



**University of Nairobi**

**Faculty of Engineering**

**Department of Geospatial and Space Technology**

**APPLICATION OF GIS IN MEDIATING TRAFFIC CONGESTION IN CENTRAL  
BUSINESS DISTRICTS. A CASE OF NAIROBI COUNTY CBD**

Research Project submitted for the Degree of **Master of Science in GIS**, in the Department of  
Geospatial and Space Technology of the University of Nairobi

**BY**



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### **Acknowledgments**

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## **Abstract**

Geo-information technology has been integrated with various sectors of development to help achieve sustainability and improve the delivery of services and smooth operation of activities within the economy. However, considering the technology was not given much importance in the previous decades, integrating it has been a slow process as people are still stuck in the traditional way of doing things. The world is generally changing daily with new technologies being introduced and new problems arising due to the growing population and an increase in demand for services and goods. The issue of traffic congestion is among these problems and solving it will involve integrating various measures, and GIS is what this study intends to propose to support this move. Third-world economies are experiencing rapid urbanization and this is exerting pressure on the existing infrastructure and resources due to the high population growth. The high rate of urbanization has created more employment opportunities in these urban areas and this has attracted many people to the cities. One such effect is being experienced by Nairobi city, Kenya's capital. In as much as the growth of the city has trickled down benefits to the neighboring areas, the city experiences problems of traffic congestion which has led to a deterioration in its aesthetic value, pollution, and a delay in the delivery of services. Nairobi Central Business District is a key administrative center, business center, and commercial center, among others contributing to a myriad of its woes among them being congestion. Being a core economic center for the county and the country in general, there is a major need to come up with effective strategies to decongest the city's CBD. Considering that several strategies have been tried before without much impact, the strategy therefore ought to be sustainable. This study therefore aimed at incorporating GIS in developing strategies that support traffic decongestion of the study area. Both spatial and non-spatial data was collected and GIS was the main method of data collection, as well as data analysis. The geographical location of friction points along the identified streets were picked and visualized on a map, and these constituted of on-street parking, street vending, and undesignated bus drop-offs. These were identified to be the key causes of traffic congestion along major streets such as Moi Avenue, and Kenyatta Avenue. Since the study was only limited to Nairobi's CBD, it further recommends for same to be extended to the larger Nairobi metropolitan, as it also contributes to the traffic congestion within the CBD.

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## CHAPTER 1: INTRODUCTION

### 1.1 Background

Most nations experience rapid urbanization in a majority of their cities due to population growth being witnessed and several developments taking place. This is what affects the growth and character of Central Business Districts. It is expected that most people in the city access the CBD daily as this is where most city functions are situated. There is often a variety of shopping stalls, government offices, and various job stations and this situation makes congestion in the area inevitable. Given the level of urbanization globally, traffic congestion in particular has become a major concern in CBDs. Throughout the day, CBDs are quite busy with several activities taking place concurrently and therefore traffic congestion heightens within the streets as well as in the mornings when people are flowing in and in the evening when they are leaving for their homes (Aderamo, 2003).

The UN (2022) identified the dominance of the urban population in the year 2010 which further revealed that close to 50.5% of the world population resides in cities. By the year 2050, the situation is expected to be different, with the population rising to 5.2 billion people. What this means to cities is that more pressure is expected on their CBDs and congestion will heighten as well, unless proper interventions are done. CBDs are core areas for city activities and businesses due to their economic and geographic dynamics. Fact that more investments are to be made in CBDs and employment opportunities generated, a large population is therefore expected to access the area. The aftermath is congestion either as a result of the traffic, the people themselves, and a mushrooming of activities such as hawking on the streets. These activities strain the available infrastructure and resources and lead to difficulties for the authorities to manage CBDs and the city in general (Willett, 2006).

Aderamo, (2003) further explains the impact this congestion in CBDs has on urban development and the associated issues that make it difficult for decisions and policymakers, scholars as well as other experts responsible for managing CBDs. In a similar strain, African cities are no different, particularly in major cities such as Lagos (Nigeria), and Kampala (Uganda), which are well-known for their infamous traffic congestion. Robinson, (1978) notes that the congestion is a result of failure to enforce traffic rules and regulations and notorious motorists and commuters as well. This means there exist traffic rules and issues therefore, are enforcing these rules for the road users to understand and know these rules.

Nairobi, Kenya is no different. Over the past decade, traffic congestion has been a topic of concern and the effects are being seen in the amount of noise and environmental pollution being witnessed, delays experienced in the conveyance of goods as well as avoidable accidents occurring daily. Population in the city is only going to keep growing and urbanization is only going to keep increasing but land or space is going to remain the same. For this reason, proper management is necessary before the situation becomes unmanageable.

## **1.2 Problem Statement**

Traffic congestion is a global urban problem that cannot go unnoticed considering the much impact it has on the economy of the countries and the environment. Mahendra, (2011) identified Sao Paulo, a Brazilian city, as the one experiencing the world's worst traffic congestion with residents getting stuck in traffic for a period of two to three hours daily. The impact this has on the city is a drastic reduction in productivity and socio-economic development. This is characterized by delays, `wastage of fuel, and loss of revenue. Moore *et al*, (2007) assert that transportation is a key factor that determines the urban form most importantly throughout the 20<sup>th</sup> century. Good transportation is what aids in opening up an area to develop as well as attracting human settlement. There is therefore the necessity to efficiently integrate a good transportation network with sustainable land uses and proper management and planning of towns and cities. The linkage between land uses and transportation is more ostensible in the milieu of key quality-of-life concerns such as population growth rate, rising congestion, and mileage of vehicles (Perry *et al.*, 2008).

Urban transport in Kenya is pigeonholed by overcrowding and pollution, insecurity, derisory transport infrastructure, and the neglect of eminence (Aligula *et al.*, 2005). Nairobi being the capital city of the country and having a central position, is undergoing rapid urbanization and this pressure is now being felt by its metropolitan towns such as Kiambu, Machakos, and Thika towns. This has resulted in issues of traffic congestion in and out of the city as people and commodities are being transported daily. Massive traffic congestion is therefore being felt more within its CBD which is the city's core economic area. The County government has tried numerous times to decongest the CBD by coming up with policies and regulations such as prohibiting motorcycles within the CBD, as well as passenger vehicles which received a huge backlash from the residents and led to this ban being lifted within a couple of days. Failure to decongest the CBD has resulted in increased crime, especially pick-pocketers who take

advantage of the overcrowding of both people and vehicles, as well as frequent accidents (Komollo, 2010).

This research, therefore, seeks to evaluate traffic congestion in Nairobi's CBD using GIS. A multicriteria evaluation method will be used to identify specific areas within a CBD that are prone to traffic congestion as well as factors contributing. Further, this research will look into other forms of congestion while identifying gaps in the existing traffic congestion evaluation methods in the area and further propose effective proposals to curb traffic congestion within the study area.

### **1.3 Objectives**

The main objective of this study is to mediate traffic congestion in Nairobi's CBD with the aid of GIS.

The specific objectives include;

- a) To identify the causes and the extent of traffic congestion in Nairobi's CBD
- b) To evaluate the impacts of traffic congestion in Nairobi's CBD
- c) To provide relevant recommendations on the use of GIS in mitigating traffic congestion in Nairobi CBD

### **1.4 Justification for the Study**

Efforts to decongest the Nairobi CBD have been a topic of discussion for a long time. Several professionals and the authorities have tried to suggest measures to decongest the CBD but these efforts have been futile. Policies and regulations alone cannot end this nightmare. Neither will forcefully impose bans on public transport access to CBD alone to help. There is a knowledge gap in finding the most appropriate action that will solve traffic congestion without offsetting the existing balance.

This research study mainly focuses on introducing the use of GIS to support the decongestion of traffic within Nairobi CBD. Considering this has not been given much priority before, the study is set to evaluate ways GIS can be integrated. Factors such as real-time monitoring of viable routes, and identifying a potential location for streets and parking is what GIS is capable of helping realize and much more, depending on the situation at the moment. What this will also bring to the table is the ability of authorities to make more informed decisions based on the evaluation done and hence the regulations and policies will be more practical and easier to implement.

### **1.5 Scope of work**

Nairobi City County, Central Business District area, is the study area for this research. The study will focus on evaluating traffic congestion and the contributing factors. The existing policies and regulations will be evaluated and their effectiveness gauged. Other forms of congestion affect CBDs. However, this study will just highlight them but give greater focus to traffic congestion. The study will make use of GIS applications to evaluate the congestion situation as well as propose GIS-based interventions to solve the issue in the area.

## **CHAPTER 2: LITERATURE REVIEW**

### **2. 1 Definition of Issues**

#### **2.1.1 Central Business District**

The business center of a city or an urban area is its central business district. The presence of administrative offices, and business spaces, is what leads to the area being defined as a financial district. Oftentimes, this space coincides with the city's middle point geographically. This notion is however not always tantamount considering some cities do have CBDs that are situated in areas away from the city's commercial, and main business areas. In some cases, a city could have several CBDs within it. As compared to other areas within the city, the CBD will have an assortment of specialized services and goods (Ye, 2012).

