1. Project Outline

1.1. Background and Context

- The Government of Kenya (GoK) is in the process of establishing a national development plan called "Kenya Vision 2030" in 2008 with the goal of becoming an industrialized middle-income country with per capita income of US $ 10,000 by 2030.
- Nairobi, the capital city of Kenya, is a little bigger than Seoul, and the road area rate is 11%, which is half of that in Seoul. The average travel time is 64.7 minutes when commuting to work and the annual social cost of traffic congestion is close to around US $ 175 million. Hence the citizens' "quality of life" as of 2017 is ranked 188th out of 189 countries around the world.
- In order to solve these traffic problems, GoK established an integrated mass transit system (MRTS) plan, which will gradually build Metro, LRT, and BRT on Nairobi Citys' nine major arterial roads by 2030. However, the progress is slow sluggish and there is concern about consistency because each agency is undergoing the BRT project individually ; That is, KeNHA is in charge of Line 1, Line 3 and 5 by KURA, and Line 4 by MOTI. Currently, the only undergoing project in the MRTS is to build the BRT Line 1 on the A104 Highway supported by the World Bank.
- The Government of Kenya has requested the Government of the Republic of Korea to support the project to build the BRT Line 5 on the Outer Ring Road, which is the secondary arterial road of Nairobi City. This road supported by AfDB is now being constructed and will be completed in September 2017. The outer ring road currently has a three-lane carriageway for accommodating the BRT system but was originally planned to construct two lane carriageway without considering the MRTS.
- This project is financed by EDCF funds and the "2017-2018 Detailed Action Plan" was prepared based on the joint declaration adopted by the 5th Korea-Africa Ministerial Economic Cooperation (KOAFEC, 2016.10).

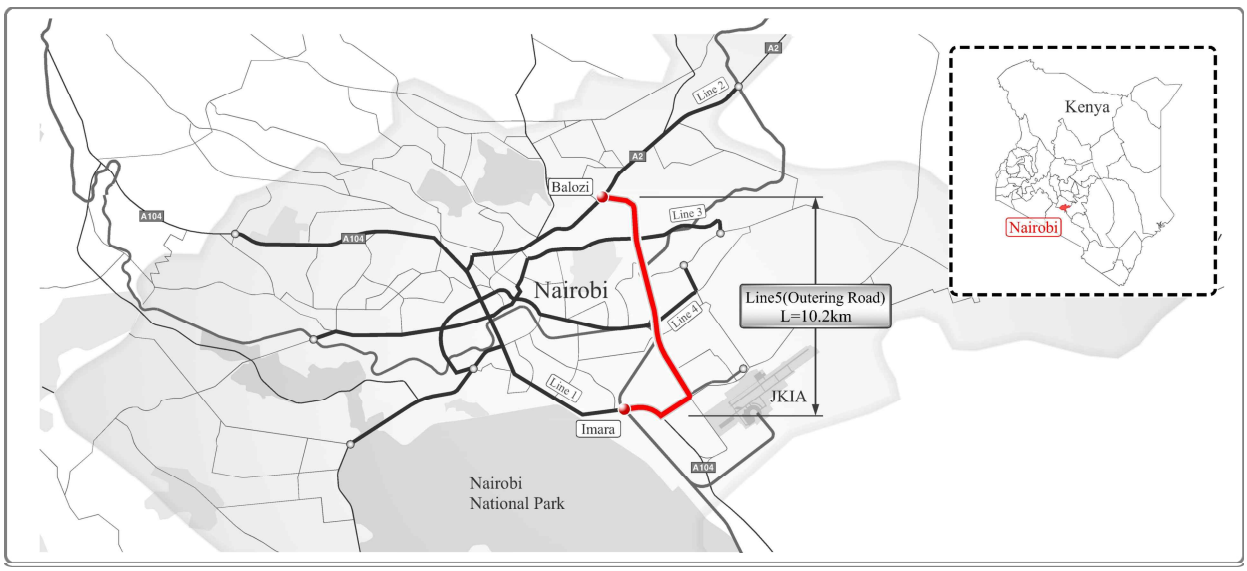
1.2. Purpose and Work Scope

1.2.1. Purpose of Project

- Build an economically feasible BRT system that is appropriate to Kenyas' economic status and citizen's income level
- Build an eco-friendly BRT system that minimizes damages to the citizens' lives and the environment
- Build a convenient BRT system that guarantees mobility, accessibility and safety of users
- Build an advanced BRT system by using advanced engineering technology
- Build a BRT system that can improve the quality of life of citizens and as a sustainable public transport
- Build a systematic, rational and successful future-oriented BRT system that will be positioned as an important transportation infrastructure to facilitate the development of the Northeast region as the future development axis of Nairobi

1.2.2. Work Scope

Outline	Comments
Project Name	• Feasibility Study for KENYA Bus Rapid Transit System
Location	• Nairobi, the Republic of Kenya
Study Area	• Primary : Outer Ring Road • Secondary : Nairobi city
Time Scope	• Target Year : 2030(short-term), 2040(long-term)
Work Scope	• Field Study • Travel demand forecast • Conceptual plan for BRT • Feasibility Analysis



2. Literature Review

2.1. Urban Development

2.1.1. Vision 2030

- The republic of Kenya is one of the fastest developing nations in Africa. The country's economy has benefited from government policies and structural reforms, which have resulted in strong inclusive growth. Substantial economic activity has been maintained through a strong aggregate demand and increases in investment, both in the public and private sectors.
- With a total area of 582,646 Sq. kilometers, Kenya has a population of 47,251,000 inhabitants (UN estimate, 2016) of which 3,915,000 (UN estimate, 2015) live in the capital city Nairobi. The population of Kenya grows at a rate of 2.7% (UN estimate, 2010-2015) and the urban population grows at a rate of averagely 4.3% annually (UN estimate, 2010-2015).
- Due to its uncoordinated economic and population growth, there is an over dependence on the use of private cars, which causes serious congestion problems in the capital. This has resulted in the degeneration of social conditions, pollution of the air and noise, and causing unnecessary delays to its citizens.
- The Government of Kenya recognizes the transport sector as a facilitator of rapid economic growth. Realizing the negative effects of these worsening conditions, it planned a national long-term development policy that aims to transform Kenya into a newly industrialized, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment. This plan is termed Vision 2030. The Vision comprises of three key pillars: Economic; Social; and Political.
- The Economic Pillar is geared towards achieving an average economic growth rate of 10 per cent per annum and sustaining the same until 2030. The Social Pillar seeks to engender just, cohesive and equitable social development in a clean and secure environment, while the Political Pillar aims to realize an issue-based, people-centered, result-oriented and accountable democratic system. The three pillars are anchored on the foundations of macroeconomic stability; infrastructural development; Science, Technology and Innovation (STI); Land Reforms; Human Resources Development; Security and Public Sector Reforms.
- The vision is to achieve *"a national long-term development blue-print to create a globally competitive and prosperous nation with a high quality of life by 2030 that aims to transform Kenya into a newly industrializing, middle-income country*

providing a high quality of life to all its citizens by 2030 in a clean and secure environment".

- Some of the developmental projects in the infrastructural sector are the rehabilitation and expansion of Kisumu Airport, building a Nairobi Metropolitan region bus transit system, development of light rail for Nairobi and suburbs and development of new transport corridors among others.
- In line with these developments, many studies have been conducted to understand the transport congestion situation since it forms an important component of a country's economic growth indicator.

