



University of Nairobi

School of Engineering

DEPARTMENT OF GEOSPATIAL ENGINEERING

WEBGIS PARKING MANAGEMENT SYSTEM FOR VOI TOWN

BY

OKINA OTIENO, Dip (Land Survey), B. Sc. (Computer Science)

F56/74545/2014

A project submitted in partial fulfillment of requirement for the Degree of Master of Science in Geographical Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

June 2018

Declaration

I, Okina Otieno, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for examination in any other university.

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OKINA OTIENO

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Date

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

.....

DR. D. NYIKA

.....

Date

Dedication

I dedicate this work to God first for giving me the will to read and ability to understand. Second is to my parents Mr. Michael O. Ogodo and specifically to my late mum Mrs. Rosa A. Okina for the inspiration and moral support that have kept my dreams alive despite glaring challenges. Third is to my family especially my two sons Hashil and Nassor for the patience and understanding while daddy is away studying.

Acknowledgements

Thank you to my family and friends for their continued support throughout my graduate coursework and project writing. Their continued support has allowed me to pursue my dream of finishing my master's degree. Thank you to all Professors and Doctors at the Department of Geospatial and Space Technology and all the staff for a conducive studying environment. My gratitude especially goes to my supervisor, Dr. D. Nyika, whose guidance has seen me complete this project.

Abstract

Urban transport faces several challenges, among the most important being the time-consuming challenge of finding and accessing parking spaces by automobile users. In Voi Town, the problems associated with parking include insufficient data and information on parking (parking slots' inventory), lack of accountability to fees collected from owners of parked automobiles and lack of documentation including location of the number of vehicles parked at a given period of time.

In a bid to solve the above challenges in Voi Town so as to develop Voi Parking Management System (VPMS), the study technologies were established from a thorough review of literature related to application of GIS in its entirety and specifically in parking systems. The reviews factored in all the spatial and non-spatial elements to come up with the design that has been implemented and tested and results as well as recommendations presented.

The gaps within the present system were identified and a well thought out design of a system that integrates different inputs while leveraging on available technologies was presented. VPMS was developed by identifying a solution in the perspective of inventory of the parking slots, accountability for the fees collected from parked vehicles and a mechanism to report the location of each parked vehicle within Voi Town.

This study concludes that, with the available technology it is possible to have an inventory of all the parking slots/areas within Voi Town and that it is possible to integrate several layers or shapefiles besides the parking slots to provide auxiliary data that can help in parking analysis. A further demonstration that an e-payment system is also viable was illustrated by the use of Safaricom Sand box. In conclusion, the study recommends implementation of VPMS and also suggests implementation of such system where location is key to the realization of the project in question.

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List of Abbreviations

APIS	Advanced Parking Information System	17
APTIS	Advanced Public Transport Information Systems	18
API	Application Programming Interface	27
ASTDR	Agency for Toxic Substance and Disease Registry	11
CBD	Central Business District	5, 13, 21
CAD	Computer Aided Design	27, 28
CRUD	Creation, Retrieval, Update and Deletion	32
DBMS	Database Management System	30, 57
XML	Extensible Markup Language	9
GB	Gigabyte	29
GI	Geographical Information	2, 3, 9, 12
GIS	Geographical Information System.....	.v, 1, 2, 3, 5, 10, 11, 12, 20, 21, 22, 27, 56, 58, 59
GPS	Global Positioning System	5, 10
GUI	Graphical User Interface	2, 44
HTML	Hypertext Markup Language	2, 9
HTTP	Hypertext Transfer Protocol	9
ITS	Intelligent Itransport System.....	18
JSON	JavaScript Object Notation.....	9
KR	Kenya Railway	4, 24
M-Pesa	Mobile Money	v, 56, 58, 59
OSM	Open Street Map.....	27, 54, 57
PC	Personal Computer	13
PGIS	Parking Guidance Information System	17, 60
PHP	Hypertext Preprocessor.....	30, 35
QGIS	Quotum GIS.....	3
RAM	Random Access Memory.....	29
RVR	Rift Valley Railway	4, 24
SGR	Standard Gauge Railway.....	4, 24

SRID	Spatial Reference System Identifier	36
SQL	Standard Query Language	xv, 54, 55, 57, 58
GPS	Global Positioning System	10
UTM	Universal Transverse Marcator	10, 27
VCA	Vehicle Control Agents	22, 23, 60
VGI	Voluntary Geographic Information	9
VPMS	Voi Parking Mnagement System	v, 5, 26, 31, 32, 33, 34, 40, 53, 54, 56, 60
WebGIS	Web Based GIS	5, 8, 9, 31
WWW	World Wide Web.....	1, 2, 7
XML	Extensible Markup Language	9

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CHAPTER ONE

INTRODUCTION

1.0 Background

Kenya is on the way to becoming a highly urbanised Country (Government of the Republic of Kenya, 2007) which will lead to an influx of vehicles within towns and cities. Urbanization shall present several challenges of that impact on service provision by town planners and managers. The particular challenge focused in this study is transportation, especially for vehicles on transit; parking. A parking is a particular space set aside within a town plan for the purpose of parking vehicles; it is either paved or unpaved. Parking is a facility that means a lot, garage building or structure or combination or portion thereof, in or on which motor vehicles are temporarily parked (US Government, 1974).

Parking spaces exist in several forms; a parking garage, parking lot or on street parking in a city/town street. Parking space is usually delineated by road surface markings where automobiles fit either by parallel parking, perpendicular parking or angled parking depending on the design (Wikipedia, 2017).

Parking is a service provided within the transport sector and lack of or inefficient provision of parking may lead to traffic congestion, increased carbon emissions, time wastage, which then leads to low productivity and general loss of economic opportunities. In summary, lack of parking is an aspect of inefficient town/city hall service delivery.

Information technology has advanced and gained importance in organizations world over due to their efficiency with low costs. These technologies include internet, the World Wide Web (WWW) and Geographical Information Systems (GIS).

The Internet is a global interconnected network of computers with which one can look at documents, images, view videos and listen to sound files from anywhere in the world. The internet is sometimes referred to “the Net” since it is a worldwide system of computer networks. It is indeed a network of networks in which users at any one computer, if they have permission, can get information from any other computer (Venkateswarlu, 2012). Some of the areas of application are e-commerce, on-line surfing, and interactive chatting. The ubiquitous access

nature of the internet has made it an integral part of the society, in conjunction with the WWW and its interactive content has made internet a powerful means for people to access, exchange and process data and information.

The enabling technology for the internet is WWW which is a hypertext retrieval system for the internet. It is a branch of the internet that can display images, sound and animation, it provides the links among the aforementioned media. It provides capability for cross checking between internet sites as you may do with books in a library, which is made possible by the application of Hypertext Markup Language (HTML) (Pat, 2000).

GIS is an organized collection of computer hardware, software and geographic data designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information (Johnstone, Petterson, & Fulton, 1992). GIS technology has been applied in various industries and fields which include parks and recreation, environmental monitoring, emergency management and citizen information/geodemographic. The core functions include spatial analysis, network analysis, geo-visualization and modeling.

GIS is a flexible technology whose strength is the ability to integrate data sets, functionality and output. It can be used as a decision support tool, planning (housing, transport, urban design, landscape planning), street network based application, natural resource based application, view shed analysis, land parcel based application and facility based management, among other applications.

The operation of a successful GI system coalesces around five key elements. These are hardware, software, data, methods and people. Hardware is the computer on which GIS operates. It is also important to mention that within this Hardware, there exists a software (Operating System) which accepts installation of the second element. Software provides interface through which tools needed for storage, analysis and display of geographic information are connected. The core software components are: a geodatabase management system that supports storage of spatial data for query and analysis, software tools for input and processing of geographic data and a Graphic User Interface (GUI) for interaction with the system. Data is the core and reason why GIS is needed. GIS integrates spatial and non-spatial data which are at the core of its functionality. There are several ways of gathering data for this purpose which include remote sensing and ground surveys. Methods are well designed plans and business rules which are models and

operating practices unique to each organization and its reason to adopt GIS and which must be adhered to so as to achieve a successful GIS. The methods perform complex spatial analysis providing qualitative and quantitative results (Jatin & Darshana, 2014). The last element is people; the stakeholders involved in conceptualizing, setting and operating a GI system.

Internet GIS, also called web GIS has resulted from web technology which has revolutionized information technology. According to Zhong-Ren & Ming-Hsiang, (2003) Internet GIS is a research and application area that brings about WWW, the internet technology to enable the access, processing and dissemination of data and information spatially as well as enable spatial analysis of knowledge. The advantage of internet GIS as compared with the desktop/standalone GIS is that one does not need to own a GIS software (e.g. QGIS, Arc GIS or Grass).

The combination of the technologies provides two important capabilities that greatly help geoscientists. First, the web allows visual interaction with data which is achieved by setting up a web server that enables clients to produce maps published in the internet for other clients to view the updates. This helps in speeding up the evaluation process. The other capability is the wide accessibility due to the fact that internet is nearly ubiquitous in nature. This enables clients to work from almost any location. Combination of ease of access and visual presentation addresses some of the difficulties in performing geoscience evaluations.

This study intends to look at ways of using GIS and related/associated technologies to minimize the aforementioned parking problems in Voi Town.

1.1 Problem Statement

One of the crucial challenges in urban transport is parking; the challenges include finding and accessing a parking space. Finding and accessing a parking space is a time consuming activity which substantially impacts the everyday lives of urban residents as well as visitors. In Voi Town, the problems associated with parking include insufficient data and information on;

- Available parking slots
- Fees collected from the vehicles parked and therefore unaccountability on the collected payments
- Locational report on the number of vehicles parked at a given period of time.

The intended system was expected to provide solutions to the three mentioned problems. This was to take a perspective of real time data transfer of the parking slot occupancy, parking plan data, parking utilization rate data and parking characteristics' data.

1.2 Objectives of the study

The objective of this study was to design an operational web-based GIS for a car Parking Management System (PMS). Specifically, the resulting system was expected to demonstrate capabilities for real-time streaming of parking activities, queries and visualization of the location of available car parks, the capacities, the available spaces and the possibilities for users to make online payments for the parking services.

Specific Objectives

The following were the specific objectives of the study:

- To identify and digitize designated parking areas from county/sub county records.
- To design a GIS database of the designated parking areas and other auxiliary data that are relevant for the access and integrated management of parking areas, and
- To integrate an e-payment system to operate alongside the GIS database.

1.3 Justification for the Study

The current parking management system in Voi Town as in many other towns in Kenya is largely manual. This means that a parking attendant commonly known as Vehicle Control Agents (VCA) has to physically monitor, charge and receive payments from the different users of the parking services within the town. A manual system is faced with a number of challenges, which include inadequate spatial data on the designated parking areas, lack of real-time information on the use and capacity of the parking spaces, high supervision costs for the parking services, late and often unverifiable submission of parking data (including parking fees collected) since all the staff must physically report to the central office after each day's work.

The location of Voi Town is very strategic; it is centrally located in terms of transportation network. It is at the junction of the two major transport systems; rail transport and road transport. The Standard Gauge Railway (SGR) and its old counterpart Kenya Railway/Rift Valley Railway (KR/RVR) both pass within Voi town. The KR line to Taveta branches off from Voi Town. The

Mombasa-Nairobi Highway and the newly tarmacked Voi to Taveta road all meet within Voi. Taveta is the Kenyan Boarder town with Tanzania. These characteristics make Voi a potential stop over town for most motorists. It was also been chosen for the study because it is the largest town in Taita Taveta County, yet it lacks a proper car parking management system. As such, the findings are also an important resource for town managers and planners in respect to parking management in the entire County.

1.4 Scope of Study

The scope of the study encompassed creation of a web-based GIS Parking Management System for Voi Town. The system was to show parking lot inventory, monitor collection of parking fees, automate production of visual reports as per user specified parameters or provide reports as stipulated or programmed. The system was also expected to be used as a decision support system for locating parking spaces. The study was carried out in Voi Town Central Business District (CBD).

1.5 Significance of the Study

There are several benefits of this study especially to the Voi Sub County Administration. First is to know the current capacity of the parking/parking lot inventory. Second, the administration will be in a position to know the number of vehicles parked either daily, weekly or monthly for the purpose of future decision making for development of parking systems.

1.6 Organization of the Report

The study is organized into five chapters. Chapter one introduces the topic, presents the problem statement, outlines the objectives of the study, provides a justification for the study and presents the scope of the study and its significance. The remainder of this project is divided into four chapters. Chapter Two provides an overview of internet, Web GIS and GPS technology and assesses the use of GIS in various fields such as the health sector, transport, payments and parking management systems. Chapter Three provides a detailed overview of the application requirements including design principles and choices. It presents the detailed application development process of the WebGIS Voi Parking Management System (VPMS) for Voi Town. Chapter Four analyses the results of the application, determining if the web application has fulfilled the application requirements. Chapter Five presents conclusions and recommendations

while addressing opportunities for future studies as well as other viable application areas for such systems.

1.7 Definition of Key Terms

The following are definitions of terms used in this report.

Parking: The act of stopping a vehicle and leaving it unoccupied or occupied.

Parking: A designated area for parking vehicles in a town/municipality

Parking lot: A cleared area that is intended for parking vehicles.

Parking Slot: This is parking area subdivided to accommodate a single vehicle at a time.

Parking Adequacy: Sufficiency of a parking to accommodate parking demand.

Parking Capacity: This is the volume of vehicles that can be accommodated by a parking at a given time when fully parked.

CHAPTER TWO

LITERATURE REVIEW

2.0 Background

Geographical Information System or Geospatial Information System (GIS) is a computer based system of hardware, software and methods that is designed to support capture, manipulation, analysis and output of spatially referenced data to solve complex planning and management problems.

GIS has been widely used in solving a variety of planning and management problems together with the use of the World Wide Web (WWW). GIS could be further developed to allow many more people to have access to its functionality and to enhance both community participation in management and monitoring of revenue collection.

The application of GIS is interdisciplinary; the most common application within local authorities is resource mapping, planning and management.

2.1 Internet GIS and Web GIS

The popularity of internet is due to its wide applicability and ease of accessibility which has enabled e-commerce and social media such as interactive chatting. Internet is a powerful means for access, exchange and processing information due to its availability everywhere/ubiquitous access. The interactive nature of the contents within WWW has acted as an enhancement for the same and GIS has leveraged on this functionality. Data in GIS is can be transferred over the internet due to this capability. Internet GIS is the use of the internet as a means to exchange data, perform GIS analysis and present results. Scholars also argue that it is a framework of network-based GIS that utilizes the internet to access remote geographic information and geoprocessing tools Zhong-Ren & Ming-Hsiang, (2003).

Web GIS refers to the use of WWW as a primary means of access to disparate GI data and information (Zhong-Ren & Ming-Hsiang, 2003). It is a system to manage and deploy spatial and associated data on the web. It offers innovative means to access, collect, disseminate, and process spatial data and information on the Internet as compared to traditional desktop GIS. Some of the innovative means include easy access and web-compatible user interface, which

makes it a great means of spatial information sharing and processing, as well as multimedia presentations and public participation over the Internet. This solves the demerits associated with the traditional Desktop GIS such as the limit of accessibility with users only accessing the installed GIS software and requiring specialized training to access such systems. Accessibility challenges can also be viewed in terms of resource sharing, where the only resources capable of sharing are those within the system on the local machine. At the same time, it is very important to transmit different information to various users efficiently because most tasks such as analysis incorporate use of different data from diverse sources or heterogeneous data.

