University of Nairobi

School of Engineering

Development of a Web Based Geo-Visualization Tool for Secondary Schools in Nairobi County

By

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F56/69322/2011

A Project report submitted in partial fulfilment of the requirements for the Degree of Master of Science in GIS, in the Department of Geospatial Engineering and Space Technology of the University of Nairobi

May 2013

Declaration

I, David Muthami hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

David Muthami	……………..…………	…………..
Name of student	**Signature**	**Date**

This project has been submitted for examination with my approval as university supervisor.

…………………………..	……………….	…………………
Name of supervisor	**Signature**	**Date**

Abstract

Societal need for information products has led governments the world over to adopt policies of open government where they promote accountability and transparency. In Kenya, the government has availed a platform called the Kenya Open Data Initiative (KODI) that promotes interagency collaboration between government bodies as well as engaging its citizens. In the education sector massive datasets on educational institutions have been availed in KODI and indications are that the government in a bid to conform to open government trends is willing to continuously provide current, complete, consistent and credible data and information to the public. Currently, the Government of Kenya is utilizing KODI and is looking at setting up a National Spatial Data Infrastructure (NSDI).

This research involved the development of a solution that seeks to make the provided datasets on secondary schools in Kenya intelligent. It seeks to avail useful information products to the citizens of Nairobi County about secondary schools in the county. For, example, the solution offers parents seeking Form 1 places every year an easy and user friendly tool to access performance information about secondary schools in the county as well as valuable information on their distribution, enrolment, teachers etc.

The web based geo-visualization tool for secondary schools in Nairobi county solution provides a way in which a rich interactive web mapping application can be embedded in the KODI platform and provide useful information to stakeholders and citizens without the need to keep on pushing data from Ministry of Education (MOE) for upload in KODI. The backend enterprise geodatabase offers a solution for update of secondary school data to MOE officials without need for duplication thus maintaining currency of the data.

The solution achieved the project objectives of developing a spatial database of secondary schools in Nairobi County and enables the use of the database by the community through an online geo-visualization tool. Furthermore, this solution is in line with the lines of thought of GIS as a platform supporting Gov. 2.0 with a view to build mapping applications that engage citizens and enhance transparency and accountability by governments.

We propose the use of web mapping applications e.g. the web based geo-visualization tool in secondary schools in Nairobi County - for delivery of information about our educational institutions for all the 47 counties in Kenya. A research in the utilization of the emerging mobile technologies such as smartphones and tablets needs to be conducted.

Dedication

This project is dedicated to my wife, Loise, who has been a pillar of strength in my endeavour to pursue a Master's degree in GIS. Additionally, the project is dedicated to my parents for their support and encouragement in my pursuit of further studies in the field of GIS.

Acknowledgements

First and foremost, I thank the Almighty God for giving me life and the means to come this far in the realization of my dream to attain a Master’s Degree in GIS.

I wish to thank my supervisor Prof. G.C Mulaku for his support, assistance and guidance offered at all stages throughout the course of preparing for and conducting my project research. He has always been there to offer technical support, provide ideas, pace the project with great finesse and skill.

I also wish to acknowledge my colleague Accadius Sabwa for particularly providing technical support with knowledge domain expertise in the field of client side scripting using the now immensely popular JavaScript platform and asynchronous messaging. Particularly, he proved very helpful in solving cryptic problems relating to JavaScript frameworks such as JQuery as well as other important programming tasks.

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ABBREVIATIONS

AGOL	ArcGIS Online
API	Application Programming Interface
BI	Business Intelligence
CSV	Comma Separated Values
CSW	Catalog Service for the Web
DBMS	Database Management System
DDL	Data Definition Language
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite System
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
IEBC	Independent Electoral and Boundaries Commission
JSON	Java Script Object Notation
KCPE	Kenya Certificate of Primary Education
KCSE	Kenya Certificate of Secondary Education
KODI	Kenya Open Data Initiative
KML	Keyhole Mark-up Language
LINODE	Linux Node
MDG	Millennium Development Goals
MOE	Ministry of Education
NGO	Non-Governmental Organization
NSDI	National Spatial Data Infrastructure
OSM	OpenStreetMap
PAAS	Platform As A Service
PDA	Personal Digital Assistant
PDA	Personal Digital Assistant
PHP	HyperText Preprocessor
REST	Representation State Transfer
RSS	Really Simple Syndication
SOAP	Simple Object Access Protocol
SOK	Survey of Kenya
SQL	Structured Query Language
SRID	Spatial References Identifier

UNESCO	United Nations Education, Scientific and Cultural Organization
URL	Uniform Resource Locator
VF	Vestergaard Frandsen SA
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Mapping Service
WPS	Web Publishing Service
XML	Extensible Mark-up Language

1. Introduction

1.1. Background

Education has been defined as the process through which knowledge and skills are imparted for the purpose of integrating an individual in a given community, or radically changing the cultural ways of a given society. At the individual level, education begins at birth and ultimately ends at death. The UNESCO international standard classification of education defines education as comprising organized and sustained communication designed to bring about learning [1].

1.1.1. The Education Sector in African Countries

Africa has laid emphasis on the significance of education. For instance, In Nigeria the National Policy on Education (NPE) was adopted by the Federal Government in 1981. The NPE later spearheaded the abandonment of the British System in favour of the American 6-3-3-4 system that is six years of primary education, three years of junior high school, three years of secondary, and four of university. Another country of great interest is Egypt which in terms of population is one of the highest populated countries in Africa that has made significant success in the education sector compared to other countries in Africa. In Egypt, elementary education is free and compulsory coupled with high enrolment in secondary and university second only to Nigeria in Africa [2].

In Eastern Africa, millions are denied the chance to go to school despite progress by various governments. Despite huge investments in the education sector by government within the region, challenges in the quality of education offered indicate that many once in school are not learning the basics. This is partly due to the fact that teachers lack the necessary subject knowledge [2].

1.1.2. The Education Sector in Kenya

In Kenya, as in any other country, this sustained communication is organized and managed through a coherent system put in place by the Government. The education system in Kenya is modelled on the 8-4-4 System of Education which was commissioned in 1981 by a Presidential Working Party tasked to examine curriculum reform of the entire education system in the country. The 8-4-4 system was launched in January 1985, and was designed to provide eight years of primary education, four years of secondary, and four years of university education.

Funding of the education sector in Kenya is primarily conducted by the Government of Kenya and takes about 30% of the government's annual expenditure accounting for the largest share of the annual budget [3].

Secondary school education in Kenya begins after the successful completion of primary education marked by the Kenya Certificate of Primary Education (KCPE) examination. The time period spent in secondary schools is 4 years upon which a student is allowed to sit for the Kenya Certificate of Secondary (KCSE) Education. The average grade attained is based on performance in seven subjects and is the basis for university admission coupled with performance in particular subjects relevant to the degree course of interest. The large increase in primary school enrolment due to the Free Primary School program introduced by the Government of Kenya has had a ripple effect where the number of students seeking secondary school education has grown significantly [3].

1.1.3. GIS in the Education Sector

Geographic information systems (GIS) technology provides important tools that help educators, students, institutions and the community answer questions that are spatial in nature. The general trend is that more and more schools are including GIS in their curricula to help students gain valuable knowledge and skills with which to face local and global challenges. School administrators are turning to GIS to help with facilities management, vehicle routing, boundary mapping, safety and preparedness and more [4].

The web is rapidly changing the face of GIS. Web services and new tools are making it easier to develop geospatial applications for the web, share and collaborate geospatial content on the web. In the context of the education sector, web GIS has enabled development of web applications, web maps and other tools for the education sector. Additionally, Web GIS education focusing on Web GIS technologies has resulted in good web GIS professionals that are addressing real-world challenges.

1.2. Problem Statement

The Government of Kenya has availed information about education institutions to the wider public. Part of the information contains information about secondary schools whose data is dated 2007[5]. The information provided is in tabular format as a list of GIS coded schools with descriptive information on location and non-spatial data such as enrolment, teachers, pupils and exam results.

The challenge with the furnished data is that it requires above average skills in data processing to integrate the various datasets and map it out in an online environment. There is a need for a solution that offers improved data management and visualization that focus on the map.

Additionally, the availed information needs to be refined in a format that the citizens of Kenya and specifically the residents of Nairobi County can readily consume and utilize. For instance, if the community wants to find schools nearby based on location and parameters such as performance, gender, school sponsor etc. they would need to seek for the services of professionals to turn the available data to information needed. Therefore, an easy to use web based geo-visualization tool is required for the community to easily access information products about secondary schools in Kenya.

Updating data is currently an issue with the data availed to Kenya Open Data Initiative (KODI) from the Ministry of Education (MOE). Currently, spatial information is current up to the year 2007 while the series of KCSE exam results are available starting from the year 2007 to the year 2010 [5]. There is need to provide a system that utilizes DBMS technology that offers user and permission management coupled with capabilities for adding and updating secondary schools data efficiently and effectively for MOE.

Access to quality data from MOE in KODI is still a great challenge. Stakeholders such as donors, researchers, scientists and non-governmental organizations require access to quality data for further analysis and policy formulation. In this context, quality data implies, accurate, complete, consistent and credible implying that which emanates from authoritative sources. This web based tool will offer readily access to quality data to stakeholders.

1.3. Objectives

1.3.1. General Objective

The Government of Kenya has availed data on education institutions to the wider public but this requires skillsets to turn this data into quality data and information that is easily accessible and consumable by the community of users.

1.3.2. Specific Objectives

- To design and implement a spatial database of secondary schools in Nairobi county.
- To develop an online geo-visualization tool that can enable use of the database by the community of users.

1.4. Organization of the Report

The project report is organized in five chapters.The first chapter provides background information on the education system in Kenya as well as in selected countries in Africa namely Nigeria and Egypt. It also briefly introduces the use of GIS in the education sector.

Chapter two contains literature review that dwells on the school mapping exercise carried out by the Government of Kenya, the emerging web mapping technologies and their application in the education system.

Chapter three on methodology, looks at the study area, data collection, database design, implementation,deployment and ultimately the web linkage implementation.

Chapter four looks at the results attained and the analysis of results.

Chapter five is the last chapter of the report and gives the study conclusions and recommendations.

2. Literature Review

2.1. School Mapping

School mapping consists of the building of geospatial databases of educational, demographic and socioeconomic data for educational institutions in order to support educational planning and decision making. Such databases contain data such as the geographic location of schools, the numbers of existing schools of different levels in the public and private sectors, their capacities, physical condition and facilities, enrolment and the number of teachers and their attributes. Also often included are data on related natural features and infrastructure such as rivers, roads, economic and administrative centres, medical facilities and religious facilities [6].

In Kenya, the school mapping exercise was carried out in the year 2007 with the objective of collecting data for all education institutions in Kenya and integrate them in a geodatabase. The information generated from the published database proved useful in providing information for decision makers in MOE, stakeholders, professionals and the greater public.

2.2. Web Mapping and Web GIS

The fusion of the internet, the Web and traditional disciplines has created many new ones, and Web GIS is one of the disciples. Web GIS has evolved so rapidly especially in the so called "Web 2.0" era. Web GIS has considerably changed the way geospatial information is acquired, transmitted, published, shared, and visualized. It represents a significant milestone in the history of GIS [7].

Web mapping is the process of designing, implementing, generating and delivering maps on the web. While web mapping primarily deals with technological issues, web cartography additionally studies theoretic aspects: the use of web maps, the evaluation and optimization of techniques and workflows; development of map cache, utilizing scale dependencies, symbol scaling, application of web optimized symbols, the usability of web maps, social aspects, and more. On the other hand, web GIS is similar to web mapping but with an emphasis on analysis, processing of project specific geodata and exploratory aspects [8].

Web maps contain a basemap (background data that doesn't change often and operational layers e.g. analysis results, frequently changing and live data. Basemap layers can be cached and included as a tiled map service that will ensure they draw quickly. Many web maps also contain interactive elements such as a basemap gallery that lets you switch between maps like imagery and streets, plus measure tools, pop-up windows that display attributes about a specific feature, and buttons for playing data over time if the data is time enabled. Some web maps contain a series of annotated slides, each showing a specific view into the map with associated text and graphics. These are known as presentations.

Web maps can be opened in standard web browsers, mobile devices, and desktop map viewers. They can be shared through links, social media, embedded in websites, and used to create browser-based and device-based applications. Web Maps are authored through a variety of means but the traditional method would be through the desktop. A typical work flow would be the standard author, share and use process. The author process is carried out by standard desktop GIS software such as ArcGIS for Desktop or free and open source open source such Quantum GIS. The share process is done on either enterprise systems or cloud based platforms that avail the resource into the online platform. [9] An alternative workflow but based on the web would be to create a data store in GeoServer and or PostGIS, style layers, edit layers and/or cache layers, publish a geospatial service and create and develop a customer facing application.

A special case of web maps are mobile maps, displayed on mobile computing devices, such as mobile phones, smart phones, PDAs and GNSS. If the maps on these devices are displayed by a mobile web browser or web user agent, they can be regarded as mobile web maps. If the mobile web maps also display context and location sensitive information, such as points of interest, the term Location-based service is frequently used [10].

The use of the web as a dissemination medium for maps can be regarded as a major advancement in powering GIS and opens many new opportunities, such as real-time maps, cheaper dissemination, more frequent and cheaper updates of data and software, personalized map content, distributed data sources and sharing of geographic information. It also implicates many challenges due to technical restrictions (low display resolution and limited bandwidth, in particular with mobile computing devices, many of which are physically small, and use slow wireless Internet connections), copyright and security issues, reliability issues and technical complexity. While the first web maps were primarily static, today's web maps can be fully interactive and integrate multiple media. This means that both web mapping and web cartography also have to deal with interactivity, usability and multimedia issues [10].

A first classification of web maps has been made by Kraak [10]. He distinguished static and dynamic web maps and further distinguished interactive and view only web maps. Today, there are additional possibilities regarding distributed data sources, collaborative maps and personalized maps. Examples of several categories of web maps that are widely being used currently are;

- Analytical web maps. These are maps that offer GIS analysis, either with geodata provided, or with geodata uploaded by the map user.
- Animated web maps.
- Time aware maps that show changes in the map over time by animating one of the graphical or temporal variables.
- Collaborative web maps. Maps that offer capabilities for real time updating and other exciting capabilities like web editing thereby providing much needed functionality for crowd sourced solutions [11].

2.2.1. Web 2.0 Technologies

Like all modern day technologies, acronyms appear to be the mainstay of those behind Web 2.0 technology and our ability to access geospatial data. Before considering the geographic data transmission, we examine some protocols and processes behind Web 2.0 technologies as well as the three most common acronyms that surfaced during research for this chapter. The first, XML or Extensible Markup Language, provides a language that allows structured data sharing between diverse information systems, especially sharing across the Internet. In addition, XML allows developers to define formatting tags as they deem necessary. A second acronym, Simple Object Access Protocol (i.e., SOAP), stands for an XML protocol that transfers minimal amounts of code via HTTP – the common Web transfer protocol. The third acronym, Ajax or AJAX, stands for Asynchronous Java Script and XML. AJAX is used to develop interactive and responsive Web applications, which allows a single Web page to asynchronously send and receive responses to multiple XML requests that dynamically update the page's content. AJAX is a method that allows minimal data exchange with servers and does not require the page to be completely redrawn each time a user changes their request. Developers are consistently attempting to increase the speed of delivery of Web 2.0 applications. Speed and interoperability are important in the exchange of large geospatial data sets and leads to another set of acronyms associated with GIS [12].

a) Background on Geographic Information and Web 2.0 technology

The International Standards Organization Technical Committee 211 (ISO/TC211) oversees the minute engineering and technical details of sharing Geographic Information (GI) data.

