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A geographic information based parking management prototype: a case of Nairobi

Ogenche, J. R.
Faculty of Information Technology (FIT)
Strathmore University

A Geographic Information Based Parking Management Prototype: A Case of Nairobi

Ogenche Joan Rabera

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Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Ogenche, Joan Rabera Name of Candidate

…….. Signature

…….. Date

Approval

The research thesis of Ogenche Joan Rabera was reviewed and approved by:

Dr. Vitalis Ozianyi,
Lecturer, Faculty of Information Technology,
Strathmore University

Dr. Joseph Orero,
Dean, Faculty of Information Technology,
Strathmore University

Prof. Ruth Kiraka,
Dean, School of Graduate Studies,
Strathmore University

Abstract

The purpose of this research paper is to identify a solution to parking in Nairobi's central business district having factored in all the spatial and non-spatial elements. The problem is that a new wave of people are flooding the city to live, work and do other activities and many arrive on four wheels thus creating massive headaches for city planners and drivers in reducing parking issues that cause street congestion and wastage of time in searching for parking spaces. The methodology that will be used to achieve the overall objective is the software development lifecycle. This involves sequential phases, with some overlap and splash back of activities between phases in development of the final product. A Geographic Information based parking management prototype that will factor in spatial and non-spatial data is the solution that is proposed herein to facilitate good quality secure parking in maintaining the vitality and viability of town centres in enabling retail and leisure uses to flourish. The output is a seamless mobile-web interface that will enable the county government as well as key players to access and monitor space availability which the users will be able to access from their mobile phones. Parking being a major use of land and the supply is frequently a factor that influences trip generation, the implications of this research is that all spaces available will be tapped into to strike a balance between encouraging new investments in the town centres and increasing parking spaces. The application created was able to reap parking space information from the map server which will greatly reduce the trial and error involved while in search of a parking space thus increasing a driver's confidence, cutting down on the amount of parking time and the emotional stress associated with finding a parking space.

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I would like to thank Dr Vitalis Ozianyi for his careful and systematic guidance, constructive criticism and open-door policy as he supervised my project. His humility and good cheer are admirable and to be emulated.

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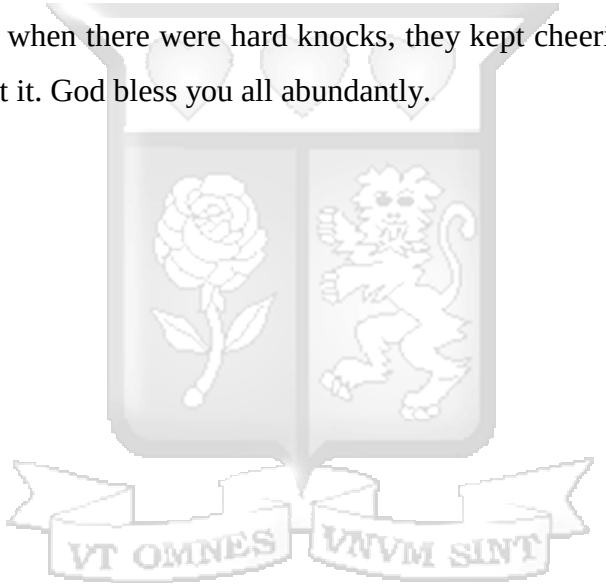

Dedication

This research proposal is dedicated to my father, who has instilled in all of us a true love for God and learning. It is also dedicated to my family, for their unwavering support for my education and the impetus to enrol and complete this program. My sincere gratitude to my colleagues and friends for their prayers and invaluable insights during the writing period.

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Abbreviations/Acronyms

CAD	-	Computer Aided Design
CBD	-	Central Business District
DB	-	Database
GIS	-	Geographic Information System
GPRS	-	General Packet Radio Service
HTML	-	Hypertext Markup Language
ITS	-	Intelligent Transportation Systems
MODEM	-	Modulator Demodulator
NCIC	-	National Cartographic Information Center
OOP	-	Object Oriented Programming
PHP	-	Hypertext Preprocessor
RDMS	-	Relational Database Management System
RS	-	Remote Sensing
SPSS	-	Statistical Package for the Social Sciences
SQL	-	Structure Query Language
SVG	-	Scalable Vector Graphics
TIFF	-	Tagged Information File Format
TM	-	Thematic Mapper
UNIX	-	A multiuser Operating System
URISA	-	Urban and Regional Information System Association
WRS	-	Worldwide Reference System
XML	-	Extensible Markup Language

Definition of Terms

Aerial Photograph	The taking of photographs of the ground from an Elevated/direct-down position. Usually the camera is not supported by a ground-based structure (Chang, 2008).
County Government	Government responsible for county legislation, establishment and staffing of a public service (Alex, 2010).
Digital Mapping	To encode map features as x, y coordinates in digital form. Lines are traced to define their shapes. This can be accomplished either manually or by use of a scanner (Kim, 2014).
Geographic Information system	A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface (Chang, 2008).
Spatial Analysis	The process of modelling, examining, and interpreting model results. Useful for evaluating suitability and capability, for estimating and predicting, and for interpreting and understanding (Kim, 2014).
Spatial Data	Information about a physical object that can be represented by numerical values in a geographic coordinate system (Mwehe, 2012).
Raster Data	Data consisting of a matrix of cells organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps (Mwehe, 2012).

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Chapter 1: Introduction

1.1 Background Information

The Kenya Vision 2030 statistics show that 65% of Kenyans will be living in the urban centres by the year 2030 ("KENYA: Vision 2030 Implementation, 2008). Urbanization is growing rampantly, and this calls for an action to manage it other than containing it because in the long run, there is no other way to it other than taking it head-on (Government of the Republic of Kenya, 2007). Urbanization comes with its demands and in Kenya, authorities are facing pressure in service delivery in the various facets within the economic bracket. One of the essential components of urban development is urban transportation. The world factbook estimates that 78% of urban dwellers in Kenya commute by road (Buneman, Müller & Rusbridge, 2009). These numbers are made up of the low-income folks traveling by public transport while the middle and high-income groups prefer private vehicles.

The World Urban Development Magazine shows that urban transportation is not designed for safe traveling by non-motorized means but rather to upsurge vehicle speeds (Bowden, 2014). Most victims of road traffic accidents from a trend analysis are low and moderate income pedestrians which in turn makes motorised road transport the preferred choice by the majority of the urban residents. As Kenya envisions becoming a middle-income country, most Kenyans are expected to be classified in the middle-income bracket and adoption of private transport will emerge gradually. Therefore, there is an urgent demand for an application that will manage urban transportation.

The development partners and the donor community dwelt more on full recovery for water services and food security which are mostly relied on to by the poor population but very little focus was put on urban road users who generate a large income that would be used to steer grant economic gains and in the long run address the transport menace in Kenya. The idea of vehicle parking administration is likely take care of this problem and furthermore contributes to the general administration of urban roads and in urban roads. Streamlining the administration of parking management is one of the reasons public management boards and local governments need to consider investing resources into legal and institutional frameworks that deal with the utilisation of the parking spots in their administrative areas.

Nairobi is a city in which land is expensive, thus space dedicated to the transport system is vital. Everyone can see the influence of highways and their interchanges, and large car parks close to shopping centres and business parks congested with cars in dense areas. All these contribute to congestion caused by excessive use of available space. Further, the transport system has been seen to be critical to achieving the Millenium Development Goals (MDGs), which are essential in macro planning for the country. The number of vehicles in Nairobi is becoming larger and hence making it increasingly challenging to find parking.

The Global Parking Survey, 2016, conducted by the IBM estimated that drivers in 20 international cities have to deal with parking problems daily (Chen et al, 2016). Six out of ten drivers abandoned their search for an area at least once. The report also revealed that over 30 percent of traffic jams in a city is caused by drivers roaming in town streets searching for parking spots. Over half of all the drivers in 16 out of the 20 cities surveyed stated that they have been irritated enough that they gave up looking for a car park and only opted to drive to somewhere else. Many drivers find themselves making guesswork while looking for parking area since they are not aware of the parking situation in their immediate environs.

In the last three years, one of the major investments in the Kenyan urban transportation that was the construction of Nairobi-Thika super-highway as well as Eastern and Southern bypasses. For improved service delivery and sustainability purposes, it is definite that a digital application is required to accurately map parking spaces and improve the spatial access to these parking spaces.

This can be done through identification and interfacing three-dimensional and non-spatial parking information and avail it to customers. Technology solutions to various problems in and around the city have been set up in the past, and substantial advancement has been observed in other areas of economic management by the City Council of Nairobi (Kuntz, 2012). Technology has made people realize critical development in income and other administration changes. This makes it a relevant part of the compelling administration of assets and procedures by the urban management.

The innovation not withstanding needs one measurement that should not be overlooked and that is the spatial measurement or part of any trait or element in these regions. Nairobi central business district parking areas have about 200 parking spaces. Likewise, there are about 1000 motor vehicle trips per day. It cost a vehicle Ksh. 140.00 parking fee per day. A reservation of

up to three hours cost Ksh. 40.00 and the balance is paid when the spot is occupied. The Nairobi Municipal By-Laws prohibit picking or dropping of passengers outside bus parks. It is, therefore, a major challenge for buses roaming around town looking for available parking. Wastage of fuel, pollution and traffic jams, therefore, become the order of the day in Nairobi (Waema & Mitulah, 2008).

Traffic on a city-wide street network can be imagined as a collection of vehicles, each moving towards a destination. This is viewed as a large and complex circle of traffic where vehicles enter the circle from an origin and then progress to a destination, interacting with other vehicles on the way. The rate at which vehicles arrive at their destination is reffered to as outflow representing trips ending by either having reached their destination within the city or they pass out of CBD. Ideally, the maximum outflow depends on the infrastructure and control of the street network as well as the number of vehicles using the streets. The relationship between the number of vehicles in the system and the rate of trips reaching their destination should be intuitive such that when few vehicles are using the network, the outflow should be low since there are not many vehicles on the network as shown in green. As the number of vehicles increase, the rate at which trips end should also increase until a point indicated by the yellow region. Once too many vehicles are on the streets, thy get in each other's way and travellers are delayed. When the vehicles continue to enter th system, this can ultimately decay into a state of perfect gridlock whereby the outflow will be low because every vehicle is blocked by those around it. This is represented by the area in red (Daganzo & Geroliminis, 2010).

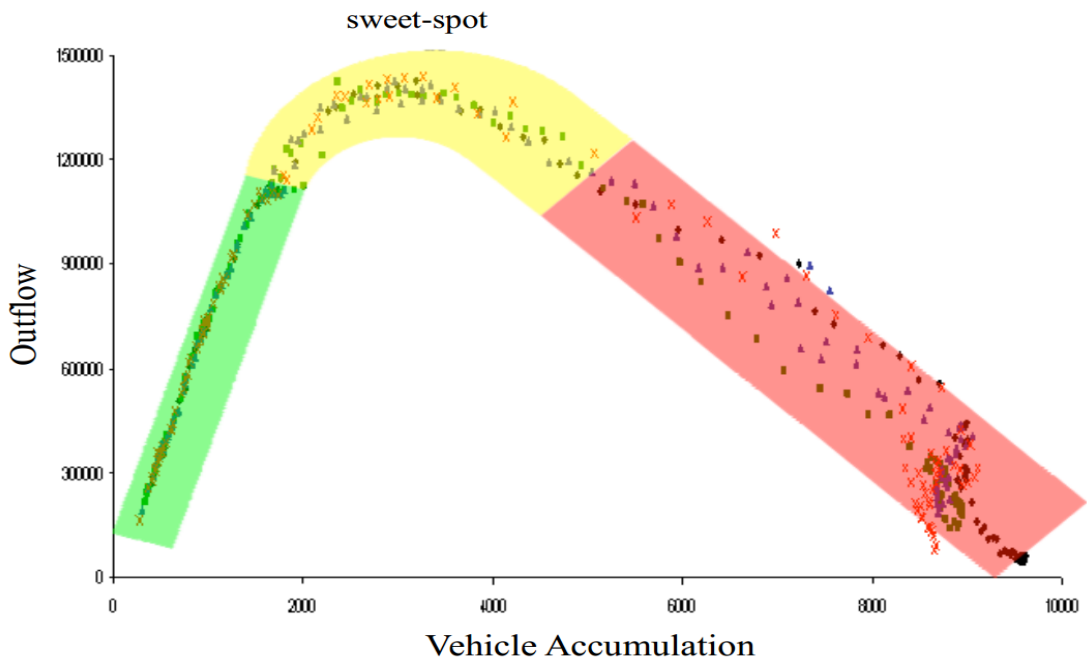

Figure 1.1: Fundamental diagram of outflow relative to accumulation for a city (Adapted from Nairobi Mappery, 2012).

Most of the time, city officials presume that the provision of more parking spaces for the citizens implies meeting the usual mobilty needs. On the contrary, every car that is on the road requires a place to be parked. This is a key issue in almost all urban places. Bayless and Neelakantan, 2012). Evidence from drivers suggest that a lot of savings can be made by providing alternative payment options for the customers, and providing the parking workforce with more sophisticated technology. This technological change is bound to contribute to the development of more flexible and convenient parking services (Walker, 2011).

The process of traffic flow, allocation and parking space availability within the streets of Nairobi is a major concern for every motorist. Normally, parking is managed by the former city council of Nairobi and the exercise is and has proven to be a nightmare for the officials of the county government (Kinyanjui, 2010).

The parking offered in a basic urban area is very diverse and difficult to estimate. It consists of:

i. Public pay car parks
ii. Parking on streets
iii. Outdoor non-paid car parks: city blocks and parking lots

iv. Parking inside dwellings: garages, underground residential car-parks

v. Parking on the premises: garages, underground car parks to shops and businesses

Parking has always and will always be dynamic. This is a fac that many traditional parking systems fail to address. Many drivers find themselves making guesswork while searching for a parking space simply because they may not be aware of the parking situation in their immediate environment. To disseminate parking inromation which is ever changing, ther eis a requirment for a fast medium of communication like the internet. It ahs revolutionized the domain of communication thus many people are using it as a main source of information. It has already been incorporated in developed countries and is quickly penetrating developing ones. The widespread internet access from the 1990's has not only thinned the lin separating office and home, but sunstantially contributed to the increasing mobility of people's working and everyday life. This is especially evidenced by the advent of smart phones, a metaphor to spatialize the information space and as a collaborative thinking instrument shared by spatially separated users. The general realization of wireless internet access has brought web maps back to mobile environments where they are most needed.

Mobile maps are more personal and provide a better platform to relay spatial information of a temporal nature unlike web-maps. A mobile map is like a snapshot of an environment around a certain location and time, but with highly selective information and integrated intelligence. Most of peoples' daily activities require motion and driving is no exception. With parkin spaces being engaged on and off, a standalone or static system, would seem handicapped in relaying parking information. Mobility is unquestionably a fundamental aspect of contemporary life. With a GIS based mobile-web paltform, drivers will be better informed of events from near and far, past, present and future. This will ensure they are better prepared for their task. The figure shows an example of a street map annotated to show classisfication of streets and intersections. The assigned categories are not accurate, but this is an illustration of the type of map that would be useful in fulfilling data requirements as per the first research question.

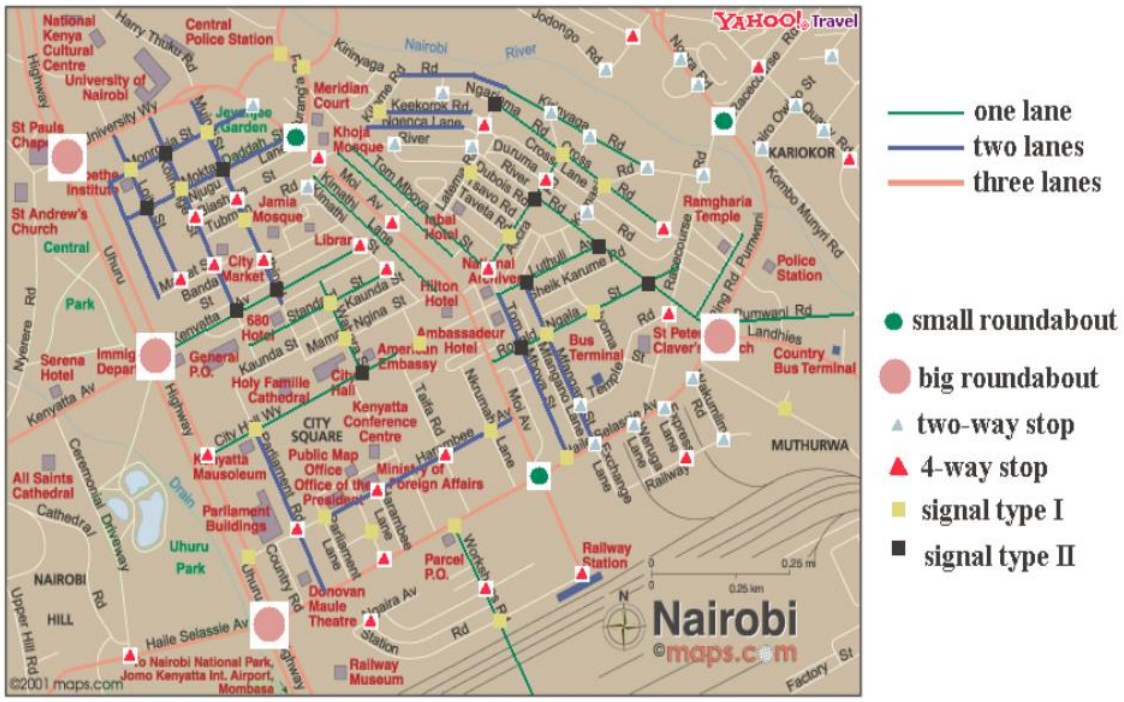

Figure 1.2: Required map for Nairobi Central Business District (Adapted from Nairobi Mappery, 2012).

Urban planners tend to suggest some ways of solving the parking problem in cities. One is to increase the supply, by providing more parking slots. However, as a city develops with more high-rise buildings, skyscrapers and people, this becomes totally and more unsustainable. An example is road construction, it is very difficult for supply to keep up with the demand. The other solution is parking management, this involves assessing urban land use, optimally utilizing available space and providing non-motorized and rapid transit alternatives so that parking demand is reduced. This holistic approach is what oughts to take place but it is being ignored by the county officials.

Nairobi city needs to look at the latter. Though the CBD already has several privately run surface level parking spaces, better quality parking management is required. Provision of non-motorable means of mobility and an improved rapid public transport system would reduce the demand for parking. With this, it would be possible for parking fees to be increased even to an hourly rate and get optimum returns from use of the space. More automated systems of collecting parking fees are also required. Parking consumes land and if less parking is required, more land is available for alternative uses like wider pedestrian walkways, spaces for hawkers, loading and

drop-off zones, etc. This attempt at shifting transportation behaviour will be key towards reducing the demand for parking, utilizing spaces well and creating a comfortable urban framework for citizens.

Services that are modern are designed to get drivers to their ultimate destination without searching as well as the uncetainty related to the cost, payment, time of travel, and other practical considerations. Smart parking service providers usually take advantage of the users' willingness to pay a marginal mark-up over existing parking fees in exchange for the convenience. This need coupled with the extensive use of mobile devices and the convenience of mobile payment has given rise to inclusion of devices in the parking industry to improve performance and gain a competitive edge. (Wan and Wenbo, 2013). This study seeks to fill this gap and will present a criticcal discussionon the dynamics of the adoption of a GIS-based application and identiftying potential gaps for future research.

1.2 Problem Statement

In the current modern society, there is an ever-increasing number of vehicles (Shoup, 2005). It is estimated that nearly 30% of urban congestion is created by drivers cruising for parking. Finding a parking space in most metropolitan areas, especially during the rush hours, is difficult for drivers. The difficulty arises from not knowing where the available spaces may be at the time; even if known, many vehicles may pursue very limited parking spaces to cause serious traffic congestion. (Wang and Wenbo, 2013).

According to (Shoup, 2005), the difficulties in searching for parking space lead to wastage of time and fuel. High-stress levels experienced due to the random search for parking spaces and its impact on economically productive activities is wanting (Mwehe, 2012).

The systems in place currently lack the spatial element and a lot of components that should be considered in managing parking. A GIS based prototype that manages the cycle of parking and ease of accessing and managing parking spaces is the solution this research seeks to provide (Jung, 2013).

1.3 Research Objectives

i. To determine the different types of data that will model a parking solution.
ii. To assess the challenges encountered in accessing and managing parking.

iii. To review current tools and techniques used in managing urban parking.
iv. To develop a prototype for parking management.
v. To test and analyse the prototype.

1.4. Research Questions

i. What is the data required for modeling a parking solution?
ii. What are the challenges encountered in accessing and managing parking?
iii. Which are the existing tools and techniques for managing parking?
iv. How will the prototype be developed and implemented?
v. How will the prototype be tested and analyzed?

1.5 Justification for the Study

This research is significantly paramount for planning transportation in the city, particularly the Nairobi central business district. This is the area where most economic activities take place, thus the conditions should be made conducive for the activities to thrive. The fact that parking is quite dynamic in that, one minute the parking space is engaged and the next or so minutes it is vacant, it is vital that a solution should be developed to efficiently and effectively manage it. The county government will have a proper ground for structuring parking space utilization and traffic police will strain less in terms of controlling traffic and congestion on the roads. This research will shed more light in decision making for city engineers particularly on the use of spatial and non-spatial data in space management. The effect of this congestion has a spiral effect on all stakeholders therefore a GIS-based solution will be effective in alleviating drivers' pain of finding and reserving parking spaces.

1.6 Scope of Research

The scope of this research is a parking setting within Nairobi's central business district area which is used for a lot of activities and serves a large number of people. It will assist various users who will be involved in pre-arrival parking, parking reservation, payment, thus require a corresponding visualization of the parking slot by use of the GIS module. The visualization tools created in this study is a web based component, which is sufficient since many computer and mobile applications can run ordinary web browsers in the current technologically enhanced systems.

This research therefore confines itself to the issues of a GIS-based vehicle parking management prototype since in the past, the spatial component of this matter has not been explored and dealt with comprehensively (Mwehe, 2012). There will be geo-referenced aerial photos of the area of study as well as an engineering design layout to reflect the overall picture. Data will be collected and mapped seamlessly from the urban space within the area of study out of which it will be used in determining the management of parking and modelling of the solution.