The problems created by the shortcomings of Desktop GIS include the limited sharing of data and information due to the absence of a suitable dissemination method or medium on the network. This means that in case the desktop system fails, the whole system is grounded. This however, is not the case with Web-based system and its applications on the internet, where they have efficiently solved this problem of performance and unreliability of desktop GIS applications. As a result, most GIS applications have been enlarged gradually from traditional desktop GIS applications to Web-based GIS applications (Brandon, 1997). This technology is emergent in the field of geographic information systems for Web Applications and is termed as WebGIS. It is also known as web-based GIS or Internet GIS and is implemented on a web browser. WebGIS has been developed and used extensively in real-world applications (Chawei (PHIL), David, Ruixin, Menas, & Qili, (2005).

The two technologies (GIS and Internet) combined rapidly increase transparent and efficient management and sharing by standardizing, structuring and archiving geographic data. It is used in various fields such as government services, agriculture, land use, oil and mineral exploration, emergency services, environmental monitoring, ecological research, urban planning, vehicle monitoring, etc. Geospatial information can be published, searched, analyzed, processed and displayed on the internet on a WebGIS website. This technology supports sharing of geospatial information over the web (Michela, Cyril, & Xiang, 2008).

The Internet and GIS have been integrated to form WebGIS which is an effective mapping application for presenting important information to the public as well as revealing anomalies to the professionals in the revenue sector. The following chapter explores and presents application of GIS in various fields including parking management systems (Michela, Cyril, & Xiang, 2008).

(Fu & Sun, 2011), define WebGIS as a network of information systems. A networked GI system has several advantages over a traditional GI system. These advantages are viewed in terms of capabilities, which can be accessed across WWW without the need for installing GIS software on the local machine. The second such capability of WebGIS is provision of infrastructure for data integration and interaction to enable visualization representation which affords the users the ability to make and publish maps via the Internet. Once published, the maps can be accessed from diverse and remote locations so long as there is provision for internet connectivity with ease of access. Geoscientists using conventional GIS faced challenges of access and visualization difficulties, problems that have been significantly reduced through WebGIS (Alesheikh, Helali, & Behroz, 2002). The enhancement of GIS with the integration of internet also introduced functionalities such as querying of attributes on a layer and data collection, for example, in Voluntary Geographic Information system (VGI), finding locations, etc. The learning curve for the users, costs of training and software licenses have also been greatly reduced to minimum level. WebGIS domain is characterized by a great deal of research especially where visualization and analysis are involved, GIS as a tool has gained prominence with dynamic web applications depicting analysis and visualization. Although there are two types of web-based GIS applications, static and dynamic Web-based GIS, dynamic application is gaining popularity due to its real time streaming of data and information.

WebGIS, like any other internet based application, uses Hypertext Transfer Protocol (HTTP) technology a media of communication through its request sent to a web server through a browser and response through the same. The request sent to the server are processed and sent back as response in form of Hypertext Markup Language (HTML) or in other forms such as Extensible Markup Language (XML), etc. (Fu & Sun, 2011). The languages/technologies aforementioned reduced some of the performance issues faced by GIS applications over the Internet. The issues were due to exchange of bulky/large quantity of data between servers and clients as explained by (Alesheikh, Helali, & Behroz, 2002). With the appropriate choice of architecture for WebGIS application, the problem can be fairly reduced. The major architectures are thick client/thin server or thin client/thick server both have advantages depending on what one wants to achieve in a project.

One of the greatest capabilities of GIS technology is the ability to allow for the development and integration of non-spatial and spatial databases, covering small or large geographical areas. This is important in planning, monitoring and decision-making. The spatial data, once made available up to a micro level, can be used by planners and managers to provide a great increase to revenue budgeting and planning and monitoring collection activities. This segmentation of data to a very minute level can also be explored in developing systems for monitoring social infrastructure projects such as water supply projects, health, school, higher education, roads, telecommunications, etc.

Connections between pieces of information and data and their locational distribution can be used in GIS to create a visual representation that aids revenue administrators and managers in decision making as well as suggesting solutions through analysis of the representations related to revenue collection (Riner, Cunningham, & Johnson, 2004). The reason for employing GIS in the revenue management systems is to comprehend the locational layout of the sources of revenue for the purpose of making intelligent decision.

2.2 Satellite Positioning

One key element of a GIS is data; satellite positioning is one of the various methods used for data collection. In satellite positioning, a prominent system called Global Positioning System (GPS) is used in collection of data using UTM coordinates, a key format that works in GIS. GPS is a system of satellites orbiting around the earth with a total of 27 satellites, while receivers stationed on the earth's surface are used to collect data from these satellites. Data collected by GPS receivers are Northings, Eastings, and Elevation or Latitudes and Longitudes and height.

Some of the application areas of GPS technology include electrical systems management, surveying, water systems management, logistics, traffic management, security, marketing, fishing, farming, banking, rental car industry, weather forecasting, etc. With the development of our society, GPS is providing more information and better services. Also, more and more privates and companies begin to use GPS technology and develop new applications with it.

2.3 Application of GIS in Health Sector

GIS has been used in monitoring and assessing health problems, which requires high quality information in order to identify correctly and prioritize problems, develop and evaluate policies

and actions which are anchored on spatiality of these problems. By 1990, the Agency for Toxic Substance and Disease Registry (ASTDR) in America had already adopted GIS for the purpose of evaluation of demographic characteristics of populations around sites and in identification of features in the community that were relevant to the protection of the populations as well as monitor health related data and health complaints by the community members (Wolfgang & David, 2012).

Those involved in detection of diseases as an aspect of public health (epidemiologists), took cognizance of the triad of person, place and time in their disease investigations and analysis. The triad basically applies the association among the person, place and time to explain a diseases phenomenon which helps them in responding to disease outbreaks and other community health problems.

The applications at the time were the best by the then standards. However, with the entrance of the Geovisualization (application of web GIS) where visual geospatial display is used to explore data in order to generate hypotheses, develop problem solutions and construct knowledge, the applications in health could have been very satisfying (Hari & Rama, 2006). It is also important to note that most of these solutions are based on proprietary GIS software which increases their cost of implementation.

2.4 GIS In Transportation

One of the key elements in GIS is data, both spatial and non-spatial, and its management. It is therefore important that in transportation there is provision for data aggregation and a manipulation mechanism that deals with railroad, roadway, structure inventories, safety and traffic data. This can only be provided for in GIS for transportation (GIS – T).

2.5 GIS in Inventory Management

Hrjit, (2011) describes inventory as the stock of any item or resource displayed in a retail shop. GIS has been used in many inventory management projects, for example, natural resource inventory, equipment location and utilization and interagency healthcare logistical support.

Natural resource management has leveraged on the use of GIS, for example, in wetland and environmental application. The need for a regional wetland inventory, which is always

controversial (John & Jack, 1995), makes GIS more acceptable due the fact that historical maps or evaluations, field records, current and historical aerial photographs, remote sensed data and any other available data can be processed in overlays, a capability that can only be provided by GIS technology.

In order for engineers to choose the right equipment and equate them to the right task, it is important that the location of such equipment as well as the job site are known. Although certain equipment stays within the confines of the project, other equipment moves from one site to the next. In their book, Douglas *et al*, (2006) categorizes equipment into these two basic categories, equipment that stay within the general confine of the construction site and equipment that transport material to and from the site. GIS is used in construction equipment management to permit real time monitoring of actual equipment location (Douglas, Calin, & Richard, 2006).

Applicability of GIS in interagency healthcare logistical support comes in handy when emergencies occur. In this case, for example, it is important to know where the catastrophic event has occurred, which can be done because of the spatial component of data in GI systems. GIS allows the participating stakeholders to view, understand, question, interpret and visualize data in terms of collaborating agencies in dealing with the logistics. They are also able to clarify the relationship between agencies in terms of accomplishing the common goal that has brought them together. Indeed, parking slots may be viewed as a list (inventory) of items, though in terms of service, to be offered to clients.

GIS has been used in inventory management for some time; however, it is important to note that this is the very basic of its application and organizations should think of exploring the full potential of GIS beside inventory. Don *et al* (1995), laments that despite the obvious power of GIS to manipulate and integrate data and to perform spatial analysis, many agencies use GIS only for inventory management.

2.6 Parking and Parking System

Parking lot or car lot is a cleared area that is intended for parking vehicles. Usually, the term refers to a dedicated area that has been provided with a durable or semi-durable surface. It has been established that parking lots is a problem in most countries where cars are the dominant mode of transportation since they are a feature of every city and suburban area in such countries.

In fact, in such countries, parking lots are a major facility in shopping malls, sports stadiums, megachurches and similar venues which are often immense in size/area. The term "parking lot" is an abbreviation of the term "parking lottery", which arose from the difficulty in finding spaces (Wikipedia, 2016). Parking requirements recognize the shared parking concepts using a variety of mechanism such as defined reduction factors or allowing for special studies. Many CBD parking regulations in cities have already transitioned to shared, market-based parking arrangements where some uses have no minimum requirements (Richard, 2013).

Parking has been attracting serious attention from policy makers, regulators and planners since 1990. Since then many research projects have been dedicated to address the issues of truck parking. The simplest application of GIS is in the location of a parking space. The city of Nanaimo in Canada has used MapGuide to create an on-line mapping tool for public use. The city's map provides users with the ability to locate city parking lots. There is also an automatic parking arrangement in shopping malls, where each car with its auto-PC may build network connections with the parking lot server when the car enters the parking lot of the mall. The parking lot server will tell whether there is parking space available and indicate where the nearest parking lot is from a favourite shopping store (Zhong-Ren & Ming-Hsiang, 2003).

2.6.1 Parking Strategy

This is conceptualization of parking in very broad terms. In his book, Michael, (2016) cites five models of parking concepts.

- Area-shared

This deals with provision of parking within a walking distance. The model is always adopted by cities that provide parking within a CBD. It is also found in commercial operations that provide parking for a particular area. It also finds application in private-public joint ventures.

- Destination-shared

This model targets a specific project or several uses around each other. The model suggests a private sector development rather than public venture. However, in some cases some projects tend to be private-public ventures opportunities.

- Central focus

This model is composed of a large centralized parking facility in the center of a zone with a pedestrian distribution system connecting the facility to many diverse destinations. This model has the disadvantage of bringing all the vehicles in the core area. They focus on good vehicular access at the center of the activity

- Intercept

The model intercepts the parkers at the perimeter of an activity center. The philosophy here is that auto congestion within the core creates air pollution and unnecessary congestion and that environment within the activity center should be kept pedestrian in scale and free from auto traffic.

- Regional intercept

This model intercepts parkers farther away from the activity center.

2.6.2 Parking Requirements

Two considerations are important in parking requirements: productivity versus utilization of the parking spaces. The performance measures at this level include:

- Duration

This denotes the length of time a vehicle is parked. The average duration is the average length of time all vehicles are parked in a facility over a specific period. In this definition All-day parking, for instance, refers to vehicles parked for the hours of a typical working day.

- Parking adequacy

This is the degree to which the supply of parking is adequate to handle the parking demand. This is one of the most important factors, which underpin the comparison between the peak parking demand and the effective supply.

- Parking capacity

This denotes the number of vehicles that can be parked at a given facility. It goes hand in hand with parking supply which is the total number of spaces available to serve a destination.

- Turnover

This is the number of different vehicles parked in a specific area or facility in a given period of time divided by the number of spaces. Underutilization of a parking facility is denoted by low turnover rate and vice versa. This rate can be calculated periodically.

- Utilization

This is the usage of a space or a facility over a given period of time. Parking occupancy can be recorded and measured at hourly intervals or only at expected peak time periods.

2.6.3 Parking Responsibility

Parking responsibilities in many cities are often fragmented among numerous departments or agencies. In a municipal context like Voi Town, public works may control most of the physical aspects such as building and maintaining on – and – off street facilities. The police or council Askaris department provides enforcement and finance responsible for revenue collection. In all these the common characteristics of any parking program includes: -

- Clear mission and vision

It is important to know why a parking system is to be created. This will guide and be a litmus test for the very existence of a parking system. Again, there must have a compelling and inspirational statement(s) communicating hope for the future of a parking system. That mission and vision of a parking system must resonate with the expectations, have support and be purposefully crafted to integrate with the community's development plan. Viable parking systems are those that are professionally managed in the perspective of cleanliness, safety, attractiveness and maintenance.

- Parking philosophy

According to Feit & Feehan, (2006) parking is not about cars, the focus is on the people and it is not only the act of temporarily storing cars. It's a transitional experience from vehicular to

pedestrian. They further agree that parking should be friendly and not free. In towns land values are very high, therefore any space is seen as a source of income and thus parking space becomes a source of return or revenue on investment.

- Strong planning

Development of a well-managed parking planning function is a requirement in parking responsibility, which requires an understanding of existing parking resources. Some of the planning considerations are: parking inventory, which is complete and up-to-date and categorization of parking inventories in terms of type and use of space. This enables the utilization of parking by type of spaces to be known and the trends to be tracked. It also enables changes in supply to be documented and changes in utilization to be tracked and understood.

- Organization

This is how well the parking organization is structured and staffed to best achieve its goals.

- Staff development

The organization should recognize the unique knowledge, complexity and broad skill sets required to be successful in parking. They should also invest in parking specific training and educational opportunities to develop their staff into parking professionals.

- Consolidated parking programs

For comprehensive and effective parking programs, the systems approach is an important dimension. It consists of having control on all or most of the aspects of parking. This is due to the interactive nature of parking systems.

- Financial planning

There are three perspectives to this characteristic; is it expected to be a self-supporting entity, a profit or revenue center or a support service sustained by other primary revenue sources. In a self-supporting scenario, there are several considerations including market rates for parking, parking mix, availability of on street parking revenues, availability of parking enforcement revenues Policies, and economic development policies.

- Creative, flexible and accountable parking management

Different clients need different parking arrangements to be accommodated in a parking system. In their summary (Marvin & David, 2006), affirm that a well-managed parking is a key component in attracting and supporting new developments and is essential to sustaining healthy and vibrant downtowns.

The influx of vehicles in cities and towns around the world has posed a challenge to city and town managers and the aforementioned characteristics are illusive and hard to achieve. This has taken dimension of traffic congestion and insufficient parking spaces. In parking, congestion is usually mathematically evaluated and is the number of vehicles that pass through a point in a window of time, or a flow. Again, principles of fluid dynamics are borrowed from where congestion flow is likened. It can therefore be understood that the influx can generate demand for space greater than the available street capacity. Other causes can be attributed to traffic incidents, road work and weather events (Wikipedia, 2016). The reality of insufficient parking spaces has led to significant technological development on parking lots management. These developments include: -

2.6.4 Parking Guidance and Information System (PGIS)

As per the literature review, the most prominent system is Parking Guidance Information System (PGIS). The GIS-based PGIS guides the driver by providing a view of the parking area depicting in real time the parking situation of his destination, allowing him/her to reserve a space as well as have his smart phone enabled to notify him once he approaches a vacant space or even perform routing functions (George, Douglas, & Charles, 2013).

PGIS, also known as Advanced Parking Information System (APIS) aims to promote the effective utilization of parking lots and adjacent roads, to provide parking location, condition, road traffic routes and other information related by variety ways to induce the driver to find the parking most effectively. The objectives of the system can be summarized into the following: The angle of road use: this helps drivers to shorten the time at queues and avoid creation of traffic at the time of getting a parking slot, which leads to improved road usage. The angle of road use by some margin, helps in easing the pressure of guidance area traffic thereby, improving urban traffic congestion situation. The angle of parking facilities: this has been

established to reduce the vacancy rate, promote balanced use of parking, improve parking turnover rate, protect the economic benefits of car parks and promote the economic vitality of commercial facilities within the system (George, Douglas, & Charles, 2013).

