UPGRADING LUNGA LUNGA- LIKONI JUNCTION TO AN INTERCHANGE- CITY COUNTY OF NAIROBI

BY

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DECLARATION

This dissertation is my original planning development project work and has not been presented for a degree in any other University.

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This dissertation has been submitted for examination with my approval as a University supervisor.

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DEDICATION

I dedicate this project to my beloved parents Mr and Mrs John Nguthuku. Special dedication to my siblings Loise, George, Fred and Mary for their moral support in my undertaking of this project.

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ABSTRACT

Lunga Lunga road experiences traffic congestion which have become perpetual due to some factors listed in chapter one of this project i.e. Narrow road, poor configuration of junctions, pedestrians walking on the carriageway, malfunctioning railway line. The effects of the jam manifested itself in the form of delays, fuel consumption and pollution. This project thus develops a traffic interchange on Lunga Lunga- Likoni Junction to ensure that is no more traffic conflicts and vehicular queuing along this road. The designs on these project aims at solving this problem by finding a long term solution. The designing of this interchange is in line with the project objectives that will lead to its implementation. After evaluation of alternatives the designer opted for the appropriate design that would conform to the site and help solve traffic congestion. The design process entailed a series of steps including problem identification, situational analysis, and design of alternative proposals and choice of the preferred alternative. A detailed framework for project implementation, monitoring and evaluation is also included in the report to help guide the implementation of the project as stipulated in the objectives.

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LIST OF ACRONYMS

CBD- Central Business District.

CCN- City Council of Nairobi.

EMCA- Environmental Management and Coordination Act.

GDP- Gross Domestic Product.

GIS- Geographical Information System.

GoK- Government of Kenya.

KeNHA- Kenya National Highways Authority.

KURA- Kenya Urban Roads Authority.

NEMA- National Environment Management Authority.

PSVs- Public Service Vehicles.

CHAPTER 1: INTRODUCTION

1.1 Statement of planning research project

A study of vehicular traffic congestion along Lunga road- Nairobi.

1.2 Summary of main findings

1.2.1Narrow carriageway

The road is a two way traffic which has 9m carriageway. According to the field survey this road being a collector street should be wider since it conducts more vehicles. This narrow carriageway causes traffic congestion at peak hours to queue at one side of the road especially at junctions where vehicles have to wait for the others to pass so that they can proceed. According to industrial planning standards an industrial collector is designed to conduct 1000- 8000 vehicles a day hence it should be wider than 9m due to presence of heavy commercial vehicles. This is evident that this does not meet the required planning standards.

The road is narrow it has not matched the increase in traffic volumes as urbanization increases this has resulted in the vehicles outstripping the road capacity. This is evident since the number of vehicles that use this road are many. This is the spill over of traffic congestion of Jogoo road. The road therefore is not able to conduct the high volume of traffic since it does not match the urbanization and development taking place. The road is still the way it was planned to handle the traffic decades away and traffic generated currently is more than earlier planned hence its outdated.

1.2.2 People walking on the carriage way.

Pedestrians usually walk on the carriageway during the rainy season. The walkways are not paved hence they are muddy when it rains. People walking on the carriageway during the wet season results in the worsening of traffic congestion along Lunga road since it results to completion of space use by both the vehicles and the motorists. This leads to lessening of the space left for the vehicles to operate. This creates traffic conflict since the space left for vehicles is not adequate. Trucks also park on the sidewalks leaving no space for walkability especially near Wudanyi Road junction. This leads to people walking on the carriageway since all the path is blocked. The trucks park on the pedestrian walkways thus resulting on the pedestrians walking on the carriageway. This has resulted in the worsening of the congestion along this road. The trucks park along this road since there is no parking facility provided for by the industries. Space use conflict manifests itself in the pedestrians using walkways when it is rainy. This is a result of unpaved pedestrian walkways.

1.2.3 Poor design of the junctions

There is poor design of junctions along Lunga Lunga Road. Junctions usually are both T and cross junctions. Which results in conflicts when trucks are turning. Likoni Road junction forms a T- junction with Lunga Lunga Road and this is where most respondents said vehicles queue a lot waiting for others to pass. This makes the vehicle to form a long queue thus contributing to congestion. The other junctions filtering traffic to these roads form cross junctions and when vehicles are turning there is conflict. The junctions are not controlled by traffic lights hence vehicles enter the main road inconveniently. The junctions contribute to

traffic conflicts at their intersections which leads to vehicles overlapping as they join Lunga Lunga Road.

Also, given that vehicles from various roads i.e. Mogadishu, Wudanyi and Lunga Lunga roads) exceeded the capacities of these access roads and so when they met at the junctions, for one road to be cleared, those waiting on the other roads queued and took so long.

1.2.4 Increase in number of vehicles.

Increase in the vehicles is also a cause of traffic congestion along Lunga Lunga Road. This was attributed to the increase in private vehicles and public transport vehicles operating along this road. Most people said that all vehicles contribute to this problem. This is evident since the population of Nairobi has been increasing hence leading to an increase in demand for road transport.

The increase in the number of vehicles is a result of vehicles using this road as an alternative to Jogoo Road. This results to high volume traffic which uses this road. This has resulted to the spill over effects.

They occur when vehicles use a corridor as alternative to others so as to avoid traffic snarl ups on a particular road. Traffic congestion along Jogoo Road has also worsened to the congestion along Lunga Lunga Road due to the above factors

1.2.5 Private vehicles

The influx of private vehicles has contributed to worsening of traffic congestion. Most people said that private vehicles cause traffic snarl ups along this road. This may be attributed to the number of the people moving from the city centre to the adjoining residential areas. This vehicles use this road as an alternative to Jogoo road in evasion of traffic congestion which is also common along Jogoo road. This has resulted to the spill over on this road. Responses from field survey prove that private vehicles are on the causes of traffic congestion along Lunga Lunga Road. This picture shows private cars along Lunga Lunga Road.

Private vehicles cause traffic congestion in that they do not utilize the line corridor capacity. i.e a car carries on passenger who is the owner. Three cars can occupy the same space occupied by the bus. A bus may carry upto 25 passengers. This means that cars don't utilize the corridor capacity of the road hence they use more space contributing to congestion.

1.2.6 Trailers/ oil trucks

Trailers and oil trucks also contribute to the problem of traffic since they hinder smooth traffic flow of the other vehicles. This is because the trucks are loaded and move slow thus worsening this problem of congestion. Most of this trucks come from industrial area and Jogoo Road. Oil trucks originate from the KPC depots North of Lunga Lunga Road. They normally cause conflicts when they are joining the main road. This is attributed to the turning of the trucks as they manoeuvre their way in the traffic. The pictures below shows trucks on the road and trucks originating from KPC depots. 7% of this people said that this is a cause of traffic congestion a long Lunga Lunga too.

1.2.7 Lunga Lunga-Likoni Road junction

This junction is a T- junction where traffic from various origins converge. This creates problem since there are too many vehicles that queue on Lunga Lunga road to allow others to pass. According to the field survey conducted the researcher found that this is a major

bottleneck of the traffic flow. The configuration of the junctions usually affects traffic flow on given roads. T- Junction is usually seen as bottleneck since vehicles have to wait others to pass so they can proceed. This junction creates a conflict also since it is not controlled by traffic lights. Traffic generated within the industrial area and Donholm usually converge here. The queue waiting the ones on Likoni Road to pass. This shows that the junction is inefficient in interchanging traffic from the both roads that form the junction. The junction should be upgraded to interchange to enhance smooth traffic flow.

This is in relation to junction systems bus stops and interchanges. There are many junctions along Lunga Lunga road for instance were also found to be contributing to the impeded traffic flow. All these junctions channelled traffic from various directions into already congested inadequate Lunga Lunga road. Moreover, while the traffic joined the main road, they tended to cause the approaching vehicles to stop, hence reduced flow. Also, given that vehicles from various roads i.e. Mogadishu, Wudanyi and Lunga Lunga roads) exceeded the capacities of these access roads and so when they met at the junctions, for one road to be cleared, those waiting on the other roads queued and took so long.

1.2.8 Decayed railway line.

The railway line was constructed to serve the heavy industries so as to ferry goods interdependently with the road network. However the railway has collapsed due to the managerial problems leading to the increase in use of road transport. The railway line serving this industries is not operational hence contributing to the transportation of goods via the road network. according to the observations made by the researcher lack of operational railway line in this area has contributed to traffic congestion. This is evident since all goods from this place are transported via the road. This was not the planned traffic by the 1948 master plan which set out the guidelines for the industrial district. The roads in the industrial area especially heavy industrial district were planned to be interdependent with the railway line.

This has led to the transport of goods via the road transport thus contributing to the traffic congestion. This was not the planned traffic by the 1948 master plan which set out the guidelines for the industrial district. The roads in the industrial area especially heavy industrial district were planned to be interdependent with the railway line. This factor has contributed to worsening of congestion. Industries transport goods via the road network since the railway is not operational.

1.2.9 Effects of traffic congestion

Delays

Traffic snarl-ups are said to be the source of delays for the travellers. 64% of the respondents said that congestion had an impact on them on the travel time. It resulted in lateness in arriving at work places and residence too. This created a situation where the road users are unlikely to predict the time travels due to this anomaly. Congestion also impacts on the delivery of goods to their destination which affects the time they are supposed to reach their destinations. Vehicles spend some hours in the jam thus delaying to deliver their goods in time.

Delays leads to the loss of time due to the people spending much time on the road other than engaging in other productive activities. According to the survey conducted most people said that this is one of the effect of traffic congestion along this corridor. Traffic jam also reduced accessibility through impacting on the travel time. Since accessibility is measured on how a

place is reachable in relation to the time aspect. This makes a place in accessible when the traffic congestion sets in mostly in the peak hours.

Fuel consumption

Most motorists complained this as another effect of traffic congestion. They said that their vehicles use more fuel in traffic jam compared to when there is no jam this leads to extra operational costs of the vehicle. In Matatus there is variance in bus fare due to this anomaly in which the fare rises from 10 Kshs – 40 Kshs per ride or 50 Kshs sometimes. This leads to a conclusion that congestion is expensive hence it impacts on the economy directly.

Traffic congestion triggers more fuel consumption due to the slow movement of vehicles. This is because vehicles suddenly accelerate and stop due to the traffic snarl-ups. The fuel consumed is twice compared to when there is no traffic jam this is due to the slow movement of traffic in a congested road.

Pollution

Vehicles pollute most when they are stationary and the engine is running. The air pollution occurs through emission of SO_2, CO, CO_2, N_2O and NO_2. These gases are detrimental to both human and natural environment. They contribute to the formation of acidic rains and depletion of ozone layer. Some of the gases above are said to cause fatal diseases to human beings.

Loaded trucks emit a lot of smoke when they are stopping and moving slow due to sudden acceleration and stops. Some people said they were affected by environmental pollution around this place which worsens due to emissions from heavy industries adjoining the road.

There is production of noise from the vehicles as they are taking off and stopping suddenly. Noise comes from hooting by the frustrated drivers on the road.

Pollution is usually experienced in this area due to the heavy industries but it worsens due to the traffic congestion which causes vehicles to emit more smoke.

1.3 Summary of main recommendations

1.3.1 Short term recommendations

Expanding the road to a dual carriageway

The road should be upgraded from single carriageway to dual carriageway this will help in accommodating the excess traffic thus solving the problem of congestion. The road currently is a single lane hence it should be upgraded to a double lane carriageway. This will assist in the smooth traffic flow of the vehicles by accommodating excess vehicles. This will help balance the demand and the supply thus solving the problem. Expansion of the road has been used as a remedy in many countries to solve the problem of traffic congestion since it increases the road capacity to accommodate the increased number of vehicles.

Install traffic lights on main junctions for controlling traffic

This will help in the controlling of traffic from the junction which is joining the main road. However this is dependent on the compliance and behaviour of road users. Traffic lights should be installed at the main junctions so as to reduce conflicts level on the main road. This is a short term recommendation which helps to maintain smooth traffic flow along main roads while maintaining effective filtering from the junctions.

Paving pedestrian walkways
Sidewalks should be paved so as to as to contain the pedestrians on the walkways. They walk on the carriageway when it's raining since the sidewalks are muddy. The pedestrian walkway in the study area should be paved so as to promote pedestrian safety while maintain smooth traffic flow. This will ensure that there is no traffic conflicts with pedestrians. Paving the walkways will restrict pedestrian movement on the sidewalks thus solving this problem when it's rainy.

1.3.2 Long term recommendations

Revitalization of the railway serving heavy industries
Railway revitalization will promote movement of goods via the railway line thus reducing the demand on road infrastructure. Railway which serves this industries is not operational hence industries opt to ferry their goods via road transport this in turn contribute to the congestion. Railway revitalization will make industries shift to rail transport as an alternative to the congested road. Railway will reduce the overreliance on the road transport by transporting some goods on it. This will ensure that these modes of transport are interdependent thus helping to solve congestion in the long run.

Designate a parking lot for trucks
Trucks usually park on sidewalks which makes pedestrians walking on the carriageway. This results to further motorist- pedestrian conflict. Parking space should be identified and designated so as to move the trucks from these walkways. Trucks usually park along the sidewalks as they wait to be loaded with cargo.

Redesign Likoni road- Lunga Junction to an interchange
This junction is a T- junction it should be redesigned so as to promote smooth traffic flow. This junction results in vehicles queuing for a long time waiting for the others to pass this results in traffic snarl ups. This leads to vehicles slowing down and stopping for a longer period of time. This contribute to this problem. The junction should be upgraded so as to promote free and uninterrupted vehicular flow. The T- junction should be upgraded to a traffic interchange so as to enhance efficient traffic flow in different directions along this roads. Traffic interchange conducts traffic in different directions without impending on traffic flow on the main road through queuing.

Provision of truck lanes
This is providing truck lanes by segregating trucks from the rest of traffic some lanes are reserved for these vehicles so as to ensure they are not stuck in traffic in peak hours. The truck lanes are separated from the main carriageway by a curb or a median. The lanes can also be separated by lane markings on the road. This will ensure that traffic congestion will be reduced in the long run.

1.4 Development title chosen for implementation

Upgrading Lunga Lunga- Likoni junction to an interchange

1.4.1 Reasons for choice of development

The justification of these project is Likoni- Lunga Lunga junction is the main cause of traffic congestion in Lunga Lunga Road. It needs to be upgraded to an interchange to promote smooth flow of traffic in Lunga Lunga Road

This road is used an alternative road to Jogoo road which is already congested. Vehicles using this road will continue increasing as problem along Jogoo road persists.

Interchanges are more efficient in filtering traffic from the roads connected to them. They ensure there is smooth traffic flow of traffic without conflicts around the junctions. This will reduce traffic congestion on these road and support the increasing number of traffic on this road. Adverse effects on the climate will reduce such as air pollution thus promoting a clean healthy environment around this place.

There is commercial facilities located along this road. This will ensure reduced travel time hence promoting businesses along this road. This will ensure that goods and human labour arrive at the work place in the appropriate time and vice versa. This will be good for the economy since traffic congestion wastes a lot of time.

1.4.2 Location and coverage of the development project

The project is located within the industrial district of Nairobi which lies at latitudes -1.311679N, 36.871038E. The project are lies where Lunga Road Starts at Likoni Road Junction. This road is located in the north of industrial area and traverses across the industrial area.

1.4.3 Area coverage of the project

The project site covers an area of 74400m2 (7.44Ha). The area is owned by the Nairobi City County and private owners. There will be need to acquire land for the construction which will be followed by compensation.

1.4.4 Objectives of development project

1. To determine suitability of proposed site for Likoni road- Lunga junction
2. To review and propose the relevant planning and design standards guiding a traffic interchange.
3. To develop a site plan for Likoni Road- Lunga Lunga junction
4. To propose project's implementation, monitoring and evaluation framework and institutional structure for upgrading of Lunga Lunga- Likoni road junction geared to alleviating traffic conflict and congestion.

1.4.5 Assumptions

The assumptions of these project are:

Population of Nairobi will continue increasing due to the increasing rate of urbanization hence this population will keep on putting pressure on existing road network.

Traffic congestion on Lunga Lunga Road will continue increasing unless the core problem is solved which is the junction. This is the main cause of traffic congestion according to field study conducted is this junction which causes traffic conflict and vehicular queuing.

There is redevelopment occurring along this road and this will increase traffic generation within heavy industrial zone. There is commercial activities that are being incorporated within the industries like the supermarkets and restaurants. This will lead to increase in road usage thus worsening the situation if no measures are put into place.

