. This enhanced data cleaning, database configuration and the development of the prototype GIS based database which is more user friendly, lower in cost during the design and maintenance phases than commercially designed model. To ensure database accessibility by all the stakeholders in the industry, the web server was configured so that it could read the PostgGIS based database. This was made possible by configuration of the mapbook and the dotmap files which gives the scale, spatial features extents, the zoon levels, colour and the address to the location of the host sever through an IP address to the localhost, password and user name to be used to portray these files on the Bitnami webserver under ms4w geomoose open source programme. These files act as the link to the postgres database and the configured web page for access and interoperability. The web portal was customized to read Westlands FOCI Database as the database holder.

Data analysis comes in handy after the database is created and cleaned. It was achieved through accurate examination of the information derived from the database through buffering the routes for ease of identification and determination of areas under conflict. Overlays and database query to determine where each and every route passes for determination of the best placement of optimal infrastructure routes by the regulators before the database is released for public consumption. This formed the major aspect of the research and was done using GIS spatial analysis tools such as buffering, overlay, proximity operations and database query to produce well thought out answers to this huge problem that faces our infrastructure development and utilization of road reserves. The database interoperability was realized by posting the data in a web portal through which other stakeholders in the ICT industry could access and read from the same database hence establishing a common platform and standards in the ICT operations. The FOCI database is aimed at aiding decision makers in proper management and use of the road reserves. This could only holds with an active user friendly interface that can be used to query and output the results also engage the database in an editing mode at real time. Hence system was to hold a display, query defined feature results that are interactive and achievable.

Data presentation and output was realized through publishing data to the web portal hosted by Bitnami web server in which the data that is hosted by the regulator is accessed via an URL linking the database and the host server IP address. The soft copy output of the single interoperable database for the FOC infrastructure was developed and tested for operation through the web portal under the name Westlands FOCI Database.

3. Results and Discussions

A prototype GIS based FOC infrastructure management database for Westlands District was developed. The database contained information about the currently laid down FOC infrastructure network from 80% of the CSPs in the study area, road network, place names and river layers. This was attributed to many CAD plans that have been submitted to the NCCG for approval over time yet covering very small portions with regard to extents making pile of files and plans of the disjointed sheets is enormous. The database developed was capable of handling spatially referenced data therefore, affording the capability to tell the use, location and number of FOC passed through any part of the road reserves at a glance. The results of the questionnaires on how the CSP use their FOC indicated that 80% of the companies outsource the design part of their FOC routes to private companies while 20% do their FOC designs both in house and outsource for effective utilization of their manpower but they outsourced digging, trenching and lying of their FOC to private companies with their technical staff supervising the work. 18.18% of the companies lease their extra FOC ducts while 81.81% installed the FOC for their own consumption. 0.01% responded to having a mixed use of the laid down FOC infrastructures.

The estimated maintenance cost from damaged, uprooted or terminated cable lines in the industry based on the contractual arrangements and estimated at 0.05% of the capital cost of installation was highest with ICT authority leading with 150,000 US Dollars per month and the lowest cost being 20,000 US Dollars per month on an average basis. The estimated level of investment in the ICT industry covering the country at large was rated as from USD 30 - 72.5 Million from 2007. The companies that currently use a relational database in their management of the FOC infrastructure was 0%, CAD soft copy database was 84.64% while the use GIS based database in the industry was found to be 0.07%. Those companies that were found to be having a mixture of CAD system and GIS based MapInfo database were found to be 15.32%. This established the need of establishing a GIS based database in the operation of the ICT sector. The few hard copy databases were found to be instituted for in house use to guide in the connection of new customers and aid in the application for permit from the NCCG in a CAD system. The CAD system was an effective way for doing quick print out for application of digging and trenching diagram for various regulating bodies but were not standardized.

On the analysis of the individual parts of the road reserves the GIS based database revealed through generation of a 2M buffer that there were some routes that hold up to four (4) different FOC designs on the same side of the road reserves with the same digging and ducting specifications (Figure 5 below). They also crossed each other five times in a span of 500M. During field verification these were some of the area where a lot of FOC cases of uprooting, termination and general damages were the highest.