Frustration of drivers can be reduced by parking systems that use internet enabled smart phone drivers (Simon, 2011). Simon (2011), further states how in many parts of the world and Australia ubiquitous adoption of phones that implement such systems has made it feasible for drivers to access real time parking information prior to arrival. He further advises that if such systems are integrated with technologies, it opens up possibilities of a parking system with pre-arrival functionalities that inform drivers of the parking situation prior to arriving at site, direct drivers to parking lots and thus reduce chances of traffic and queuing for parking.

2.6.5 Transit Based Information System

This is an example of Intelligent Transport System (ITS) which focuses mainly on efficient management of public transport operator resources. There are two important resources here; the crew and the fleet of vehicles. Advanced Public Transport Information Systems (APTIS) shifts focus to travelers. Nigel & Agostino, (2004) argue by doing so they make the system an effective tool for improving the quality and effectiveness of services. These systems provide accurate and timely information to travelers before their trip. This qualifies their decision on route and departure time. APTIS provide two types of information, descriptive and prescriptive. The descriptive information describes the network condition e.g. waiting time at the stop for a given transit line. The aim is to improve travelers' knowledge and awareness of the actual state of the network. The second deals with the actual advice about travel choices. These could be departure time and route choices which the travelers have the right to choose to follow or ignore

2.6.6 Smart Payment System

This consists of several technological advances, Smart meters which are used for collection of on street revenues, a system that accepts coins. Smart meter can be provided in a multi-space meter format in which a single meter or pay station serves as a revenue collection point for more than one parking stalls.

- Automated Parking

There are four stages in this system. The first step is to scan the vehicle number plate and record it. Second is a cognitive process where the recorded information is analyzed appropriately. In the third stage a decision is made as to which parking is appropriate for the car based on the analysis. The fourth stage deals with the action necessary for the implementation of the decision reached (Kim, 2015).

- Parking Information Sharing

This is one of the most common strategies adopted by a smart parking system. In this system, drivers can check real time parking information for a certain area and choose a desired place according to their preference.

2.7 Revenue Management and Mobilization

Revenue management entails identification of sources of revenue, organizing the sources to channel output in controlled destination so as to ensure accountability through maintenance. Mobilization on the other hand ensures the sources are identified positively and necessary resources deployed for success in their management. The capacity of local authorities to generate sufficient funds from all available sources can only be evaluated if sound revenue management is put in place. The revenue is often used to support policies regarding service provision (Gerasimos & Clifford, 1999).

Revenue management involves several essential considerations that can be categorized under three general headings; revenue development, revenue analysis and lastly support systems. The development of revenue management is concerned with establishing a tax structure that considers both short term and long term resource needs. Conventionally, revenue management stresses a time horizon that reflects election cycles and short term political needs. The objective of the analytical process is to systematically examine the salient characteristics of each revenue source available to local governments, including the yields, equity issues and cost of administration, with a view to clarifying alternatives and their implications. The support system deals with the day – to – day management of the revenue sources. It produces the data required by the revenue development and analytical process.

The main source of revenue to the county government is grants from the National government. Article 202 (1) of the Constitution states that revenue raised nationally shall be shared equitably among the national and county governments. Another source of revenue for county governments is taxes. Article 209 (3) of the Constitution states that a county may impose – a) property rates b) entertainments taxes c) any other tax that is authorized to impose by an act of parliament (Kenya Law Reports, 2010).

2.7.1 Revenue Administration, Management and Monitoring

Web GIS also finds its applications in resource management, which is necessitated by the conflicting nature of the resource management processes, and the multiplicity of local communities. In this front the objective in such Web GIS technology is to offer capabilities with which resource managers can adopt to create and alter resource plans and also incorporate new conditions when environmental conditions change. This basically explores the analytical capabilities of GIS.

2.7.2 Toward Diversification in Implementation

At the beginning stage of a Web-based GIS for revenue management and monitoring application, implementation requires purchase of proprietary software. However, this is no longer a headache. Much work has been done recently on the implementation of web GIS applications using free software and open source software (Songnian, Suzana, & Bert, 2011).

2.7.3 Managing and Generating Revenue

GIS technology gives financial and accounting managers an alternative way to view revenue and shows the geographic links between accounts and revenue streams. According to (Christopher & Milton, 2004) financial managers continue looking up from their spread sheets and asking the question: “at what location is revenue generated?” From this perspective, it is easy to see how geography enhances revenue management when one sees a link between a geographic area and successful revenue generation through application of WebGIS.

Christopher and Milton (2004) further state that traditional financial management tools and software do a good job performing routine audits and analysis, but GIS can help enhance the analysis by answering spatially related questions. The answers can help identify revenues that

might have slipped through the cracks. A GIS enables you to see where these “cracks” are, and enhanced revenue streams are a significant benefit of integrating GIS into traditional work flows.

2.8 Why GIS?

There are several reasons why GIS has been chosen as the preferred technology to be used in the implementation of the system. It brings to the fore the location of a given phenomenon as well as features of other elements to which it relates, which is very important when it comes to analysis. Relationships of phenomena are always very complex. GIS provides complex analysis of the interrelations between different layers of geographical information through a process of gathering, presenting, analyzing, and visualizing data and images that may be available from different sources.

The second benefit of GIS is its ability to combine several layers into one map with additional capability of putting off and on a layer as per the requirement. Most importantly, the user is able to generate new information from the existing layers by carrying out combination of different layers in a GIS system.

Lastly is querying of the system which is synonymous with carrying a search in a web page, a query action retrieves data from the systems database which relates to the required data and provides it as a new theme, the queried data can be visualized. This brings in efficient means for data distribution and handling and since the data is organized in a repository/database, redundancy is eliminated.

As mentioned earlier, GIS is crucial in carrying out analysis which can only be done if diverse data sets are brought together and their relationship studied. This is basically integration of data from various and diverse sources. Analysis is basically done to aid in decision making which improves and maximizes efficiency of planning.

2.9 Vehicle Parking Challenges

Typically in Central Business Districts (CBD) of large urban areas, a significant amount of driver time is spent on looking for a parking space. When drivers are provided with information on parking availability, there is a reduction on their search time, the congestion in the impacted roadway network, as well as at the entrances of parking lots. In addition, the search for parking

space availability increases the stress of the travelers. Furthermore, it has been found that the economic competitiveness of an area can be benefited by accurate parking space information. It is not uncommon for travelers to choose a specific area to do their business due to the availability of parking and parking information, and vice versa, to avoid a specific area due to the frustration associated with finding a parking space – if a good transit system is not in place (Kyriacos, Neville, & Maria, 2007).

Major cities have a major responsibility to create curb turnover for short-term parking and rein scofflaw who ignore parking regulations. To succeed in this, management in such cities employ Vehicle Control Agents (VCA), these are also called ticket writers. Even with efficient use of these VCAs, it is still difficult to visualize, analyze, and take action from traditional written reports due to scarce on-street space, off-street lots, and garages. The problems are also exacerbated by the dynamic nature of parking patterns over the course of a day and across an entire city parking landscape. To ensure maximum collections from parking, efficient management of VCAs is imperative and should be a top priority to the management of a parking management program. Visualization capability of GIS aids performance monitoring of the VCAs.

Integration of performance hits by the VCAs and performance standard is necessary during implementation of the GIS application, the performance beats if established in the system as attribute data and well plotted against employee performance standards and spatially mapped, supervisors are able to access the GIS to view daily performance summaries. Visualization allows division within the system to allow supervisors to view areas where hits and beats are mapped. This is an advantage that comes with GIS in form of analysis and can be used as a decision support system for implementing decisions or basis for the supervisor to take appropriate action.

The GIS systems analysis outcome may be used to redesign, as well as allow for easy accommodation of revisions if at all there are. In a conventional system where GIS is not employed, the above mentioned might take unnecessary longer time re-mapping, while GIS remapping of any aspect within the parking or revision requires very little setting of criteria into the system GAEA Systems Pvt. Ltd, (nd).

2.10 Literature Review Summary

The above review reveals several factors considered in parking management systems. First and foremost, the available literature reveals the importance of pre-arrival parking information systems for motorists and the general public regarding parking availability. The second emphasis is on putting in place accurate mapping of parking slots and parking bays. The third is the creation of customer interface of spatial and non-spatial parking data. The fourth is ensuring that all users of the parking slots are reached and that they comply with the parking regulations; a top priority of a parking management program as mentioned above. Another is to monitor VCAs and counsel them with respect to their performance. Lastly but most importantly, the literature has revealed that there is limited focus on the revenue collected by these systems. Due to this lacuna in the literature, the focus of this study is to incorporate demonstration of revenue collected from the parking systems into focus.

CHAPTER THREE

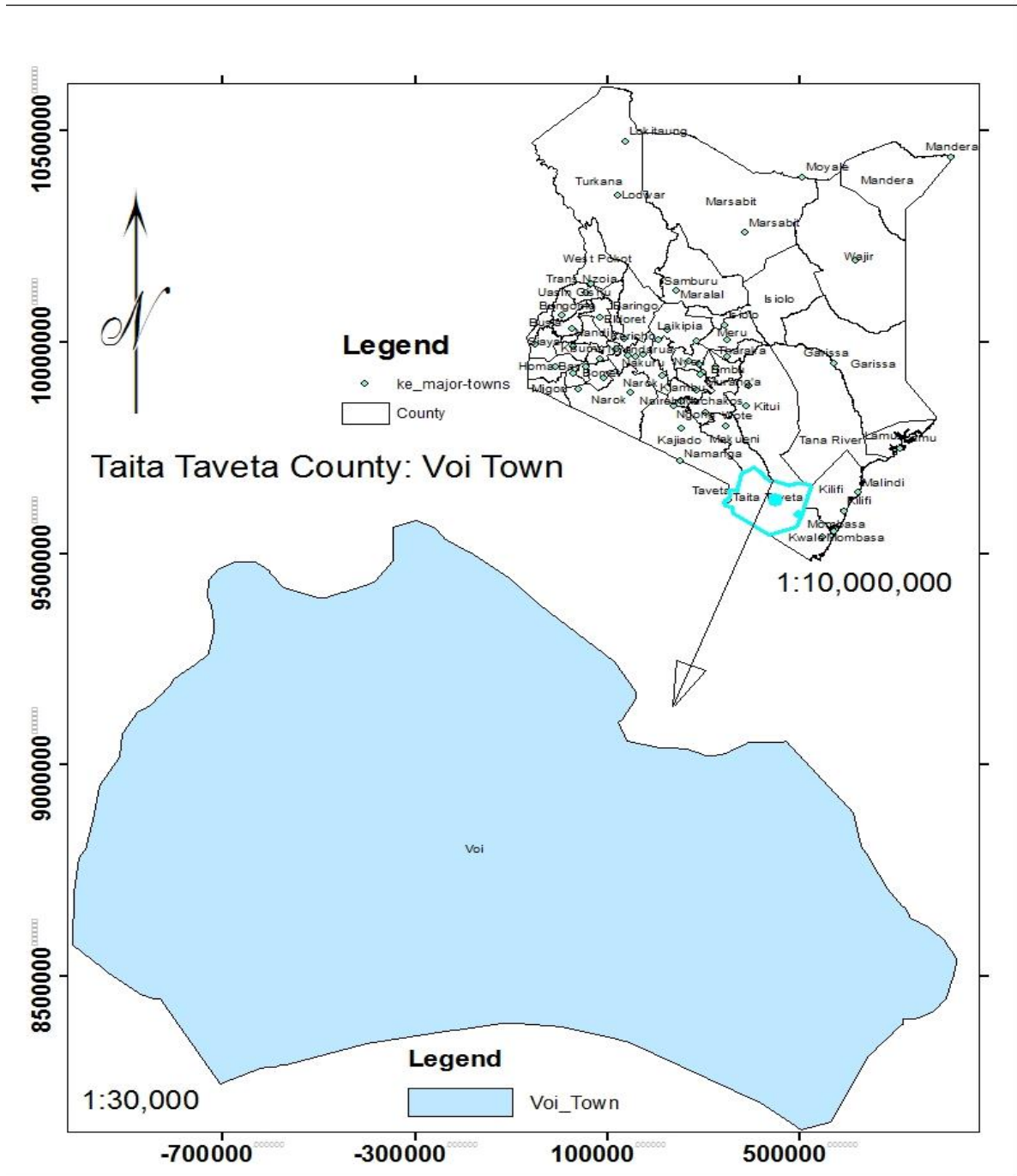
MATERIALS AND METHODS

3.0 Study Area

This research was carried out in Voi Town, Voi Sub County of Taita Taveta County. Voi Township is at the junction of the two major transport systems; rail transport and road transport. The Standard Gauge Railway (SGR) and its old counterpart Kenya Railway/Rift Valley Railway (KR/ RVR) both pass within Voi town. The KR line to Taveta branches from Voi town. The Mombasa-Nairobi Highway and the newly tarmacked Voi to Taveta road meet within Voi. Taveta is the Kenyan Boarder town with Tanzania. Voi town therefore connects Taveta (boarder town), Mombasa and Nairobi. The town is developing fast and there is a notable influx of vehicles. Infrastructure wise, Voi Town is more developed than the other remaining three Sub Counties of Mwatate, Wundanyi and Taveta in Taita Taveta County. The location of Voi town is very strategic and aids its growth fundamentally.

The above description makes Voi a potential stop over town for most motorists. It was also chosen because it is the largest town in Taita Taveta County, an upcoming promising town yet there is no proper car parking facility.

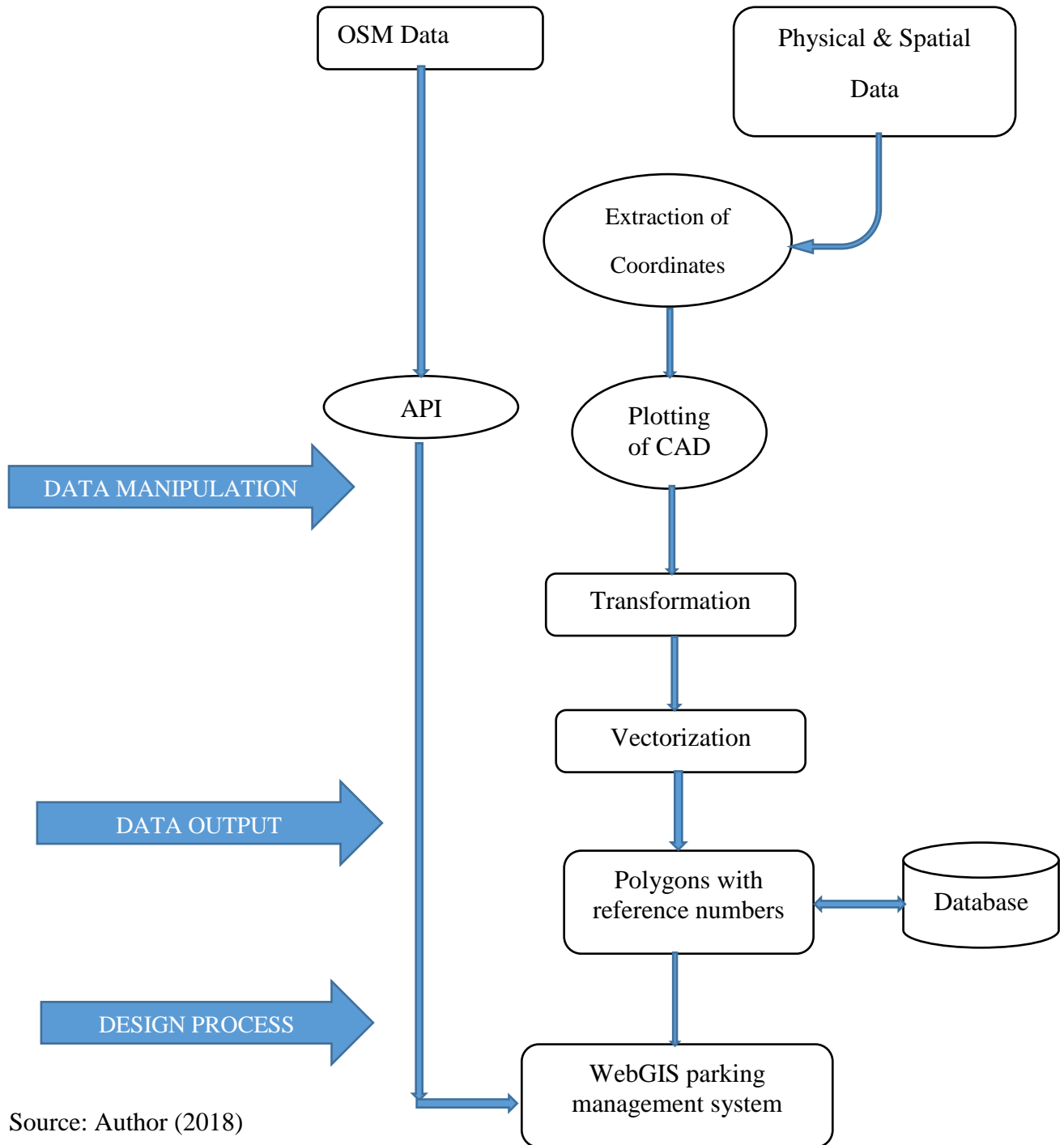
Figure 3-1 Map of the Study Area



Source: Author (2018)

The following flow chart summarizes the workflow which was employed in the development of VPMS.