1.4.6 Scope of development project and organisation chapters.

The project aims at developing an interchange design model for smooth traffic flow and circulation at Lunga Lunga- Likoni Road Junction. The project will be organized as follows:

Chapter one:

This chapter consists of the title of the research project, summary of the main findings, and summary of main recommendations. In this chapter there is the title of development project chosen for implementation, reasons for the choice, location and coverage of development project. The chapter basically outlines the transition from the research project to the development project which is derived from the recommendations.

Chapter two:

This chapter consists of relevant policy guidelines that inform this development project. They include relevant policy guidelines and design standards.

Situational Analysis:

It contains comprehensive site analysis of the study area.

Project planning and design

This entails plan design formulation process, design development, choice of preferred strategy and spatial drawings.

Monitoring and evaluation

This is the monitoring and evaluation of the project which consists of site management plan.

1.5 Research methodology

Data needs and requirements

The information that was required in this project was on policy and legal guidelines which comprised of zoning regulations and international design standards; planning standards for various land uses, lessons from relevant case studies; location and historical development of the project area physical and environmental characteristics of the area, population and demographic characteristics of the area and land use patterns of the project area.

Data sources

The data was obtained from both primary and secondary sources. The physical and environmental characteristics of study area were gathered through site analysis. The other data was sourced from various secondary materials. The major policies that were reviewed were Kenya Vision 2030, National Urban Development Draft Policy (2012), the Kenya Integrated Transport Draft Policy (2009), National Land Policy (2009) and the Nairobi Metro 2030 (2009).

The legal framework were the Kenya Constitution (2010) and the relevant Acts of Parliament. The Acts included Local Government Act (Cap 265), Physical Planning Act (1996), Urban Areas and Cities Act (2011), Devolved Government Act (2011), Environmental Management and Coordination Act (1999) and the National Land Commission Act (2012).

Planning standards obtained from Physical Planning Handbook (2008), the A.J. Metric Handbook and the Building Code.

The population and demographic information was majorly got from the Kenya National Housing and Population Census Report (2009).The rest of the information was obtained from various books and internet.

1.5.1 Methods of data collection

Primary sources

Interview schedules
Interviews were conducted one on one to the motorists to establish the root causes of traffic jam and traffic conflicts.

Photography
The photography captured the situation in the study area in relation to the traffic congestion phenomenon. The areas captured in the photographs were the adjacent developments. The nature of the congestion configuration of junctions and on street parking

Field sketching
The researcher drew various sections of the road and the adjacent land uses to provide an insight to this development project. They includes cross section of the road reserves, configuration of junctions and conflict sections.

Observation
It involved capturing the variables and writing them down in an observation list. Some of parameters that were observed included size of carriageway, modal splits, configuration of junctions, road user behaviour adjacent land uses and the railway line. This gave the researcher first hand info on the road parameters

Secondary sources

This was mainly done through reading of books, journals, periodicals, previous research works in the library. Internet sources were also used by the researcher to guide on the development project. Design and planning standards were also used by the researcher to guide on the implementation of these project.

Data analysis and presentation

Data analysis- data collected was cleaned and synthesized to arrive at findings.
There were two forms of data that were analysed they included both qualitative and quantitative data. This two form of data were analysed in two different ways.
Quantitative data was analysed using Social package for Social Scientist (SPSS) and Microsoft Excel application in the computer which led to formulation of research findings.

Qualitative data was analysed through a clear thought process. The researcher also analysed the spatial data using GIS mapping tool

- Data presentation- the analyzed data shall be presented in the form of pie charts, bar graphs, tables and maps.

Limitations
The researcher experienced time and financial constrains

Reluctance of the respondents to avail the required information.

Project objectives	**Data needs**	**Uses of the data**	**Source/Subjects**
To determine suitability of proposed site for Likoni road- Lunga interchange	Field survey Policy review Case studies	To access if the site earmarked for this project is appropriate. To identify the parameters needed to be incorporated in the design process	Site analysis and observation
To review and propose the relevant planning and design standards guiding a traffic interchange	Policy review Case studies	To guide the designing and implementing of the project	International design standards
To develop a site plan for Likoni Road- Lunga Lunga junction	Field survey Policy review(relevant acts design standards) Case studies	Understand site parameters Apply the lessons learnt from the case study in the study area.	Physical planning handbook Site analysis and researchers observation
To propose project's implementation, monitoring and evaluation framework and institutional structure for upgrading of Lunga Lunga-Likoni road junction geared to alleviating traffic conflict and congestion	Literature review Case studies	To ensure the project follows the recommended design standards and in line with the existing legal framework Assigning responsibilities in the implementation and monitoring framework appropriately	Constitution Acts of Parliament and national policies -Physical Planning Handbook Past interchanges that have been implemented and have been successive.

Table 1: Data needs Matrix

Source: compiled by Author

1.6 Definition and key operational terms

Traffic

This is the movement of goods, people and vehicles using various modes it usually manifests itself in terms of volume and generation.

Traffic flow

This is the study of interactions between vehicles, pedestrians, drivers, and the road. This aims at providing a road to enhance smooth traffic flow.

Collector Street

This is a road that conducts traffic from access roads before their capacity is exceeded. Collector Street links them to arterial streets which later conduct them to urban highways.

Pedestrian walkways/ sidewalks

The width of the road usually reserved for movement and which is restricted to vehicles. The y are usually located on the both sides of the carriageway.

Traffic congestion

This is a condition where demands exceed supply in a road. This is usually characterized by vehicular queuing where traffic stops for a long period.

Carriageway

This is the width of the road in which the vehicles operate and not restricted.

CHAPTER 2: LITERATURE AND POLICY REVIEW

2.1 Kenya Vision 2030.

This is a new National development strategy that was developed for the period of 2008-2030. It aims at developing the Kenya Economy and Employment levels by the year 2030. Its goal is to transform Kenya into a newly industrializing, middle income country providing a high quality of life to all its citizens in a clean and secure environment. The vision targets to attain MDGS that were given a time limit to 2015.The vision has three pillars: Economic, social and political governance. Economic pillar aims at achieving an economic growth rate of 10% per annum. This vision has flagship projects to address the same which are in various sectors such as agriculture, education, water and environment. The vision envisages a country firmly interconnected through network of roads, railways, ports, airports and waterways. It envisages that by 2030, it will become impossible to refer to any region of the country as remote and so the focus would be on investing in the nation's infrastructure.

For Kenya to achieve a middle economy status it has to invest in its road network that conforms to article 70 of constitution on environmental issues and article 43 on economic and social rights among others by following these actions:

- To upgrade road links in order to reduce traffic congestion and improve accessibility and mobility to cope with increasing road traffic
- To expand the road network by construction of new roads
- To construct to paved standards all economically viable major urban arterials.

2.2 Millennium Development Goals

The eight Millennium Development Goals (MDGs) provide a framework to plan and implement development, and include time-bound targets and indicators by which progress can be measured over the period from 1990 until 2015 when the targets are expected to be met. Particular interest is given to the goal number seven which is to ensure environmental sustainability. Target seven aims at integrating the principles of sustainable development into country's policies and programmes and reduce loss of environmental resources. The development project will take into account these principles and will ensure that the sources of the materials used do not hamper environmental sustainability.

2.3 Nairobi Metro 2030.

It takes into account that more than 57% of world population will be living in cities hence there will be need for efficient transportation system. It envisages transport as a key component in promoting a competitive business environment as well as a viable means in which other economic and social objectives can be attained. This therefore creates the need for an efficient transport system which minimizes travel times and distance.

Nairobi Metro was formulated in line with the vision 2030 key development agenda which include: rapid economic growth, employment and balanced wealth creation, poverty alleviation. Policy concurs with the fact that efficient transport minimizes travel time. The policy document has measures dealing with transportation:

- Mass rapid transit

- Traffic management structures
- Traffic law enforcement
- Demand management
- Road transportation infrastructure measures.

2.4 Legal framework

2.4.1 Constitution

The Constitution classifies land as public land, private land and community land. The Constitution also gives guidelines on how land is to be used equitable, efficiently, productively and sustainably, Article 60(1). The State is given the authority to regulate the use of land or any interest on or over land as stated in Article 66, for reasons as defence, public safety, public order, land use planning, public morality and public health. The Constitution states that all land in the country belongs to the state therefore any mineral within Nairobi is owned by the state.
The Constitution also requires that there is environmental conservation without which there would be legal consequences.

The constitution stipulates that all Kenyans with any disability are entitled to reasonable access to all places, public transport and information. This implies that traffic congestion must be alleviated in order to promote accessibility. Traffic jams impedes accessibility.

Draft Integrated National Transport Policy Of 2003
The transport policy provides strategies that can be used to manage transport planning in the country to facilitate movement and accessibility. This policy provides guidelines on the linkages that should be established in the country.it aims at providing integrated, efficient, reliable and sustainable road transport infrastructure that meets national and regional passenger and freight transport goals. Its envisions a transport system that is effective and efficient in which there is a faster flow of goods and people while being environmentally and economically sustainable.

2.4.2 Physical planning Act Cap 286 1996

The physical planning act states that:

The Director may prepare with reference to any Government land, trust land or private land within the area of authority of a city, municipal, town or urban council or with reference to any trading or marketing centre, a local physical development plan.
A local physical development plan may be a long-term or short-term physical development or for a renewal or redevelopment and for the purpose set out in the Third Schedule in relation to each type of plan.
The Director may prepare a local physical development plan for the general purpose of guiding and co-ordinating development of infrastructural facilities and services for an area referred to in subsection and for the specific control of the use and development of land or for the provision of any land in such area for public purposes.

This act gives power to the local authorities' currently county governments to:

Prohibit or control the use and development of land and buildings in the interests of proper and orderly development of its area;
Control or prohibit the subdivision of land or existing plots into smaller areas;
To consider and approve all development applications and grant all development permissions;

To ensure the proper execution and implementation of approved physical development plans;
To formulate by-laws to regulate zoning in respect of use and density of development; and
To reserve and maintain all the land planned for open spaces, parks, urban forests and green belts in accordance with the approved physical development plan.

2.4.3 Environmental Management and Coordination Act (1999)

It establishes an institution responsible for the safeguarding the environment. It states that every Kenyan is responsible to healthy and clean environment.it states that Environmental Impact Assessment must be undertaken on the earmarked area of the project. These projects maybe major

Changes on the land use i.e. construction of roads, buildings, airports and many others

The Act entitles every person in Kenya to a clean and healthy environment and vests them with the duty to protect and conserve the environment. The entitlement to a clean and healthy environment includes the access by any person in Kenya to the various public elements or segments of the environment for recreational, educational, health, spiritual and cultural purposes. The Act, in the second schedule, identifies a number of projects for which Environmental Impact Assessment has to be done before their undertakings. These projects include:

(a) An activity out of character with its surrounding;

(b) Any structure of a scale not in keeping with its surrounding;

(c) Major changes in land use.

The transportation oriented projects include:

(a) All major roads;

(b) All roads in scenic, wooded or mountainous areas and wetlands;

(c) Railway lines;

(d) Airports and airfields;

(e) Oil and gas pipelines;

(f) Water transport

The ACT further establishes National Environmental Management Authority (NEMA) which is the institution mandated to monitor and facilitate the enforcement of the ACT.

2.4.4 Kenya Roads Act Cap 2 2007

It is the act of parliament that provides for the establishment of KURA under section 9. The road act also provides for establishment of Kenya National Highways Authority, Kenya Rural Roads Authority. The act also stipulates the powers of these authorities in provision and maintenance of good road network in their area of jurisdiction. These authorities are supposed to ensure there is a good road network in the country which promotes movement of goods and people.

2.4.5 Traffic Act

This act was formulated to consolidate all the laws relating to traffic on the roads. Section 3 of the act stipulates that there be an appointment of the motor Vehicle Registrar who would be responsible for registration and licensing of motor vehicles. Traffic Act also provides for the licensing of motor vehicles, issuance of driving licenses and it also stipulates regulation

for speeds, driving under influence of drugs, reckless driving, use of proper fuels, obeying signals.

Traffic act part VI relates to regulation of traffic which is vested in the police including the Highway Code. The act also has a provision which states that there be designation of parking facilities which include powers of the local authorities to formulate by laws relating to parking,

Part VII provides for regulations relating to accidents, including power to stop and report accidents. Inspection of vehicles around accident scenes is also provided.

The act is responsible for monitoring all traffic offences on Kenyan roads. Some traffic offences are directly linked to traffic congestion since they trigger non recurrent congestion.

2.4.6 Land control Act

In article 43 of the act which entails the public right of way the commission may create a right of way which shall be known as public right of way.

A right of way created for the benefit of the national or county government, a local authority, a public authority or any corporate body to enable all such institutions, organisations, authorities and bodies to carry out their functions

A right of way created for the benefit of the public.

A public right of way shall attach to and run with the servant land in respect of which it has been created and shall be binding on all owners from time to time of the servant land, any manner they are occupying the land, whether under a land or a derivative right thereof, or under customary law or as a successor in title to any such owner or as a trespasser.

2.4.7 National Land commission Act of 2012

This act establishes the national land commission whose functions are:

Manage public land on behalf of the national and county governments
Recommend a national land policy to the national government
Advise the national government on a comprehensive programme for the registration of title in land throughout Kenya
Conduct research related to land and the use of natural resources, and make recommendations to appropriate authorities
Initiate investigations, on its own initiative .or on a complaint, into present or historical land injustices, and recommend appropriate redress
Encourage the application of traditional dispute resolution mechanisms in land conflicts
Assess tax on land and premiums on immovable property in any area designated by law; and
Monitor and have oversight responsibilities over land use planning throughout the country.

This means that this commission will oversee land use planning throughout the country which includes transportation planning to ease traffic jams and snarl ups. It will also conducted research related to land use which will lead to effective transportation planning. National land commission will be the overall coordinator of planning throughout the country hence planning for all land uses in Kenya.

2.4.8 County Governments Act, 2012

This is an Act of Parliament to give effect to Chapter Eleven of the Constitution; to provide for county governments' powers, functions and responsibilities to deliver services and for connected purposes. It is the legal framework from which county governments are governed and developed.

Part (viii) of the act talks about citizen participation in the county. Section (87b) asserts that citizens should have reasonable access to the process of formulating and implementing policies, laws, and regulations, including the approval of development proposals, projects and budgets, the granting of permits and the establishment of specific performance standards. This as a result ensures that projects in the county are owned by the residents and are not forced unto them. Citizen participation also ensures that priorities of the people are addressed first.

Part (xi) establishes the principles of planning and development facilitation in a county. According to the act, the county planning framework shall integrate economic, physical, social, environmental and spatial planning. Therefore all funds will be disbursed according to an integrated county development plan which every county must prepare. It is important therefore that all spatial plans be in line with the CIDP for it to be implemented with ease.

2.4.9 Roads policy

Road development shall be in accordance with social and economic objectives determined by the government. As traffic on existing network changes, it is necessary to improve the road through upgrading, road widening, junction improvements and new construction. Road development will be focused on improving accessibility, increasing the variety and quality of affordable urban and rural transport and improving accessibility for the development of key economic sectors. In order tom achieve the above the state department responsible for roads shall develop, implement and periodically update a road investment plan.

Department in charge of infrastructure shall be the one in charge of roads so that the planning for roads and other infrastructure can be done in an integrated manner and while acquiring land for physical infrastructure is done holistically for enhanced efficiency.

2.4.0 Land Acquisition Act

This gives the state power to acquire land for any development which will be in the interest of the public (Eminent Domain). In the constitution it is also stipulated that the State may regulate the use of any land, or any interest in or right over any land, in the interest of defence, public safety, public order, public morality, public health, or land use planning.

Part II of the land acquisition Act states that:

The Commissioner may in writing authorize any person, together with servants and workmen, to enter upon any land specified in a notice published under section 3 and to

survey the land and to do all things which may be reasonably necessary to ascertain whether the land is suitable for the purpose for which it may be required.

Where the minister is satisfied that:

the acquisition of the land is necessary in the interests of defence, public safety, public order, public morality, public health, town and country planning or the development or utilization of any property in such manner as to promote the public benefit; and the necessity therefor is such as to afford reasonable justification for the causing of any hardship that may result to any person interested in the land.