1.7 Limitations of the Research

The research will experience various limitations. Generally, the update dates are not the same for aerial photos and google maps. Similarly, road equipment which avert parking are imperceptible from aerial photography and google maps confirm the fact that there will be no free parking spaces. Unavoidable inaccuracies introduced by the digitization of continuous data as well as the projection of three-dimensional data onto a two-dimensional plane will be the other major limitation in this study. Incompatibilities of data sets stored in different formats will also affect the process of data collection. Still on data, instances existed such that both primary and secondary research techniques will not be offer sufficient and accurate information which will be needed to meet the ultimate research objectives. This in turn forced the researcher to scale down the research depending on the suitability and relevancy of the dissertation in order to meet the objectives. Inconsistency checks and technical challenges will be encountered during system development and testing as well. During the whole process of carrying out this project, there were many other things that were taking place hence time was insufficient therefore causing a lapse in effective completion. Thus it was empirical for the researcher to assure that adequate time is allocated to each phase. When this is done, the successful completion of the dissertation will hardly be compromised by the limitations of time.

1.8 Ethics in research

Ethics are the standards of behavior to be adopted while interacting with other people during the research (Barone, 2014). The aim of this section in the research is to encourage integrity and morality during the whole phase of conducting the research. All the stakeholders involved must be respected and seen not as passive sources of data but as people whose rights and welfare should be protected. This research is comprehensive and will involve a lot of data

hence the quality and integrity of these data has to be top-notch. During data collection, the researcher has to respect the confidentiality and anonymity of the research respondents and ensure that all participants get involved with the study voluntarily. Any harm to the participants was avoided at all costs. Ultimately, the whole research was independent and impartial from the onset.

Chapter 2: Literature Review

2.1 Introduction

While evaluating the prerequisites of a portable GIS-based parking administration framework, this chapter of study audits an immeasurable archive of data which is secured under urban transportation studies. Much of the literature investigated in this chapter exhibits deviation from the old worldview that parking is continuously accessible and that it is not a subject of judicious administration. As per Rashid, et al (2012) shrewd parking administration frameworks and ITS techniques are investigated to impact parking request administration procedures to the city supervisors for enhanced administration conveyance, client relationship administration and income accumulation. In that case, the purpose of this chapter is to identify some of the preveious studies on this topic and determine the ones that can give light to a more advanced finding that will address the research question and problems, and overall objectives in the use of GIS in urban transportation planning and management within the Nairobi CBD. The literature garthered therefore investigates the advances and foundation in the management of parking in urban communities and their utilization for all classifications of clients.

2.2 The Parking Situation in Kenya

Nairobi is currently facing a severe problem on congestion, especially when it comes to car parking. As a matter of fact, the current situation in Nairobi's CBD reveals that looking for parking is like going through a maze (Katahira Engineers International, 2005). A Parking Survey by IBM in 2011 found that motorists on average take 31.7 minutes against a global average of 19.8 minutes to find a vacant parking slot. The CBD has about 9,000 parking slots operated by the county government. These include 243 parking slots at the Sunken Car Park on Taifa Rd, 220 parking slots at the Law Courts Car Park also on Taifa Rd, and the parking slots on the streets, catering for an estimated 10,000 cars per day passing through the city centre (Waema & Mitulah, 2008). Each of these two off street county government car parks have a daily turnover of over 700 cars, which is very small according to the volumes of car flow into the CBD every day. Such difference on the available parking lots and the existing cars has resulted to numerous problems both to the car owners and the city's management. Reports have indicated that due to the scarcity of parking space in the city, the County Government allows double parking within the off street car parks and charges Ksh 400 per day, while those parking on the streets pay Ksh 300 per day.

City drivers lament that they are forced to pay an additional amount of between KSh20 and KSh50 to parking boys every day to guarantee the security of their vehicles, since the County Government distances itself from this responsibility (Waema & Mitulah, 2008). The current rate of Ksh 300 was increased from Ksh 140 in February 2014, and Ksh 70 in November 2008. Prior to that, the city had parking meters that were removed in the late 1990s and a flat rate of Ksh 70 per day introduced.

Those who have lived in the city for over 20 years will recall that there used to be a public car park behind Jamia Mosque between Tubman Rd and Kigali Rd. , and another one behind Central Bank of Kenya. Both have since been disposed of, and the land developed by their new private owners. The County Government also reconfigured many streets in the CBD that used to have parking slots and turned them into no-parking zones and one-way streets. It is not clear what informed such decisions, but it is evident that the County Government has contributed significantly to the current shortage in parking spaces in the CBD, and will continue to do so if the plans to offset their debts by giving up the Sunken Car Park among other assets sails through. In that case, many planners have aggreed with the fact that if the county government fails to do something regarding the problem, the situation might even worsen come the year 2030.

Normally, on-street parking is popularly used by the short-time car parking users such as businessmen and shoppers. However, these users in Nairobi's CBD are forced to double and triple park on streets because many of the on-street car parking slots are occupied by commuter cars. Many car user commuters prefer to park on-street because of the cheap parking fee (Ksh70 /day) as compared to off-street and building car parking (Ksh 3,880 /month) (Waema & Mitulah, 2008). According to the recent statistics, sixty-five percent (65%) of the total car parking facilities are operated privately by the property owners. Therefore, it is necessary to coordinate with the private sector for the development of the countermeasures for car parking policies and facilities (Alex, 2014).

Table 2.1 shows a list of Car Parks in the CBD operated by the County Government and private organizations. Some of the private ones are seriously underutilized due to prohibitively high charges.

Table 2.1: List of car parks in the CBD

Location	Capacity	Ownership
Sunken Car Park Taifa Rd, open air	243	Nairobi City Council
Law Courts Car Park Taifa Rd, open air	220	Nairobi City Council
Gichamu Lane Car Park Near Shell/BP Hse, open air	80	private
KICC Grounds Parliament Rd, open air	150	Private
Kenyatta Ave. Car Park Loita St opp GPO &KipandeHse, open air	150	Private
Loita St. Car Park Behind Laico Regency Hotel, open air	100	Private
Utalii St. Car Park Opp Utalii Hse, open air	70	Private
KEMU Towers Monrovia St., in-building	25	Private
Intercontinental Hotel on Parliament Rd., in-building	70	Private
Nakumatt Lifestyle Monrovia St., in-building	25	Private

Parking areas outside the Nairobi CBD are different from the current CBD parking pattern. Taking the case of industrial area and shopping malls, there is a notable diference between the areas' parking patterns and trends.

2.2.1 Parking in Nairobi's Industrial Area

Parking in Industrial area is a typical built using block paving by the businesses operating there. Initailly, parking within this area was built and managed by the structure onwers to serve their customers (Waema & Mitulah, 2008). However, the reports have indicated that of late the County Government is now swooping in to start collecting Ksh 140 parking fees for on street parking, which appears unfare to the customers visiting the area. It is unlikely there is any revenue shared with the businesses who invest in building the parking areas, so this seems to be one of the numerous forms of indirect taxation borne by businesses in Kenya (Waema & Mitulah, 2008). No statistics are available on the number of parking slots in Industrial area, but, like the CBD, places like Dar-es-Salaam Road do experience parking shortages similar to those in the CBD.

2.2.2 Shopping Malls

Practically, all the Shopping Malls in the outskirts of Nairobi have signed up for parking management services from KAPS, a virtual monopoly in this service sector in Kenya. Typical vehicle turnovers at these malls ranges from 1,000 to over 3,000 vehicles daily, on account of their retail businesses patronized by short stay customers, unlike office workers who park for the whole day in the CBD Car Parks (Waema & Mitulah, 2008). Most of the Shopping Malls take advantage of lower traffic volumes on weekdays to host the vibrant maasai market once a week as part of their car park. Parking charges vary from mall to mall, based on its popularity.

Three car parking surveys namely; car parking count, car parking interview and car parking inventory were conducted. Figure 2.1 shows the survey locations and the summary of the survey results discussed afterwards. The locations looked into are on-street, off-street , survey buildings and study areas. The survey shows the different sub-sections in which rampant parking type was identified.

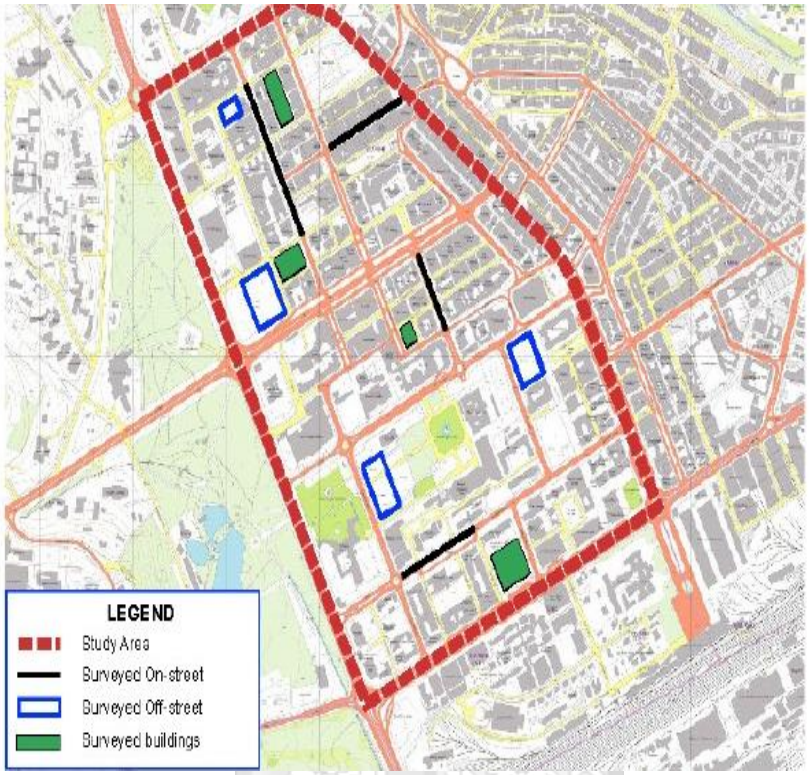

Figure 2.1: Study area and car parking survey location (Adapted from Nairobi Mappery, 2012).

2.2.3 Parking Count Survey

In order to collect the data on demand and supply and parking duration by type of car parking, car parking count surveys were conducted in selected 12 car parks including on-street, off-street and car parking in the buildings. The output of the survey is as follows:

In and out traffic volume by time and maximum occupancy of the car park. In and out traffic volume determined by time and maximum occupancy in relation to the three surveyed car park locations by type is shown in Figure 2.1

The double and/or triple parking of on-street parking along the street is obvious because the maximumoccupancy is much higher than the number of slots at all of the surveyed parking locations.On the other hand, the demand (maximum occupancy) of most of off-street parking and parking in the buildings is lower than the supply (number of slots available).

According to Katahira Engineers International (2005) in Kenya, parking improvement intercessions have not contained interest for parking, this has far-quite exceeded supply. The study depended on aerial photographs, site research in the Central Business District (CBD) and interviews from significant offices and associations. The study, however, found out that the interest for on-road parking is higher for the accompanying reasons:

It is more helpful because a driver might stop near his/her destination contingent upon the accessibility of parking spot. On road parking is less expensive since it is not time-based or space based and one can stop any place and whenever since the charge is level rate (at the time KES 140 and now KES 300). A portion of the off-road parking are storm cellar parking and are held for building inhabitants.

Similarly, the report by Waema & Mitulah (2008) has indicated that different prefences by the cummuters on the best parking to use depends on some benefits, like the , the accesssibility and saftey of the cars. In that case, Nairobi's condition may be addressed through some implementations of new and more effective systems of management and set-ups. For example, a study by the kenya transport authority has clarified that the satisfactory parking guide structure should expand the parking spot use and minimize activity blockage brought on via vehicles searching for an empty parking spot in the occupied focal business area. According to the study, the parking guide framework should be introduced at the passage way of the focal business region. For instance, in Nairobi CBD this should be done at Kenyatta Highway/Uhuru Highway. Such a parking guide structure is a an electric board that educates the parking circumstance: whether the parking is entirely occupied or there is a slight space available for the next car(s).

Another alternative measure to solve the situation regarding the Nairobi's CBD parking system is a GIS-based parking administration framework, which has already proven to be effective in both management and commuters' satsfaction. The system is digitized and has been of great help in reducing various parking issues, including the problems of car blockages, security and enhancement of data storage and processing.

2.2.4 Global Practice in Parking Management

According to the study by Wang & Wenbo (2003) parking management has been taken by different institutions and indivutual in various parts of the world. The author further argues

that parking management therefore involves all the activities that involve planning, budgeting and payments of the parking lots. These types of developments in other countries imply that urban planning was signed off as an administrative activity with its own professional culture and heritage. To a large extent, the occurrence varies between different countries based on the division of responsibilities between central and local government as well as the nature of the local government. In the Netherlands, for instance, there is a strong central government dimension to planning which is evident in the series of notes setting out national strategies that have been released periodically by the National Physical Planning Agency since the early sixties (Faludi & van der Valk, 2001). In Britain, in contrast, the centralized government has played a much less prominent role in strategic planning and as a result, planning is almost exclusively a local government activity as opposed to other European countries.

There are also major differences between countries with respect to the nature of local government itself. For instance, Britain is divided up into unitary and two-tier authorities with an average population of around 150,000, the average size of a French municipality is only 1,500. With these circumstances, the potential of the former for the development of an in-house professional planning culture is considerably greater than the latter which is heavily dependent upon both centrally provided and private sector consultancy services. Nevertheless, the production of implementation plans, development and building control, activities that follow-up spatial plan-making have become major tasks of many local governments in Europe and some parts of Africa.

Various studies have indicated different major parking systems have been developed in different parts globally. A Federal Highway Administration the United States conducted a top to bottom examination of examples of overcoming adversity from six destinations in the United States of America and came up with a report on the best recommendations for the improvements. The report indicated that the full cycle of efficient parking administration procedures was satisfactorily secured from pre-entry parking data frameworks, parcel particular parking data frameworks, floors, walkway, and spatial mindful parking data structures. The study also noted that parking reservation frameworks and parking route frameworks were enormously utilized to accomplish group objectives. The study presumes that any innovation empowered Parking administration framework that is well arranged, partners included, very much financed and

conveyed and in the end executed will continuously acquire support for the occupants. A mixing illustration is the city of Baltimore parking administration framework venture in the US (Wang & Wenbo, 2003). It is said, amid a starting test period, the structure expanded consumer loyalty and enhanced movement stream in the hourly offices. The project partners' applause for the framework is clear and a number of stakeholders approved it. An assistant assistant manager for the Maryland Department of Transportation's office of transportation and terminal services at BWI Airport, commented "*The effect of Smart Park in the Uited states at BWI has been gigantic it has not just made parking simpler and quicker. However it has enhanced consumer loyalty and decreased illegal parking*." This clarifies the requirement for a client-centered parking administration framework for the general population of Nairobi.

2.3 Parking Technology Options Reviewed

There are different technology options that have been used in diferent GIS within the cities around the world. This section evaluates the necessary literature regarding such technologies, which may be used in improving the situation in Nairobi CBD. Some of such technologies developed by different scholars include: Smart parking administration structures, Intelligent Transportation administration frameworks and Geographic Information Systems-based parking administration frameworks.

Smart/keen parking administration structures exploit inventive innovations for drivers to get to pay for parking utilizing individual specialized gadgets or the standard shrewd cards. According to Wang & Wenbo (2011), hunting down an empty parking spot in a metropolitan region is a tedious sympathy toward generic drivers. This ordinarily results in antagonistic activity blockage and air contamination. To ease such a movement clog and enhance the accommodation for drivers, numerous intellectual parking administration frameworks need to be produced and conveyed. By flawlessly incorporating pay-by-phone innovation to deliver a brilliant, quicker, and more productive approach to the park, a portable parking administration framework is the convenient parking installment and administration answer for our nation.

At present, most research works on keen parking is from the point of view of framework configuration, which concentrate on actualizing a remote sensor system to distinguish parking data and give real-time parking benefit. Clever transport frameworks change in innovations

connected from fundamental administration frameworks. Such frameworks include; the autoroute; movement signal control frameworks; holder administration frameworks; variable message signs; programmed number plate acknowledgment or pace cameras to screen applications, such as CCTV cameras and to more propelled applications that coordinate live information and input from different sources. These sources are parking directions and data structures, climate data, and so forth.

Parking administration has been more useful in income gathering and a bit of pre-landing data procurement. The author indicates that the vehicle enlistment number plate acknowledgment recognizable proof is a critical application in the field of Intelligent Transport System and Electronic Toll Collection. The goal is to separate and perceive vehicle enlistment numbers from vehicle pictures, handle the image information at long last use for access recording and getting the electronic bill ready (Cook & Das, 2004).

Payment is one of the significant examination themes in Intelligent Transportation System (ITS). The framework is separated into sub-frameworks which are 'FULL ‘display frameworks, picture procurement and plate number acknowledgment, auto bearing framework and auto installment structure. Firstly, information is gained from ultrasonic sensors of every parking spot to check the accessibility of parking spots in the parking zone. At that point, a picture of the auto is obtained in the passageway to be dissected, from my own perception on the development of this innovation, it is about information obtaining and handling that are much more considered in this venture albeit imperative development for progression of the same.

Geographic Information Systems, (being a PC-based framework is intended to capture, store, control, dissect, oversee, and show a wide range of land information). These parking frameworks have the capacity of using the two checked on innovation choices and present another and capable measurement to Parking administration, deceivability to the parking information that is disconnected in their database and content reports of the promptly audited innovation choices (Rashid, Musa, Rahman, Ataur & Fahana, 2012). In Kenya, GIS has been used in area data frameworks, general wellbeing, farming and open works. It has been my perspective that if the innovation was bridled to oversee parking then every partner would accumulate gigantic advantages. Parking administration suppliers and troughs will have the

capacity to screen parking status which changes more proficiently than in utilizing the manual non-spatial information. The perception from the spatial information also, investigation force of GIS expands utilization of data for choice making and administration purposes. Portable GIS-based vehicle parking administration framework is linked to the next two looked into advances because of the one of a kind force of GIS, which particularly are:

Examination-Spatial investigation is a major motivation that requires GIS since it incorporates the greater part of the changes, controls, and strategies that can be connected to spatial and non-spatial information. It increases the value of the information collected, fosters choices, and uncovers examples and oddities that are most certainly not promptly self-evident (Rashid, Musa, Rahman, Ataur & Fahana, 2012). This can rapidly permit the parking administrators' analysis of the spatial circulation of parking status and precision.

Parking directors can utilize CAD information from Engineers, digital maps from surveys, applications from computer scientists, information from databases, web servers, map servers and so forth (Rashid, Musa, Rahman, Ataur & Fahana, 2012). This makes GIS a reasonable inclination over the other two innovations. With propelling advances, GIS has all-inclusive openness and dispersal modes which are; portable, desktop, the web, cloud and manual. Information Management-GIS can deal with an assortment of information in different structures, vector, raster for spatial purposes.

2.4 Research on Parking Sytems

In undertaking this venture, new research systems have been translated into parking issues that are being attempted inside of colleges and other major institutions within the city. One of the paapers reviewed was:

'Examining and organizing compelling sub-national government systems to diminish nursery gas discharges from street transport'.

This task is being attempted at Oxford University and, to some extent, by the British Parking Association. It is a global study surveying the adequacy of different arrangements actualized by an assortment of sub-national state governments and their capacity to lessen the atmosphere effects of transport - particularly autos. The fundamental goal of the study was to

explore the inward structures, transaction and flow at the state government level, both between divisions which build and administer these particular arrangement zones, additionally between the ranges of obligation and between levels of government. The part of the private area of this choice making procedures is additionally inspected. The primary speculation of the thesis is that there is a difference between natural/environmental change approach and transport strategy, which causes these arrangement to be inadequate (Wang & Wenbo, 2003). The study indicates that without effectively connecting structures and partners simultaneously, unmistakable emanations will be hard to manage. This information and knowldge is vital in this study because it also revolves around the same components of a transport system within Nairobi. The second paper is:

'Parking Research Review: A study of whether more competent individuals' states of mind to street valuing are not quite the same as the ones of other age bunches'.

This task is additionally being embraced by the University of the West of England. Right now there are noteworthy research gaps in evaluating the causal relationship between more established age and street estimations. The goal of this study is to distinguish the different parts of a beneficial parking arrangement and requirement administration and produce a toolbox that will empower a nearby power to judge whether their parking approach and implementation administration are successful. It includes the information and the data accessible to illuminate the effects and the practices by mutual parking authorization and dominant voices in connection to conveying a compelling and all around respected parking implementation administration (Kim, 2014).

Real, far-reaching parking concentrates on two ample parking considers have been looked into: Bristol 201 and Hong Kong. They were not just expensive but also endeavored to address an extensive variety of parking and related issues. In 1991 a noteworthy thesis project was propelled into urban blockage in London, its causes, and possible cures – incompletely utilizing knowledge from Bristol as contextual investigation material. Three papers were distributed in Traffic Engineering and Control in 1997 that portrayed the methodology:

2.5 Intelligent Transportation Systems

These are systems which are used in developed countries to improve mobility and enhance productivity through the integration of advanced communications technologies into the transportation infrastructure and in vehicles. They generally encompass a broad range of wireless and wire line communications-based information and electronics technologies. They include: wireless communications, computational technologies, floating car data and floating cellular data which is comprise of other methods which are; triangulation method, cars contain mobile phones and as the car moves, so does the signal of any mobile phone which is inside the vehicle. Therefore, the network data is measured and analysed using triangulation. The other method is vehicle re-identification in which a set of detectors are mounted along the road and a unique serial number for a devise in the vehicle is detected. The travel times and speed are calculated by comparing time at which a specific device is detected by a pair of sensors (Ranga, 2010).

GPS based methods are also used, sensing technologies such as inductive loop detection, video vehicle detection, bluetooth detection, auto detection and information fusion from multiple traffic sensing modalities. The other methods of ITS are; Automatic road enforcement whereby a camera and a vehicle monitoring device is used to detect and identify vehicles disobeying parking requirements or some other road legal rule and automatically ticket offenders based on the license plate number. Basically, all ITS sytems comprise of these elements in their application and operation: Internet-of-Things, wireless sensor networks, smart parking, radio frequency identification and optimal sensor placement (Ranga, 2010).

2.6 The ICT tools for parking management

There are various tools used in managing parking in the modern urban setting, this section describes some models, frameworks and architectures for existing systems upon which the current application will be based on. The various applications involve different components to achieve the same objective.

2.6.1 NTES Parking Framework

This is a parking framework which was adopted in China to enhance proper traffic flow as well as congestion management due to increase in vehicles and people. The architecture is centralized and there is a detailed integration which eventually is geared towards controlling the lot at the parking with inflow and outflow of cars. The framework is very reliable apart from a

few constraints such as complexity and non-interoperability. This limits the usage as well as efficiency. The proposed application is geared towards filling this gap.