Figure 3-2 Project Workflow



Source: Author (2018)

3.1 Data Preparation

This section details the collection, processing, and design processes applied in the study as illustrated the flow chart in at the data manipulation stage.

3.1.1 Base Data

Base data was used to bring the application map into context. There are several web map providers who provide APIs to allow integration of the base map with applications for development purposes this they offer under open license. To act as a check to area of study, from all the solutions available; Google Maps, OpenStreetMap and WikiMapia, the most appropriate was found to be OpenStreetMap. It was found to be most suitable for different web application platforms, map contains features needed for car parking lot management system/roads and has an open data license as a very important condition, and consequently it was the most useful tool to help in the achievement of the goals of the project.

3.1.2 Base Data Processing

Open Street Map (OSM): this data has been incorporated into the study through Application Programming Interface (API) provided by OSM organization.

3.1.3 Cadastral Parcels/Property Boundaries

Cassini coordinates were extracted from several Folio Register Numbers also known as FR Nos. from the Director of Survey and plotted to form Computer Assisted Drawing (CAD).

3.1.4 Transformation of Coordinates

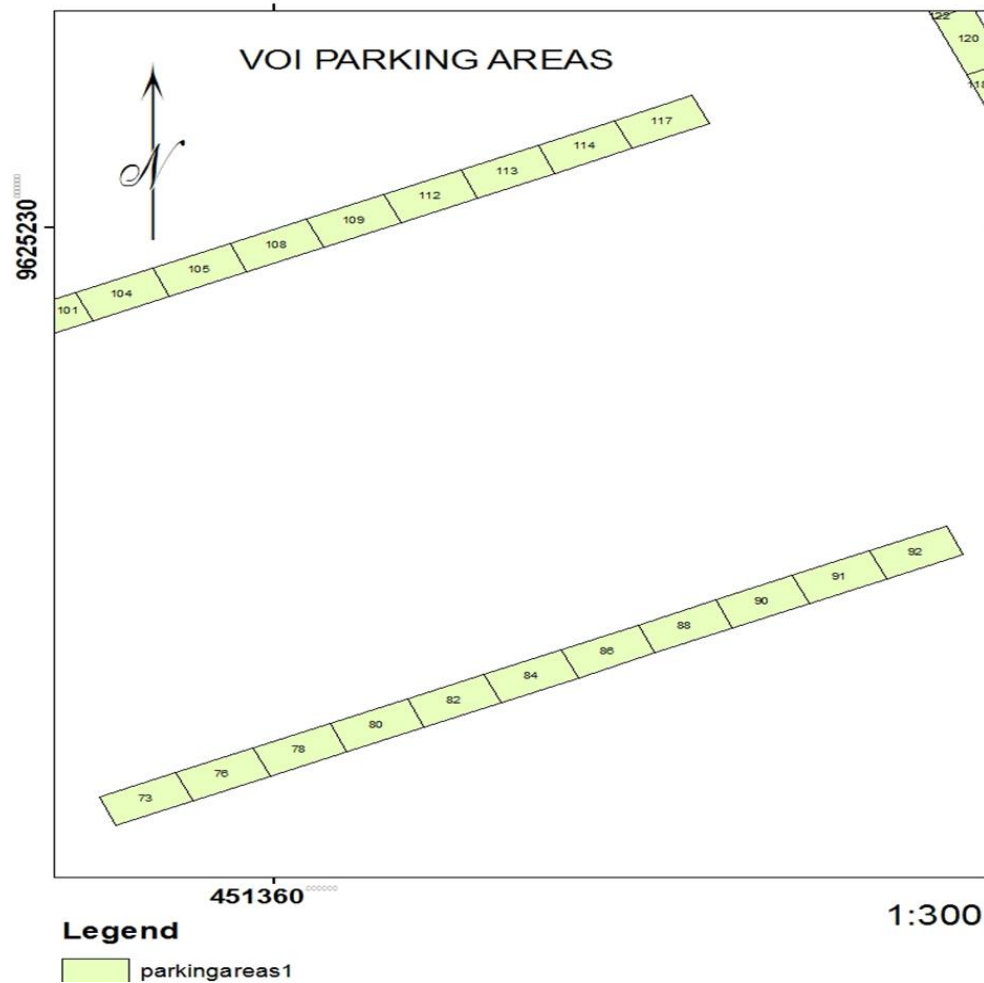
It was necessary to convert all coordinates from Cassini into the UTM system so as to have all the spatial data compatible with the GIS software systems. The transformation sheets obtained from Survey of Kenya were used to accomplish this task, first the sheet covering Voi was identified positively as sheet no. 189/IV and the spread sheet accompanying the sheets was used with the transformation parameters to transform the coordinates.

3.1.5 Parking Area Data Processing/Parking slots

Field data collection was carried out to pick the parking spaces as indicated/drawn (by Voi Parking Management) on the road reserve pavement and georeferenced with the existing datum

from the Director of Survey. This data was added to the CAD to form parking slots/area layer (Figure 3-3). During vectorization parking slot numbers were assigned automatically by adopting gid as the parking slot numbers.

Figure 3-3 Map of Voi Parking Slots



Source: Author (2018)

3.2 Sources of Data, Software and Hardware

It was a deliberate decision to use open source in this study because of their relatively low cost; cost of internet connection at the time of downloading and, updating and configuration. The software is being maintained by community of developers who keep on improving them, thus another advantage. The project was executed with a personal computer with the following

specifications; 2.00GHz processor speed, 4 GB Random Access Memory (RAM), 32 bit Microsoft Windows 7 Professional Operating System and 500 GB Hard disk.

Table 3-1 Software and Tools used in the Project

Item	Category	Source	Remarks
GeoServer Ver. 2.11.2	Server	http://geoserver.org	Open source
PostgreSQL 9.5.11	DBMS	https://www.postgresql.org	Open source
PostGIS 2.2	Extension	http://postgis.net/2015/10/07/postgis-2.2.0	Open source
PhpPgAdmin III 5.1	Tool	https://www.phpPgAdmin.sourceforge.net	Open source
pgAdmin III 1.22.2	Tool	https://www.postgresql.org/ftp/pgadmin/pgadmin3	Open source
PHP Version 5.6.36	Language	https://www.php.net	Open source
Parcel plans/FRs	Data	SOK (Survey of Kenya)	Data fees
Personal Computer	Hardware	Self (Okina Otieno)	Initial cost
Wireless Router	Tool	Self (Okina Otieno)	Initial cost
AutoCad 2010	Tool	https://www.autodesk.com/education/free-software	Free
Open Street Map	Data	https://www.openstreetmap.org	Free

Source: Author (2018)

The following figure shows part of Cadastral plan of Voi Town with road reserves where parking slots were measured, demarcated and picked for processing during the study. The plan is a combination of several FRs acquired from the Director of Survey.

Figure 3-4 Surveyed Parcels in Voi Town

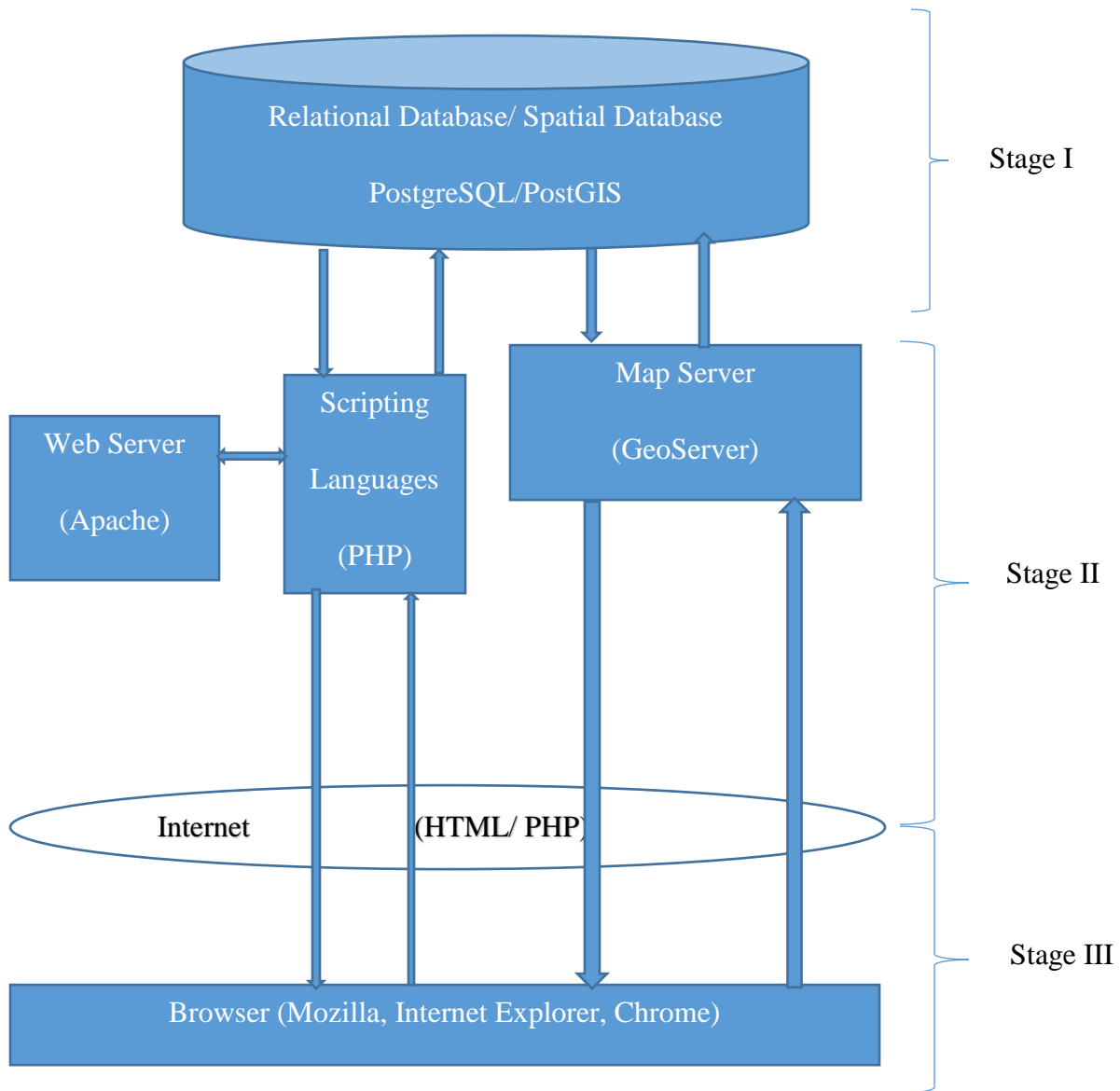


Source: Survey of Kenya (1980s)

3.3 Application Development/Design process

This is the design process and it described the development of the Application and it was guided by the architecture illustrated in Figure 3-5, the details regarding uploading of the shapefile to PostGIS database/pgAdmin III, the creation of tables for the application and lastly development of the WebGIS application (VPMS).

Figure 3-5 Architecture of VPMS



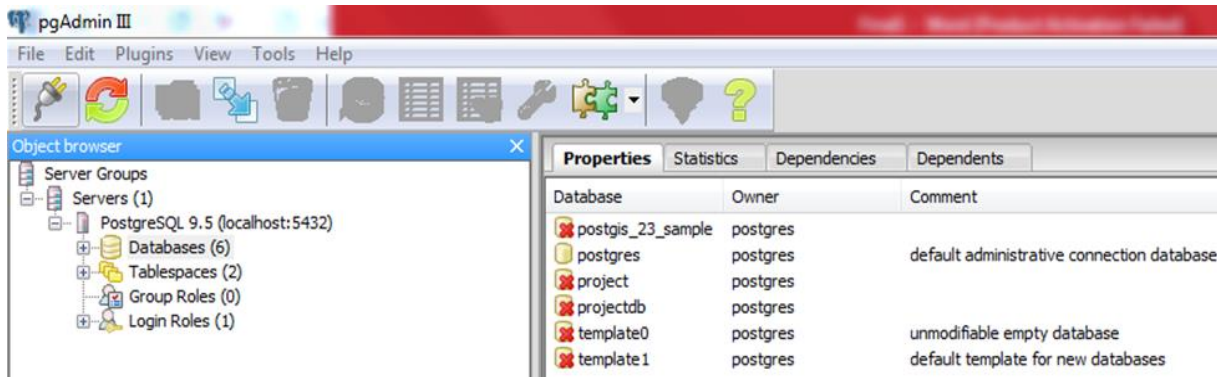
Source: Author (2018)

3.4 Stage I

This involved installation of the prerequisite database management systems for the management of the envisaged data for the system; PostgreSQL for storage and manipulation of attribute data and PostGIS for manipulation of spatial data, pgAdmin III was installed. In order to hasten creation, retrieval, update and deletion (CRUD) of data during development and testing, phpPgAdmin (a web-based administration tool for PostgreSQL) was installed to handle the

attribute data. After installation, configuration was done to enable their applicability to the development process of VPMS.

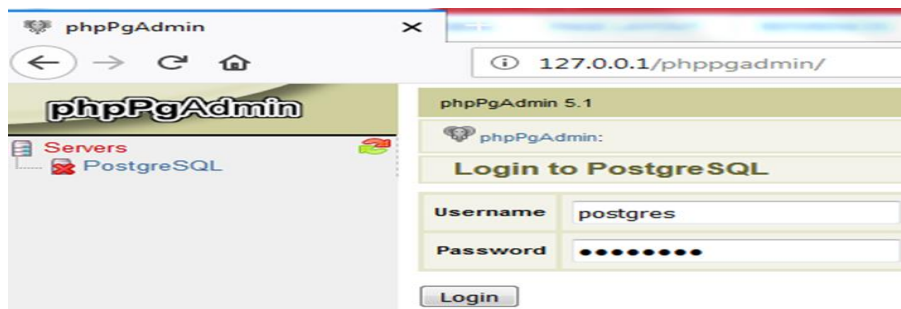
Figure 3-6 Configured pgAdmin III



Source: Author (2018)

Database has sensitive information and access to the same needs to be controlled; configuration was done to enable users to use credentials to access VPMS.

