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DEVELOPING A GIS WEB BASED INFORMATION SYSTEM FOR POPULATION DATA MANAGEMENT

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Dedication

In dedication to God, my loving mum and dad.

Acknowledgement

It is with a humble heart I express my gratitude to God for having seen me through the postgraduate studies journey. It has had its fair share of challenges and through His grace I have weathered the storm.

My gratitude also is extended to my family and in particular my parents for their unfailing moral, financial and motivational support. To you I am indebted.

To my able supervisor Mr. D.K Macoco, thank you for the insights, selflessness and patience you extended me throughout the project period, I am and will always be grateful. To the department, the Professors and Lecturers thank you for sharing the wisdom and knowledge as with it I have emerged better and grown holistically.

Finally, to my classmates, a new web of professional network and friendship has been established since the day we set foot into our masters' class. You have encouraged me and your fortitude and determination as a class has been a pillar as we matched ahead. God bless you all and as we conclude, let us go make the world a better place in our own small ways.

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Abstract

The status of population data currently is not up to date and largely based on manual systems. This is so because despite the biggest databank being at the Kenya National Bureau of Statistics custody, a large amount of the same data is held by other organizations such as the many non-governmental organizations (NGOs) and Government agencies within Kenya. This has resulted in conflict of interests in the data and due to lack of standardization procedures, sharing and discovery of the data is also a big challenge in Kenya.

Web GIS has been identified as a powerful tool that easily and effectively can disseminate integrated spatial and statistical information about the population online via a web browser. All that is required for this endeavour is the internet map server for this case ArcGIS server. For the rendering to be as expected, the various data layers need to be pre-processed such that they are in the same projection and be standardized for ease of sharing and interoperation. The database to be utilized need to be properly formulated with the schemas having the appropriate fields and populated accordingly before utilized locally and also published online.

The system would be a critical tool for online provision of population data to planners and other development agencies for on demand analysis to support decision making. This will go a long way in reducing the amount of time to reach certain critical decisions thus efficiency enhanced. The ability to model in a GIS environment is also scaled by the system allowing users to model different 'what if scenarios' with the availed data for better appreciation of their interest at hand

In future, the prototype will need more patching to enhance it and improve its capability especially with regard to user interaction and analysis scalability. For instance, the aspect of multi-layer analysis and overlay need to be investigated and implemented in the web environment as many factors come into play while for instance thinking about population of a given region. The issue of geodata rights management also needs to be investigated as it is still a very grey area especially in Kenya. This is in appreciation that population data is sensitive data and injury can be occasioned hence need for relevant policy framework to support the dissemination in web GIS platforms as demonstrated on the prototype.

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List of Abbreviations

GDO	Geographic Data Objects
ASP	Active Server Pages
CGI	Common Gateway Interface
JDBC	Java Database Connectivity
DBMS	Database Management Systems
CSS	Cascading Style Sheet
API	Application Programming Interface
DOM	Document Object Model
XML	Extensible Markup Language
GIS	Geographic Information Systems
GPS	Global Positioning System
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
DHTML	Dynamic HyperText Markup Language
JVM	Java Virtual Machine
IMS	Internet Map Server
URL	Unified Resource Locator
JSP	Java Server Pages

CHAPTER 1: INTRODUCTION

1.1 Background

The management of population data generated after every 10 years when Kenya conducts its census, an activity enshrined in the constitution. Several initiatives have been utilized to manage it since 1948 when the colonial government carried out the first census in Kenya. The main agenda for the said initiatives was to organize the data for ease of analysis, access, archiving, and visualization for various applications (Wiesmann, et al, 2014).

It is important to note that every utilization of population data is unique and thus requires individualized key elements that will support its application in the field. As such, the main question asked before population data is applied in any decision support forum is whether it is fit for use and also the verifiability of its source. Thus the determination of the data precision and accuracy of representation forms the basic initial facets that are considered as suitability test for a given population data repository.

1.2 Problem Statement

The population data available is in form of excel tables and is scattered in various databases that are maintained by different organizations in Kenya. It is obtainable in the form of HTML files from various websites especially government maintained but which are unstructured. This means that they are non-compatible and non-interoperable with normalized databases hence making it difficult for the end user to extract information to satisfy specific needs.

The data on population has both non-spatial and spatial attributes that interest the user. This presents a big challenge when the users of population data endeavour to gather this information from static maps, charts and other visual devices from different websites spread across Kenya. This is because there is no centrally located database with a well maintained website that is designed to offer integrated population data request retrieval and while at it be reliable. The first problem therefore is that, the spatial aspect of population data is not occasionally well maintained and also depicts gaps with regard to coverage. Secondly, the spatial reference applied to the different population data is dissimilar and in most cases not georeferenced. This makes it very difficult to carry out a spatial comparison of the population data or allow further spatial measurements and analysis to be done to enhance understanding.

Thirdly, the static devices applied to represent most of the population dataset available is impossible to change in an effort to make it suit the users need. For instance, it is not possible to carry out spatial analysis of the static data, change the scale for better visibility or at the least select to display an area of interest.

The fourth issue is that most of the current population information available is inform of charts and tables of figures with no backend link to their location to spatially reference the data. This therefore makes the user of the data lack the full integration of utilizing the data as it is limited to only visual analysis of its developer's choice mode of display. The other important spatial and non-spatial information that may be of importance include, topography of the area of reference, other resources on the ground utilized by the population, land use and land cover information, transport networks among others that will better help to explain the population dynamic visualized. Therefore, for the reasons advanced above it becomes difficult for integrated information to be found on population in Kenya.

Therefore this research seeks to:

- Develop a prototype information system that is web based capable of disseminating and managing integrated population data.
- Come up with access control protocol mechanism to protect integrity and security of the data disseminated deemed sensitive
- Propose legal considerations to be implemented in the event the prototype is assimilated into the any mandated body dealing with population data

1.3 Objectives

Main objective

- Develop a web based GIS system for population data management.

The specific objectives are:

- Analyse user needs
- Analyse available softwares in the market for internet map server with an objective to point out the most appropriate and applicable for a population data server
- Design a web-based GIS population data management system
- Test the prototype system

- Reinforce the security structure of the web map shared over the platform with a keen focus on data security and access control.

1.4 Justification for the Study

The integrated information, is key for proper population management in Kenya and in any republic in the world. For instance, an investor seeking to build a community health facility, will need integrated population information to come up with the ultimate locality where the impact of the facility will be maximum to realize a healthy populace. It should be easily accessible and locatable and as such data on infrastructure, topography and traditions of a people would interest such an investor. Moreover, information on the buying capacity of the people will be crucial to the investor so that to help in pricing the services at the facility hence better decisions made.

Information sharing is critical in supporting decision making processes. However, information shared needs to be of high integrity and reliable hence proper structures have to be in place from the point of gathering or collecting the raw data, database design to be populated, all to ensure ease of overlaying and integrating the final piece of information with other important datasets available. This allows for complex modelling, analysis and querying better understanding. A well designed structure especially of the database makes efforts to enhance it minimal thus increasing its scalability and enhancement to capture aspects not previously incorporated for instance security controls. Population data, is highly sensitive due to it being highly private in nature as it is household based. This makes it sensitive for blatant public dissemination over the internet. In that regard, the website to deal with such data need access control to the database to avoid injury on individuals.

The research is an attempt to develop and implement an easily accessible Web GIS prototype on population information complete with legal aspects applicable and the spatial notation too accompanying the data. The envisioned integrated system will be online and thus easily accessible and is geared towards decision support at all levels that seek to improve the livelihoods of the public in diverse ways. This will be made possible following efficiency improvement for accessing the population related information, ease of conducting analysis hence reduce significantly the period of decision making process. It will also avail the capability of remote governing and management of population datasets available, making information processing timely and on where is basis as GIS queries will be done on-line including the generation of “what if” simulations models on population issues.

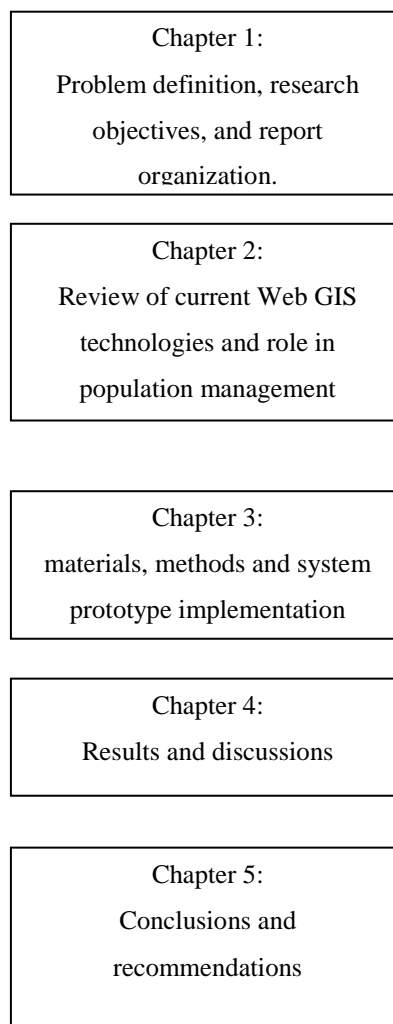
1.5 Scope of work

In order to achieve the objectives set, the study will deal with core components of the Web GIS with respect to population which include data, people, policies and technology. The data will entail both statistical and spatial data. The reason why the statistical data is collected is to enable spatial analysis of statistical data by users. The data will not be collected from the entire organization of Kenya National Bureau of Statistics but only from one of the six directorates in the organization, namely Population and Social Statistics Directorate since it is the major user of the spatial data.

1.6 Organization of the report

The research report will be organized in the following five chapters:

Figure 1.1 Report Organization



Chapter 1: The chapter will introduce the problem the report will handle review the objectives of the study outlining what the research seeks to achieve. This chapter will include the methodology to be applied in achieving the set objectives and lastly will summarize the final report organization and layout.

Chapter 2: The GIS technologies will be analysed with a view to connect their ability with population data management. The different system architectures are compared and the most applicable based on need for the system to be developed chosen.

Chapter 3: The chapter will entail the system design and prototype development with a view of the envisioned web population system. There will be illustrations of the system and its functional aspects. At this state the various enhancements are highlighted and implementation captured

Chapter 4: The results of the research will be discussed and outlined including highlighting the limitations encountered during the study.

Chapter 5: This chapter will conclude the report recommend and suggest future research aspects that can be explored for further study.

CHAPTER 2: LITERATURE REVIEW

2.1 Kenya Population and Housing Census

A population census is a complex and expensive operation as it consumes quite astronomical amounts of money and involves very intricate logistical arrangements, thus, it is usually not possible to carry it out every so often. In Kenya, like in many other countries, a census of the population is conducted once in every ten years as per the United Nations (UN) recommendations. While mapping exercise is expected to be completed at least one year before enumeration and it is in view of this that plans to undertake the cartographic mapping begin at least three years before the census enumeration.

To date, Kenya has undertaken seven population censuses, two before independence and five after independence with the first one being conducted in 1948 and successive ones in 1962, 1969, 1979, 1989, 1999 and 2009 respectively. The 2020 round of Population and Housing Censuses will be carried out between 2015 and 2025 (DeSA, U. N., 2013). For Kenya, the enumeration is planned to be conducted in August 2019 in conformity with the decennial pattern that Kenya has adhered to since 1969.

Cartographic mapping is a key population census preparatory activity whose outcome has immense contribution to the overall success of the entire census process. However, evidence of mapping and use of maps for 1948 and 1962 censuses does not exist. The third population census was done in 1969 and the available maps used show that the enumeration areas (EAs) were as big as a division. Subsequent to this was that of 1979 which saw an improved mapping process where the sub-location was used as the unit of reference for the EA delineation. Both in the 1969 and 1979 censuses, EA delineation was done mainly in the office with little field work.

In 1989, the village concept was introduced as the unit of reference for EA delineation, an approach that proved to be very successful. With reference to the village concept, an EA was either a village, part of a village or a combination of villages. Similarly, the concept of household listing and structure numbering was introduced. Subsequent census mapping activities i.e. those of 1999 and 2009 were successfully achieved with reference to this concept. However, the introduction of GIS and the use of aerial photographs in mapping urban areas made the work easier, faster and of higher quality.

In view of the forgoing, Kenya National Bureau of Statistics (KNBS) plans to use emerging geospatial technologies for the 2019 KPHC in compliance with UN recommendation for the 2020 round of censuses. KNBS plans to carry out a country wide cartographic mapping using these technologies, which is estimated to culminate in the delineation of approximately 130,000 EAs.

2.2 Geographical Information Systems (GIS)

Many people at individual levels, businesses and corporate entities in Kenya and around the globe have come to appreciate and are enthusiastic to tap into social, political, geographic, economic and environmental digital information to tackle complex practical questions that surround them. This has led to the need to interact and explore geo-referenced digital information which is only made possible through the use of specially designed hardware and software able to handle the spatial dimension incorporated into this digital data. The said hardware and software capable of capturing, storing, analysing and displaying geographically referenced information, that is data defined by location, is called a geographic information system or a GIS (Broda, and Baxter, 2003).

2.2.1 How GIS works

GIS models the world and displays it on a computer screen. This can be equated to how cartographers have been mapping since early days by drawing maps of their expeditions on paper. This means that GIS and maps are similar in that they show what is at a given location and at a particular time. However, the synergy and flexibility that a GIS system offers beyond that of a paper map include: one can play around with map layers in a GIS environment to give a complete different theme of a particular area on a map. Map scale in GIS, just like in the traditional cartography, influences the size of what appears on screen and the amount of detail visualized although the zooming feature makes GIS superior.