However, for the majority of developers and technicians, the Open Geospatial Consortium (OGC, formerly known as the Open GIS Consortium) works on GIS industry standards. OGC is an open source group that is attempting to design workable standards, disseminate information, and increase interoperability between all GI interest groups. The OGC has undertaken a multi-phase OGC Web Services (OWS) initiative to specify and standardize geospatial Web services and architecture that support the development of Web location based services (LBS) and geoprocessing applications. This open source group has already set standards for Open GIS Geography Markup Language (GML) for vector geographic data and numerous Web services: Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS) [8].

b) Spatial Databases

Geodata is information about geographic locations that is stored in a format that can be used with a geographic information system (GIS). Geodata can be stored in a database, geodatabase, shapefile, coverage, raster image, or even a dbf table or Microsoft Excel spreadsheet. Of great interest is the utilization of spatially enabled DBMS such as PostgreSQL coupled with PostGIS that will be the data repository of choice. [10]. Other spatially enabled databases in the domain of open source is SpatiaLite – Spatial extensions for the open source SQLite database, allowing geospatial queries, TerraLib – Provides advanced functions for GIS analysis. On the other hand, there are commercially available (COTS) DBMS that support data management of spatial content such as Oracle and Microsoft SQL Server that compete against free and open source software (FOSS) DBMS [8].

c) Service Oriented Architecture

Service-oriented architecture (SOA) is an architectural style of building business applications that utilize common loosely coupled and distributed services to support business functions. SOA has a couple of definitions regarding what it consists of, sometimes driven by big industry player’s e.g. Microsoft, Google solutions instead of a general architecture. In response to lack of standardization in the SOA space, the Organization for the Advancement of Structured Information Standards (OASIS) has recently provided a reference model for SOA that promotes industry consensus and standards on its key components [13].

SOA offers several big advantages to IT departments. IT departments are able to make the transition from an application-centric view of the world to a process centric one. IT departments now have the freedom to mash up web services from multiple locations which is described as mashing up web services to deliver true end-to-end support for business processes. IT can upgrade their enterprise applications or data centres without impacting other applications in the SOA by utilizing easier integration mechanisms such as Web services since data format is no longer a barrier.

Web services are a new breed for information sharing and collaboration. A web service is a program running on a web server and exposing programming interfaces to other programs on the web. Web services perform functions provided remotely by a web server, which can be anything from simple requests to complicated business processes. Once a Web service is deployed, other computer programs as well as other web services can discover and call the deployed service and their result are in either XML, JSON or other structured formats that computer programs can reuse. Worth noting is that web services are not synonymous to SOA but web services are important and one implementation method among many for SOA. The geospatial industry too supports and extends the use of web services evidenced through the authorship, publication, discovery and consumption of GIS web services. For instance;

- Server products such as the commercial ArcGIS Server, free and open source GeoServer can publish geospatial services hence serve maps, data and analytical models across the web.
- Geoportals for the sharing and collaboration of metadata.
- Client products on the desktop, web and mobile platforms consuming web services in their mapping applications

Web Service Standards

These standards specify the format of HTTP requests and HTTP responses and thus facilitate interoperability and ensure smooth flow of geospatial resources from different vendors across the web.

Within the broader context of Web Services, OGC founded in 1994 launched OGC Web Services (OWS) initiative which aimed at representing an evolutionary, standards-based framework that enables seamless integration of a variety of web applications e.g. online geoprocessing, location services and mainstream IT. OGC Web Services is neutral, interoperable for web-based discovery, access, integration, geo-analytics and visualization of geospatial resources. OGC standards are WMS, WFS, WCS, CSW, WPS, GeoRSS and KML standards.

d) HTML5

This is the new web standard for HTML and is quickly replacing the previous standard HTML 4.01. It is a mark-up language for presenting and structuring the content of the web.

2.3. Web Based Geo-Visualization Tools

In a GIS study that used a thin web mapping application, Chinese researchers were interested in an inexpensive and efficient means of providing spatial data about the forests of China to those who have little ability to access the information. In 2007, it was demonstrated that sustainable forest management decisions could be made using available OGC-compliant free and open source GIS programs, relatively hardware and geospatial web services. They used a scalable, four-tiered framework of client layer, web layer, application layer and a database layer. By utilizing open source software, they built a rich web mapping application that was effectively and easily queried. [12]

In the domain of natural resources, environmental issues are keenly on people's minds as disasters such as Hurricane Katrina and the 2007 wildfires in California are analysed from web browsers. For example, if someone searches on "California wildfires" in Google maps, the system calls up a series of satellite images with the fires pinpointed. Many people are using Google Earth, Microsoft Bing Maps and other "earth browsers" to examine the globe from space. These systems use XML file types known as Keyhole Markup Language (KML) that allow for three-dimensional display of geo-referenced data (i.e., X, Y, Z or latitude, longitude and orthometric height). Crowd sourced Volunteer Geographic Information Systems (VGI) are bringing people together to make decisions, provide valuable community feedback about the locations where they live and work. Social media and decision-making ability of such systems has not only increased citizen's awareness of their environment, they have also come together to discuss public health and safety. [12]

In the realm of health care, Vestergaard Frandsen SA (VF) a Europe-based international company specialising in complex emergency response and disease control products made great strides to develop disease-prevention interventions, which when implemented with VF's dedicated partners, contribute to the realisation of the United Nations Millennium Development Goals (MDGs). VF is especially interested in addressing Goals 4 (reduce child mortality), 5 (improve maternal health), and 6 (combat HIV/AIDS, Malaria and other diseases), which play a critical role in the achievement of the MDGs.

It is guided by a unique Humanitarian Entrepreneurship business model, whose "profit for a purpose" approach has turned humanitarian responsibility into its core business.

By innovating products and concepts focusing on preventable diseases like malaria, diarrhoea, HIV/AIDS and neglected tropical diseases, VF turns its commitment into action. VF innovates for the developing world, rather than developing products for wealthier regions, and then trying to adapt to those who actually need them the most. This is a large part of what separates VF from other companies working in public health.

2.3.1. Challenges

In striving to undertake the above activities, VF faced the following challenges:

- A way to present insecticide susceptibility test data for scientists, researchers and the wider public.
- A need for a user friendly approach to visualization and exploring up-to-date information on IR Mapper (IR).
- Need for up to date information on insecticide resistance for guiding the deployment of insecticide tools.
- Realise the requirement to profile and visualize resistance mechanism results
- Share & collaborate their IR research findings through an online platform that is in tandem with emerging technologies of the web/cloud and mobile.
- Query susceptibility & resistance for different malaria vector species.
- Conduct time series analysis, heat maps and other geo-analytical analysis on the insecticide resistance and susceptibility data.
- Improve functionalities and features of existing IR tool and cross platform support.

2.3.2. Solution

Esri Eastern Africa proposed a web mapping solution which currently is the customer facing solution for VF Disease Control Textiles. The web mapping solution was powered by ArcGIS Online.

ArcGIS Online for Organizations is a subscription based solution that benefits organizations by simplifying access to maps and data and by making it easy to publish and manage geographic content on the web as well as a robust hosting platform that powers and delivers the web mapping solution.

The solution was coupled with a desktop solution that conducts data management & processing and geo-analysis in readiness to publish result findings to the cloud/web platform.

In the education sector, universities and colleges have developed web mapping applications, web maps, mobile mapping application that they could use in planning and monitoring various operations within the campus and other related activities outside. The use of the afore mentioned solutions is for informative purposes on items such as;

- Development history of the university (Change analysis)
- Open space analysis for future development
- Students residential facilities
- Security and emergency services within the campuses

For instance, the Abu Dhabi Education council [17] has developed a school finder application that is enabling the community find the location of private and public schools.

3. Methodology

3.1. The Study Area

The study area is the county of Nairobi. Nairobi city (*which is Kenya's capital and largest city*) and its surroundings form the Nairobi County. The name "Nairobi" comes from the Maasai phrase *Enkare Nyorbi* which loosely translates to "cold water". The phrase is also the Maasai name for the Nairobi River that runs right through the city.

Nairobi was founded by the British in 1899 as a simple rail depot on the railway linking Mombasa and Uganda and quickly grew to become the capital of British East Africa in 1907, and eventually the capital of a free Kenyan Republic in 1963.

Nairobi is the most populous city in East Africa, with a current estimated population of about 3 million. According to the 2009 Census, in the administrative area of Nairobi, the population of Nairobi County stood at 3,138,369 people within a surface area of 695 square kilometres. Currently Nairobi County like the rest of the 46 counties in Kenya is run by a county government headed by the governor, senator, women representative, county representatives and members of parliaments.

Geographically, Nairobi County is located approximately between latitudes - 1°10′S and - 1°27′S in the north – south direction. Longitudinally it extends from 36°40′E to 37°0′E in the east-west direction. The study area is illustrated in Figure 1.

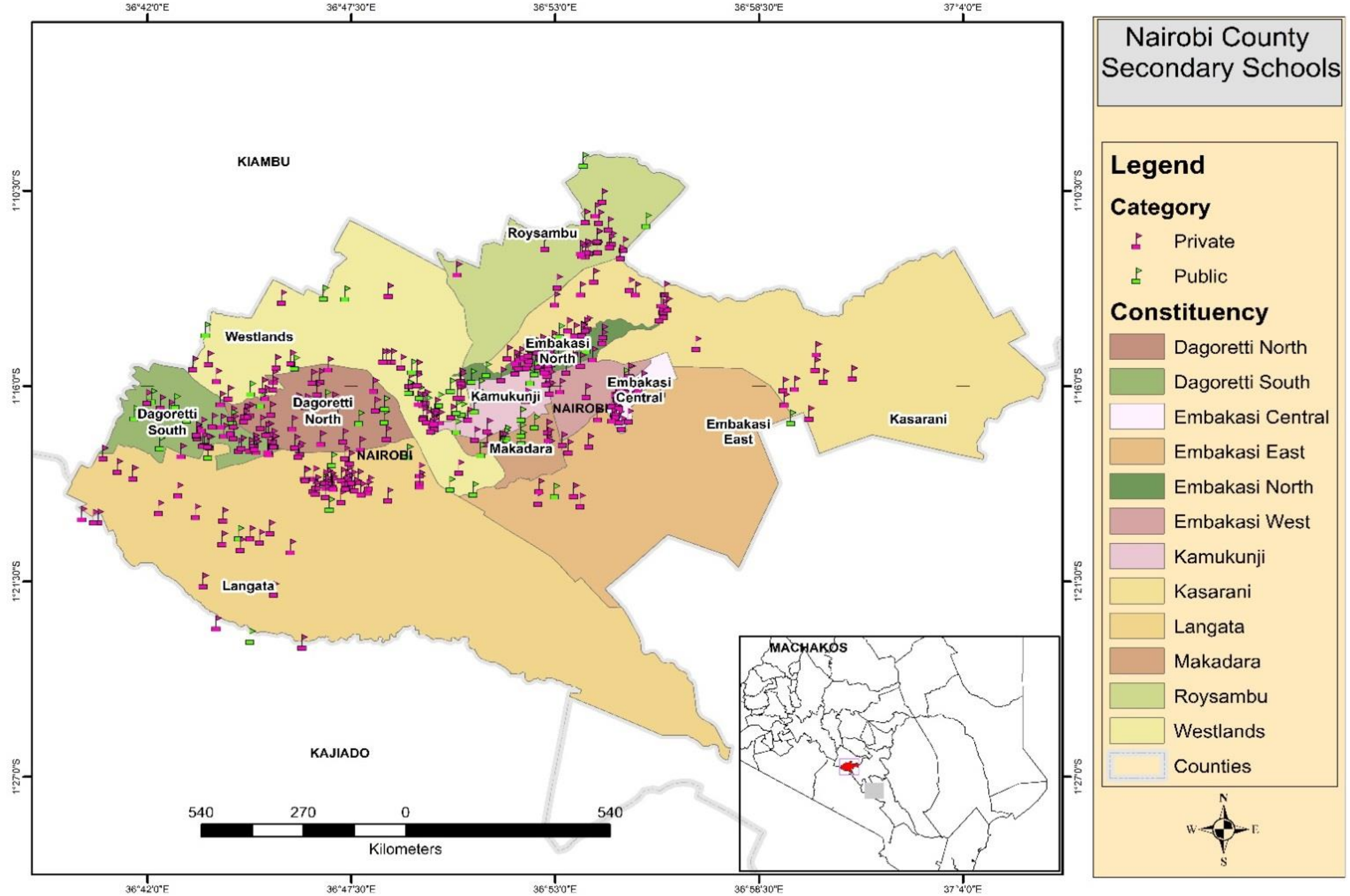

Figure 1: Study Area

3.2. Data Collection

This process involved the identification of data that is required for database design and creation as well as the development of the web linkage. The following data sources for Nairobi County collated from Survey of Kenya (SOK), Independent Electoral Boundaries Commission (IEBC), MOE and KODI were found important and relevant for the realization of the solution. MOE and IEBC are government institutions mandated with the data acquisition, data management and dissemination of the listed datasets. KODI is an initiative that with the express authorization of the Government of Kenya, SOCRATA provides a cloud based hosting plan for purposes of sharing and collaboration between institutions run by government.

a) Secondary schools
b) Constituencies
c) KCSE Exam Results
d) Counties in Kenya

a) Sourcing of Publicly Available Basemap Layers

Table 1 shows publicly available basemaps and reference layers delivered as online tiled web mapping services were identified to be useful as background layers or rather contextual basemap layers.

Table 1: Web Mapping Services

Web Mapping Services	**Rest Endpoints**
Esri World Imagery	http://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer
Esri World Street Map	http://services.arcgisonline.com/ArcGIS/rest/services/World_Street_Map/MapServer
Esri World Topographic	http://services.arcgisonline.com/ArcGIS/rest/services/World_Topo_Map/MapServer
Esri Ocean Basemap	http://services.arcgisonline.com/ArcGIS/rest/services/Ocean_Basemap/MapServer
Esri World Light Gray Base	http://services.arcgisonline.com/ArcGIS/rest/services/Canvas/World_Light_Gray_Base/MapServer
OpenStreetMap	http://trac.osgeo.org/mapserver/wiki/RenderingOsmData
Google Maps	https://maps.googleapis.com/maps/api/staticmap?parameters

a) Prepare and Gather Data for Operational Layers

a. Location and attributes information for circa 346 secondary schools in Nairobi County is sourced from publicly available sources such as the valuable datasets from the Kenya Open Data Initiative (KODI).
b. Constituency boundaries for Nairobi County are sourced from Interim Independent boundaries commission (IEBC).
c. County boundaries are sourced from Survey of Kenya (SOK).
d. Online basemaps from ArcGIS Online (AGOL), OpenStreetMap (OSM) and Google Maps as a backdrop for the maps.
e. KCSE exam results secondary schools in Nairobi County from KODI.

3.3. Database Design and Implementation

Database design is the process of identifying the data that will go into the GIS database and how it will be represented. The database forms the foundation of all activities that will be performed using GIS such as Map creation, data retrieval and spatial analysis modelling. By not going through the database design process, one risks having a poorly constructed database that does not meet the user's requirements. This can result in duplicate, missing or unnecessary data [18].

Secondary schools database in Nairobi County is designed to meet the feature functionality of the web based geo-visualization tool and how it will be represented into the database. The database design process is informed by the datasets at hand and the information products that are needed by the end users. This ensures that the resulting database meets user requirements, has efficient data structures and retrieval mechanisms having considered the normalization principles, supports data sharing, multiuser access and editing as well as is easy to update and maintain.