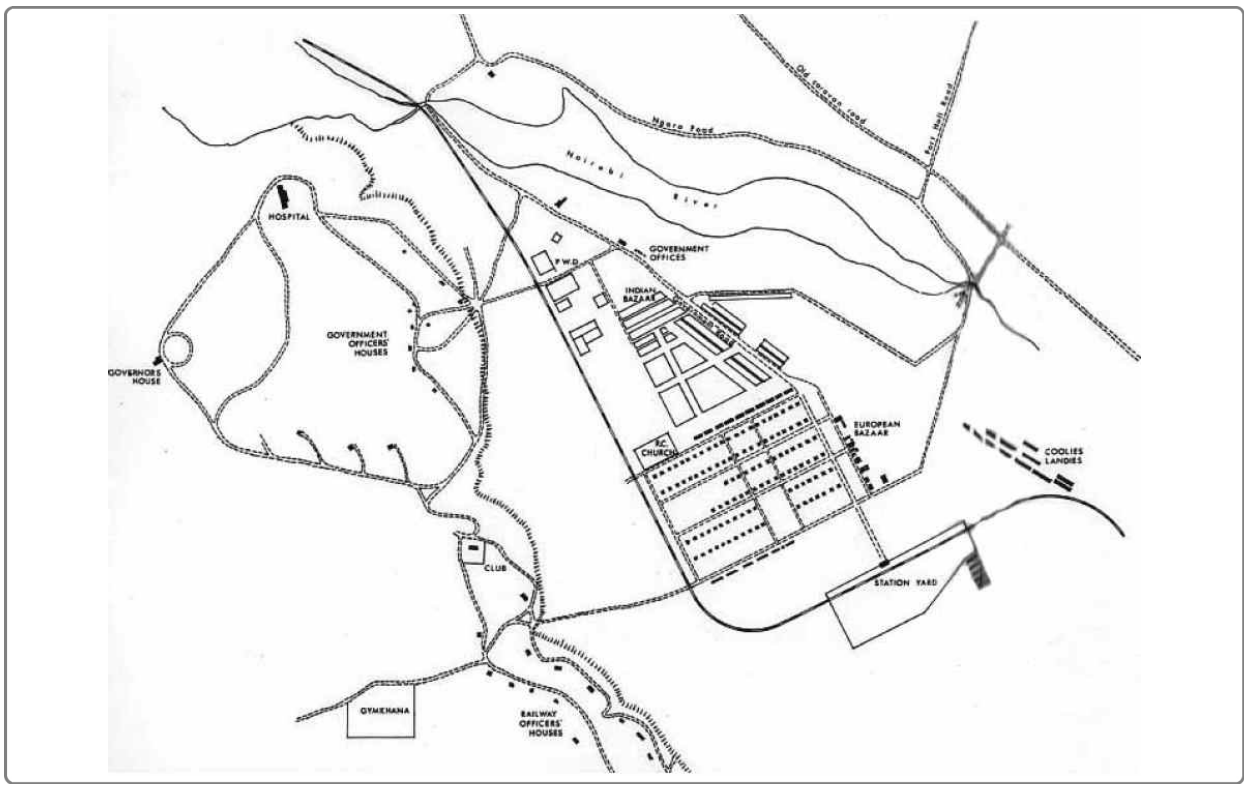
2.1.2. NIU Plan

- Due to the current transportation problems in Nairobi, many master plans and other studies have been conducted. The following components are proposed for the CBD development.
  - ✓ Road network to strengthen linkage in CBD and in the hierarchy of types of roads;
  - ✓ New urban transport system (loop monorail line) to reduce traffic to the existing CBD;
  - ✓ Urban facilities such as bus terminal, Nairobi station square, and open space and green corridor;
  - ✓ Future land use concept and development ordinance to encourage optimum utilization of the current development ordinance; and
  - ✓ Spatial development such as urban development in selected areas, land re-adjustment project, and urban renewal projects.
- The Integrated Urban Development Masterplan by JICA suggested that roads in the capital should be maintained regularly due to the fact that, traffic is slowed down when the roads are in bad conditions. Also, it was suggested that after the construction of the southern bypass, heavy vehicles should not be allowed to use the international highways since they obstruct traffic in the city

2.1.3. Urban Planning History of Nairobi City

1) First Plan of Nairobi City in 1898

- The first plan of Nairobi City was drawn by a young assistant railway engineer by the name of Arthur Frederick Church in 1898. Church was only 30 years old when he was dispatched to assist Chief Engineer George Whitehouse, and was instructed to prepare a town layout for the railway depot in "Nairobi".
- The church`s plan had the following features:
  - ✓ The Nairobi Station was just about the same location as it is today, and the railway was laid out at the same location where the Uhuru Highway is today;
  - ✓ The main street from the railhead, which was called Station Road (today`s Tom Mboya Street), was laid out to the north of the station, with a design to be wide enough for a three-axled oxcart wagons to turn;
  - ✓ Another street parallel to Station Road called Victoria Street (renamed as Government Street in 1901, and today as Moi Avenue) was laid out with the same width as the Station Road, along with 13 commercial plots called European Bazaar;
- The first town plan was approved by the Chief Engineer Whitehouse on 30 November 1898 and dispatched to London for approval. The spelling of the town was changed by Whitehouse from Nyrobi to Nairobi as is used today before his approval.
- The first plan strikingly resembles the town layout of Nairobi City`s CBD and its environs today.

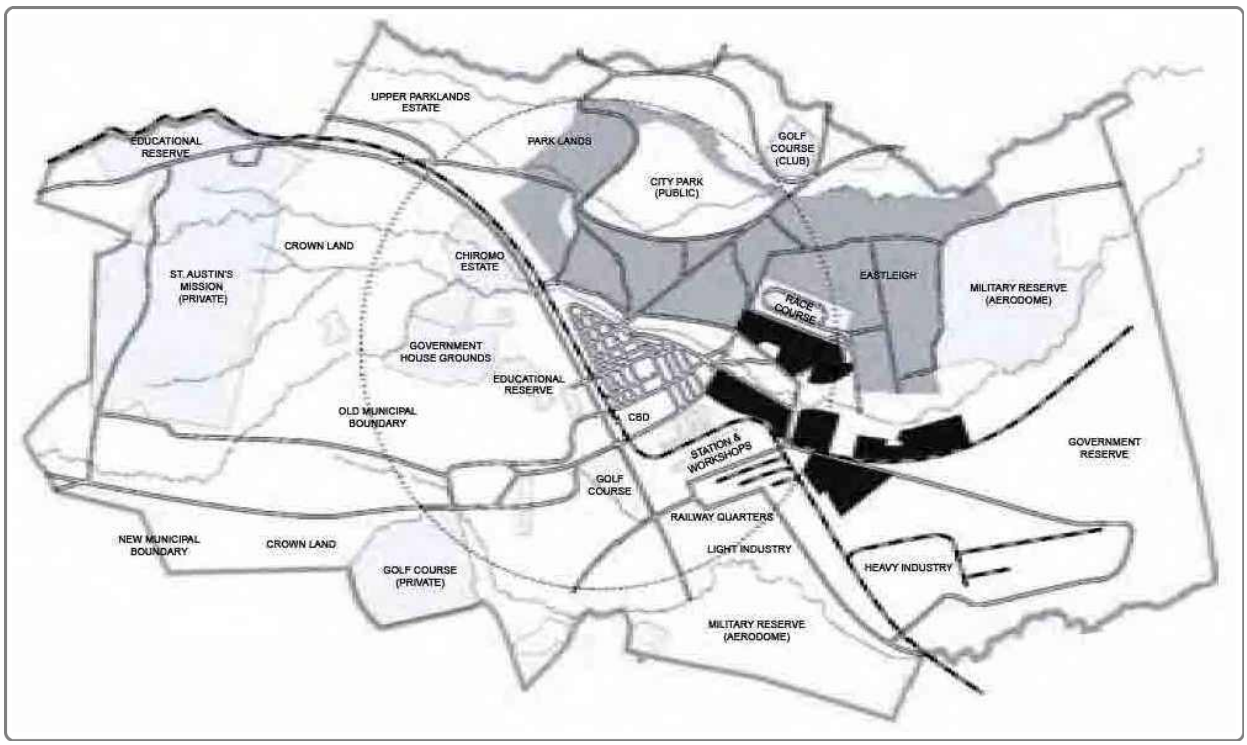


Source : S. Mills Railway to Nowhere – The Building of the Lunatic Line Nairobi, 2012

<Figure 2-1> First Plan of Nairobi City by A.F. Church in 1898

2) Plan for a Settler Capital in 1927

- The Plan for a Settler Capital was drawn by F. Walton James and planned by Eric Dutton in 1927 under the British East African rule.
- The city area was expanded to 77 km2 to accommodate the growing population. The plan focused on the improvement of drainage and clearing of swamps and regulating building and density. The plan introduced traffic regulations to reach the expanded land for residence, although the residential area was generally segregated by racial groups.