GIS can also be said to derive its superiority from the ability to relate different information in a spatial context and to reach a conclusion about this relationship on the maps. The objects or features in a GIS environment have a location reference in terms of coordinates, predetermined shape and symbol representing its easily identifiable universal characteristics for enhanced understanding. In addition, the organization of features according to relative positions on maps brings forth relationships among features in a given locality. The

relationship is called spatial relationship and when understood through studying it, it helps to solve prevalent problems.

Mathematical shapes are used in maps to model reality on ground where points represent precise locations, lines depict objects that are narrow but with length such as roads while area is used to represent phenomenon on the ground whose size cannot be represented as a point or line. Since figures are limited in terms of the information they can depict, GIS maps uses graphical symbols to add further information about a feature. The scale in a map determines the comparison between actual sizes of objects on the ground and their representative shape-size on the map. However, it is important to mention that scales as used on maps are either large or small scales with respect to what the map represents. A point in case, on a small scale map of Kenya, Nairobi would be a point of a given size. That same Nairobi would be represented as an area complete with abstractions of buildings and other features on a large-scale map (Zlatanova, et al, 2002).

In GIS, limit to the amount of information one can get about what one can see on the map does not apply as is on paper maps. This is pegged on a major capability unique to GIS of storing all map datasets in a spatial database and then linking the various features to their respective information datasets. As a result one is able to query a feature for more information on the go by just clicking on it.

In the geodatabase, information about map features is stored as map attributes. The attributes of a town, for our case, can be its name, population, number of administrative units, kind of settlements in the town, location of industrial parks and bus parks among other details. All this information is formatted in rows and columns and stored as attribute tables in the GIS geodatabase. Each column on the table contains a unique attribute while a row represents a feature. This connection between a map feature and its attribute forms a key unique component of GIS (Mathiyalagan, et al, 2005).

Linking of the attributes and map features, allows interoperability. By so doing, one can access the map features from the table or access the table information about a feature from the map on display. Hence the display on desktop GIS can be customized either from the attribute table of the feature by selection or from the map features themselves. Importantly, the link interoperation also means that any change on the attribute table results in the change on the map and vice versa as the tables save map features as themes and are managed as so. A

theme therefore refers to a single class of features for instance buildings, lanes, car parks, major roads and restaurants which are related and thus easily manipulated.

Themes or data sets of a given geographic area constitutes that area's geospatial database. The architecture of a geospatial database is unique and complex for it to achieve required flexibility. Key among them is addition of new themes to a database of old ones. On the database it is also possible to merge tables of similar characteristics to form a new complex theme with more attribute information of a feature for a given geographic area. This means that the need for a GIS database and what use it will be put to, will determine the best design for any client. Queries are applicable on the GIS database which allows a user to interrogate the database. The outcome of the interrogation is highlighted uniquely where it satisfies the query parameters indicated on the attribute table and on displayed map. (MacDonald, 2001).

In desktop GIS, information once organized and proper display design developed, the final product is presented as thematic maps and they are enhanced using graphics and charts imported from other analytical computer programs which allow further explanation of the displayed results. The presentations one creates can be printed out, projected or just displayed on a computer screen to an audience. Desktop GIS allows, in case the audience or objective at conception changes, the displayed map information is changed appropriately easily to reflect the changes without having to start over.

2.2.2 Data in GIS

GIS data can be said to be into three broad categories: spatial data, tabular data and raster data. Spatial or location data contains the X,Y coordinates referencing unique locations and outlines of features. Tabular data is descriptive in nature and is collected and compiled in excel sheets which are later linked using GIS to features. Image data on the other hand comprises of satellite imageries, aerial orthophotos and scanned topographical sheets. Data can be created using the various GIS data capture techniques available or bought depending on availability of resources and timeline to delivery of the project intended. For instance, handheld GPS gadget generates coordinates of parcel of land for adjudication purposes. On such a database for land parcels, tables are developed in a GIS environment presenting the parcel location and owner information, parcel number, size and the activity being undertaken in the parcel. The alternative to this method of data creation is purchasing data from organizations that have carried out surveys that may have created required datasets. However for imageries, mostly due to the high level of equipment required for their capture, they are

bought from firms that specialize in the collection of such data using satellites and other platforms (Arctur, and Zeiler, 2004).

Many organizations across the world use the same basic geospatial data for their application but due to lack of a platform where they can identify this data, the organizations spend a lot of resources duplicating the same data which is very expensive. In Kenya geospatial data is produced and used by both government and private organizations. These organizations duplicate this data due to lack of a systematic way of accessing and sharing it. For instance Kenya National Bureau of Statistics duplicates geospatial data every census held after every 10 years.

There should be good coordination on geospatial data to ensure all organizations that produce geospatial data adopt same standards and a common geo-referencing system to enable integration of the various data sets produced. The harmonization of the standards will help come up with national geospatial standards. Data sharing should be encouraged even if at a small fee in order to reduce duplication of data which is very expensive in terms of money and time.

In conclusion therefore desktop GIS is mainly associated with data use synonymously called manipulation and not creation. This is because it provides excellent abilities for acquired data manipulation leading to making maps, generating reports and analytical charts. Examples of desktop GIS softwares include but not limited to Intergraph GeoMedia, MapInfor professional, ESRI ArcMap, QGIS, Clark Lab's Idrisi among others.

2.2.3 GIS Applications for Population Management

Population and housing census is an activity that is spelt out in the Kenyan constitution and the Kenya National bureau of statistics mandated to carry-out the same. Being a very intricate activity, with diverse needs and constrains makes managing it a very complicated problem. This is because, it has strict deadlines to be adhered to, it is a very expensive undertaking calling for massive investments by the government, due to the interior nature of some region, accessibility is a challenge and also hostility may be experienced in the field. The constant change of administrative boundaries also presents a challenge, as every 10 years the boundaries have to be done afresh (Liu, 2007).

The population data, being very rich in content, therefore means that it cannot be represented in a relational database as this will limit the representation of the diversity thereof. As such,

GIS becomes a very key tool that integrates the population data with the spatial aspect of the same and visualize the information. This assists in population data development and management in a compounded manner. Thus, the major applications of GIS that can be highlighted with respect to population data are based on three major perspectives; database development, mapping and spatial analysis:

- The mapping capability of GIS is used to generate administrative boundaries and apportion manageable enumerations areas.
- The database functionality of the same system utilized in developing a geodatabase, populating it with data collected and managing it.
- The GIS spatial analysis functions can be used to analyze population distribution and growth ratio information.

This will be key in the rolling out sustainable development projects at the grass root level which will better boost the growth of Kenyan economy. This follows that a rich variety of information can be documented and integrated about the Kenyan population and using overlay function one is able to make key decisions.

The rationale for using GIS in population census in Kenya “is to build on the local knowledge and articulate traditional concepts and present them in a format that facilitates transactions with external agencies” (Mohamed and Ventura, 2000). As a result, GIS becomes a unique platform that generates map products for various applications hence information dissemination and also manage the population databank.

However, although GIS technology has in the recent past been adopted widely in Kenya as is in the world over, the full capacity and potential is yet to be realized and appreciated with respect to decision support at various levels in the society. This is despite literature indicating just a few but manageable technical challenges in bringing on board GIS as a platform for population data management. The major challenges however are from the political and social sectors where for example in Kenya no policy framework to smoothen the adoption process has been put up as well as the vast majority of the populace have not been sensitized on the system.

One of the main challenge identifiable with applying GIS with population data is the difficulty encountered by mapmakers, economists, statisticians and social scientist while attempting to accurately capture population data with all its richness. This is because it presents complex relationships that need to be captured and abstracted presenting a methodological difficulty synonymous in human subjects studies.

There is also political obstacle occasioned by lack of good will. The influence of local and national politics in carrying out census cannot be overlooked. The knowledge that the data generated is used in national resource allocation makes the exercise a thorny issue prone to abuse. As such cases of inflated figures become common and if not carefully handled and mitigated the reliability of the data is highly compromised. Thus, the incorporation, ownership and civic educating the society are key components to implementing an all-inclusive GIS platform for population data management to support decision making at all levels applicable (Lo, and Concepts, 2002).

Population data in any nation is a pillar that supports different development agreements and negotiations between a nation and various partners. The GIS platform performs very remarkably in analyzing the data and modelling the various case scenarios at hand. However, in Kenya despite the technology being available, there is a big deficit on the number of technical personnel who can with ease fully utilize the GIS technology hence tap into its intrinsic ability. There is also limited access to quality data that is structured to be utilized with GIS hence needing any entity implementing the technology to set up its own database from ground up. There is a challenge with policies regarding spatial data locally regarding its sharing, cost and distribution which is still not developed comprehensively to allow full roll out of the platform over the internet.

Despite the challenges, a number of approaches can be utilized for instance the universities to be commissioned to come up with a comprehensive GIS curriculum at various post-secondary education levels so as to have a pool of trainees to be engaged. The national GIS platform needs to be developed, centrally located and managed to create access for all and nature societal contribution to growing and populating it. This is in an effort to cut cost of data collection and database maintenance for each project or enterprise interested in utilizing GIS as a platform.

Availing basic GIS tools and datasets online in a web based GIS platform is also a good approach that can facilitate members of the general public unable to purchase the whole GIS package, a platform for data analysis. The web based platform should have a user friendly interface and outline to accommodate both expert and novice users of GIS technology. However, the debate on unrestricted population data access over an internet remains very highly contested as it regards sensitive information, which requires protection due to injury that can result in the event of malicious application.

2.3 Web-Based GIS

The World Wide Web (WWW) has grown as a unique space and has become one of our major channels of information and communications. The web provides a wealth of information to an incredibly diverse user population and designers, reflecting the different challenge of developing Web Based mapping. Web mapping is based on the invention of the World Wide Web and on a set of Open Geospatial Consortium (OGC) standards of which the Web Map Server (WMS) is the best known. Most web-based maps are integrated into websites used by people without experience of web-based maps or Geographical Information Systems.

Despite the rapid development of web mapping, web-based GIS and more recently web geospatial services, there remains a variety of issues that challenge students, researchers, developers, professionals and public users in the field. While some of these issues have been well discussed and addressed, others are still emerging.

The use of GIS in analysis, display and archiving population a data cannot be overlooked. This is despite currently the access to the GIS as a platform and it full utilization being limited in scale due to challenges previously highlighted. The web has revolutionized many aspects in life including the handling of spatial information, how it's is accessed and its distribution. GIS technology has not been left behind, with the development of web GIS, the technology has been made scalable, easily accessible thus cost benefits realized as full installation of the system is no longer necessary. As a result more users of the technology have been accommodated with just little limitations put up where necessary for security reason while interacting with the share resources.

In this chapter, an effort is made in comparing and contrasting the various Web GIS technologies available, with a keen focus on the commonly used architectures, web viewers, and map servers. According to Fu and Sun, (2010), ESRI ArcGIS server and Geoserver Web Map being the most common platforms for this application, will be focused on in this report.

2.3.1 Global outlook of Web mapping Application

A number of projects around the world can be pointed out as to have utilize the web GIS successfully. Notable examples include in Canada and the USA where agencies concerned have succeeded in creating a platform where spatial data is made available to users including map rendering services over the internet. It is key to mention that in this platforms, the data which is considered public good as it has been put up using state resources, is also

downloadable into local drives for further analysis over and above allowing interactive display of the same on the web (FGDL, 2005).

There are however some map services that are strictly meant for online viewing and appreciation thus the data cannot be downloaded by a client. In the website, 'Surf Your Watershed' a platform by US Environmental Protection Agency, only maps are rendered on the website but data sets are not accessible (U.S. Environmental Protection Agency, 2004). An example of interactive web GIS platform in is the Watershed Atlas site by Seminole County in Florida where clients are able to actively interact with the service including conduct queries and analysis (Florida Seminole County, 2004).

On addressing the various challenges in web mapping, OMIMA a web map application by Fisheries and Oceans Canada (DFO) went into great lengths to prove that it is possible to work with raster and vector datasets concurrently to communicate efficiently over the internet (Michalak and Wojnarowska, 2002). For Iqualuit city, an elaborate interactive map of the city and its surrounding is available on the internet (Siekierska et al, 2000). In Kentucky, an example exists of a community centered web map service by the water information authority where citizens are able to share their local knowledge of water resources around their neighborhoods which is integrated with the officially held data on the same by the authorities (Harvey, 2002). This allows community participation in the decision made by the authority enhancing democracy and ownership of various decisions reached for implementation.

2.3.2 Overview of Web-Based GIS Technology

At the beginning, web based GIS was majorly developed to visualize maps online with the example for platforms such as MapViewer (Xerox, 2004). This later evolved out of need to development of query capabilities on the maps visualized hence the emergence of the MapServer platform by University of Minnesota (2004) and USCB Tiger mapping service (U.S. Census Bureau, 2004).

The above examples helps to conclude that a good web GIS has several key components which are; the client, the connecting network, and the database hosting server. The three main components are arranged in that we have a server side where the database resides and most of the processing and responses are processed and responded to and the client side where the display of the map is rendered using a web browser. Major developments have evolved this cycle from the older one of map publishing to one that enables web mapping applications.

2.3.2.1 Publishing Web Map

This refers to the provision of geospatial data online without any GIS aspect to the data. As such all that is required to achieve this is a web server and compiled maps to be shared. The only other requirement is that the maps should be saved in a format which is browser friendly to allow distribution for example in JPEG or GIF image formats. This follows that, it is standard application for web browsers to communicate using HyperText transfer protocol (HTTP) and the responsible server to give maps requested to display on the browser. The HTTP is the standard for transferring World Wide Web documents. The simplest HTTP message is "GET url", to which the server replies by sending the named document.