2.4.0 Urban Areas and Cities Act NO. 13 0f 2011

This act sets out the criteria upon which urban areas and cities will be established. Part V is about integrated development planning. Section 36 (1) requires that every city and municipality established under this Act shall operate within the framework of integrated development planning. Urban and city planning shall ensure provision of physical and social infrastructure and transportation facilities. According to the act the capital city shall decentralize its functions and the provision of its services to the extent that it is efficient and practicable to do so. Citizen participation is also emphasized through citizen fora. The city or urban area integrated development plan shall align to the county development plans. An integrated urban area or city development plan shall reflect a board's or committee's vision for the long term development of the city or urban area with special emphasis on the board's or committee's most critical development needs. These critical development needs will be arrived at through citizen participation.

2.5 Planning standards of roads (physical planning Hand book)

Wide roads in industrial areas are required to provide easy movement of people and heavy trucks, storm water drainage, conveyance of industrial effluents. Adequate road reserve is required too for laying out subsystems like water mains, electrical cables, gas mains and for curb parking. The following are recommended widths of carriageways:

(a) Major Communication routes (Highways)……...13.5m to 16m.

(b) Spine roads (Major roads) ……. …11.5m to 13.5m

(c) Collector Roads ……...9m to 11.5m

(d) Access streets ……..7m to 8.5m

The above road reserves should take into account provisions for storm water drainage, water mains etc. the following are recommended road reserves:

(a) Major communication routes (Highways) …….60m.

(b) Spine road (major roads) ……...25m.

(c) Collector roads ……18m

(d) Access streets …… ……. ….15m

(e) Service lanes …… ……6m.

Carriageway widths

- Trunk and Major Roads…… 7.5m or more
- Commercial and Industrial Streets……... 7.0m or more
- Spine Roads and Bus Routes……... 7.0m
- Access roads (in residential areas)……..... 5.5m
- Cul-de-sac (not exceeding 60m)…….. 5.0m

The following are the road dimensions according Neufert Handbook.
Bus/ bus- 6.50 m
Lorry/ lorry- 6.25m
Lorry/ car-5.50m
Lorry bicycle- 4.25m
Van/ van -5.45m
Van/ car -5.10m
Van bicycle- 3.85m
Car/ car -4.75m
Car/ bicycle- 3.50m
Bus/ bus -6m
Lorry/ lorry- 5.50m
Lorry/ car -4.75m
Lorry/ bicycle- 4m
Van/ van -4.70m
Van/ bicycle- 3.60m
Car/ car -4m
Van /Car -4.35m
Car/ bicycle- 3.25m

Storm water drainage way leaves

Storm water drains are normally located on the road reserves for collecting the runoff from the carpeted road surface. They should be provided where annual rainfall exceeds 200mm with a minimum of 2m provided for each facility.

Table 2: storm water drainage way leaves

Source: physical planning Hand book

Facility	**Preferred Way leave**
Drainage way leaves	3m – 4.5m
Anti-Malarial Way leaves	4m
Building clearance	1.5m, 2.5m and 7.5m

Septic Tank clearance	6m
Sewer line	3m

Electricity way leave

Electricity Cables

These are the utilities that are normally located on the road reserves for the provision of energy to the adjacent land uses along the road and those located far away.

Table 3: electricity way leaves

Capacity of line	Way leave
11 KV	10m
33KV	20m
40KV	20m
66KV	30m
132KV Single circuit towers	50m
132KV Double Circuit towers	60m

Source: Physical Planning Handbook 2008

The building code

Design requirements

Any building, structural element shall be designed to provide strength, stability, serviceability and durability in accordance with accepted structural design and so that it will not impair the integrity of any other building or structure.

Building materials

The structural system or any building shall be constructed in line with the following building regulations regarding the materials:

- Structural use of concrete
- Structure use of steelwork
- Structural use of masonry work
- Structural use of stone masonry
- Structural use of timber Structural use of aluminum
- Steel fabric for reinforcement of concrete
- Size sawn and processed softwood
- Code for design and installation of damp proof course in masonry construction
- Composite construction in structural steel and concrete

- Reinforced and pre-stressed concrete structure for storage of water and other aqueous liquid
- Protection of iron and steel structures from corrosion
- Cement, aggregate and sand for concrete works
- Specification for lightweight aggregate for masonry units and structural concrete
- Testing concrete
- Design of concrete structure for retaining aqueous liquid

2.6 Design standards for an interchange

Interchange

An interchange is a system of interconnecting roadways in conjunction with on more grade separations that provides movements of traffic between two or more roadways or highway on different levels. (AASHTO Green book, 2004)

An interchange is defined a road junction that typically uses grade separation, and one or more ramps, to permit traffic on at least one highway to pass through the junction without directly crossing any other traffic stream. It differs from a standard intersection, at which roads cross at grade(source www.wikipedia.com).

Each interchange is designed to fit the individual site characteristics. The final design can either be a minor or major modification of one of the basic types, or it may be a combination of two or more

Interchange types. The following basic definitions apply to interchange designation:

1. ***Systems Interchanges***. These are interchanges between two fully access-controlled highways (freeways).

Types of systems interchange

- Cloverleaf
- Trumpet

2. ***Service Interchanges***. These are interchanges where one or both of the intersecting highways is not a fully access-controlled facility.

Types of service interchanges

- Diamond
  - Conventional
  - Compressed
  - Split
- Partial Cloverleaf
  - Partial cloverleaf A
    - Exit Ramps from the major roadway
  - Partial cloverleaf B
    - Exit loops from the major roadway
  - Partial cloverleaf AB

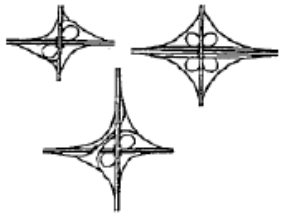
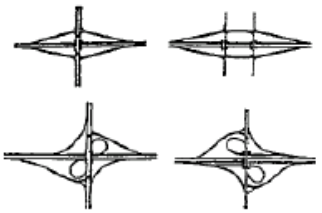
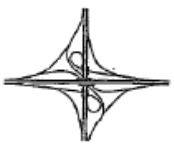
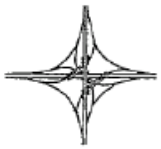
Interchange classification

Table 4: classification of interchanges

source: interchange types online

Functional Category	Type of Intersecting Facility	Three-Leg Interchange	Four-Leg Interchange
Service Interchange	Local Collector Arterial	Trumpet Diamond (Directional occasionally used)	One quadrant Diamond SPUI Partial cloverleaf (parclo)
System Interchange	Freeway	Directional (Trumpet occasionally used)	Full cloverleaf (rarely used today) All directional without loops All directional w/loops (not shown)

Interchange types responsive to various facility classes and area types.
The table below shows various interchanges and the appropriate road classes.

Functional Category	Intersecting Facility	Area Type	
		Rural	Urban
Service Interchange	Local Road or Street		
	Collectors and Arterials		
System Interchange	Freeway		

Right-of-way, construction cost, safety, and operations are likely to dictate interchange type selection for any specific location. In fact, in most instances only two or three interchange types are likely to satisfactorily accommodate these factors
Intersection types and patterns

Selection of the final design is based on study of projected traffic volumes, site conditions, geometric controls, criteria of intersecting legs and turning road ways.

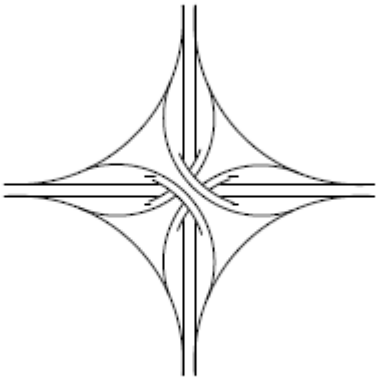
There are six intersection types which include the following:

Directional
The diamond interchange is often the best choice where the intersecting road is not access Controlled. This is the most effective design for connecting intersecting throughways. It has an advantage of reduced travel distance, increased speed of operation and higher capacity.

However this type of interchange is costly to construct, commonly using a four-level structure.

Semi directional

Semi directional has ramps that loop around the intersection of the highways. This leads to a multiple single level structures and occupying more area than the directional interchange.



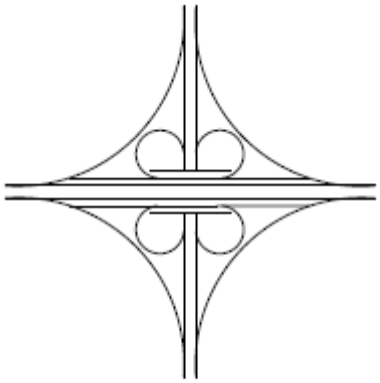
Directional

Cloverleaf

The full cloverleaf interchange has four loop ramps for the left-turning traffic.
Outer ramps provide for the right turns. A full cloverleaf is the minimum type interchange for a freeway-to-freeway interchange. Cloverleaf designs often incorporate a C-D road to minimize signing difficulties and remove weaving conflicts from the main roadway.
The principal advantage of this design is the elimination of all left-turn conflicts with one single-level structure. Because all movements are merging movements, it is adaptable to any grade line arrangement. The cloverleaf also needs a large area.

Figure 1: cloverleaf interchange

source: interchange types and classification



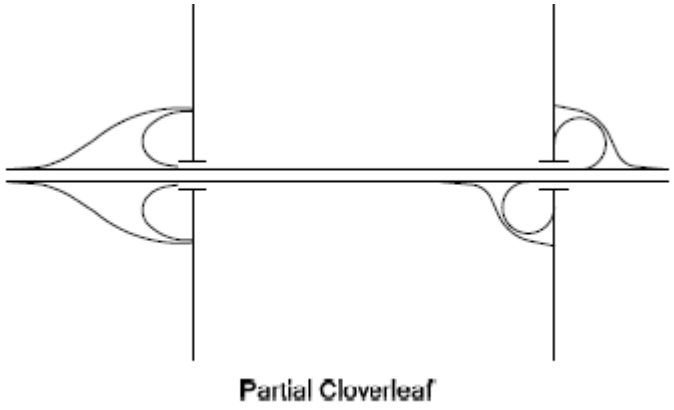
Cloverleaf With C-D Roads

Partial cloverleaf

This design has loop ramps in one, two, or three quadrants that are used to eliminate the major left turn conflicts. These loops may also serve right turns for interchanges where ramp cannot be built in one or two quadrants. Outer ramps are provided for the remaining turns. Design the grades to provide sight distance between vehicles approaching these ramps

Figure 2: interchange PARCLO

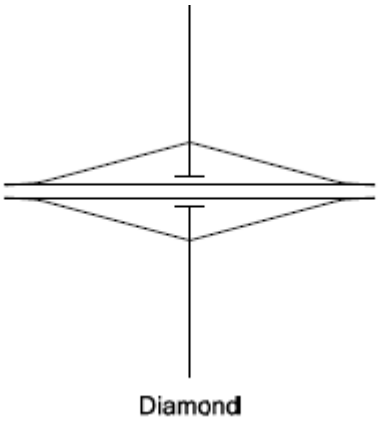
source: interchange type and classification manual



Diamond,
This interchange has four ramps that are essentially parallel to the major arterial. Each ramp provide for one right turn and one left turn movement. This is the most generally applicable and serviceable interchange configuration. Diamond interchange occupy smaller footprint than any other type.
Single point (urban) interchange.

Figure 3: Diamond interchange

Source: interchange type and classification manual



There are three basic types of intersections which include:

- Three leg intersection.
- Four leg intersection
- Multi leg intersection.

The type is determined by the number of legs, topography, character of the intersecting roads, traffic pattern and speeds desired type of operation.

2.6.1 Intersection design speed

This is the principal design parameter upon which the geometrical layout and the capacity is based. The speed is not the same with that of the road design it may be higher or lower. Intersection design speed shall not be more than 20 km/ hr. higher than the average speed of

the major road. For safety reasons it should be lower. The design speed should be between 50% and 85 % of the design speed of the main line.

Interchanges

There are a number of controls guiding the selection of the most appropriate interchange. This is in the context of sensitive design and they include:

• Safety

• Adjacent land use

• Design speed of both the freeway and the intersecting road
• Traffic volumes of the through and turning movements
• Traffic composition
• Number of required legs
• Road reserve and spatial requirements
• Topography
• Service to adjacent communities
• Environmental considerations
• Economics
• Stakeholders

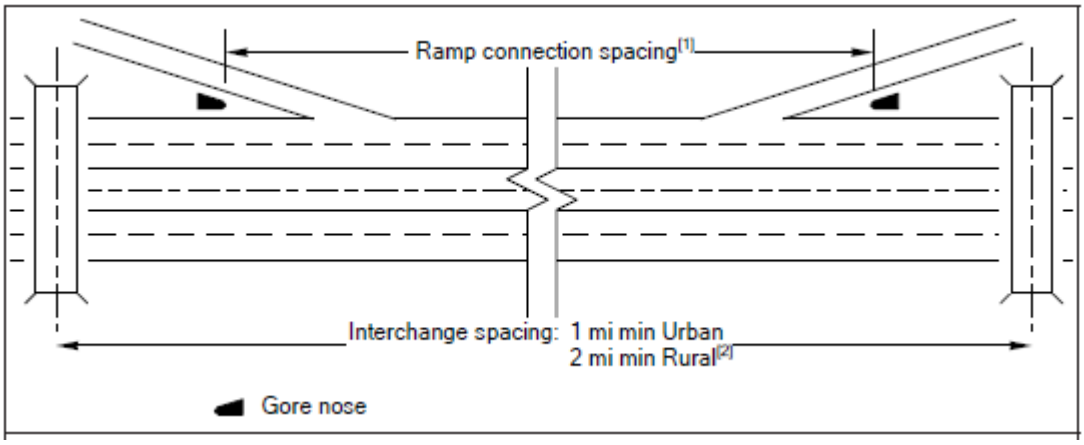
However an interchange design requires a ramp for connecting two separated grade roads.

2.6.2 Interchange spacing

To avoid excessive interruption of main line traffic, consider each proposed facility
In conjunction with adjacent interchanges, intersections, and other points of access along the route as a whole. The minimum spacing between adjacent interchanges is 1 mile in urban areas, 3 miles on the Interstate in rural areas, and 2 miles on non-Interstate in rural areas. In urban areas, spacing less than 1 mile may be used with C-D roads or grade-separated ramps. Interchange spacing is measured along the freeway centreline between the centrelines of the crossroads. The spacing between interchanges may also be dependent on the spacing between ramp connections. The minimum spacing between the gore noses of adjacent ramps

Figure 4: interchange spacing

source: interchange types classification manual



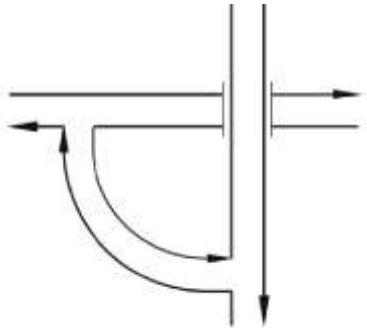
2.6.3 Ramp design

A ramp is defined as a roadway, usually one-way, connecting two grade-separated through roads. It

Comprises an entrance terminal, a midsection and an exit terminal.

Figure 5: ramp design

source: interchange design and types manual



The general configuration of a ramp is often determined prior to the interchange type being selected.
The specifics of its configuration, being the horizontal and vertical alignment and cross-section, are influenced by a number of considerations such as traffic volume and composition, the geometric and operational characteristics of the roads which it connects, the local topography, traffic control devices and driver expectations.
A variety of ramp configurations are used and they include:
The outer connector, which serves the left turn and has free-flowing terminals at either end;

- The diamond ramp, serving both the left-and right-turns with a free-flowing terminal on the freeway and a stop-condition terminal on the cross-road
- The Par-Clo ramp, which serves the right turn and has a free-flowing terminal on the freeway and a stop-condition terminal on the crossing road, with a 180 degrees loop between them;
- The loop ramp, serving the right turn and which has free-flowing terminals at both ends and a 270 degrees loop between them
- The directional ramp also serving the right turn, with a curve only slightly in excess of 90 degrees and free-flowing terminals at either end, and,
- The collector-distributor road intended to remove the weaving man oeuvre from the freeway.