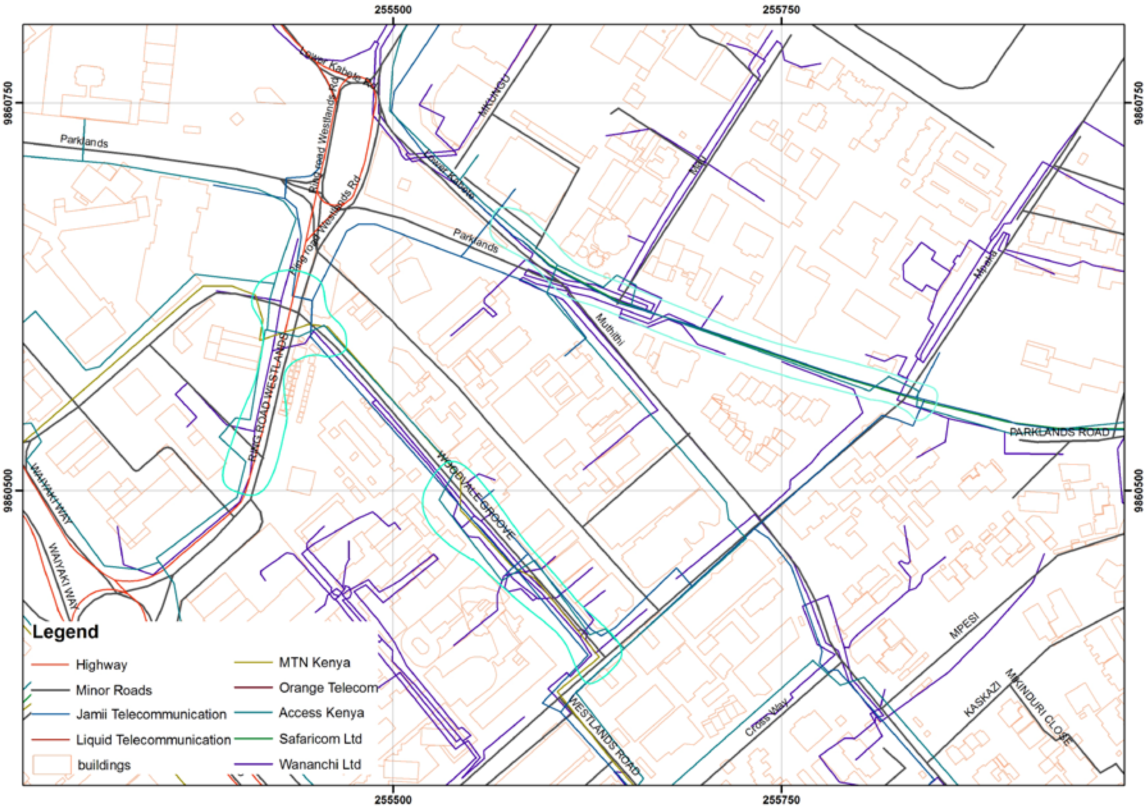

Figure 5: examples of FOC areas under conflict

Before the GIS system was developed it was very difficult to tell where these actual paths that have been used and the level of conflict likely to be experienced by approving new designs based on the CAD maps that were being done for approval purposes. Comparison of the different design from the CSP during the approval process was now possible and the regulator could tell where more supervision was necessary at both the approval and design execution stages within the database system. The GIS based database also affords planning and output standards in that any new designs could be done on the system and out becomes a proof of planning designs based on the same basemap.

Westlands FOCI database with the same user name and password as the database in PostgreSQL was interoperable by linking it to phpPgAdmin. The link was made possible by starting the apache web server license. They were running on the same port with postgres license it port was changed. The interoperability was realized through customization of a new icon on the web.

4. Conclusion

A prototype GIS based FOC infrastructure management database for the case study was developed. The database carried both spatial and aspatial information related to the FOC infrastructure designs. They included the existing FOC CAD maps, investments and cost of maintenance and place names. The GIS based FOC database developed retrieves the spatially referenced information from the database for the regulator as well as other authorized stakeholders from a remote location through an enabled IP address.