#### **2.1.2 Definition of Urbanization**

Many scholars have given various definitions for urbanization, which is an area of concern currently in the world, with many nations facing a high rate of urbanization. Tisdale, (1941) defines urbanization as the process of a significant human population settling permanently in a small area hence leading to the formation of a city. The term urban has several definitions in each nation, hence the varying definitions of the term. In the United States, for example, an urban place is used to define an area with a population of more than 2500 living there. On the other hand, in Peru, a population of 100 or more is what defines an urban area.

#### **2.1.3 Traffic Congestion**

The term does not have a huge variation in most of the definitions given to it by various scholars, as it takes its literal meaning. Koźlak and Wach, (2018) for instance, define traffic congestion to be the impediment of traffic by motorists mutually, due to the existing interrelation of the volume of flow and the speed of the vehicles. In this case, infrastructure capacity is inadequate, that is the roads, parking spaces, as well as pedestrian walks. The road capacity, therefore, has been exceeded by the level of traffic, and this limits free movement.

### **2.2 Causes of Traffic Congestion in CBD**

(Agyapong and Ojo, 2018) asserts that traffic congestion is mainly brought about when there exists a misalliance between the existing transportation infrastructure and the travel demand. Being a key problem in many countries currently, it has proven to be a hard issue to combat as it

continues to affect and disrupt the development and growth of various sectors which depend on transportation to thrive, such as the social and economic sectors, education, and the hospitality sectors (Ye, 2012). There are various factors that scholars have identified and more specifically, Noor *et al.*, (2021) such as;

a) Increase in vehicular population

Noor *et al.*, (2021) in their study on traffic congestion in Khulna's CBD identified the impact of vehicles being introduced into the city daily due to the growing city population. There is no balance between the number of vehicles getting into the city and the roads being expanded or improved, resulting in traffic congestion

b) Illegal road occupancy

Being key economic zones, CBDs attract informal businesses such as street vending. They therefore illegally occupy streets which reduces the space left for vehicles to maneuver the town. These vendors take up space for footpaths and parking as well and the overall impact trickles down to pedestrians encroaching the streets rather than the designated footpaths, the vehicles being parked within streets as well, hence general traffic congestion.

c) Violation of building setback rules and insufficient parking capacity

CBDs are characterized by dense human populations, busy streets, administrative buildings, a variety of commercial activities, and oftentimes hawking. You will find the headquarters of various businesses there, as well as retail and wholesale shops. For this reason, it is expected that there will be a significant number of vehicles getting into and out of the area, as people try to access these services. To ensure pedestrians get to move freely, sidewalks with adequate width are essential in every street to enable their free circulation to various points in the CBD. There exist Building construction regulations that guide the required space in front of the buildings whether for commercial, or any other purpose within the CBD. When these regulations are not followed, it leaves no room for adequate parking space or sidewalks hence causing encroachment into the road. This, in the long run, interferes with the road width hence interrupting traffic flow.



#### d) Poor public transport mode

In a situation where the existing modes of public transportation are of low quality and standards, it is going to affect traffic flow. The type of vehicles affects to a big extent the traffic flow. From a study done by Noor *et al.*, (2021), on transportation in Khulna city whose main mode of public transport is Easy-bikes, the situation is bad as the capacity of these bikes is not enough to accommodate the demand for transport that is there. The fact that these bikes have to make more trips, reduces the efficiency of the transportation sector, hence traffic congestion in the area.

#### e) Poor enforcement of the law

There exist traffic rules and regulations in almost all parts of the world. However, following these rules has been a major concern as most people both motorists and non-motorists tend to break or disobey them. The aftermath is accidents and traffic congestion. Other times, people are unaware of the rules or do not understand the road signs either due to ignorance or the local authorities not educating the public. In other cases, political interference happens when unscrupulous politicians, encourage hawkers to set up stalls along the streets (Mahmud *et al.*, 2012). When this happens, it is hard for law enforcement officers to evict these businesses even though the existing regulations prohibit such activities along the streets. The result of this is encroachment into the road reserve or parking spaces, and this leads to traffic congestion. (Sharmeen and Houston, 2019).

### **2.3 Impact of Traffic Congestion in CBD**

After World War II, the population has been growing rapidly and urban areas have noticeably expanded in the United States. Vehicles being the main means of transport within the urban areas, traffic congestion has then become a norm, hence threatening the sustainability of these areas. Expanding the streets is what most governments go for to try and find more space for vehicles, but this is slowly facing challenges due to lack of funds and more so, physical restraints. Among the many implications of traffic congestion is environmental pollution brought about by the emission of harmful gasses that cause harm to the residents, noise pollution as well as loss of general aesthetics of the urban area due to crowding. This also makes the urban area unattractive to investors who would have otherwise contributed to the growth of the urban area and more revenue production for the residents and the government. The loss in productive work

hours for labor also affects businesses, which means less revenue is generated (Kozlak and Wach, 2018).

#### **2.4 GIS and Solving Traffic Congestion**

The emergence of GIS as a key and efficient technology in transportation engineering has opened up the eyes of various scholars to explore its different applications in solving some of the problems in the field. One major application is the identification of friction points which greatly affect the speed of vehicles on the roads, and this has been applied in cities such as Delhi in India. Measuring the speed of a vehicle that is on the road is something that is not easy to accomplish using conventional methods. This then calls for modern technology such as the use of GPS which can help trace the speed. Huang, Z. (2021) highlights that different variables affect the speed at which a vehicle is moving. These factors include the width of the road, and the adjacent land uses, that may attract both pedestrians and motorists. These land uses could be large malls, hospitals, or even colleges. The ability to map out these areas will ensure efficient management and valuation of traffic congestion.

Owusu *et al.*, (2006) also emphasizes the importance of using GIS to map various traffic parameters that affect traffic speed. The ability to do this allows one to do a pre-evaluation of several procedures which prove to be conclusive. Chen *et al.*, (2011) on the other hand after studying the various problems that face the transportation sector in Guangzhou city in China, presents an important creed of coming up with an integrated, and efficient Urban Transportation Information System that will help in managing, planning and monitoring to ensure developments that come up can conform and coincide with the area's pace of growth.

Likewise, Kalaga Rao and Mohan Rao (2009) also studied the use of GIS in acquiring traffic data, that is the speed, and time of travel and further validated the fact that by using GPS, the data obtained is more accurate as compared to other conventional methods that were being used before. A further study by Anitha *et al.*, (2013) who define traffic congestion as the slow and increased vehicular movement on roads, emphasizes the importance of knowing the actual location of the existing road network, and a clear interpretation of the flow patterns. As well as the transportation measurements to effectively monitor and manage traffic. All these are made possible through GIS applications.

## **2.5 Theoretical Perspective**

This section looks into the various theories of transportation and central business districts. The theories try to explain the influence a transportation network has on the growth of areas as well as influencing the human settlement pattern therein. Theories that give insight into how a city grows explain the concepts one should look into when trying to understand the direction of growth a town is taking.

### **2.5.1 Central Place Theory and Concentric Rings**

Thunen, (1826) gave the initial attempt to explain the concept behind concentric zones where a central marketplace is surrounded by plain land of uniform fertility. The market grew as it provided the rural zones with already manufactured goods and emphasized transportation cost being a key determinant due to the cost of transporting bulky goods. The market would also be a market for the surplus agricultural produce in the rural area. This is what led to the emergence of the concentric rings. The central place theory attempts to explain how settlements, are located near one another. The theory was developed by Walter Christaller in 1933 and his main idea was that the central places or towns get to provide goods and services to the surrounding areas. Their growth is influenced by their central position; hence people prefer accessing goods and services from a central place that is convenient for everyone.

Christaller, (1933) further asserts that threshold and range are key determinants of the central place location for any area. He defines threshold as the smallest market area necessary for services and goods provided to be rendered economically viable, and range as the shortest distance one is willing to travel to access a good or service. Practically, this theory informs the growth of central business districts in urban areas. These districts are geographically located at the core or center of towns as they offer the threshold and range best manageable by the population and the economy of the area.

Ullman and Harris (1945) have identified that the majority of urban areas are dependent on transportation for growth. Urban areas recognize the importance of efficient transportation and this is seen with the freight-rate regulation, new highways being constructed, ports, and airstrips. Given these theories of the agglomeration of activities in central places, Nairobi CBD is a clear presentation of a dominant central place.

### **2.5.2 Sector Theory**

Hoyt, (1939) developed the sector model and according to his theory, the city develops in a series of sectors. In this sense, certain sectors or areas are more attractive than others for different activities, with the CBD being in the middle. The sectors grow outwards and sectors with high-class housing are located in the outermost area. The model, therefore, explains the impact the transportation network has on the growth of these sectors. This means that transportation has a direct impact on land use.

Cities would grow along these transport corridors which further gives transportation an important factor in the growth of cities. The more efficient transportation is, the more positive impact it will have on the growth of the city or urban area. The theory then holds the same idea of the center of the city having greater economic value as most economic activities are expected to take place there due to its geographical position (Chapin *et al.*, 1972).