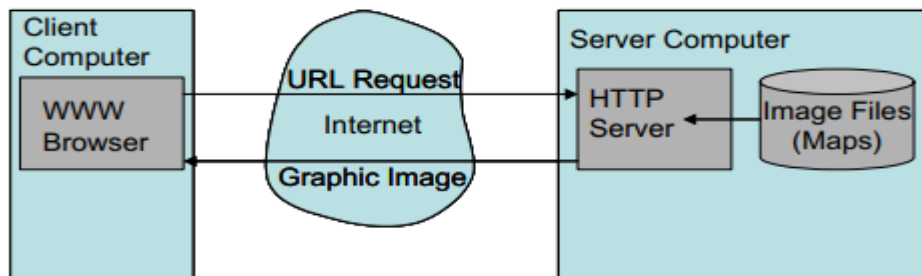


Figure 2.1: Internet Map Publishing depiction (Plewe, 1997).

Beyond this static maps, is the display of maps with hyperlinks or what is commonly referred to as clickable images. This is made possible with the use of HTML (HyperText Markup Language) which makes it possible to create hyperlinks that link to other resource URLs. As a result, clicking on the image, is equivalent to sending a request to the web server to provide further information not on display but relevant to what is displayed.

2.3.2.2 Web Interactive GIS Mapping

Whilst static publishing of maps is equivalent to using paper maps since a client is limited with regard to level of interaction with the map another option exists of publishing interactive map. The static map publishing is less interactive because, HTTP server has no capacity to change the map based on client's interaction but is merely a platform to convey the map form the sever response. This necessitate the development of web mapping which would allow user-map interaction.

Web maps utilizes a data on a database to compose maps on the go for the clients. This is a dynamic process which takes place on both the client side and the server side of the platform allowing user involvement in the kind of map displayed. Joint Photographic Experts Group (JPEG) and Graphics Interchange Format (GIF) are the standard computer file formats for storing graphic images in a compressed form for general use.

The figure below depicts the interaction in web mapping rendering of interactive maps. In the depiction, the HTTP server connects to a map server hosting a standard GIS software able to carry out the various functions of the mapping software. Thus once the request is received, it invoke a process on the software to act on the data in the database to produce a map in response hence referred to as a GIS server. The result is displayed on the browser thus unlike on the standard computer display qualifying the set up as Internet Map Server.

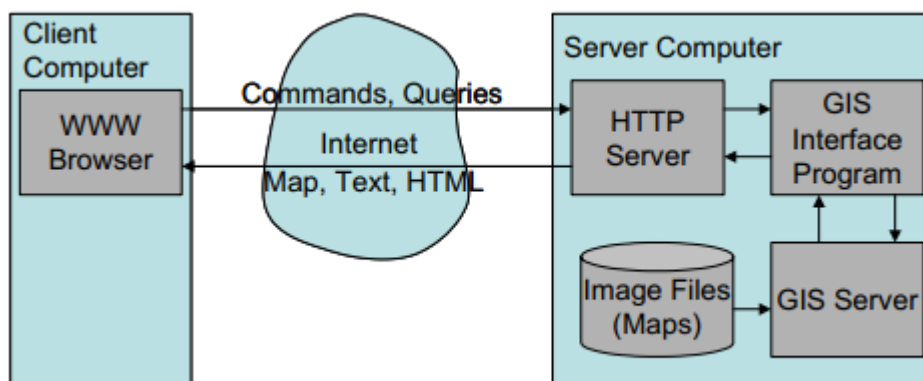


Figure 2.2: Internet Map server Set (Plewe, 1997).

2.3.3 Components of WebGIS

HTTP server

This is a computer whose function is to respond to other computers' request referred to as client computers in a network setup by way of delivering web pages. The communication is made possible by way of the HTTP server having an IP address and a in some cases a domain name (URL) enabling the client computers with the right credentials to discover it hence establish communication. It is therefore possible to convert any computer into a server by way of installing a server software and providing it with internet connectivity.

Interface program

Because there are many ways to link the HTTP server with the GIS server through interface programs, specific applications may adopt various settings based on the different interface programs available. Literature shows there is a common architecture that dominates the early-stage Web mapping applications, as shown in the figure below.

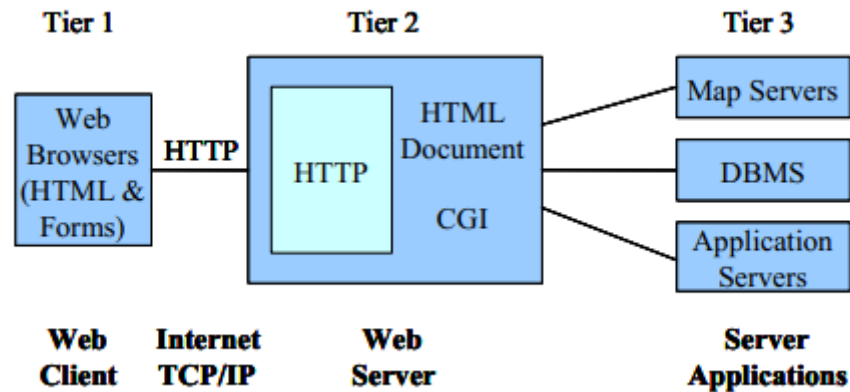


Figure 2.3: Internet GIS Architecture (Tang & Sun, 1997).

In the above set up, a request is sent to the HTTP server by the client via a web browser of the parameters for the map required e.g. extent, layers, scale e.t.c. The HTTP server has no capacity to respond to the request as it does not understand them, it only retrieves HTML files with the received URL. As such, the HTTP server pushes the request to a Map Server which using its mapping capability functions is able to understand the user requests thus enabling the HTTP server to respond. A common gateway interface (CGI) is used by the HTTP server to transact with the map server the users' requests

The interpretation and processing of the request occurs in the server side which hosts the map server and the database management system (DBMS) responsible for search and retrieval of needed data. Therefore, any client-server GIS set up has the capacity to become a map server. This is because the map server only serves to fulfil the requests by the clients and give results where applicable to the Web server via the CGI gateway.

It is the function of the web server to communicate the results of the map server to the web client. As such the web server become the linkage between the client and the map server applications hosted somewhere off client's site. Therefore this form of architecture relies

entirely on server side applications with the web browser being just the display conduit of map created by the server acting on request parameters.

2.3.3.1 GIS server

The market currently has many GIS server packages available to users and marketed by different enterprises. Web GIS servers on the other hand are in their thousands around the world. However, the user requirements of the platform helps in choosing the best applicable one based on need satisfaction on the client side and ease of application.

Key components to consider however include the cost implication of the Web GIS server to be implemented, the skill level of the intended users of the system and the cost of running the web servers. A GIS professional, however, unlike a manager will be more concerned with the functionality of the web servers, system requirements and configurations and the ease with which the server integrates with other servers holding different information (Peng and Tsou, 2003).

Thus the guiding questions to guide the web GIS initial set up and shopping are:

- The GIS program to use
- The system architecture to implement
- The kind of server platform that can easily satisfy needs and execute tasks envisioned
- The most suitable client view i.e. HTML or Java based viewer
- The stability of the system while perform to inform reliability

Having carefully considered the above key guides, then a client is ready to settle on a good platform or at least one that can to a high degree help them achieve their objectives. The most common and popular WebGIS softwares are: Esri's ArcIMS or simply called ArcGIS server and Integraph's GeoMedia WebMap (Geoserver)

a. ArcIMS

The ArcIMS platform is an Esri product who were the pioneer industry layers to apply Web GIS ability in their mapping platform ArcGIS desktop application. Since this initial stages, ArcIMS has been patched and reprogrammed to enable easy creation and publishing of maps

online and to include business logic and data storage workflows coupled with other data management applications all as one package known commonly referred to as ArcGIS server.

Below is an illustration of the ArcIMS structure and workflow logic:

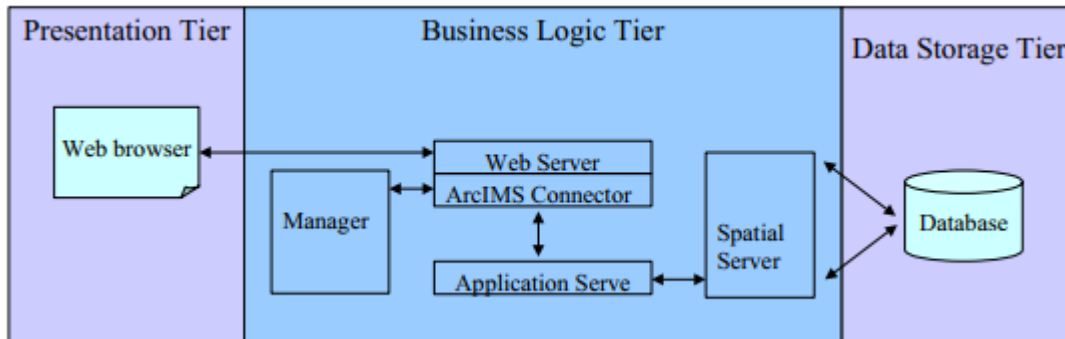


Figure 2.4: Architecture ArcIMS (ESRI, 2004).

i) Display(presentation) tier:

This is mainly the client side platform which presents the user interface of the system commonly referred to as ArcIMS viewers. The main functionality of this tier is to enable the client to send requests to the web server and to view the results in form of data or maps.

There are several types of client viewer that ArcIMS provides: Custom HTML, Java Standard, Java Custom and HTML Standard. The Java viewers are typical of more client side processing ability allowing image support thus can support ArcMap Image, and feature services rendering. On the contrary, the more common web browser HTML viewer needs the use of ActiveX, .NET link, Java connectors or CloudFusion to render custom image services beyond the common image and ArcMap Image.

ii) Business workflow tier:

This is the server side component of the set up that hosts the web server, the application and connectors server, and the spatial data server.

iii) Storage tier:

This is the data bank for the ArcIMS. Besides the components mentioned above, the Web server, Java Virtual Machine (JVM) and servlet engine are supporting components necessary to successfully run ArcIMS. These components are not included and must be supported for use with ArcIMS.

b. GeoMedia WebMap (GeoServer)

This platform was developed and brought into the market in 2004 by INTERGRAPH. The platform is based on the three tier set up as in ArcIMS as illustrated below:

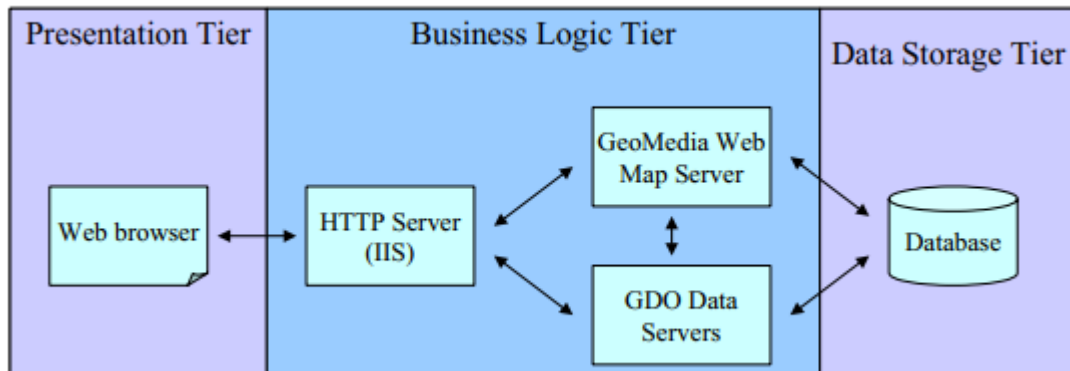


Figure 2.5: Architecture of GeoMedia WebMap (Francica, 2004).

i) Display (Presentation) tier:

In this phase of the set up, it contains the client viewer which is on the web browser. The tier uses an ActiveX component to enable internet connectivity and discoverability and makes use of plug-ins to scale its functionality online hence the user is able to interact with web map on the Geomedia platform. The viewer with the use of plug-ins is able to provide vector and raster viewing capabilities coupled with a powerful client side processing ability enabling the client to execute client side analysis. Dynamic HTML is incorporated to allow further interaction for the client when JPEG images are published on this platform.

ii) Business workflow tier:

This part of the set-up is responsible of processing the user requests and providing the needed connection to the spatial data base. It has got the following distinct parts:

- a HTTP server, specifically Microsoft's IIS. This is what communicates with the web browser hence enabling the user request to be received and transmitted to the Geomedia webmap server and GDO server and communicating the results back to the client via the web browser. In essence it becomes the middleware between the client side and the server side.

- a Geomedia WebMap server – is the component that acts on user request parameters and composes the map required.
- a Geographic Data Objects (GDO) server – this is the platform that integrates the various data formats received from different sources so that communication is established (Francica, 2004). Each data format is managed by a specific GDO server developed internally thus enabling the Geomedia WebMap to retrieve, understand and utilize different data formats without pre-processing as is the case in ArcIMS where translators are used.

iii) Storage tier:

This is where all the data with its original projection and format is stored. The data can be at a central location or in distributed locations. Using GDO, the data is sourced from its location and combined with other relevant data and worked concurrently.

b. Comparison Summary

Below is a table highlighting the difference between ArcIMS and Geomedia Webmap

Table 2.1: Comparison between ESRI ArcIMS and INTERGRAPH Geomedia Webmap

	<i>Advantages</i>	<i>Disadvantages</i>
<u>ArcIMS</u> <u>9.0</u>	<ul style="list-style-type: none"> • Can provide service with or without a required plug-in download • Provides Java and HTML viewer, but customers can also build their own using ASP, ActiveX controls ,ColdFusion, and Java • Easily integrated with other ESRI GIS software 	<ul style="list-style-type: none"> • Must first create an Image or Feature Service • Requires middle-ware XML translation
<u>GeoMedia</u> <u>WebMap</u> <u>5.2</u>	<ul style="list-style-type: none"> • Compatibility and interoperability with other file formats from various databases without conversion. • Provides raster and vector viewing, It also provide rendering and manipulation in the browser. 	<ul style="list-style-type: none"> • Need ActiveX control component for Internet Explorer and plug-in For Netscape Navigator. • Customization of applications can add time and cost to an initially expensive project.