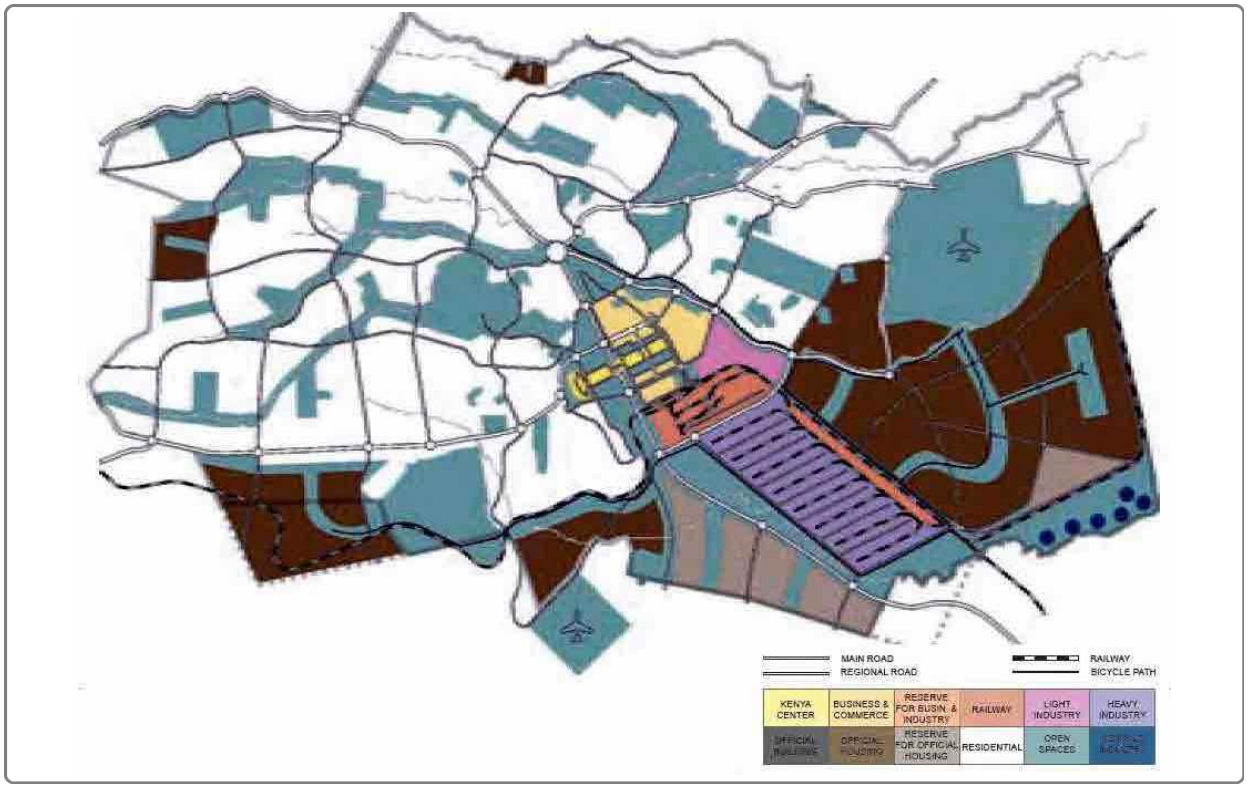
Source : ETH Studio Basel, History of Urban Planning in Nairobi City, 2008

<Figure 2-2> Plan for settler Capital in 1927

3) Master Plan for a Colonial Capital in 1948

- The new plan was an experiment in town planning for the colonial Nairobi City, prepared by L. W. T. White, architect and town planner and head of the Department of Architecture, University of Cape Town and others.
- In this plan, a zoning scheme was introduced with zones for official buildings, business and commercial, industry, railway, residential, official housing, open space, forest reserve, and parks.
- Also the plan was expected to make Nairobi more attractive for industrial investments.
- It is noteworthy that the alignment of the railway had been changed to the present one along the western part of the town, which gave way for the expansion of the Uhuru Highway today.

- The area to the south of the railway station was converted to an extensive industrial zone.



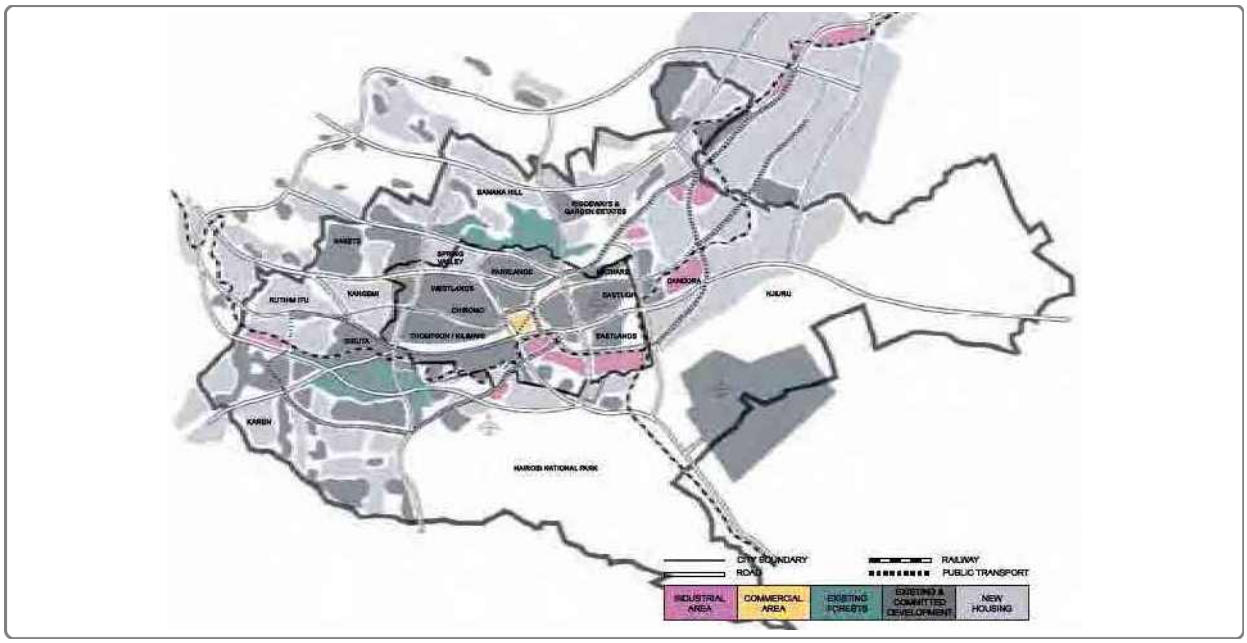
Source : ETH Studio Basel, History of Urban Planning in Nairobi City, 2008

<Figure 2-3> Master Plan for a Colonial Capital in 1948

4) Nairobi Metropolitan Growth Strategy 1973

- In 1971, the United Nations assisted the formulation of the Metropolitan Growth Strategy in collaboration with the UN experts, urban planners in the City Council of Nairobi, and urban planning consultants to form the Nairobi Urban Study Group. In 1973, Nairobi Metropolitan Growth Strategy was published.
- The Metropolitan Strategy set the ultimate target year of 2000, and an intermediate target of 1985. The population of Nairobi City was about 590,000 in 1971, and projected to be 2.88 million in 2000, which was composed of 1.94 million for NCC and the remaining balance in adjoining areas outside of NCC, including Ruiru and Western Shamba. The actual population of NCC was 2.20 million in 2000, so the target was slightly surpassed.
- The recommended strategy of the 1973 Plan contains six parts, as listed below:
  - Regional Strategy
  - City Strategy
  - Description of the Strategy by Area
  - Phasing of Development
  - Recommended Transport Policy
  - Implementation Resource