### **2.5.3 Multiple-Nuclei Theory**

Harris and Edward (1945) developed a more advanced theory to Hoyt's sector model which sought to generalize more on the urban land uses, the multiple-nuclei theory. The main idea is that most towns and cities do not grow only around one Central Business District but are formed through a progressive integration of several separate nuclei in the urban area. The nodes have different and special growth processes and their location is not necessarily in relation to distance but several attributes such as;

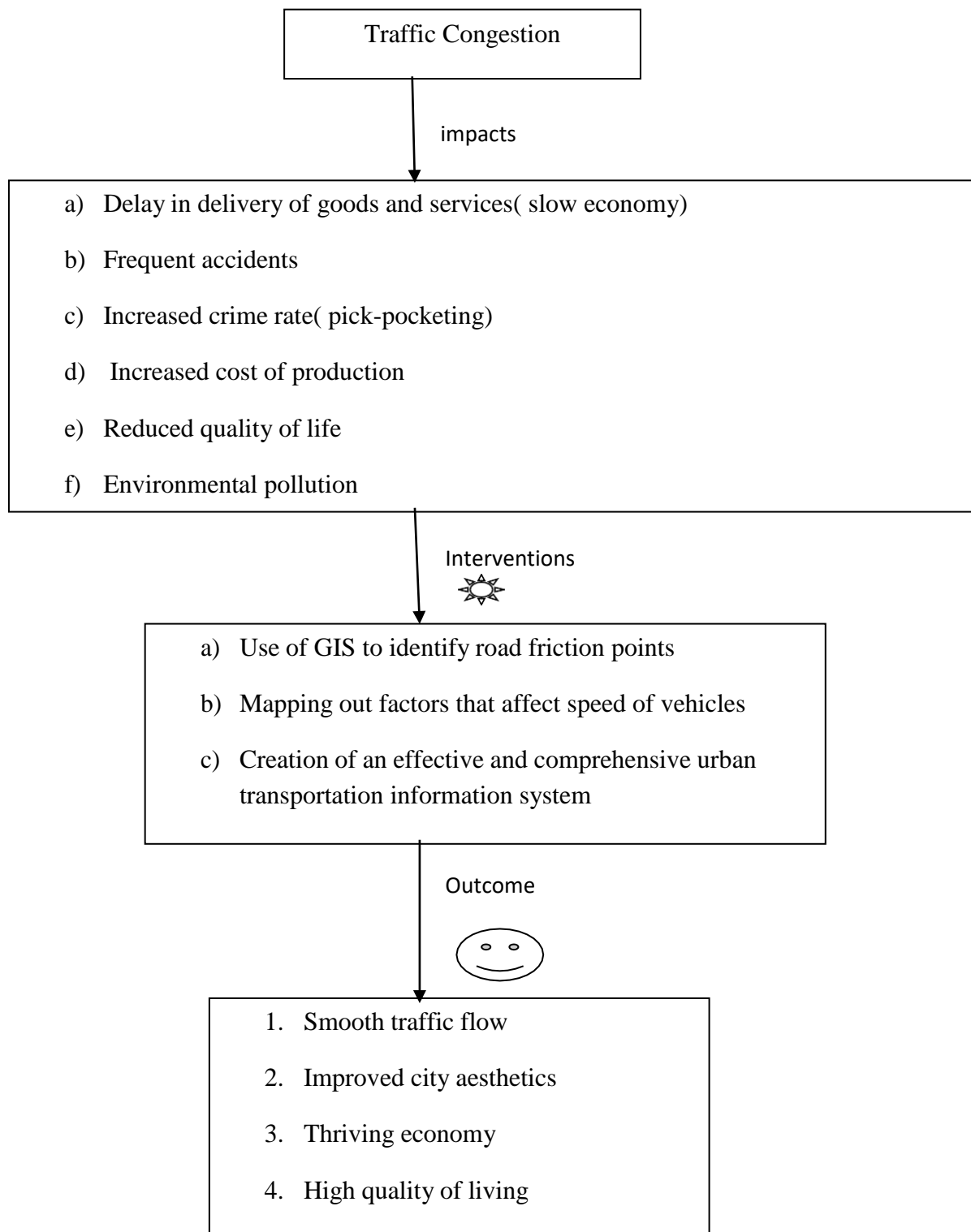
- a) Differential accessibility. Some activities require specialized facilities such as port and rail terminals. For instance, the retailing sector demands maximum accessibility, which is often different from the centrality offered in the CBD.
- b) Land use compatibility. Similar activities group together since proximity implies improved interactions through the process of economies of agglomeration. Service activities such as banks, insurance companies, shops, and institutions are strongly interacting with each other. This can be defined as centripetal forces between activities.
- c) Land use incompatibility. Some activities repel each other such as high-quality residential and heavy industrial. This may be defined as centrifugal forces.
- d) Location suitability. Some activities cannot afford the rent of the optimal site for their location. They may thus locate at cheaper places, which are not optimal, but suitable for these activities.

## **2.6 Conceptual Perspective**

Traffic congestion can be analyzed and studied by looking into the various traffic parameters which can be mapped using GIS. Several impacts of traffic congestion have been identified to be most prominent such as reduced quality of life, slowed economy as well as environmental pollution. These situations end up reducing the competitiveness of the city, making sustainable development and growth hard to achieve.

Joseph Owusu *et al.*, (2006) explain the various ways GIS can be used to come up with an extensive database system that brings together vital information such as the geometry of the road, friction points, and speed information. Integration of GIS into traditional transportation research methods consents to the formation of a robust platform for innovative transportation and traffic activities. A considerably large database can be stored by GIS, allowing for data from various sources to be unified. Using GPS, various traffic parameters can be mapped out. One key intervention is identifying the road friction points which affect the speed of the vehicles. Friction points are brought about by events taking place on the roadsides, hence interfering with the traffic flow, such as hawking, and unauthorized parking. Using GIS, these friction points can be mapped out and their influence on traffic performance is assessed.

After the aforementioned intervention measures have been applied, monitoring of the traffic flow is easily done, and an integrated comprehensive urban transportation information system can easily be established to ensure that transportation is uniformly linked to any developments that take place later on (Anitha *et al.*, 2013).



**Figure 1: Conceptual Framework**

## **CHAPTER 3: MATERIALS AND METHODS**

### **3.1 Introduction**

This research will use both qualitative and quantitative approaches. Using GIS as the main tool of analysis, relevant data will be collected, evaluated, and analyzed in a quest to achieve the research objectives. The research study will therefore logically follow the set objectives and this will ensure each of them is exhausted before completing the research study.

### **3.2 Study Area**

Nairobi City County in general, lies geographically on  $1^{\circ} 09'S$   $36^{\circ} 39'E$  and  $1^{\circ} 27'S$   $37^{\circ} 06'E$ . The study area is, however, the County's CBD which takes up a rectangular shape. The boundary of the area is defined by Uhuru Highway, Haile Selassie Avenue, Moi Avenue, and University Way as shown by the study area map in Figure 5. It covers approximately 1.70 square kilometers. It is within Nairobi Central County Assembly Ward, within Starehe Constituency (Omwenga, 2010). The maps in Figure 2 show the location of the study area in a national context, Figure 3 shows the regional locational context of the study area, and Figure 4 demonstrates the local context.