2.4 Digital Right management in WebGIS

2.4.1 Introduction

The complexity encountered and experienced in geospatial information access, discovery and use of the information has hit many professionals and organizations hard as most often they do not squarely fit with the individual interest of a particular party about service to the public, private sector business needs satisfaction, or consumer wants. This has been made more complex with the advent of the internet which has opened up many diverse ways of data sharing and accessing geospatial data through the web making handling of rights to the information more difficult across the board.

In the today's world, free information is so widespread, derived from the government and other sectors. There is also information that can be provided at a cost for use although this information tags a limited right to redistributing. This presents a dynamic environment for geospatial information industry with the trends either influencing the sector positively or negatively hence calling for more effort to be put to accommodate the diverse needs and conditions satisfactorily. This will go a long way to redeem time and resources lost when important progress on the project is curtailed by lack of technologies and a legal framework to straighten and hasten geospatial processes.

2.4.2 Description of GeoDRM

The highly dynamic nature of geospatial data requirements directly makes its enabling technology equally dynamic hence complex. The advent of DRM can be traced back to the era of the internet with the unprecedented development of computer networks across the globe. This shift in communication across the globe shifted the way geospatial data and other content providers view the rights to the data management and together with participating firms and policy formulators in various jurisdictions, efforts were commenced to bridge the imbalance between the technology and the laws governing the platform. The key attribute of the efforts was to handle the massive redistribution capability newly found of materials that are copyrighted but in digital formats.

GeoDRM can thus be understood as development, documenting, passing on, managing and tracking digital geospatial content using a licensing framework to safeguard the rights of the data developers. GeoDRM borrows heavily from Content Management System which is the technology that came up with metadata creation of the content to be distributed in digital

format. The use of workflows to organize the data and storing the same is also utilized in GeoDRM to make data discovery easy. This idea of workflows also makes content retrieval easy where users are categorized as workgroups, information communities or enterprises to enable the administrators of the data to give priority and appropriate levels of access. GeoDRM finally, is dependent on security technologies for information systems available that make it possible to provide trusted infrastructure for DRM and other online transactions that are financially related that enable the procurement of geospatial content rights by the various interest groups (Murthi, and Tadimeti, 2011).

2.4.3 GeoDRM – its relevance and application

Digital rights management synonymously known as DRM is an area within the geospatial spectra that has been discussed, written on and researched in depth and widely. The reason for this wide attention into DRM can be attributed to what can be termed as 'copy protection technology and mechanisms' or 'digital management restrictions' as regards to geospatial data. The two aspects above alluded are however some of the least understood technologies in the contemporary geospatial world up to today. As a consequence, the geospatial digital rights management - GeoDRM has for long been focused on discourse regarding allowing or denial of sharing and copying geospatially related data. For long, regularization, legal, market and technical issues related to GeoDRM have not been put into perspective due to the aforementioned difficulties resulting from the skewness of the previous discussions.

Geospatial Digital Rights Management (GeoDRM) in a broader perspective refers to the utilization of technology to manage data utilization through access of information stored on digital platforms. For instance, concerning the entertainment sector, digital rights management concerns itself mainly with the protection of intellectual property of the artists thus prohibiting the redistribution of the pieces created without proper compensation to the owners. In other instances, DRM is utilized to protect the privacy of information that may be contained in such digital platforms. For instance, in the case of health records captured in a health facility, while making it available for use (Coene et al, 2007).

The geospatial sector as opposed to other sectors which generate and possess digital data, collect diverse spatially referenced data with the main agenda of analyzing it through manipulating it to come up with needed information to support a decision. This is done through classification and altering the data to develop new hybrid information that communicates a given objective intended. The geospatial sector players are also highly

dynamic as compared to players in other sectors about the data. As such the incorporation of technology in licensing for the data use enabling the use of the same at various cost becomes a big challenge. This is over and above ensuring that the data is of high integrity and it benefits trick down to both the users of the data and the developers.

The importance therefore of GeoDRM is towards achievement of better, precise, and equitable utilization and distribution of geoinformation. Thus, GeoDRM seeks to increase awareness and develop acceptable standards to be used for geodata distribution supported by a workable legal framework, memoranda of understanding for distribution rights and specifications for management. Many key institutions in that regard have placed the work on GeoDRM in a context of technical and policy aspect which is meant to make easy the geographic information flow. Therefore, GeoDRM efforts target the private and the public institutions to realize its objective bringing to the table professionals in the geospatial sector at both technical and managerial levels.

2.5 Web-based GIS in population data management – Case study in Italy

Population census and the activities around it is a very complex undertaking. From the experience of the Italian Census, this has led to the development of innovative methodologies in an effort to handle the census complexity in the Italian bureau of statistics. The innovations include a shift towards a register based census and also implementation of user personalized questionnaire response and feedback strategy during census. Although the innovations are great and per se simple, they have increased instances of error and introduced new levels of complexity in the census survey. Thus the introduction of web GIS by the Italian Statistical Institute (Istat) was an attempt towards mitigating the concerns and improve the quality of the survey as a whole while keeping the cost margins within range.

The introduction of the innovations however according to Crescenzi and Mancini (2010) improved the methodology and procedure of census by way of making it more efficient and effective despite the complexity and management nightmare introduced. The register based innovation although a good innovation is however prone and affected by survey errors such as gaps, over-raps, duplication, and lost questionnaires.

The web system

The errors have raised the following concerns with the Italian census bureau, quality of the census data being of paramount importance. How can the census undertaking be:

- i. Innovative in method and cost effective
- ii. Easy to manage and handle the monitoring aspect of the exercise

These two major concerns, has driven the bureau to seek solutions from web technologies hence Istat came up with an information system that is inclusive and able to manage all the facets of census. The system comprised of a combination of 3 web applications: the questionnaire (QPOP) for enumerators and the citizens for information gathering, a documenting system that is online able to integrate the various data contents such as manuals, legal guideline e.t.c. and finally a web monitoring platform for managements and operations control and checks. The questionnaire is formulated in such a way it incorporates the guidelines for the citizens to be guided to properly fill it out and avoid un-necessary errors. The QPOP is also sequenced in such a way that the questions follow a procedure that makes it easy to flow hence answering made more efficient and ensure only the right questions are answered. This has improved the quality of the data collected by minimizing the errors and making it faster as compared to the traditional manual census.

The system received enormous approval and support from the general citizenry with many opting to fill the questionnaire on QPOP platform. This is evidenced by the platform being responsible for 33% of all the questionnaires filled. As a consequence the enumerators were less engaged in the field activities thus cost cut. Moreover the quality of the data collected was significantly higher than in the previous census activities where web map technology was not used widely, Virgillito and Tininini (2012).

In the system, the online documents act as the point of reference for the census management who oversee the survey. The online portal is an up-to-date channel for the data being generated offering an on the go analysis channel and also the much need timely feedback on issues raised by the citizens interacting with the platform. As such the SGR is an all inclusive system that offers the detailed coverage for census with all its aspects and survey follow ups too.

The system is a viable option especially in monitoring. This is in comparison to the previous systems that offered only dashboard quantitative indicators acting as questionnaire trackers but lacked in management tools for any census activities. The SGR is formulated in a manner that permits information continuous visualization and display as it is generated with unique representation for each category of users of the system all the way to an individual household level. The system allows multiuser-multitask functionality thus team workflows made possible by the questionnaire guide life cycle. This is very important as it reduces the occurrence of errors that may be occasioned by commission or omissions as monitoring is throughout the life cycle of the questionnaire. Management of error prompts in the system and supervising the field enumerators as they work is also very efficient as the system is online and networked.

CHAPTER 3: MATERIALS AND METHODS

The chapter will deal with will developing a web prototype system for population data management. This will adhere to the system design as discussed and the technical aspect for its ultimate functionality will be of focus.

Web GIS Design Procedures

The methods applicable for developing a GIS tool involved the coming up with the spatial and attribute datasets, putting up information processing capabilities, installation of required hardware and software, implementing the human resource requirement all for a successful system setup.

The system design therefore will generally follow the following steps; user needs assessment where requirements and objectives are articulates clearly. This will be followed by prototype development with functionalities and interface put up, where the next step will be the evaluation of the system to inform refinement before the final implementation of the prototype. At this final stage of final implementation, staff changes are necessary where training needs are accessed for further action to ensure support. Critical at this juncture are also the aspects on legal issues such as liability, and privacy protection.

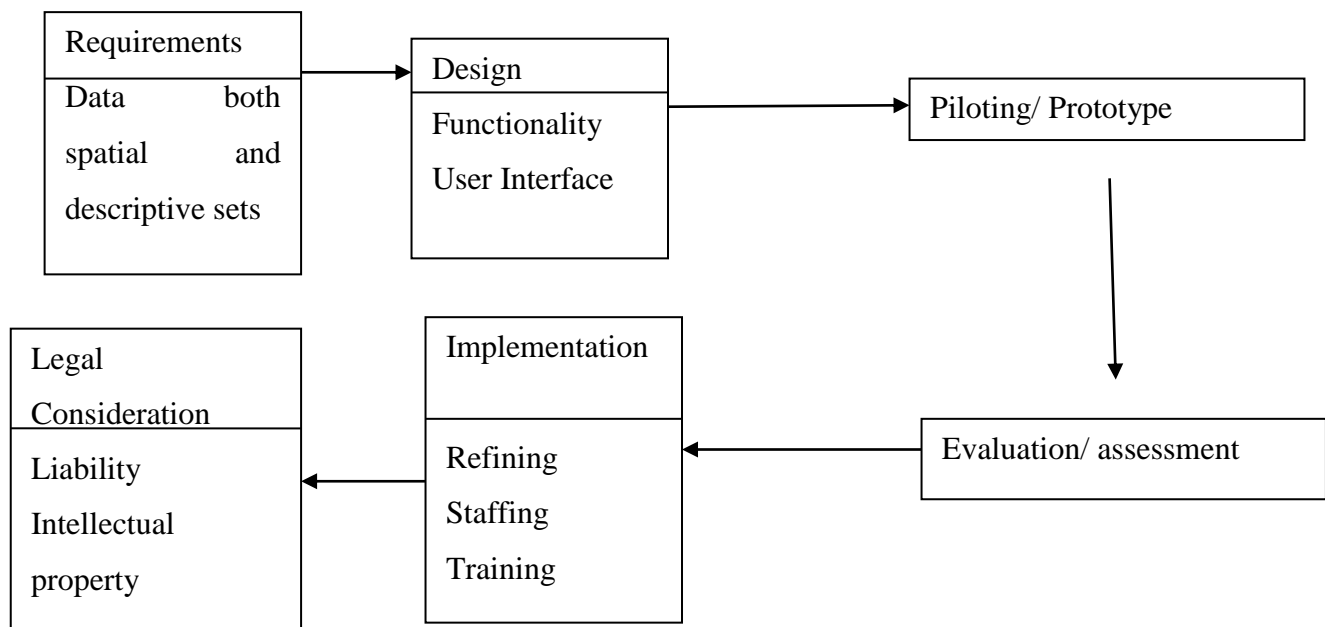


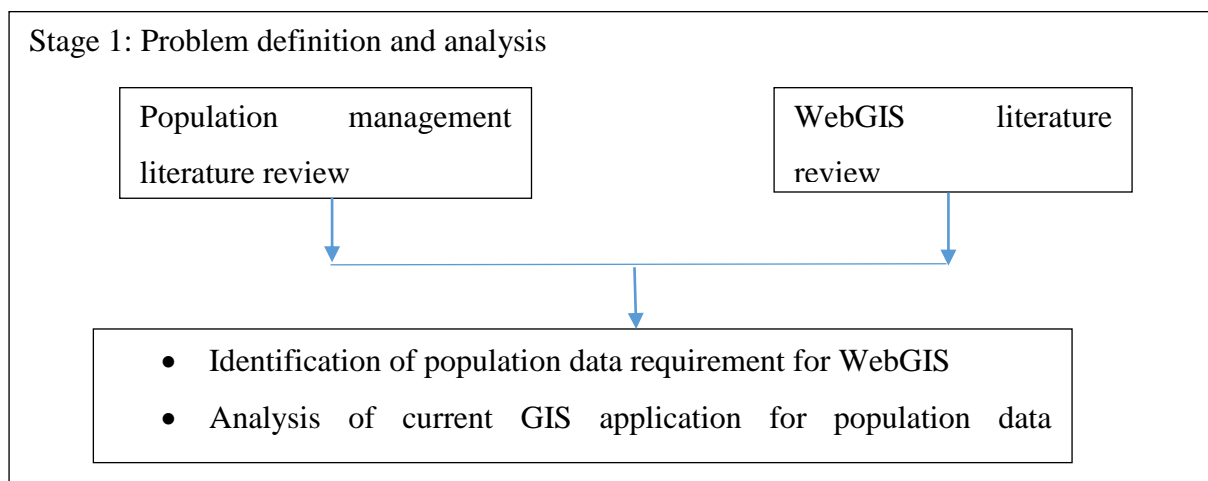
Figure 3.1: Design Procedure for a GIS web System

3.2.2 Tools

Geographic information systems (GIS) has over the years gain momentum as the ultimate tool to manage, integrate and visualize a great deal of spatial data through mapping of the same. Web GIS, on the other hand is the evolution of desktop GIS that has developed as a result of robust growth and integration of internet in the recent past globally. This has provided a platform which is very effective and efficient for data dissemination and discovery across board (Bernhardsen, 1999).