The solution employed a 3-step database design process;

- External modelling
- Conceptual modelling
- Logical modelling

3.3.1. External Modelling

The external model identifies what the user needs are and how they should be accessed to determine and identify the potential users of the web based geo-visualization tool and assist in building a database. The main aim of the external model is to help ensure that there is a common understanding of the organizational goals, technical expertise and business processes. The external model is shown in Figure 2.

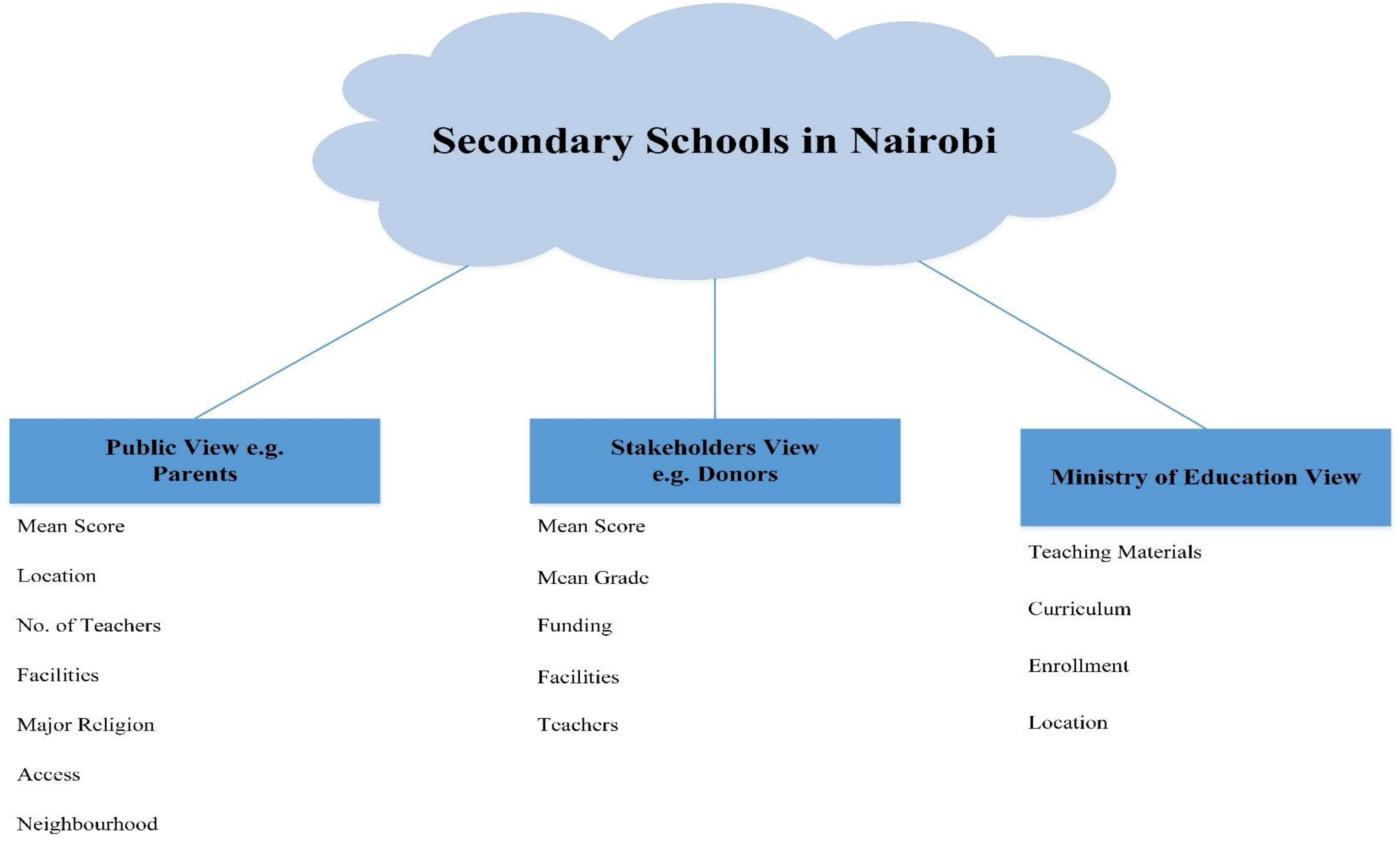

Figure 2: External Model

The potential users of the online database are;

- Ministry of Education (MOE)
  MOE officials are tasked with the update of the database by either adding details about new schools or running edits on existing schools. This exercise involves maintaining both spatial and non-spatial data.
- The Kenya National Examination Council
  Officials are tasked with the update of the database by either adding details about exam results for the secondary schools in the count.
- Stakeholders
  These are donors, NGO's and other bodies that collaborate with government by funding various projects within the schools as well as ensuring quality of education. They are consumers of information such as school facilities, staffing, enrolment that can be drawn from the online tool
- Citizens
  The general public are interested in the performance of secondary schools with a view to gaining insights when informing their children of the choices to make during Form 1 selection. School board of governors and other interested parties can easily track school performance over the years with a view to finding out trends and patterns.

3.3.2. Conceptual Modelling

This is the synthesis of all the external models into an E-R diagram showing all entities involved, attributes and relationships as illustrated in Figure 3 and Figure 4.

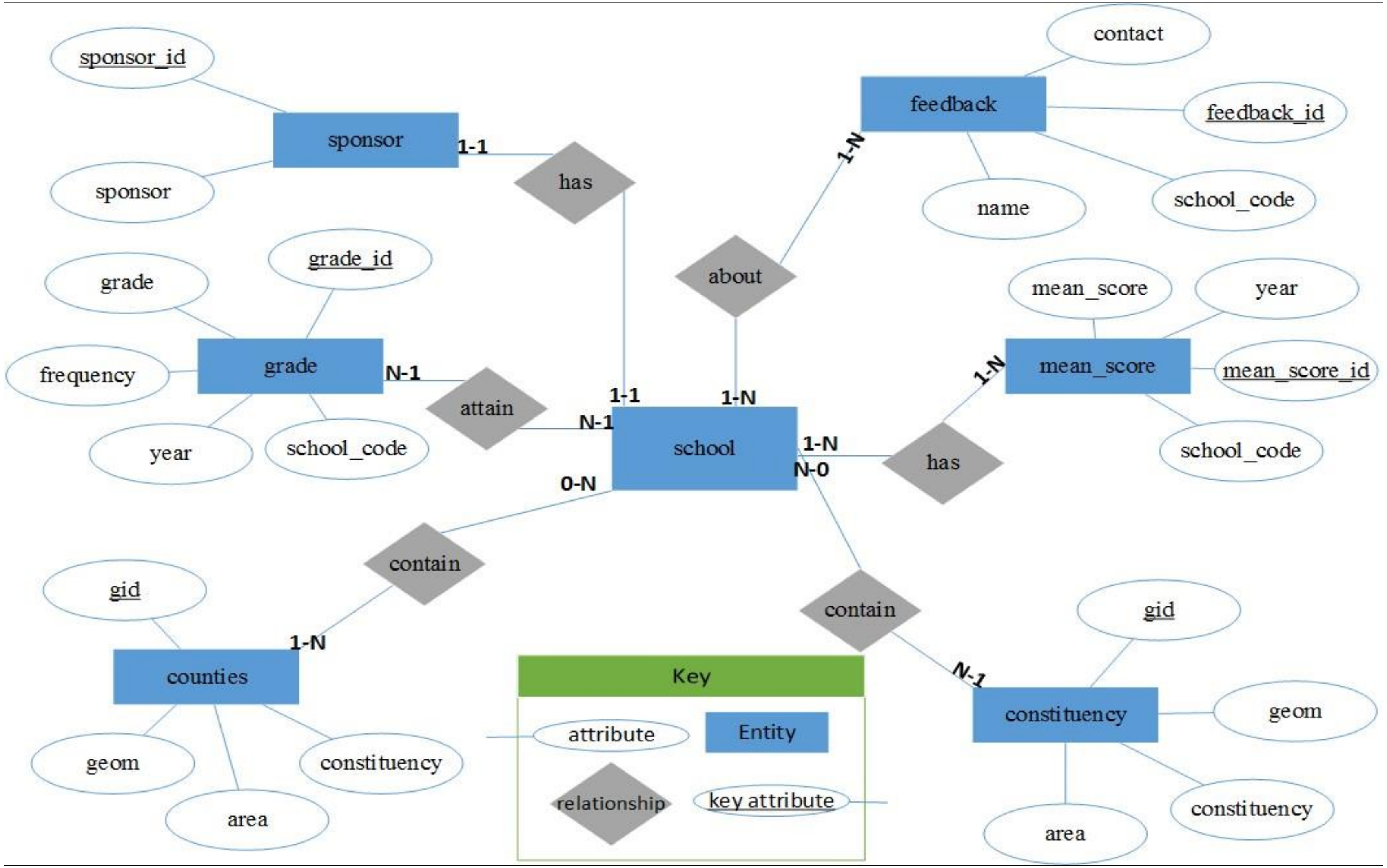

Figure 3: Conceptual Model (Chen's Notation)

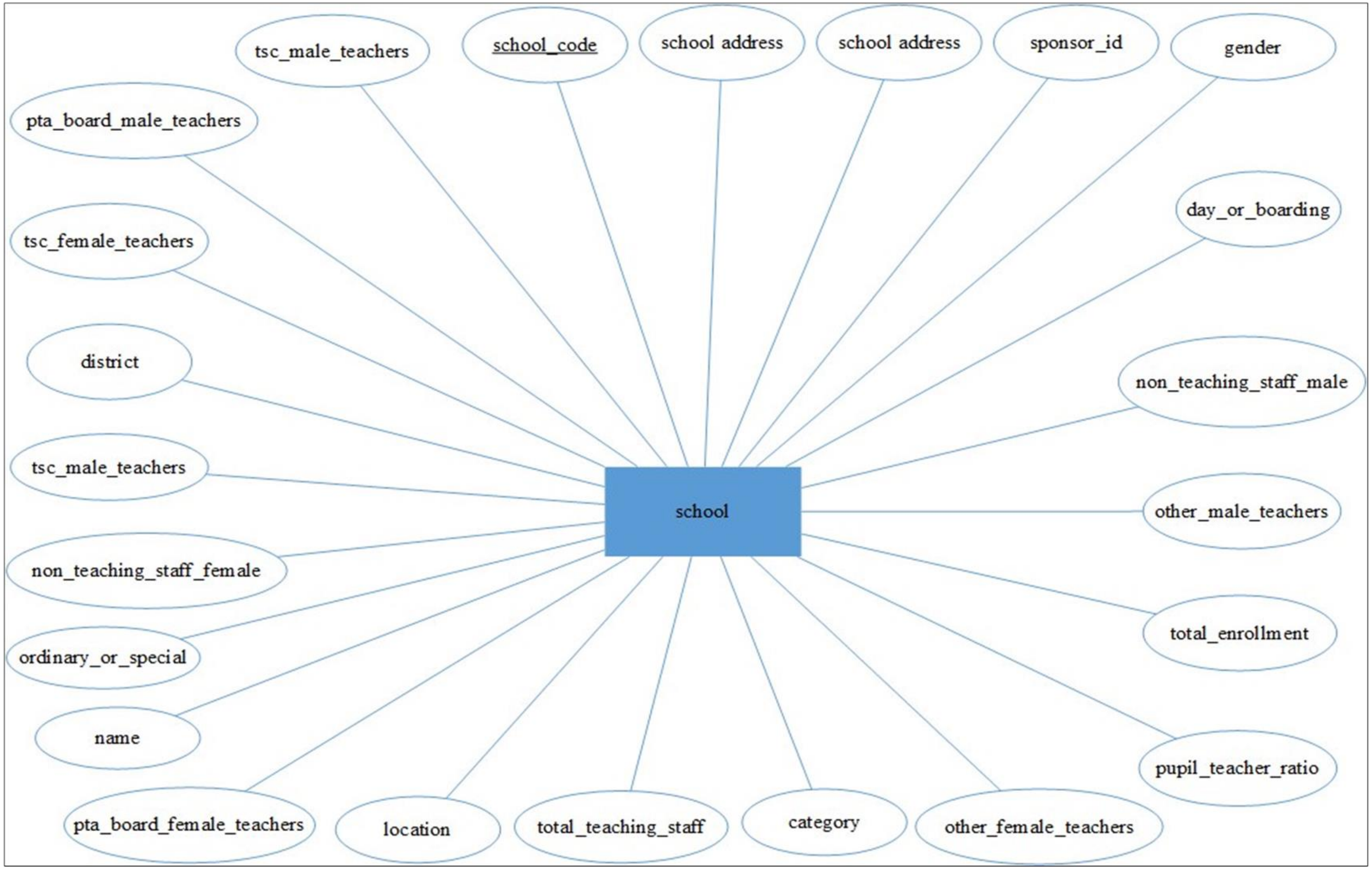

Figure 4: School Entity

3.3.3. Logical Modelling

The conceptual model was mapped onto the logical model DBMS. The following steps were carried out;

a) The database was created in the PostgreSQL relational database by running the commands below. The first command creates the database in the database cluster. Second command allows you to log in as the super user while the third command allows you to enable geodatabase capability on your database.

b) The DDL was created from the matching conceptual model. This created the skeleton or schema of the entities described in the conceptual model. A sample of the schools table schema is shown below; Appendix B describes the process of database creation and table schema development for the entities;

   a. school
   b. sponsor
   c. mean_score
   d. grade
   e. feedback
   f. constituency
   g. counties
   h. nairobi_county

c) The data sources were split to match the data tables shown in the conceptual model in figure 3 and figure 4.

   a. The publicly available data sources from KODI namely "Kenya Secondary Schools" and "KCSE examination results" were mapped to the entities "schools", "mean_score", "mean_grade" and "sponsor".
   b. Spatial entities such as "constituencies" and "counties" were loaded into the relational DBMS in addition to the existing spatial entity "schools". The spatial entities "constituencies" and "counties" were projected from WGS84 Geographic Coordinate System (SRID: 4326) in Quantum GIS to WGS 1948 Web Mercator (auxiliary sphere) (SRID: 3857). Appendix E contains the procedure of loading Shapefiles.
   c. An additional table for capturing valuable community "feedback" named feedback was created as well.

d) Data manipulation queries to load the data currently held in Office Libre spreadsheet into the entities described above were generated using Office Libre Office in readiness for the data migration exercise. The following database constraints were applied in the database to maintain data integrity of data held in the entities within the relational DBMS.

    a. “school_code” code attribute in the entity “schools” was made a primary key
    b. “school_code” code attribute in the tables “schools”, “mean_score”, “mean_grade”, “feedback”, and “sponsor” was made a foreign key.
    c. <entityname>_id field in all the non-spatial tables was made a primary key with the exception of the entity“schools”. “school_code” for the entity school was made the primary key.

e) Data migration carried out from Office Libre spreadsheets employed the use of SQL insert statements. Appendix D contains all the data manipulation queries for all the tables except “constituencies”, “counties” and “nairobi_county” spatial tables.