**Figure 2: Map of the National locational context**



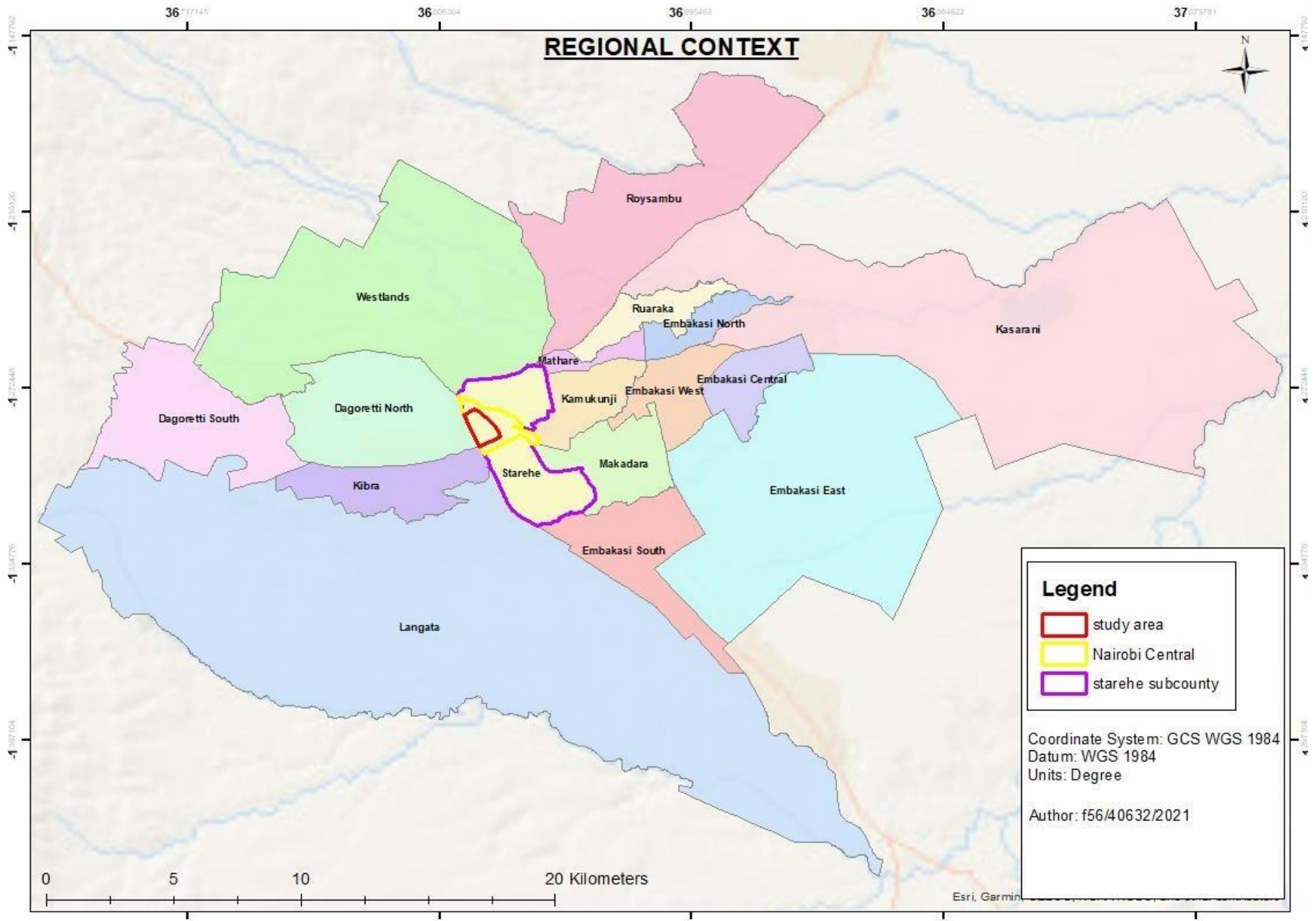
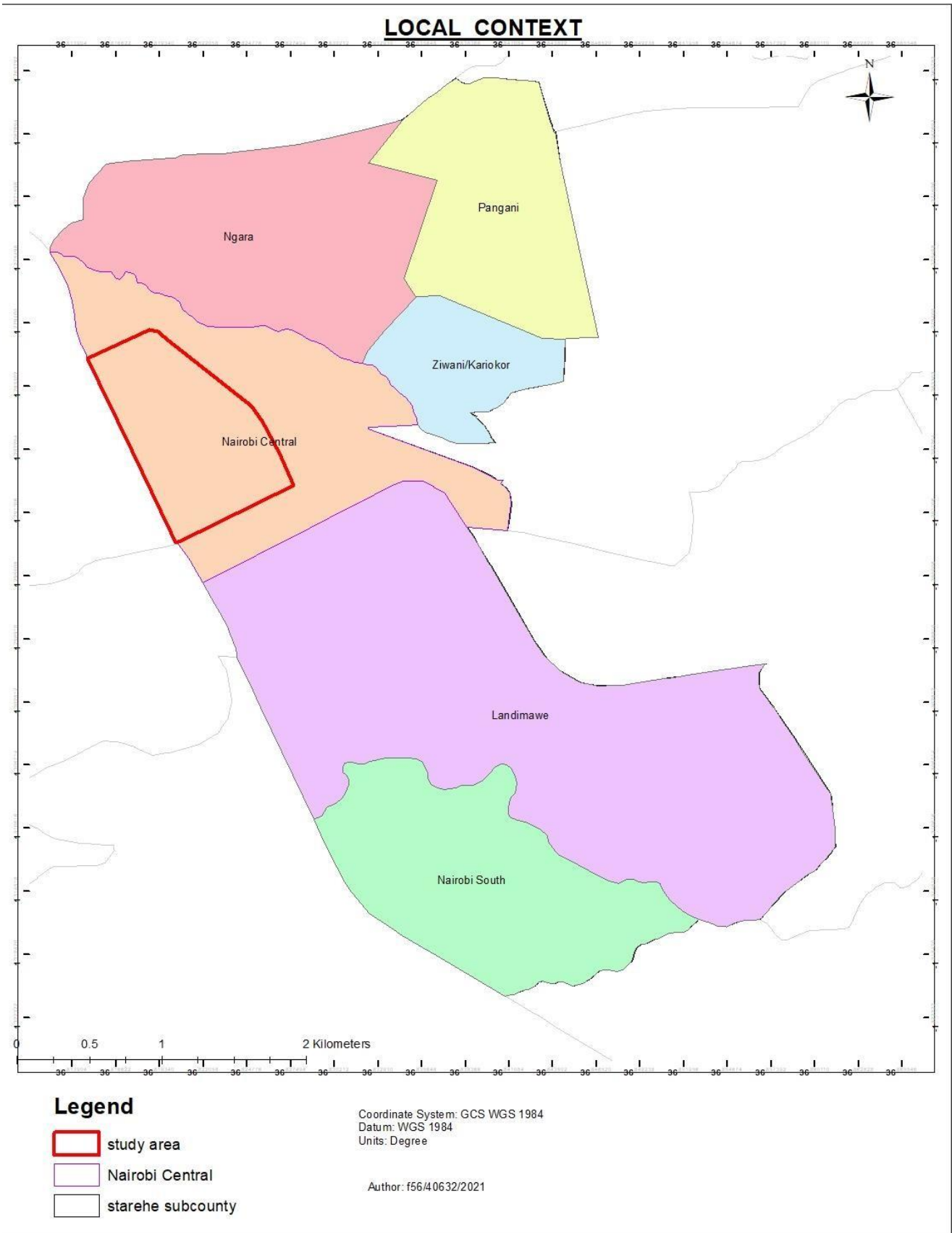


Figure 3: Map of the Regional locational context



**Figure 4: Map of the Local location context**

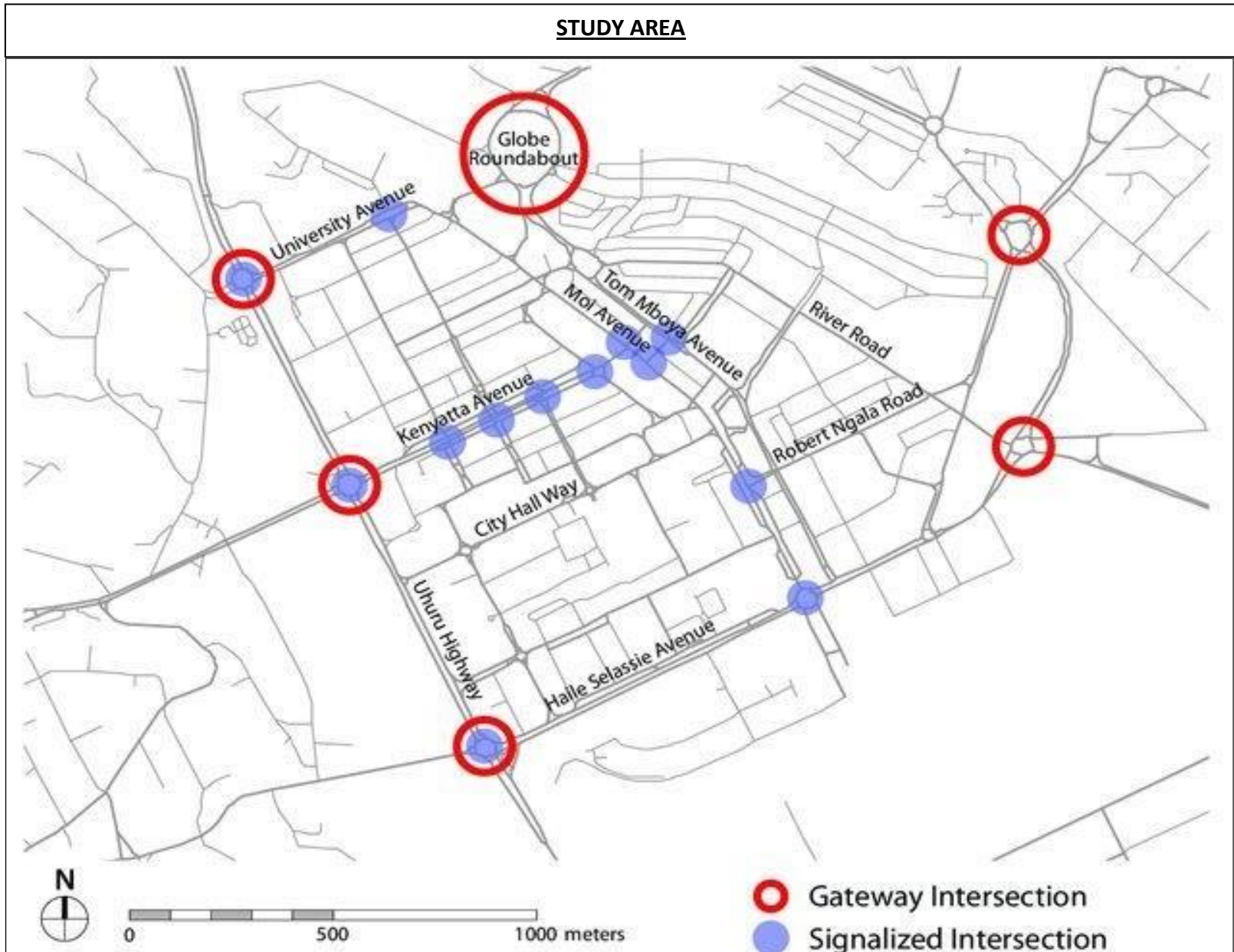


Figure 5: Map of the Study Area

### 3.3 Methodology

The methodology that will be adopted for this research study will be guided by the steps illustrated by the flow chart in Figure 3.