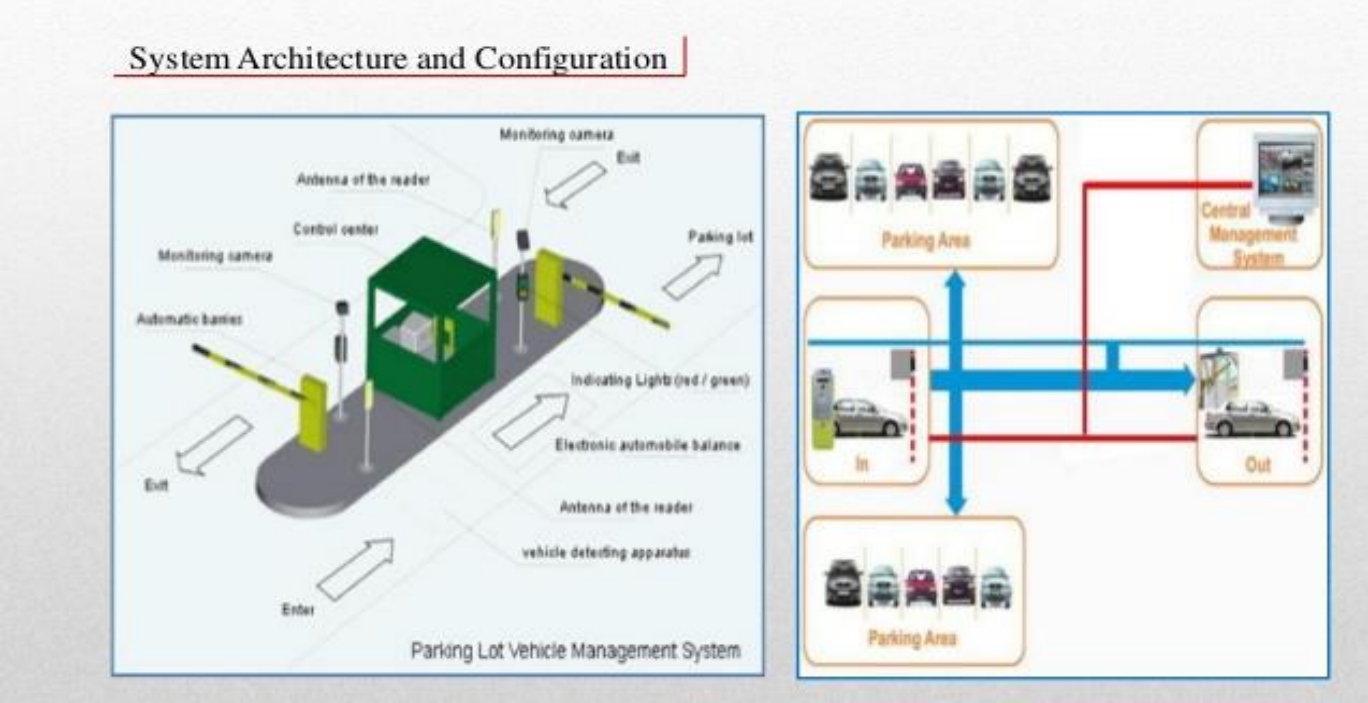

Figure 2.2: Parking Lot Vehicle Management System (Adapted from Barone et al, 2012).

2.6.2 Wireless Parking Guidance Framework

This is composed of large number of tiny sensors, low-power and self-organizing wireless communication technology interconnect a large number of low-cost sensors, monitoring of real-world perception, and may bear an appropriate amount of information services. It is a typical embedded system, each wireless sensor node integrated data acquisition, data processing, wireless communications, organizational networking, power management features, and function seemingly single but actually complex. This system selects the Hall sensor to detect the parking spaces. In the site simulation, using the optical sensor, simulation of car parking spaces of light changes the photosensitive resistor value changes to indicate that the appropriate vehicle to enter or go out. When the resistance value increases, indicating that at this time a car came in, the light dimmed. When the resistance value increases when the car came in at this time, the light returned to normal. (Wei et al, 2008).

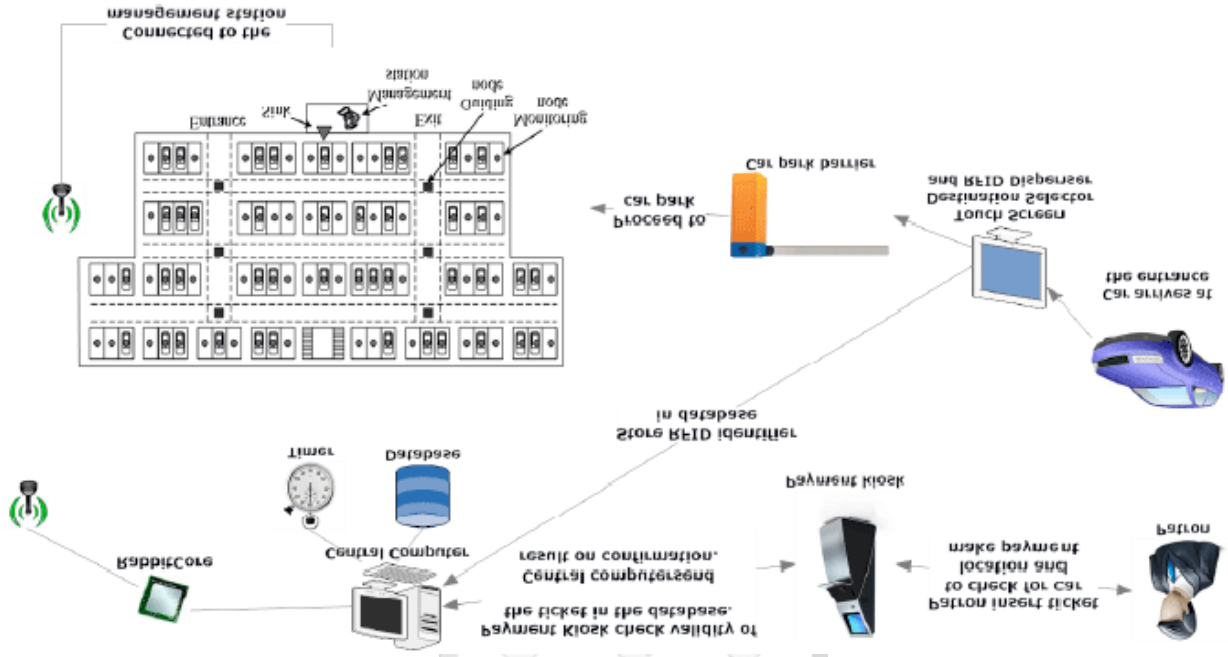

Figure 2.3: Wireless Parking Guidance Framework (Adapted from Kim, 2014).

The cost of implementing such kind of a system in a developing country setting is quite costly. The components involved are very costly and require high levels of maintenance.

2.6.3 Real Track Parking Lot Management Model

This is a system which will is ideally customized according to the customer requirements. It directly integrates with the smart instrument to provide real-time data. It is a fully web based system which also supports window based functions. The system covers the complete parking zones available around a particular area. The user or administrator can create different zones and assign time to each zone, add additional information about restrictions, time limitations, important people parking zone and other details. To create the zone, user / administrator needs to go to **configuration site** and say **create zone** command to create the zone and to record additional information.

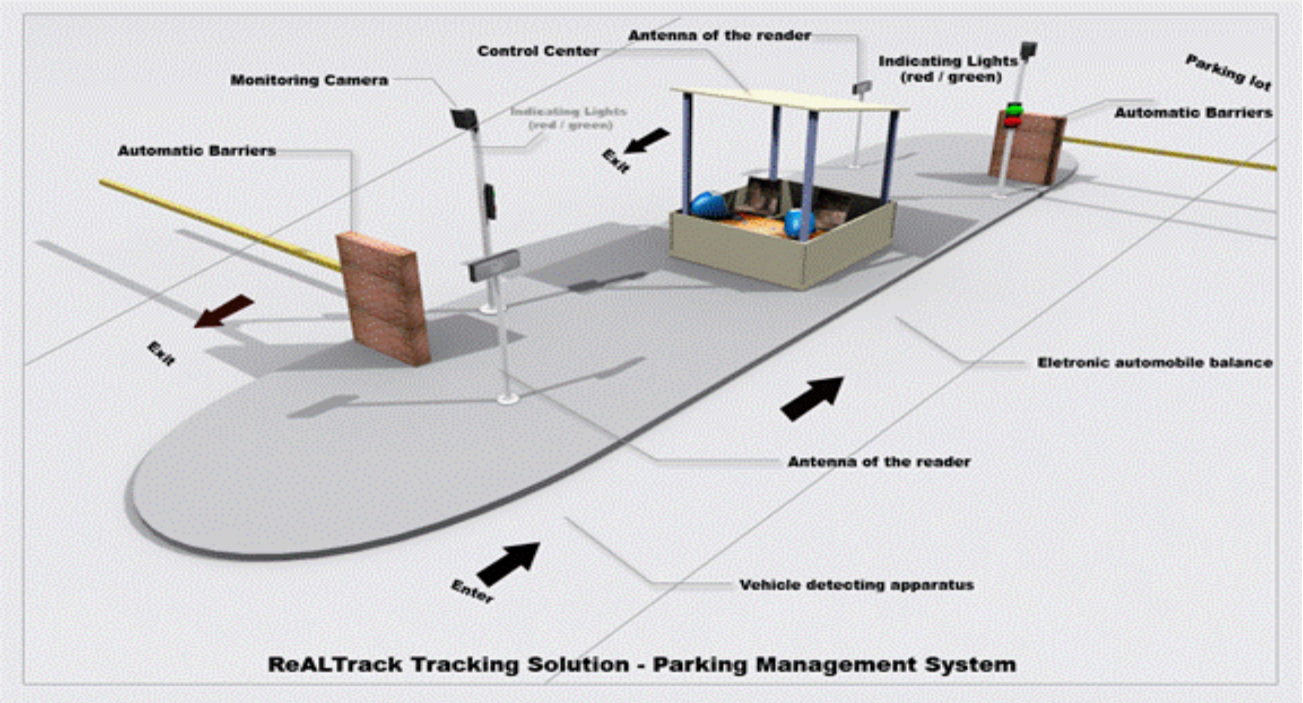

Figure 2.4: Real Track Parking Lot Management Model (Adapted from Walker, 2011).

It provides a robust, scalable and highly extensible parking system management solution and achieves it by proper designing of the parking zones, standard compliant tracking hardware, managed resource utilization using future ready technologies and best of breed application created with new generation languages with highly customizable and user friendly interfaces. The major demerit is that it is very complex and involving.

2.6.4 Smart Parking System Architecture

This architecture involves magnetic sensors mounted in the surface of individual parking spots, sensing vehicles that disturb the uniform intensity and direction of the earth's magnetic field. Ultrasonic sensors mounted on the ceiling to measure the distance between the sensor and the first obstacle, which could be the pavement or a vehicle (Kianpisheh et al, 2012).

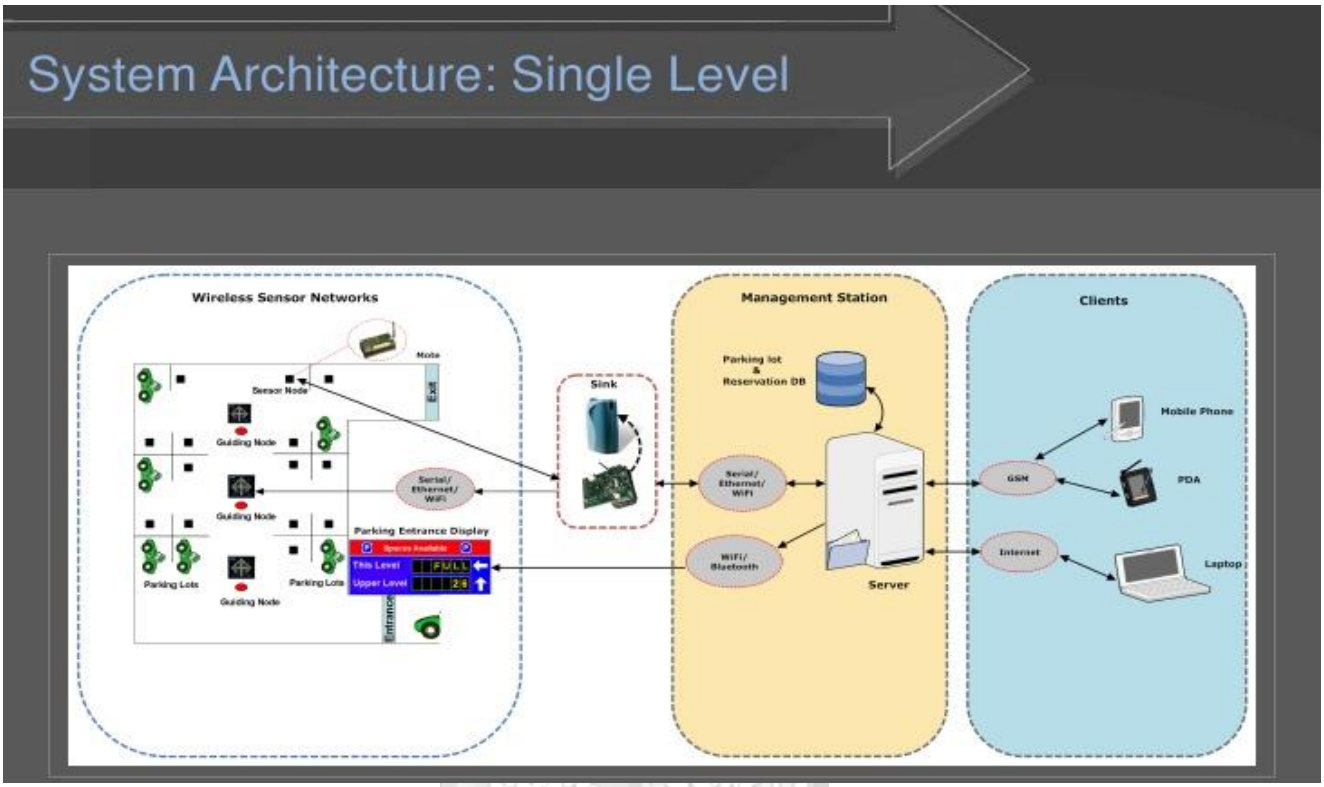

Figure 2.5: Smart Parking System Architecture (Adapted from Zhang, 2011).

The major contribution of this study was to introduce the most significant parking space problem (finding a vacant slot) and propose a solution. Infrared sensors can be used to detect the parking spaces. The customer can reserve a parking slot before his arrival. The parking operator can handle the customer data. The architecture for a parking detection system would decrease searching time for vacant spaces by reserving a parking space online (Kianpisheh et al, 2012).
The time among transmitted sound and reflection is lengthier in a vacant space than in an occupied space, hence the sensor can detect when a space is occupied.

2.6.5 Intelligent parking system architecture

The basic infrastructure of a parking system relies on devices to detect if parking spaces are occupied. Several approaches are employed to detect reliable information. First wired sensors are widely used, inductive loops, pneumatic road tubes, magnetic sensors, piezoelectric sensors, weigh-in-motion systems. The Earth's magnetic field is used to detect parking spaces. These devices or sensors are physically wired to the control computers. One shortcoming of the wired

sensor systems is that long and complicated wiring is required from parking lots to the central control unit. Also, the cost for developing this system is high because a large amount of sensor units are required. Therefore some wireless sensors can be applied to the parking space detection.

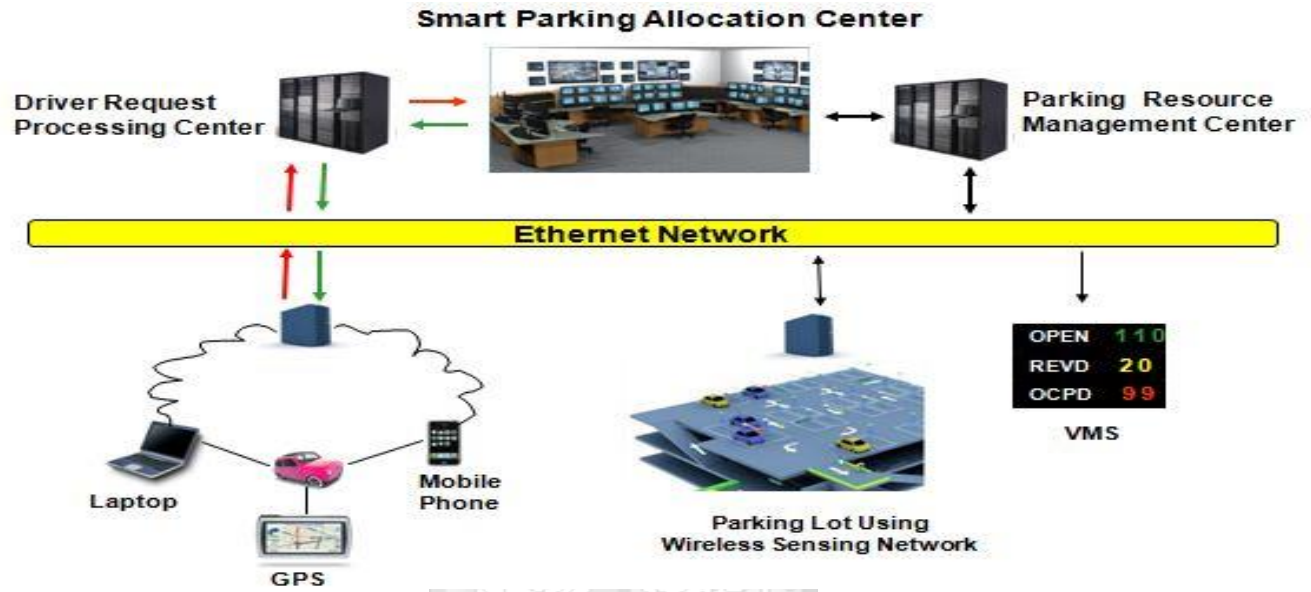

Figure 2.6: Intelligent parking system architecture (Adapted from Jung, 2013)

This system uses roadside units to relay parking messages and GPS to locate vehicle position. Roadside units maintain the security certificates and parking information. The security issue addressed in this paper is to ensure fare-play among drivers by encryption and frequently sensing the available spots. The underlying philosophy behind this architecture is that the decision about traffic-related information dissemination should rest with the infrastructure but not with individual vehicles. This enhances security and privacy.

2.6.6 An IOT Intelligent car parking model

These include integrated electromechanical transmission control, security control, detection systems and automated placement. The systems can fully support vehicle measurement, image analysis, electronic payment scanning, and automatic retrieval. The drivers will only park at an entry pallet or port. Images of the car are captured and transmitted to a controller where dimensions of the car are read and the license plate recorded. Meanwhile, the

driver pays by card and the system provides authorization, possibly via voice recognition. Once sensors have verified the entry pallet or cabin is empty of occupants, the process of automatic moving and parking will be initiated. The car will be moved by an elevator or a carousel system up to the storage floors and parked into an appropriate space with security guarantee.

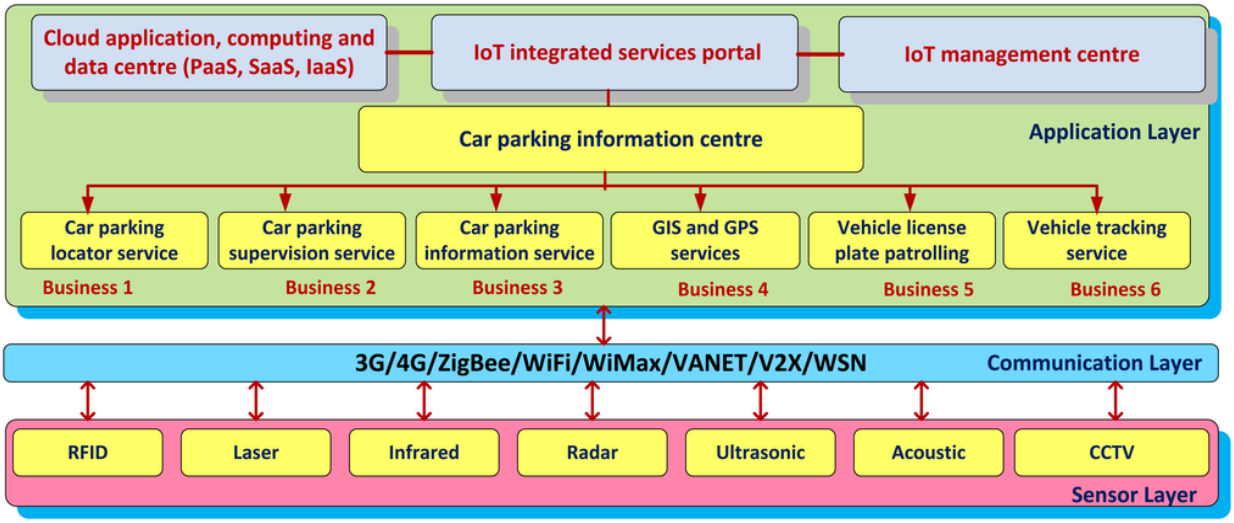

Figure 2.7: Internet of Things Intelligent Car Parking Model (Adapted from Bowden, 2014)

To command and coordinate all the controllers and subsystems, the system require s precise control, robust and reliable networking, and secured system maintenance. Using an Internet of Things gateway to connect with the programmable logic controller, however, sensors and other edge devices, field data can be retrieved, analysed and stored to the cloud. This allows the parking system to be monitored and controlled from a remote control centre in real time, providing considerable benefits to the management and efficiency of the parking systems.

2.7 Mapping tools used to navigate to the parking

There are various tools which are used by drivers to navigate to the parking. Low are the various tools: Google Maps: This entails the user dragging the map, the grid squares are downloaded from the server and inserted into the page. When a user searches for a parking, the results are downloaded in the background for insertion into the side panel and map; the page is

not reloaded. Various locations are drawn dynamically by positioning a red pin (composed of several partially transparent data on top of the map images.

Location based Sytems: These are systems which offer navigation services that allow locating the exact geographical position of a parign spot using one of available positioning systems and get direction and/or navigate user to required location. They potentially gives user the access to the real-time data. The limitation of large volumes of data needed to be transferred over wireless network is decreasing as many network operators offers unlimited or reasonably priced data transfer.

Aerial Photography: This is the taking of photographs of the ground from an elevated and direct-down position to capture the exact cartographic image. GIS engineers can acquire the images remotely and get the exact space that is available to be used for parking.