- In the 1973 Strategy, a variety of proposals were made in relation to the urban planning of Nairobi City, major parts of which are listed below:
  - ✓ The Central Business District (CBD) was already congested, and it was proposed to supplement some of the functions of CBD in some suburban sub-centres to avoid excessive concentration in reference to the experiences of some major metropolitan areas in the world. For Nairobi City, a wide road surrounding CBD was proposed with bus ways to connect residential and industrial areas, and use of private cars was curtailed so that the increasing number of population would shift to public transport.
  - ✓ The industrial area close to CBD was providing a large number of employments, but was already heavily concentrated. Excessive concentration should be avoided. When necessary, the expansion may be limited to capital-incentive, urban industry type with limited employments. For other existing industries, expansion of production shall be recommendable in suburban locations.
  - ✓ The northern part of the city, which then had mostly been taken in as coffee plantation and estates, was expected to be an urban area by the turn of the century. As some areas are steep-sided hills that are not easy to convert to high to medium density housing area or industrial area, they will be used mainly for low density housing development.
  - ✓ The southern part of the city, which includes Kibera and Wilson Airport, was proposed to be used chiefly as residential area for low to medium income population. Wilson Airport was proposed to be relocated to a site outside of Nairobi. The site after relocation may be suitable for industrial area.
  - ✓ Dagoretti is an area located in the west of the city, which was expected to have rapid population growth. In order to absorb employments within the zone, provision of industrial area and commercial centres would be necessary.
  - ✓ The eastern part of the city continues to serve for low to middle income population except for few high end estates.



Source : ETH Studio Basel, History of Urban Planning in Nairobi City, 2008

<Figure 2-4> Nairobi Metropolitan Growth Strategy 1973

5) The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014

- Proposed Structure Plan

- Based on the selected Sub-centre System (Bi-polar Corridor Development) structure, the technical working group on land use and settlement discussed the structure plan with the existing conditions and location.
- Road Network and Node
  - ✓ Residential and Commercial : Runda-Ruaka, Ruiru, Ruai, Karen and Langata
  - ✓ Office and Commercial : Uthiru and Kabete
  - ✓ Industrial and Commercial : Donholm and Airport, north
  - ✓ Residential, Commercial and Entertainment (Sports Facilities) : Ruaraka (Kasarani)

Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014

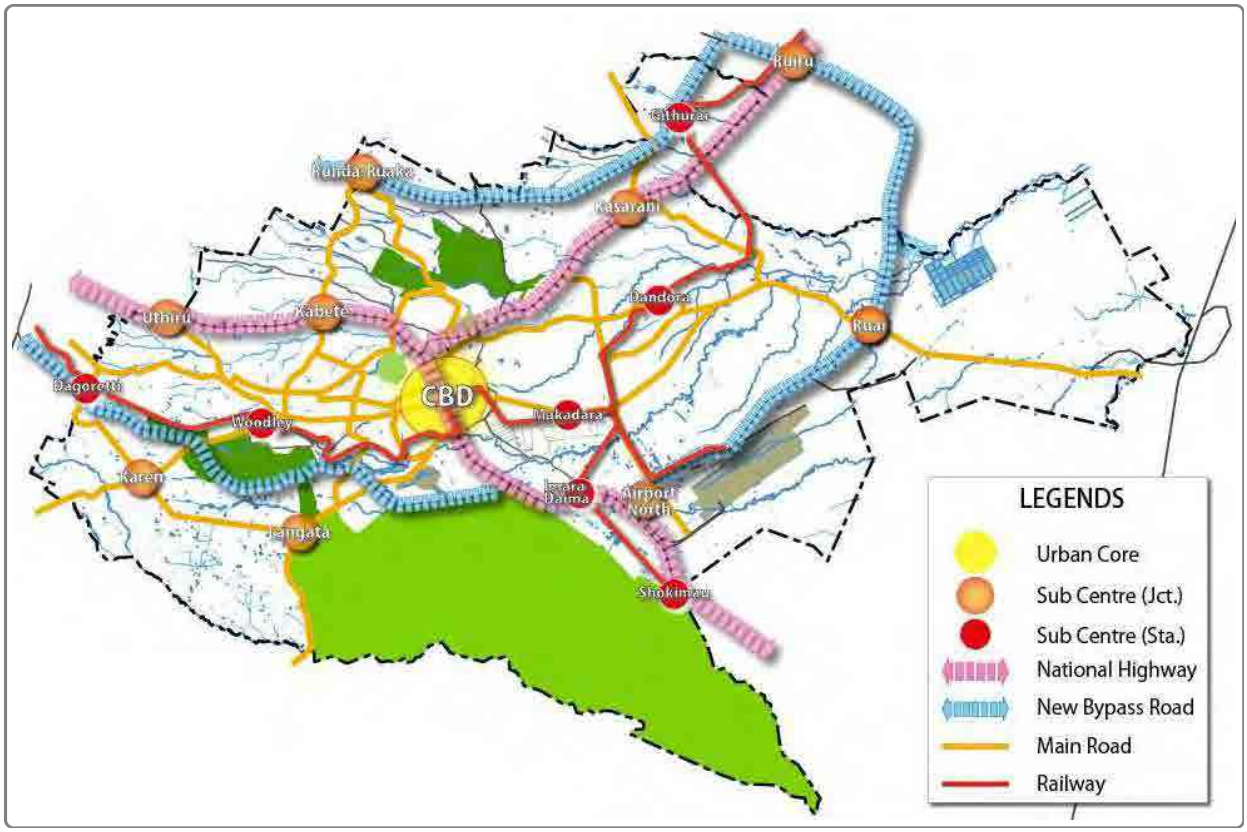
<Figure 2-5> Road Network and Nodes

- Railway and Road Transit Interchange
  - ✓ The red line in Figure 3-11 shows a railway corridor which is proposed in the Nairobi Metropolitan Services Improvement Project (NaMSIP).
  - ✓ As the railway stations are assumed to be utilised by a large number of passengers from surrounding areas, they have development potentials. It is expected to develop the area around main stations as sub-centres.

Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014

<Figure 2-6> Railway and Road Transit Interchange

- Proposed Structure Plan
  - ✓ A structure plan for Nairobi City is proposed based on the urban conditions including CBD, transport, and proposed development vision.
  - ✓ To realise a symbolic status as the centre of Kenya, and a gateway to East Africa Region by strengthening the function of Nairobi City's CBD;
  - ✓ To strengthen sub-centres to promote balanced development: narrowing the east-west gap, easing development pressure for the existing CBD, and dispersing social economic activities throughout NCC; and
  - ✓ To establish sub-centres along the interchanges of urban transport system to synchronise urban development and urban transport development: interchanges of major road network, interchanges of road and railway (including Light Rail Transit (LRT)).
  - ✓ The sub-centres (Runda-Ruaka, Ruiru, Kasarani, Uthiru, Kabete, Ruai, Karen, Langata, Airport north, Githurai, Dandora, Dagoretti, Woodley, Makadara, Imara-daima, and Shokimau) are located on interchanges in consideration of the road network and railway corridor. It is expected to make economic activity more efficient by the promotion of distribution of daytime population which is concentrated in CBD currently. The location of proposed sub-centres is shown in Figure 3-12.



Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014

<Figure 2-7> Proposed Structure Plan for Nairobi

2.1.4. Strategy and Spatial Planning Concept for Nairobi Metropolitan Region

1) Nairobi Metro 2030

- Nairobi Metro 2030 is a part of an overall national development agenda for Kenya towards 2030 and aims at optimizing the role of Nairobi Metropolitan Region(NMR) in the national development context.
- The Nairobi Metro 2030 is composed of: (i) growth and development framework; (ii) Metropolitan Nairobi`s strategic challenges; (iii) vision and goals, (iv) growth management structure, the goals, strategies, and actions; and (v) strategic vision to reality: employing class metropolitan governance systems.
- The vision, goals, and strategies set in the Nairobi Metro 2030 are summarized below.