Figure 3-7 Configured phpPgAdmin III with Credentials for Access

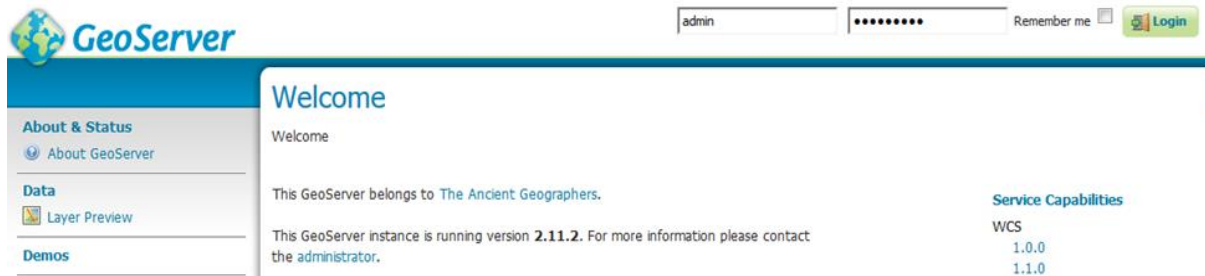


Source: Author (2018)

3.5 Stage II

At this stage the prerequisite servers were installed, configured and integrated to allow seamless communication between them. The first to be installed was map server (GeoServer), second to be installed was phpPgAdmin, which comes with Apache server. They were all configured for use. The following figure shows Geoserver home page with Login panel.

Figure 3-8 Configured GeoServer



Source: Author (2018)

After installation of phpPgAdmin, a confirmation was made to ascertain whether Apache Server was also automatically installed and ready for development. Indeed, Apache Version 2.4.33 had been installed.

Figure 3-9 Confirming Apache Version with Command Prompt

```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\Muarice Okina>cd c:\
c:\>cd bitnami\
c:\Bitnami>cd wappstack-5.6.36-1\
c:\Bitnami\wappstack-5.6.36-1>cd apache2\
c:\Bitnami\wappstack-5.6.36-1\apache2>cd bin\
c:\Bitnami\wappstack-5.6.36-1\apache2\bin>httpd.exe -v
Server version: Apache/2.4.33 (Win32)
Apache Lounge UC11 Server built: Mar 29 2018 13:09:52
```

Source: Author (2018)

After installing the servers, which now could be provided by the operating system, the next step was to create a middle ware; the interface between the inputs and outputs to provide service to the installed software applications. To create this software a php scripting language was used. However, before this could be done, it was ensured that php was properly installed and configured. The following code (testingforphp.php) was run on localhost via a web browser.

Figure 3-10 Testing for the Installed Php Version


```

1  <?php
2  phpinfo()
3  ?>
    
```

Source: Author (2018)

The test yielded the following; PHP Version 5.6.36 with a configuration path in Windows Drive C/... (Figure 3-11).

Figure 3-11 Result of the Test

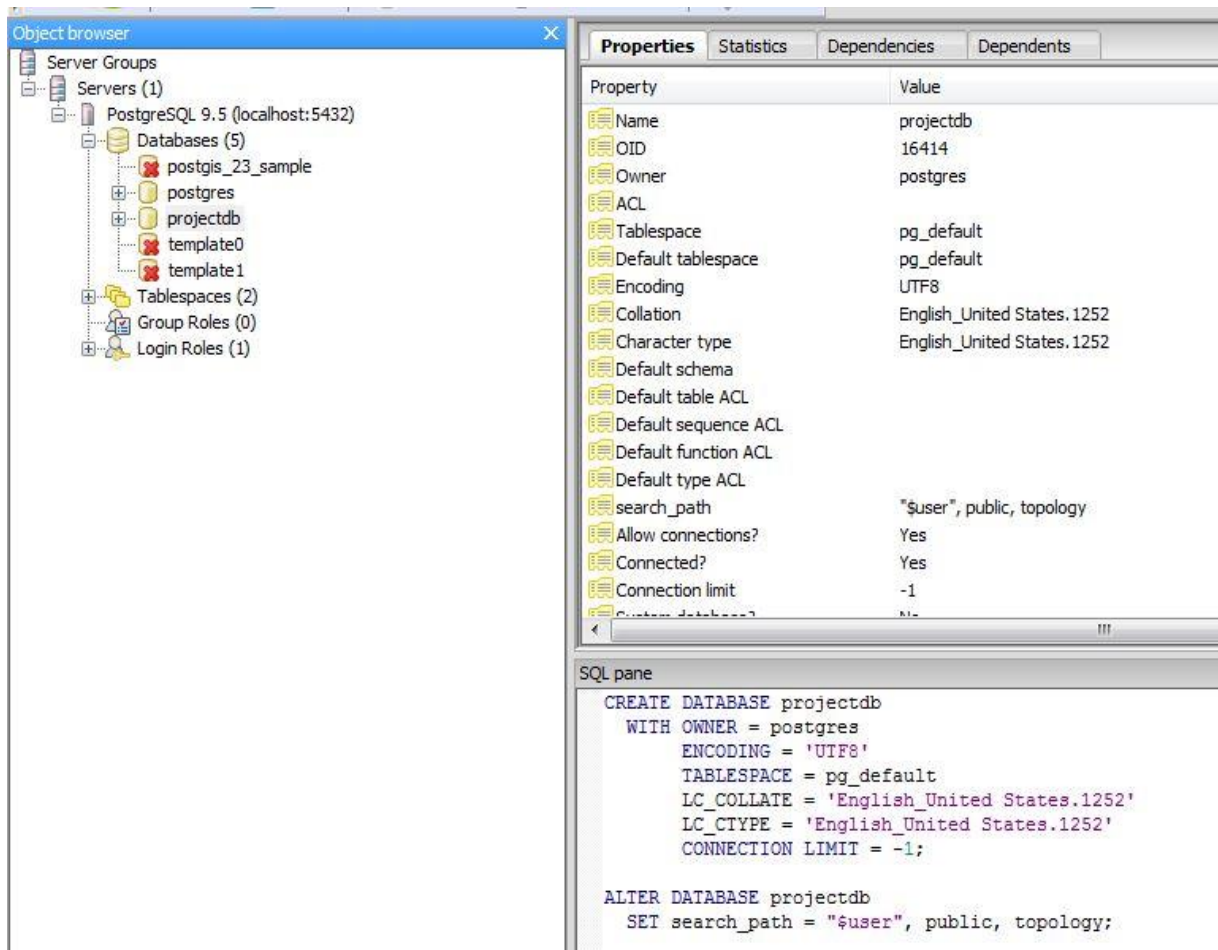
PHP Version 5.6.36 	
System	Windows NT MUARICEOKINA-PC 6.1 build 7601 (Windows 7 Professional Edition Service Pack 1) i586
Build Date	Apr 25 2018 16:38:50
Compiler	MSVC11 (Visual C++ 2012)
Architecture	x86
Configure Command	cscript /nologo configure.js "--enable-snapshot-build" "--disable-isapi" "--enable-debug-pack" "--without-mssql" "--without-pdo-mssql" "--without-pi3web" "--with-pdo-oci=c:\php-sdk\oracle\x86\instantclient_12_1\sdk,shared" "--with-oci8-12c=c:\php-sdk\oracle\x86\instantclient_12_1\sdk,shared" "--enable-object-out-dir=../obj" "--enable-com-dotnet=shared" "--with-mcrypt=static" "--without-analyzer" "--with-pgo"
Server API	Apache 2.0 Handler
Virtual Directory Support	enabled
Configuration File (php.ini) Path	C:\Windows
Loaded Configuration File	C:\Bitnami\wappstack-5.6.36-1\php\php.ini
Scan this dir for additional .ini files	(none)
Additional .ini files parsed	(none)
PHP API	20131106
PHP Extension	20131226
Zend Extension	220131226
Zend Extension Build	API220131226,TS,VC11
PHP Extension Build	API20131226,TS,VC11

Source: Author (2018)

- Uploading data to GeoServer

First, a database called projectdb was created by the use of the graphical interface of pgAdmin III. By use of pgAdmin III plugin for loading shapefiles (PostGIS Shapefile and DBF loader 2.2) a shapefile named cenroid3.shp was uploaded to PostGIS, SRID set to 21037 and imported successfully. This table was to be populated with shapefile containing center of each parking slot in the parking area and was to be consumed by the system as will be seen later on.

Figure 3-12 Database Called projectdb Created

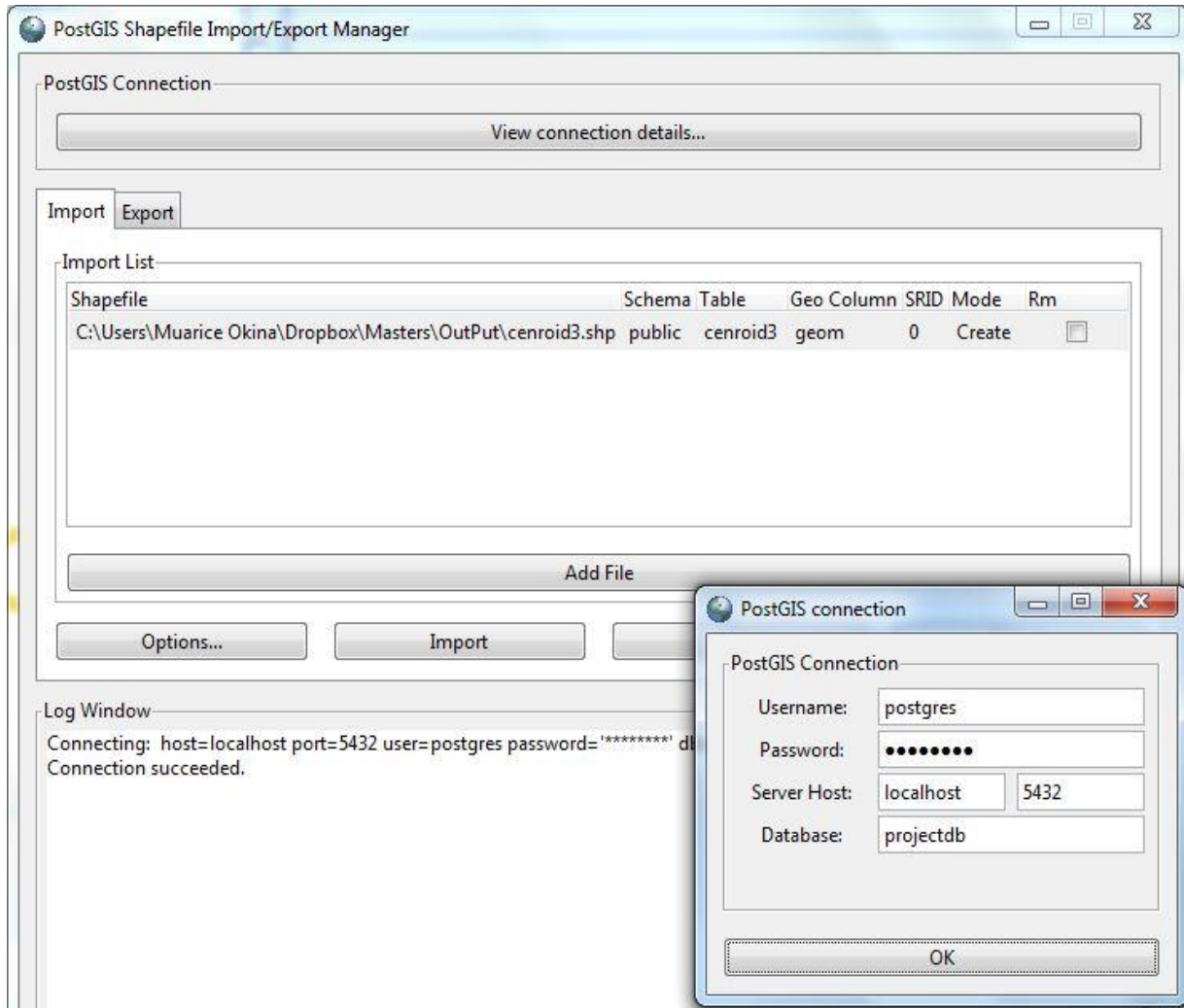


Source Author (2018)

- Procedure

Using dbf Shapefile loader plugin (Figure 3-13), import button was clicked to access the folder containing shapefiles, cenroid3 shapefile was selected SRID set to 21037, the file was successfully loaded.

Figure 3-13 uploading cenroid3 Shapefile



Source: Author (2018)

After successful upload of cenroid3 shapefile data into the database projectdb, a query was done and the following result was found.

Figure 3-14 Query Showing Shapefile (cenroid3) Loaded Successfully

SELECT * FROM cenroid3

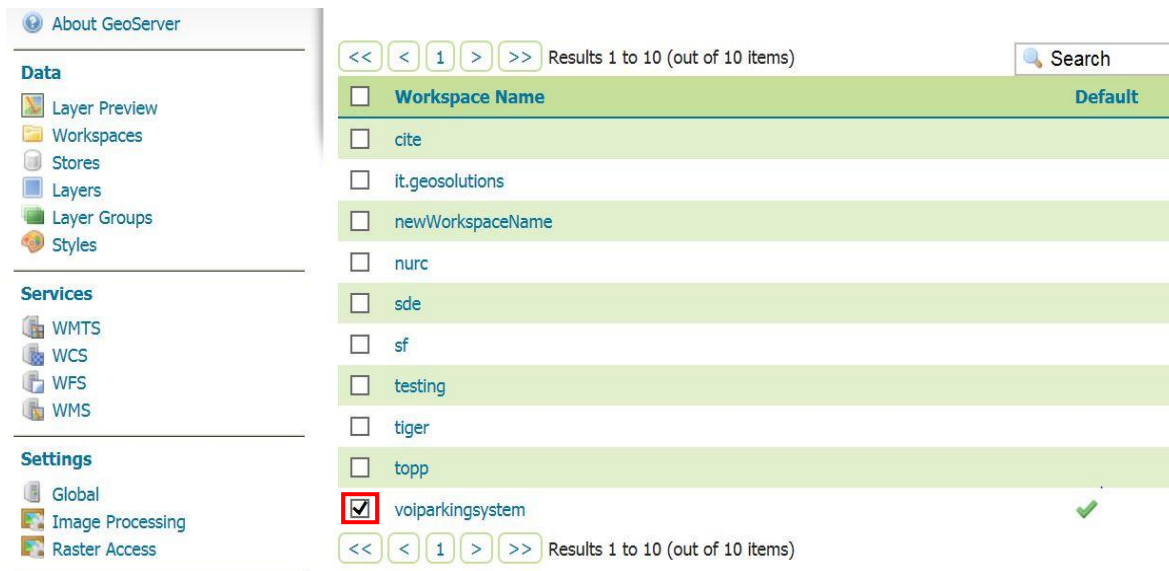
Output pane

	gid integer	id integer	eastings numeric	northings numeric	orig_fid integer	geom geometry(Point)
1	1	1	451299.695158	9625053.78275	0	0101000000AE6DD7C78E8B1B41AC530CB9BB5B6241
2	2	2	451297.701235	9625058.36798	1	0101000000E36D10CE868B1B415779C64BBC5B6241
3	3	3	451295.707311	9625062.95320	2	0101000000F16D49D47E8B1B41019F80DEBC5B6241
4	4	4	451293.713388	9625067.53842	3	01010000003F6E82DA768B1B41ACC43A71BD5B6241
5	5	5	451291.719465	9625072.12365	4	0101000000B96EBBE06E8B1B4158EAF403BE5B6241
6	6	6	451344.262903	9625073.37183	5	01010000008E5F360D418C1B41AA0FE62BBE5B6241
7	7	7	451289.725542	9625076.70887	6	0101000000D6FF4E6668B1B410310AF96BE5B6241
8	8	8	451342.268980	9625077.95706	7	0101000000BE5F6F13398C1B415535A0BEBE5B6241
9	9	9	451287.731619	9625081.29409	8	01010000006E6F2DED5E8B1B41AE356929BF5B6241
10	10	10	451340.275056	9625082.54228	9	0101000000D15FA819318C1B41FF5A5A51BF5B6241
11	11	11	451285.737695	9625085.87932	10	01010000008F6F66F3568B1B41575B23BCBF5B6241
12	12	12	451338.281133	9625087.12750	11	01010000001360E11F298C1B41AA8014E4BF5B6241
13	13	13	451379.094243	9625088.51441	12	01010000007B5B8160CC8C1B4126097610C05B6241
14	14	14	451283.743772	9625090.46454	13	0101000000926F9FF94E8B1B410281DD4EC05B6241
15	15	15	451336.287210	9625091.71273	14	01010000009A601A26218C1B4156A6CE76C05B6241
16	16	16	451377.100320	9625093.09963	15	0101000000B05BBA66C48C1B41D12E30A3C05B6241
17	17	17	451281.749849	9625095.04976	16	0101000000DF6FD8FF468B1B41ADA697E1C05B6241
18	18	18	451334.293287	9625096.29795	17	0101000000E160532C198C1B4101CC8809C15B6241
19	19	19	451375.106397	9625097.68485	18	0101000000BE5BF36CBC8C1B417B54EA35C15B6241
20	20	20	451279.755926	9625099.63499	19	0101000000537011063F8B1B4159CC5174C15B6241