2.7.1 Analysis of the Review

Few thesis papers straightforwardly address every one of the issues in which DfT are intrigued. Accurate holes emerge in assessment contemplates, connecting parking to blockage, CO2 discharges, and economical transport. The effect of parking procurement upon the urban environment and streetscape have scarcely been considered in the papers and report looked into. While a few studies examine the impact of parking controls on activities (Rashid, Musa, Rahman, Ataur & Fahana, 2012). This is normally just by implication concerned with blockage and carbon emanations; movement levels can be seen as a surrogate for these variables (Hester, Fisher & Collura, 2002). As a premise for the arrangements sketched out in DaSTS, the discoveries overall do not give as clear and unequivocal confirmation exhibiting the effects of various parking approaches. Nevertheless, a few papers report extremely intriguing results or translations that would add to decide research needs. This report has constructed the confirmation base for other theses and arrangement improvement.

Levels of parking charges give off an impression of being moderately subjective: parking charges don't inexorably mirror the expense of procurement, particularly of multi-story auto parks; whilst, in the meantime, they don't mirror the business sector cost and what clients would be arranged to pay (Barone et al, 2014). Parking is costly to give in new improvements. A few papers report parking costs, now and then in locational concentrates, yet these may not

presently be proper because of expansion and the time subsequent to the study was embraced. One issue is that while charging for parking is generally a stage capacity, with costs expanding incrementally at occasional interims, parking interest is a constant capacity, having encountered consistent development over the late years. Thus, parking charges tend to fall behind expansions sought after so much weight is persistently set upon the through way system.

Numerous studies are concerned about the use of business sector measures to oversee parking, particularly in urban focuses. Confirmation of value flexibilities is accessible, yet these will be liable to an assortment of impacts, not just outright and relative costs: accessibility of option parking; open transport procurement; genuine earnings; charging limits; trip purposes and so on. These will fluctuate between areas so the versatilities for one area may not be repeated somewhere else (Ando, Morikawa, Miwa & Yamamoto, 2010). Travel conducts rely on upon an extensive variety of mental, sociological and also monetary issues which likewise should be comprehended; and specifically driver conduct.

2.8 Conceptual Framework

This framework describes a connected traffic management system with a GIS enabled digital road map of the city, occupied with the power of analytics. After collecting the information from the spatial and raster environment, the web tool aligns the data in real time with GIS mapping and parking spaces to provide information to motorists on the best route to take, therby helping to reduce traffic pile up. This framework should produce a product which will easily interface with the other systems in, setting up and tuning the model, initializing all the territorial and mobility data and finally adapting the product to the specific user needs and situations. All the data used can be shared with the planning environment: real observed traffic conditions, reconstructed network states, and other estimations. This can take place through data exchange according to defined formats and protocols. This helps in tuning the model and in carrying out predictive simulations based on sets of real data.

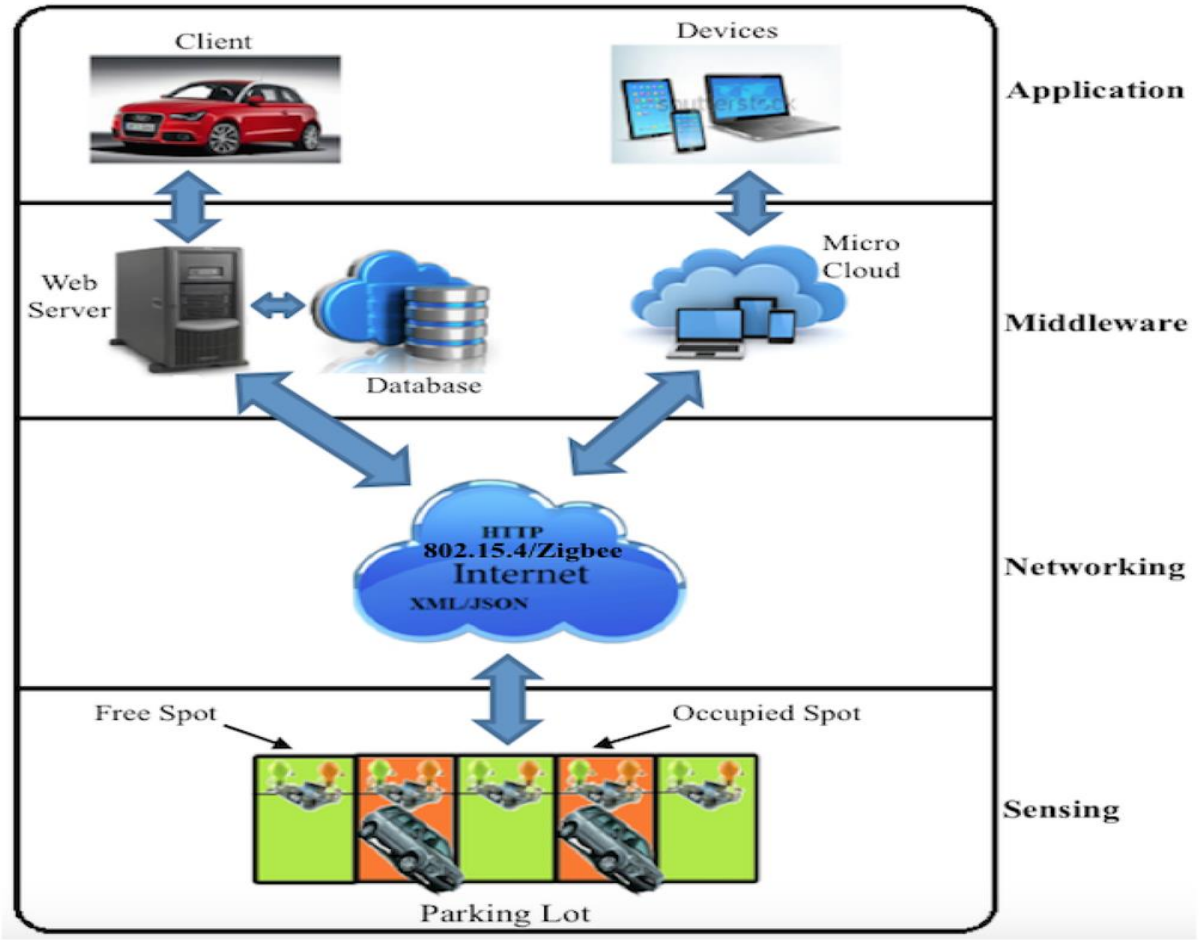

Figure 2.8: The Conceptual Framework

2.9 Conclusion

It is clear that the parking problem is a global pain from the studies discussed in this chapter. There have been numerous studies and projects geared towards addressing this issue implying that it is being given a lot of attention. The impact is paramount in addressing both economic and social facets of any urban city. The notion is that an urban environment has a high population and the economic activities are numerous. Basically, GIS is seen as a good tool to better the services of a parking guidance. Traditional methods of relaying parking informaton which included road signs and off-road visual displays as per the studies were rather limited in that only a portion of road users could access the information at a time. The studies show some optimism in eventually addressing the whole problem and the subsequent consequences. A lot of efforts have to be incorporated to address the problem since the elements involved are interrelated.

Chapter 3: Research Methodology

3.1 Introduction

This chapter introduces the general research strategy in terms of data gathering and the precise techniques that will be used to achieve the overall research objectives. As from the previous parts, the purpose of this study is to examine the perceptions of GIS regarding the quality and condition, maintenance, improvement, utilization and renovation of existing urban plans within the city of Nairobi. In that case, this chapter defines the scope and extent of the research design as well as the methods that are implemented to acquire the necessary and diversified data to answer the main research questions.

3.2 Research Design

The overall approach will be descriptive and analytical. The study is a typical example of an empirical design research project. In this case, the main goal for the entire study is to describe and analyse the main components around the city of Nairobi that forms its political, social and environmental systems. Based on such a nature of study, the descriptive-analytical design is ideal for the collection of unbiased information thus coming up with the best ways of answering the main research questions and attaining the objectives. This will ensure an effective understanding of the problem statement making sure it is well addressed without any omissions in relation to the city's geographical information system. As a matter of fact, the GIS is composed of diverse data, which requires proper evaluation through a well organised and planed descriptive-analytical research approach.

Following the complexity of the study, the design is also complex in way that a number of components will be evaluated, described and analysed at the same time. It entails population and sampling, tools and methods of data collection and gathering, the time and methods of collecting the data as well as methods of analysing the collected data in CBD that will refine the research into a more clear ground of creating the proposed solution.

The existing system is evaluated. Deficiencies are identified. This can be done by interviewing users of the system and consulting with support personnel. The new system requirements are defined. In particular, the deficiencies in the existing system must be addressed with specific proposals for improvement. The proposed system is designed. Plans are laid out concerning the

physical construction, hardware, operating systems, programming, communications, and security issues. The new system is developed. The new components and programs must be obtained and installed. Users of the system must be trained in its use, and all aspects of performance must be tested. If necessary, adjustments must be made at this stage. The system is put into use. This can be done in various ways. The new system can phased in, according to application or location, and the old system gradually replaced. In some cases, it may be more cost-effective to shut down the old system and implement the new system all at once. Once the new system is up and running for a while, it should be exhaustively evaluated. Maintenance must be kept up rigorously at all times. Users of the system should be kept up-to-date concerning the latest modifications and procedures.

3.2.1 Descriptive Analysis

A number of scholars have defined descriptive study as the one in which the information is collected without necessary altering the environment or manipulating the aspects surrounding the nature of that information or the sources. In some cases this kind of study is known as observational or correlation. The Office of the Human Research Protections (OHRP) defined descriptive study design as the one without any nature of experimental. In this study, the descriptive design helps in providing information regarding various components within the CBD area of Nairobi. Some of the components include; social behaviours, economic, environmental, political, and characteristic aspects of the city. The design is also used to describe the relationships and associations of different things within the city's environments.

Descriptive study design will take several forms in this research. It will involve an interaction with a group of people, which is known as the cross-section study or follow individuals for a stipulated period of time. There are those other descriptive studies, which will help the researchers to interact with the participants through interviews, and surveys to collect the right information. The other form of descriptive study involve those in which the researchers will not necessary interact with the participants. This will be observation and the review of the existing records and materials.

To be effective in data collection, this study involves a descriptive design that involves participants' interactions and those without such interactions. Interviews will be conducted and

distributed questionnaires as well as observing some trends within the city. The data collected through observation and other descriptive methods will include geographic images, which will provide a good basis for a parking typology database. The geo-referenced images will be used to generate an accurate vector map of CBD area. This will be used for the on-going design of services and infrastructure.

3.2.2 Analytical Approach

As the descriptive approach of the study describes various components of the area of study, the analytical approach aims to discover the quality of the influence each research determinant has on the social, economic and environmental aspects of the city. To gain the most effective knowledge regarding the research questions, the study involves a number of comparisons between different components. For instance, the observations and information collected through description will be compared to determine their influence depending on each hypothesis in this research. The use of spatial and physical data, for instance, will be used to create an overlay of the design framework on the base data. In that case, analysis and manipulation will take place to generate the different parking techniques and other developments the city has experienced and intends to experience in the future. As an analytical tool, the google street view will be used since it is an efficient complementary data source especially where the city's visibility is unclear through aerial photography due to trees and other objects.

3.3 Population and sampling

The study involves the collection of data from the city's central business district, which has an approximate population of 100000 people. To come up with the correct data, the best sample size has to be established. This was determined using the Krejcie and Morgan (1970) formula:

Sample Size=X2NP (1−P) d2 (N−1) + X2P (1−P)

Population: 150; Accuracy: 90%; Margin of error: 5%

Equation 3.1: Equation for calculation of sample size

Note: This sample size calculator uses a normal distribution of (50%) to calculate the optimum sample size.

The sample size stands for the number of the completed responses from the participants. The term samples originated from the fact that the figure only represents a portion of the total population within the area of research. The total population of the Nairobi CBD is around 100000. 150 participants are used to produce relevant information, which address all the research questions. From the 150 respondents, 50% are male and 50% female all aged between 25 to 55 years. 20% will be from the county and national government offices, 30 percent from other business offices, 35% will be activists and clergy communities and 25% the unemployed common citizens within the CBD. The reason for selecting a diverse sample is that the study aims to collect diverse information regarding the entire GIS of Nairobi city and then narrow down to the area of study.

3.4 Data collection instruments

The study involves a number of data collections instruments. Geographic information system (GIS) captures, saves, analyses, manipulates and manages any form of geographical statistical data. GIS is mainly used to study the geographical systems of a certain area or environment. In this study, the GIS are used to describe the information system that stores, integrates, edits, analyses and displays graphic information regarding the Nairobi CBD. By using the tools of GIS, the researcher gets a chance to come with effective and interactive queries, conduct a spatial information analysis, edit some data in map, and present the results in a clearer manner thus making the entire study a success. The main data utilized in this study include that involving; tax files, parking preference, transport methods, number of garages, the years of construction, owners' information, private tenants and social housing proportions. Due to its complexity, the data to be used in this GIS study is collected through both primary and secondary methods such as observations, document reviewing, surveying, and questionnaire methods.

3.4.1 Observation

Observation is one of the research methods that have been used in numerous studies across different disciplines. It has been defined as a systematic approach of collecting data in which the researchers utilize all their senses to evaluate and examine the naturally occurring components or settings within the area of study. The main types of observation include the social situation or the prolonged engagement.

In this particular study, the researcher will take some time to observe the different patterns within the city regarding the city's population pattern, parking system, payment activities, movements of people and vehicles, among other things that are targeted to address the research question. For instance, observation of the physical and spatial data in CBD carefully. The observation will be made in public parking lots, public recreational centres, streets and other major structures within the CBD. Enough time will be taken to capture possible information from the activities. The capturing process will be aided by some digital cameras and other recording items, like smart phones, pens and notebooks.

Observation method has its advantages and limitations. For instance, through its application in this study, there will be a direct access to reliable data about all variables. The data collected will have a high level of flexibility and easier reference. On the other hand, some of the limitations include loss of time and unnecessary spurn of time staring at irrelevant features. The other one is that the collected through observation may lack credibility and may be biased. This is because due to lack of clarifications, the observers may record their data wrongly.

3.4.2 Document Reviewing

To get the relevant information regarding different components of the city's GIS, reviews of some of the documents from different offices and websites will be. One of the major document review utilised in this research involves library search whereby a number of materials from the local libraries will be reviewed. This will be to collect the information regarding the traditional development of the city's GIS. The library search will also help in collecting the right knowledge regarding the best study theories and models, which will make it easy to conduct a successful research. Additionally, both the local and international newspapers, magazines, periodicals and journals will be reviewed to collect all the important information required.

The research will concentrate on online research to study different websites regarding the GIS of Nairobi CBD. For instance, to understand the patterns of parking within the CBD, the payment strategy and other management structures, the researchers reviewed some of the county's websites and planning programs found online. Generally, this method will entail going through documents and literature related to parking systems as well as urban transportation in

cities. The whole idea will be to provide a clearer view of the research area to build on the proposed solution.

3.4.3 Surveying

Surveying is the other method, which will be used in this particular study. Surveying research is one of the crucial measurements employed across study disciplines, such as social research. This method will involve an approach that collects data from the respondent by asking some questions. The main survey approaches will include questionnaires and interviews whereby the respondents are required to answer some questions as directed by the researcher.

In this study, applied survey method will be deployed to obtain data on parking capacity in the CBD by parking type (on-street, off-street and buildings).In order to collect the data on demand and supply and parking duration by type of car parking, car parking count surveys will be conducted in approximately 12 car parks including on-street, off-street and car parking in the buildings.

3.4.4 Questionnaires

As part of the survey study, some questionnaires will be distributed to the respondents who will then be given some time to answer the structured questions. To allow all respondent a chance to participate in the process, the questionnaires will be made available online and in public offices from where the sampled respondents will collect and fill them with the right answers. The questionnaires seek some answers regarding the preferences of the people within the CBD on various modes of transport and the patterns created regarding parking and the movement within the streets. There are numerous advantages of using this method of data collection in the case of this study. For instance, by distributing the questionnaires among the respondents, the researcher gave then an allowance to freely contribute their suggestions, views and critiques of the current patterns within the CBD transport patterns. Also, the method allowed the respondents to provide even the most critical information because their confidentiality was observed. Additionally, collecting direct information from the respondents through this method will allow capturing of the views, suggestions and reaction of people on the current GIS within the CBD of Nairobi city. In generally, the method should give a big picture view of the various

parking characteristics of people which will help in the future decision making in parking management.

3.4.5. Interview

A part from the questionnaire method of collecting data, the study will conduct some structured interviews. Prior to the study, a set of questions will be prepared to be asked during the interviews. Then, the respondents will be alerted on the procedures where those interested will volunteer for the interviews sessions. It will be a voluntary process so that the willing respondents may comfortably produce unbiased information. The actual interviews will then be conducted in different offices to different respondents from different offices within the city's CBD. The first section of the interview will involve questions regarding the personal information of the respondents, the second part about their knowledge on the city's GIS development, the third part about their reactions regarding the current systems and management and the last part about their preferences and suggestion for future developments.

Conducting such interviews will be advantageous to this research in different ways. For instance, the interviews will pave way for a chance to evaluate even the emotional and physical responses from the interviewers. This will increase the quality of the data collected. There will be an improvement in the relationship between the researchers and their respondents thus allowing them to harness even the deepest of the city's hidden information, such as social and cultural aspects of its development. Some of the shortcomings of this method will include cost of arrangement and the fact that some respondents will not be comfortable in answering some questions to the strangers.

3.5 Phases of the Application Development

The application will follow the software development lifecycle model. This is whereby the steps will be sequential and will be seen as flowing steadily downwards from conception, initiation, analysis, design, development, testing, production and implementation and maintenance. The next phase is started only after the defined sets of goals are achieved for previous phase and it is signed off.

3.5.1 Requirement Gathering and analysis

All possible requirements of the system to be developed are captured in this phase and documented in a requirement specification document.

3.5.2 System Design

The requirement specifications from first phase are studied in this phase and system design is prepared. This will help in specifying hardware and system requirements and also helps in defining overall system architecture.

3.5.3 Implementation

With inputs from system design, the system will first be developed in small programs called units, which will be integrated in the next phase. Each unit will be developed and tested for its functionality which is referred to as Unit Testing.

3.5.4 Integration and Testing

All the units developed in the implementation phase will be integrated into a system after testing of each unit. Post integration the entire system will be tested for any faults and failures.

3.5.6 Deployment of system

Once the functional and non-functional testing is done, the product will be deployed in the production environment for use.

3.5.7 Maintenance

There are some issues which may come up in the client environment especially the android studio platform. To fix those issues some patches will released. Also to enhance the application, some better versions will be released. Maintenance will be done to deliver the different changes in the live environment.

3.6 Data Analysis

In this study, a cluster sampling approach will be used, the data will be analysed using a statistical cluster data analysis techniques and excel program. To make it more accurate and effective, the analysis uses the cluster application in the statistical package for the social sciences software. The software offers a number of three types of cluster analysis, which are applied in

different forms of analysis. Such types include the K-Means Cluster, and Two-Step Cluster. In the case of this study, the hierarchical cluster method will be applied, whereby it clusters data into large sets and starts computing. This normally takes a longer time than the rest and produces results easier to interpret. Before the analysis, it begins by identifying the number of clusters in advance in order to set different models with a different assumed numbers. The figure 3.1 shows a screenshot of the SPSS cluster analysis application.

The clusters created in this analysis include the information relating to nature and pattern of the streets, density of the population, and the costs of parking. The information analysed therefore reveals the relationships, patterns and trends among the data that was found from the study. The point in terms of evaluation is to get an accurate assessment in order to better understand the research work and the overall existing situation. The following chapter illustrates the actual analysis and the findings.

3.7 Research Validity

The research validity determines the criteria for how effective the research design has been in terms of implementing measurement methods that accurately capture the data required to address the research questions. Based on both qualitative and quantitative results from this study, it is clear the study has been of great success depending on the way various research problems have been addressed. Even if the findings are not discussed, the study manages to tackle the major areas of study interest thus addressing most hypotheses. The study has been carried out and illustrated based on the alignment to the theoretical framework highlighted. Triangulation of the results has also been used to enhance the viability of the findings as well as validation of the methodology by an examination of the results from several perspectives of geographic information systems with urban planning, urban transportation specifically.

Chapter 4: System Design and Architecture

4.1 Introduction

This chapter reviews an analysis of the data collected using the different methods across the areas of study. This is geared towards providing the exact picture on the ground for a better approach to the whole problem subjected in this research.

Nairobi being the capital city of Kenya and a major commercial centre in the Eastern African region is undermined by the inefficient use of road space such as illegal parking on-street, the lack of a convenient public transport system as well as the cheap parking fees levied in the CBD. Based on the document reviews, car parking surveys, parking questionnaires and the interviews that were carried out, the following was derived;

Three car parking surveys namely; car parking count, car parking interview and car parking data were conducted. The Figure 4.1 below shows the survey locations and the summary of the survey results discussed afterwards. This figure covers the area of study, which is the central business district. It clearly shows the parking area for cars and the surrounding environment. Form the aerial photo below of an area around the central business district depicts the dense population of buildings, cars and definitely people. This covers the area where the study will be carried out.