This research incorporated the current Web GIS strategies applicable for developing a prototype to suite population data management. This follows that many web GIS installations have a software for commercial purposed packaged in then such as Internet Map server (IMS) for example as it is found on the ESRI's ArcIMS which is the most common of all and on Intergraph Geomedia Webmap. This makes the website setting a fairly straightforward affair with the implementation of the commercial software and it avails basic tools and functionality such as querying, search, browsing and accessing the population data made available. For the purpose of this research, more information including but not limited to textual data both tabulated and un-tabulated for instance privacy legislation applicable will form a key component of the website. Interactive queries and analysis tools of spatial ability will need to be developed and incorporated for instance buffer and overlay capabilities.

This project research has three main distinct phases established: problem analysis and definition, designing the prototype followed by implementations, enhancing the prototype by incorporating security measures for integrity purposes. This is depicted as below;



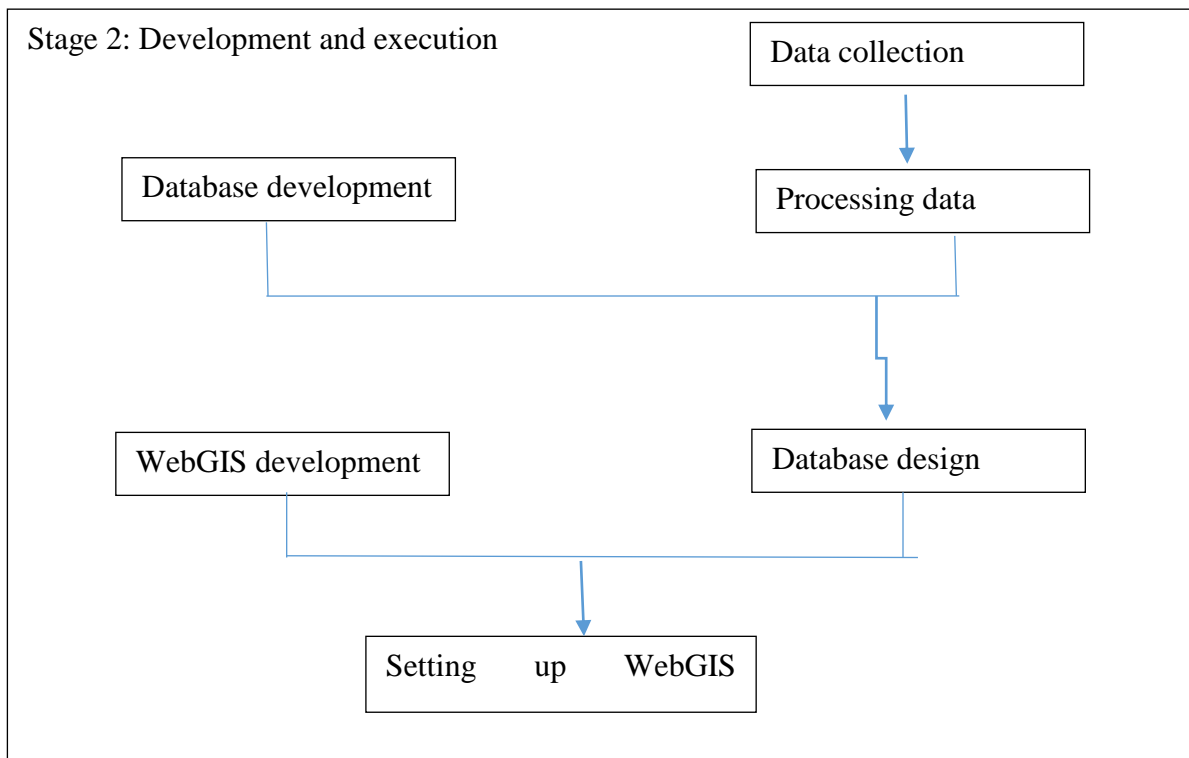


Figure 3.3: Stage 1 and 2 of the study

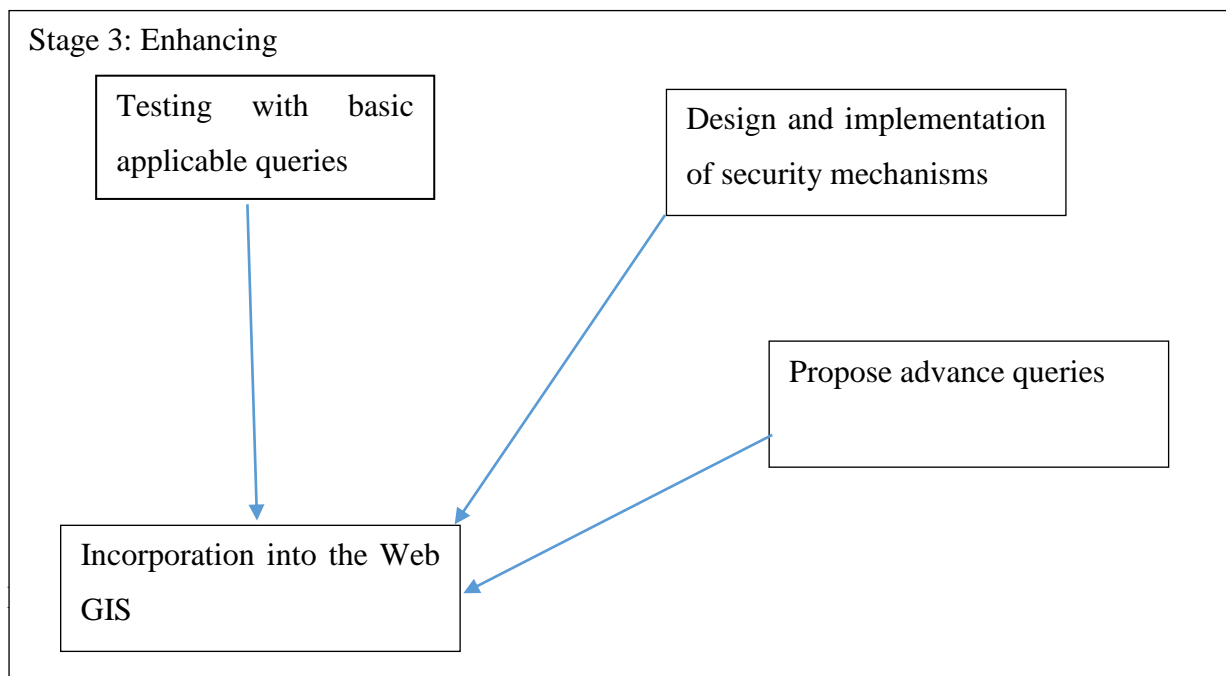


Figure 3.4: Stage 3 of the study

Stage 1

The phase commences with a review of literature detailing issues with regard to population data in Kenya. The review then accentuates to focus on WebGIS technology with a keen interest on its application in management of population data. This will form the basis for determining the need for Web GIS. The Web GIS draws its capability from internet map server, a commercial entity of software package. The most common one being ESRI's ArcIMS and Intergraph's Geomedia WebMap. For this research the two will be accessed and compared for best fit selection to be used with the population data available. Their architecture will thus be studied in depth including the way the two work, which will be instrumental in providing the foundation for implementing and developing the prototype envisioned in this study.

Stage 2

Data collection and gathering will be from Kenya National Bureau of Statistics mainly although additional data for the project will be sourced from other government agencies and private bodies. Local websites will also come in handy, as are books in libraries and journals having detailed specialized population datasets including applicable videos that can be easily hyperlinked in the prototype.

Having successfully collected the data, with the spatial and attribute data for various features, a database is developed and populated with this data ready for use. This is followed by careful analysis of different applicable architectures for the intended system to choose the most suitable to be developed and implemented. Finally, the required software are gathered and installed ready to implement and run the prototype.

Stage 3

Having installed the internet map server software, customization where necessary will be done using ArcXML. The various desirable enhancements on security are carried out to achieve system integrity. It is at this stage analysis tools available are tested and user rights customized to avoid unrestricted access to the data available.

3.3 Web-based GIS population data management system

It is in the view of this paper that for a successful web system for GIS, the implementation phase be considered continuous as opposed to being a step process. Implementing this

prototype has highly borrowed from what is available in the market and its capability with respect to the required outcome of the system.

3.3.1 Analysis of System Requirements and user analysis

User requirement determination is a major step in designing any system. This is because a system is meant for a given purpose that focuses to satisfy a target user segment. As such, each user has a unique view of the system as a whole bias towards what its capability and products and their level of satisfying the need being addressed.

The web GIS system for population data management potential users include firstly the staff of Kenya National Bureau of Statistics, population researchers, economists, and other government departments as they plan for service delivery. The main objective therefor for this prototype is thus to give an overview of the population data in every location in relations to other spatial phenomena. The functionality require will thus be browsing to gauge fitness, retrieval of population information, querying information available, analysing the information basing it on the location and most importantly modelling the “what if” scenarios for better understanding to support decision.

The above user requirements will be realised if source of the data to be used is verifiable and of high standard. In the current state, at KNBS the raw population data is in digital format as a whole on spreadsheets. However, the analysed population data set are in hard copies which will expose their utilization to be affected by issues that regard conversion of analogue to digital format of the said data. Therefore, appreciating the data source will make it possible to envision limitations expected and thus put in precautionary measures to handle them. This enhances the application of the data in the system using appropriate graphical representation. The lack of metadata in many shared dataset has resulted in users not appreciating the data’s limitations as foreseen by the own. As such the data used for this project will be well documented to guide the user to making the right decision while using it.

3.3.2 Data Collection

3.3.2.1 Framework Data at KNBS

There are various organizations and government agencies that hold a repository of population data that this study requires. However, having assessed them carefully, I have determined that

they all draw the data from Kenya National Bureau of Statistics the official government agency on statistics. Therefore, I will solely source my data from the bureau.

The data to be used for the research will have base maps which will include administrative boundaries, towns, rivers in the area, and roads. The data will have point data on households which is the key component in any population dataset under which the size of the household, mode of production of the household and the head of the household will be stipulated.

KNBS works in collaboration with other government organizations and private sectors that provide the base data which is updated during the census cartographic mapping. The major aim of collecting geospatial data is to help the organization come up with EA maps which are used to assist in population census enumeration and analysis of the census data. KNBS Framework data is divided into two categories namely the spatial data and statistical data.

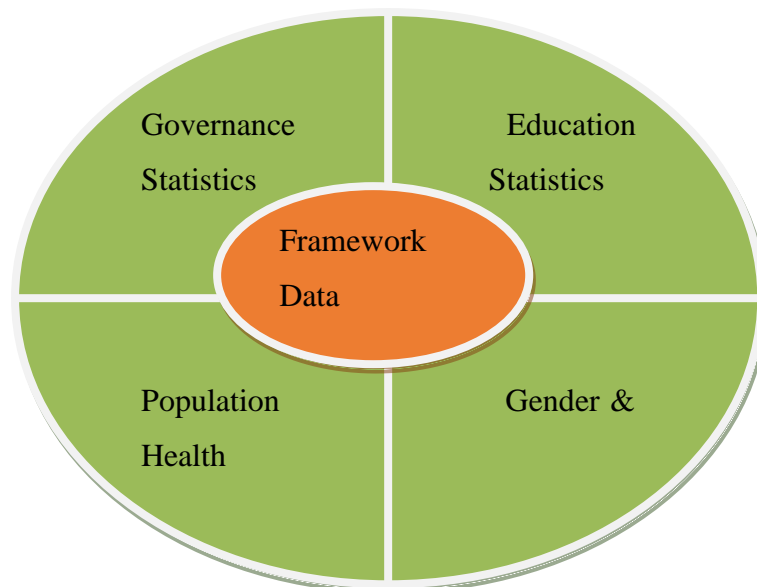


Figure 3.5: KNBS Framework Approach

3.3.2.2 Spatial Data

The spatial data comprises of boundary data and geographical features that can be used to identify the boundaries. These form the core or base of the framework and include:

1. Administrative Boundaries such as of county, sub/county, division, location, sub/location and enumeration area
2. Political Boundaries such as constituency and ward
3. Transportation data: Roads, railway lines
4. Hydrography: rivers, lakes, ocean, wells, springs, boreholes, swamps and dams
5. Location data: schools, health facilities, markets and buildings.
6. Imageries and Open source data such as the Google earth which can be used to overlay of boundaries
7. Forests, national parks and reserves
8. Maps

3.3.2.3 Statistical data

Most data types (variables) studied by statisticians have a spatial component for it is collected somewhere on the earth surface and statisticians are uniquely aware of how boundary conditions can affect sampling and therefore their results. GIS is therefore a useful tool in many different areas of statistics, including population census, social and demographic statistics (health, justice, education, and labor), economic statistics (business surveys, trade, transport, tourism, agriculture, etc.) and environment statistics. The KNBS statistical data comprises of data sets from population census, social and demographic statistics. This data will be integrated with geospatial data to show spatial distribution.

3.3.3 Data Processing

The datasets are collected from various sources thus are received in different formats, projections and coordinates. As such for the various datasets to be integrated into one system a uniform file format that is highly representative has to be used. Shapefile being the acceptable format for ESRI environment is the preferred format hence all the data will be converted into it.

There has been a challenge however in this endeavour due to lack of metadata of most of the datasets. This has resulted in datasets not overlying due to difference in projection parameters

that results in shifts. To handle this challenge, different applicable projections have been tested to settle on the best approximate for all the data layers available to which they are all re-projected. The WGS84 geographic projection parameter are used for this purpose as the common projection.