3.4. Web linkage Implementation

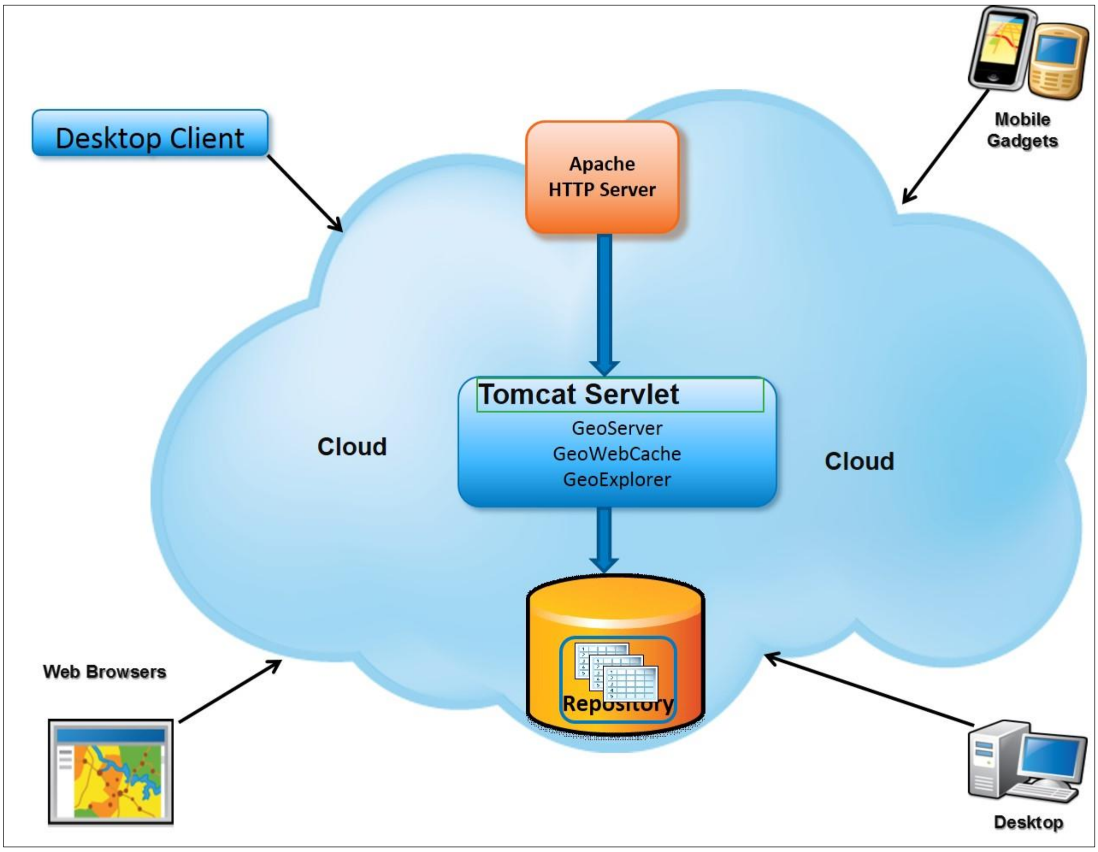

Figure 5: Solution Architecture

The solution architecture for the web linkage geo-visualization tool is summarized above in Figure 5.The web linkage tool is hosted in the cloud and its components are;

- Web server. Apache HTTP server and accessories such as PHP libraries.
- GIS Server. Tomcat servlet container with deployed components of GeoServer.
- Spatial database. PostgreSQL and PostGIS DBMS
- Client application that interact with the web linkage tool running on;
    - Web browsers
    - Smartphones and tablets and
    - Traditional desktop platforms such as Quantum GIS

The web implementation was carried out in two phases;

a) Setting up of a development environment.
b) Setting up of a production environment.

General steps that serve as a guideline to set-up the development environment are as show below;

- Installation and configuration of Quantum GIS as the desktop GIS platform necessary for authoring the maps.
- Editing and verifying that the spatial entities "constituencies" , "counties" , "schools " loaded into the relational database named "msc" in the PostgreSQL database cluster are complete, accurate, consistent and credible.
- Installation and configuration of open-geo suite on a development environment. This caters for the component of sharing geospatial resources by enabling web services from the relational DBMS and thus availing operational layers which combined with publicly available basemap layers from Google, AGOL and OSM complete the spatial component of the maps online. Appendix C describes the procedure.
- Design and development of the web linkage tool. This component carried the bulk of the work and involved the following steps;
    - Development of screen mock-ups for the web based geo-visualization tool
    - Web programming which involved writing both client side scripts using JavaScript frameworks like JQuery and server side scripts using PHP.
    - Integrating operational map services and basemap web mapping services into the web based geo-visualization tool.
- Installing & configuring Apache and open-geo suite integration.

The setting up of the production environment in the LINODE cloud followed the same script with the following exceptions;

a) Quantum GIS platform was not setup in LINODE since it's not needed in a production environment.
b) Additional security measures were put in place to fully secure the production environment from external hacks.

Appendix A describes the process for setting up a production environment on the LINODE PAAS cloud platform.

4. Results

4.1. Results

a) Database Queries on Academic Performance

Samples of the queries run against the database are as shown below;

a) Top ten boy's secondary schools in Nairobi County. The SQL query is described below and subsequently its result are displayed in Table 2.

```
SELECT
  mean_score.school_code as School Code,
  school.name as Name,
  mean_score.mean_score as Mean Score,
  mean_score.year as Year,
  ST_AsText(school.geom) as Geomtery
FROM
  public.mean_score,
  public.school
WHERE
  mean_score.school_code = school.school_code AND
  mean_score.year = '2010' AND
  school.gender = 'BOYS ONLY'
ORDER BY
  mean_score.mean_score DESC
  limit 10;
```

The results display the unique school identifier (school_code), name of school, mean grade, and year as well as location information for the top ten boys' school in the year 2010.

Table 2: Top Ten Boys School

School Code	Name	Mean Score	Year	Geometry
P1010091	STRATHMORE SCHOOL - SEC	10.176	2010	POINT(36.776616 -1.268038)
N1010956	STAREHE BOYS CENTRE	10.109	2010	POINT(36.8393 -1.276776)
N1010089	LENANA SCH	9.391	2010	POINT(36.727556 -1.297674)
R1010088	SUNSHINE SEC SCH	9.178	2010	POINT(36.808488 -1.317807)
N1010254	MOI FORCES ACADEMY (SEC)	8.668	2010	POINT(36.872433 -1.262655)
N1010196	UPPER HILL SCH	8.364	2010	POINT(36.817364 -1.297473)
N1010013	LIGHT ACADEMY	7.750	2010	POINT(36.789076 -1.298113)
P1010860	QUEEN OF APOSTLES SEMINARY SECONDARY SCHOOL	7.684	2010	POINT(36.883509 -1.225958)
R1010019	ST. HANNAHS BOYS HIGH SCH	7.586	2010	POINT(36.72191 -1.325525)

N1010121	DAGORETTI HIGH SCH	7.287	2010	POINT(36.712737 -1.273893)

b) Top ten girl's secondary school in Nairobi County. The SQL query is similar to the above query with a sight modification

```
---------SQL Code--------------------
WHERE
  mean_score.school_code = school.school_code AND
  mean_score.year = '2010' AND
  school.gender = 'BOYS ONLY'
ORDER BY

--------------SQL Code-------------------
```

Output results similar to Table 2 but now filtered for girls only secondary schools.

Table 3: Top Ten Girls School

School Code	Name	Mean Score	Year	Geometry
N1010164	PRECIOUS BLOOD SEC SCH RIRUTTA	10.787	2010	POINT(36.738443 -1.281323)
P1010098	KENYA HIGH SCH.	10.117	2010	POINT(36.780629 -1.271937)
P1010137	KIANDA SCH - SEC	10.072	2010	POINT(36.756861 -1.262284)
N1010890	PANGANI GIRLS SEC SCH	9.749	2010	POINT(36.836614 -1.266466)
N1010015	MOI GIRLS SCH - NAIROBI	8.817	2010	POINT(36.783265 -1.301216)
P1010337	BURUBURU GIRLS HIGH SCH	8.693	2010	POINT(36.874429 -1.283508)
P1010013	ST. GEORGES GIRLS SEC SCH	8.681	2010	POINT(36.795417 -1.281603)
P1010381	APOSTOLIC CARMEL GIRLS SEC SCH	8.667	2010	POINT(36.880596 -1.28954)
R1010310	MT LAVERNA SEC. SCH	8.424	2010	POINT(36.917028 -1.219165)
R1010110	NAIROBI MUSLIM ACADEMY- SEC	8.277	2010	POINT(36.822695 -1.309647)

c) Top ten secondary schools in Nairobi County. The SQL query is as provided below;

```
SELECT
  mean_score.school_code as School Code,
  school.name as Name,
  mean_score.mean_score as Mean Score,
  mean_score.year as Year,
  ST_AsText(school.geom) as Geomtery
FROM
  public.mean_score,
  public.school
WHERE
  mean_score.school_code = school.school_code AND
  mean_score.year = '2010'
ORDER BY
```

```
mean_score.mean_score DESC
limit 10;
```

Query results in Table 4 showing top ten secondary schools in Nairobi County for the year 2010 ordered from the highest score to the lowest score but limiting the results to only the first ten records from the results query.

Table 4: Top Ten Secondary Schools

School Code	Name	Mean Score	Year	Geometry
N1010164	PRECIOUS BLOOD SEC SCH RIRUTTA	10.787234	2010	POINT(36.738443 -1.281323)
P1010091	STRATHMORE SCHOOL - SEC	10.175676	2010	POINT(36.776616 -1.268038)
P1010098	KENYA HIGH SCH.	10.117371	2010	POINT(36.780629 -1.271937)
N1010956	STAREHE BOYS CENTRE	10.109453	2010	POINT(36.8393 -1.276776)
P1010137	KIANDA SCH - SEC	10.072464	2010	POINT(36.756861 -1.262284)
N1010890	PANGANI GIRLS SEC SCH	9.7491039	2010	POINT(36.836614 -1.266466)
P1010251	NAIROBI SCHOOL	9.7185185	2010	POINT(36.766416 -1.255741)
N1010089	LENANA SCH	9.3911290	2010	POINT(36.727556 -1.297674)
R1010088	SUNSHINE SEC SCH	9.1782609	2010	POINT(36.808488 -1.317807)
N1010567	RIARA SPRINGS GIRLS HIGH SCHOOL	8.8382353	2010	POINT(36.875946 -1.319325)

b) Sample Spatial Database Query

a) Find all schools in Dagoretti constituency using a spatial relationship (*completely_within*). For instance the query below shows all secondary schools within "Dagoretti South" constituency.

```
---Pass the filters query private, public between the '%' operators
with query1 as (
        select
                constituency.geom, constituency.constituen
        from
                public.constituency
        where
                public.constituency.constituen = 'DAGORETTI SOUTH'
)
select
        c.school_code as School Code,
        c.name as Name,
        c.address as Address,
        c.category as Category,
        c.gender as Gender,
        c.day_or_boarding as Day/Boarding,
        c.sponsor as Sponsor

from
        (select
                a.*, b.sponsor from school as a inner join sponsor as b
        on      a.sponsor_id = b.sponsor_id )  as c, query1
where
```

ST_Within(c.geom, query1.geom) = true
and lower(category) like '%%' and lower(sponsor) like '%%' and lower(gender) like '%%' and lower(day_or_boarding) like '%%' and lower(ordinary_or_special) like '%%' ;

Query results after executing the SQL statements in the section "Spatial Database Query" against the database.

Table 5: All Secondary Schools in Dagoretti constituency

School Code	Name	Address	Category	Gender	Day/boarding	Sponsor
N1010028	GOOD SAMARITAN MIXED SEC SCH	40747 NAIROBI	PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
N1010034	RIRUTA CENTRAL SCHOOL	14309-00100 NAIROBI	PRIVATE	MIXED	DAY & BOARDING	PRIVATE INDIVIDUAL
N1010045	SHILCE SCHOOL	25-00200 NAIROBI	PRIVATE	MIXED	DAY ONLY	NGO/CBO
N1010061	KABIRIA SEC SCH	79420-00200 NAIROBI	PRIVATE	MIXED	DAY ONLY	RELIGIOUS ORGANIZATION
N1010063	BROOKLANE HIGH SCH	127857 NAIROBI	PRIVATE	MIXED	DAY & BOARDING	COMMUNITY
N1010064	EVA SEC SCH	76043-00508 NAIROBI	PRIVATE	MIXED	DAY ONLY	RELIGIOUS ORGANIZATION
N1010066	LE PIC SEC SCH	21659 NAIROBI	PRIVATE	MIXED	DAY & BOARDING	PRIVATE INDIVIDUAL
N1010070	KINGS PAVILLION SEC SCH	6508-00200 NAIROBI	PRIVATE	GIRLS ONLY	DAY ONLY	RELIGIOUS ORGANIZATION
N1010073	SATELITE STAREHE SEC	55454	PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
N1010079	IMPREZZA SEC SCH	20665-00200 NAIROBI	PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
N1010080	TOP MARK HIGH SCH	75195-00200 NAIROBI	PRIVATE	MIXED	DAY ONLY	NGO/CBO
N1010083	ST HELLEN IMANI SEC SCH	9291-00100 NAIROBI	PRIVATE	MIXED	DAY ONLY	COMMUNITY
N1010090	ST CHARLES MUTEGO HIGH SCH		PRIVATE	MIXED	DAY & BOARDING	PRIVATE INDIVIDUAL
N1010091	MUTUINI HIGH SCH	24893 NBI	PUBLIC	BOYS ONLY	DAY ONLY	CENTRAL GOVERNMENT/DEB
N1010110	RUTHIMITU HIGH SCH	53399	PUBLIC	MIXED	DAY ONLY	LOCAL GOVERNMENT AUTHORITY
N1010116	RUTHIMITU GIRLS SEC SCH	10598-00100 NAIROBI	PUBLIC	GIRLS ONLY	DAY ONLY	CENTRAL GOVERNMENT/DEB
N1010118	BATIAN CHRISTIAN SCH	1400 NAIROBI	PRIVATE	MIXED	DAY ONLY	RELIGIOUS ORGANIZATION
N1010120	ENNA GIRLS SEC SCH.	40987 NAIROBI	PRIVATE	GIRLS ONLY	DAY ONLY	PRIVATE INDIVIDUAL
N1010121	DAGORETTI HIGH SCH	21070-00505 NBI	PUBLIC	BOYS ONLY	BOARDING ONLY	CENTRAL GOVERNMENT/DEB
N1010124	WAITHAKA RIVERSIDE SCH (SEC)	67364 NAIROBI	PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
N1010135	NEMBU GIRLS HIGH SCH	21153-00505 NBI	PUBLIC	GIRLS ONLY	BOARDING ONLY	CENTRAL GOVERNMENT/DEB
N1010153	GRACIOUS CLIMBERS EDUCATIONAL CENTRE	400200	PRIVATE	MIXED	BOARDING ONLY	COMMUNITY
N1010198	GITU ACADEMY SEC SCH	49038	PRIVATE	MIXED	DAY & BOARDING	PRIVATE INDIVIDUAL
N1011066	KINGS HIGH SCH AND CENTER-SEC	53818-00200	PRIVATE	MIXED	DAY & BOARDING	NGO/CBO

N1011076	ELYON HIGH SCH	76589-00508 NAIROBI	PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
P1010905	GORD RICH GIRLS HIGH SCH	BOX 8745-00100 NBI	PRIVATE	GIRLS ONLY	DAY ONLY	PRIVATE INDIVIDUAL
P1010950	KERITH BROOK SCHOOLS - SEC	57071-00200	PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
P1010954	NATIONAL HIDDEN TALENTS ACADEMY - SEC	55443-00200 NAIROBI	PRIVATE	MIXED	DAY & BOARDING	RELIGIOUS ORGANIZATION
P1010957	ST. EUNICE ACADEMY SEC SCH		PRIVATE	MIXED	DAY ONLY	PRIVATE INDIVIDUAL
P1011195	HEART OF MERCY SCHOOL SECONDARY	16139 NAIROBI	PRIVATE	MIXED	DAY ONLY	NGO/CBO
P1011197	EUTYCHUS EDUCATIONAL CENTRE SEC SCH.	954 NAIROBI	PRIVATE	MIXED	DAY ONLY	NGO/CBO
R1010008	FOREST VIEW ACADEMY SEC	24588 NAIROBI 00506	PRIVATE	GIRLS ONLY	DAY & BOARDING	PRIVATE INDIVIDUAL

b) Web Linkage Tool Overview

A web based geo-visualization tool with the following features and functionality:

Visualization & Dissemination- The web linkage tool enables easy and ready access of secondary schools on a rich interactive web application. The web application contains interactive maps which comprise basemap layers from Open Street Maps, ArcGIS Online, Google Maps and an operational layer showing constituencies in Nairobi County and adjacent counties. Additionally a schools operational layer served dynamically dependent on the query parsed by the user is displayed on top of all the other layers. This is illustrated in Figure 6.