Components of a ramp

- Connecting Roadway

Connecting road way is determined by the following factors

- Design speed
  - Alignment
    - Horizontal
    - Vertical
- Cross section
- Pavement width
- Shoulders
  - Type
  - Width
- Roadside
  - Fore slopes
    - Recoverable (4:1 or flatter)
    - Non-recoverable (slopes between 3:1 and 4:1)

        - Critical Fore slopes (slopes < 3:1)
    - Clear zone
    - Ditches
    - Back slopes

- Length
    - Diagonal ramp, 1200 ft.
    - Long ramps promote passing

- Terminals- they may be free flow or at grade separation

Free flow

Changing speed

Deceleration (Diverging)

Acceleration (Merging)

- Deceleration Length
- Type
    - Parallel
    - Taper
        - Divergence Angle 3°-5°
- Route continuity
- Gore

Figure 6: deceleration lengths of a ramp

source: interchange design manual

US Customary

Deceleration length, L (ft) for design speed of exit curve, V_N (mph)

Highway design speed, V (mph)	Speed reached, V_a (mph)	Stop condition	15	20	25	30	35	40	45	50
		For average running speed on exit curve, V'_a (mph)								
		0	14	18	22	26	30	36	40	44
30	28	235	200	170	140	—	—	—	—	—
35	32	280	250	210	185	150	—	—	—	—
40	36	320	295	265	235	185	155	—	—	—
45	40	385	350	325	295	250	220	—	—	—
50	44	435	405	385	355	315	285	225	175	—
55	48	480	455	440	410	380	350	285	235	—
60	52	530	500	480	460	430	405	350	300	240
65	55	570	540	520	500	470	440	390	340	280
70	58	615	590	570	550	520	490	440	390	340
75	61	660	635	620	600	575	535	490	440	390

V = design speed of highway (mph)
V_a = average running speed on highway (mph)
V_N = design speed of exit curve (mph)
V'_a = average running speed on exit curve (mph)

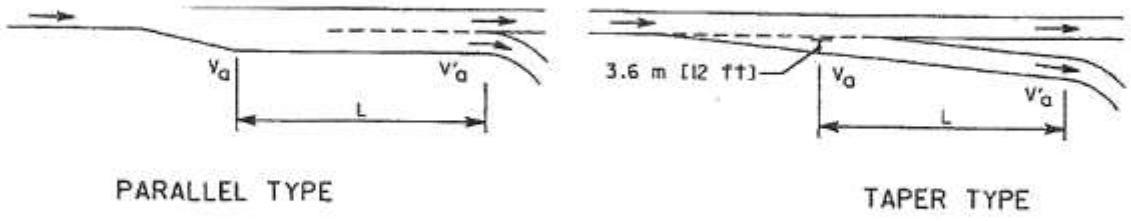


Exhibit 10-73. Minimum Deceleration Lengths for Exit Terminals with Flat Grades of Two Percent or Less

Source: (AASHTO Greenbook, 2004)

At-grade

Turning

Intersection control

- Signed
- Signalized
- Circulatory

Operational analysis

Turn lanes

Number of turn lanes

Length of turn lanes

- Intersection angle
  - 60° minimum
  - 75° preferred for older drivers
- Departure sight distance (ISD)
- Design vehicle
- Pedestrian accommodations

Figure 7: a ramp

source: compiled by the author adapted from Wes Mayberry interchange design

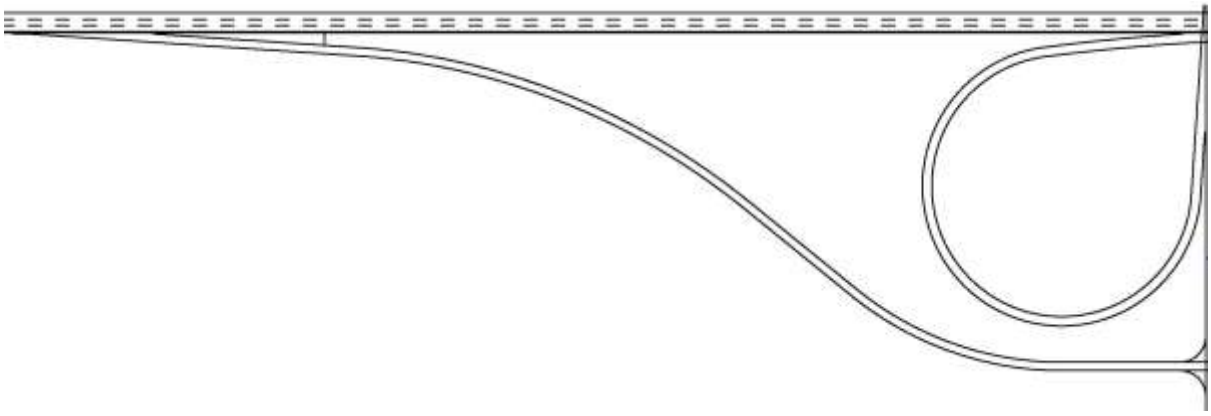
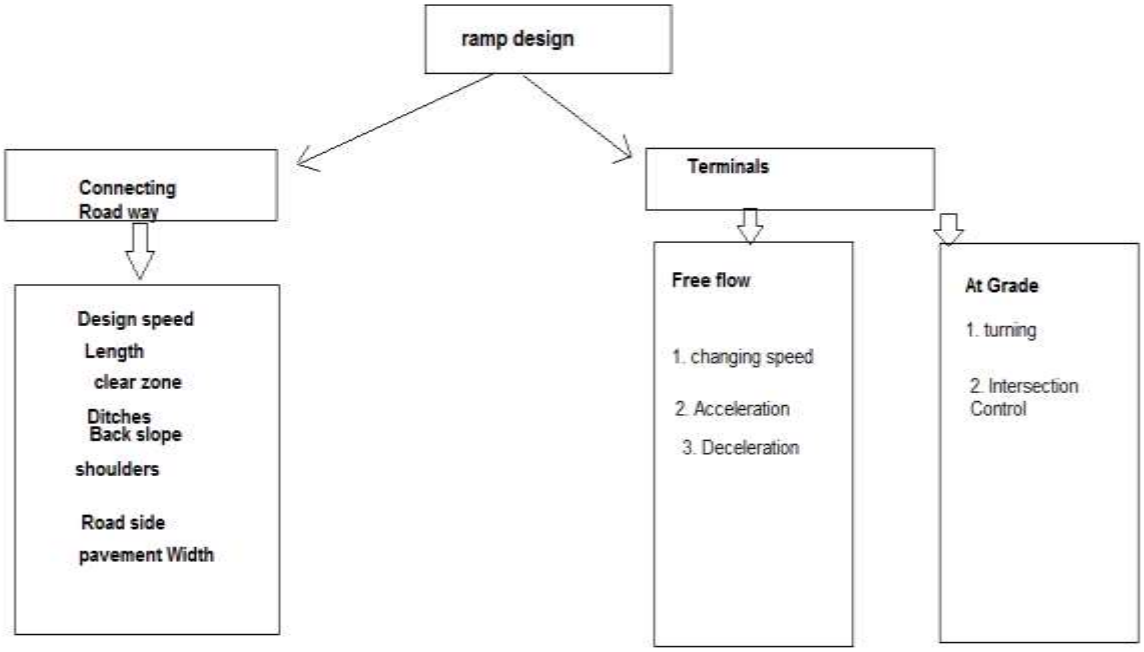


Chart showing summary of ramp design

Figure 8: ramp design



Source: author

2.6.4 Design speed of a ramp

The design speed of a ramp should be related to the design speed of the through and intersecting roads, and should preferably not be less than the operating speed of the through

road. Ramp design speed can, however, gradually be reduced to half that of the through road under restricted circumstances. In general, a design speed of 40 km/h is adequate for loops as the advantages of a higher design speed will very often be nullified by the additional distance of travel resulting from the correspondingly larger radii required. As the free-flowing ramp terminal is designed to the speed of the through road it may be necessary to achieve the minimum radius by compounding it with larger radii.
A semi-directional layout is selected for a given ramp when a high volume of turning traffic is expected. Free-flowing terminals at both ends of the ramp will accommodate traffic entering and leaving the ramp at speeds close to the operating speeds of the through and intersecting roads. A low design speed on the mid-section of the ramp will clearly have a restrictive effect on the capacity of the ramp and is therefore not acceptable. The minimum design speed of a semi- directional ramp should not be less than the speed in the table below
Table 5: design speed of a ramp

Source: adapted from Webster interchange design source: compiled by the author

Through roads km/ hr.	Ramp km/ hr.
60	**60**
80	**70**
100	**80**
120	**90**

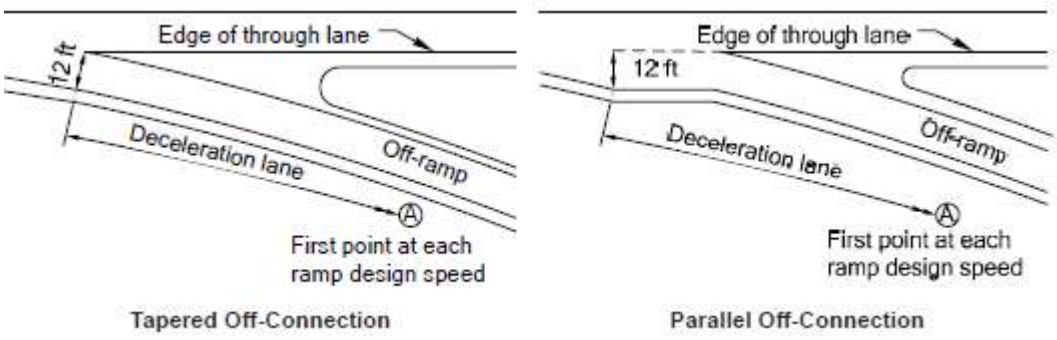
Direct connections, such as the outer connectors of a cloverleaf interchange, should also to be designed for the speeds suggested in the table.
Diamond ramps always and Par-Clo ramps usually, have a free-flowing terminal at one end and a stop-condition terminal at the other. The free-flowing terminal and the section of ramp immediately following should have a design speed equivalent to the operating speed of the through road, and the design speed should not be less than 80 km/h. After that the design speed may become progressively lower, but must be at least 40 km/h at the stop-condition terminal. As in the case of the loop, the
Partial-Clover leaf ramp may also have a minimum radius appropriate to a design speed of 40 km/h.

2.6.5 Requirements of a ramp

Deceleration lane

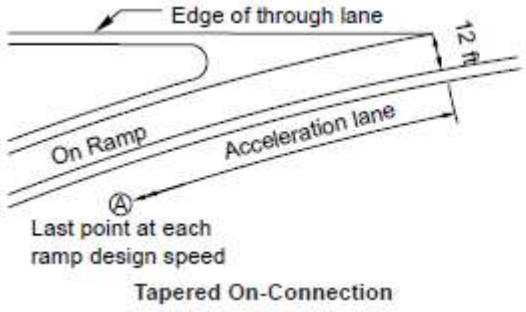
All exit ramps for non-freeway interchanges require a deceleration lane. Deceleration lane can be a freeway style exit taper with gore area or an intersection right turn deceleration lane.
Figure 9: deceleration and acceleration lanes

source: adapted from Webster

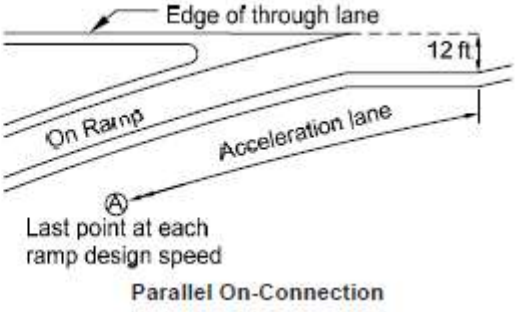


Acceleration lane

Decision to use acceleration lane will vary depending upon the speed of a highway, ramp volume, and highway volume



Tapered On-Connection



Parallel On-Connection

Access control

Overpass and underpass

The elimination of frontage roads increases the range of options available when developing the major-road and crossroad profiles through the interchange. This added flexibility can translate into more cost-effective designs because the designer can tailor the ramp configuration solely to the topography and the interchanging traffic movements. A fundamental consideration in interchange design is whether the major road should be carried over (i.e., an overpass design) or under the crossroad. When topography does not govern, the relative advantages and disadvantages.

Should be considered when selecting an overpass or underpass design. They also provide Some insight as to the merit of locating the crossroad below, at, or above the existing ground level. Underpass design offers greater benefit when ramp safety and operations are key considerations. The underpass design with the crossroad elevated "above" ground level is often the most advantageous because it provides major-road drivers with:

i. Ample preview distance as they approach the interchange.
ii. Ramp grades that are helpful in slowing exit-ramp drivers and accelerating entrance-ramp drivers.

The underpass design with the crossroad "at" ground level is preferred because it provides the driver the best view of the ramp geometry in the terminal area.

The table below identifies advantages of the overpass and underpass designs

Table 6: components of a Ramp

source: adapted from Webster

Crossroad Location Relative to Existing Ground	Major Road Location Relative to Crossroad	
	Overpass	**Underpass**
Below	 ● Offers best sight distance along major road.	Not applicable.
At	 ● Offers best possibility for stage construction. ● Eliminates drainage problems.	 ● Reduced traffic noise to adjacent property. ● Provides best view of ramp geometry.
Above	Not applicable.	 ● Ramp grades decelerate exit-ramp vehicles and accelerate entrance-ramp vehicles. ● Eliminates drainage problems. ● Typically requires least earthwork.
	Other Overpass Advantages: ● Through traffic is given aesthetic preference. ● Accommodates oversize loads on major road.	Other Underpass Advantages: ● Interchange and ramps easily seen by drivers on the major road. ● Bridge size (for crossroad) is smaller.

Source:

2.6.6 Three leg interchange

They are also designated as T- or Y-interchanges. The trumpet provides three turning movements with direct or semi-direct ramps and one movement by a loop ramp. In general, the semi-direct ramp should favour the heavier left-turn movement and the loop the lighter volume.

The diagrams below shows examples of three leg interchange.

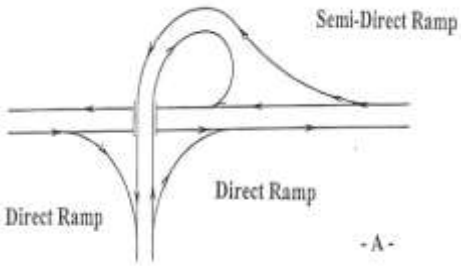
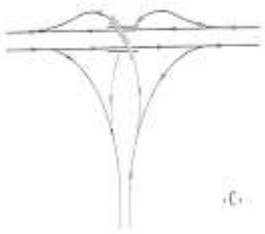
		

Table 7: types of three leg interchange

source: adapted from Webster

2.7 Case study 1:

2.7.1 Elrod Road/ Natcher Parkway Interchange- Kentucky Warren County

Location

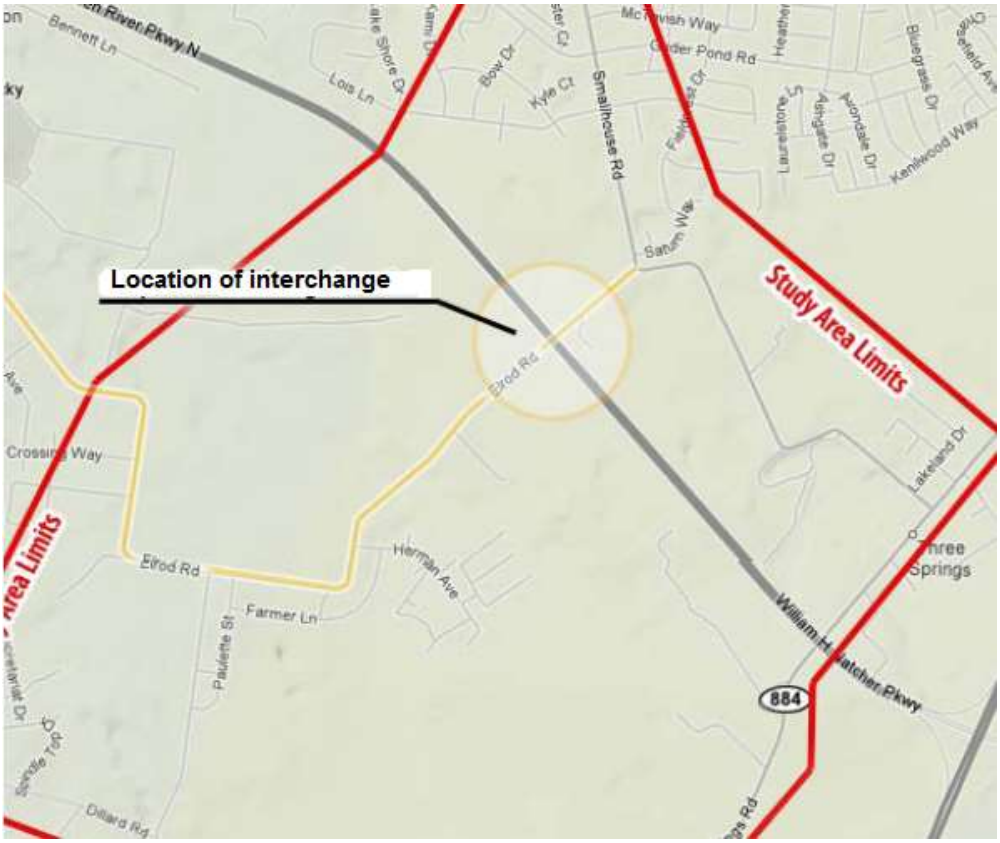
The case study is located in Warren County in the suburbs of United States of America.