✓ Vision

Metropolitan Vision 2030:

To be a world class African metropolis, supportive of the overall national agenda articulated in Kenya Vision 2030

Four principals :

(1) A world class working environment.
(2) A world class living environment.
(3) A world class business environment.
(4) World class metropolitan governance.

Key foundation for Metropolitan Vision 2030

(1) Building an internationally competitive and inclusive economy for prosperity
(2) Deploying world class infrastructure and utilities in the region
(3) Optimising mobility through effective transportation
(4) Enhancing the quality of life and inclusiveness in the region
(5) Delivering a unique image and identity through effective place branding
(6) Ensuring a safe and secure region
(7) Building world class governance system

✓ Goal, Strategies and Actions

Goals	Strategy and Action
Building an internationally competitive and inclusive economy for prosperity.	• Building a regional and global financial services, regional trade and business services hub. • Regional manufacturing, industrial technology parks initiative. • Building the Jomo Kenyatta International Airport City. • Diplomatic initiative. • Bringing the world to Nairobi Metropolitan Region: a tourism initiative. • Regional and global research and education hub. • Enhancing service culture in work organisations.
Deploying world class infrastructure and utilities in the region.	• Service level mapping exercise and benchmark nationally, regionally and globally. • Energy demand management initiative. • Water master plan. • Integrated waste management project. • A comprehensive stormwater drainage and flood water mitigation plan. • A metropolitan wide strategic environment assessment. • Integrated information communication technology infrastructure plan. • Smart city/villages strategy.. • Develop and integrated metropolitan infrastructure master strategy and plan.

Goals	Strategy and Action
Optimising mobility and accessibility through effective transportation.	• Metropolitan road transport infrastructure measures. • Metropolitan mass rapid transit program. • Traffic management strategies. • Central business district access strategies. • Demand management. • Logistics and supply chain management. • Land use measures. • Information and communication technology in transport measures. • Coordination of institutional interventions. • Metropolitan road safety program.
Enhancing quality of life and inclusiveness in the region.	• Housing and elimination of slum program. • Environmental management strategy. • Enhancing access to medical services strategy. • Enhancing access to and performance of education. • Enhancing food safety and security. • Ethnic and race relations. • Integrated spatial strategy for the Nairobi Metropolitan Region.
Delivering a unique image and identity through effective branding.	• Branding and promoting the Nairobi Metropolitan Region. • A Nairobi Metropolitan Region heritage and culture strategy. • An identity building urban design and landscaping strategy.
Ensuring a safe and secure Nairobi Metropolitan Region.	• An effective metropolitan policing strategy. • Street light program. • Building an effective metropolitan emergency service. • Metropolitan street addressing program.

2) Spatial Planning Concept for Nairobi Metropolitan Region

- Nairobi Metropolitan Development and approved in March 2013.
- According to the staff of the Ministry of Nairobi Metropolitan Development, despite the fact that the Ministry Nairobi Metropolitan Development does not exist in the new government structure, the plan is still valid and the NIUPLAN has to be in line with the Spatial Plan Concept for NMR. Some important contents of the plan, such as population framework, settlement pattern (build up area and new town), settlements hierarchy, land use/land cover, design intervention of NCC, which will be a base for NIUPLAN, are summarized as shown below.

Population Framework

- The gross density of NCC, by 2030, is proposed to be limited to 75 persons per ha increasing from 52 persons per ha in 2009. The assigned population size of NCC is 5.21 million and housing demand is forecasted at 1,303,125 in 2030.

<Table 2-1> Population of NMR

Sr. No	Spatial Units	2009	2030
1	**NMR**	**6,658,000**	**15,131,435**
	Urban	4,924,286	13,073,459
	Rural	1,733,714	2,057,976
2	**Nairobi City**	**3,138,369**	**5,212,500**
3	ONMR	3,519,631	9,918,935
	Urban	1,785,917	7,860,959
	Rural	1,733,714	2,057,976
4a	**Northern Metro**	**3,519,631**	**9,918,935**
	Urban	1,785,917	7,860,959
	Rural	1,733,714	2,057,976
4b	**Eastern Metro**	**3,519,631**	**9,918,935**
	Urban	1,785,917	7,860,959
	Rural	1,733,714	2,057,976
4c	**Southern Metro**	**3,519,631**	**9,918,935**
	Urban	1,785,917	7,860,959
	Rural	1,733,714	2,057,976

Source : Spatial Planning Concept for Nairobi Metropolitan Region

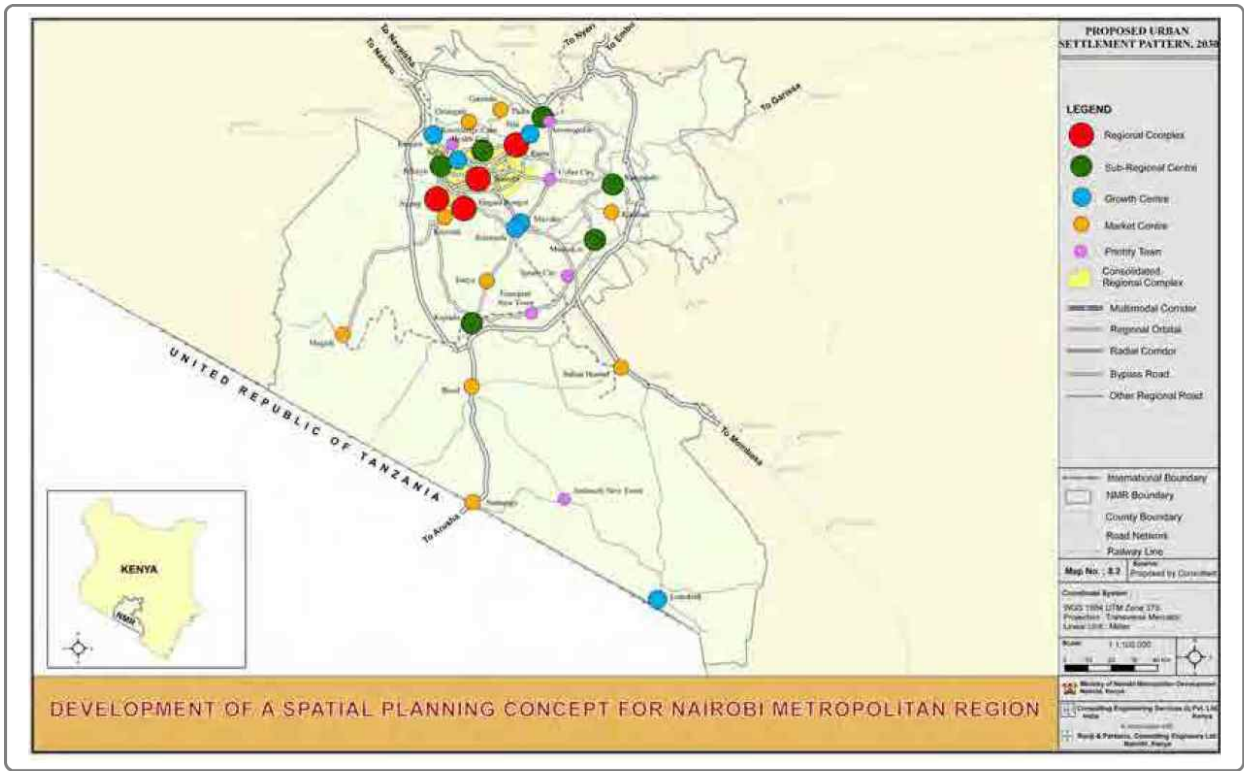
Settlements Hierarchy of Settlements

- Proposed Settlement Hierarchy for NMR in 2030 is summarized below. NCC is classified in the "Regional Complex".