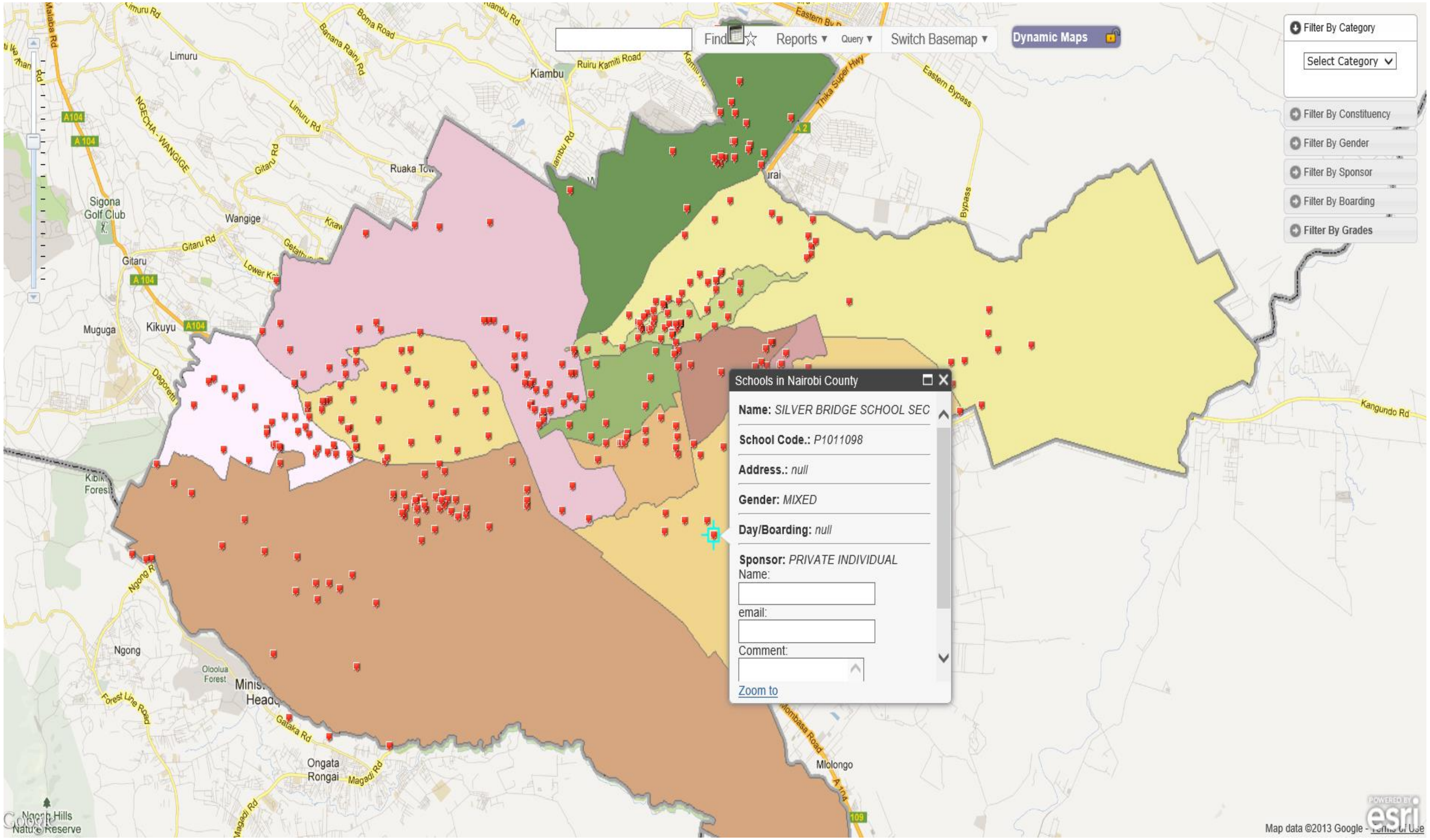

Figure 6: Web Linkage Tool

Search- Versatility in the search capabilities includes search by sponsor, category, name or any other parameter so desired. The search results are displayed both on the map and in a tabular format.

Export Capabilities- Additionally reporting capabilities has been provided through charts that provide summary statistics depending on the queries run by the user. The export capabilities to Excel format allows users to conduct further analysis on the downloaded data by utilizing the robust analytical capabilities of desktop applications such as Microsoft excel and other BI tools.

Dashboards – The look and feel of the web based geo-visualization tool utilizes widgets for the various components on the application. A query filter widget has been implemented that filters by various categories e.g. by name, category, sponsor etc. An advanced dashboard for advanced queries enabling and providing the user with more flexibility in the querying process has been applied. Additionally, a dynamics maps widget has been provided enabling users to switch between the dynamic maps layers provided.

c) Web Linkage Tool Workflow

The web linkage tool is deployed in a Linux cloud platform named LINODE .This tool can be accessed from the publicly available link by the community of users. The workflow described below summarizes how the tool can be used from a browser. Launch the application by typing the URL (http://176.58.114.103/msc/) which is a publicly available URL in your browser

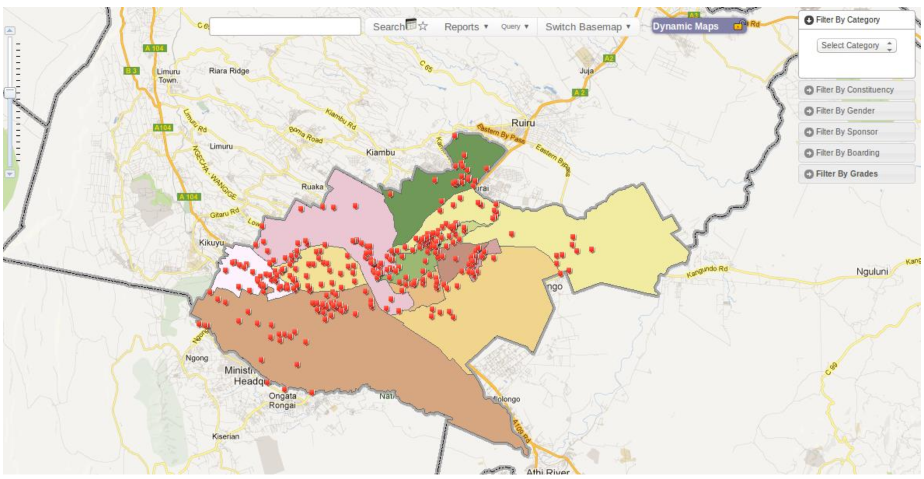

Figure 7: Launch Web Linkage Tool

The web linkage tool is an intuitive rich interactive web mapping application that offers you the following features and functionality

a. Pop up dialog

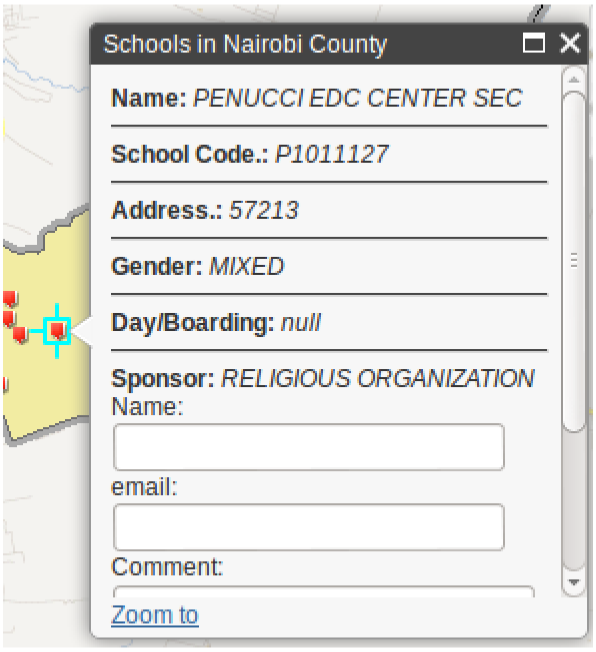

Figure 8: Pop Up Dialog Box

A pop up providing more information on the secondary school plotted on the map. Additionally, a form is provided that enables MOE officials to engage citizens by soliciting feedback from the users.

Widgets

a. *Filter Widget.*

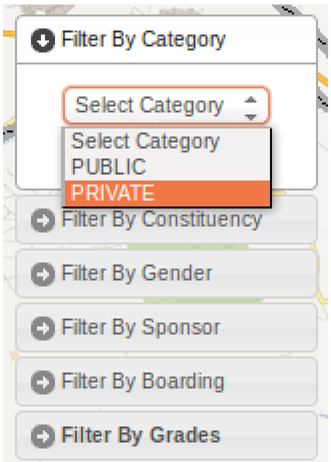

Figure 9: Filter Widget

This allows the user to filter display of information on secondary schools. A user selects the parameter of choice in the filter widget. The parameters availed to the users are; filter by constituency, filter by gender, filter by sponsor, filter by boarding, and filter by grades. The filters are exclusive of each other.

For flexibility in applying the filters, try the Query Widget.

b. Dynamic Maps Widget

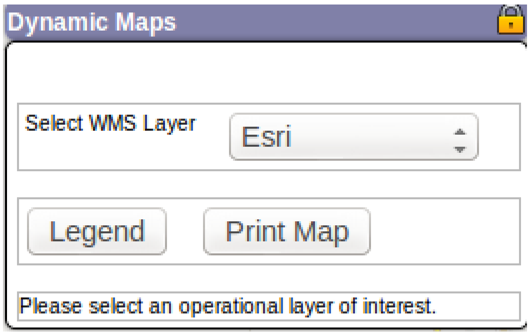

Figure 10: Dynamic Maps Widget

Dynamic maps widget allows users pick from a list of dynamic map services. There are four dynamic map services;

Table 6: Dynamic Map Services

Operational Layers	
Name	**URL**
Esri WMS	http://168.63.184.124:6080/arcgis/rest/services/Base_Layers/MapServer
Nairobi county	http://176.58.114.103:8080/geoserver/msc/wms?service=WMS&version=1.1.0&request=GetMap&layers=msc:nairobi_county&styles=nairobi_county_68b11033&bbox=4081370.25,-160555.3125,4130358.25,-128905.984375&width=512&height=330&srs=EPSG:3857&format=application/openlayers
Counties	http://176.58.114.103:8080/geoserver/msc/wms?service=WMS&version=1.1.0&request=GetMap&layers=msc:counties&styles=counties_970fd095&bbox=3774854.5,-534828.8125,4664969.0,603596.4375&width=400&height=512&srs=EPSG:3857&format=application/openlayers
Constituencies	http://176.58.114.103:8080/geoserver/msc/wms?service=WMS&version=1.1.0&request=GetMap&layers=msc:constituency&styles=constituency_a47d0701&bbox=4081370.25,-160555.3125,4130358.25,-128905.984375&width=512&height=330&srs=EPSG:3857&format=application/openlayers

c. Operations Widget

Figure 11: Operations Widget

The operations widget contains an array of widgets namely, Find, Reports, Query and Switch Basemap.

i. Find Feature

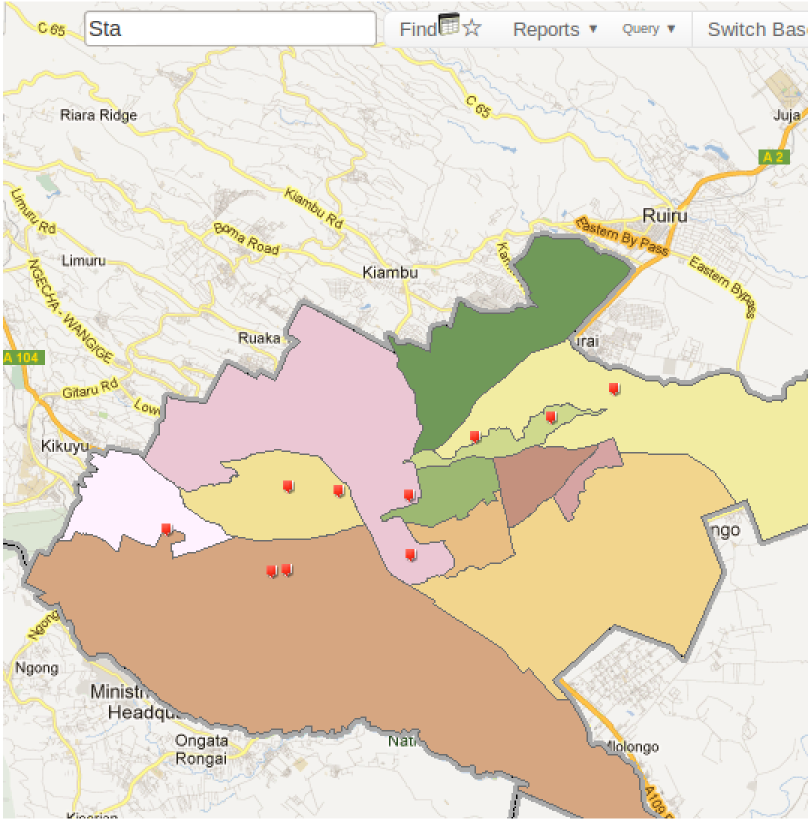

Figure 12: Find Feature

Typing text on the dialog box e.g. “Sta” will find all secondary schools whose names have the characters aforementioned. This provides a quick method to search for a certain school easily and quickly whose full details are not clearly known.