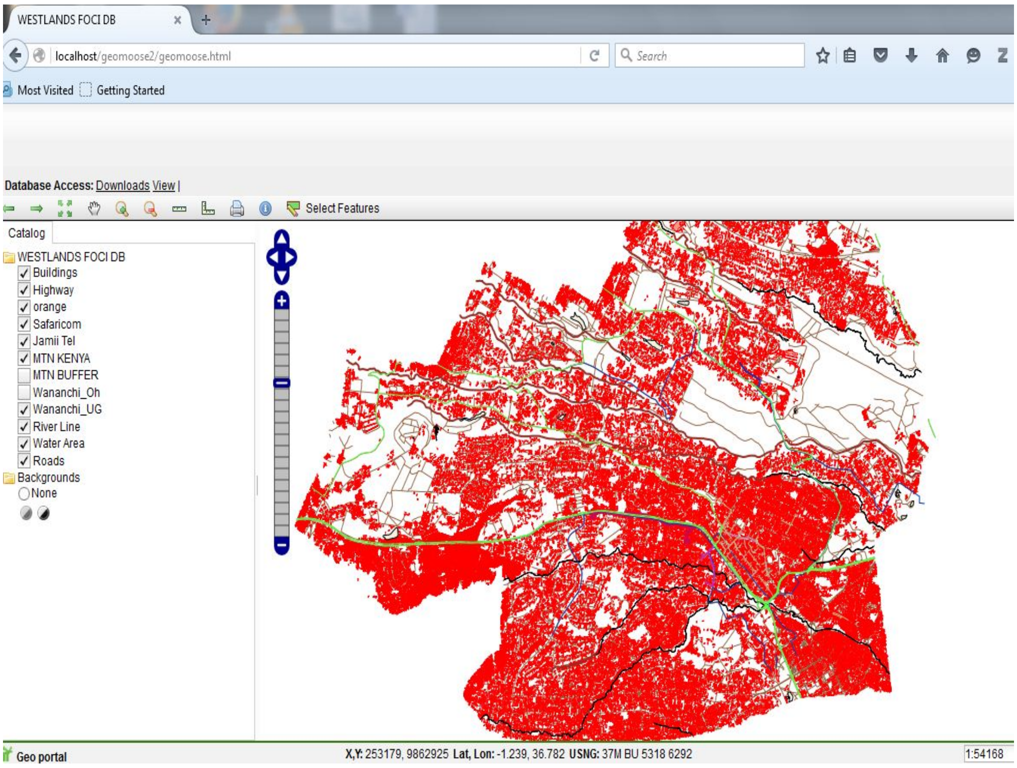

Figure 6: accessing the web portal

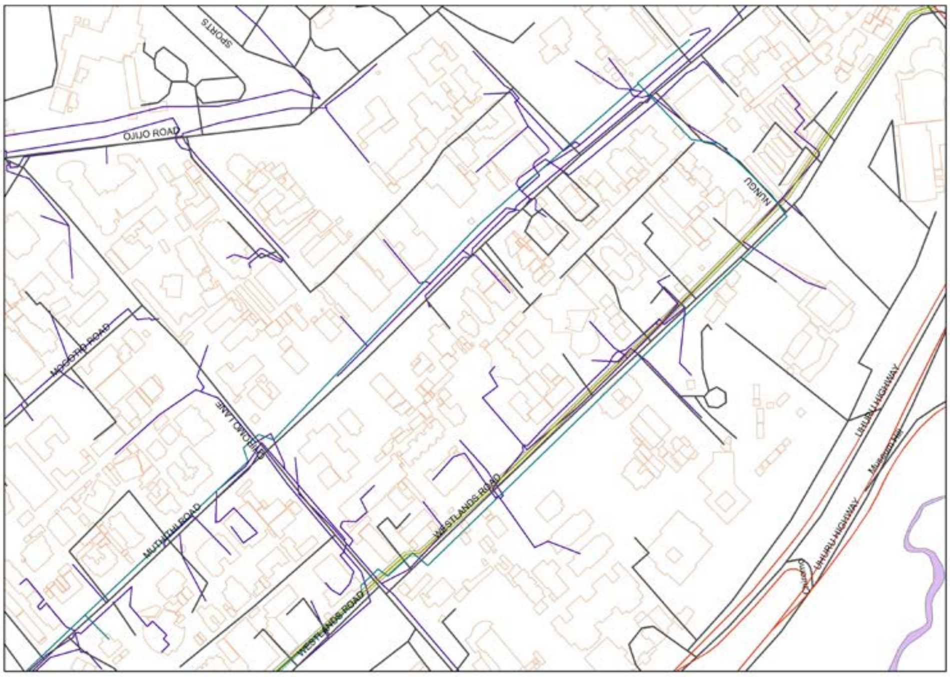

Figure 7: FOC optimal lasing infrastructure along Westlands road

The system performs analysis, statistic works and updates of the database giviging the regulator and the CSP desired results in a timely effective and efficient way. The uptake of the database system can result in efficient management of road reserves and standardized designs, digging and output CAD FOC routes. The study has also demonstrated the effectiveness of using GIS as a tool in the management of FOC. From the study NCCG has not effectively managed the use to which the road reserve has been put to and it is therefore recommended that they develop a centralized leased piping infrastructure along the road reserves through which the FOC CSP should be using to pass through their FOC s. The research was only carried out in one district in NCCG and its adoption duplicated in other districts and the country at large.

Acknowledgement

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