Source: Author (2018)

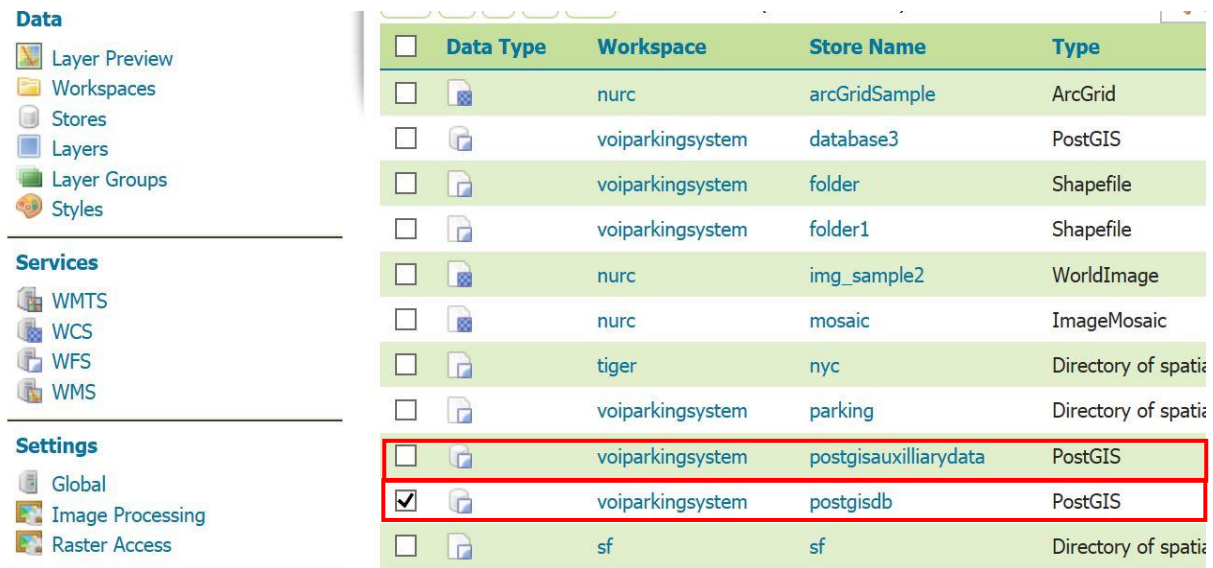
In GeoServer, a workspace called voiparkingsystem was created (Figure 3-15), the main data store was then created; postgisdb (Figure 3-16) which is a PostGIS data store in GeoServer. It holds (Figure 3-17) cenroid3 layer as centroids, all_parking_slots layer and two temporary tables called parking and empty_parkings_slots created dynamically by the system. The second data store is postgisauxilliarydata holding Voi Town Surveyed Parcels.

Figure 3-15 Created Workspace



Source: Author (2018)

Figure 3-16 Created Data Store



Source Author (2018)

Figure 3-17 Layers Used in the Project

<input type="checkbox"/>	Type	Title	Name	Store	Enabled	Native SRS
<input type="checkbox"/>		Parcels_Clip	voiparkingsystem:Parcels_Clip	parking	✓	EPSG:21037
<input checked="" type="checkbox"/>		all_parking_slots	voiparkingsystem:all_parking_slots	postgisdb	✓	EPSG:21037
<input type="checkbox"/>		cenroid3	voiparkingsystem:cenroid3	folder1	✓	EPSG:21037
<input checked="" type="checkbox"/>		empty_parkings_slots	voiparkingsystem:empty_parkings_slots	postgisdb	✓	EPSG:21037
<input checked="" type="checkbox"/>		parking	voiparkingsystem:occupied_parkings	postgisdb	✓	EPSG:21037
<input type="checkbox"/>		parcels_clip	voiparkingsystem:parcels_clip	postgisauxilliarydata	✓	EPSG:21037
<input type="checkbox"/>		parkingareas1	voiparkingsystem:parkingareas1sql	database3	✓	EPSG:21037

Source Author (2018)

3.6 Database Design

This involved use of Database Life Cycle, a waterfall cycle was used to model the projectdb database. The design and implementation was carried out following the steps outlined below.

- Establishment of requirements for the system (VPMS)

This involved consultation with the Sub County Town Administration, people parking vehicles and vehicle attendants. This was to enable an understanding of what they want from VPMS, which composed our requirements specifications.

- Analysis

The user requirements were studied and as a result, system specifications were generated which is a formal representation of what a system should do; they were expressed in terms that are independent of how it may be realized.

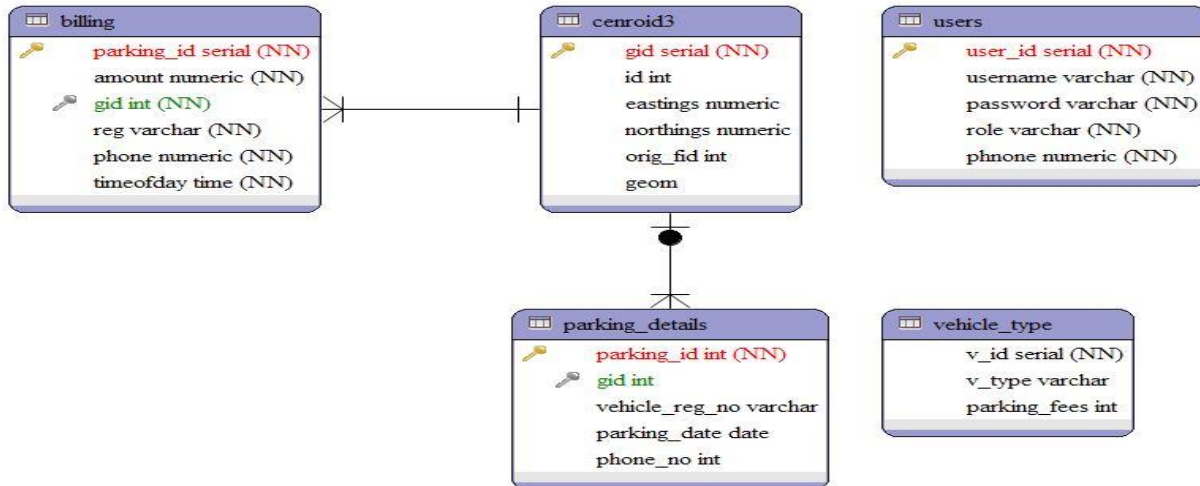
- Design

After system specifications were derived, the design of the system was documented and this described in detail how the description of how VPMS was to be constructed.

- Implementation

This involved putting the design into work, constructing the system according to design specifications. Data modelling was done and the following ERD was formulated to aid in the construction of the database.



Figure 3-18 Entity Relationship Diagram



Source Author (2018)

Completion of data modeling was followed by creation of database tables; the first table to be created was table billing. Table 3-2 where the parked vehicle details are populated, the table has six fields; parking_id which is a unique identifier generated automatically whenever a vehicle is parked on a parking slot in Voi Town and information sent to the system. Second is the amount, in the database each of the vehicle categories is assigned a given amount to be paid by the vehicle owners parking this field is populated by parking fees chargeable on each vehicle category. Third is the gid column; a spatial data that contains coordinates in terms of eastings and northings, it is the field that is plotted to the map to indicate the position of a parked vehicle. Fourth is the reg column; a column for holding the vehicle registration number. Fifth is the column for holding the driver’s phone number, this tells the management who paid the money and in case the management would want to move the vehicle this is the contact number. And, lastly, the timeofday field that accepts the time the vehicles is parked.



Table 3-2 Table billing

Column	Type	Not Null	Default	Constraints
parking_id	integer	NOT NULL	nextval('billing_parking_id_seq'::regclass)	
amount	numeric	NOT NULL		
gid	integer	NOT NULL		
reg	character varying	NOT NULL		
phone	numeric	NOT NULL		
timeofday	time without time zone	NOT NULL		

Sources Author (2018)

The second table to be created was a table to hold information from the parking slots as the vehicles are parked; and parking_details where information on the vehicle being parked are sent. This has five fields; parking_id a column that is generated automatically whenever a vehicle is parked on a parking slot number. The second column is gid, which is the geometry data for the parking slot. The third column is vehicle_reg_no; it holds the registration number plate details of the vehicle parked. The fourth column is the parking_date which basically captures the date the vehicle is parked. Last column is the phone_no; this captures the driver's phone number.

Table 3-3 Table parking_details

Column	Type	Not Null	Default	Constraints
parking_id	integer	NOT NULL		
gid	integer			
vehicle_reg_no	character varying			
parking_date	date			
phone_no	integer			

Source Author (2018)

The third to be created was the table to store all the available vehicle categories in Voi Town. The following table illustrates the table fields and their associated data types. The table has three fields: the first column is v_id; a unique number generated automatically for any vehicle category entered into the system. The second one is the v_type column, which holds the specific category of vehicles. Last column is parking_fees; this holds the parking amount payable by a given category.

Table 3-4 Table vehicle_type


Column	Type	Not Null	Default	Constraints
v_id	integer	NOT NULL	nextval('vehicle_type_v_id_seq'::regclass)	
v_type	character varying			
parking_fees	integer			

Source Author (2018)

Lastly, a table storing users of the system was created and the following table illustrates the fields and their data types.

Administration of the system requires giving roles to a given group of people to manage it. In order to aid in carrying out their roles, a table called users was created. It has five fields; user_id which is a unique number assigned as the users are registered by the system administrators. The second column is username, a unique name assigned to any registered user for accessing the system. The third column is the column for the password, which is a unique character or alphanumeric assigned to each user of the system for its security. The fourth column is the role column; this defines what each user of the system is allowed to perform when using the system. Lastly is the phone column; this is for communication purposes.

Table 3-5 Table users

Column	Type	Not Null	Default	Constraints
user_id	integer	NOT NULL	nextval('users_user_id_seq'::regclass)	
username	character varying	NOT NULL		
password	character varying	NOT NULL		
role	character varying	NOT NULL		
phnone	numeric	NOT NULL		

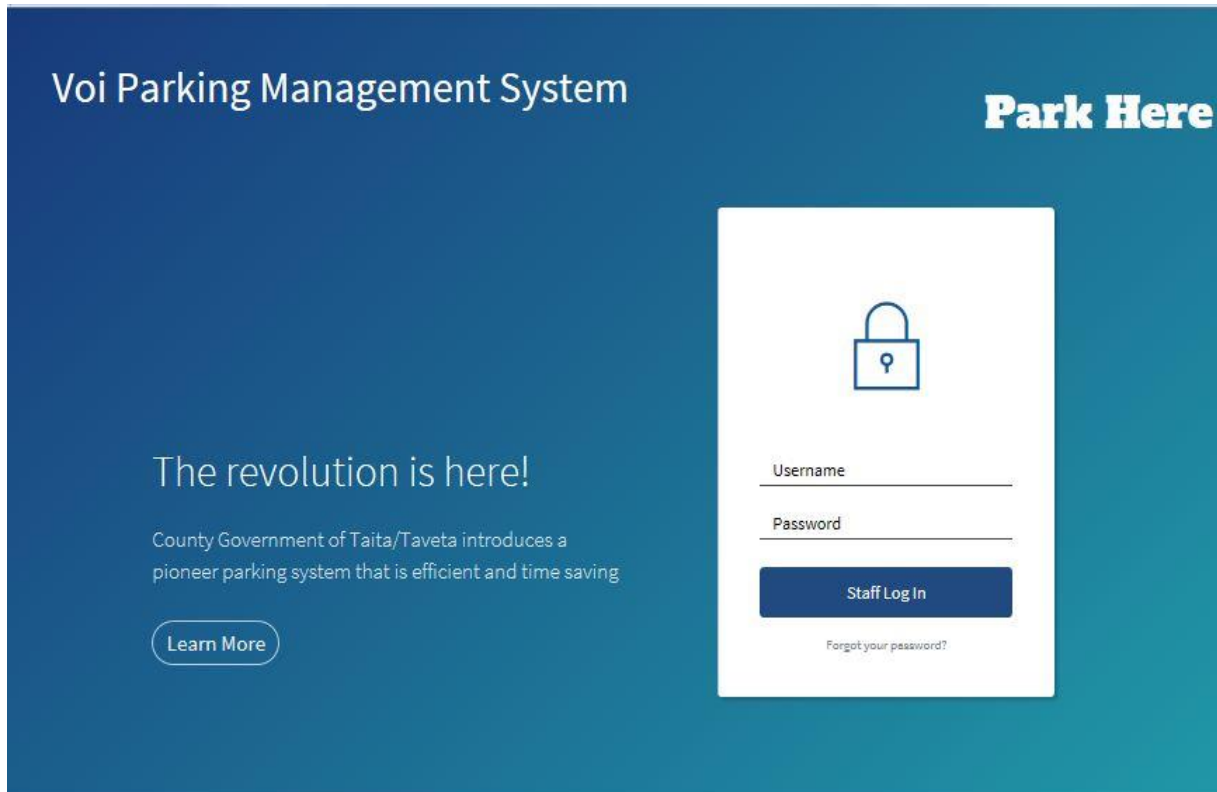
Source Author (2018)

3.7 Creation of the Middle Ware or the Software

After the database was created and populated with the tables above, configured and tested, a graphical user interface was designed and implemented with php, javascript, css and html. The GUI included Admin Login/Logout Panel, General Admin functions, panel for managing users of the system, admin panel for managing vehicle categories and the main application window panel.

The following page (Figure 3-9) has two features a login panel for staff login and a menu labelled “park here” for drivers. All registered staff must login to access the system; however, the drivers do not need to login they just click the “park here” menu to access a page with a form (Figure 3-23) to fill and park a vehicle.