The data collected in this case entailed demand, demand and supply and parking duration by type of car, this was done in twelve car parks including off-street parking, on-street parking and car parking in the buildings. The output of the survey was as follows:

In and out traffic volume by time and maximum occupancy of the car park

It was observed that double and triple parking on the street is a common thing due to the fact that the maximum occupancy is much higher than the number of slots at all of the surveyed parking and parking in the buildings. There is a high demand of most of the off-street parking and parking in the buildings is lower than the number of slots available. In this case, there is an inverse proportional relationship which creates a disconnect in parking. This is as shown in Figure 4.1

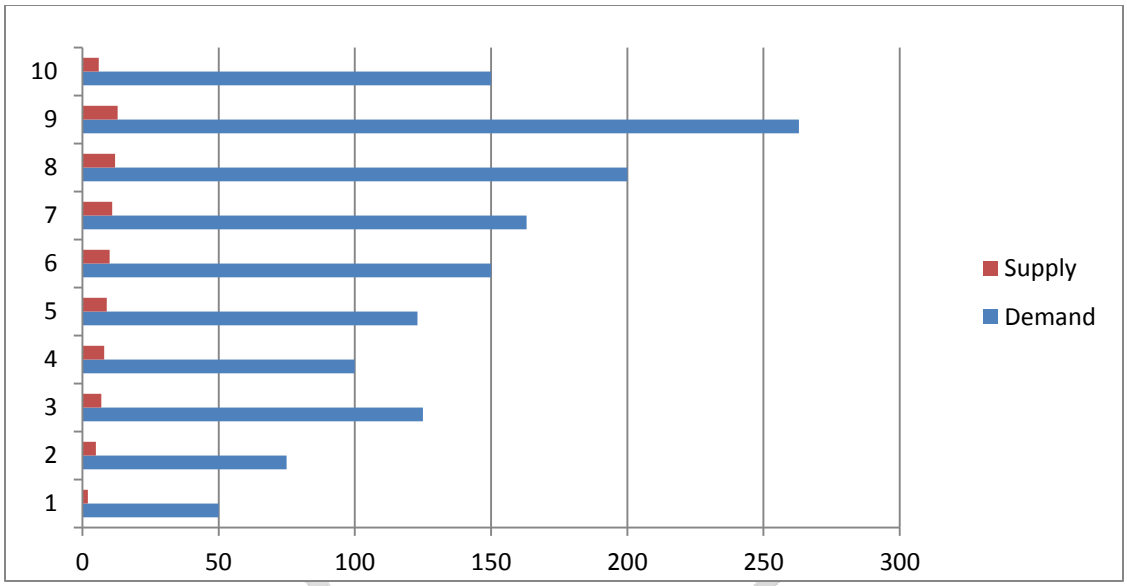

Figure 4.1: Study area and car parking demand and supply at Nairobi CBD

4.1.1 Average Parking Time

The number plate matching for cars was carried out which was to determine the average time of parking which was as follows:

Total cars recorded revealed to be taking approximately 3 and a half hours. Off-street parking and parking in the buildings takes more than 5 hours. For on-street parking, the average parking time is 1 hour and 45 minutes, this is quite a shorter time compared to the other types of parking. This is summarized in the table 4.1:

Table 4.1: Parking Place and Average Parking

Parking Place	Off-street	On-Street	Building
Average Parking Time (min)	250.6	150.00	300.1

4.1.2 Parking Interview Survey

Approximately 150 samples were collected from the twelve parking locations around Nairobi's CBD and it was found out that: On average, 50% of users prefer to drive to town and 50% do not drive into town. Approximately 80% of them are working, implying that on a weekly basis, the number goes higher. The number for those schooling and jobless is quite low at about 23%. The pie-chart in figure 4.2 gives a visual view of the above statistics.

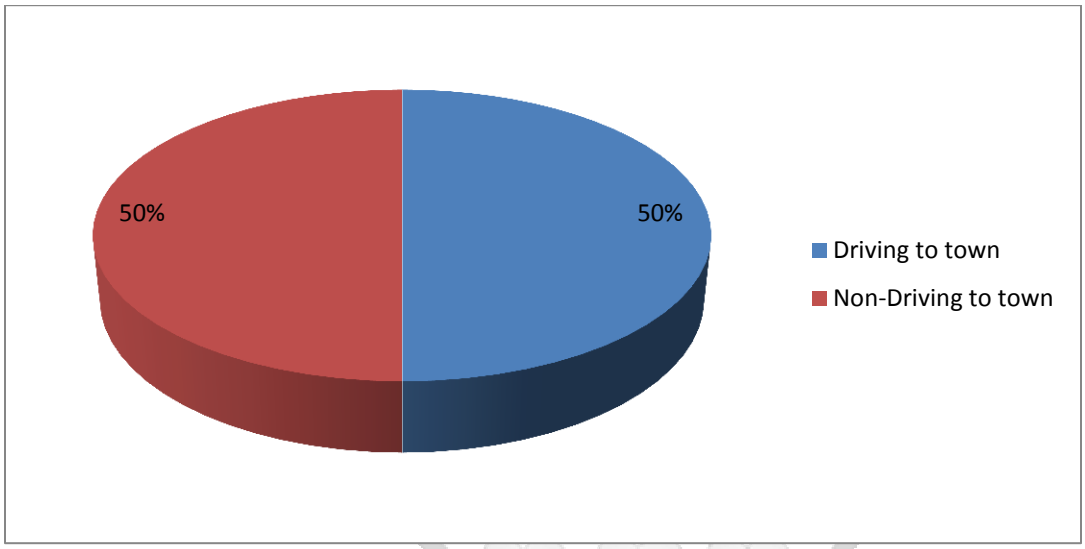

Figure 4.2: Parking Interview Survey

Figure 4.3 shows the different things different people come to the CDB to do, a bigger chunk is occupied by those working since majority of the institutions such as banks, schools, colleges and offices are based in town, a centralized area. These institutions form part of the global innovation index factor for any city.

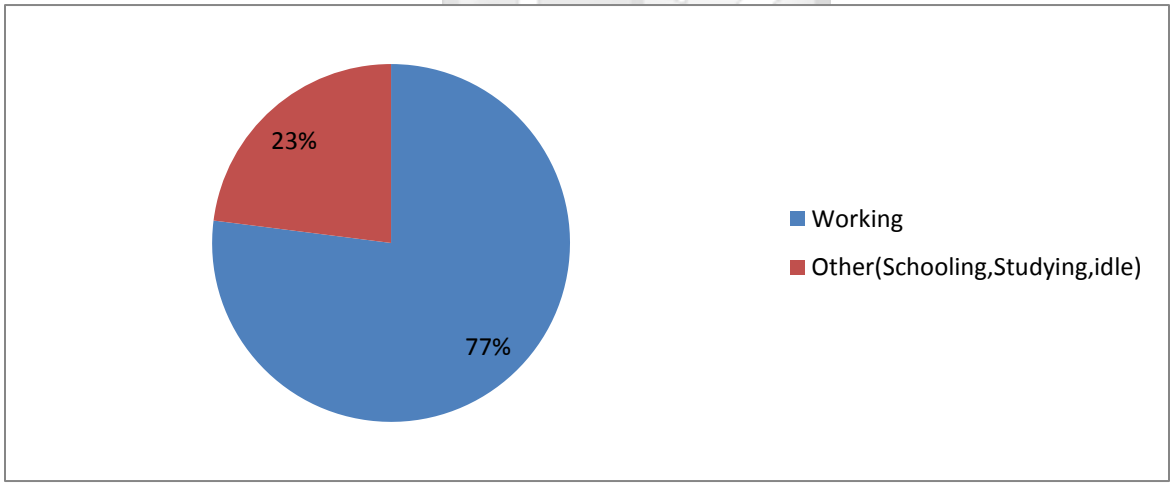

Figure 4.3: Parking Interview Survey

4.1.3 Selection of the parking Location

From the surveyed samples, there were two main reasons for parking at the selected locations which are proximity to their location (50% on average) and cheap (42%). This is as described in figure 4.4:

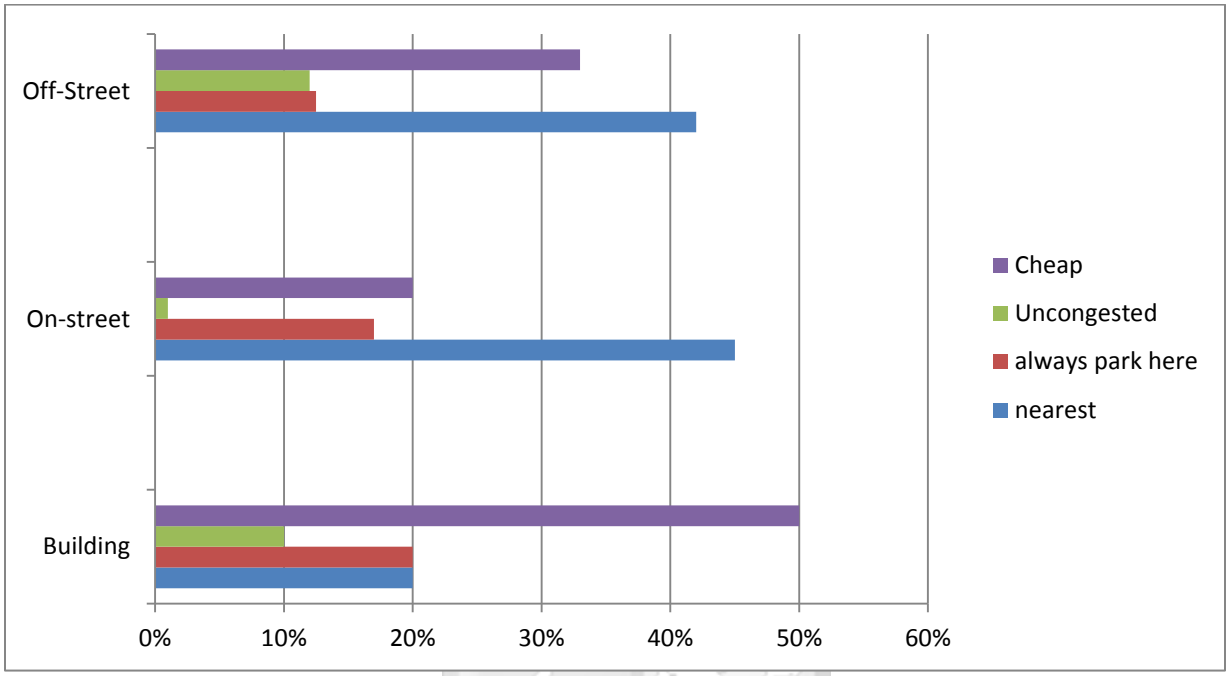

Figure 4.4: Reason for selection of the parking location

4.1.4 Countermeasures to Decrease Traffic Jam in Nairobi

The parking survey which was carried out via questionnaires on survey monkey tool revealed that most people think that the most effective way to reduce traffic jams is by improving public transport and ensuring proper utilization of the urban space. This will in the long run play a major role in reducing congestion on the roads which is the root cause of huge traffic on the roads. Figure 4.5 describes the whole picture of the results of the survey as outlined below:

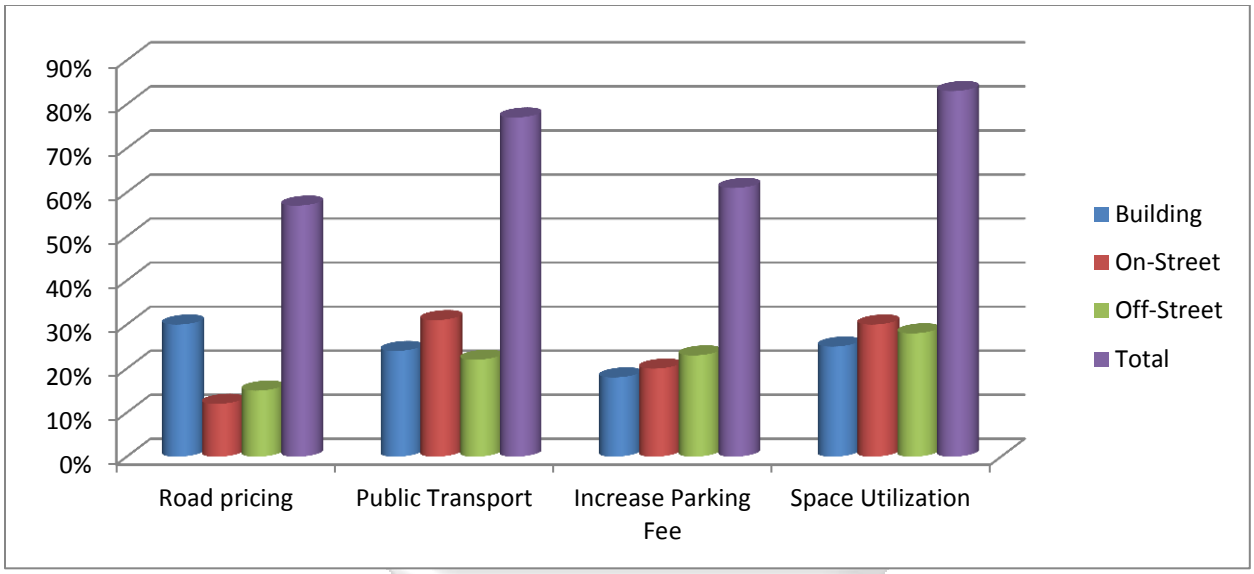

Figure 4.5: Counter measures to decrease traffic jam

4.1.5 Parking Data in the CBD

The survey required immense detailed data from the CBD which was very pivotal in giving the system development an overview of how it will meet the functional and non-functional requirements. The survey was conducted based on the three major types of parking as mentioned earlier which are; on-street, off-street and building. The study was divided by metrics such as the building used in parking as well as the road network along the particular areas of study. Below were the major findings also based on the Nairobi integrated masterplan statistics:

The total car parking space in the CBD is 14,864, of which 3,941 are on-street parking (26.5% of the total), 3,834 are off-street parking (25.8%) and 7,089 are building parking (47.7%) The zone which has the highest car parking space is zone 5 with 2,756 slots. The total area in the CBD is approximately 106 ha. based on the total number of cars. Parking slots and the area in CBD, the number of parking slots per 100m2 is 1.4. The highest and lowest parking density can be seen in zone 9 (3.1) and zone 7 (0.6) respectively. The average fee for off-street and building car parking is Kshs.4,500 per month.

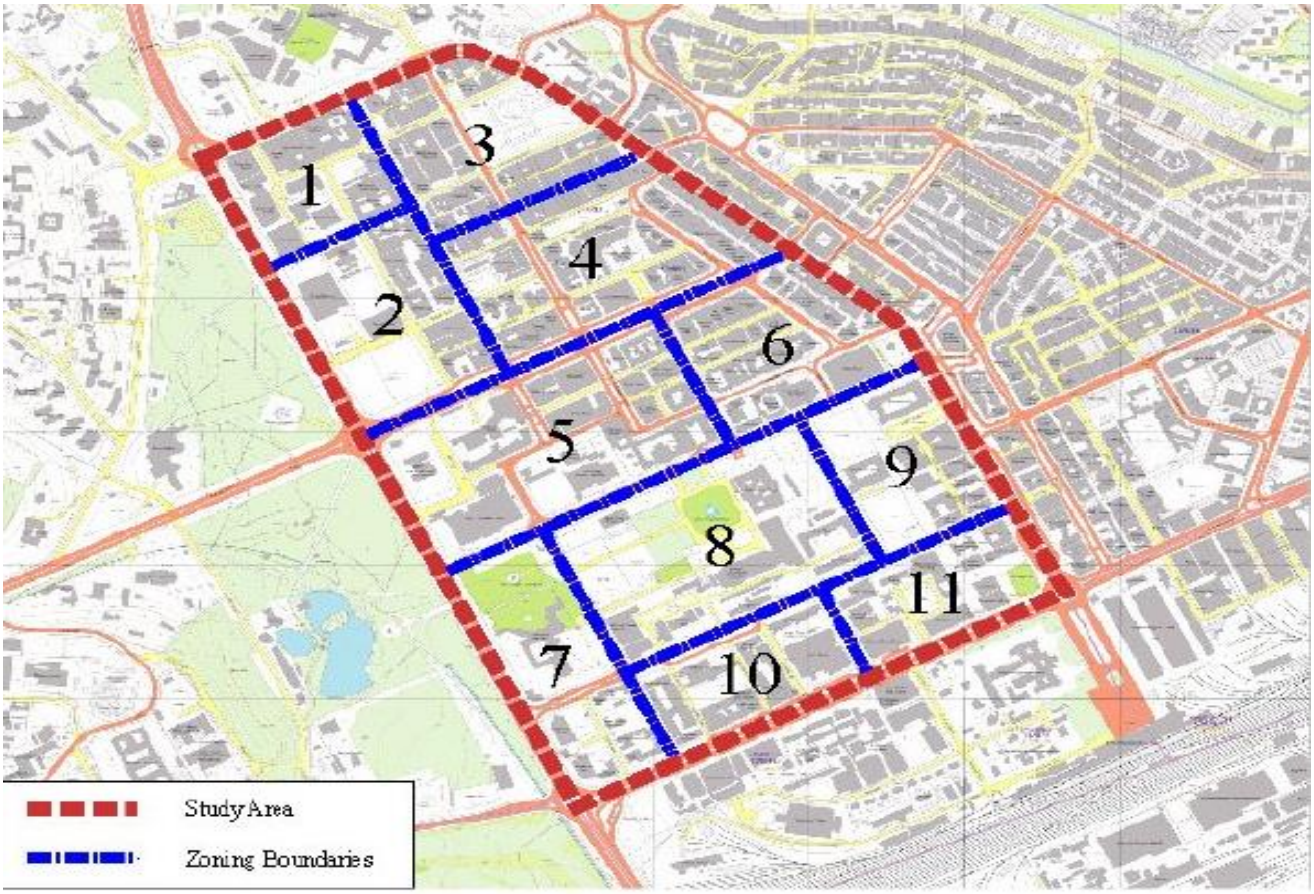

Figure 4.6: Showing the location of parking zones

4.1.6 Other Findings

Other data included in the various methods of data collection were discussed. These are; road conditions, levels on congestion and the general conditions of the CBD. This was aligned to the overall objective of strategizing a way by developing a GIS-based software prototype which will counter the overall problem. The details are outlined below:

On-street parking is rampantly used by short-time car parking users but then these users have to double park and triple Park because the slots are usually occupied by cars commuting.

Many users with personal cars prefer to park on the streets due to the cheap fees levied which is (Ksh70 /day) as compared with off-street and building car parking (Ksh 3,880 /month).

70% of the total parking facilities are usually privately owned implying that there is dire need to incorporate the public sector too to deal with problem. The economy is structured to be dualistic therefore countering the whole discrepancy of congestion and parking problems.

The road network connecting to Nairobi's CBD and eastern Nairobi is scoped down by a poor road connection. These roads are; Muranga road, River Road, and Ronald Ngala Street. On-street parking is major in Moi Avenue whereby illegal double parking between City Hall way and Kimathi street create a lot of havoc.

The corridor on Moi avenue has a very huge number of pedestrians compared to other places within the CBD. This is because it is a central point where Bus/Matatu terminals are located especially Tom Mboya Street. The pedestrian paths along Moi Avenue are well-developed but the intersection between them is generally poor due to the huge pedestrian flow.

Moi Avenue has the highest concentration of economic urban activities which generate high traffic in terms of demand while commuting to business, school, shopping and hospital among others. Most of bus / matatu terminals are concentrated along the corridor of Moi Avenue. This adds on to the fact that there are many economic activities concentrated along the same corridor. This congestion in Moi Avenue, creates a huge constraint to economic development because there are a myriad of urban activities taking place as well as the huge pedestrian flow, this in turn paves way for a stagnated economy.

4.2 System Design

This chapter has Unified Modelling Language (UML) diagrams for the logical design to represent the system. These diagrams have been described to provide a standard technique to write the system's blueprints and they cover conceptual things, classes which will be written in PHP, MY SQL database schemas, and other reusable components for deployment of the final product. The diagrams are; use case, sequence, class, entity relationship and a flow chart. Each of them is followed by a detailed explanation of how processes flow in the actual system. The first figure 4.7 is a data flow diagram generally showing the flow of processes and activities throughout the system. The arrows pointing to each object show the interactions and relationships between the different entities and this defines the system structure.

4.2.1 Data Flow Diagram

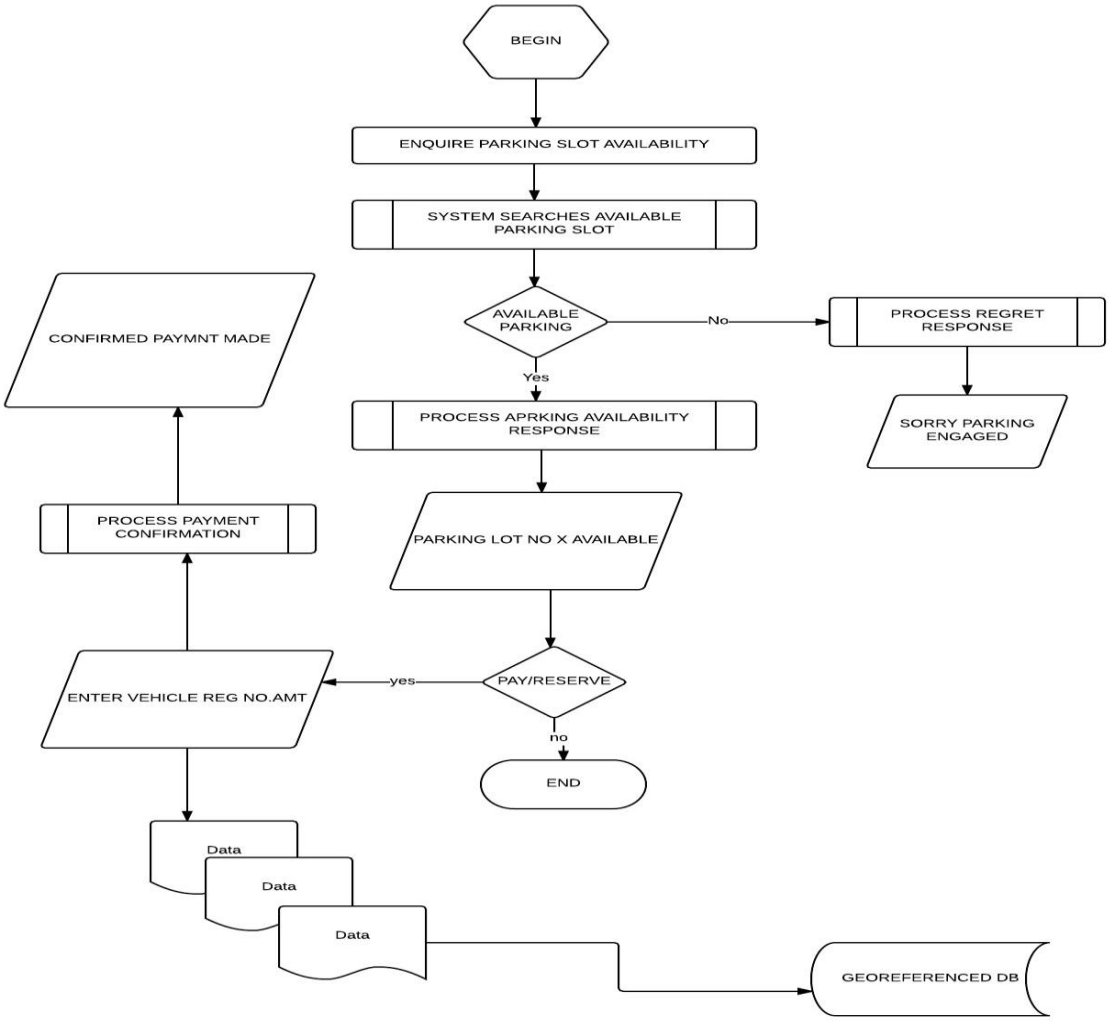

Figure 4.7: Data Flow Diagram

4.2.2 Entity Relationship Diagram

This diagram illustrates the relationship between the people, objects, places, concepts and events within the system. As described below, the users and places show the interaction of business and operational processes in the system which will be used as the foundation for the relational database. This is key as part of the system development process. Each object is defined by the attribute and data type for instance the user has a name, an ID, a telephone number and an address among others, the data types are shown below for each of the attributes. The data in the system is represented by this relational structure. The diagram also shows the cardinality which defines the different relationships in terms of numbers.