<Table 2-2> Settlement Hierarchy of NMR

Level	Settlement Hierarchy	Settlements	Characteristics
Ⅰ	Regional Complex	Nairobi City-Ngong-Ongata Rongai-Ruiru Complex	• Highest administrative functions • Specialized and world class facilities • Tertiary activities
Ⅱ	Subregional Centre	Thika, Kikuyu, Kiambu, Machakos, Tala/Kangundo, Kajiado	• Administrative functions/county headquarters • Higher level infrastructure • Secondary and tertiary activities • Strong industrial base
ⅡA	Priority Town	New Towns	• Planned to decongest Nairobi City and developments in the surrounding regions • Designed with specialized facilities on the basis of world class norms • To be planned as special packages and special focus for development
Ⅲ	Growth Centre	Limuru, Karuri, Juja, Mavoko, Kitengela, Loitoktok	• Intermediary towns • Important role in promoting rural development and in achieving a balanced distribution of urban population • Provide functional linkages between the smaller towns and subregional centre
Ⅳ	Market Centre	Gatundu, Githunguri, Kathiani, Kiserian, Namanga, Isinya, Bissil, Sultan Hamud Magadi	• Small town having linkages with immediate rural hinterlands. • Is the higher order village having central location and potential for development within its catchment area, with relatively better services and facilities in terms of education, health, communication, accessibility and has the capacity to serve a group of basic villages.
Ⅴ	Central Village Centre	To be identified as part of subregional plans	• Would cater to the rural hinterland as agro service centre in the collection and distribution of agricultural goods and services with processing, marketing, warehousing, and storage facilities
Ⅵ	Basic Village	All villages	-

Source : Spatial Planning Concept for Nairobi Metropolitan Region

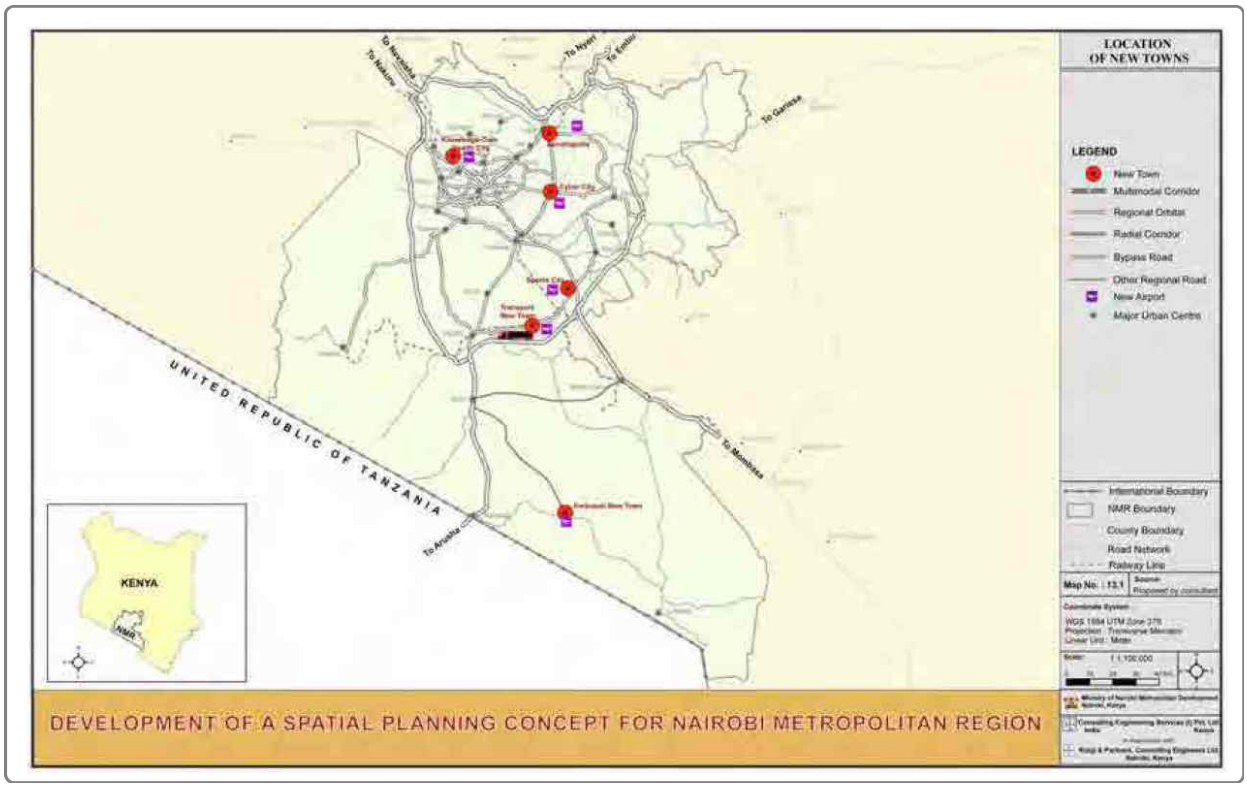


Source : Spatial Planning Concept for Nairobi Metropolitan Region

<Figure 2-8> Proposed Urban Settlements Pattern

New towns

- Six new towns are proposed within the NMR such that each county has two new towns. The six proposed new towns are as follows:



Source : Spatial Planning Concept for Nairobi Metropolitan Region

<Figure 2-9> Location of New Town

<Table 2-3> List of New Towns Proposed

No	New Towns	Characteristics
1	Aerotropolis	**Function** The Aerotropolis will comprise aviation-intensive businesses and related enterprises. Aerotropolis typically attracts industries related to time-sensitive manufacturing, e-commerce fulfilment, telecommunications and logistics, hotels, retail outlets, entertainment complexes, and exhibition centres; and offices for business people who travel frequently by air or engage in global commerce. . **Location** The Aerotropolis is proposed near Thika Municipality, north of Garissa Road in between the proposed regional orbital and Greater Eastern By-pass extension to Thika at a distance of approximately 40 km from CBD, Nairobi City.
2	Knowledge-cum-Health City (Nairobi City)	**Function** The Knowledge-cum-Health City would comprise agricultural research centres, technological university, management institutes, agro-based health centres, hospitals, and other institutions. **Location** The Knowledge-cum-Health City is proposed north of Limuru Road, coffee and tea plantations at a distance of approximately 20 km from CBD, Nairobi City.
3	Cyber City	**Function** The Cyber City would comprise service oriented industries in the field of information technology and information technology enabled services (IT/ITeS) for the region. **Location** The Cyber City is proposed at the junction of Greater Eastern By-pass and Kangundo Road in Machakos County at a distance of approximately 30 km from CBD, Nairobi City.
4	Transport New Town	**Location** The Transport New Town is proposed along the regional orbital near the transport-cum -logistic hub near Kajiado in Kajiado County at a distance of approximately 60 km from CBD, Nairobi City. **Population and Density** It has been envisaged that by 2030 the Transport New Town will accommodate a population of 100,000 with a population density of 50 ppha
5	Sports City	**Function** The Sports City would incorporate world-class sporting venues and sports academies, as well as residential and commercial properties and all related amenities such as hotels, entertainment outlets, schools, medical facilities, and retail opportunities. It is envisaged that the main sports complex will have a multi-purpose outdoor stadium of a capacity of 60,000 seats. The stadium could be used for athletics, cricket, and football. Also a 25,000 seat cricket ground, a 10,000 seat indoor arena, and a 5,000 seat field hockey stadium are proposed apart from sports academies and institutes. **Location** The Sports City is proposed on a relatively flat land at the junction of the Mombasa Road and the regional orbital in Machakos
6	Amboseli New Town	**Function** Amboseli New Town will comprise the hospitality industry to boost tourism in the area. It will consist of hotels, resorts, entertainment outlets, gaming arcades, outdoor activities with plush green landscaped gardens. **Location** The new town is proposed adjacent to the Amboseli National Park at a distance of approximately 150 km from CBD, Nairobi City.