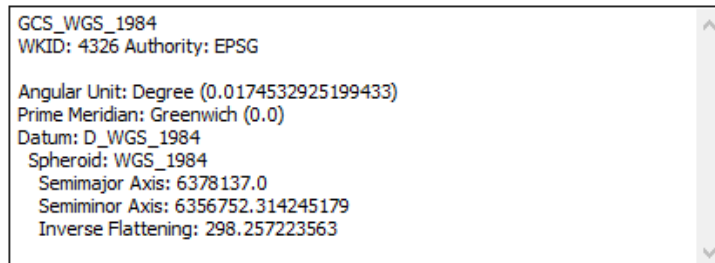


Figure 3.6: Parameters for WGS84 Projection

3.3.4 Database Design

This step followed data cleaning and processing to the required standards. The database was designed and data loaded onto it ready for utilization. It is important to know that the database is the core to any web-based system for any given application intended. Some basic concept of database to be adhered to in this prototype are:

The database adopts a relational design in storing spatial data. Thus it is a handler and storage for spatial data and attribute data with the relationships between them embedded to facilitate interaction. As such vector data, raster data, tables in a spatial database can work together interchangeably based on rules laid out for their relationships, topology and intricate relationships. This allows for complex models to be built for data visualization.

Two types of spatial databases exists: personal and multiuser. The distinction between the two is, a personal database with the extension .mdb for its files can be accessed by many users but it is only edited by one user at given time who is granted the administrator privileges

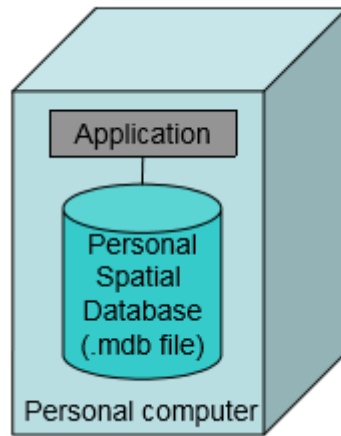


Figure 3.7: Personal database for Spatial data

Multuser databases on the other hand can be accessed and edited concurrently by many users at a go hence very instrumental in enterprise setups of GIS environments and when working with a big workgroup. This database makes use of DBMS (database management system) and utilizes ArcSDE capabilities to be implemented. The use of ArcSDE is majorly to facilitate an interface for storage and management of spatial data onto the DBMS platform.

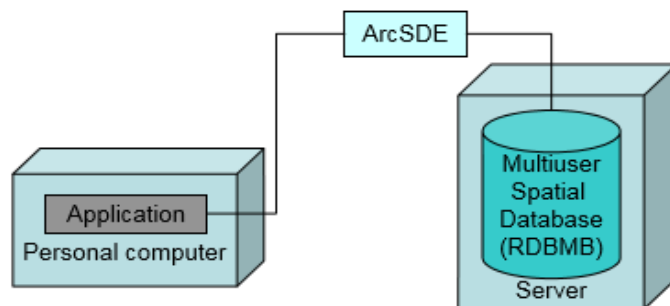


Figure 3.8: Multiuser database for Spatial data

For my prototype, I will use the personal database setup due to limit in resource available for hardware and software acquisition. However, extension into multiuser database is possible with minimal efforts.

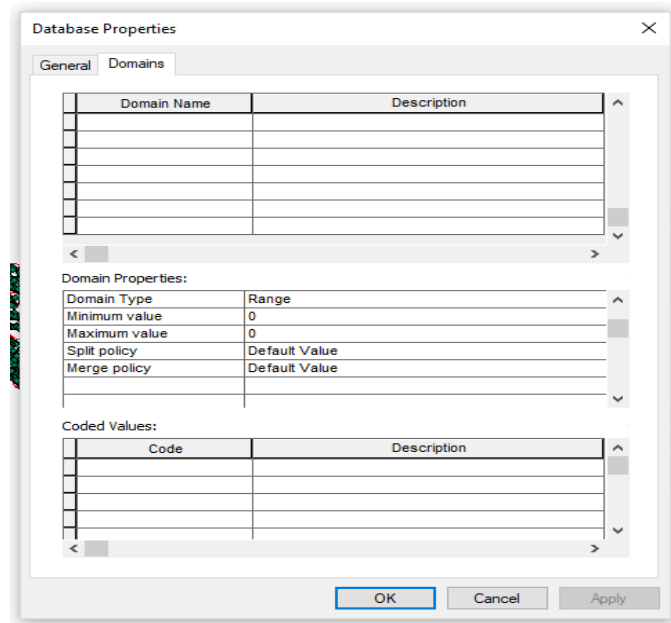


Figure 3.9: Database properties for the prototype

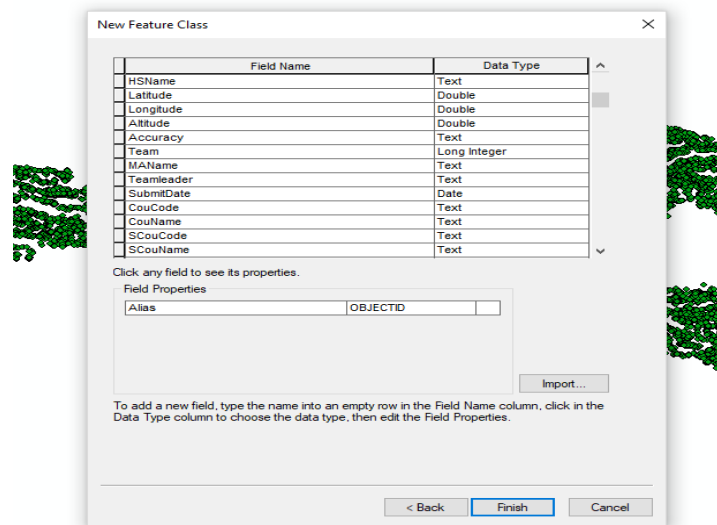


Figure 3.10: Schema developed for Point Features in the database

3.3.4.1 Implementation the spatial database

The major challenge at this point is usually the linkage between the various data types in the database to be implemented. This follows that while part of the data is structured thus easily normalized to be stored as records hence easily made into fields, other data is unstructured thus not easily presented as fields in the database. To handle the challenge, a mixed method for storage is opted where some information is pulled from the general data and added as records hence making it structured. In the case that the unstructured data to be used has rich

semantics in its core information making it hard to incorporate in fields, hyperlinks are preferred hence keeping this information as intact as possible. The hyperlinks are accommodated easily on the database as fields thus enabling the retention of pictures and other media files. To achieve efficiency on the databases, cleaning by editing out unrequired fields and duplicates is carried out to ensure its smooth operation seamlessly.

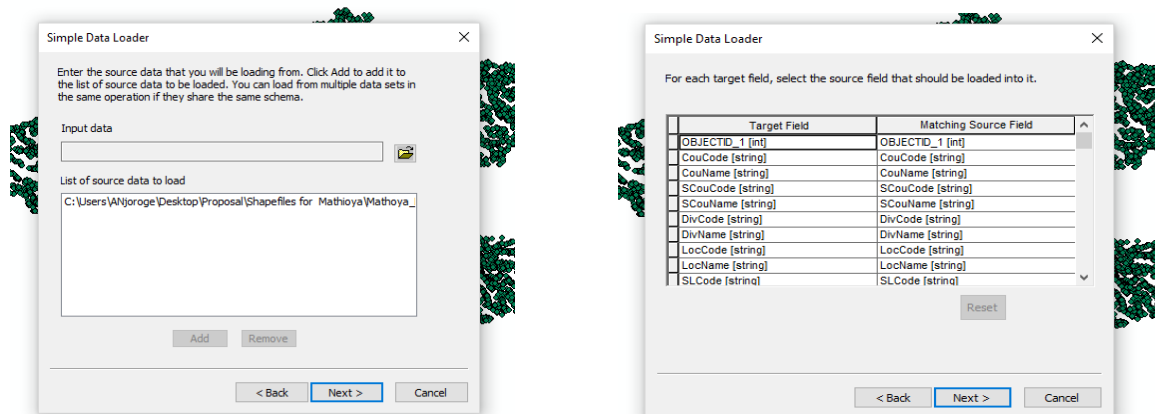


Figure 3.11: Adding data into the geodatabase

3.3.5 Website development

Typical web GIS build up has the client side which is an extended web browser and the server component that has the web server, programs for interface, software and the database. This gives rise to the architecture being a thin client or server side architecture with each having its advantages or disadvantages to boot the choice of either.

For the prototype a more hybrid architecture has been chosen for this purpose of application. The reason for the choice of HTML viewer is because for Web GIS neither the thin nor server side architecture is suitable for the prototype. This follows that the prototype calls for implementation of functions to increase interactivity at the client side drastically without the need to download or install anything on the side of the client as it will be a public gateway. Therefore to achieve this in the prototype system design, it uses the hybrid system architecture by taking both the advantages of the server side application and client side application.

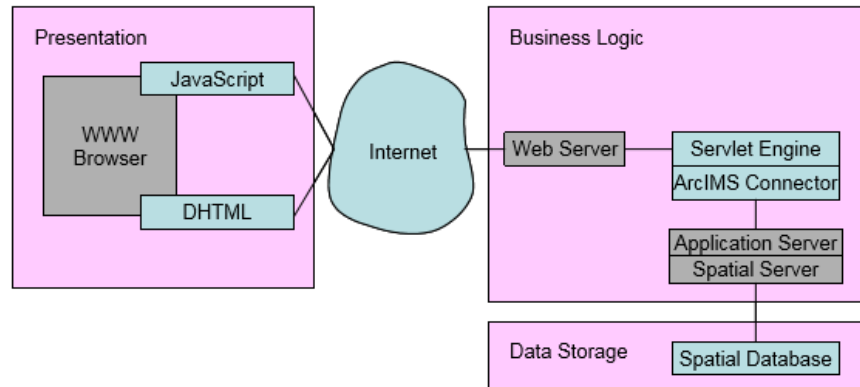


Figure 3.12: Architecture of the prototype system

The figure above depicts the hybrid architecture of the prototype with three tiers namely the business logic, presenter view and the storage tier. The business logic follows the architecture of ArcIMS and the function of each component was discussed previously in chapter 3. In the prototype implementation, Apache 2.0.42 is installed as the Web Server, while Tomcat 4.0.5 is installed as the Servlet Engine. ArcIMS connector is used in this project as the interface program. At client side, the HTML viewer is developed through customization using Dynamic HTML and JavaScript. The choice of DHTML is to make the normal HTML more interactive with the introduction of server side scripting, cascading style sheet and document object model. This thus means that an already loaded page on the browser can change for instance colour change as mouse moves over the map or new pop up appears as one explores the map.

The use of DHTML therefore accords the user ability for map displayed to respond to user action without them getting sent to the server for processing. This reduces server data traffic hence higher response times achieved. There is no need for supportive plugins for the browser bypassing the headache of sourcing for the right software to patch the browser.

Thus DHTML achieves the intended HTML dynamics by:

- Client-side Scripting: Here JavaScript which is universal to all browsers and VBScript specific for Microsoft's internet explorer is used to alter HTML.
- Document Object Model: Refers to the hierarchy with which elements appear on the browser. The elements alluded to are browser properties and HTML elements such as tables where a client can point to a particular check box and alter its default settings to suit need. The DOM is involved in specifying events that accompany a given action by the client. For

example, the DOM defines an event “OnMouseOver” for a link. This enables you to write a script for something to happen when the user passes the mouse over the link.

- Cascading Style Sheet (CSS): controls rendering on the browser without altering the structure of the web document. This is through styling various values for easy manipulation using a scripting language. The use of common terms used for desktop publishing make it client friendly and hence features are easily utilized by designers. The CSS approach of centralizing style information increases power and flexibility not previously possible with old HTML approach of the same. For instance with CSS, tags are used to reference rather than describe it each time it is used. As such only a reference declaration is needed to change a given style in use and not at all the instances it has been used.

In conclusion, java scripting and dynamic HTML programming are the key elements to increased cartographic functionality of the prototype website. This follows that it interlinks the server side application and client side application without use of plug-ins on the later side.

3.3.5.1 Website Setup

ArcIMS will be instrumental in coming up with the basic template for website initial set up. The other functional enhancements and interface will be developed through customization.

There are three major steps involved in developing an ArcIMS website (ESRI, 2004):

- a. Using ArcIMS author a map to display on the website is created. In this platform, the various layer that make the map are added and arranged logically to suit need. Once satisfied the map is exported or rather saved in text format of AXL extension known as the map configuration file which is the building block of any map service.

- b. Having created the configuration file, registration for internet publishing follows using the ArcIMS Administrator synonymously called starting ArcIMS service. The file developed previously is input to an ArcIMS service which allows that when a request is received on the map server, the service uses the instructions on the map configuration file to respond to the request.

- c. Once the ArcIMS service is up and running in the administrator, the next step is site design for public display. For this step, the ArcIMS designer wizard is utilized and it guides through the HTML pages creation process including the supporting files required.

3.3.5.2 User Interface Development

HTML is posed as the best for webmap rendering and viewing which incorporate one image service. This is because the website intended will have no feature service thus the choice of HTML becomes the best efficiency wise as it require no plug in to accomplish map rendering online. As mentioned earlier, a custom HTML viewer will be developed using DHTML and JavaScript, containing the two types of files interlinked. It is important to note the JavaScript and the HTML forms the basis of the HTML viewer.