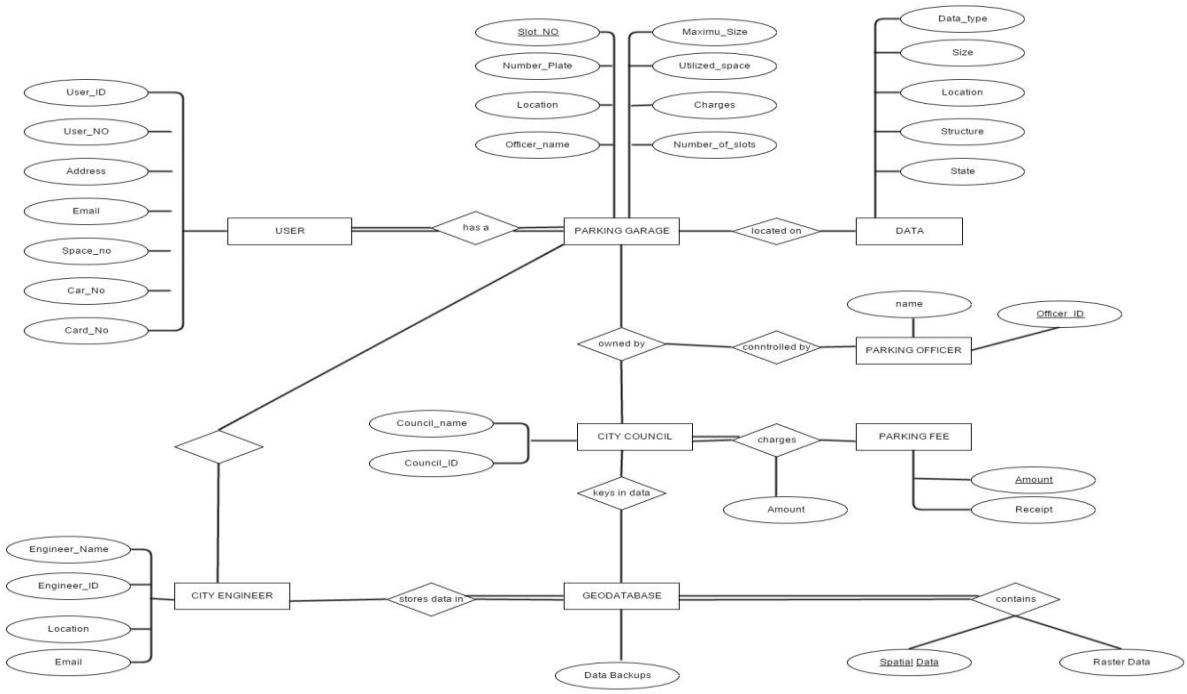

Figure 4.8: Entity Relationship Diagram

4.2.3 Use Case Diagram

The use case diagram in figure describes the various actors and processes that are involved in the system. The primary actors are; the parking user, parking officer, the county council and the GIS engineer. The secondary actors are; the traffic police, the city engineer and the georeferenced database. From the arrows, every actor is associated with at least on use case. Every actor can be associated with multiple use cases and several actors can be associated with a

single use case. These generally describe the association in the system. There are scenarios in the system whereby an actor for example the county council can inherit the role of another actor such as the parking officer. This shows a generalization relationship which makes the system to be dynamic.

One use case can be described as per below outline in which all the other use cases will follow the same procedure. For example, the use case of a parking user will be as follows:

i. User arrives at the parking area
ii. User enquires about a parking space
iii. User is allocated a parking
iv. System records space occupied and captures the details
v. System prints receipt
vi. User pays
vii. User leaves with a receipt and presents it to officer for verification

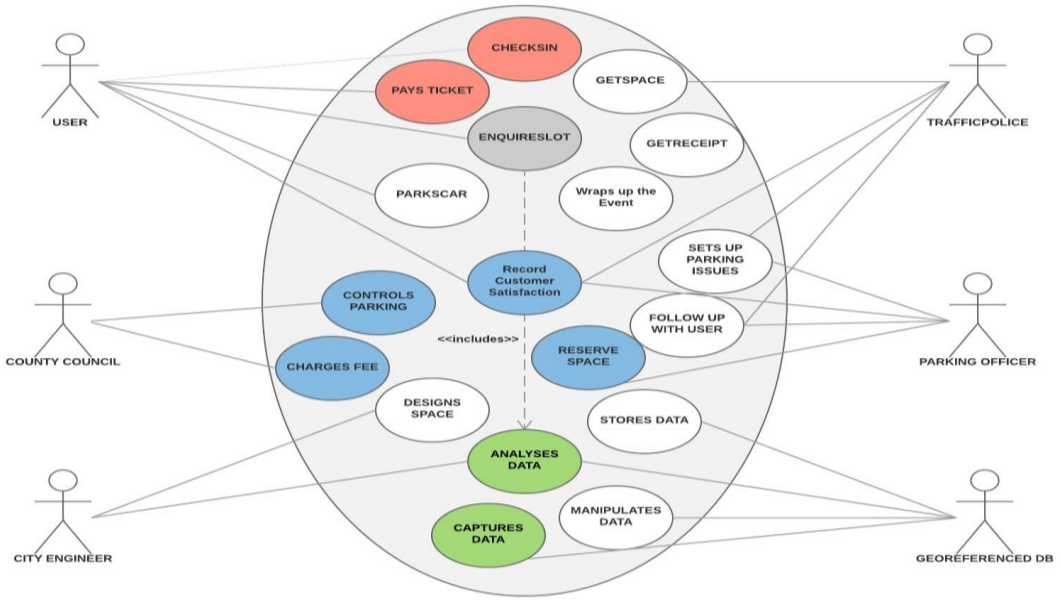

Figure 4.9: Use Case Diagram

4.2.4 Use-case Narrative

Table 4.2: Use Case Alternative Scenario

Alternative Scenario
At any time where there is no space available
Parking officer notifies parking user
When a motorist pays by credit and the system does not acknowledge authorization
Parking officer notifies the motorist and asks for payment by cash
Passenger pays by cash and system handles payment
System presents a receipt
Passenger leaves with a receipt4
This same case will apply to all the other use cases.

4.2.5 Sequence Diagram

This diagram shows the interaction of how processes will operate with one another in the system and in what order. It shows the construct of a message sequence chart. There are parallel vertical lines that interact simultaneously and horizontal arrows which describe the messages which are exchanged between the processes systematically. This interaction allows specification of simple runtime parking scenarios in a graphical manner and provides a comprehensive understanding of how the system will operate in all stages.

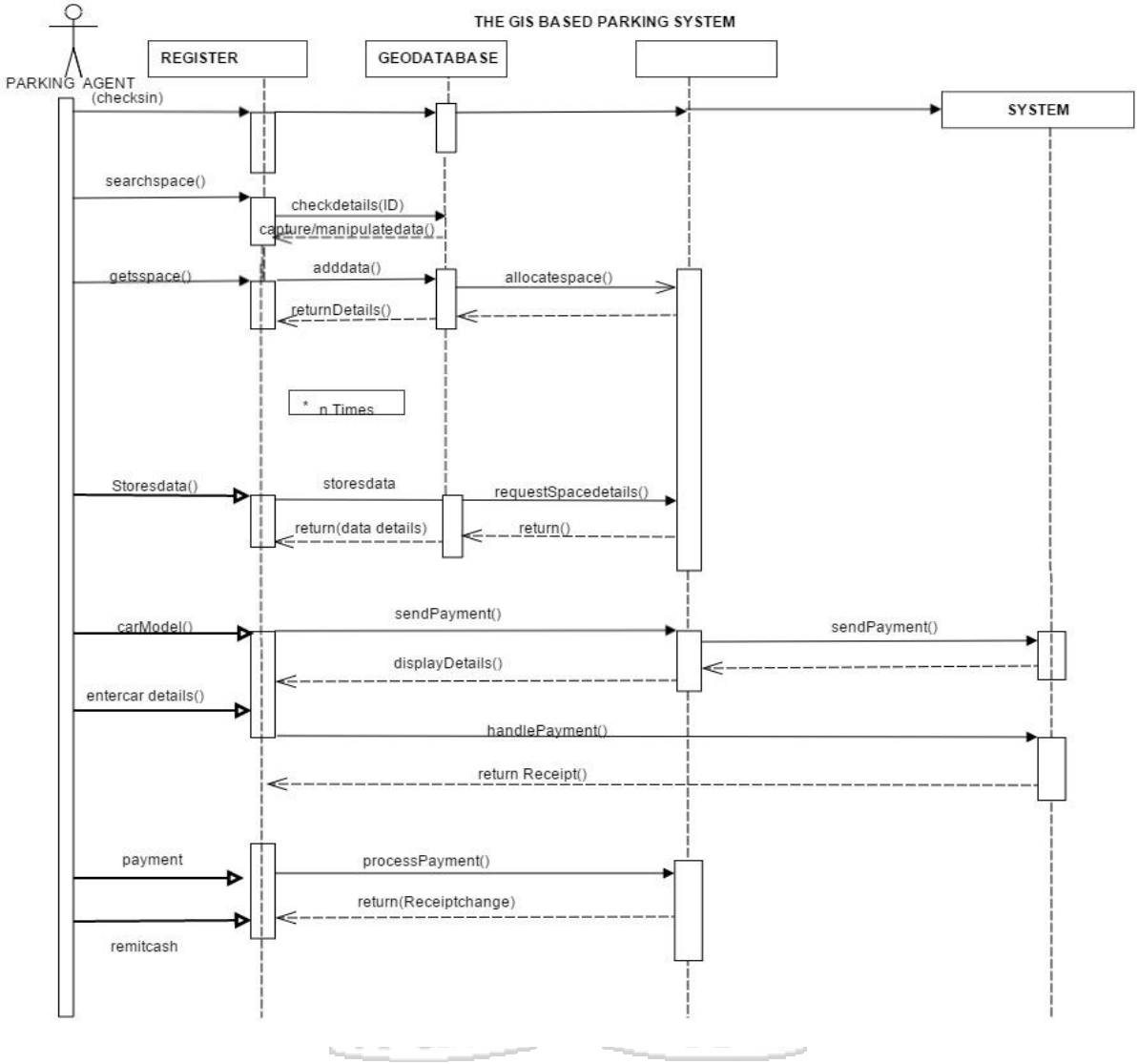

Figure 4.9.1: Sequence Diagram

4.2.6 Class Diagram

This diagram is a visual representation of the static structure and composition of the parking management prototype. It shows how the objects in the system interact with each other for instance; The parking officer and the county council interact at some point as described by the arrows. The diagram is the primary reference for translating the system into a programming code. The first square shows a class called 'parking user' which is the top partition and contains the name of the class. The middle part contains the class's attribute which is the name, id, telephone number, and address. The attributes can be as much but these are limited due to the scope of the system. The bottom partition describes the possible associations that are associated

with the class. These in the first square are; check parking, book parking and make payment. The same applies to allt he other classes as described. The classes are all interrelated in specific ways this is decsribed by the arrows. The arrows shows various types of relations which are; associations either direct or reflexive, inheritance and generalization, aggregation and multiplicity.

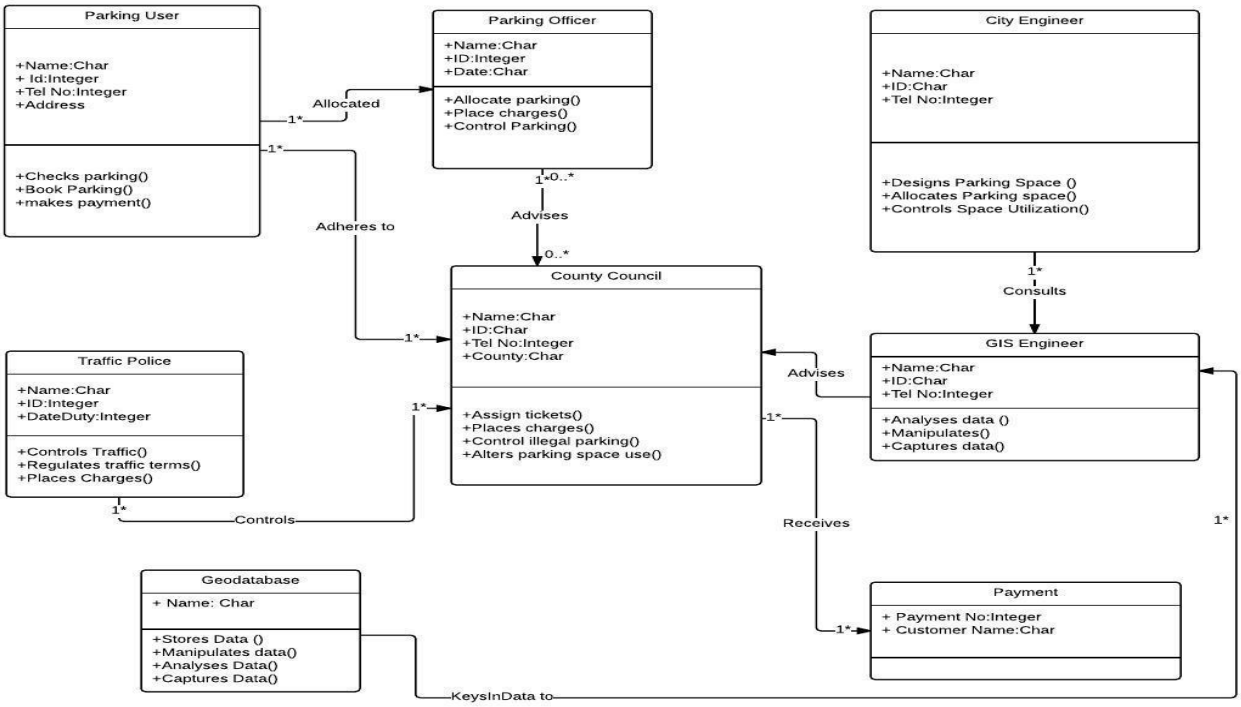

Figure 4.9.2: Class Diagram

4.3 System Architecture

The overall architecture is composed of three major layer which are; Presentation layer, business logic and the data access layer. All these components will interact and will be interdependent with each other during system implementation. Ideally, the system is of a three-tire architectural model. This infrastructure will incorporate different system components to which an integration of the applications will facilitate the client to get some output from the system. It is a multithreaded environment which factors in the three layers which eventually will form a distributed relational database. The whole of this interaction forms the three layers.

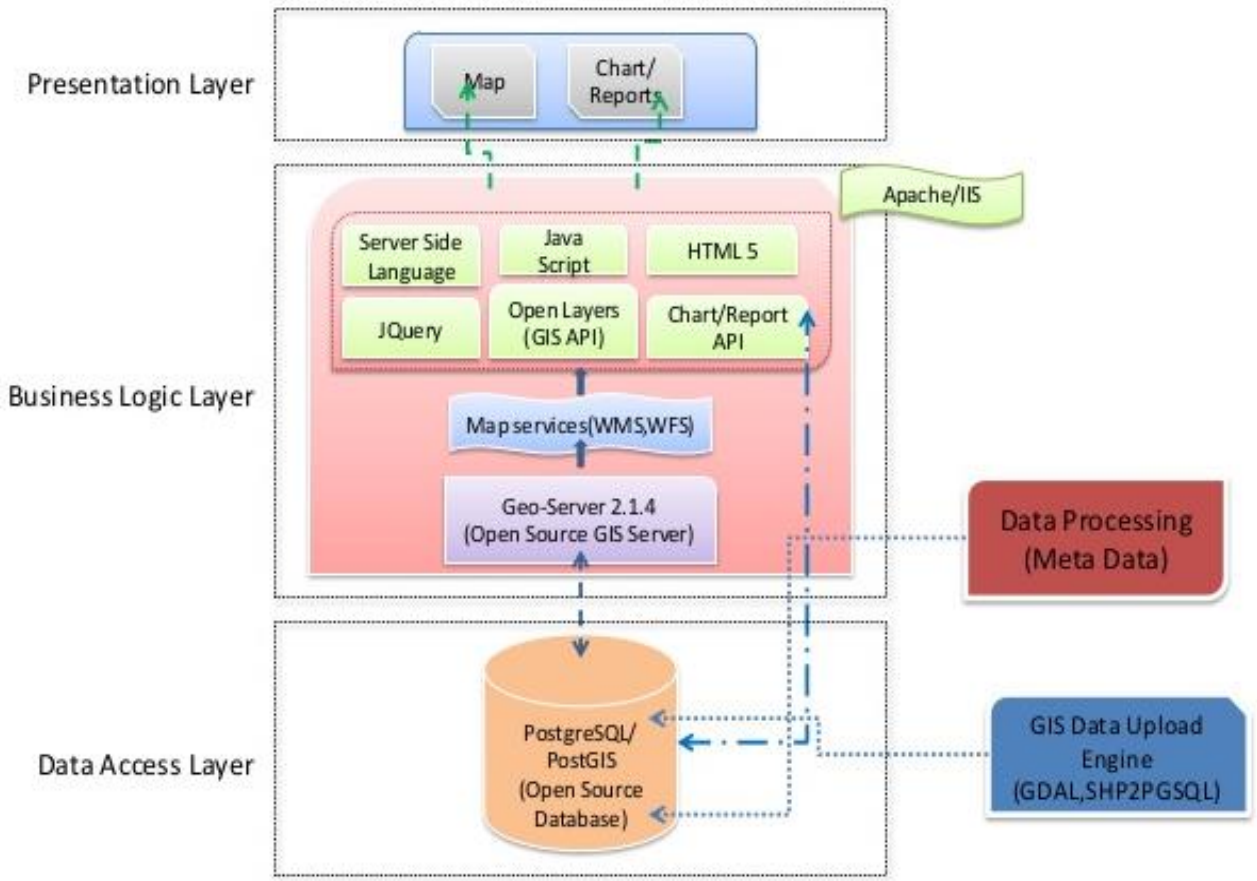

Figure 4.9.3: System Architecture

4.4 Functional Requirements

The system is able to: Allow input of both data raster and spatial data for better analysis of these data types into parking space creation. Provide a user-interface for inputting the required data. This is to enable a user-friendly interaction with the different players within the system. Show all the data stored in the database at any given time including the purged data. This will ensure a key reference point of data which may be used for different things like key decision making to mention but a few. Hence enabling policy makers to make informed decisions pertaining to parking management. Provide appropriate views for the users to have a clear picture of current trends in parking space management.

4.4.1 Non-Functional Requirements

The system is designed to be flexibility such that it should be very responsive and adaptive to change in terms of user requirements and environment. Scalability; the system can allow for future enlargements so as to add more functionality. Usability; the platform is easy to understand and use by the users. Reliability; the system can perform its required functions under stated conditions for a specified period of time. Response time; the system can respond to users in real time for quick and informed decision-making. There should be exception handling such that in cases of an outage or unavailability of the network, a pop-up is shown to display the error and recovery should be less than a minute. This will be very ideal for the web-interface ideally because the user requires real-time data.

Chapter 5: Implementation and Testing

5.1 Introduction

This chapter describes the implementation and results obtained by using the features described in the previous chapter. The GIS-based parking management system will entail two major datasets. These will be key in every phase of development. .The first set of data will contain parking space which will ultimately represent the spatial, non-spatial and physical data. The second set of data pertains to the vehicles using the parking space, services and revenue data which will be application data and attribute data.

5.2 Programming/Coding (language to be used)

The project has been developed using the following tools: HTML which will be used to outline and project the interface. Javascript and associated frameworks: The frameworks include jquery to enable client interaction on the front end. Google Maps which has been used in mapping the areas. This will provide a drawing of layers and overlays as well. PHP Language: This has been used to save and retrieve data dynamically from the server. MySQL which has been used to save data as sent by user. Hosting platform: This is essential to ensure easy and convenient accessibility of the application. Android Application: This will be essential for accessing user geo-location to map user distance and slot. Arc GIS desktop & Mappetizer CAD parking design and a Fast Report Writer to generate the reports from the database.

The system structural elements will be parking slots and the vehicles occupying that parking. The unique identifier will be the owner and car number. On the database implementation, the car number and owner have been given a unique idenfier whereas the rest of the data have a relational flow by being linked to each other. The two sets of database elements have been linked where required as described in the entity relationship diagram, in each attribute, there is a unique key or identifier. In this context still, the primary data has been clustered in different techniques and the underlying logic is based on the data flow diagram as described in figure 4.7. On the diagram, the major types of data are classified as physical-spatial data and base data.

5.3 The Interface

As highlighted earlier, the major data types spatial and physical data whereby the term 'spatial' implies non-physical definition of the site. This is comprised of spatial structuring elements and layout boundaries which were/are already designed for the particular site in question. The key sources of data are a geo-referenced aerial photo of Nairobi's CBD area and the structured master plan for urban transportation. The CBD structure will involve recursive partitioning, in order to calibrate ratios (places per km, and places per sq.) this will depend on street width, flow direction and urban environment. Ultimately, this will help to counter the issue of misappropriate space consumption by road infrastructure and parking. This is geared towards ensuring that the system meets its functional requirements as well as non-functional ones.

This data from this aerial photograph in figure 5.1 will be used to create an overlay of the design framework. On the base data. This section deals with the integration of the different data sets. The resulting geodatabase will be used to create a web mapping prototype that will be used to access the map data. The success of this phase heavily relies on the creation of an interactive application that will be used to search, find and identify map features hence enhancing parking management efficiency in terms of service allocation and proper space utilization.

The image properties will be reviewed and analysed in table 5.1:

Table 5.1 Image properties that will be reviewed and analysed

NAIROBI CBD AERIAL PHOTO IMAGE PROPERTIES	
Raster Information	
Number of Bands3	
Extent	
Top	
Left	
Right	
Bottom	
Spatial Reference	
Linear Unit Metres	
Width	

The AutoCAD dataset will be transformed by making use of the georeferencing tools which is ArcGIS of; rotate, shift and scale to get a sketch such as: Image

All the geospatial information is consolidated and later subdivided into two main categories which are as outlined below:

i. Spatial and physical data
ii. Base data

Processing of Base Data

High accuracy will be required to determine the positions of the parking layout thus, two categories of images are required; aerial photographs and satellite images.