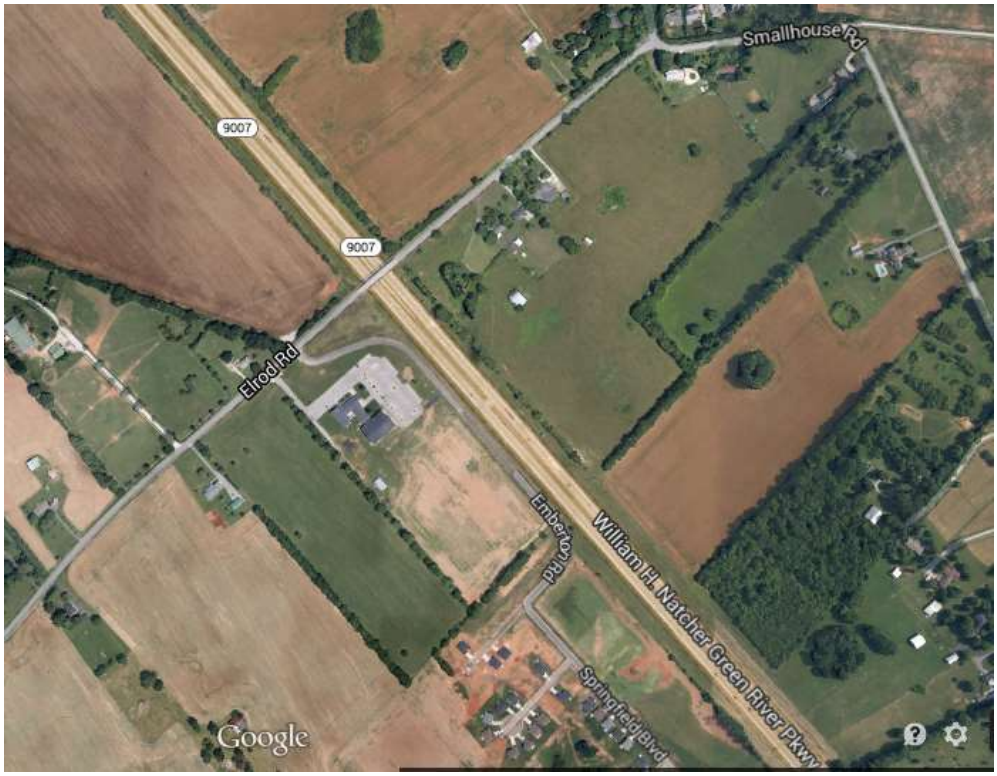
The study area centres on the existing Elrod Road overpass at Natcher Parkway, which is approximately 1.6 miles west of the I-65/Natcher Parkway interchange. The study area limits encompass Small house Road north to Cave Mill Road, Three Springs Road to the east, and extends south to Neal Howell Road.

The Elrod Road corridor provides a vital link and serves as the primary collector between Three Springs Road to the east, Cave Mill Road to the north, Nashville Road (US 31W) to the west and the growing residential development extending south in the study area.

Figure 10: Location of Elrod Natcher Park Interchange

source: google maps





Concept

The Natcher Parkway divides the study area. This north-south urban freeway carries over 17,000 vehicles per day. The Natcher Parkway is a divided freeway with two, 12-foot lanes in each direction and a 28-foot median. The closest access point to the Natcher Parkway is at US 31W (Nashville Road), approximately two miles from the Elrod Road overpass.

Small house Road is located north of the Natcher Parkway.

The intersection of Elrod Road and Small house Road is currently configured as a three-way stop.

It is observed that motorists traveling through this intersection tend to treat the stop sign as a yield condition. This occurred on each leg of the intersection.

The intersection of Small house Road and Cave Mill Road on the north side of the study area offsets the north/south segment of Small house Road in effect creating two intersections.

It was observed that motorists turning left onto Cave Mill Road have a difficult time, thus intensifying queue lengths along Small house Road.

New residential development along Elrod Road as well as development extending south of Neal

Howell Road impacts the study area. Other notable destinations contributing to or expected to contribute to congestion in the area include several churches, the Western Kentucky University Farm, Griffin Park and a proposed elementary school.

Lessons learnt

a) To improve circulation around two roads joining together to solve congestion
b) There is land use changes taking place in the case study area there is more growth of residential which demand transportation facilities.
c) Developing an interchange would require upgrading all roads within the vicinity of n interchange and completion of all road projects.
d) It can be used as an alternative route to already congested roads to spur economic growth.

e) Improving efficiency and effectiveness thus promoting accessibility within the area.

2.8 Case study 2:

2.8. 1 Uhuru Highway- Museum Road Hill Road Interchange City County of Nairobi-Kenya

Location

This interchange is located in Nairobi. It's near the University of Nairobi field along Uhuru Highway. Museum of Kenya is found north of the interchange. Chromo campus is found south west of the interchange.

Concept

The place was initially a roundabout which was used to divert traffic to different direction. This place usually faced the worst congestion ever as some vehicles had to wait others to pass for them to proceed. Vehicular queuing started from the round about all the way to wetlands at 7 pm- 8 pm Kenyan time. Traffic conflicts and minor accidents were also experienced in the area.

The interchange was constructed as part of Thika super highway to ease movement in the city of Nairobi and reduce traffic congestion. Traffic congestion has reduced but remains a challenge in Uhuru Highway due to the university way- Uhuru Highway Roundabout. The interchange now uses grade separated movements to conduct traffic in various directions.

Lessons learnt

a) Improved vehicular circulation and smooth traffic flow.
b) Enhanced aesthetic value of the area.
c) Reduced traffic conflicts and vehicular queuing around the area
d) Improved air quality.
e) Use of grade separation to conduct traffic
f) Minimal effects on the environment.

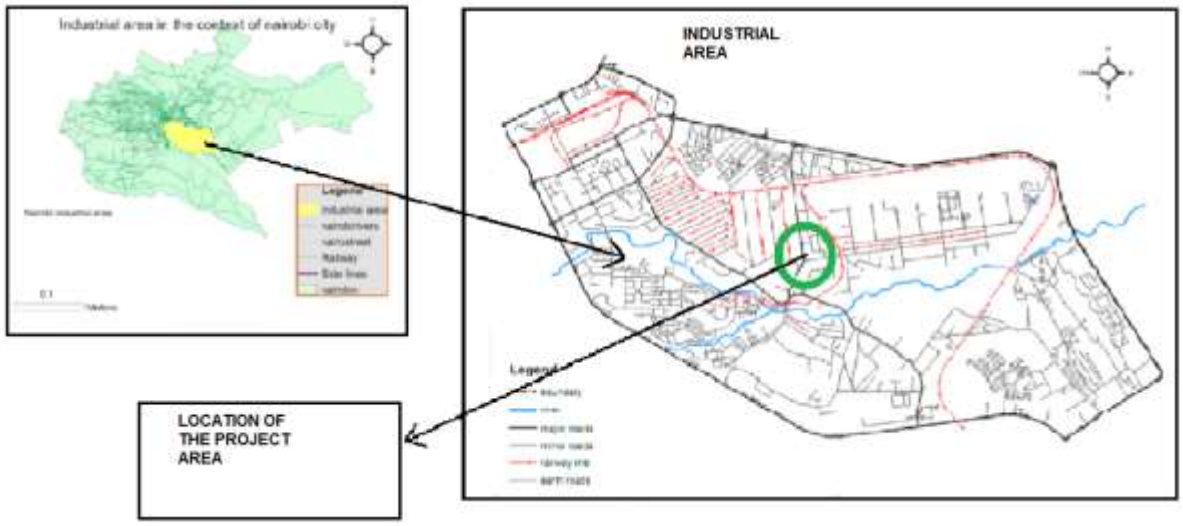
CHAPTER 3: SITUATIONAL ANALYSIS

3.1 Location context of project area

The industrial area is located in the southern eastern of CBD. Nairobi industrial area in the south edge of the city, it is located at -1.311679N, 36.871038E.However the study area is located in the heavy industrial cluster. Lunga Lunga Road serves the heavy industrial cluster it traverses through the northern part of the industrial area. The adjacent roads are Jogoo Road, Likoni Road, Mogadishu Road, Pate Road, Mogadishu Road, and Wudanyi Road in which they form both T and cross junctions.

Figure 11: map showing case study

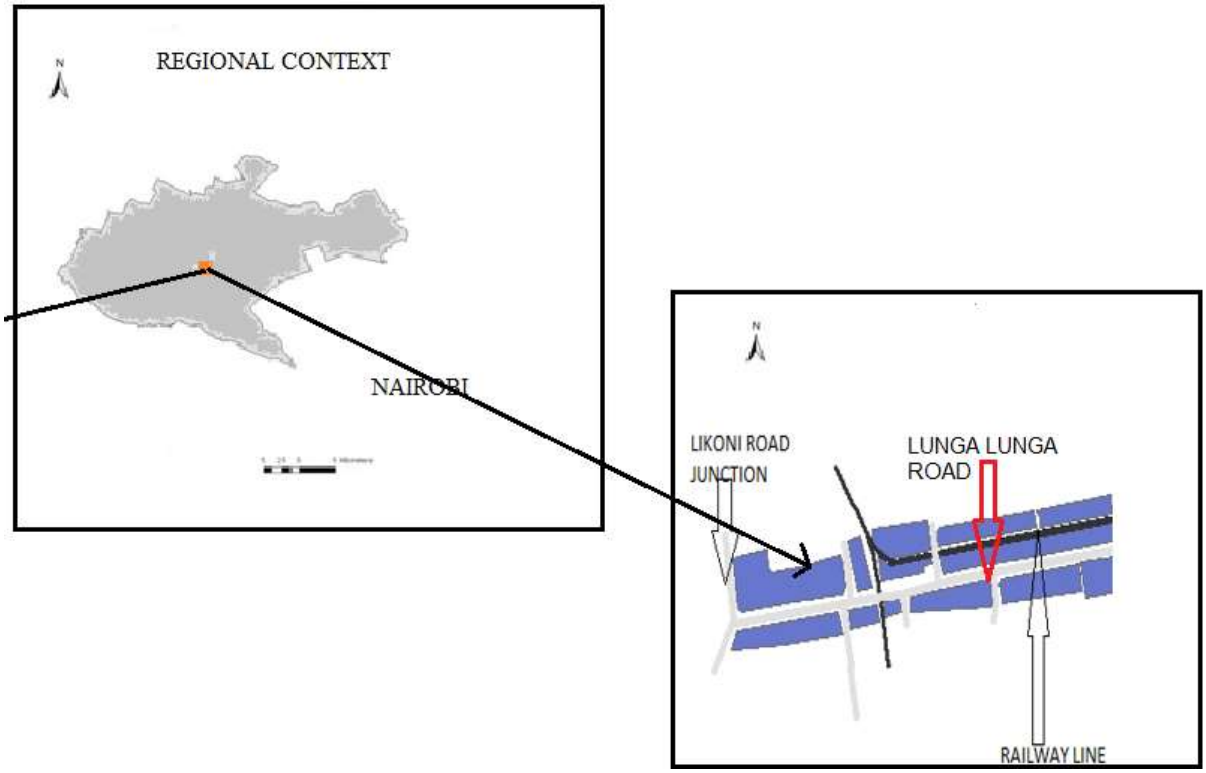
Source: compiled by author



3.2 Regional context

Figure 12: Regional context of the study area

Source: compiled by author



3.3 Background of project area.

3.3.1 Historical Development of Nairobi city

The earliest account of Nairobi's history dates back to 1899 when a railway depot was built in a brackish African swamp occupied by pastoralist people, the Maasai, as well as the agriculturalists kikuyu people who were displaced. The railway complex and the building around it rapidly expanded and urbanized until it became the largest city of Kenya and the country's capital. The name Nairobi comes from the Maasai phrase "Enkare Nairobi" which translates to "place of cool waters"

The former swamp land occupied by the city now was once inhabited by the herding people, the Maasai, under the British East Africa protectorate when the British decided to build a railroad from Mombasa to Kisumu on the edge of Lake Victoria in order to open East Africa and make it accessible for trade and encourage colonial settlements. The Maasai were forcibly removed to allow land for white ranchers.

The completion of the railway line saw the British moving their administrative headquarters from Mombasa to Nairobi thus making it the capital of British East Africa.

Nairobi's first town planner and district railway engineer, Patterson set out a gridiron for the streets. Starting from the railway headquarters going north, he planned streets to be laid equidistant. According to his 1901 map, these are numbered chronologically from the south, making the headquarters building the point of his reference since the first Avenue(Haile

Selassie) is the closest to it while the Tenth is the farthest from it. In the engineer's map only first and fifth avenues feature. The rest must have been added as the township grew. The first avenue while the fourth is city hall way. A busy route- to and from the railway station developed and was naturally called station road. It extended from the station to Sergeant Ellis road.

The town was totally rebuilt in the early 1900s after an outbreak of plague and the subsequent burning down of the original town. By 1907, Nairobi was a humming commercial center and replaced Mombasa as capital of the British East Africa. The city expanded, supported by the growth in administrative functions and in tourism, initially in the form of British big game hunting. As the British colonialists explored the region, they began using Nairobi as their first stop. This prompted the colonial government to build several grand hotels in the city for British tourists and big game hunters.

Nairobi continued to grow under British rule, and many Britons settled within the city's suburbs. In 1919, Nairobi was declared to be a municipality by the British. (Source daily nation 2012).

In 1900 an arbitrary circular boundary of half mile radius was declared town consisted of the railway center, Indian Bazaar, the railway quarters, European residential suburbs and military barracks outside the town (Kingoriah 1980).

In 1919 Nairobi became a municipality with a corporation and the initial circular boundary was changed to include some of the residential estates like Park Lands.

In 1948 master plan prepared for the first time for a colonial capital brought separation of residential areas into European, Asians and Africans.

3.3.2 Historical development of industrial area

The birth of industrial estate of Nairobi dates back in 1895 when a depot caravan trade was established at the present Ngara area. This can be traced from the birth of the city of Nairobi in 1898 when the railway depot was situated at the heart of Nairobi city. The railway line led to the emergence of premises within the city including industrial premises. There were branches of railway line that served these industries that had sprung in Nairobi.

In 1919, Nairobi became a municipality with a corporation and the initial circular boundary was changed to include some of the residential estates. The residential estates were based on segregation where Europeans, Asians and African lived in separated locations. It was during this period that an industrial zone was developed as a separate entity from the CBD.

Between 1948 and 1963 the city of Nairobi more or less on the same lines as depicted in the 1948 master plan that followed the modernist separation of different functions. There was provision for the following:

- ✓ Industries dealing with bulky goods- they were located on the railway line
- ✓ Light industries- they were built closer to the center.
- ✓ Smaller strip for noxious industries- these were planned in a separate position in the east.

However this plan had limitations since it under estimated the development potential of the industrial area in terms of the need labour. In its proposals for industrial location, it was defined that the greater majority of workers should reside within a one mile radius of the industrial area. These are the people that provided these industries with the labour required for production. However the low density areas were designated to be exclusively for settlers'

At this particular time industrial area of 9.6 km2 was the largest of East Africa. The master plan advice of 1948 resulted into nearly static plan of population of 250,000 people occupying an area of 87km2.

The low income areas supposed to serve the industrial Area with the required labor were:- Kaloleni, Ofafa Jericho and Makongeni. However the space designated for these industries were rigid and they underestimated the expansion potential of the industrial area, hence there was need for more workers when the industries diversified.

The plans intention of zoning the industrial estate where the industries would be located was dependent on whether they were

- ✓ Heavy industries
- ✓ Light industries
- ✓ Noxious

However this has not been followed at all. Oil and gas refineries next to the railway are the only zoning policy that has been effectively implemented. The parts closer to the centre can on the other hand be characterized by a large amount of all kind of factories, showrooms, restaurants all mixed up. The total mix up of different types of industry is what makes an efficient upgrading of infrastructure almost impossible.