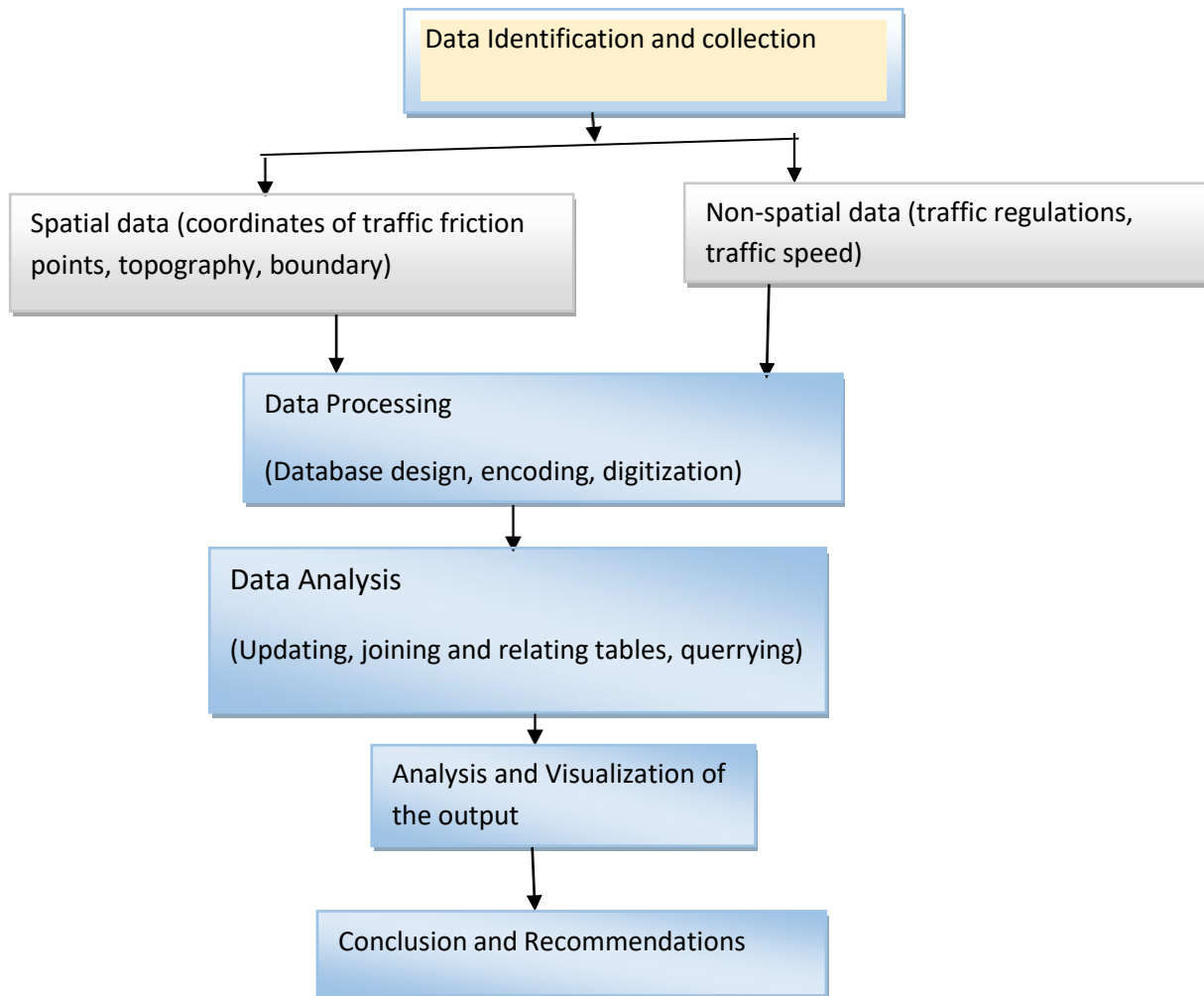


Figure 6: Methodology steps

#### 3.3.1 Desktop Research

This being the initial step for the research study, it will first involve identifying relevant data and information which is identifying key topics of research and necessary spatial data needed for scrutiny through the preliminary literature review. The second step is data collection to try and gather and build useful data for the project. The third and final step will be identifying the gap in the data and their classification.

### **3.3.2 Field Mission**

The initial stage for this process will include, preparing field survey materials that will facilitate easier field data collection or what is popularly referred to as primary data collection. Questionnaires that target the achievement of the study objectives will be prepared as well as an observation checklist, to ensure that when in the field every data item needed for the study is captured. This will reduce any instances of missing data. Other than these questionnaires, research assistants will be brought in to help in conducting interviews and any other necessary data needed from the study area. Photographs of the study area are necessary to help depict the situation on the ground, and therefore, acquiring a good camera will be necessary.

Secondary data collection will involve gathering data from the literature that already exists. Some scholars and researchers have tried to do research for the same study in different areas such as the one done by Rao *et al*, (2014) on managing traffic congestion using GIS. Reviewing their findings and results will give some insight that can be adopted in this study.

### **3.3.3 Documentation**

After data collection, the data obtained will be compiled and a detailed analysis carried out. The findings and results will be logically explained following the research objectives. The output for the stage will be a draft of the key findings, threats, and opportunities.

### **3.3.4 Results Validation**

This step will involve going through the gathered data to double-check for any errors and relate them to the actual situation on the ground. This exercise will therefore ensure the reliability and validity of the results which will allow for the comprehensiveness of the analysis.

### **3.3.5 Recommendations**

At this point, various mitigation measures will be recommended based on the results of the study. This will include other ways of dealing with traffic congestion in CBDs, areas for further study as well as other areas the study can be applied to obtain similar results.

### **3.3.6 Finalization**

This is the last stage of the research study as any final additions or changes are made and the outcome of the process, is a satisfactory document.

## CHAPTER 4: RESEARCH FINDINGS, ANALYSIS, AND DISCUSSION

### 4.0 Overview

This chapter contains the findings of this study and is based on the primary and secondary data collected. The chapter has systematically organized the results as per the research objectives, hence ensuring these objectives were all sufficiently met. The data that was collected outlines the characteristics of the Nairobi CBD streets and maps out the various parameters that cause traffic congestion. The analysis involved the combination of different data collected from major streets within the study area using GIS applications.

### 4.1 Causes of Traffic Congestion in Nairobi's CBD

To identify key causes of traffic congestion in the study area, geographical points of the friction points along the streets were picked and processed to come up with a visual representation of these hot spots within the study area. For a better understanding, friction points refer to the activities that take place adjacent, and sometimes within a travel way. These activities interfere with the traffic flow hence causing traffic congestion. There are particular land uses that attract large traffic flow and using GIS, these were also identified and mapped. The major streets that were used for this study are shown in Table 1, alongside their current conditions.

**Table 1: Present condition of the Nairobi CBD streets**

Road Name	Road reserve	Carriageway	NMT	Pavement	Drainage
Moi Avenue	18m	15m	Fair	fair	Underground- not functioning well
Kenyatta Avenue	28m	4-lane road 18.05 m	3.8 to 4.50 m for On each side, poor	Good condition	Underground- not functioning well
Haile Selassie	24m	18m	fair	fair	Underground- not functioning well
City Hall way	28m	15m	good	fair	Underground fair
University Way	40	30m	good	Fair	Underground fair
Harambee Avenue	26m	2-lane road 9.75 m w/ kerb-side parking lane	3.6 to 3.7 m for each side, fair	fair	Underground fair
Parliament Road	25m	2-lane road 13.75 m	3.4 to 4.75 m for each side, fair	good	Underground, fair
Uhuru Highway	40m	30m	good	good	Poor- heavily flooded during the rains



### 4.1.1 Friction points

The friction points along the streets consisted of undesignated bus drop-offs, on-street parking, and street vending activities. Figure 7, gives a geographical representation of these friction points.

#### a) On-street parking

Currently, the number of public parking slots within Nairobi CBD stands at 9000. These are managed by the County Government and are preferred to the private ones as they are cheaper. Due to the increasing number of vehicles getting into the CBD daily, the available parking slots are hardly enough. However, at other times, motorists notoriously park wrongly along the streets and on undesignated spots as shown in Plate 1, and Plate 2. This ends up interfering with the travel way for both vehicles and pedestrians, hence slowing down traffic.

As shown in Figure 7, on-street parking is the leading cause of traffic congestion in all the streets, with Kenyatta Avenue and Moi Avenue being the most affected. Considering, all these streets are connected, interference with traffic on one street ends up affecting other adjacent streets.