The first steps of development are as described in figure 5.1:

5.3.1 First Phase of Development

Parking slots are created through the web platform by creation of layers over google map tool**.** On the monitor slots module: user should be able to view slots available and those full. For every slot created on the web platform, it should reflect on the android app data capture: web platform and android data analysis: Data manipulation: the application sends raw data in terms of user information, user location, user reservation and user parking history to the web platform**,** once fed with the info, system uses same data to fill up slots to notify other users of whether the slots are still available or not. The data is also used to notify admin on whether the slots still has space or not. This is also essential in indicating the users who are occupying a given parking slot. Data Output: Parking slot layers for the map, information to the users whether a slot is available or not Informs users of slot status: available or not**.** Process design: Google maps are used to show parking slots on the web interface.

The Android application map to inform users of available slots. Geospatial: identifying the parking slot through the use of google map or via physical identification of slots. Vectorisation: Mapping the identified slots as vector layers on top of the map interface. Superimposition: overlaying the vectors on the google map. Vector polygons with ref numbers: The layers are referenced and sent to the database for storage and later retrieval. The Web based parking: Online platform to indicate the parking slots and show parking status.

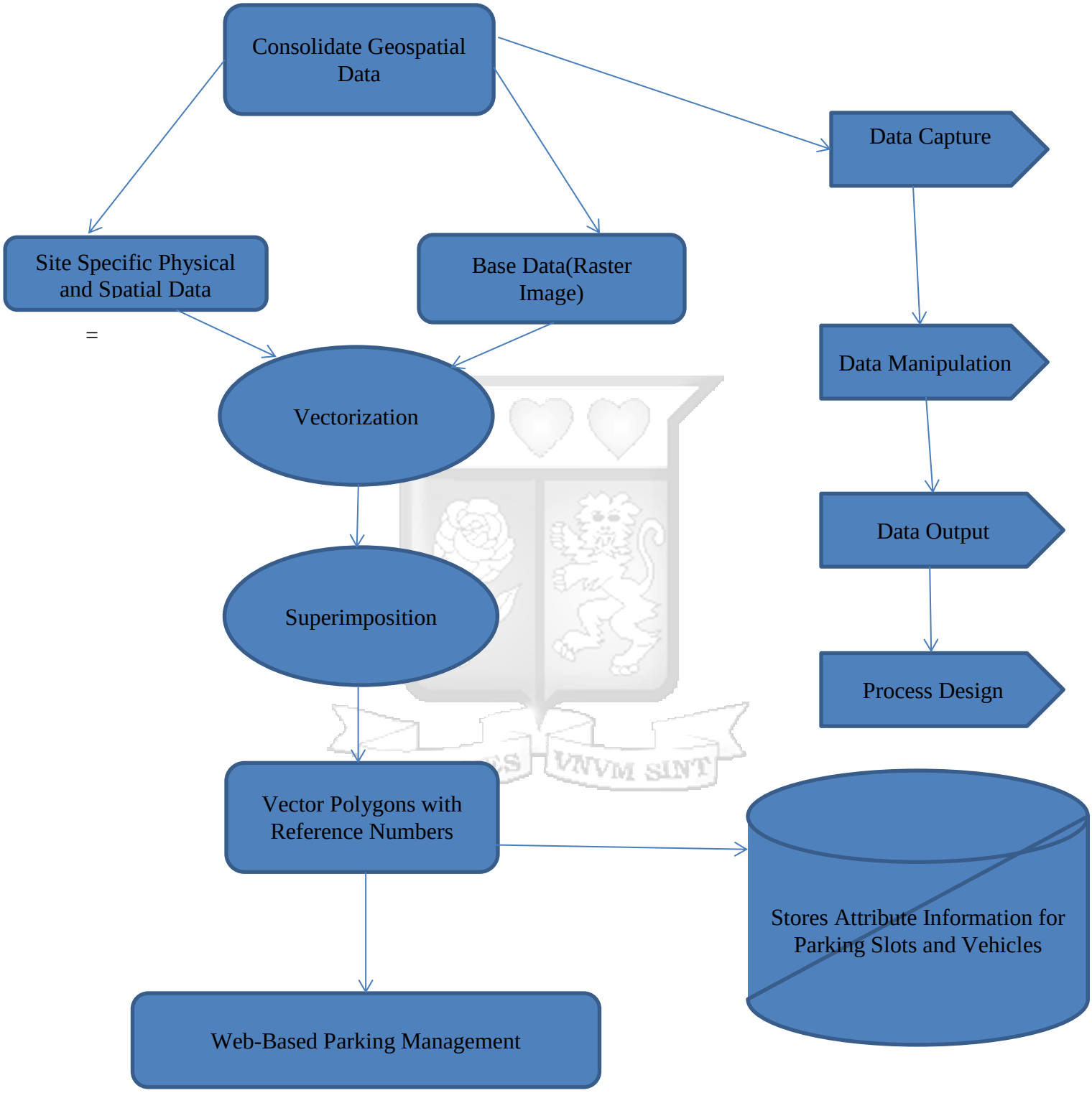

Figure 5.1: First Phase of Development

The image above (figure 5.2) showing the first phase of development creates a proper basis for the parking typology database in which the georeferenced images are used to generate some accuracy of the vector map of the area. These data will be used for the overall design of services and infrastructure and the slots will be numbered in creating attributes.

5.3.2 Vectorization and Editing

The CAD parking representation will be imported into ArcGIS, and then the parking layout will be edited for making sure that each parking slot is an entity to which an attribute can be assigned. This is described in figure 5.2:

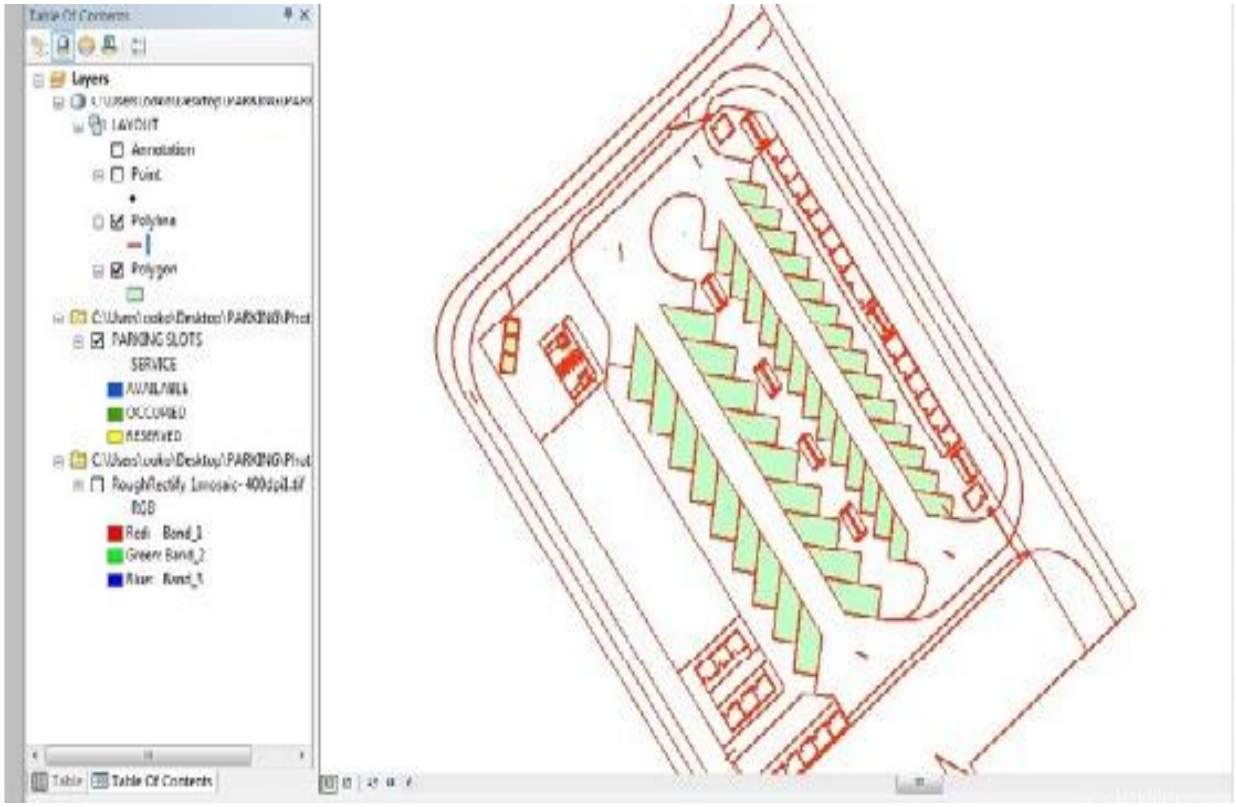

Figure 5.2: Second Phase of Development

5.3.3 Physical and Spatial Data

These two types of data will be used for creating an overlay design framework for the base data. This is the component that will deal with the integration of the various sets of data. The output of all this phase will be a geo-database which will be used in creating a web mapping

application that will be sued to access the map data. At this juncture, an interactive application which will be sued to search, find and identify features of the map should be seen.

5.3.4 Georeferencing

The data will be manipulated to ensure the parking layout is georeferenced and accurately superimposed on the raster image backdrop; this will be the second phase of data manipulation. Scales will be altered by leveraging the scaling resource on the georeferencing toolbar in the google maps as described in the figure 5.3.

Figure 5.3: Third Phase of Development

The attribute data will be added to the vector format data. This database will contain various fields which will be; vehicle plate number, service, amount and identification number. The parking services will be uniquely represented in a dynamic colour scheme where orange represents available slots, black for occupied slots and green for reserved spaces. Every time the database is updated, the vector layer will changed for visualization a key component of the GIS component and querying of the application interface.

5.4 Web mapping application for access and querying of the map data mappetizer for ArcGIS

The main purpose of this tool is to convert maps within ArcMap into the SVG format. It enables the XML based files to be viewable on a local machine and thereon get published on the web. This tool supports both vector based object data and image based data. The GIS engineer will ensure that the parking lot layout plan will be made ready for export into scalable vector graphics by ensuring that all desirable layers visible. The mappetizer add-on will be used to configure application settings for object information and display.

Figure 5.4: The Mappetizer Tool

The overall custom information will be added to the application and search tools which can search and identify specified fields and values then highlight them for visualization

depending on the chosen color. The final output will be a web interface through which users may interact with the GIS system and they range from a manager who is office-based and needs to monitor parking space status. This is a prototype that can be conveniently implemented at the scale of Nairobi Central Business District.

5.5 Testing Plan for the System

The system was tested by unit testing, integration testing and system testing. Each module will be tested separately, the different modules will then be tested together and after completion, the whole system will be tested as a whole. This has been geared towards convincing the researcher and users that the software is good enough for operational use .it's also intended to build confidence in the software. Testing the website to see if it will work across the different browsers and the various devices only needs one to run it on the various websites, but during the development phase one can use different emulators from different browsers (Marini, 2011)

Testing for the different software will also be done in order to give a clearer view of the system scalability as well as the fault tolerance. This two metrics will be paramount in determining future modifications of the system. Figure 5.6 shows a screenshot of what is expected for backend users. This shows the information window which displays details of a particular area. The same details are the ones highlighted on table 5.1. Ideally, an administrator should interact proactively with this window to fit the requirements.

5.5.1 Test Plan

The system was tested using the blackbox method. This is whereby the whole idea is to examine the functionality of the application. The internal structures and workings do not play a major role in this testing. As mentioned above, this method of test was applied to virtually every level in the testing which is; unit, system and acceptance testing. Unit testing involved all the modules being tested separately in line with the expected requirements. System testing was where the whole application was tested centrally to verify that it is working as expected when all components are inter-linked together.

5.6 Actual System tests

The actual tests will involve the user creating maps on the web interface whereby the user should be able to view the available or booked spaces from their phones.

Table 5.2: Actual System tests

Test Case Summary	To test if all components of the application are working as expected
Related Requirement	Accessing parking space via the mobile-web interface as well as google maps
Prerequisites	Internet and Android phone availability
Test Procedure	Step-by-step procedure to execute the test.
Test Data and test tools	Internet access Google maps/google earth Android phone Polygons Mapping Points
Test Environment	Android phone, web browser, MY SQL database, desktop machine or laptop
Expected Result	A user should be able to book or reserve parking using their android phones. The administrator (county government/GIS engineer) should be able to create the locations via google maps They should be able to view via fast reports all the points created as well as the spaces utilized All these information should be stored on the database
Actual Result	An end to end working GIS mobile –web parking application
Status	Pass- Means the tests are successful Fail-Means the tests have failed Not Executed– Means the testing is not performed Blocked-Means testing is blocked.

5.7 Test Results

This section captures the expected outcome from the different scenarios in which the system will interface with the user as well as other parameters. If the outcome is opposite of what is expected, then the requirements have to be reviewed and code has to be debugged. This is to ensure that good quality assessment is done end to end for a fully-functioning system.

5.8.1 Test Scenario One

The first scenario is the administrator mapping the parking spaces available from google maps. This is dependent on the respective environment or vicinity. Figure 5.7 shows the expected outcome.

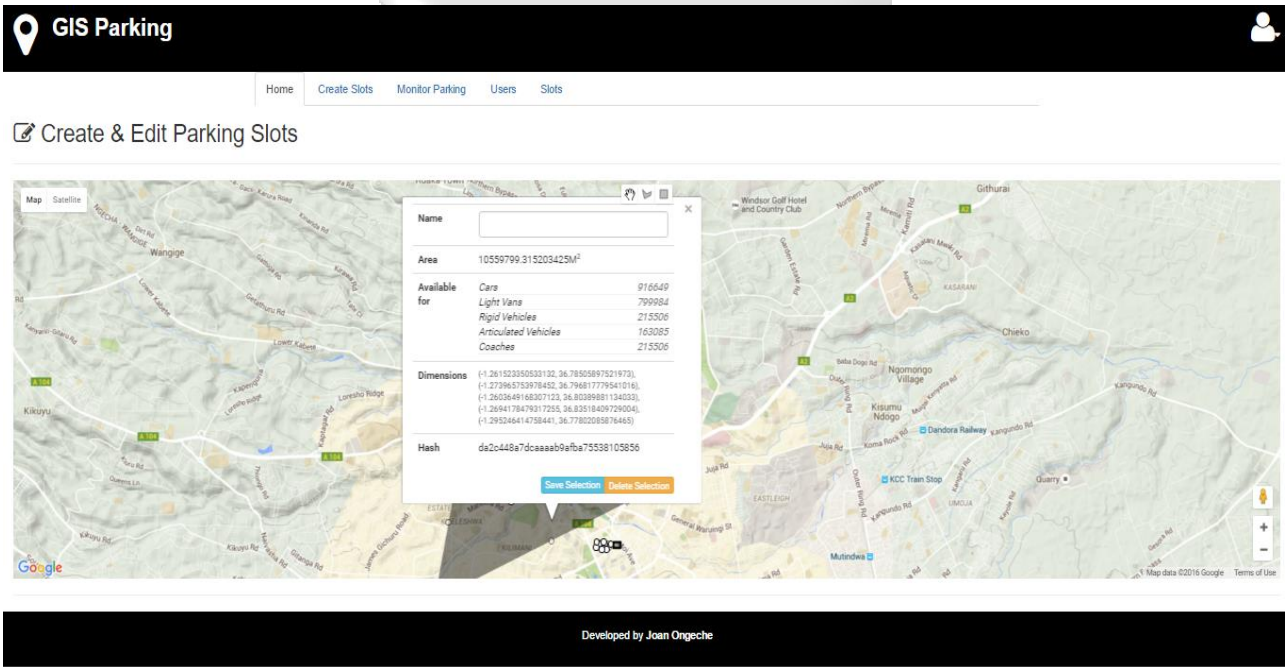

Figure 5.5: Creation of Parking Slots

5.8.2 Test Scenario Two

The web interface is linked with the android application through which the users will access directly from their phones. Once they download the application, they should be able to see the system as indicated in figure

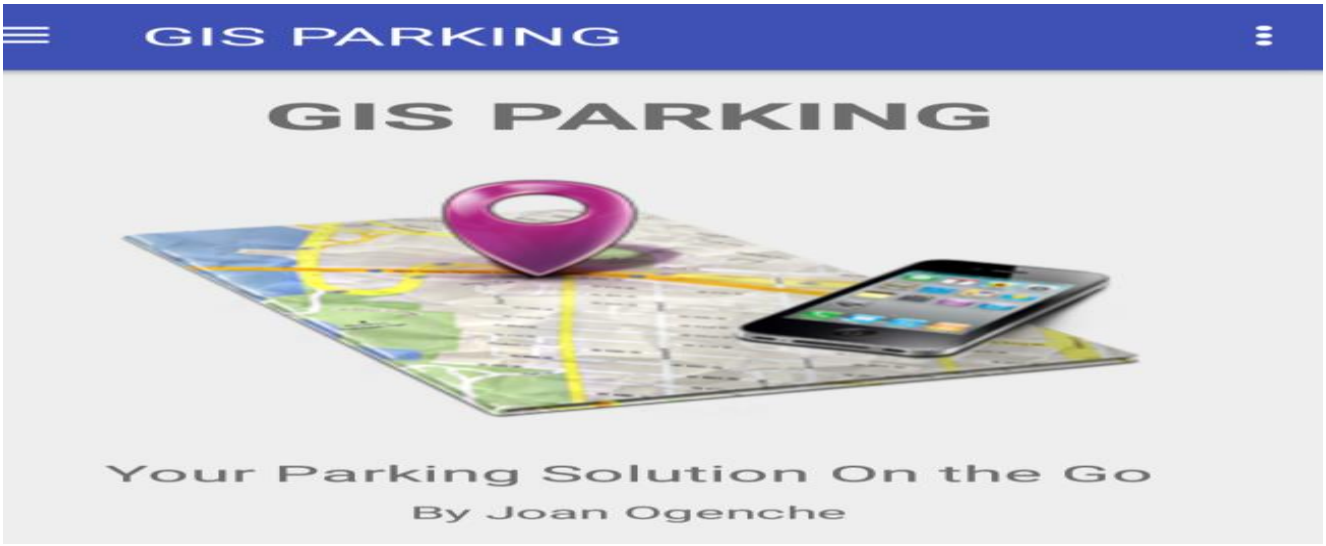

Figure 5.6: Test Scenario Two

5.8.3 Test Scenario Three

As the user navigates through the application, the tab on the left side displays some parameters which user should key in prior to which they will not be able to proceed to book, reserve, or view parking information. It is a prerequisite for the details to be filled.

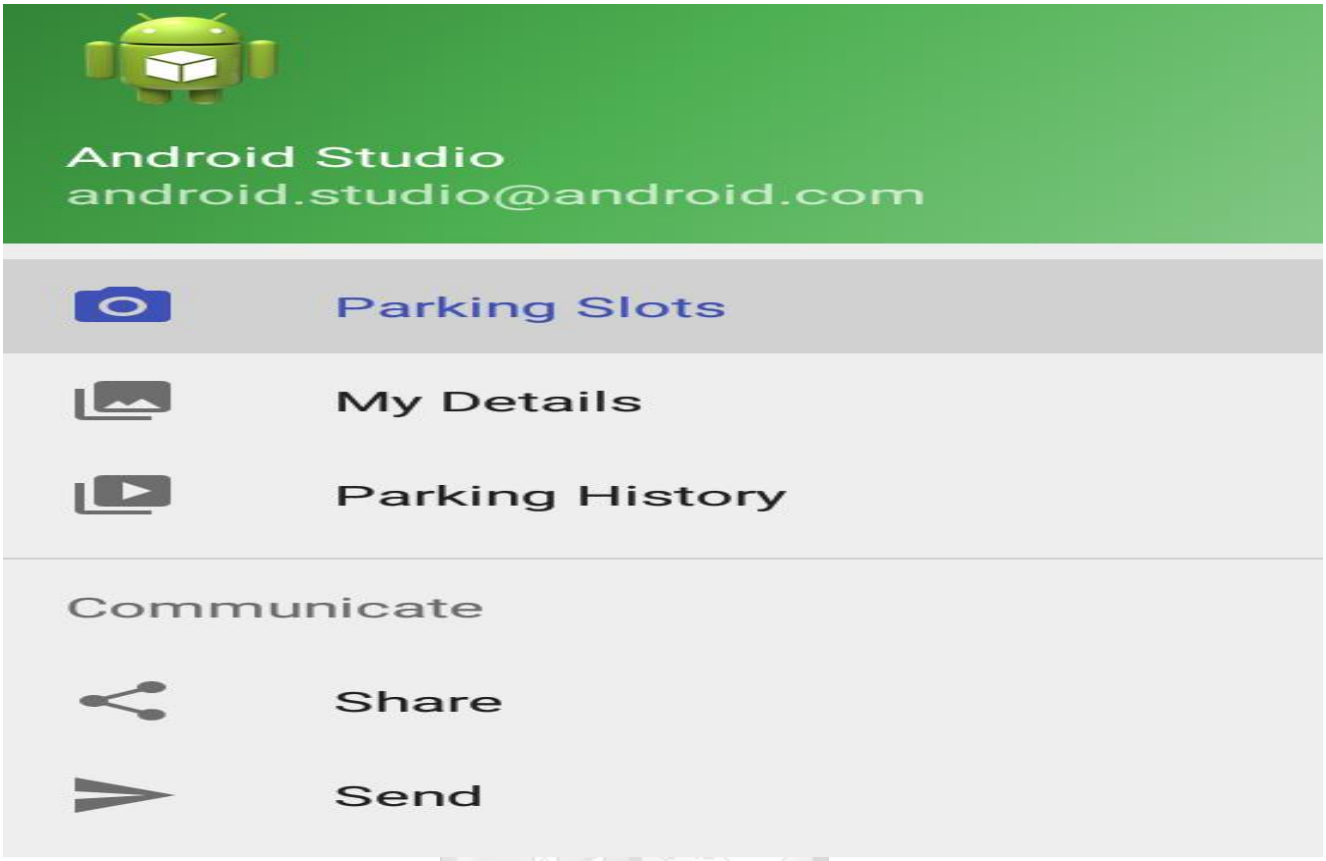

Figure 5.7: Test Scenario Three

5.8.4 Test Scenario Four

Once a parking is created by the administrator from the google maps environment, once a user opens the application from their smart phone, all the specified locations and the respective spaces should be visible in real time. This is what informs the user of a specific locality where there is available parking space, whether the space is reserved and whether they can cancel an already reserved space. The question of collision of users will be solved by having alerts or signals in use since same message can be sent to nearby users which may create a deadlock.