ii. Reports

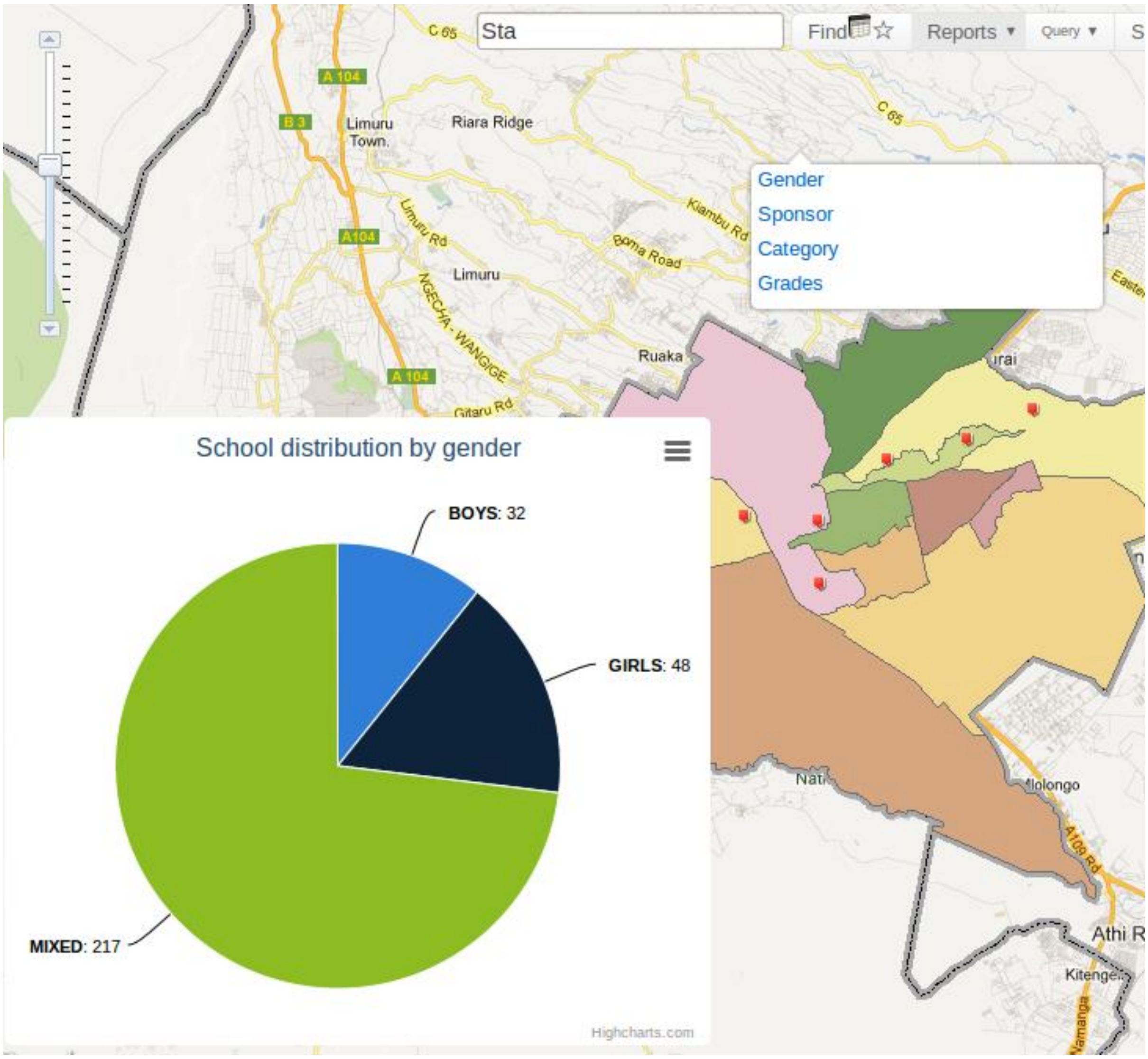

Figure 13: Reports Feature

Clicking on Reports button provides a way for reporting through charts. Depending on the query supplied by the user, a chart (pie chart or line graph) by gender, sponsor, category and grades is displayed.

iii. Query Widget

1. Wizard Query Tab

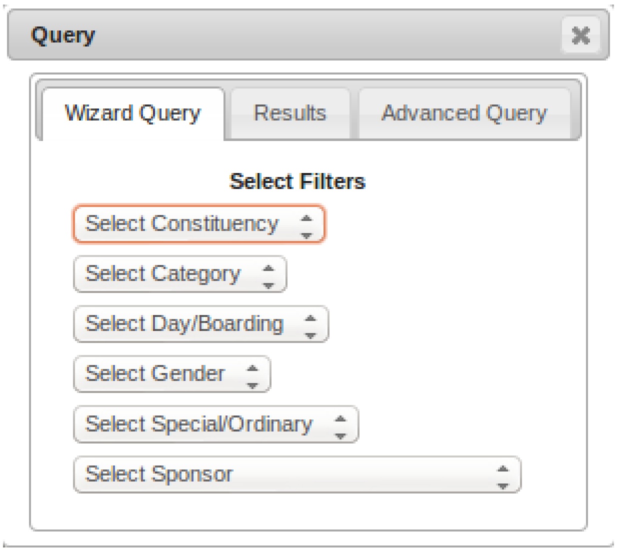

Figure 14: Wizard Query Tab

The Wizard Query tab offers users functionality for combining all parameters in a single query asynchronously. This advances the capabilities of the Filter Widget in figure x

Functionality supporting export to CSV format for further analysis using BI tools has been provided.

2. Results Query Tab

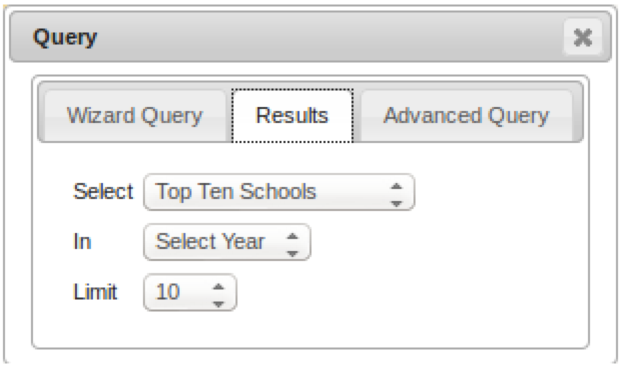

Figure 15: Results Query Tab

The Results tab allows a user to query secondary schools within Nairobi County based on exam results. Three queries are provided;

- Top Schools
- Top Girls School
- Top Boys Schools

The results are ordered by descending order and parameters applied to the result query are by year and limit. The available exam results are for the years 2006 to 2010. The limits available are 10, 20, and 50,100

Functionality supporting export to CSV format for further analysis using BI tools has been provided.

3. Advanced Query Tab

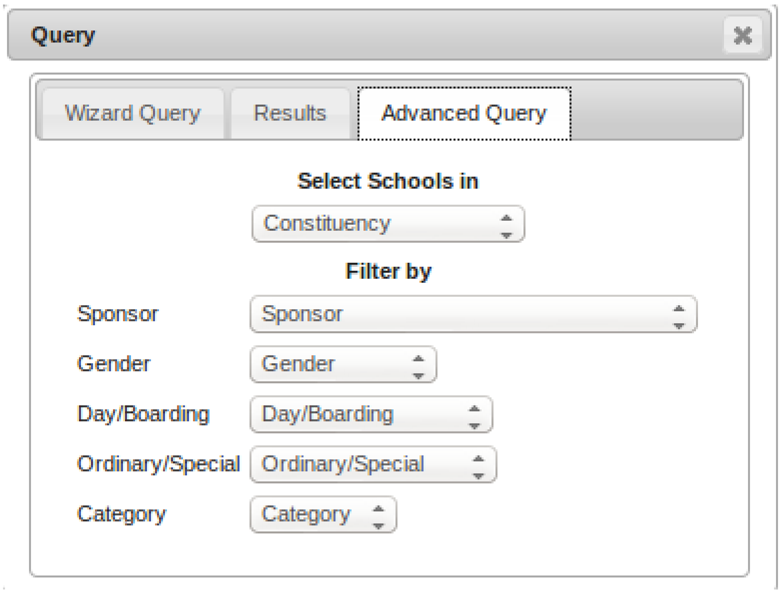

Figure 16: Advanced Query Tab

This allows user to drill down to schools within a certain constituency of choice and apply filters such as sponsor, gender, day/boarding, ordinary/special and category. This offers one the capability to conduct a spatial query coupled with an attribute query.

Functionality supporting export to CSV format for further analysis using BI tools has been provided.

iv. Switch Basemap Widget

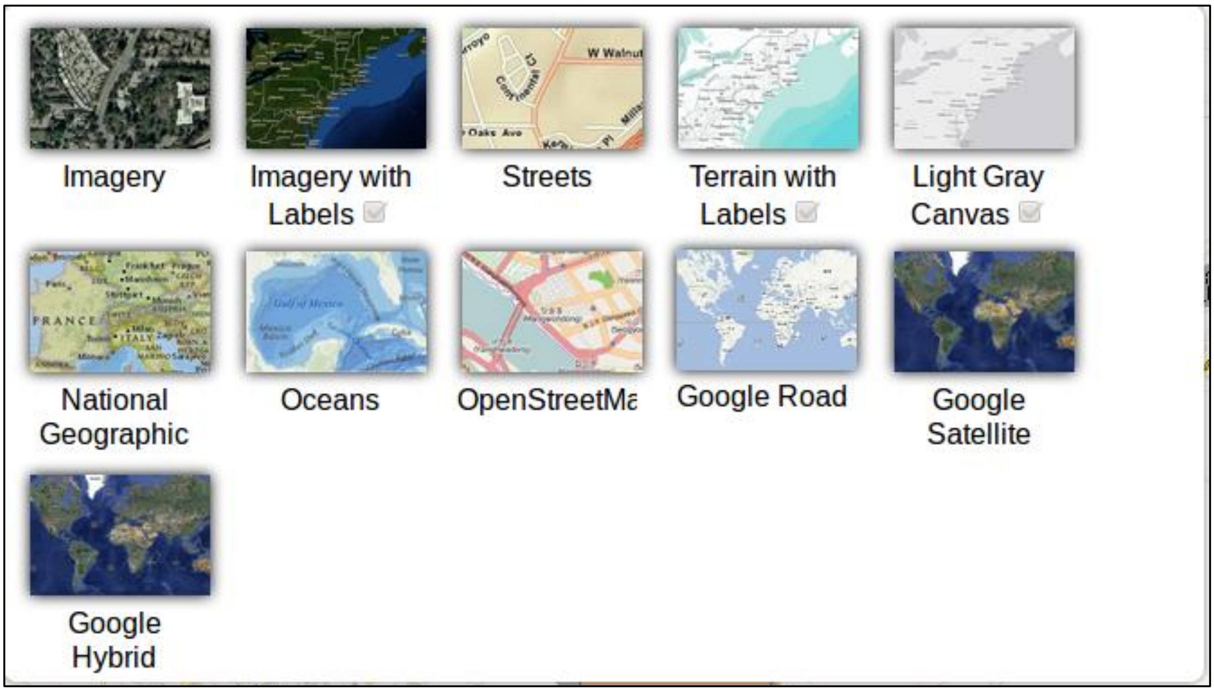

Figure 17: Switch Basemap Widget

Clicking on the "Switch Basemap" button results in a pop up window allows one to switch basemap from an array of basemap from three main vendors namely; AGOL, Google Maps and OSM. This provides the user with the choice of selecting a basemap layer of their choice.

Appendix F describes the process of accessing and forking the most recent code repository from GITHUB. At the root of the code repository you will be provided with a README.md file containing instructions on how you can configure and set-up the code on your machine.

4.2. Analysis of Results

The results indicate that the web linkage tool developed provides refined information for different categories of users. For instance for the general public, they are able to find out useful information on top performing schools such as the top ten boys secondary schools, top ten secondary schools etc. from a rich internet application . This kind of information requires a web browser and access to the internet.

The visualization of data both spatial and non-spatial about schools on the web platform underscores the importance of spatial details.

Utilization of a spatial enabled DBMS such as PostgreSQL allows one to store both spatial (schools, counties, constituencies) and non-spatial data (grades, mean scores, sponsor) in a central location and in one platform. This has the benefit that data security is not compromised should one need to configure users and their permissions on the relational database.

The deployment of the web linkage tool to the cloud provides for a wider community of users. This additionally offers capability for high availability and scalability of the solution. Many are the times when systems fail due to the high number of user's e.g. release of exam results. However, the benefits of the cloud provides for the solution to scale in and out depending on usage. Additionally, the effect of downtimes prevalent in enterprise systems is minimized.

Though the solution has overemphasized the web linkage solution, the desktop GIS solution available through open and free open source software Quantum GIS offers capabilities for MOE officials to easily update the data since they can easily log into the relational DBMS through the backend and conduct edits on the data to ensure currency.

5. Conclusion and Recommendations

5.1. Conclusion

The goal of the project was to develop a web based geo-visualization tool for secondary schools in Nairobi County. By and large this objective has been achieved and it is concluded as follows.

- Data on education institutions is available as a rich interactive map. One is able to visualize location information about secondary schools and access descriptive information from intelligent pop ups.
- Useful information is readily available to the wider public. For instance one is quickly able to find top performing schools in the county
- Ability to conduct a drill down on the information provided not only through pop-ups but through versatile queries allows the user to filter out data and remain with relevant data.
- The integration of exam results and schools data enriches the information available to the average citizens who though they may have the skills in data processing do not have the time to download and conduct analysis on the desktop.
- The utilization of a free open source relational database management system in PostgreSQL marries together seamlessly spatial data and non-spatial data. This makes it possible for the integration of disparate systems maintained by agencies. This has realized the application of enterprise spatial databases that offer the capabilities of centralized database management as well as supporting distributed database management systems.
- The deployment of the solution to a PAAS cloud implementation enjoys the benefits of cloud computing as well as riding on the emerging cloud and web technologies.

5.2. Recommendations

In order for initiatives like KODI that promote principles of open government, transparency and accountability to succeed there needs to be a paradigm shift on policies relating to technology use. The recommendations from the project are;

- Efforts by the Government of Kenya to share data with the public are noble and in line with principles of transparency and accountability. However, initiatives like KODI may wither and ultimately die out. Intelligent data/web mapping applications e.g. the web linkage tool should be shared out that is ready for consumption by the citizens of Kenya since this will attract many users to KODI and provide useful information for decision support.
- Blanket dismissal and disapproval of cloud options by many government agencies is counterproductive in nature. The notion of insisting on enterprise architecture for delivery of solutions has failed in the past since it requires specialized skills, expensive to maintain, unreliable for delivery of services.
- Further study needs to be conducted on how data on school facilities can be integrated in a new version of the web based geo-visualization tool. The delivery of information is primarily through the web/cloud platform. It is thus proposed that delivery through the emerging mobile platform (smartphone and tablet) should be explored with a view to reaching a greater number of users in the community. Currently, the application can only be accessed as a mobile web application but there is a need for further study on how native mobile applications can be developed smartphones.