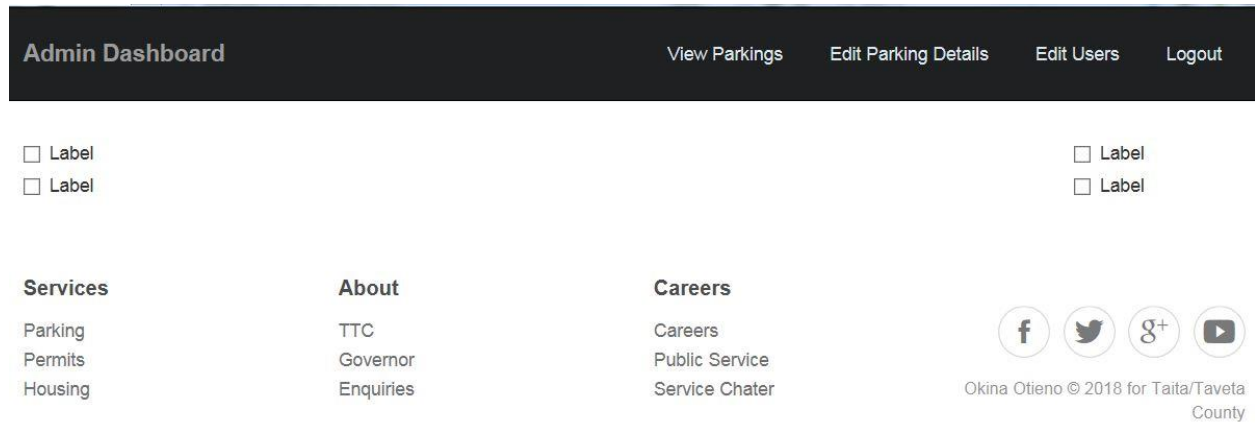
Figure 3-19 VPMS User Interface



Source: Author (2018)

The administrator has several functions to carry out when using the system. Such functions are captured on the admin page (Figure 3-20). They include viewing parkings, editing parking details (Figure 3-22); and adding or deleting vehicle categories. Editing users (Figure 3-21); this entails adding users to the system, changing user names, passwords or phone numbers as the case may be.

Figure 3-20 Admin Page



Source Author (2018)

Figure 3-21 Admin Page Managing Users

Edit User Details

Add New User

Users

No.	User Name	Password	Role	Phone	Update	Delete
1	Akinyi	admin	administrator	722222222	Update	Delete
2	Karanja	user	user	720720720	Update	Delete
3	okina	admin	administrator	724037984	Update	Delete

Source Author (2018)

Figure 3-22 Vehicle Category Table

Parking Details Admin Panel

Add New Type

Parking Details

No.	Vehicle Type	Parking Fees	Update	Delete
1	private	50	Update	Delete
2	Minibus	100	Update	Delete
3	Trailer	150	Update	Delete

Source Author (2018)

Figure 3-23 Parking Site Page

Please Enter Details

Bus

Parking Amount

120

Parking Slot Number

234

Vehicle Registration Number

Please Enter your vehicle Registration number

Drivers Phone Number

Drivers Phone Number

Please Enter your phone number

[Click Here To Pay](#)

Source Author (2018)

3.8 Stage III

At this stage a software application for accessing the system through the www was to be installed. However, windows operating system comes with one; Internet Explorer. Again there are open source such as Mozilla Firefox, Chrome etc. In the study Internet Explorer was used and complemented with Mozilla Firefox.

CHAPTER FOUR

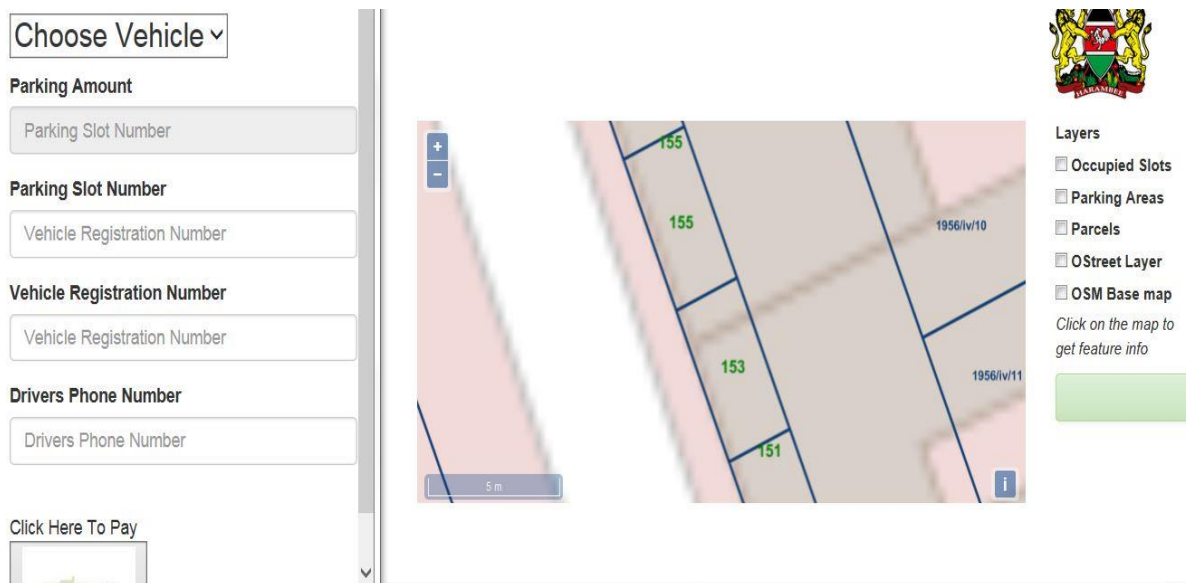
RESULTS AND DISCUSSIONS

4.0 Presentation of Results

4.1 Real Time Streaming of Parking Activities

The system offers the users' (Voi Town Administrators) real time streaming of data as parking takes place on the parking slots, Figure 4-1 shows the administrator and parking site pages before transaction (parking) takes place on parking slot number 155, Figure 4-2, demonstrates a driver with a private car with registration number KRT 345T choosing to park on parking slot number 155, as she/he clicks the button “click here to pay” the information is captured by the system and centroid of parking number 155 is marked/plotted with a yellow dot indicating occupancy.

Figure 4-1 Driver and Administrator pages before Transaction



Source Author (2018)

Figure 4-2 Real Time Parking on Slot No. 155



Source Author (2018)

4.2 Querying Information on Individual Parking Slot

Figure 4-3 Vehicle Parked on Slot No. 155



Source Author (2018)

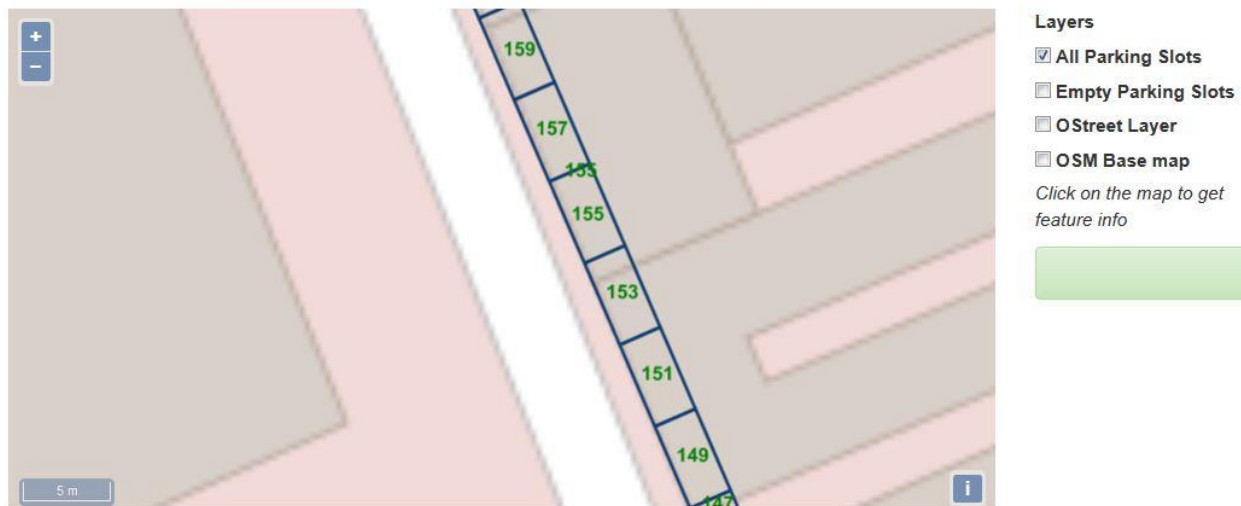
The system has functionality for checking the status of a parking slot, the status include the details of vehicle parked; registration number, parking slot number and its location (Eastings and Nothings), time the vehicle was parked and driver's phone number. Figure 4-3 shows the results

of a mouse click on the yellow dot dynamically plotted by the system on the map after the vehicle is parked yielding the information as shown.

4.2.1 Visualization of all and Occupied Parking Slots

Inventory was one challenge for the system which was being used in Voi Town for managing parking, VPMS provides functionality for viewing all parking slots as well as empty parking slots in tiled layer format. By switching layers, the administrator is able use the function for layer visualization. Figure 4-4 shows parking slot number 155 before parking while Figure 4-5 shows that it is occupied and thus does not exist hence the gap on the map.

Figure 4-4 Parking Slots Before Parking



Source Author (2018)

4.2.2 Report on Availability or None Availability of a Parking Slot

The report is composed of two layers; all parking slots and occupied parking slots. In Figure 4-5, Empty Parking Slots layer is selected as the current layer and shows parking slot number 155 missing, this is because it is already occupied; such is the situation for all occupied slots.

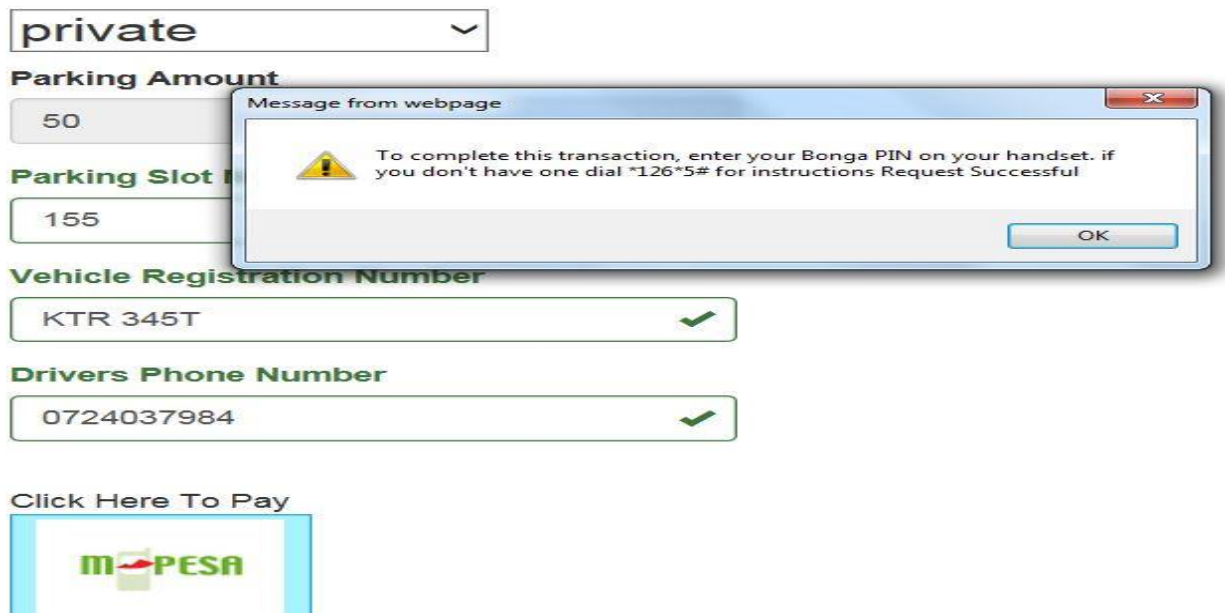
Figure 4-5 Showing Slot No 155 is Occupied



Source Author (2018)

4.2.3 Online Payment

Figure 4-6 Acceptance of Mobile Money Payment



Source Author (2018)

The current system in Voi Town is based on receipts issued to drivers as they park. VPMS demonstrates that mobile money payment is possible, when the driver clicks “click here to pay” button, Figure 4-6, a confirmation message is sent alerting the driver of where the money goes (M-Pesa) account.

4.3 Other Functionalities

VPMS offers other functionalities to the system administrator, these include Pan and Zoom tool facility to handle zoom level on the map layers, on screen click function performed on the map layer to query a feature to show both attribute and spatial data, Layer Selection Panel allowing for selection and deselection of layers within the main web page, Login panel giving restricted access to authorized user to view map data.

4.3.1 Pan and Zoom Functionality

The users of the system are able to pan and zoom to a scale 1:2 and 1: 200. The figure below shows zoom in level of up to a scale of 1: 5.

Figure 4-7 Pan and Zoom Functionality



Source: Author (2018)

4.3.2 Query Feature on a Layer

This functionality enables users to get information on particular parking slot by using the mouse to click on the slot on the map or any other feature. The details of the parking slot/feature can be viewed by single click on that feature and the information (spatial and attribute) related to feature displayed. The data is pulled from database stored in PostgreSQL/PostGIS. Figure 4-3 shows a

VPMS administrator querying occupied parking slot number 155 for details. The information is for accountability purposes for the driver as well as management by the administrators just in case the vehicle needs to be removed.

4.3.3 Map Layers

The panel provides for tiled map layers approach, the layers include OSM as the base layer, surveyed parcels layer, all parking slots layer and occupied slots layer which is dynamically created from an SQL view (Figure 4-9) in GeoServer; SQL query that gets a join between centroid3 table and billing table to create table parking.

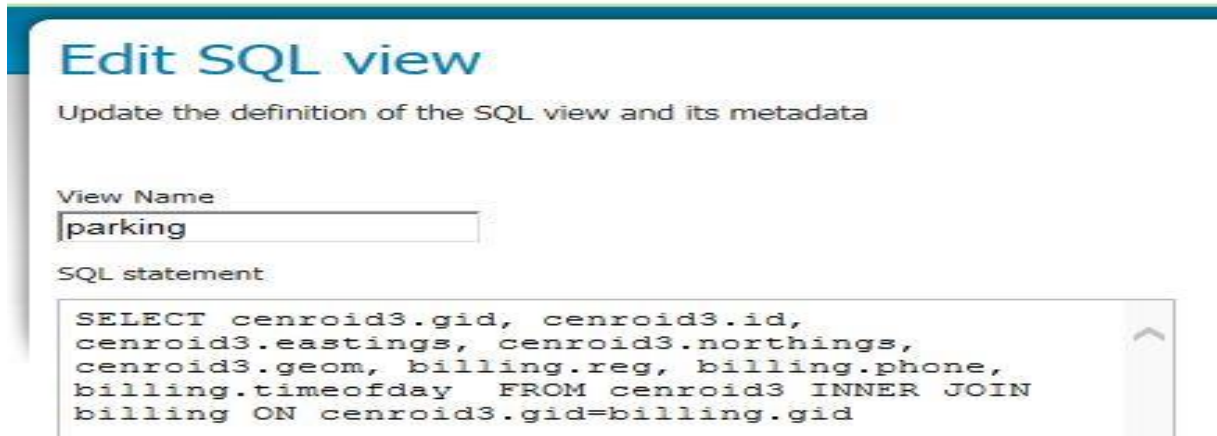
In Figure 4-8 below, all layers are highlighted, occupied slot are plotted yellow, all parking slots are polygons which are numbered in green, the big polygons are surveyed parcels in Voi Town and last is the OSM layer providing base layer for the system.