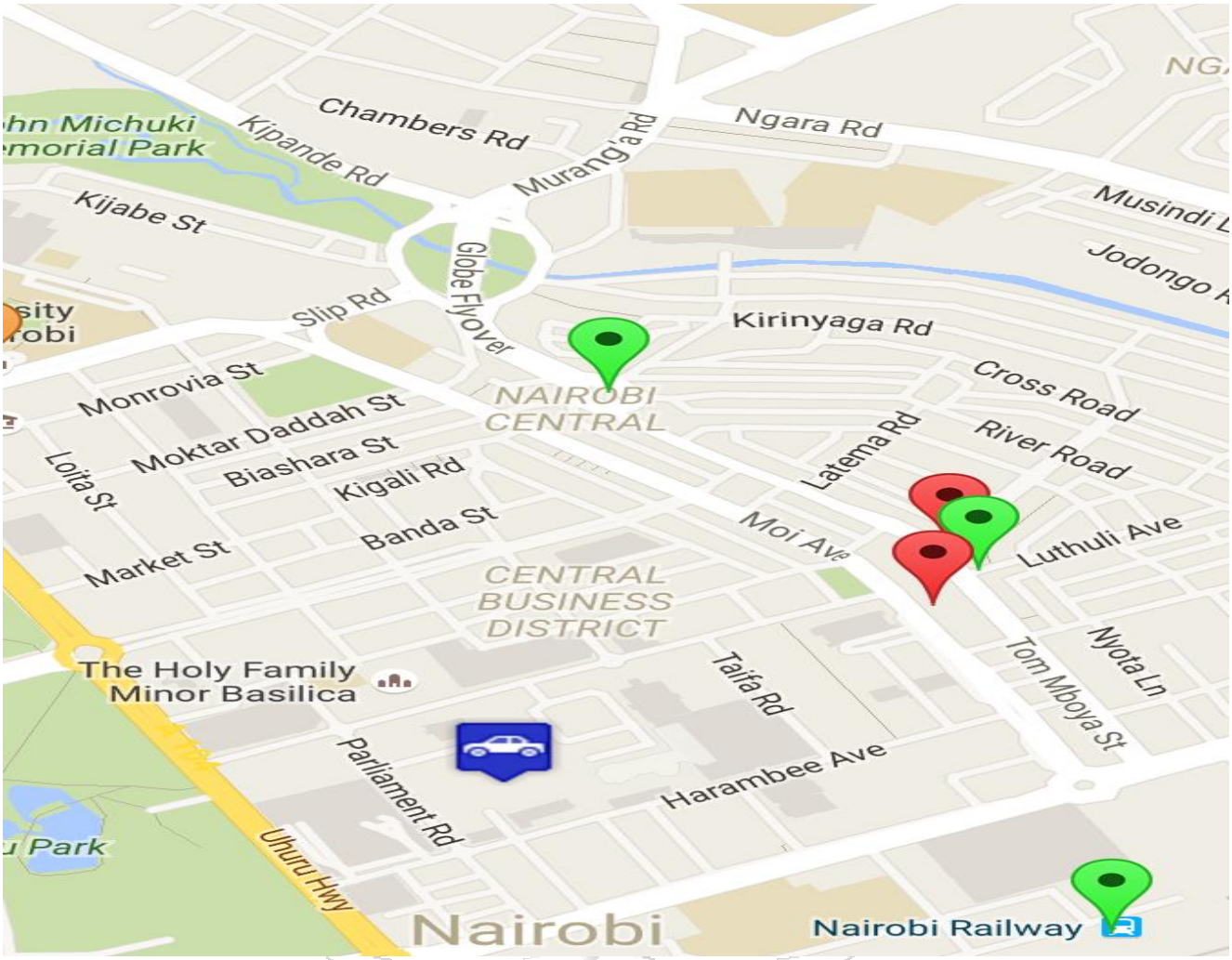

Figure 5.8: Test Scenario Four

The green labels indicate that there is free space available for parking, the amber labels indicate the space is reserved and red shows that the space is already parked on.

Chapter 6: Discussions

6.1 Introduction

This chapter involves the interpretation and explanations of the results from the entire research. It answers the research questions comprehensively as well as digging deeper into metrics like critique of the key concept and justification of the ideas mentioned. The discussion follows from the results and also relates back to the literature review. The overall purpose of this section is to state the interpretations and opinions, explain the implications of the findings and suggestions for future research. Below are the parameters that will be compared to existing solutions in discussing the application.

6.1.1 Interface

The system has a user friendly interface which creates an interaction between the stakeholders which is easy to understand. One of them is the web interface which operates on a near real-time mode since it will automatically update itself and reflect the situation on the park lots. The interface is connected the database server hence every request booking and space utilization will be reflected on the web map. The web page allows one to have a real-time visual look of the parking within the area. On the other hand, the county government interact with the city and GIS engineer to ensure that they control and manage the space available well, tapping every resource to facilitate a smooth flow of the operation. As the use case diagram indicates, each of these stakeholders has a role to play in achieving the overall objective. This system has been designed and developed in a way that it has a universal accessibility and can be modified into various flexible dissemination modes which are; cloud, web, desktop, mobile and manual.

6.1.2 Integration

This prototype is structured and developed in a way that it handles huge data. The spatial and non-spatial data is conveniently integrated and distributed to concurrent users with different backgrounds and use of the information. The parking officers will use CAD data from the GIS engineers, digital maps from surveyors, applications from computer scientists, data from other databases, webservers and map servers among many others. The system will definitely require modifications by the day depending on the dynamic environment and user requirements, therefore this integration is key.

6.1.3 Performance

The system is expected to perform optimally based on the runtime environment. The internet is one basic requirement because it is entirely web based. This implies that, if the internet is down, then the application is not available. The major reason it is web-based is because, currently technology is dynamic and the world has already become a global village thus, the application should be up and running at whatever time for accessibility and effective utilization. Ideally, the users and output of this system as below:

The Motorist: the geodatabase created in the study interfaces with the motorist through the mobile application. Nairobi Urban Government: The entire system and components is of great use for further advancement, decision making and overall policy and strategic uses. Hardware, software, and infrastructure were**;** a desktop application that interfaces with the web is developed in the study, which allows the parking management enforces the request made by customers and customers interact with the system conveniently.

6.1.4 Efficiency

The first element of efficiency relates to data. The adequate data from the onset has to make this prototype very useful. The second element relates to technology, specific computer hardware and software were incorporated in creating the prototype; this would call for some training for the users. The third area concerns methods; the different methods used in this GIS are geared to improve the understanding of spatial and non-spatial data and how useful it is shaping an efficient parking structure that will reduce congestion on the roads.

The system allows data to be centrally stored for more efficient management and sharing. Different stakeholders are able to view and query the facility data at any time from whichever location. Departments can tailor a map service to meet their needs, and data can be updated and served to stakeholders in a timely manner.

6.1.5 Accuracy

The accuracy of this system ultimately depends on the data. This is the spatial and non-spatial data that will be captured, analysed, manipulated, and stored in the georeferenced database. The accuracy specifically touches on how the data was collected and how it was reported. If any of these steps will have a disconnect, then there will be an impact in the overall results. Generally, any GIS system is accompanied by major a complexity which is the reason

why accuracy is key. The aerial photographs were and had to be accurately captured and well-stored in the database. The interpretation had to be accurate as well since that is what is expected to inform decision making for some stakeholders like; the county government and the GIS technocrats. The population was reliable enough to manage levels of accuracy but off course it is bound to change overtime. That will call for ideas for further development if the system.

6.1.6 Maintainability

This is a measurement rating used to assess the amount of effort or resources currently committed to an application. Previous automated parking solutions offer an accurate and objective way to measure each program in an application such as the intelligent transportation systems. A case in point is the smartrep parking management system which supplies a benchmarking measurement for reducing application complexity, improving quality, and mitigating risk as it was being created, enhanced, or maintained. The automated analysis is a viable, cost-effective approach to identifying software maintainability issues and determining what actions should be taken to reduce programming efforts or costs. The current application has the capability to assess multiple languages based on the number of functions required by a new program or enhancement. It may be used at any point in the development life cycle to identify the maintainability issues. The application at hand has factored in some parameters under maintenance which are; code quality, code defects, undetected vulnerabilities, as well as scalability (Pigoski, 2007).

6.2 Flexibility

The application is a single threaded application. This is because threading adds some complexity that will detract from the core of the functionalities. Error handling has also been kept to a minimum throughout the code to remove any unnecessary clutter and no exceptions are harmed. Most of the previous application, frameworks and models are structured and designed in a way that the source code is reused to avoid a lot of errors and exceptions. The idea of code reuse is very efficient since new modifications can be made without necessarily interfering with the entire functioning of the system and without involving a major downtime. Thus in terms of flexibility, the application is efficient and up to standard.

6.3 Availability

The parking models, frameworks and architecture which were discussed earlier on in this document indicate the high availability of the software since there are more of real time applications as compared to the other desktop applications serving the same purpose. The current application is expected to be up and running most of the time because people in an urban environment are always on the move for various reasons. Ideally, the application should have (1 – (down time/ total time))*100%. Although the minimum required availability varies by task, the system should typically attempt to achieve 99.999% (5-nines) availability. The availability will be measured by its performance when a subsystem fails, its ability to resume service in a state close to the state of the system at the time of the original failure, and its ability to perform other service-affecting tasks (such as software upgrade or configuration changes) in a manner that eliminates or minimizes down time (Barone, 2014).

6.4 Robustness

This is a feature which has thrived well with previous models of parking management systems. Most of the applications have the the ability of a computer system to cope with errors during execution and cope with erroneous input even during the testing phase. Robustness in the architectures and frameworks compared to this application in this paper has encompassed many areas of development such as robust programming, robust machine learning, and robust Security Network. Formal techniques, such as j-unit testing, have been essential to showing robustness since this type of testing involves invalid or unexpected inputs. Alternatively, fault injection has been used in intelligent transportation systems for testing robustness. Other intelligent systems have tested robustness of the system through pair programming and some have implemented some forms of incremental delivery in the development of the software. Due to the large requirements analysis of GIS systems, robustness of any such system is key to facilitate effective application performance and future modifications that may arise due to new requirements as well change of code.

6.5 Fault Tolerance

Most architectures for parking management have applied fault tolerance ways, which are deterministic and repeatable. They have been and can be removed through rigorous and extensive testing and debugging. But, as argued in previous systems, no amount of testing can

certify an application as fault-free, that is fault avoidance and fault removal cannot ensure the absence of faults. Therefore, any practical piece of software can be presumed to contain faults in the operational phase and designers must deal with these faults if the software failure has serious consequences. The remaining faults in software after testing and debugging are usually bugs which elude detection during the testing. Fault tolerance makes it possible for the software system to provide service even in the presence of faults. This means that an imminent failure needs to be prevented or recovered from. In this paper, we will only discuss methods to deal with software in the operational phase. The two common strategies for software fault tolerance which have been implanted far and wide are error processing and fault treatment. Error processing aims to remove errors from the software state and has been implemented by substituting an error-free state in place of the erroneous state, called error recovery, or by compensating for the error by providing redundancy, called error compensation. Error recovery has been achieved by either forward or backward error recovery. The second strategy, fault treatment, aims to prevent activation of faults and so action is taken before the error creeps in (Ranga, 2010).

6.6 Usability and Accessibility

Usability and user experience design in most of these parking application models ia all about designing the systems to be effective, efficient, and satisfying especially to the end-user. Specifically, according to the conventional software standards, usability is the "extent to which a software can be used by specified users to achieve specified goals effectively, efficiently and with satisfaction in a specified context of use. Accessibility in these systems addresses discriminatory aspects related to equivalent user experience for people with disabilities, including people with age-related impairments. For the web- interface, a module in this application, accessibility is manifested in a way that people with disabilities can perceive, understand, navigate, and interact with the interface tools, and that they can contribute equally without barriers. This is a major contribution this application is serving as compared to previous applications in the same domain of study.

6.7 Platform Compatibility and Portability

The application is portable across multiple vendor platforms as compared to other existing models and frameworks. Others are portable across which enables application developers to reduce the software development costs and bring the application to market quickly,

and enables users to upgrade hardware while retaining their software applications and minimizing conversion costs. GIS technology continues to advance rapidly, but the need to remain competitive requires vendors to minimize their costs and to maximize their investments. As new technology is introduced, there is a need for the existing software investment to be preserved. This is a component which the current product needs to put in place. The application is very inclusive such that it includes products that are usable by everyone to the greatest extent possible, without the need for adaptation. These are; the internet and the android smart phone.

6.8 Security

Various architectures have highly embraced security in every aspect of the development. It is a key area since most applications loose credibility if from a security standpoint there are major loopholes. The state of GIS applications against intrusion and unauthorized use of resources is highly implemented because of the underlying fact that data and a lot of data is required and accessed. Most of the intelligent transportation systems operate and are designed in a way that is consistent with the potential harm that could result from the loss, inaccuracy, alteration, unavailability, or misuse of the data and resources that it uses, controls, and protects. According to various researchers, it is very difficult to hack into a GIS-based application at all costs.

6.9 Functionality and Correctness

This application is devoted in solving the problem of locating parking places and better utilization of packing spaces. A GIS based parking prototype has been developed to act as an information system for the purpose. The system is supposed to locate available packing spaces and provide user with pre-information on the nearby packing space which is free. The major question is how this system is going to function on reality and how users shall receive information in real time bases while driving. Here the question of usability and case of use must be looked at critically in comparison with what the other systems have approached it. The question of collision of users shall be controlled by having instant alerts once a user has booked the parking since same message can be sent to nearby users. From previous studies, collision is rarely a factor during system development.

6.9.1 Contribution of the study

In this application, privacy is considered in the infrastructure. Vehicles 'privacy information is transmitted from belt to belt or belt to parking site, instead of being exposed to other vehicles. Security of transaction and user information is considered. The communication is activated only when a vehicle's front wheels press on a belt. This mechanism prevents most security attacks. For example, roadside malicious hackers cannot eavesdrop on the communication.

Parking sites can frequently publish their advertisements. The advertisement can be transmitted through wireless transceivers and updated on the NOTICE belt infrastructure. Drivers can view and reserve parking spots on the fly. A non-stop parking service can be provided to drivers

Chapter 7: Conclusions and Recommendations

7.1 Conclusions

Parking remains a key challenge not only in Nairobi but also for many cities across the world. This geographic information based system for managing parking has many benefits such as; integration of spatial and non-spatial data that creates convenience for all users. GIS is structured in a dynamic way that paves way for capturing of data, storage, manipulation and analysis which is critical and prudent in managing parking. Searching for data in the application can easily be advanced to create specialized services like navigation and parking route access generation to mention but a few.

If this strategy is followed to the letter by all the stakeholders involved in urban planning, transportations specifically, the issue of congestion, illegal parking and high traffic volumes will be well managed to ensure a smooth flow of activities and operations bearing in mind that Nairobi is not only the capital of Kenya but also a major commercial centre in the Eastern Africa Region.

According to the traffic demand forecast, various counter measures will be applied with regard to the system in order to alleviate traffic problems which are mentioned in this dissertation. The number of automobiles is increasing by the day and traditional methods of relaying parking information which comprised of road signs and off-road visual displays are quite limited in that, just a few road users could access the information at a time. The system discussed herein can deliver adequate information to as many road users at a time.

7.2 Recommendations

It is recommended that proper training is done with the users. This is because there are a lot of challenges around getting to understand and interact easily with the software for it to deliver as expected.

Furthermore, it is recommended that road deficiencies can possibly be examined while removing or adding transportation links to the network via a GIS-Transportation model. Decision makers could then make electronic decisions and thus predict outcomes prior to any actual decision on the ground. This will undoubtedly, lead to more economically optimum decisions and reasonably, predict the consequences.

In order to address the strategies and measures of revitalizing of the central business district area, a lot has to improve such as; improvement of the carriageways, improvement of bus/matatu terminals and stops, improvement and widening of sidewalks and pedestrian crossings, improvement of intersections and installation of traffic signals and CCTV as well as pavement marking and traffic control signs that are working.

This study was limited to the central business district only in Nairobi, it is recommended that the whole city embraces the GIS based plan in urban planning across all sections, this is because the effect would be spiral since the city's parts are interlinked. When this is done, then the other subsequent areas will also follow suit.

7.3 Suggestions for future research

In the future work, I plan to use spatial-based sensors which will allow usage of a central supervisory station user interface, albeit at increased cost. An active sensor may be added to validate the collision information. The system can be further extended to include the augmented reality which is a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer generated sensory input such as sound, video, graphics or GPS data. Microcontrollers can also be used bearing in mind that the current dynamism in technology is creating a huge investment in microcontroller applications whose accuracy is high.

Ideally, maps take time to make, and to justify the cost of making them, it is important that they be valid for as long as possible. Traditionally, this has meant that maps are made up only of the more permanent features of the earth's surface: roads, rivers, mountains, and streets. Over the past two decades, however, the widespread availability of GPS and mapping software has changed the balance in this equation, making it possible to create maps of virtually anything for almost nothing. Neogeography is one result: the possibility of making personal maps, showing personal views that may be of interest only to the maker and for just a brief time. A GPS navigation system, fed by sensors, might show the state of congestion of the road system in real time and an air-traffic controller might see a real-time map of airplane traffic (Bowden, 2014).

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Appendices

Appendix A: List of Materials to be used in the Research

NO.	ITEM
1	Nairobi CBD Aerial Photo
2	Nairobi Parking CAD layout Drawing
3	Nairobi Engineering Parking Setting
4	Nairobi CBD Parking Layout
5	Nairobi CBD parking Layers
6	Laptop Computer
7	Windows Operating System
8	Arc GIS 10 desktop &Mappetizer
9	CAD parking design
10	Aerial Photo
11	AutoCAD software
12	Fast Report Writer
13	MS SQL server Express
14	PHP Language
15	GPRS Modem
16	Printing and Stationery
17	Internet and communication
18	Technical articles and Journals

Appendix B: Survey Questionnaires

How is the road Network and Conditions?
How Many Illegal Parkings exist in CBD?
How is the Pedestrian Traffic in CBD generally?
What is the demand and supply of parking both in and out?
What is the Congestion and Level of Service (LOS) on Moi Avenue?
Why do you prefer parking where you park?
What are the counter measures you think which will reduce traffic jams?
How is the parking space managed currently in CBD?
How are the intercity and intra-city bus stops/terminals structured?
What is your purpose into CBD?

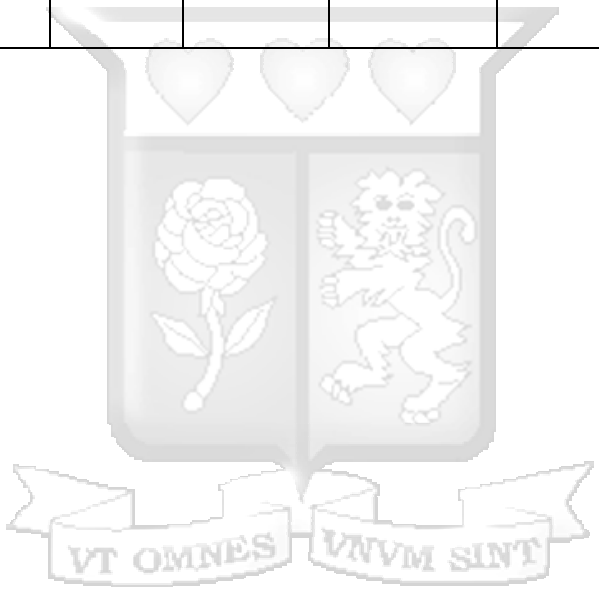
Appendix C: Interview Questions

1	Do you drive to the CBD, walk or use the public transport?
2	Do you prefer on-street parking?
3	Are the Nairobi parking lots satisfactory to you? What are the areas you think require some improvements?
4	Have you ever parked or witnessed someone parking illegally in the CBD?
5	Is the Nairobi county government doing its duties increasing sufficient parking lots for all commuters?
6	Are you satisfied with the current parking charges?
7	What amendments do you propose?
8	Are there enough pedestrian facilities in place within the CBD?
9	What are the main causes of poor parking system in the CBD?
10	What are the consequences for poor parking arrangements and poor pedestrian facilities?
11	What are some of the factors that lead of the current issues in Nairobi CBD's parking system?
12	What measures do you think will solve the problem?

Appendix D: Questionnaires

Parameters	Yes	No	Agree	Disagree	Strongly Agree	Strongly Disagree	Neutral
Do you prefer driving to work or using public transport?							
Do you prefer on-street parking?							
Have you ever parked illegally?							
Do you often park for long hours?							
Are the current parking fees favourable or not?							
Is the county government doing its duties to solve the problem in Nairobi's CBD's parking lots?							
Do you think there are illegal parking in the CBD							
What is the best solution to the illegal parking?							
Are the current fines for illegal parking effective?							
What other penalties do you suggest?							
Which streets within the CBD have the highest cases of illegal parking?							
Is the pedestrian traffic affecting parking patterns within the CBD?							
What are the							

possible solutions for the problem?							
How are the pedestrian facilities installed along the major streets in the CBD?							
Are you certified with the current arrangement of Matatu/Bus terminals?							
What should be done to minimise the congestion in the Bus terminal?							



Appendix E: Sample Code

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var selectedShape = null, infoWindow, map, carSpace = 11.52, lightVanSpace = 13.2,
   rigidVehicleSpace = 49, articulatedVehicleSpace = 64.75, coachSpace = 49;
function initMap() {
   map = new google.maps.Map(document.getElementById('map'), {
      center: {lat: -1.2901982, lng: 36.8584818},
      zoom: 13
   });


   var drawingManager = new google.maps.drawing.DrawingManager({
      drawingMode: google.maps.drawing.OverlayType.RECTANGLE,
      drawingControl: true,
      drawingControlOptions: {
         position: google.maps.ControlPosition.TOP_CENTER,
         drawingModes: [
            // google.maps.drawing.OverlayType.MARKER,
            // google.maps.drawing.OverlayType.CIRCLE,
            google.maps.drawing.OverlayType.POLYGON,
            // google.maps.drawing.OverlayType.POLYLINE,
            google.maps.drawing.OverlayType.RECTANGLE
         ]
      },
```

Appendix F: Turn It In Report

Turnitin Originality Report

joan by Cameline Mukami

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