Source : Spatial Planning Concept for Nairobi Metropolitan Region

Land cover/land use

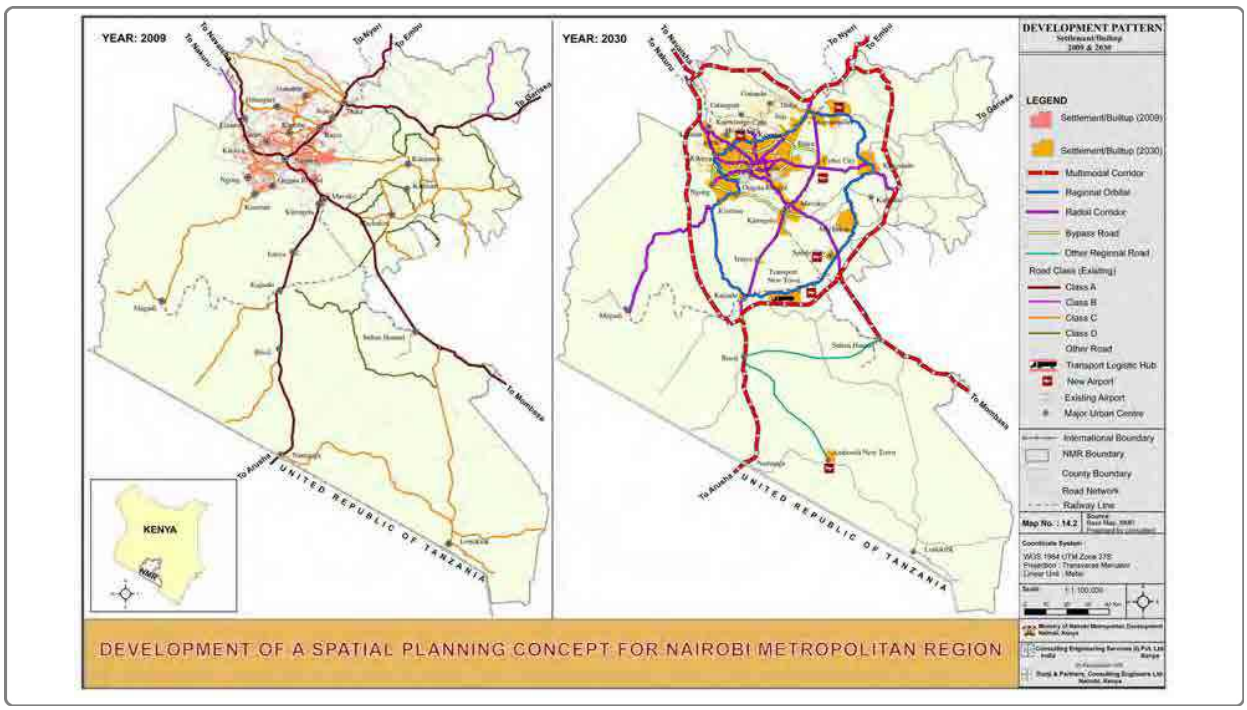
- The following land use classification is proposed for NMRs.

<Table 2-4> List of New Towns Proposed

No	Land Use Classification	Characteristics
1	Settlement Zone	Settlement zone is the spatial built up area within the region and covers both urban and rural areas.
2	Transport Zone	The transport zone includes road, rail, and airport areas within the region.
3	Forest Zone	It includes all environmentally sensitive areas which are meant to be protected. It includes existing areas under forest, national parks; conservation zone; and open shrubs, plantation, and riverine trees.
4	Water Bodies	The water bodies in the region are divided into three categories: rivers, drainage; swamps and sand; and other water bodies.
5	Agriculture and Rangeland	It includes land used for agriculture and related activities such as grazing, etc.

Source : Spatial Planning Concept for Nairobi Metropolitan Region

- Settlement zone is proposed as follows. The entire NCC and six new towns are classified as settlement zones.



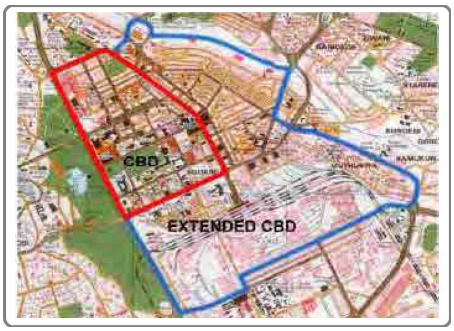
Source : Spatial Planning Concept for Nairobi Metropolitan Region

<Figure 2-10> Development Pattern, Settlement/Build Up 2009 and 2030

Design Interventions for Nairobi City

- Urban design and regional landscape is also proposed in the Spatial Planning Concept, particularly in CBD of NCC.

- The following interventions are recommended in the plan:
  - Establishment CBD as a City Precinct
  - Redevelopment of Moi Avenue
  - New square development in the CBD area
  - Air force station area reorganization
  - Industrial area reorganization and linkages
  - Capitol complex development
  - Nairobi riverfront development
- Figure 3-16 illustrates the necessity of delineation of CBD boundary based on collective strategies, for the development of the entire area.



Source : Spatial Planning Concept for Nairobi Metropolitan Region

<Figure 2-11> CBD of Nairobi City County

2.2. Transportation Infrastructure

2.2.1. MRTS Plan

- In quest of developing an integrated public transport network for Nairobi and the Nairobi Metropolitan Region (NMR), all studies and plans made were brought together. This Harmonization Study consisted of two main parts. The first part was to harmonize the previous studies and the second was to develop an integrated Mass Rapid Transit System (MRTS) network.
- The first part shows that, a consolidated procedure is important because all the studies cover the same issues but partly have different emphasis and considerations. The second part begins with an integrated traffic model, considering both commuter rail and the proposed MRTS. This model is based on the data gathered from the ongoing NCC project (NIUPLAN) and contains the most up-to-date information on spatial structure and traffic demand both for the current situation and the 2030 horizon. Using this model, the most appropriate MRTS corridors have been identified resulting in a public transportation network consisting of the corridors with the highest traffic demand. The basic routes of these corridors essentially coincide with the nine corridors identified in the 2011 MRTS Feasibility Study.
- NMR has a combined transport network comprising of Roads, Railways, Airways and Pipelines. International Trunk Roads Nos. A104 and A109 pass through the NMR. They cater to international traffic enabling movement of traffic from Mombasa Port to/from neighboring land locked countries of Uganda, Rwanda, South Sudan and Ethiopia. The International Trunk Routes A2 and A104 form part of the Trans-African North-South Road corridor from Egypt to South Africa. Presently 8 bus companies operate about 880 buses in NMR, they are:
  - · Kenya Bus Service Management Ltd (275 buses)
  - · City Hoppa Ltd (200 buses)
  - · Express Connections Ltd (180 buses)
  - · Outridge (80 buses)
  - · Star Bus (60 buses)
  - · City Shuttle (35 buses),
  - · City Fairy (30 buses) and
  - · Paradiso (20 buses)"

  (Ministry of Transport et al., 2011, Sheet 4-2)
- Matatus operate from more than 24 terminals. However the 10 major terminals as shown below, handle a bulk of the Matatu vehicles.
- The network consists of 6 BRT corridors, 3 metro corridors and 3 LTR corridors. 3

of the BRT corridors are suburban extensions of the metro corridors leading to additional transfer needs towards the City Center. The metro lines are completely in a tunnel and most parts of the LTR are elevated with only short sections in a tunnel.