The western part of the industrial area is very dense in terms of plot coverage. Half of the plots in this part have plot coverage of 75% compared to the normal plot coverage of 35%. This has impacts on the expanding industries as they are forced to relocate due to lack of space to expansion and diversification. Industrial infrastructure is outdated compared to industries in the industrial estate.

3.3.3 Site analysis

3.3.3.1 Physical features

Topography

Nairobi area is characterized by undulating hilly topography at the western side around Ngong hills area with an elevation of approximately 2200 m above sea level. The eastern side has an elevation of about 1400 m where the lowest elevation occurs at the Athi River at the eastern boundary of the city. The western side of Nairobi is also on higher elevation compared to the eastern part as the drainage follows this route where rivers and tributaries flow to the east. The baseline altitude for Nairobi lies between 1600 m to the east to 1800 m to the west. The industrial district zone also referred to as the Athi-Kapiti plains extension is located in a fairly expansive flat terrain. The area is thus economical to erect buildings and other industrial structures.

The study area is located on the low and relatively flat plateau side connected to the Athi Kapiti plains (Nairobi Master Plan, 1948).

Geology and soils

Soils in Nairobi industrial area have developed on tertiary basic igneous rocks (olivine basalts and nepheline phonolites) and are mostly black cotton soils. These soils are imperfectly drained, very deep, dark grey to black, firm to very firm and are usually bouldery and stoney due to cracking clay.

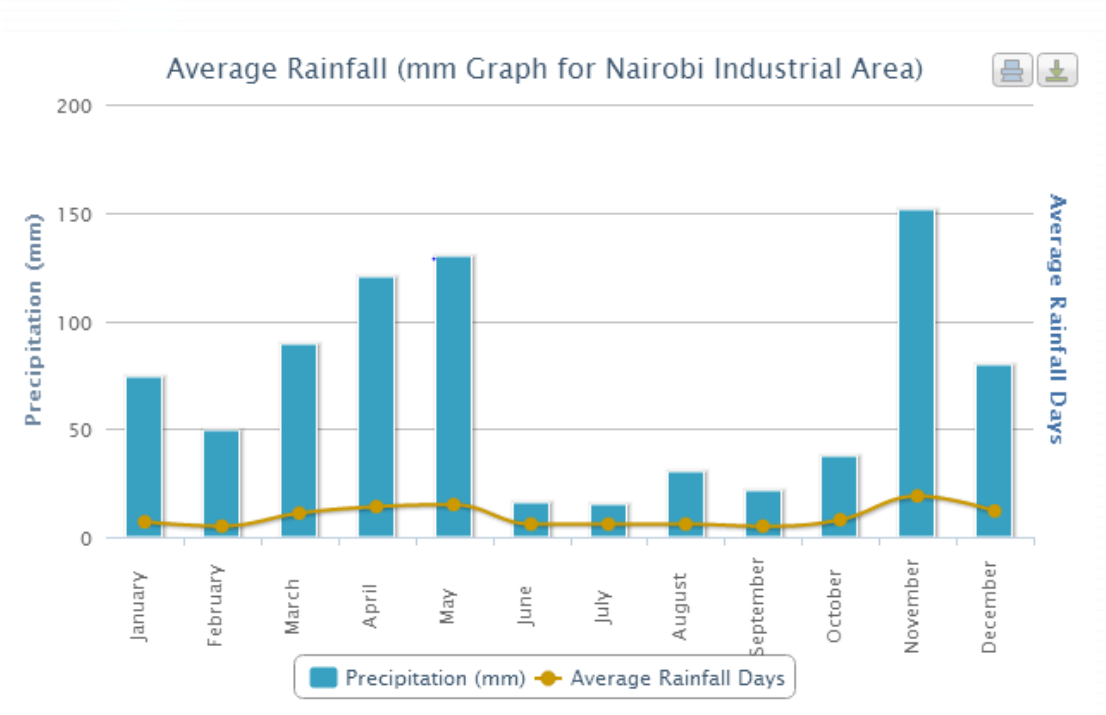
Rainfall

There are two rainy seasons, but rainfall can be moderate. Highest rainfall is received between March and April and the short rainy season is between November and December. The mean annual rainfall ranges between 850-1050mm. (CBS 2003). The mean monthly relative humidity varies between36 and 55 per cent. The mean daily sunshine hours varies between 3.4 and 9.5 hours (CBS 2003). The average temperature in Nairobi is 24 degrees.

Table 8: Table showing Rainfall

source: www. weather online.com

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	73.9	48.8	89.2	119.9	129.4	15.8	15.8	29.8	21.3	36.7	151	79.1
Average Rain Days	7	5	11	14	15	6	6	6	5	8	19	12



Hydrology
The city of Nairobi is drained by Nairobi, Mathare, and Ngong Rivers which drain into the Athi River. The rivers follow topography which is raised at the western part. Hence the flow to the east since the terrain follows the east direction.

The industrial area is drained by Ngong River which flows to the east all the storm water drains to this river. Ngong River is passes along Lunga Lunga slum and near heavy industries. The river is polluted by industries and informal settlements. The river is important in the drainage of the study area. The runoff generated from this industries and the adjoining roads drain in these river. The area is covered by black cotton soils. These soils were and are formed through the weathering of the underlying Nairobi phonolites. These rocks cover the entire area and are impervious hence do not permit water percolation. The black cotton soils don't drain water efficiently a situation that leads to rain water collecting hence flooding.

Natural drainage is inefficient and some factors hinder the capacity of existing storm water drains hence the area require more technical expertise to solve the perennial problem.

The development should be oriented in a way that it's not flooded hence drainage channels should align themselves to the watershed

Surface water
The only surface water in the area is the Ngong River and it's polluted to the limit that it's unfit for any viable use. The river is found south of the study area and it is where run off drains. Water to the premises around is provided by the Nairobi Water and Sewerage Company.

Ground water
The first stratum of water within Lunga Lunga Road is within 20ft to 100 ft. below the phonolites (Kasuku 2001). The water must be chlorinated and treated before consuming its believed that it has exceeded the fluoride limit.

The industries however have no history of sinking boreholes since they are connected to the reticulated water of the Nairobi Company.

Humidity in Nairobi
Maximum humidity in Nairobi occurs few hours before and after dawn while minimum humidity is during rainy seasons. May has the maximum while April has the least. (Www. Weatheronline.com)

Sun path and the Prevailing wind
The sun path is generally from east to west. The winds near the ground is very predominantly easterly through the year, generally between north east and east from October to April and between east and south east from May to September. The strongest winds occur during the dry season just before the long rains when speeds of 20 to 25 mph are not uncommon from mid-morning to early afternoon; at other times of the year wind speeds are usually 10 to 15 m.p.h. during the night the winds is usually light. In the squalls sometimes associated with thunderstorm, short lived from up to 70 mph have been known to occur.

Sunshine vs solar radiation
Nairobi receives a sum of approximately 2500 hours of solar insolation per annum, which is same to yearly average of close to 6.65 hours of sunshine in a day. The range of sunshine

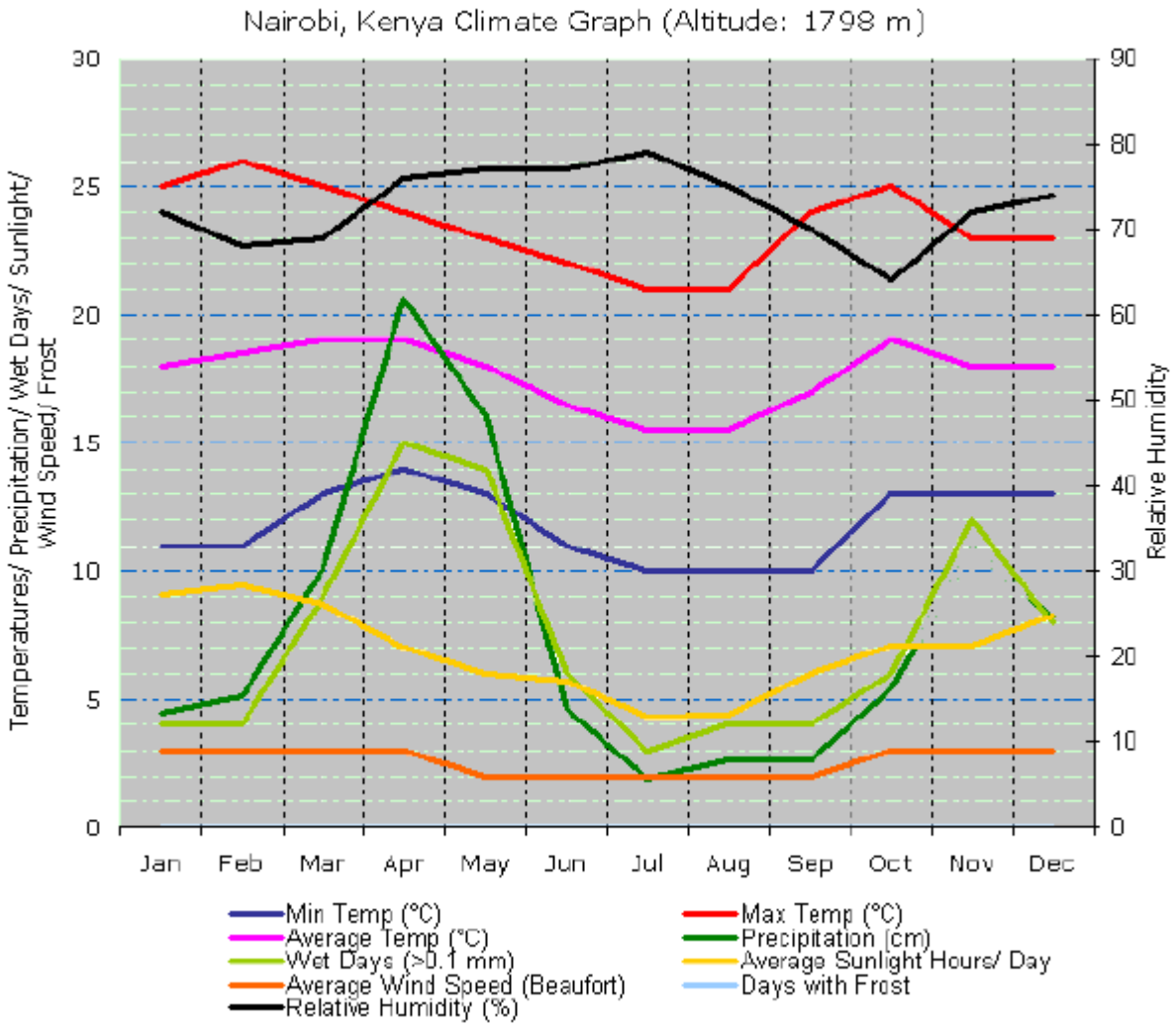
hours in the study area is 4.3 hours per day in July and 9.5 hours per day in February. Months of July and august are characterized by chilly and cloudiness and during these period the average daily sunshine in Nairobi is only 4 hours. The month of February has more insolation followed by the month of January. The sunshine increases in the afternoon with 30% more of it than it's in the morning. In the afternoon its 58%. Westerly exposures receive more insolation than easterly ones.

bar graph 1: Sunshine hours

Source: www. weather.com

Evaporation

Annual variation of evaporation is due to temperature, speed of the wind and solar insolation. The highest evaporation occurs at March due to the rainfall. January comes the followed by February and October. Annual evaporation is 172 mm



Bar graph 2: Average temperatures

Table 9: population composition source: KNBS 2009Source: www. weatheronline.com

3.3.4 Environmental pollution

This area has less vegetation compared to some parts in Nairobi. The area is prone to pollution due to the presence of heavy industries, slums and the vehicles that pass around there.

Industrial pollution- this mainly occurs since the area is a heavy industrial cluster. This industries emit poisonous gas into the atmosphere leading to environmental pollution. Industries also discharge liquid waste into the Ngong River thereby making the water composed with lethal metals. The place has a foul smell due to this industries. Industries have a big role in noise pollution too.

Vehicular pollution- this are the vehicles that use this road they usually worsen the emission of gases in the area. Tis has led to a heavy polluted area in the industrial district. The trucks and all other vehicles contribute to pollution too. Traffic congestion also experienced in these area has a great impact in pollution. However this is not common compared to industrial pollution. Vehicles also cause nuisance through noise pollution.

Household pollution- this occurs in the slums adjoining Ngong river which pollutes the river they direct their liquid and solid waste to the river thus making the water unfit for commercial and domestic uses. They have no solid waste management plan thus all this refuse end up in the river. This is minimal compared to industrial effluents in the river.

3.3.5 Population and demography

The population of Nairobi is currently 3,138,295 inhabitants (Population and housing census of 2009). Nairobi has a growth rate of 3.8% p.a. The study area has 318,542 persons according to population and housing census of 2009. Population of the study area is distributed within the 5 administrative units within the industrial area

The table below shows the population structure and composition of the industrial area

Table 10: population composition

Source: KNBS 2009Source: www. weatheronline.com

AGE	MALE	FEMALE
0-4	25654	20767
5-9	19004	15944
10-14	14214	12487
15-19	12906	15376
20-24	25525	28075
25-29	30525	24749
30-34	24017	14711
35-39	17015	9241
40-44	10529	5197
45-49	7280	3521
50-54	4269	1996

3.3.6 Demographic characteristics

This characteristics of the study are similar with the ones of the city of Nairobi and they include the fertility rates, mortality rates, life expectancy, average household size etc. the table below summarizes demographic characteristics.

Table 11: Demographic characteristics

Source: KNBS 2009

CHARACTERISTICS	**STATISTICS**
Total fertility rates	4.72
Crude death rate	13.1/1000
Infant mortality rate	53/1000
Neo natal mortality rate	32/1000
Post neo- natal mortality rate	34/1000
Child mortality rate	27/1000
Life expectancy	57
Average household size	5
Dependency ratio	82%

Social economic characteristics

The area is inhabited by low income earners who supply the industries with the labour. The residential areas include Makongeni, Kaloleni, and Lunga Lunga informal settlement. Most of these people work in the factories or engage in informal activities. There are informal activities along Lunga Lunga Road that these people engage in in order to earn a living. They own kiosks along the road, eateries and shoes outlet.

3.3.7 Land uses in context of study area.

Residential

The informal Lunga Lunga settlement relies on these road and since the population is increasing this people will keep putting pressure on the existing road network. Vehicles to Donholm uses this road too and there is a lot of development taking place in that place hence vehicular traffic will continue increasing thereby putting pressure on a road that was designed to conduct traffic lesser than it actually does.

Industrial

The area is juxtaposed to the heavy industrial cluster including the oil depots. This means that the road conducts industrial traffic. The traffic on these road consists of trailers, Lorries. Hence the area is surrounded by industrial land use which is dominant in the study area.

Commercial

There commercial land uses on these road too. However there is incorporation of businesses within heavy industrial cluster. Commercial land uses occur in form of supermarkets, restaurants and retail shops. This means that these land uses are coming up in the area which justifies the fact it needs a free congested road since more traffic will be generated.

3.3.8 Infrastructure Facilities

Water Supply

Water supply in the study area is reticulated by Nairobi City County. Most industries and premises around this area are connected with piped water through Nairobi Water and Sewerage Co.

Sewerage Services

The trunk sewer passes along the Ngong River most of the industries are connected to the trunk sewer to discharge their waste while some of the industries discharge their waste into the river direct thus polluting it.

Storm Water Drainage

The storm water drains are located on road reserves in the study area. The storm water drains are blocked by the solid waste generated from the informal food eateries along the road thus making drainage poor in the place. This leads to the flooding of the carriageway.

Solid Waste Management

There is no effective solid waste management in the study area and this leads to piling up of solid waste along the road reserve thus affecting the aesthetic value of the place. Most of the waste comes from the informal eateries and the adjacent kiosks.

3.3.8 Transportation

The study area is accessed through Likoni Road, Jogoo Road and Outering Road.

Accessibility

The heavy industrial cluster is accessed through this Lunga Lunga Road. Informal settlement are also accessed through this road.

Non-motorized Transport

Non-motorized transport is provided in the area. However the facility is not paved thus it leads to pedestrians walking on the carriageway when it's rainy thus contributing to the traffic congestion.

Parking

There is no designated parking facility along this road hence the vehicles park along the curb. When manoeuvring back to the road create conflicts.