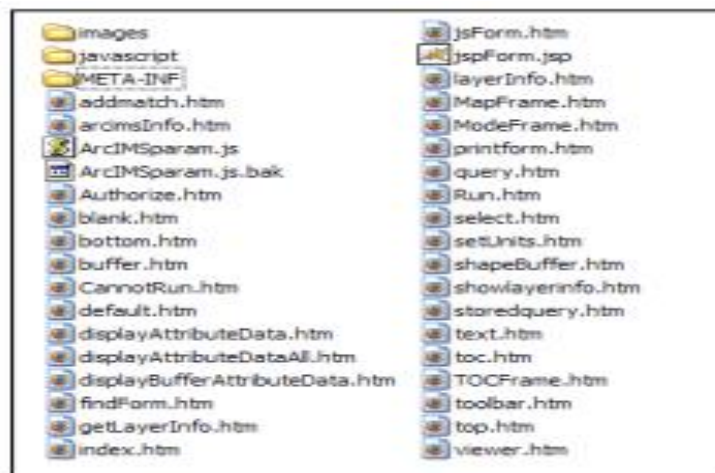


Figure 3.13: The files created for the interface

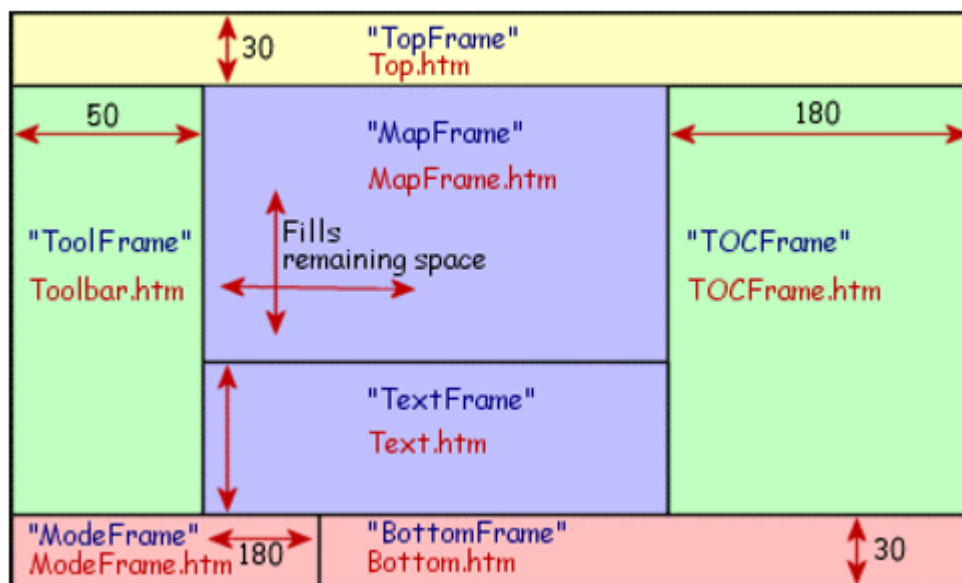


Figure 3.14: Frame layout in the viewer

The entry page into the site is default.htm. The images folder contains all the images used for the Web page, including the button icons and frame backgrounds. The HTM files as shown on the figure above are descriptive of the contents in particular frames in the HTML viewer. The files are easily manipulated hence customizable looks can be achieved e.g. the top.htm can be rearranged to fit taste.

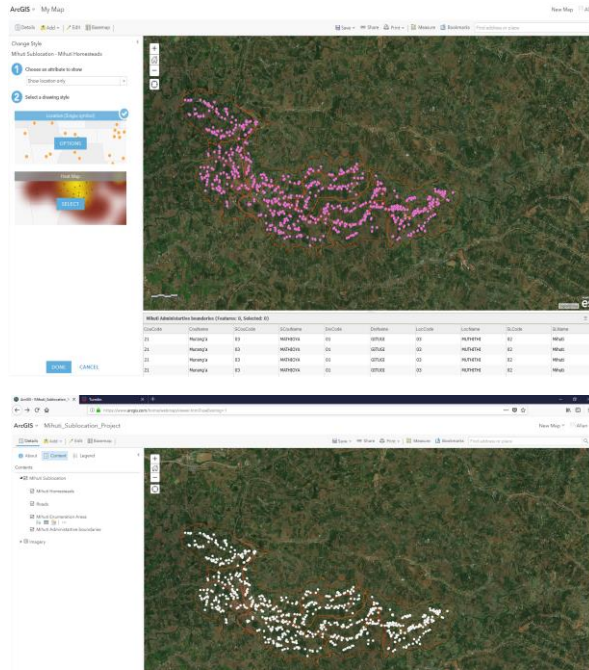


Figure 3.15: The display interface on the ArcGIS server for creating the webmap

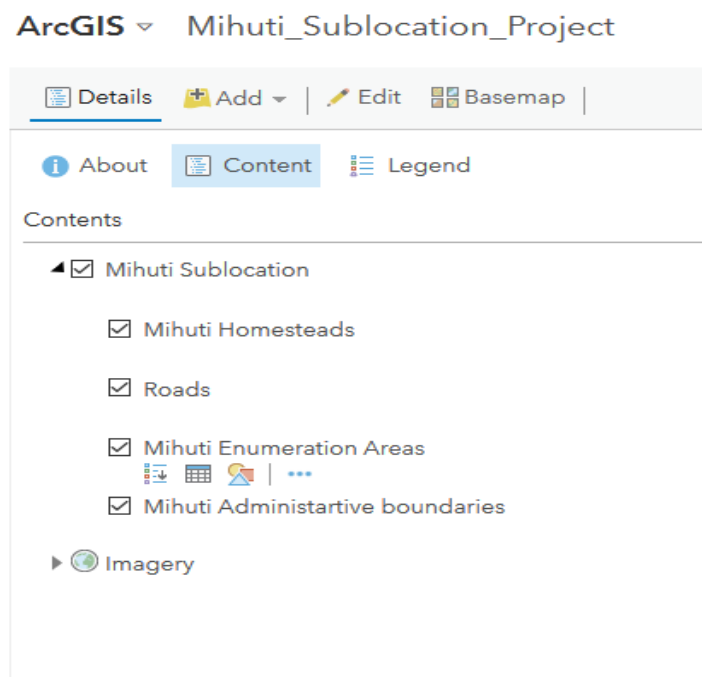


Figure 3.16: Layers on the created webmap

The interface will have the map area, the title, tools, map legend, layers, the map both at details and overview levels and the results tab for queries.

3.3.6 Testing the prototype

The map rendered will have functions such as zoom and pan to view the map, map feature selection, highlighting tool as well as attribute table data viewer functionality. A tool for measuring distance will also be available for distance determination purposes.

Simple queries will be answered in form for pop-up generated front the database about a particular feature queried:

ouCode	CouName	SCouCode	SCouName	DivCode	DivName	LocCode	LocName	SLCode	SLName
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti
1	Murang'a	03	MATHIOYA	01	GITUGI	03	MUTHITHI	02	Mihuti

Figure 3.17: Inspecting rendered attribute table functionality

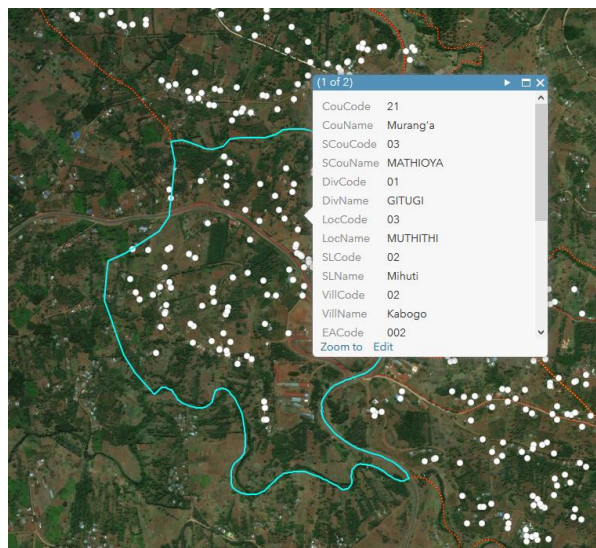


Figure 3.18: Illustration of simple query pop-up

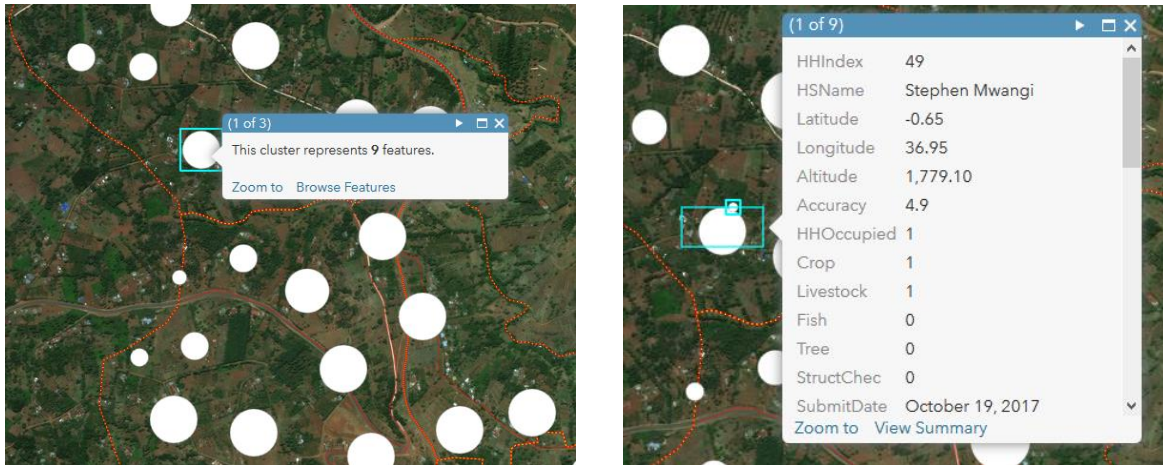


Figure 3.19: Clustering functionality on the web map

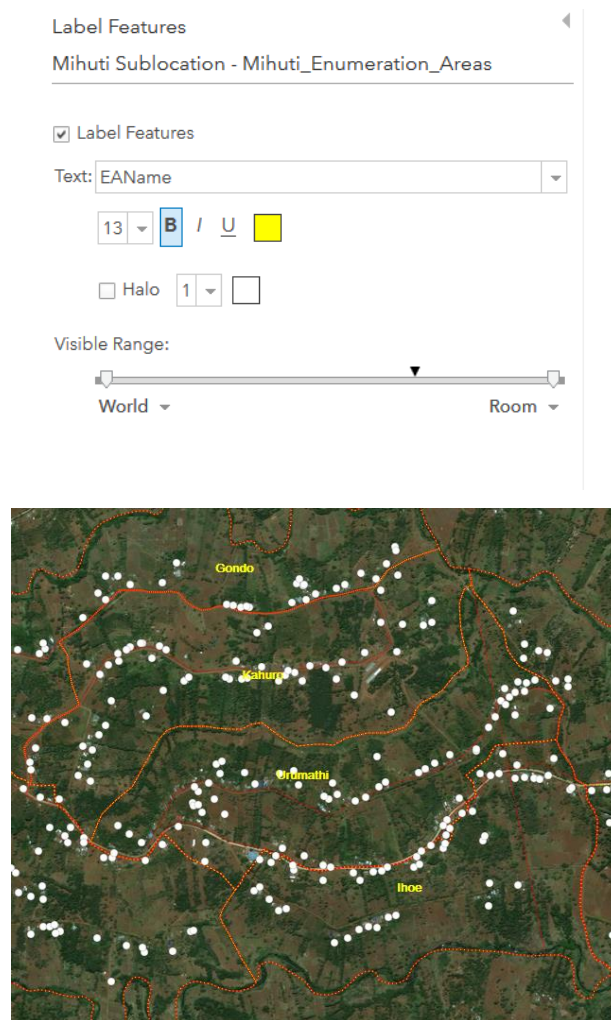


Figure 3.20: Configuration of labels on the web-map functionality and the results

The functionalities above were tested and their results assessed by visual inspection to determine fitness or correctness both in the attribute table and on the map layout. The

response time was also satisfactory hence leading to the conclusion that query is accurate and served in acceptable time.

3.4 SYSTEM ENHANCEMENT

In the previous chapter, the prototype has been presented and discussed at length. Key highlights of the prototype which is based on ArcIMS also referred as ArcGIS server is that it has a friendly and interactive user interface coupled with simple tools for querying and map manipulation. The need for enhancement is however very evident in that due to the strict nature of the data at hand, secure login is very necessary. The embedding of other useful information on the platform that go together with population data is also needed in an attempt to satisfy the diverse user needs.

One of the major form of enhancing the prototype is the use of hyperlinks to maps and other unstructured datasets in line with my last specific objective. This allows the user of the system to have an in depth query ability to better satisfy their need. However, this enhancement goes beyond the scope of this project and thus will not be attempted. The main enhancement that this project will discuss is that of secure login to the system.

3.4.1 Login Security

The internet and generally the World Wide Web has revolutionized the approach to securing information especially when shared. Population data is sensitive as mentioned before and thus needs protection from breach of its integrity. One of the ways towards its protection is restricting users' unauthorised access. This can be achieved through putting in place a mechanism where user authentication is needed before access to the web service.