**Plate 1: On-street undesignated parking**





**Plate 2: On-street parking, Moi Avenue**

b) Hawkers/street vendors

This was a predominant issue mainly along Moi Avenue and the neighboring street, Tom Mboya Street. From Figure 7, Moi Avenue is the street with the greatest population of street vending spots along it. There are no slots designated for street vending along the streets, the vendors therefore occupy pedestrian walkways as well as parts of the street travel way, as depicted in Plates 3, and 4. In Plate 4, the pedestrian walkway is interfered with, hence making the pedestrians have to use the travel way, which in turn slows down the traffic. In Figure 10, the street vendors have encroached into the street travel way which has caused traffic congestion being witnessed.



Plate 3: Street vending along a pedestrian walkway



Plate 4: Street vending along the travel way





Figure 7: Map of friction points along Nairobi CBD streets

c) Undesignated bus drop-offs and pick-ups

Despite there being various designated matatu and bus stages within the Nairobi CBD, some parts of the streets have been observed to be drop-off points as the drivers try to avoid being stuck in traffic. Moi Avenue and Kenyatta Avenue as shown on the map had the highest number of these points as shown in Figure 7. The same is seen in Plate 5. Randomly dropping off passengers stalls other vehicles that are on the street, hence causing slow traffic. If this happens on several parts of the same street, then too much congestion is experienced.



Plate 5: Undesignated drop-off at the intersection of Moi Avenue and Kenyatta Avenue

#### 4.1.2 Land uses that attract large traffic flow along the streets

It was also observed that the location of some of the land uses within the Nairobi CBD, attracted so much traffic, as people try to access those facilities. These land uses were identified and digitized to produce a land use map that shows their geographical location, along the streets. There are several retail and wholesale shops along most of the streets such as Moi Avenue, Kenyatta Avenue, and Muindi Mbingu Street. Many people stop at these shops to purchase essential items hence, being dropped off near them is convenient. As shown in Figure 14, other land uses such as public facilities, being located along busy streets, such as Huduma Centre along Haile Selassie and the one in GPO, along Kenyatta Avenue attract many people, and these facilities not having ample parking spaces, leads to traffic congestion near them.

There are also several colleges located along major streets. The University of Nairobi is along the University Way, and the Technical University of Kenya, and JKUAT town campus are both



along Haile Selassie. Having these colleges located in these spots attracts a lot of traffic as the students try to access the facility as well as the academic staff employed there. During major ceremonies in these colleges such as graduation, traffic along these streets is very slow, and there is so much congestion.

There are also various bus stages located along the streets, which were observed to also attract traffic as well as slow it down. Plate 6 shows a bus trying to make a turn at the KenCom bus stage, and blocking the entire street.



**Plate 6: A bus blocking the travel way at the KenCom bus stage**

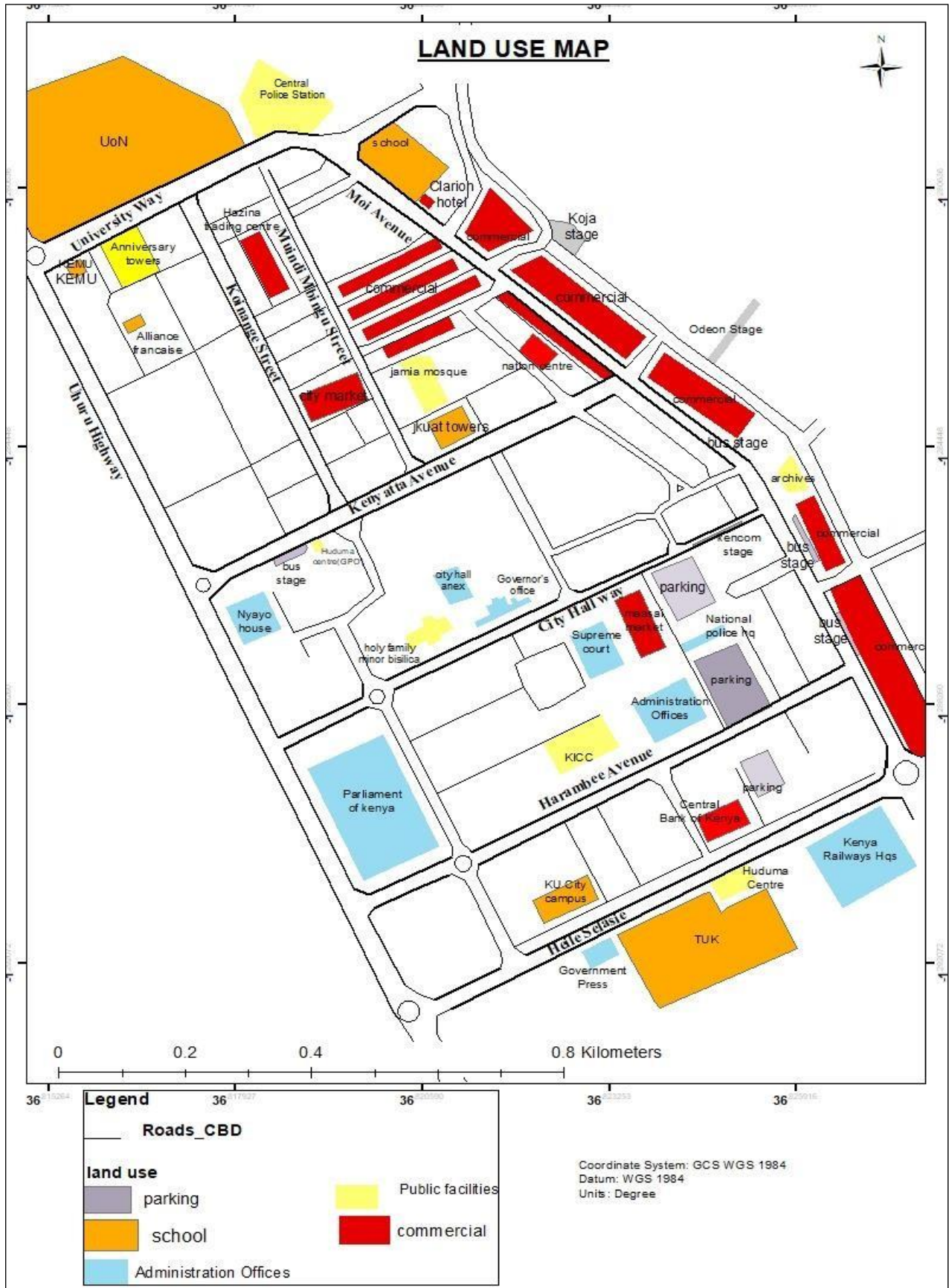


Figure 14: Map showing land uses that attract heavy traffic



### 4.1.3 Poor drainage

Nairobi CBD experiences flooding in most of the streets during heavy rains, due to the poor drainage system. Plate 7 and 8 show one of the recent occurrences, as this field survey took place during the rainy season. The flooding makes it impossible for vehicles to navigate easily, as well as pedestrians. As a result, traffic is slowed down, hence congestion.



Plate 7: Flooding along Kenyatta Avenue due to poor drainage



Plate 8: Flooding along Uhuru Highway

Using GIS, a contour map for the study area was generated and is shown in Figure 9. The area is generally flat, with the highest point being 1684 meters and the lowest being 1659 meters above sea level. From the contour map, in areas where they are closer together, it means the area is steep but where the contour lines are far apart, and the area is gently sloping.

Figure 10, shows the digital elevation model that informs the modeling of water flow to aid in improving the drainage of the area. From the map, the areas with high elevations are represented by the green color range and those with lower elevations are represented by the red color. This means that the direction of flow should be from the northern part of the area towards the south. However, in some cases, the streets like Haile Selassie, Kenyatta Avenue, and Uhuru highway where the area in the middle is higher than either side of the streets, is to be taken note of and proper considerations are taken to ensure effective drainage systems are put in place to avoid flooding as is the case at the moment.

Figure 11, shows the slope analysis of the study area, with the dark green color representing areas with a gentle slope, and the dark red symbolizing a steep slope. From the map, the study area in most parts is gently sloping, with the steep areas being along Haile Selassie and the region between Kenyatta Avenue and the City Hall Way.