6. References

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7. Appendices

Appendix A

A1 Installation and Configuration of the Production Environment in LINODE cloud

a) Authentication

Log in as root by issuing the following command

su root

Use SSH to login to LINODE instance. NB. If using SSH key pair authentication mode then username/password authentication is unnecessary as shown below.

ssh dmuthami@176.58.114.103

Login into LINODE as root in the LINODE instance by issuing the following commands

su root

A password prompt appears prompting you to supply the password

b) Install and Configure the Apache Web Server

Issue the following command to install Apache:

apt-get installapache2

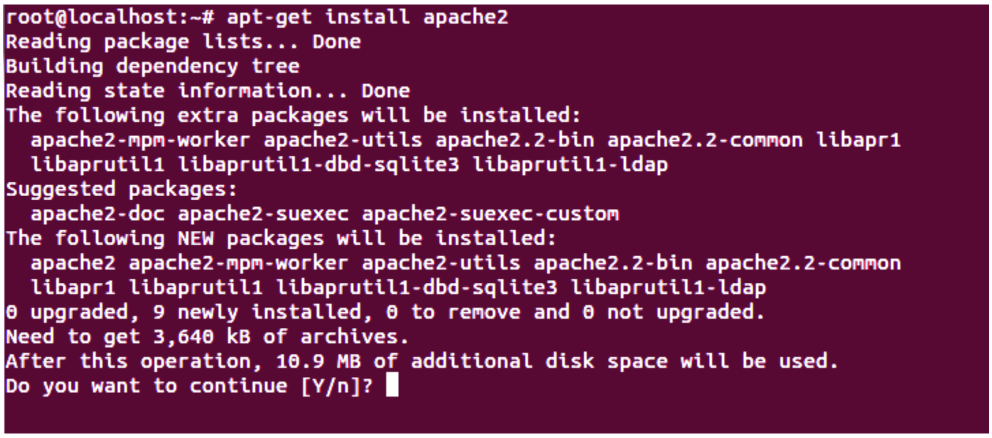

Figure 18: Installing Apache2 Web Server in Linux

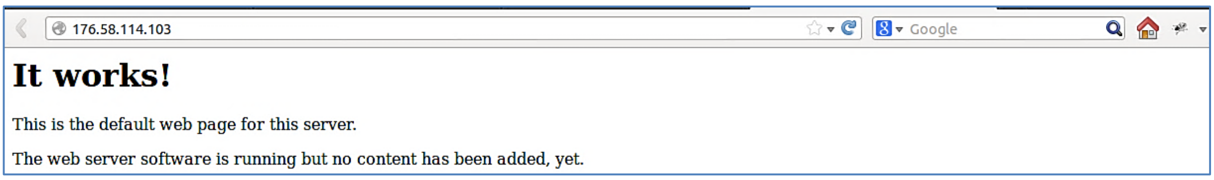

Figure 19: Testing Apache2 Web Server

Test installation of Apache webserver and if the above message is displayed then the installation is successful.

c) Install and Configure PHP

Ubuntu includes packages for installing PHP from the terminal. Issue the following command:

apt-get install php5 php-pear

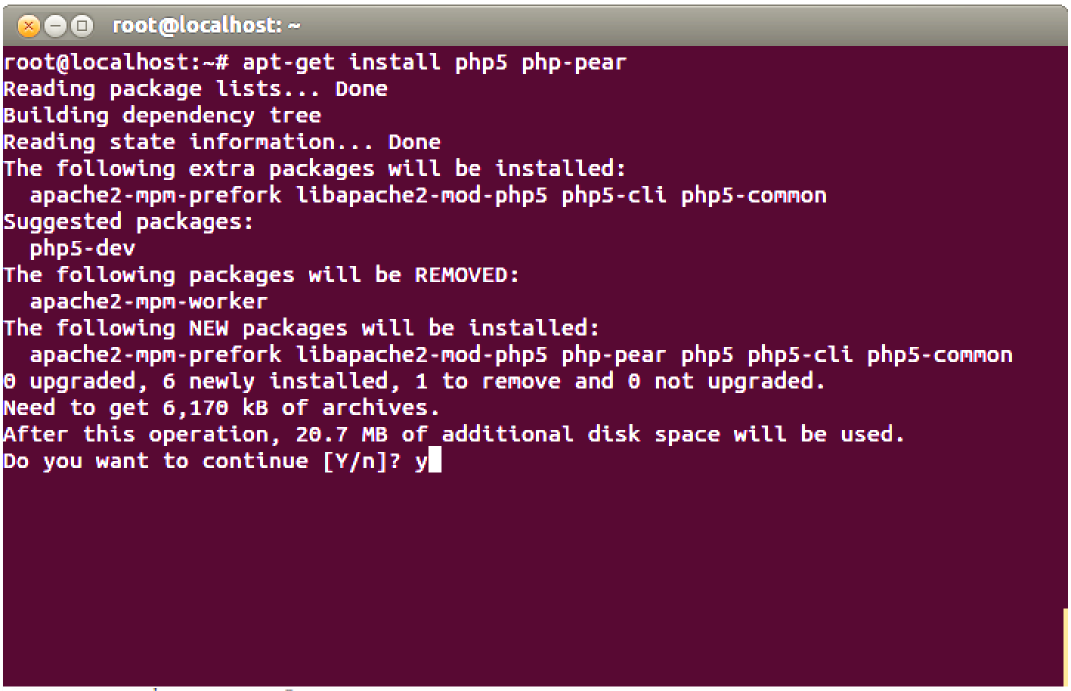

Figure 20: Install PHP5 on Linux

Issue the command below and see to it the settings below are well done.

vim /etc/php5/apache2/php.ini

Figure 21: PHP5 Environment Setting

Ensure variables within php.ini file are as indicated below;

max_execution_time = 30

memory_limit = 64M

error_reporting = E_COMPILE_ERROR|E_RECOVERABLE_ERROR|E_ERROR|E_CORE_ERROR

display_errors = Off

log_errors = On

error_log = /var/log/php.log

register_globals = Off

After making changes to the PHP configuration file, restart Apache by issuing the following command:

service apache2 restart

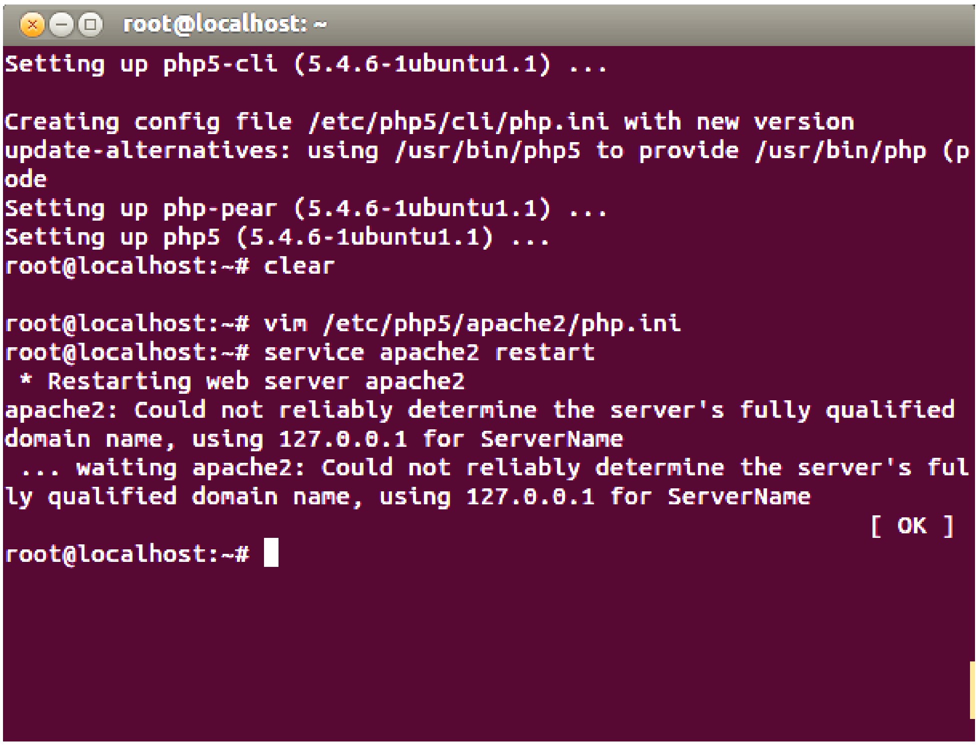

Figure 22: Apache2 Restart

If you need support for MySQL in PHP, then you must install the php5-mysql package with the following command:

apt-get install php5-mysql

To install the php5-suhosin package, which provides additional security for PHP 5 applications (recommended), issue the following command:

apt-get install php5-suhosin

Figure 23: PHP Security Packages

Restart Apache to make sure everything is loaded correctly:

service apache2 restart

d) Install OpenGeo Suite Community Edition on a Production Environment Case: LINODE

1. Login to LINODE using the below command

ssh dmuthami@176.58.114.103

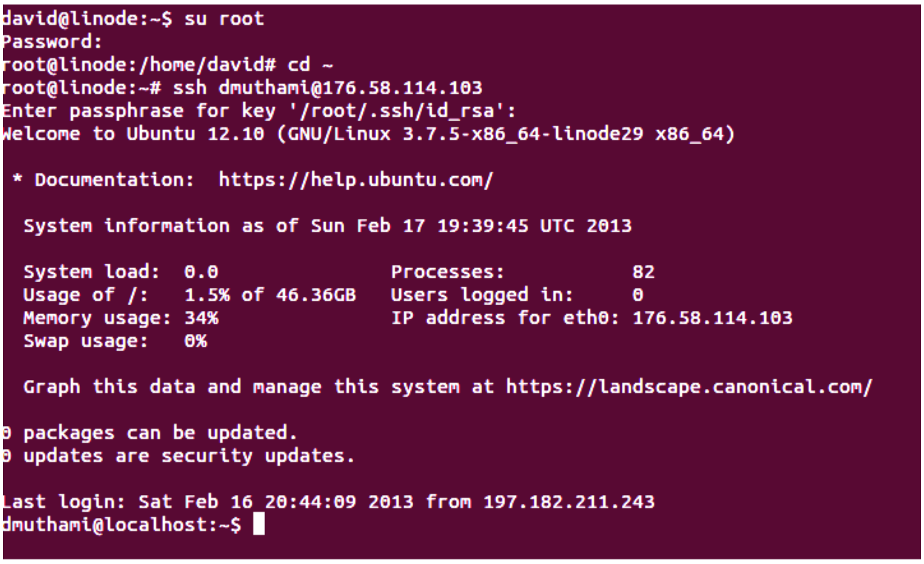

Figure 24: Login to LINODE Cloud

2. Change to the root user

```
Last login: Sat Feb 16 20:44:09 2013 from 197.182.211.243
dmuthami@localhost:~$ su root
Password:
root@localhost:/home/dmuthami# cd ~
root@localhost:~#
```

Figure 25: User Root

3. Begin by importing the OpenGeo GPG key:

wget -qO- http://apt.opengeo.org/gpg.key | apt-key add -

```
root@localhost:~# wget -qO- http://apt.opengeo.org/gpg.key | apt-key add -
OK
root@localhost:~#
```

Figure 26: Importing OpenGeo GPG Key

4. Add the OpenGeo APT repository:

echo "deb http://apt.opengeo.org/suite/v3/ubuntu lucid main" >> /etc/apt/sources.list

```
root@localhost:~# echo "deb http://apt.opengeo.org/suite/v3/ubuntu lucid main" >
> /etc/apt/sources.list
root@localhost:~#
root@localhost:~#
```

Figure 27: Add OpenGeo APT Repository

5. Update APT:

apt-get update

```
root@localhost:~# apt-get update
Ign http://security.ubuntu.com quantal-security InRelease
Hit http://security.ubuntu.com quantal-security Release.gpg
Hit http://security.ubuntu.com quantal-security Release
Hit http://security.ubuntu.com quantal-security/main Sources
Hit http://security.ubuntu.com quantal-security/restricted Sources
Hit http://security.ubuntu.com quantal-security/universe Sources
Hit http://security.ubuntu.com quantal-security/multiverse Sources
```

Figure 28: Update APT

6. Search for packages from OpenGeo:

apt-cache search opengeo

If the search command does not return any results, the repository was not added properly. Examine the output of the apt commands for any errors or warnings.

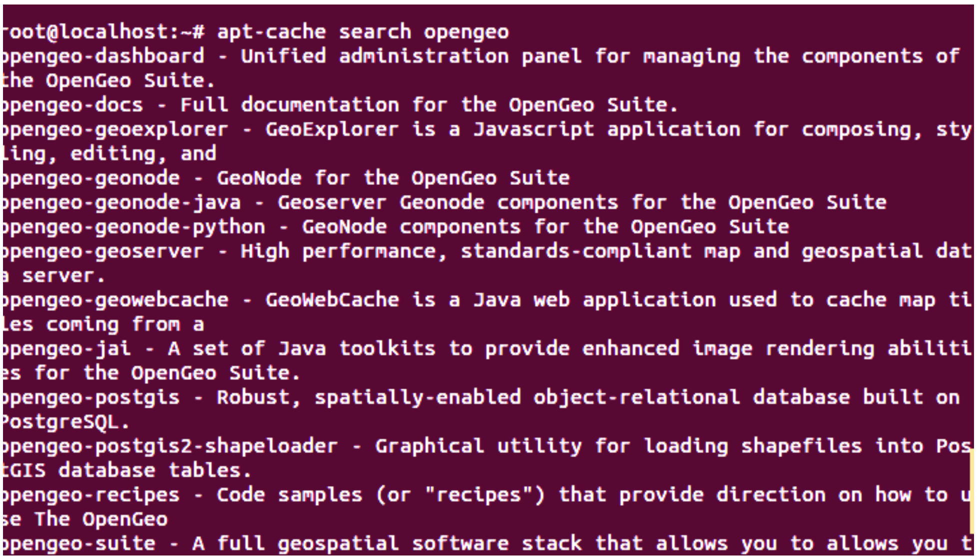

Figure 29: OpenGeo Packages

7. Install the OpenGeo Suite package (opengeo-suite):

   apt-get install opengeo-suite

8. If the previous command returns an error, the OpenGeo repository may not have been added properly. Examine the output of the apt-get command for any errors or warnings.

9. During the installation process, you will be asked a few questions. The first question is regarding the proxy URL that GeoServer is accessed through publicly. This is only necessary if GeoServer is accessed through an external proxy. If unsure, leave this field blank and just press [Enter].

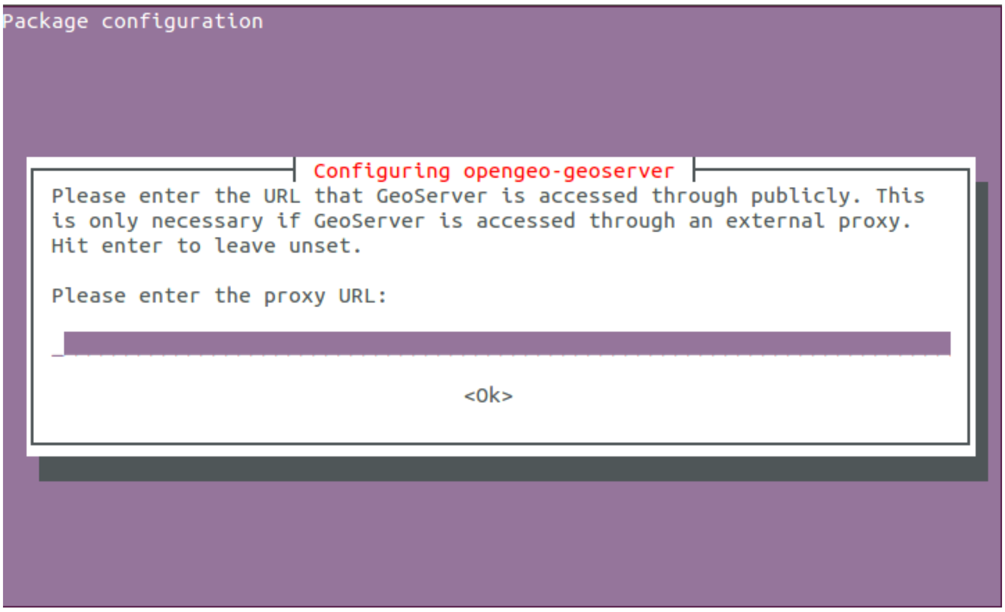

Figure 30: Configure GeoServer URL

10. You will then be prompted for the name of the default GeoServer administrator account. Press [Enter] to leave it at the default of “admin”, or type in a new name.