The user access limitation will be achieved by setting password and username for the system. In this case, using MSAccess database, user id and passcodes are created that will allow a servlet be activated at login to connect to the database of users and the passcodes to look for a match. Where a match is found then log in becomes a success and the viewer page to the system activated for the particular user by the servlet. In the event a match is not found, the servlet returns an error message to the user redirecting them to the log in interface

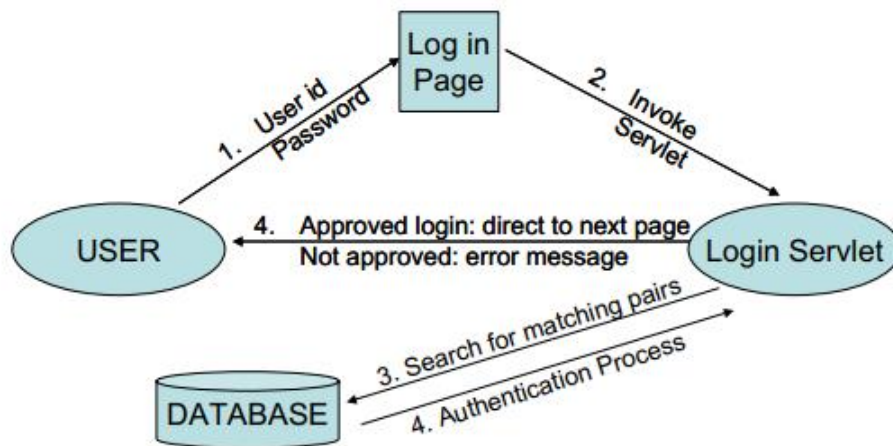


Figure 3.21: The login logic

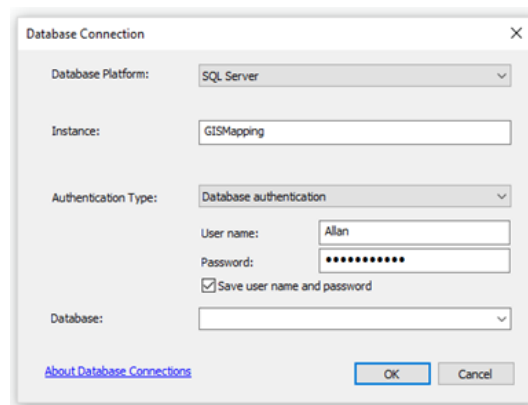


Figure 3.22: The database login window

This simple method of securing the system, however has a challenge in that once logged in, various users are able to see the details of other authorized users in the event that they are sharing the same map service. These is a challenge as the desired security would be that where only a particular user has access to their own data resources despite sharing the system and where each service requested is preceded by a login prompt before the request is served. As such, each user’s privacy is guaranteed including their activities in the system not available to other users.

The servlet connector as embedded on ArcIMS has no source code freely availed. This creates a challenge as editing the code is not possible which would allow modification of its functionality and behaviour with regard to authentication. The only availed codes are HTML and Javascript files that render the login and authorization process. Due to this reason, it

becomes difficult to customize the user categories based on their rights accorded while interacting with the system by modifying the current code.

3.4.2 Metadata

As part of enhancing the system, an attempt is made to document the various layers used and also give acknowledgement as illustrated in the figures below:

The screenshot displays the metadata interface for a web map. At the top, the title is "Murang'a County_Mathioya Subcounty_Mihuti_Sublocation_Project" with an "Edit" link. Below the title are tabs for "Overview" and "Settings".

Overview Section:

- Edit Thumbnail:** A thumbnail image of a map with a blue area.
- Description:** "A population distribution map with administrative boundaries". It is a "Web Map by Kinungi", created on Jun 30, 2018, updated on Jul 2, 2018, and has a view count of 8.
- Description Text:** "This map is created and shared with a purpose of an academic demonstration of a prototype population management system. The map is composed with data collected from the ground using collector 123 an app tool for point data collection from Esri. The administrative outline on the map has been compiled with the help of the local administrators in the area lead by the local chief. A slight shift has been noted in the boundary alignment with the features on the ground: this is because while digitizing a mosaic aerial image was used and not the world imagery from Esri thus the slight shift when the boundaries are viewed with an online world imagery."
- Layers:** A list containing "Mihuti Sublocation", "Imagery", and "World Imagery".
- Terms of Use:** "This data may be utilized but care should be taken as its author is not liable for any harm caused for using the data prior to consulting for guidance."

Item Information Section:

- Buttons: "Open in Map Viewer", "Open in ArcGIS Desktop", "Create Presentation", "Create Web App", "Share".
- Item Information:** A progress bar from "Low" to "High" with a "Learn more" link and a "Top Improvement: Add a longer summary" prompt.
- Details:** "Size: 742 KB", "Shared with: Everyone (public)", and five stars.
- Owner:** Kinungi.
- Folder:** Kinungi.

Additional Metadata:

- Details:** "Size: 742 KB", "Shared with: The item is not shared.", and five stars.
- Owner:** Kinungi.
- Folder:** Kinungi.
- Tags:** "Master project for webmapping, University of Nairobi".
- Credits (Attribution):** "Kenya National Bureau of Statistics, Directorate of Population and Social Statistics, Cartography and G.I.S Section".

Figure 3.23: The metadata preview for the web map created

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Summary of the project

Web based GIS system

This research has come up with an accessible prototype for population data management and dissemination in Web GIS. The system can be very instrumental in timely decision support at all levels of government and with the different development bodies. This is made possible by the prototype system allowing the GIS queries to be conducted online together with various spatial analysis and modelling population issues. Thus policy makers, managers and various stakeholders are better equipped with information.

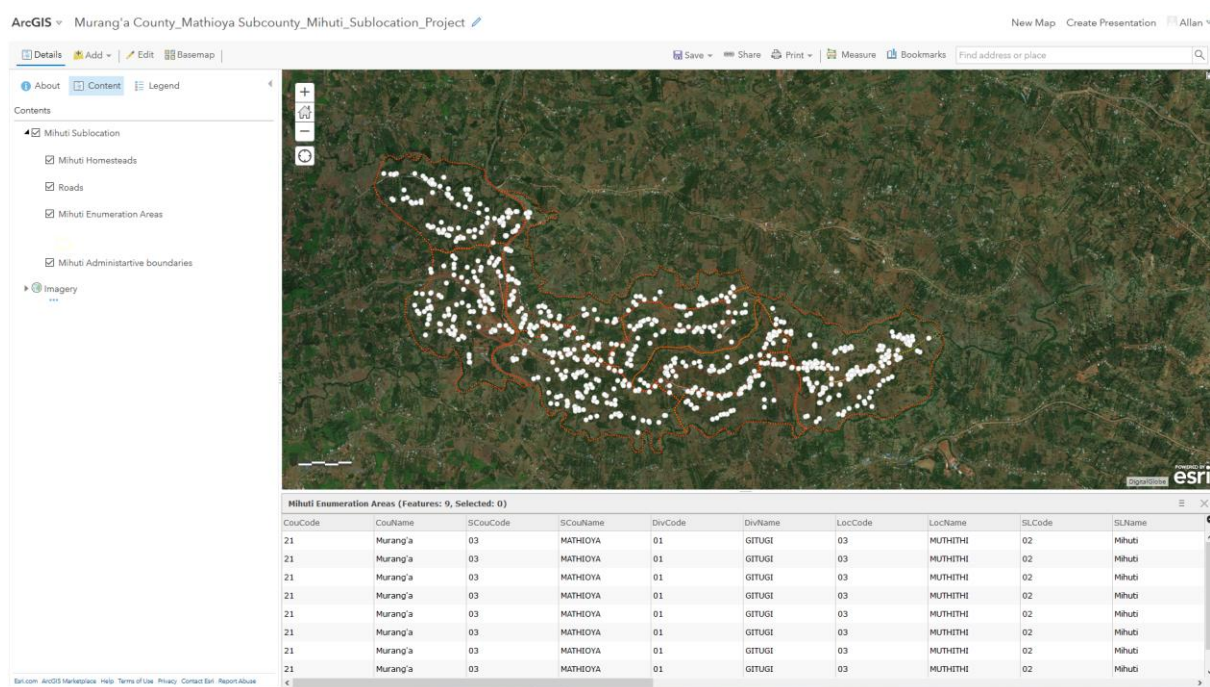


Figure 4.1: The start page of the system online

The start page is more like the arcmap interface only that it has limited functionality. Content has to be published into the system for further usage and analysis. The various functionality have been discussed at length in the implementation phase chapter and captioned.

User needs

Having carefully considered the type of data to be displayed in the platform, the web map has been formulated in a way that it accommodates diverse users to encompass highly skilled GIS professionals to the ordinary person with very limited analytical mapping skills. This makes the platform friendly and easy to use and thus its envisioned objective achieved.

4.2 Justification for use of ArcIMS

One of the main advantage that ArcIMS will accord me in trying to achieve the objective of this research is that it is more comprehensive and stable requiring no additional plug-in to boost functionality. For instance it uses HTML viewer which is the most common web site design platform meant for large audience supporting both generalized viewing and specific viewing capability. This is unlike in Geomedia where plug-in are required on the client side to achieve map viewership.

Secondly, ArcIMS being a product of Esri is easily compatible with other Esri products such ArcGIS software mapping products as produced by mainstream players in the industry. The upper hand with Geomedia however is in its ease of integration with various databases without the need to preprocess their data or converting their formats. This aspect makes Geomedia a powerful open source platform unlike ArcIMS which requires one to process the data first into compatibility before bringing it onboard the platform. Moreover, ArcXML is required as the translator for all the data communications; Geomedia Webmap, data has been taken as it is from multiple locations in various formats.

The Geomedia Webmap platform provides raster and vector data viewing and it is possible to render and manipulate the datasets in the browser. However, customizing the client viewer in this platform is almost impossible as the documentation is not readily available to guide customization at the initial stage. Thus, when specific functionality is required with the platform, it becomes costly and time consuming. This is unlike in ArcIMS where many methods and customizing documents are available with the platform at all times e.g. ColdFusion, ASP, ActiveX and Java for use by the developer to come up with their own unique viewers.

It is the opinion of this research project that for organization based implementation of web based population management system Esri's ArcGIS server software is preferable. This is because it has emerged stable and better equipped to handle complex rendering abilities with minimum need for patching and plug-in use. The ArcGIS server platform is also easily implementable in a distributed architecture design thus allowing an enterprise database set up. The enterprise set up is very applicable in an environment with multiuser application where editing is done simultaneously with the user with rights able to version the verified edits to the main database for redistribution to all users.

Finally, although this research has focused on population data, it is important to understand that any form of spatial information can easily be channelled through the same platform and effectively disseminated and managed. The in-depth analysis done at the initial stage of this research with regard to the best web GIS approaches and techniques coupled with analysis of available commercial and open source Internet Map Server soft wares, forms a fertile ground to guiding managers in implementing web GIS in their own set ups.

4.3 Limitations

The research on Web GIS as carried out was to cover population data management in Kenya. However, due to limited resource and time constraints, many aspects on population were left out as they would have needed specialized in-depth analysis and consideration to be brought on board the system. Thus the research restricted itself to only key population web GIS approaches which were the focus of the research. There were interviews to be conducted on target key persons in Kenya National Bureau of Statistics on the suitability of a web GIS system after implementation to managing population data but due to the recently launched country wide cartographic census mapping for 2019 census it was forgone. This made it impossible to receive feedback on the system and offer insights.

For the security aspect enhancement of the prototype, MS Access was used to manage the login logic mainly because the prototype was small scale and not distributed in its architecture. However, Oracle is highly preferable for large scale applications with a distributed architecture such as if the prototype is to be implemented for the whole country.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study was to create a readily available platform for Web GIS on matter of population in Kenya. The system would be a critical tool for online provision of population data to planners and other development agencies for on demand analysis to support decision making. This will go a long way in reducing the amount of time to reach certain critical decisions thus efficiency enhanced. The ability to model in a GIS environment is also scaled by the system allowing users to model different ‘what if scenarios’ with the availed data for better appreciation of their interest at hand.

Clearly a web based system that provides on demand, accurate and timely population information in Kenya and by extensions other nations is very critical for the wellbeing of any Nation. The information provided in such a system would assist the various stakeholder referred to as users of the system reach their goals with regard to the populations more easily in a cost effective manner.

Web GIS has been identified as a powerful tool that easily and effectively can disseminate integrated spatial and statistical information about the population. All that is required for this endeavour is for this case ArcIMS which is the internet map server. For it to work appropriately, the various data layers need to be pre-processed such that they are in the same projection and coordinate system. The database to be utilized need to be properly formulated with the schema to have the appropriate fields and populated before it can be utilized locally and also published online

HTML viewer as used in the prototype, being suitable and user friendly, as it does not require additional plug-ins at the client side.

5.2 Recommendations

In future, the prototype will need more patching to enhance it and improve its capability especially with regard to user interaction and analysis scalability. For instance, the aspect of multi-layer analysis and overlay need to be investigated and implemented in the web environment as many factors come into play while for instance thinking about population of a given region. The issue of geodata rights management also needs to be investigated as it is still a very grey area especially in Kenya. This is in appreciation that population data is

sensitive data and injury can be occasioned hence need for relevant policy framework to support the dissemination in web GIS platforms as demonstrated on the prototype.

Security login can be enforced using the login servlet to implement ArcIMS authentication with an MS Access database, which contains the pairs of user name and password.

In addition, focus need to be put on to provide users with different rights on web GIS prototype different views which are user defined unlike currently where a view only correspond to a particular map service. It is also recommended from this research that more effort be put into the creation of different user views using the same ArcIMS map service. For example, this would entail the inclusion of multi-media information on the web GIS prototype. Finally, for system evaluation, a mechanism for feedback giving by various users of the system need to be developed, as this will be instrumental in informing system improvement.

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APPENDICES

Work plan

Duration	March	April	May	June
Activity				
Proposal writing, presentation at the department and registration				
Obtaining relevant research permits and Field testing/preparation				
Data collection and assembling/ field work, first presentation at the department				
Literature and assembling the software				
Prototype development and presentation at the				

department				
Report writing				
Final Presentation at the department				
Corrections and Binding				

Budget

Category	Budget item	Requirements	Units	Quantity	cost per unit	Total (KSh)
						Self sponsored
A	Consumables & other costs					
	Stationery	Papers, pens, clip files	Lumpsum	5	600	3,000
		Printing, photocopying, binding	Lumpsum	10	1,000	10,000
	Field Materials	Hard-disk	Lumpsum	1	5,000	5,000
		Back pack bag		1	2,000	2,000
	Communication	Calls and internet	Lumpsum			4,000
	Sub-total Consumables and others					24,000
B	Personnel					

1	Data collection and cleaning	Technician	Man days	10	500	5,000
	Sub-total Personnel					5,000
C	Equipment					5,000 20,000
1	Software and laptop Maintenance			1		
	Publishing, conference/workshop/seminar		number	3		
	Sub-total Equipment					25,000
	Miscellaneous					5,000
	Total	Ksh. 60,000				