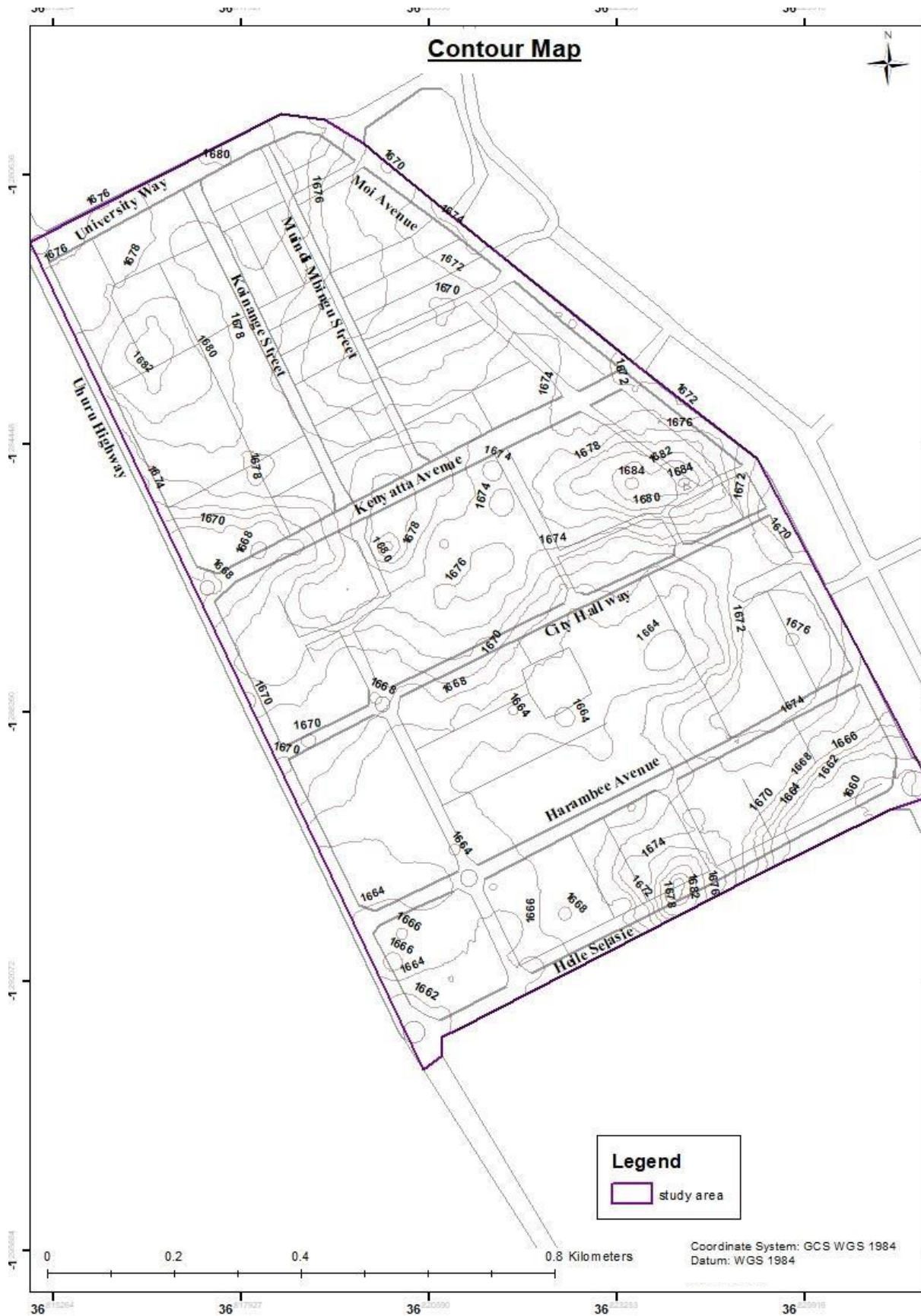


Figure 8: Nairobi CBD Contour Map

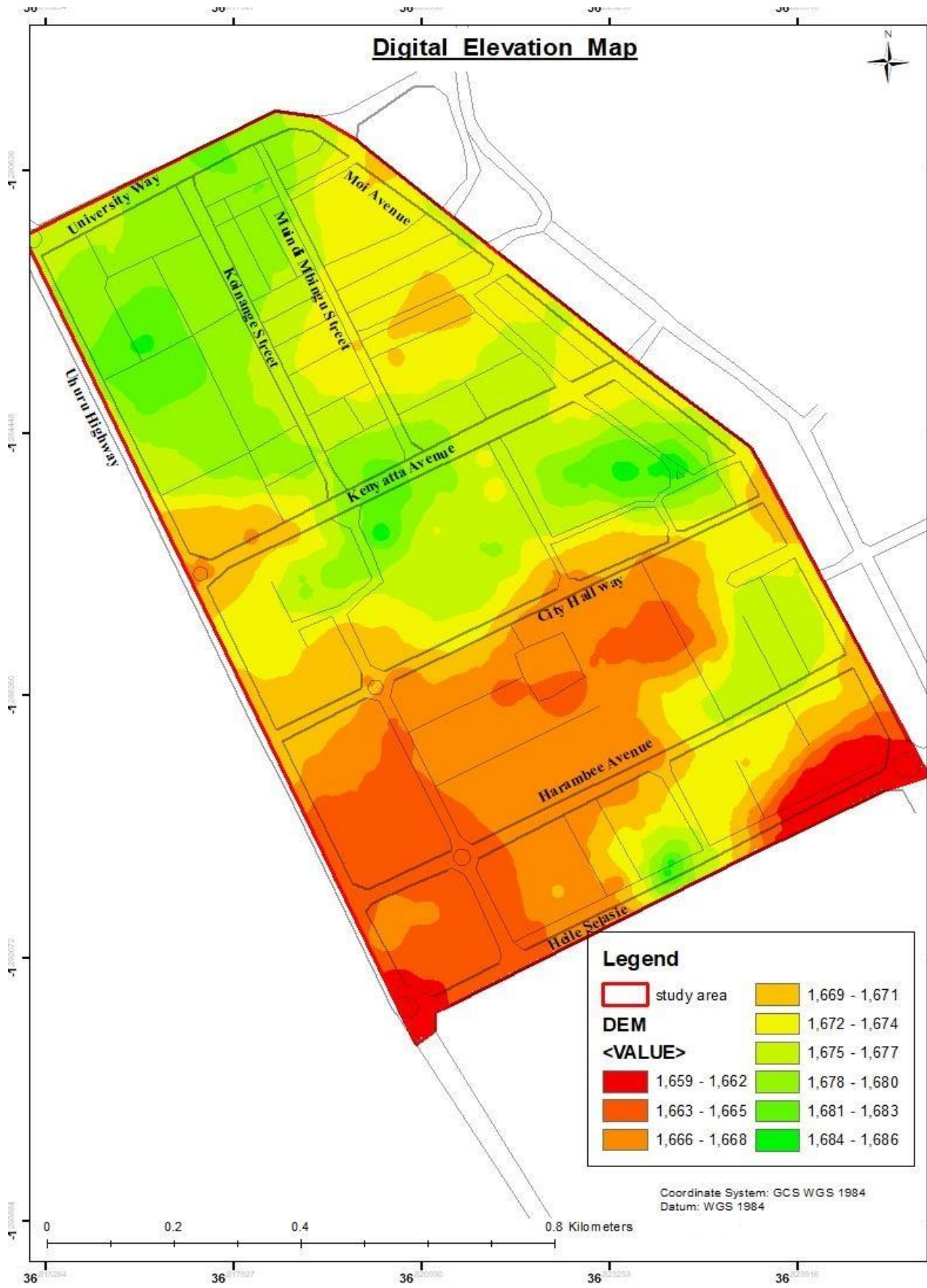


Figure 9: Nairobi CBD DEM



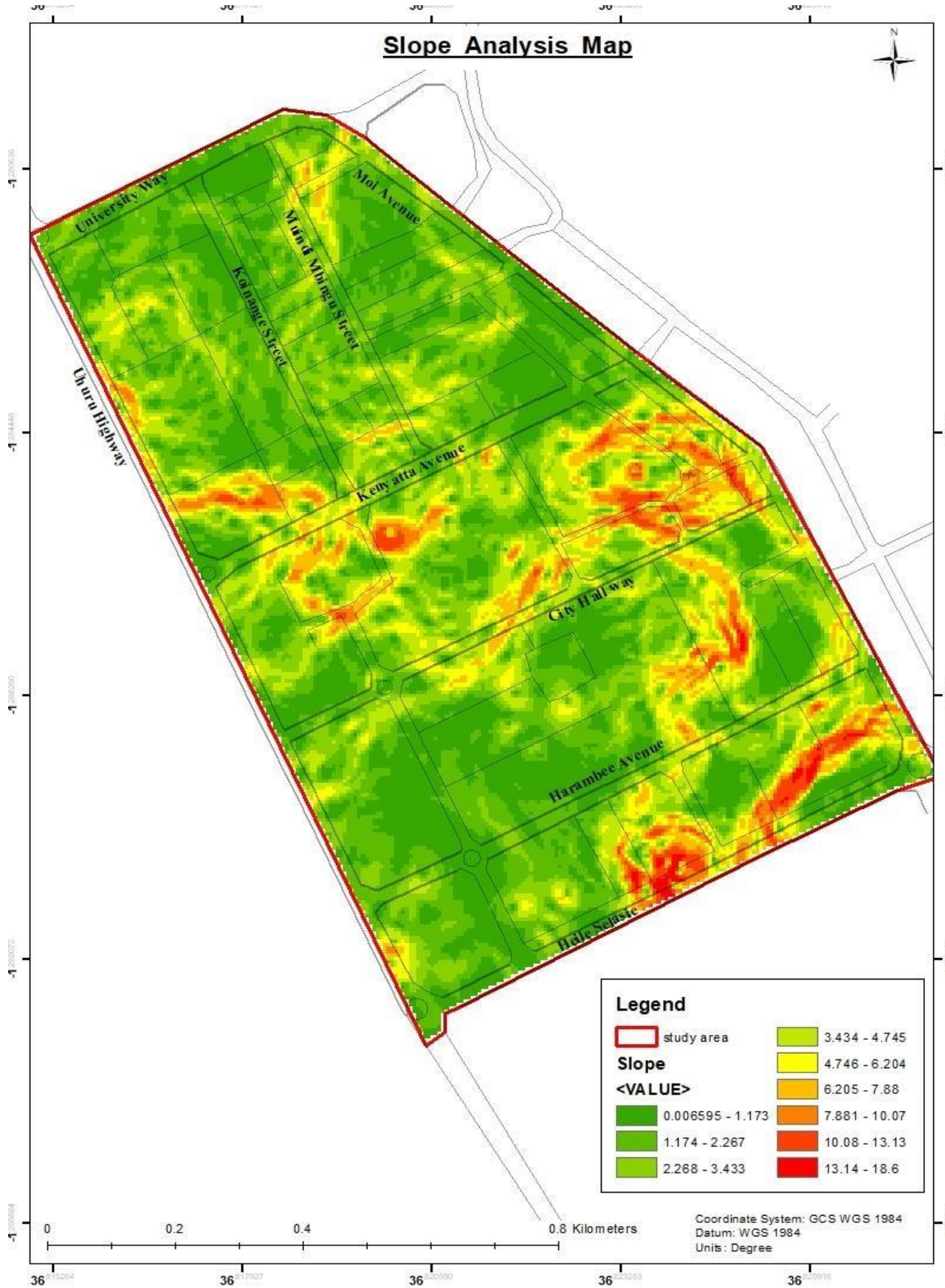


Figure 10: Nairobi CBD Slope Analysis

## **4.2 Impacts of Traffic Congestion in Nairobi's CBD**

### **4.2.1 Economic Impacts**

Traffic congestion leads to increased travel time, which in essence increases the amount of time people spend on the road while accessing their places of work, or even delivering goods and services. The same is experienced in Nairobi CBD, where most people getting into the city for the sole purpose of going to work every day. The more time spent away from their work place, the more losses they experience, hence the productivity is low. In the long run, the cost of doing business is higher than the income generated, which ends up affecting the entire revenue generation for the County of Nairobi and the individuals themselves.

Increased travel cost on the other hand is as a result of passenger vehicles transferring the loss to the passengers, which also affects their daily income. Not to mention the wear and tear caused on the vehicles and the road infrastructure ends up making the government to allocate more funds to repair the roads and for the individual car owners to spend their resources on repairing their vehicles. Therefore, in a nutshell, the adverse effects of traffic congestion generally affect the entire economic sector as well as the individual incomes of the residents.

### **4.2.2 Environmental Impacts**

Traffic congestion at arterial intersections and freeway bottlenecks degrades the air quality and threatens public health. Vehicle emissions have become the dominant source of air pollutants, including greenhouse gas (GHG), carbon monoxide (CO), volatile organic compound (VOCs), nitrogen oxides (NO<sub>x</sub>), particulate matter (PM), and polycyclic aromatic hydrocarbons (PAH). As of the high concentration of air pollutants adjacent to the freeways, the drivers, commuters and individuals living and working near these major streets appear to have an excess incidence of air pollution associated morbidity and mortality, including higher rates of asthma, cardiovascular disease, pre-term and low-birthweight infants, childhood leukemia, and premature death. Traffic congestion brings up a situation where there are many vehicles in a particular location, hence too much emission of these air pollutants. Without intervention, this affects the general health and well-being of the city occupants.

Noise pollution on the other hand is also a major impact of traffic congestion, which ends up disrupting other activities, especially since major offices and businesses are located in the CBD. This situation is unattractive to the investors and they end up going for quieter locations.

### **4.2.3 Social Impacts**

When there is so much commotion from the traffic congestion, drivers are stressed as they try to maneuver to make more trips, that would earn them more income. This leads to the road rage that is witnessed and the adverse effect is accidents that could have been avoided. The decreased mental satisfaction is also not good both for the drivers and the pedestrians. As observed, street vendors encroach travel ways often times and this causes instances of chaos and rivalry between them and the drivers

## **4.3 Use of GIS in Mitigating Traffic Congestion in Nairobi CBD**

### **4.3.1 Monitoring with GIS**

GIS represents the modern entry of multi-disciplinary fields in subject areas like computer science, surveying, geography, and cartography into statistical analysis and the management of transportation systems. A large database can efficiently be rendered using GIS and data from disparate sources can be integrated. With monitoring, it is possible to properly signal control busy streets.

For instance, if Kenyatta Avenue shows to be having high congestion at a particular time, then to reduce congestion on the street, traffic can be diverted from getting to this street and signaling it to adjacent streets such as Moi Avenue and Uhuru highway that may be having low congestion. Through monitoring, it is therefore possible to understand the right timing and how to effectively control signals hence decongesting traffic.

The study has also identified various friction points along the streets and some of the activities that cause this friction such as street vending. With a monitoring tool, these activities can be easily monitored, to ensure travel ways are not encroached and that traffic officers are distributed evenly within these areas to ensure the set regulations are followed and offenders apprehended on time.

### **4.3.2 Routing with GIS**

Timely decision making is crucial when it comes to management of traffic in a large city like Nairobi. What GIS provides, is real time information which then facilitates faster response. Roads and traffic information is crucial data and road traffic managers normally organize this information and compile it on a table so as to perform statistical analysis. This is integrated with the spatial data and with spatial analysis, then it is possible for a GIS application developed to start responding to various events, evaluate impact and answer the best route for the road users.