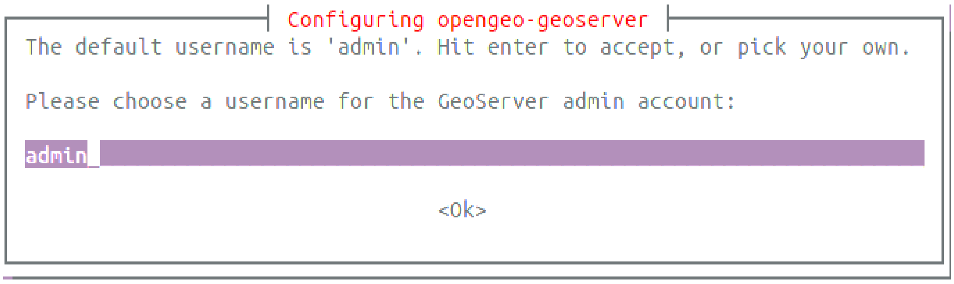

Figure 31: Configure GeoServer Username

11. Next, you will be asked for the default GeoServer administrator password. Press [Enter] to leave it at the default of “geoserver”, or type in a new password

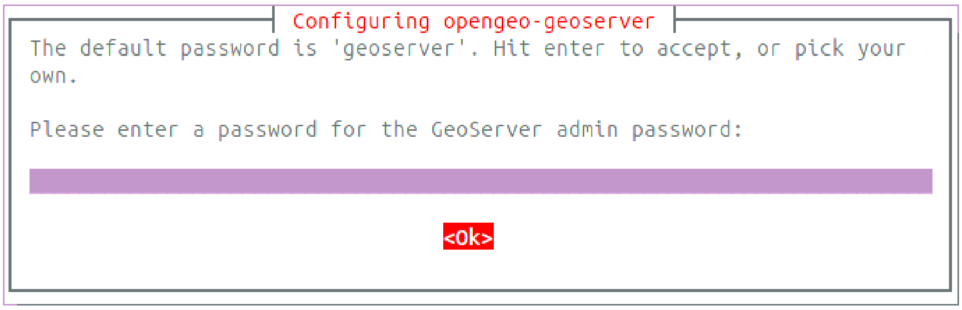

Figure 32: Configure GeoServer Password

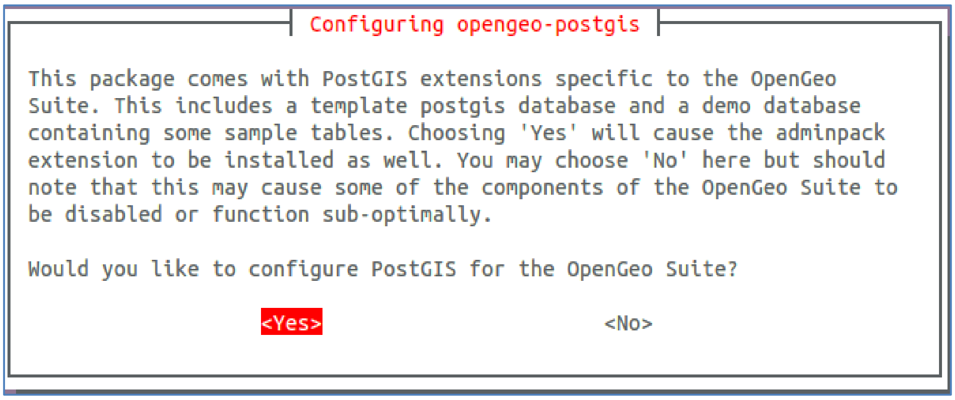

Figure 33: Configure PostGIS for OpenGeo Suite

12. You will be asked if you want to install OpenGeo Suite-specific PostGIS extensions. Press [Enter] to accept.

13. If any other warning or dialog boxes show up, you can cycle through them by pressing [Alt-O].

14. You can launch the OpenGeo Suite Dashboard (and verify the installation was successful) by navigating to the following URL: http://localhost:8080/dashboard/

Appendix B

B1 Database Creation and Table Schema Development

a) Database creation procedure in a PostgreSQL database cluster

   a. Issue the following command as “postgres” user in your linux terminal

      createdb msc ;

   b. Log into the database by issuing the command below

      psql msc

   c. Enable PostGIS functionality on the database know named “msc”

      create extension postgis;

b) Table names

   a. School
   b. sponsor
   c. mean_score
   d. grade
   e. feedback
   f. constituency
   g. counties
   h. nairobi_county

c) Schema tables implemented in PostgreSQL DBMS with the PostGIS plugin.

Schools schema

CREATE TABLE school (gid serial NOT NULL, school_code character varying(15) NOT NULL,name character varying(50),address character varying(50),category character varying(15),sponsor_id smallint,gender character varying(25), day_or_boarding character varying(25),ordinary_or_special character varying(25),enrollment smallint,teaching_staff smallint,pupil_teacher_ratio numeric,tsc_male_teachers smallint,tsc_female_teachers smallint,local_authority_male_teachers smallint,local_authority_female_teachers smallint,pta_board_male_teachers smallint,pta_board_female_teachers smallint,other_male smallint,other_female smallint,non_teaching_staff_male smallint,non_teaching_staff_female smallint,acreage double precision,latt double precision,longg double precision,district character varying(25),division character varying(25), location character varying(25),sublocation character varying(50),zone character varying(25),constituency character varying(25),province character varying(25),geom geometry(Point,4326),CONSTRAINT school_pkey PRIMARY KEY (gid),CONSTRAINT school_school_code_key UNIQUE (school_code))WITH (OIDS=FALSE);ALTER TABLE school OWNER TO postgres;

Sponsor

CREATE TABLE sponsor(sponsor_id serial NOT NULL,sponsor character varying(50),CONSTRAINT sponsor_pkey PRIMARY KEY (sponsor_id),CONSTRAINT school_sponsor_id_fkey2 FOREIGN KEY (sponsor_id)REFERENCES sponsor (sponsor_id) MATCH SIMPLE ON UPDATE CASCADE ON DELETE CASCADE,CONSTRAINT sponsor_sponsor_id_key UNIQUE (sponsor_id))WITH (OIDS=FALSE);ALTER TABLE sponsor OWNER TO postgres;

Mean_score

CREATE TABLE mean_score(mean_score_id serial NOT NULL,year character varying(4),mean_score double precision,school_code character varying(15),CONSTRAINT mean_score_pkey PRIMARY KEY (mean_score_id),CONSTRAINT mean_score_school_code_fkey2 FOREIGN KEY (school_code) REFERENCES school (school_code) MATCH SIMPLEON UPDATE CASCADE ON DELETE CASCADE,CONSTRAINT mean_score_mean_score_id_key UNIQUE (mean_score_id))WITH (OIDS=FALSE);ALTER TABLE mean_score OWNER TO postgres;

CREATE INDEX fki_mean_score_school_code_fkey2 ON mean_score USING btree (school_code COLLATE pg_catalog."default");

CREATE INDEX fki_school_code_fkey ON mean_score USING btree (school_code COLLATE pg_catalog."default");

Grade

CREATE TABLE grade(grade_id serial NOT NULL,school_code character varying(15),year character varying(4),gender character varying(1),grade_attained character varying(2),mean_grade smallint,frequency smallint,CONSTRAINT grade_pkey PRIMARY KEY (grade_id),

CONSTRAINT grade_school_code_fkey2 FOREIGN KEY (school_code)REFERENCES school (school_code) MATCH SIMPLE ON UPDATE CASCADE ON DELETE CASCADE,CONSTRAINT grade_grade_id_key UNIQUE (grade_id))WITH (OIDS=FALSE);ALTER TABLE grade OWNER TO postgres;

CREATE INDEX fki_grade_school_code_fkey ON grade USING btree (school_code COLLATE pg_catalog."default");

CREATE INDEX fki_grade_school_code_fkey2 ON grade USING btree (school_code COLLATE pg_catalog."default");

Feedback

CREATE TABLE feedback(fedback_id serial NOT NULL,school_code character varying(15),description character varying, contact character varying(50),name character varying(25),CONSTRAINT feedback_pkey PRIMARY KEY (fedback_id), CONSTRAINT *feedback_school_code_fkey2 FOREIGN KEY (school_code)REFERENCES school (school_code) MATCH SIMPLE ON UPDATE CASCADE ON DELETE CASCADE,CONSTRAINT feedback_fedback_id_key UNIQUE (fedback_id))WITH (OIDS=FALSE);ALTER TABLE feedbackOWNER TO postgres;*

CREATE INDEX fki_feedback_school_code_fkey ON feedback USING btree (school_code COLLATE pg_catalog."default");

CREATE INDEX fki_feedback_school_code_fkey2 ON feedback USING btree (school_code COLLATE pg_catalog."default");

Constituency

CREATE TABLE constituency(gid serial NOT NULL,objectid_1 integer,objectid integer,area numeric, objectid_2 integer,objectid_3 integer,county_nam character varying(80), const_code numeric,constituen character varying(80),county_ass numeric,county_a_1 character varying(80),county_cod numeric, latt numeric,longg numeric,distance numeric,shape_leng numeric,shape_area numeric,geom geometry(MultiPolygon,4326),CONSTRAINT constituency_pkey PRIMARY KEY (gid))WITH (OIDS=FALSE);ALTER TABLE constituency OWNER TO postgres;

CREATE INDEX constituency_geom_gist ON constituency USING gist (geom);

Counties

CREATE TABLE counties (gid serial NOT NULL, county_nam character varying (80), geom geometry (MultiPolygon, 4326), CONSTRAINT counties_pkey PRIMARY KEY (gid) WITH (OIDS=FALSE); ALTER TABLE counties OWNER TO postgres;

CREATE INDEX counties_geom_gist ON counties USING gist (geom);

Nairobi County

CREATE TABLE nairobi_county(gid serial NOT NULL,county_nam character varying(80),geom geometry(MultiPolygon,4326),CONSTRAINT nairobi_county_pkey PRIMARY KEY (gid))WITH (OIDS=FALSE);ALTER TABLE nairobi_county OWNER TO postgres;

CREATE INDEX nairobi_county_geom_gist ON nairobi_county USING gist (geom);

d) Views implemented in PostgreSQL DBMS with the PostGIS plugin. These views are utilized by the web linkage tool.

Grades View

CREATE OR REPLACE VIEW grades AS SELECT school.,grade.year, grade.gender AS sex, grade.grade_attained, grade.mean_grade,grade.frequency*

FROM public.grade, public.school

WHERE school.school_code = grade.school_code;

Shule View

CREATE OR REPLACE VIEW shule AS SELECT sponsor.sponsor AS sponsor,school.school_code AS school_cod,school.name AS name,school.address AS address,school.category AS category,school.gender AS gender,school.constituency, school.day_or_boarding AS day_or_boa,school.ordinary_or_special AS ordinary_o,school.enrollment AS enrollment,school.teaching_staff AS teaching_s,school.pupil_teacher_ratio AS pupil_teac,school.tsc_male_teachers AS tsc_male_t,school.tsc_female_teachers AS tsc_female,school.local_authority_male_teachers AS local_auth,school.latt AS latt,school.longg AS longg

FROM sponsor join school

ON school.sponsor_id = sponsor.sponsor_id ;

Mean View

CREATE OR REPLACE VIEW mean AS SELECT school.gid AS gid,school.school_codE AS school_cod,school.name AS name,school.address AS address,school.category AS category,school.sponsor_id AS sponsor_id,school.gender AS gender,school.day_or_boarding AS day_or_boa,school.ordinary_or_special AS ordinary_o,school.enrollment AS enrollment,school.teaching_staff AS teaching_s,school.pupil_teacher_ratio AS pupil_teac,school.tsc_male_teachers AS tsc_male_t,school.tsc_female_teachers AS tsc_female,school.local_authority_male_teachers AS local_auth,school.local_authority_female_teachers AS local_au_1,school.pta_board_male_teachers AS pta_board_,school. pta_board_female_teachers AS pta_boar_1,school.other_male AS other_male,school.other_female AS other_fema,school.non_teaching_staff_male AS non_teachi,school.non_teaching_staff_female AS non_teac_1,school.acreage AS acreage,school.latt AS latt, school.longg AS longg,school.district AS district, school.division AS division, school.location AS location, school.sublocation AS sublocatio, school.zone AS zone,school. constituency AS constituen, school.province AS province, mean_score.mean_score AS mean_score, mean_score.year AS year

FROM

school join mean_score

ON

mean_score.school_code = school.school_code ;

Mean View

CREATE OR REPLACE VIEW zote AS SELECT school.gid AS gid, school.school_code AS school_cod, school.name AS name, school.address AS address, school.category AS category, school.gender AS gender, school.day_or_boarding AS day_or_boa, school.ordinary_or_special AS ordinary_o, school.enrollment AS enrollment, school.teaching_staff AS teaching_s, school.pupil_teacher_ratio AS pupil_teac, school.tsc_male_teachers AS tsc_male_t, school.tsc_female_teachers AS tsc_female, school.local_authority_male_teachers AS local_auth, school.local_authority_female_teachers AS local_au_1, school.pta_board_male_teachers AS pta_board_, school.pta_board_female_teachers AS pta_boar_1, school.other_male AS other_male, school.other_female AS other_fema, school.non_teaching_staff_male AS non_teachi, school.non_teaching_staff_female AS non_teac_1,school.acreage AS acreage, school.latt AS latt, school.longg AS longg, school.district AS district, school.division AS division, school.location AS location, school.sublocation AS sublocatio, school.zone AS zone, school.constituency AS constituen, school.province AS province, sponsor.sponsor AS sponsor

FROM school join sponsor

ON sponsor.sponsor_id = school.sponsor_id;

Appendix C

C1 Installation and Configuration of the Development Environment

The procedure is similar to Appendix A that shows how to install and configure on a development environment with the exception of the rigorous authentication mechanisms. Additionally, a Desktop GIS environment was set-up in a Linux box using the procedure described below

a) Perform a system clean-up by issuing the following commands

apt-get autoclean

apt-get autoremove

b) Add to sources by issuing the following command

apt-add-repository ppa:ubuntugis/ubuntugis-unstable

apt-get update

c) Install QGIS, python plugins and GRASS plugins by issuing the following commands

apt-get install qgis

apt-get install python-qgis

apt-get install qgis-plugin-grass

Appendix D

D1 Data Manipulation Queries for Loading Attribute Data into Non-Spatial Tables

Data manipulation queries were created to migrate data from spreadsheets into the database for the entities school, mean_score, grade and sponsor. A full set of all data loading queries are found in the attached CD in the folder "code/msc/backup/Queries". The respective files are school.sql, school_location.sql, school_update.sql, mean_score.sql and sponsor.sql

Nonetheless, below are the SQL codes for migrating data into the entity sponsor.

```
begin;
INSERT INTO sponsor ( sponsor) VALUES ( 'CENTRAL GOVERNMENT/DEB');
INSERT INTO sponsor ( sponsor) VALUES ( 'COMMUNITY');
INSERT INTO sponsor ( sponsor) VALUES ( 'LOCAL GOVERNMENT AUTHORITY');
INSERT INTO sponsor ( sponsor) VALUES ( 'NGO/CBO');
INSERT INTO sponsor ( sponsor) VALUES ( 'PRIVATE INDIVIDUAL');
INSERT INTO sponsor ( sponsor) VALUES ( 'PRIVATE INDIVIDUAL/ORGANIZATION');
INSERT INTO sponsor ( sponsor) VALUES ( 'RELIGIOUS ORGANIZATION');
commit;
```

Appendix E

E1 Data Manipulation Procedure for Loading Shapefiles into the Spatial Tables

The shell command named "shp2pgsql" was used to load shapefiles - into the database named "msc" into a PostgreSQL database cluster hosted in a Linux box - containing existing data on constituency, county and Nairobi County layers into the entities constituency, county and nairobi_county respectively.

```
/usr/lib/postgresql/9.2/bin/shp2pgsql -ad -D -s 3857 -I constituency.shp public.constituency | psql -d msc
/usr/lib/postgresql/9.2/bin/shp2pgsql -ad -D -s 3857 -I county.shp public.county | psql -d msc
/usr/lib/postgresql/9.2/bin/shp2pgsql -ad -D -s 3857 -I nairobi_county.shp public.nairobi_county | psql -d msc.
```

Appendix F

F1 Web Linkage Tool Resources

Attached in the project report is a DVD that contains web based geo-visualization resources. At the root directory we have a folder named "MSC Project" organized into three sub directories;

- docs
- GIS
- Code

The folder "docs" contains the project report. The "GIS" folder contains geospatial resources e.g. geodatabases, shapefiles that were used in authoring and publishing map services in the Esri cloud as well as into LINODE cloud.

The folder "Code" is a repository containing all the programming source codes for the web linkage tool. A copy of the repository is hosted in GITHUB (https://github.com/) and can be accessed from the link - https://github.com/dmuthami/msc . The above code repository will continuously be maintained for some time before reaching maturity and thereafter maturity after six months of project submission and approval.