Figure 4-8 Tiled Layers



Source Author (2018)

Figure 4-9 SQL View Creating Occupied Slots



Source Author (2018)

4.3.4 Layer Switching

Layer switching functionality has been provided for switching among different layers. Users can decide which layer to view. Figure 4-8 shows all layers on a window. However, in Figure 4-10 the administrator has decided to view occupied parking slots only.

Figure 4-10 Selecting Occupied Slots Layer



Source Author (2018)

4.4 Discussion of Results

The results of the various manipulations of the system aimed at achieving the goals of the study are presented in regard to the problems outlined and envisaged to be addressed by the VPMS. The study generally was to demonstrate an operational web-based GIS for car parking management system with capabilities for real time queries and visualization of locations of available car parks slots/occupied slots.

In traditional GI systems, data and information are disparate, in VPMS, real time streaming of parking information was demonstrated by integrating Internet, World Wide Web and Geographic Information. The driver fills a form (Figure 4-6), and clicks the button labeled “click here to pay”, the information goes to a map server (GeoServer), gets plotted as a dot with the parking slot number as a label and passed through web server to be viewed by the user (Administrator) on a web browser in real time as shown on Figure 4-2.

The management of Car Parking System includes control of vehicles as they are parked and monitoring the extent to which the parked vehicles have complied with the parking rules and paid. There could at times be necessary to relocate the parked vehicles e.g. during emergencies. Control as a management function was provided for through a query function whose results show the details of the parked vehicle, and the phone number of the driver for contact purposes to overcome such eventualities (such as emergencies as discussed above). Figure 4-3 shows sample of such query.

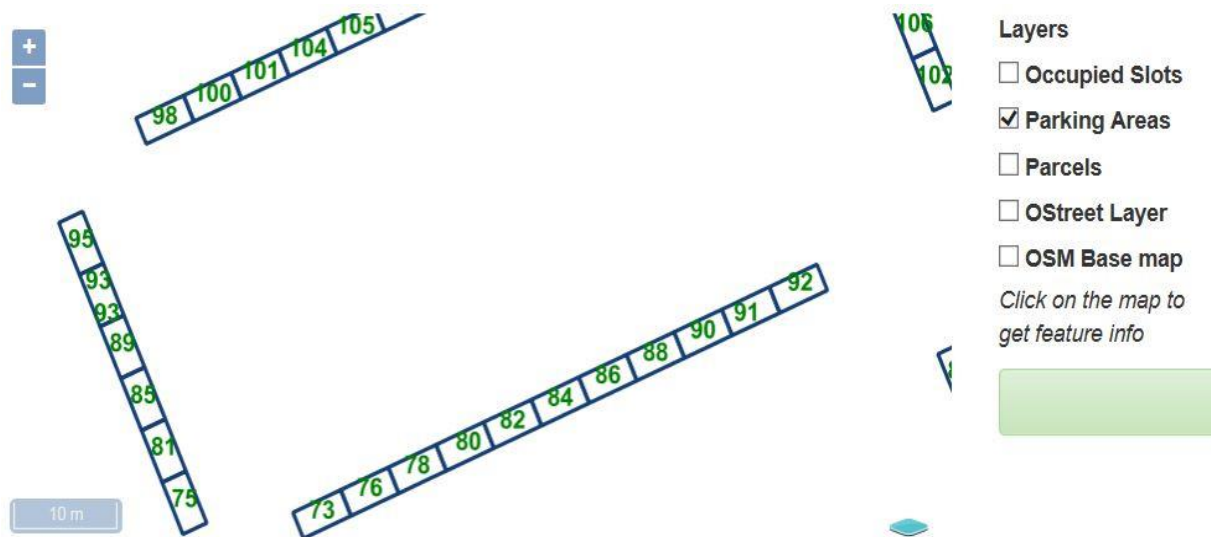
One of the most useful and attractive capabilities of GIS is visualization. VPMS was provided with a functionality to allow Voi Town Administration to have a visual view of, first, all the parking slots (Figure 4-4), and, second, have a visual view of empty parking slots (Figure 4-5) by switching through the layers. The empty slots layer is derived from all parking slots by eliminating the occupied slots, thus occupied slots are presented on the map as blanks.

Accountability to the parking fees collected was demonstrated. The parking details table populates data into a table called billing, this table has a field for amount first, is able to confirm accountability of the driver parking the vehicle by querying the phone number against the M-Pesa messages received through a pay bill number or Lipa na M-Pesa number. This thus demonstrates that there is accountability to the parking fees collected by viewing a report on the

number of parked vehicles *viz* a *viz* the amount stored in the database. This was made possible by the database management system, which has functionality for carrying out SQL queries from a table within the database.

The achievement of the specific objectives is also demonstrated. The first specific objective was to identify and digitize designated parking areas from Voi Town in Voi Sub County records including any supporting data. This has been achieved; parking slots as the core data for the system was created (Figure 4-11). Others include parking slot centroids, parcels and OSM layer to bring the study area neighborhood into focus.

Figure 4-11 Digitized Parking Slots



Source: Author (2018)

The study therefore summarizes the discussion by stating that a clear method to develop a spatial web enabled database using PostgreSQL and PostGIS extension of PostgreSQL was implemented. The DBMS was successfully used to create a spatial database by importing the relevant spatial features that were considered relevant for the study. This provided a foundation application with tools and a high level of integration with the web environment. GeoServer was used as a web map server for rendering the spatial features for enhanced visualization in a web browser. GeoServer and PostgreSQL/PostGIS have a plugin for loading spatial data which enabled seamless integration and manipulation of the layers, GeoServer also has an interface for

editing SQL view and that this feature was used to create SQL joins to create a dynamic database table called parking which is core to this application. The SQL view functionality enabled speedy manipulation of parking slots, billing information as well as query occupied slots from all parking slots. These features are not available in the traditional GIS desktop applications.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Conclusions

The challenges associated with parking are many; however, the study demonstrates that they can be overcome. Indeed, the study demonstrated how the integration of GIS, Internet and World Wide Web (WebGIS) can provide a solution to the problems affecting Voi Parking System. The study came up with Voi Parking Management System (VPMS). The general objective of the study was to design operational web-based GIS for car parking management system. The resulting system was to demonstrate capabilities for real-time queries and visualization of the location of available car parking slots, the capacities, the available spaces and the possibilities for users to make online payments for parking services. Specifically, the study was to; identify and digitize designated parking areas from county/sub county records, to design a GIS database of the designated parking areas and other auxiliary data that are relevant for the access and integrated management of parking areas and to integrate an e-payment system to operate alongside the GIS database. After the study, five conclusions were made as follows:

- The results show the potential of using WebGIS to design an operational GIS for a car parking management system.
- It is possible to create a parking slots' inventory in this case for Voi Town.
- A GI system is only complete if there exists in that system both spatial and attribute data, as well as supportive/auxiliary data. The study demonstrated the possibility of integrating the non-spatial data about the vehicle being parked and surveyed parcels data in Voi Town showing road reserves where parking areas were demarcated.
- The fourth conclusion is that it is possible to integrate an e-payment system, especially M-Pesa (Mobile Money Payment), which enables the accounting office to tie the source of the money to the source location (parking slot) and the payee (vehicle).
- Lastly, the study concludes that it is possible to get the vehicles park in real time, map their positions for visualization as well as query their positions (Eastings and Northings) as the parking information flows in.

5.1 Recommendations

This study has demonstrated that WebGIS has revolutionized parking and parking management. The study recommends the implementation of the system in Voi Town. Implementation of the system will enable location linkable parking fees collection, proper accountability for both those seeking to use parking services and the management as well as for spatial records of parking slots. The study has demonstrated feasibility in terms of technology and technical expertise or capacity; however, the study recommends financial investment towards spatial data infrastructure (SDI) to realize seamless integration of such systems.

Secondly, Voi Town has been lacking an inventory of parking slots, the study recommends creation of spatial records of all parking slots by Voi Town management as demonstrated and tested by the study. The Third recommendation is to extend GIS technology and other supporting technologies demonstrated in this study to create spatial records for other income generating sources as well. The Fourth recommendation is to adopt e-payment system/mobile money to reduce lack of accountability that is associated with receipts issued by VCAs which lacks spatial link for the purpose of integration with a GI system.

The system has focused much on the administration of the parking system and not much attention to the customer; the driver parking the vehicle. In the literature review for instance, most of the research is focused on the driver, for example (parking guidance and information system) PGIS. It is therefore a recommendation of this study that cameras, light bulbs (now that there are street light programs within the counties taking advantage of solar power), etc. be installed to enable additional functionality; guidance information to the driver to the VPMS.

Finally, it is the advice of the researcher that the system can be extended and used for other revenue generating activities or projects within the County. As demonstrated here in the case of parking, the system can show and track the location at which fees are collected in addition to the individuals making payment e.g. for market stalls, cess and other sources available to the County. A more encompassing system will leverage on the spatial attributes associated with the revenue sources.

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APPENDIX A: CODE

Sample Code Creating PostGIS Layer in GeoServer using SQL view

```
SELECT cenroid3.gid, cenroid3.id, cenroid3.eastings, cenroid3.northings, cenroid3.geom,  
billing.reg, billing.phone, billing.timeofday FROM cenroid3 INNER JOIN billing ON  
cenroid3.gid=billing.gid
```

Sample Code Calling Layers from GeoServer

```
var vectorLayer3 = new ol.layer.Tile({  
  
    source: new ol.source.TileWMS({  
  
        preload: Infinity, url:  
        'http://localhost:8080/geoserver/wms',serverType:'geoserver',params:{  
  
            'LAYERS':"voiparkingsystem:occupied_parkings", "TILED":true  
  
        }  
  
    }  
  
    )  
  
    }  
  
}); //code showing  
  
vectorLayer3.set('name','Occupied Slots');
```

Sample Code Creating OSM Layers

```
var geoLayer = new ol.layer.Vector({  
  
    source: new ol.source.Vector({  
  
        url:'roads.geojson',format: new ol.format.GeoJSON({projection: 'EPSG:4326'})  
  
    }},  
  
    style: function(feature, resolution) {  
  
        style.getText().setText(resolution < 10000 ? feature.get('name') : 'GeoLayer');return  
styles;  
  
    }  
  
});  
  
geoLayer.set('name', 'OStreet Layer');
```

Sample Code Creating Form for Entering Parking Details

```
<form method="POST" action="requestcheckout.php"  
id="validateForm">  
  
    <div id="display">  
  
        <!--<div class="row" id="heading"  
style="display:none; margin-bottom:-15px;margin-top:-5px;"><h4><div class="col-sm-  
6">Category</div><div class="col-sm-6">Fees (Ksh)</div></h4></div><br>  
  
        <div class="row" id="records"  
style="margin-bottom:25px;"><div class="col-sm-6" id="v_type"></div><div class="col-sm-6"  
id="parking_fees"></div>-->  
  
        <div class="form-group">  
        <label class="control-label">Parking
```

```

Amount</label>                                <input
id="amount" name="amount" placeholder="Parking Slot Number" class="form-control"
type="text" readonly="readonly">

</div>

<div class="form-group">

    <label class="control-
label">Parking Slot Number</label>

    <input id="gid" name="gid"
placeholder="Vehicle Registration Number" class="form-control" type="text">

</div>

<div class="form-group">

    <label class="control-
label">Vehicle Registration Number</label>

    <input id="reg" name="reg"
placeholder="Vehicle Registration Number" class="form-control" type="text">

</div>

<div class="form-group">

    <label class="control-
label">Drivers Phone Number</label>

    <input id="phone"
name="phone" placeholder="Drivers Phone Number" class="form-control" type="text">

</div>

<!--<div class="form-group">-->

```


Click Here To Pay

<button name="checkout"

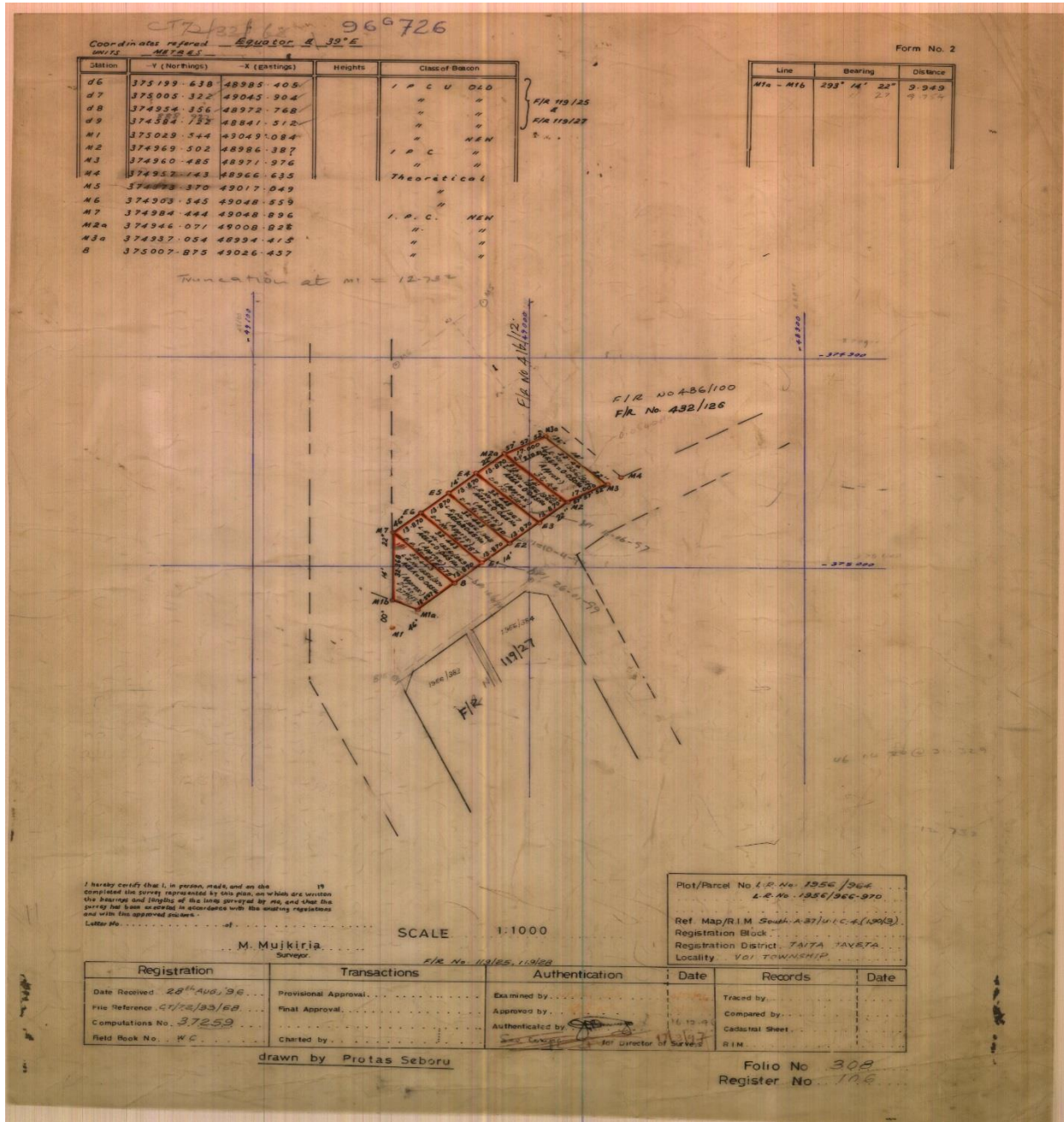
type="submit" id="insert"></button>

<!--</div>-->

<?php

APPENDIX B: DATA

Sample data from Survey of Kenya



Source Survey of Kenya (1996)