CHAPTER 4: PROJECT PLANNING DESIGN AND IMPLEMENTATION

This chapter is guided by the development project objectives which will lead to its implementation and they are:

- To determine suitability of proposed site for Likoni road- Lunga junction
- To develop a site plan for Likoni Road- Lunga Lunga junction
- To introduce a traffic interchange in Lunga Lunga- Likoni Junction that is sustainable
- To propose project's implementation, monitoring and evaluation framework and institutional structure for upgrading of Lunga Lunga- Likoni road junction geared to alleviating traffic conflict and congestion

4.2. Planning and Design of the Project

Table 12: Design of the project

Source: compiled by Author

PROJECT OBJECTIVE	PROJECT OUTPUT	PROJECT OUTCOME
To determine suitability of proposed site for Likoni road- Lunga junction	Site that conforms to the design	a suitable site for development and construction
To develop a site plan for Likoni Road- Lunga Lunga junction	A well-designed traffic interchange that is sustainable with street lighting and landscaping incorporated into its design	A smooth traffic flow in which there is no traffic conflicts which results to contribution of traffic congestion. A site plan which is aesthetic and not injurious to the environment
To introduce a traffic interchange in Lunga Lunga- Likoni Junction that is sustainable.	A traffic interchange that is compatible with adjacent land uses and is economically viable and justifiable	Smooth traffic flow with no traffic conflicts, congestion free movement of goods thus stimulating regions economic growth
To propose project's implementation, monitoring and evaluation framework and institutional structure for upgrading of Lunga Lunga- Likoni road junction geared to alleviating traffic conflict and congestion	Project's Implementation Strategies and schedules Project's Monitoring and Evaluation framework Institutional framework for project's implementation	Fully implementation, monitoring and evaluation of developments in the project in the study area

4.2.1 Expected Outputs and Outcomes of the Development Project

This project is expected to provide a detailed alternative design for the junction. This shall be in the form of two and three dimensional representations of the preferred model. This models will be guided by the project findings.

4.2.2 Criteria for selecting the preferred model

Current development trends

The current development trends along this road is incorporation of commercial land uses within the heavy industrial cluster along Lunga Lunga Road. This shows that businesses will need to move their products in a free congested road to avoid time wastage which will lead to losses. This commercial facilities will only expand if the road is good making the place accessible. There is a current development of a supermarket and it will need a good road to source its goods and labour. Increased extension of use in these area justifies the need for a traffic interchange.

The adjacent Don Holm residential area is also expanding and this route is used as an alternative to Jogoo road hence the traffic has grown due to the spill over from the Jogoo road. Public buses use this road to don holm to avoid congestion and traffic is growing because more people are moving in Don Holm. This development and traffic growth can be attributed to the population growths

Site economics

Study of the site in terms of the relation of its cost to its productivity was analysed. This is the cost of congestion to businesses around and industries. However the cost of improving this junction will lead to increase in returns for both businesses and industries thus promoting economy of entire region.

Economic perspective

The preferred alternative should not be seen as a liability to the implementer it should have an economic value to the place and to the county government. This development should stimulate growth and diversification of both commercial and industrial premises around this area. It should realize maximum economic benefits and optimally increases the diversification of industries in this place thus creating more employment and overalls regional growth.

Future anticipation of the area

The area is anticipated to incorporate more commercial land uses within the heavy industrial area. This is due to the change that is taking place in the study area. The traffic is expected to increase in the study area as a result of more vehicles opting to use that route to access the land uses juxtaposed to the road.

Sustainability

The model should be more environment friendly meaning that its implementation will not be injurious to development. The proposed development should not jeopardize the needs of the future generation by trying to meet its need. The concept of sustainable development should be in the mind of every planner so as to conserve the environment for posterity. Sustainability means also means that it should be effective in the purpose and the goal it’s meant to achieve.

Compatibility

The model was found to be compatible with the adjacent land uses which are commercial and industrial. The design is the most appropriate for this place since it will usher in a new aesthetic appeal with landscaping

4.2.3 Design of alternatives

Alternative one:

Directional interchange

A directional interchange is the most effective design for connection of Intersecting freeways

Advantages

- Reduced travel distance.
- Increased speed of operation.
- Higher capacity.
- They eliminate weaving.
- They avoid the loss of sense of direction drivers experience in traveling a loop.

Disadvantages

- This type of interchange is costly to construct, commonly using a four-level structure.

Alternative two:

Trumpet interchange

It's a service interchange that uses three leg in intersecting highways. It is used in local and collector streets to improve junctions.

Advantages

- It can be used in local, collector and arterial streets
- It can be used in three intersecting roads in any roads.

Disadvantages

- Right-of-way is likely to dictate this type of interchange.
- Construction cost may be a demerit depending on the site.
- Safety and operations in the proposed site are likely to dictate interchange type selection for any specific location.

Alternative three:

Diamond

A diamond interchange has four ramps that are essentially parallel to the major arterial. Each ramp provides for one right-turn and one left-turn movement. Because left turns are made at grade across conflicting traffic on the crossroad, intersection sight distance is a primary consideration.

Advantages

- It is the most generally applicable and serviceable interchange configuration and usually has a smaller footprint than any other type.
- Its design is not dictated by traffic, topography, or special conditions like other interchanges.

Alternative four:

Cloverleaf

The full cloverleaf interchange has four loop ramps for the left-turning traffic.
Outer ramps provide for the right turns. A full cloverleaf is the minimum type interchange for a freeway-to-freeway interchange. Cloverleaf designs often incorporate a C-D road to minimize signing difficulties and remove weaving conflicts from the main roadway.

Advantages

- Elimination of all left-turn conflicts with one single-level structure. This is because all movements are merging movements,
- It is adaptable to any grade line arrangement.

Disadvantages

- The left-turn movement has a winding route on the loop ramp, the speeds are low on the loop ramp
- There are weaving conflicts between the loop ramps.
- The cloverleaf also needs a large area. The weaving and the radius of the loop ramps are a capacity constraint on the left-turn movements.

4.2.4 Evaluation of alternatives

Solution of traffic congestion and conflicts can take different approaches as shown above in various alternatives of traffic interchanges. All these alternatives have their pros and cons. Before settling for a particular approach, it is therefore advisable to carry out a critical analysis of each approaches merits and demerits so as to identify the best approach for the situation.

Urban neighbourhood renewal can assume a number of approaches as already indicated above. Alternative two is best suited for the job since it conforms to the site and the intersecting roads. Its suitability and advantages surpasses the disadvantages hence designer chose the alternative two for the implementation process.

Evaluation of alternatives

Table 13: Evaluation of Alternatives

Source: compiled by author

Alternatives	**Advantages**	**Disadvantages**
Directional interchange	• Reduced travel distance. • Increased speed of operation. • Higher capacity. • They eliminate weaving. • They avoid the loss of sense of direction drivers experience in traveling a loop	• This type of interchange is costly to construct, commonly using a four-level structure.
Trumpet interchange	• It can be used in local, collector and arterial streets • It can be used in three intersecting roads in any roads.	• Right-of-way is likely to dictate this type of interchange. • Construction cost may be a demerit depending on the site. • Safety and operations in the proposed site are likely to dictate

		interchange type selection for any specific location.
Diamond	• It is the most generally applicable and serviceable interchange configuration and usually has a smaller footprint than any other type. • Its design is not dictated by traffic, topography, or special conditions like other interchanges	
Cloverleaf	• Elimination of all left-turn conflicts with one single-level structure. This is because all movements are merging movements, • It is adaptable to any grade line arrangement.	

4.3 Site Planning and Design Process Stages

Site planning is a tool that is used to determine appropriate development outcome based on the problem experienced in Lunga Lunga Road in its endeavours to come up with a sustainable design that is economically plausible. The site must be understood in terms of:

- Existing form
- its effects
- Solution to the identified problem.

The following stages were followed in the design process.

Field survey

This was undertaken in the research process it aimed at establishing the causes of traffic congestion along Lunga Lunga Road. This field survey addressed various parameters that were identified at the initial stages of the research project. Field survey assisted the researcher in making valid inferences of the conflicts and the causes of this traffic problem. In the field survey poor configuration of junctions, increased in the number of vehicles decay of the railway line were identified as one of the congestion triggers. However the main cause of this congestion was a junction which caused vehicular queuing and conflict. The researcher

identified this as the main cause and opted to provide a planning solution by introducing a traffic interchange.

Data analysis and synthesis

This was adhered to, to provide insights into the findings of the field survey. This led to findings which established the actual causes of traffic congestion. They included the following: narrow carriage way, people walking on the carriageway, poor configuration of junctions, and increase in the number of vehicles, private cars and Lunga Lunga- Likoni junction.

Logical synthesis of the findings led to the researcher identifying to the major cause of this congestion which was identified as on junction which is a bottleneck. This junction leads to traffic conflict which worsens the problem.

Program Development

This stage is the blueprint in the development project it consisted of the designer to draft a guide to enable him accomplish his task. The items in the guide are as follows:

- A statement of goals that the project should achieve.
- A list of project objectives by which these goals will be accomplished.
- A list of project elements that will be included and a description or analysis of their interrelationships.

Table 14: Program Development

Source: compiled by author

THE DESIGN PROGRAM

Goal Statement

To redesign Likoni- Lunga Lunga to an interchange.

Objectives

5. To determine suitability of proposed site for Likoni road- Lunga junction
6. To review and propose the relevant planning and design standards guiding a traffic interchange.
7. To develop a site plan for Likoni Road- Lunga Lunga junction
8. To propose project's implementation, monitoring and evaluation framework and institutional structure for upgrading of Lunga Lunga- Likoni road junction geared to alleviating traffic conflict and congestion.

Program Elements

Two Ramps on both sides of Lunga Lunga Road

- Deceleration lanes
- Footpaths

- Storm drains
- Electricity lines
- Street lighting
- Landscaping element

Overpass on Likoni Road.

- Street lighting
- Storm drainage channels
- Footpaths
- Acceleration lane

Underpass on Likoni Road.

- Street lighting
- Storm drainage channels
- Footpaths
- Deceleration lane

Choice of preferred strategy

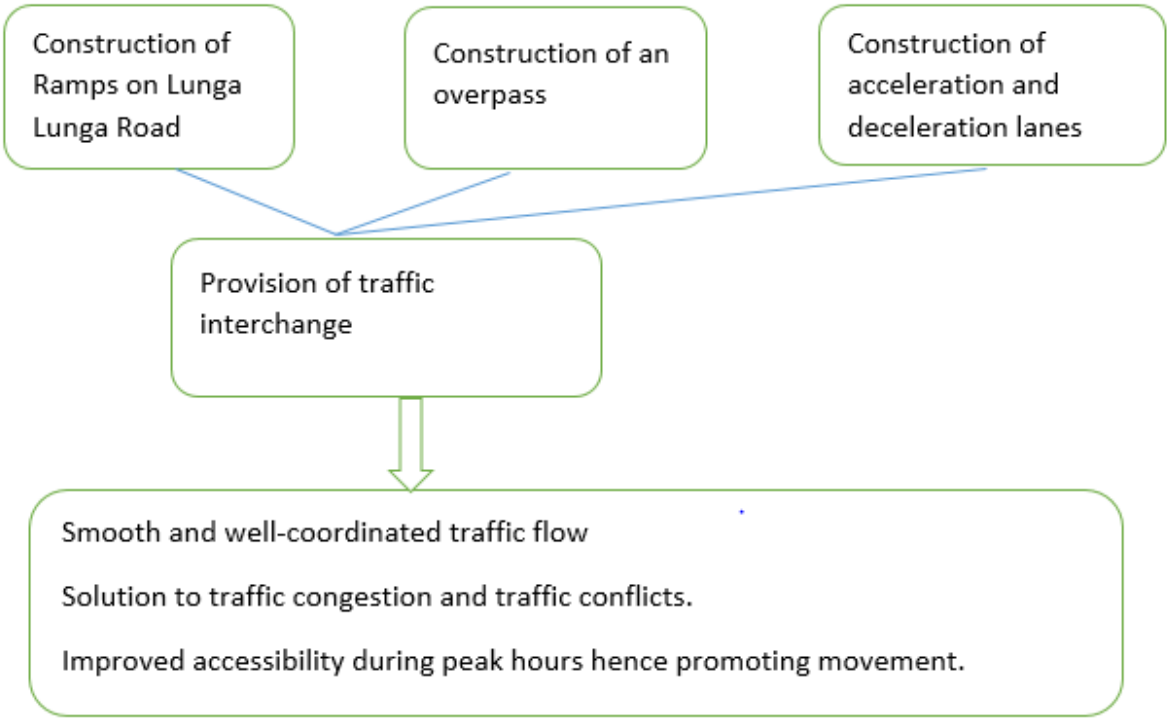
As seen in the analysis the best suited design is the trumpet interchange considering the site conditions and the nature of the intersecting roads. This interchange will conform in the proposed site in relation to the adjacent developments and the site parameters. The situation on the road (Traffic congestion) necessitates a prescriptive measure to address the existing situation. Traffic in Nairobi is projected to increase in relation to the increase in population. This means that vehicles both personal automobiles and public transport vehicles will increase too. This will lead to the worsening of the situation in the study area visa Vis Nairobi. The design may be sustainable and economically viable since it will solve conflict that manifests itself on Lunga Lunga Road and around Likoni Road.

Justification

- The road is used to access heavy industrial cluster and also used as an alternative road to Jogoo road.
- This alternative is the most plausible economically
- The alternative will help solve the problem of traffic congestion and conflict that occurs on these road hence leading to smooth traffic flow and increased returns to business.
- The proposed design conforms to the proposed site hence improving aesthetic value of the site.

Figure 13: conceptual framework of an interchange

source compiled by author



Above shows Conceptual framework for redevelopment alternative

Recommendations

This section led to the inception stage of this project it proposed planning prescriptive measures to address this problem. It was the section that had solutions to the problems identified in the findings section. It proposed an interchange as a planning recommendation to solve this problem.

Inception of the development project

Development project was informed by the recommendation section in the research project. These recommendation were of planning nature meaning they were prescriptive and implementable.

Design of alternatives

The preferred design was selected to solve the problem in the junction. This was the best design chosen was the most appropriate. The planner chose the model that was plausible economically and respond effective to the problem at the Likoni- Lunga Lunga junction. The alternative was to redesign that junction into an interchange in order to promote smooth traffic flow and alleviate conflicts and congestion.

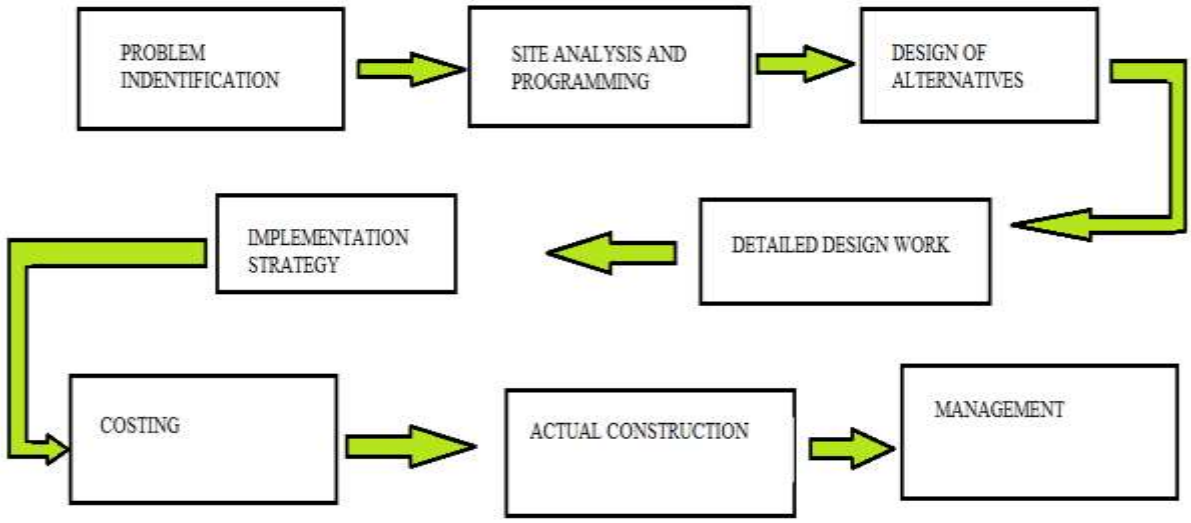
Implementation monitoring and evaluation

The alternative was implemented. This section constituted of: costing, time frame, actors and the roles with forms and steadiness to investigate the receptiveness of the development alternative model in line with the stated objectives

Schematic diagram showing stages of site planning

Figure 14: stages in site planning

source: compiled by author



Source: compiled by author 2014

4.4 Development of spatial models/ drawings.

The study that was done in December 2013 and January 2014b necessitated the inception of this project which is guided by its objectives to implementation.