This is possible with the Nairobi CBD, where public vehicles can now be installed with an application that will give them real time traffic congestion situation on the streets and give them alternative routes to use. This will be different from the usual google earth, in that the drivers are able to perform functions such as querying on the condition of the roads, as well as the available parking space available along the street. GIS being able to integrate all this information in on database will ensure all these factors that would cause congestion are factored in before advising on the best route to use.

#### **4.3.3 Congestion Spots Reduction**

GIS is one of the powerful tools for analysis the spatial and attribute data for effective traffic management. Regional planning is essential for proper transportation management. GPS data was used to identify the spatial location of traffic congestion and other location based spatial information. One of the useful GIS functions to be used for this purpose is known as shortest path. It refers to the process of creating a map of the shortest path from one point to another. The GIS tool requires that the user should have road direction table containing a list of directions stored as a database table as well as a set of reference data such as roads on which the addresses can be located. This can help in Reducing the congestion spots on the roads by providing the shortest and easiest part to the user.

GIS has a wide variety of applications in road traffic direction and traffic planning in transportation networks. It is a bonus to all sorts of traffic direction; the blending of GIS with other schemes is perhaps the best principal potential for the expectations of GIS. The priority results are utilized in evaluating congestion points according to roads direction.

Parking space has been seen to be a critical issue within Nairobi's CBD, as the slots allocated have become less than the demand due to high number of vehicles getting into the city. This has led to cases of parking on undesignated areas which causes traffic congestion. In other cases, drivers maneuver the streets trying to find slots, hence more congestion within the streets. A proper GIS database for monitoring will inform on the streets to allocate more parking slots, that is where there is less traffic. For streets identified to be facing higher congestion, traffic slots are minimized.

The same can be applied to monitor and control the designated bus stages, such that the spaces allocated are sufficient to hold a particular number of vehicles at a certain time as well as

## **CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS.**

### **5.1. Conclusions.**

The objectives of this research study were to, identify the causes of traffic congestion in Nairobi's CBD, to evaluate the impacts of this traffic congestion, and to finally provide relevant recommendations on the use of GIS in mitigating traffic congestion in Nairobi CBD. These objectives have been achieved and it is concluded that;

- The friction points along the streets studied were as a result of, on-street parking, street vending and undesignated bus drop-offs, which were the main causes of traffic congestion.
- Moi Avenue and some parts of Kenyatta Avenue were found to be populated by most street vending spots, which contributed to slow traffic.
- Poor drainage is another contributing factor to the traffic congestion, as roads flood during the heavy rains.
- The location of some of the land uses adjacent to the major streets attract heavy traffic, which slows down traffic.
- Traffic congestion within the CBD, negatively impacts the environment through air and noise pollution from the vehicles.
- Increased travel time and travel cost lead to an increase in cost of doing business, which eventually slows down economic growth.
- A GIS database consisting of data from various sources when used to guide routing, and monitoring the streets, and the general development of Nairobi CBD, would effectively reduce traffic congestion.

### **5.2. Recommendations.**

From this research study, it is then recommended that;

- A similar study be extended to other cities in the country, such as Mombasa, Eldoret, Nakuru and Machakos which face a similar problem of traffic congestion.
- Further research to be carried out focusing on the greater metropolitan area. All roads are connected and activities that may cause traffic congestion within the metropolitan areas, will end up affecting the traffic in the CBD.

- Combining traditional maps and web-mapping is recommended as it will ensure information dissemination, making data available to various organizations that have taken interest in solving traffic congestion in Nairobi County CBD.
- Proper measures to enforce traffic regulations, and good conduct within the roads. Much could be done technically to reduce traffic congestion but all efforts would go to waste if there are no proper polices to instill discipline within the roads.



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