The following are illustrations of the site plan of the interchange:

Photo 1: Site plan

Source: compiled by author

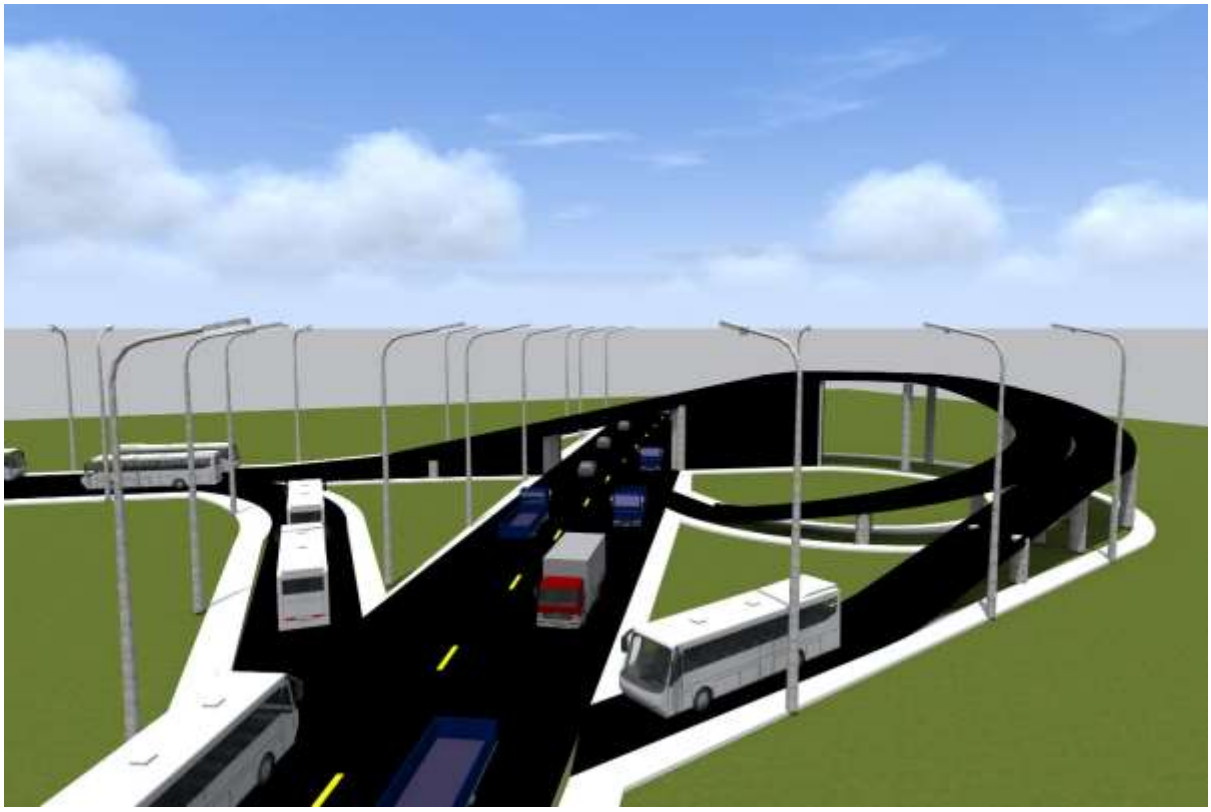


Photo 2: 3D perspective

Source: compiled by author

Population projection of study area.

Population projection is based on the 2009 population and housing census in which the current population of the industrial area is 318,542 persons.

Population of Nairobi growth rate= 3.8%

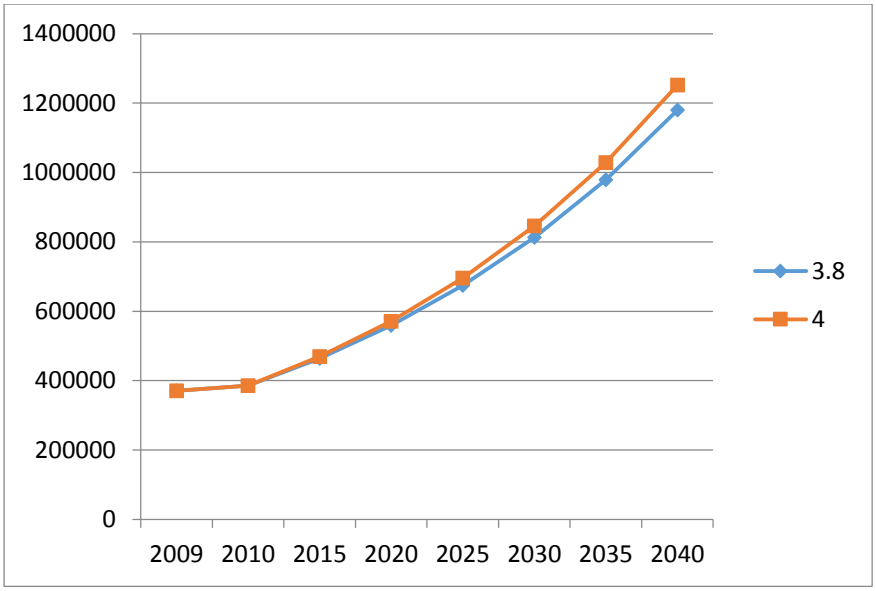
Total population= 318542

Period of a long term plan= 40 years

Projected population after 40 years= 1415992

Using the 4% growth rate the population at the end of the year will be 1529326(source author)

The population is projected on geometric projection method.



Bar graph 3: Population projection

Source: compiled by author

Proposed land budget

The total suitable land for this type of an interchange is 7.44 ha as estimated in the field of which 3.44 ha can accommodate some premises together with landscaping. This land is enormous due to the turning movement of heavy commercial vehicles since the place is a heavy industrial area.

Table 15: Land Budget

Source: compiled by Author

Land use	**Actual area**
Ramps	6ha
Overpass and acceleration lane	1.44ha
Total land(7.44- 3.44)	7.44- 3.44(buildable land)= 4.00 ha

Budget for Lunga Lunga- Likoni interchange.

It is proposed earlier that Likoni Road- Lunga Lunga Junction will be upgraded to an interchange and below are the components of an interchange.

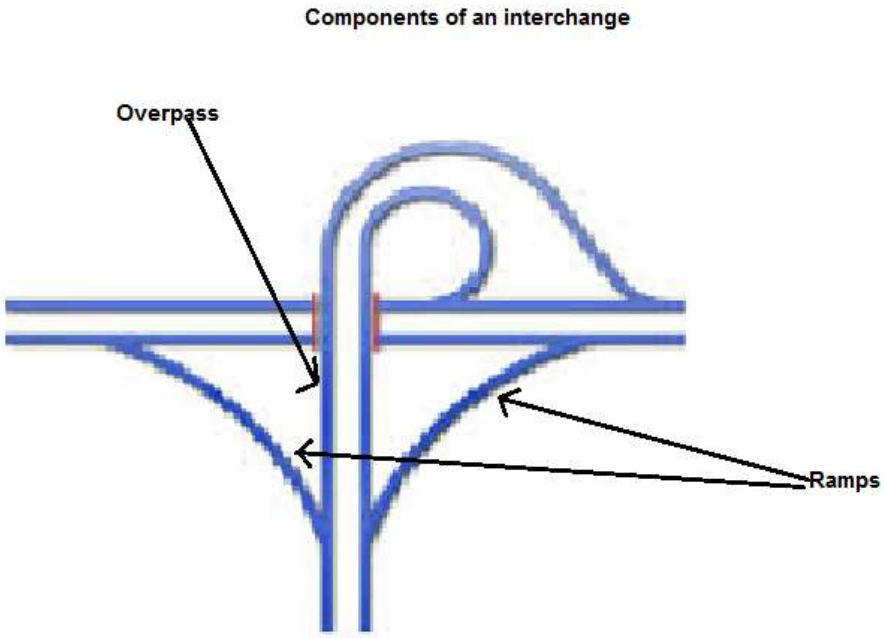


Photo 3: components of an interchange

Source: adapted from Webster interchange design and compiled by author

Ramps
The ramps will be used by the vehicles which want to enter a particular road as it will be shown in the designs. I.e. the right ramp will be used to turn right and join traffic on the vertical roads while the left ramp will be used to turn left and join traffic using the horizontal road.

Under pass
This will be evident after construction of overpass it will be used for through traffic along the horizontal road hence reducing conflicts as experienced earlier.

Overpass
This is crucial for the traffic on both horizontal and vertical roads. Vehicles on the vertical road will join other traffic on horizontal road via this overpass and they will use ramp which is extremely above.

Vehicles on horizontal road will access the vertical road via the ramp that is curved to the left. All movements in these junctions are catered for.

Acceleration lanes
Acceleration lanes will be used by the ramps joining the main traffic.

Deceleration lanes
They will be used by the vehicles exiting the main traffic on the road to join the ramps for turning movement.

4.5 Implementation strategies

The implementation matrix below shows how the objectives outlined in chapter one of this project are achieved through the designs proposed in this chapter. In this section various actors involved as well as implementation and timelines are also indicated.

4.6 Indicative project matrix

Table 16: Indicative project matrix

source : compiled by author

Projective objective	**Tasks to be done**	**Time frame**	**Actors**	**Indicators of success**
To develop a site plan for Likoni Road- Lunga Lunga junction	• site analysis • Identifying the affected land (where there will be land acquisition) • Monitoring and evaluation • Commissioning of construction	6 months	• City County of Nairobi • Ministry of transport • KURA • Engineers and architects • NEMA	Reorganization of adjacent land uses. A design that conforms to the site.
To propose project's implementation, monitoring and evaluation framework and institutional structure for upgrading of Lunga Lunga-Likoni road junction.	**Redevelopment of the project area** • Notification of the public for the redevelopment • Land acquisition • Design of the Project • Environmental Impact Assessment reports	2 ½ years	• KURA • NEMA • Ministry of transport • Land owners	A traffic interchange that is aesthetic. Smooth traffic flow and conflict free road.

	• Verification of evaluation • Notification of private land owners • Negotiation of Private land owners who are affected • Payments to owners of land acquired • Nominating the contractors • Actual construction • Restoration of all land affected by project			

4.7 Implementation schedule

Implementation schedule shows the timelines that all stages of the project must meet in line with the project objectives. The table below shows the implementation schedule of this project.

Table 17: Implementation Schedule

source: compiled by Author

Activity	2014		2015				2016			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Initial designing of the interchange										
Environmental Impact Assessment										
Project design and approval										
Preparation of land acquisition process										

Verification of evaluation										
Notification to land owners										
Negotiating with private land owners										
Acquisition of land										
compensation										
Nomination of contractors										
construction										

CHAPTER 5: MONITORING AND EVALUATION

Monitoring and evaluation is essential in any project since it ensures the project is implemented in line with its objective thus leading to the project success. The process below will enable the review of progress, identification of problems in design and/or implementation and initiation of relevant adjustments.

5.1 Monitoring and Evaluation Stages in the Implementation of Project

This process is done throughout the cycle of the project. The stages in which monitoring and evaluation were done are as follows.

Implementation stage	Expected outputs and outcomes	Indicators	Baseline status	Target	Means of monitoring and evaluation	Actors	Resources
Plan/ designs drawing approval	An approved trumpet interchange plan for the project area	General improvement of traffic flow and circulation patterns by the approved design/ plan.	The plan that exists of the area is not updated hence it has not met the traffic demands of the present	A design that will promote smooth traffic flow thereby alleviating traffic congestion and conflicts.	Assessing the effectiveness efficiency of traffic flow on the interchange presented in the design -Assessing the level of the design's conformity to policy framework and zoning plan of the area.	City planning department city hall KURA	Funds Human resource and time.
Notify landholders on the compulsory acquisition of land for expansion	Sufficient land for construction Smooth and efficient construction work	Size of land required for the development	The land available for the construction is not adequate. The area was not speculated to accommodate that kind of development.	Acquisition of sufficient land for construction and compensation of the owners.	Assessing amount of land acquired in relation to the land budget	KURA. City County of Nairobi. Ministry of Transport. Landholders.	Funds Human resource.
Developing traffic interchange	Good designs that conforms to the site	Effective and efficient traffic flow backed by	The junction is the source of traffic	Traffic interchange that enhances	Ensuring this design follows stipulated	Architects. Planners. City county of	Funds. Human resource.

designs		the design	congestion on the site/ project area.	smooth traffic flow on the road.	guidelines and international standards.	Nairobi. Ministry of transport.	
Environmental Impact Assessment of the project	EIA reports Project that is not injurious to the environment	Attainment of environment standards by the project in relation to ecological zone of the area.	-	Sustainable development	Regular monitoring	NEMA	Funds Human Resources.
Tendering process and nomination of contractors	Arrival of materials in the site. Organizing and division of construction labour in the site.	Construction materials. Hierarchy of expertise and their duties.	-	Work to be completed in stipulated timeline. Sourcing of competent technical expertise and quality materials.	Vetting of contractors. Assessing the standards of materials in the site.	KURA City county of Nairobi. Ministry of transport.	Funds and Human resources.
Actual construction	A trumpet traffic interchange.	Reduced or alleviated traffic. congestion Less traffic conflicts. Smooth traffic flow.	No interchange.	Construction to be done as required in timelines. Smooth traffic flow and faster movement of goods and people.	Construction is guided by the designs and plans	Contractors. KURA. Ministry of Transport.	Funds. Labour Time. Construction materials.

Table 18: monitoring and evaluation strategies of the project

source: compiled by author

5.2 Guidelines to implementation process

Implementation of the project will be according to the planning and design standard of chapter two of these project. However the implementation process of this project will be guided by the following:

Community awareness and public participation- this is to ensure the development process is in line with the constitution that allows the public to own the project in their area. The public should also be sensitized on the importance of the project to the area and to the community at large.

Involvement of the stakeholders in the implementation process- this is to ensure that stakeholders are involved in this process and each of stakeholder contribute to the success and the realization of these project.

Use of blend of both qualitative and quantitative approaches- this will ensure process of monitoring and evaluation is effective and efficient since it will be a participatory process.

The project shall adhere to the design standards and the county integrated development plan- this project conform to both the national and the county vision and objectives contained in the development plans hence the design will be guided by the regional plan in achieving the transport goals of improving all roads. The project should be a result of trickling down of goals and objectives of county integrated development plan. The project must comply with the standards.

Concept of sustainable development shall be the blueprint of these projects- the interchange must not be injurious to the environment. It must not compromise the needs of the future generations as it meets the needs of the present generation.

City planning department shall approve all the designs and drawings of the area- all designs and plans must be approved by the authority in which the project is in their jurisdiction.

5.3 Site management plan

The relevance of the site management plan is to provide a solution to the environment impacts that are anticipated off in the project lifetime. It will provide the environment impacts and the mitigation measures. The table below shows the environmental site management plan.

5.4 Environmental site management plan

Table 19: environment site Management plan

Source: compiled by author

Expected environmental impact	Activity	Mitigation measures
Construction waste • Demolished debris • Smoke.	Site clearance and construction	Loading debris on trucks for safe disposal. Fencing off the area from the public to prevent smoke inhalation. Fill any depression to bring about levelling to promote landscaping
Loss of flora	Site clearance and removal of vegetation	Land scaping incorporated in the design to compensate for the lost vegetation. Cutting of trees if need arises. Incorporating natural vegetation in the design.
Noise	Site clearance and construction.	Construction be done during the day time only. Provide workers with ear muffs. Using equipment with noise suppressing technologies. Buffering the area with iron sheets to contain the noise within the site.
Dust	Site clearing and construction	Watering to prevent the dust from being blown off by wind during the levelling and excavation process.
Soil erosion	Site clearance and construction	Excavate in the designated areas to avoid soil erosion. Landscape with grass after completion of project to prevent further erosion.

Conclusion

The main goal of these project was to develop a traffic interchange for Lunga Lunga road. According to the research done this will help solve conflicts and delays along this road hence improving the accessibility of the area. Trumpet interchange will have an overpass, underpass and ramps to facilitate movements in these junction. This will lead to effective and efficient movement around this junction. An interchange is said to be effective and efficient in conducting traffic without conflicts hence promoting congested free areas. The inception of these project is the blueprint to the solution required on the ground however it must follow the objectives to guide its implementation.

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