- Nairobi was founded as a railway town, and the main headquarters of KRC is still situated at Nairobi railway station, which is located near the city center. The line runs through Nairobi, from Mombasa to Kampala. Its main use is freight traffic, but regular nightly passenger trains connect Nairobi to Mombasa. A number of morning and evening commuter trains connect the center with the suburbs, but the city has no proper suburban rail, light rail or tramway lines.
- One study (MRTS, 2011) recommended that the eight major radial corridors that serve Nairobi should be expanded to 2, 4 or 6 lanes so that Bus Rapid Transit (BRT) and other High Occupancy Vehicles (HOV) can use them. It also proposed that an appreciable amount of resources should be invested in diverse public transport modes such as commuter rail, light rail and BRT. The BRT was selected by the Mass Rapid Transit Harmonization Study (MRTHS) in a way so as to have a higher priority among the other options which was conducted to reduce the proposals of the MRTS due to the geographic scale and funding requirements. The criteria used by the MRTHS was based on finding a mode that could be executed with ease and at minimal cost but with a high level of abstraction from both existing bus routes and the private motor car.
- The MRTS study generally prescribed a closed BRT system that would run on four radial routes with a harmonious commuter rail system, plus bus/matatu feeder routes.
- The population size of Nairobi Metropolitan Region (NMR) is estimated to be 13 million by 2030, and 5.21 million in Nairobi city, while a 10% economic growth per annum is assumed. The workforce in Nairobi should grow from 1.09 to 1.82 million and the formal to informal ratio of 1:3.96 should become 1:2 in NMR. Currently, 67% of Kenya's motor vehicles are to be found in Nairobi. 47% of the trips are by walking. 70% of the motorized transport is made up by public transport (Matatus and buses), accounting for around 4 million passengers a day. The current transport network of the city is inadequate, in need of upgrading and restructuring. The vision of the Kenya National Urbanization Policy is to

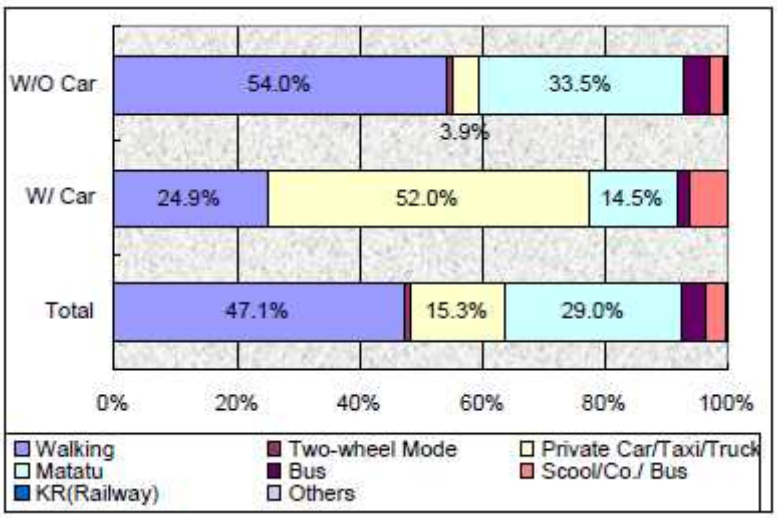
"…promote a hierarchically balanced, economically prosperous, socially cohesive, culturally Vibrant and functionally interlinked and sustainable urbanization and urban settlement pattern enabling the cities and towns of Kenya to be productive, prosperous and competitive; and transform Nairobi as a World Class City and the Socio-Economic

– *Diplomatic Capital of Africa."* (Ministry of Nairobi Metropolitan Development et al., 2012, p.2.6)

- The vision for the transport network system planning is to:

"(…) conceptualize and recommend an integrated, multi-modal transport system for Nairobi Metropolitan Region to enable the region to be economically efficient, socially cohesive, and environmentally sustainable; and to provide high quality transport service to people and goods on an efficient, productive and equitable basis. The vision of NMR Transport System plan may be stated as: "Mobility to all – efficient, equitable and safe."

- Considering the population who do not own a car in the NMR, 54% go to their destination by walking while 33.5% rely on public transportation. In total 47.1 % of the population walk to their destination, 29% rely on Matatu services and 15.3% use private cars. On average each person in Nairobi makes 2.25 trips a day. 46.5% of the total daily trips are aimed at returning home, 25% for work purposes and 9.8% for school purposes. In Nairobi 47% of all trips are by walking. Walking should be promoted both as a primary and as an access mode to the transit system, though appropriate development strategies.



<Figure 2-12> Choice of mode and car ownership Commuter Rail, Ministry of Nairobi Metropolitan Development et al., 2012, p.9.9

- Since most of the trips are on foot, pedestrian facilities should be planned well so as to promote walking. This can be done by cultivating measures that increase safety, improve accessibility for the disabled and disadvantaged, providing consistent levels of walking environment and improving pedestrian facilities.
- By 2009, the commuter rail service levels had deteriorated significantly; hence a

Joint Development Agreement (JDA) was signed by the KRC and InfraCo to develop the Nairobi Commuter Rail system. Key Objectives of the Project were, *"…develop the Nairobi Commuter Rail system, which includes a rehabilitation of the public rail assets in and around Nairobi, development and redevelopment of stations, and provision, operation and maintenance of new rolling stock" (InfraCo, 2009, p.3) and "The principal objective which drove the evaluation and selection of alternative technical solutions was the establishment of a commercially viable commuter rail service capable of serving a maximum number of passengers safely, reliably and with affordable tariffs."* (InfraCo & KRC, 2009, p.5).

- A coherent MRTS network was the outcome of the Harmonization Study, and it is considered the best solution for the public transport needs of NMA. A detailed harmonisation will be required in subsequent planning phases, to integrate designs, especially at junctions of MRTS corridors.

2.2.2. BRT Plan

- The Integrated Transport Planning Ltd, ITP was appointed by the World Bank to design a Feasibility Study and Business Implementation Plan for the Line 1 of the Nairobi Bus Rapid Transit (BRT). This was conducted based on international and World Bank standards.
- The BRT system in Nairobi was developed through a number of parallel studies conducted by several consultants and their development partners. Gauff Consultants handled BRT Line 4 (east). Ingerop / Lux consultants handled BRT Line 3 and Line 4 (west).
- Line 3 and 4 were reviewed and found to be largely sound and robust but there were still some issues to be further analyzed. ITP confirmed the work that was done on the Line 3 by Ingerop Consultants but suggests that further study was done before accepting it formally.
- According to personal analysis conducted by the Institute for Transport and Development Policy (ITDP), the best BRT service that would provide a high financial return and high passenger attractiveness is a direct service with BRT infrastructure on A104 and through the Central Business District (CBD) + 15km of Langata road. In this scenario, multiple BRT services which best reflect the current matatu routes will function on mixed traffic routes as part of their routes and then continue along the BRT route along the A104. The scenario also captures the passengers using the corridor and avoids passengers making expensive transfers.

- One of the major arterial routes in Kenya, the Mombasa road and Uhuru highway also known as A104 links the port of Mombasa to Nairobi and stretches towards the Ugandan border. Even though this road provides an important function by connecting the capital and west of Nairobi's CBD, it is malfunctioned in terms of providing local access. The BRT infrastructure design for this corridor was designed by Gibb Africa and the Lot 1 of the corridor has already been completed.
- The ITP believes there are aspects of the completed parts of Lot 1 that has to be revisited. An area that must be revisited is the architectural design which makes use of the "Ocean Waves" concept. ITP argues that Kenya is very far from the Indian Ocean and the citizens would find it difficult associate with. An updated form makes use of colours and symbols of four animals native to the Nairobi National Reserve.
- The station locations would be reviewed and placed at centers by judging from demand forecasts and validations of land use relationships.
- It was suggested by the ITDP that a fleet of 385 busses that cost $239,650 should be used for the 450,000 passengers who use that route daily. The estimated benefits would be $25,286,662. But ITP believes that, once the vehicle type to be used on the BRT corridor is selected, the number of vehicles to be used would be calculated based on a desired and comfortable vehicle occupancy figure.
- According to the National Transport and Safety Authority, there are 18,850 matatus and buses registered in Kenya, with 279 Sacco's operating within the Nairobi Metropolitan Area. The ITDP in 2013 conducted a survey which indicated the average occupancy of both matatus and bus services along the corridor.

<Table 2-5> ITDP (2013), Mean Vehicle Occupancy by Vehicle Type

Vehicle size	14 seat	25 seat	33 seat	39 seat	45 seat	52 seat
Mean Occupancy	11.2	16.9	24.4	28.4	34.0	38.7

- From JICA's study, widening of the highway and redefining of Nairobi's CBD as an "ITS- Smart City" is important. This incorporates a strategic terminal plan which includes the proposal for a relocation of the Inter City Bus Terminal on the BRT network and the provision of a new city center situated adjacent the network.
- From assumptions made by ITDP based on patronage levels, it is suggested that by the second year, BRT line 1 has the potential of generating enough cash which could be channeled into wider system operations.

3. Current Status of Nairobi

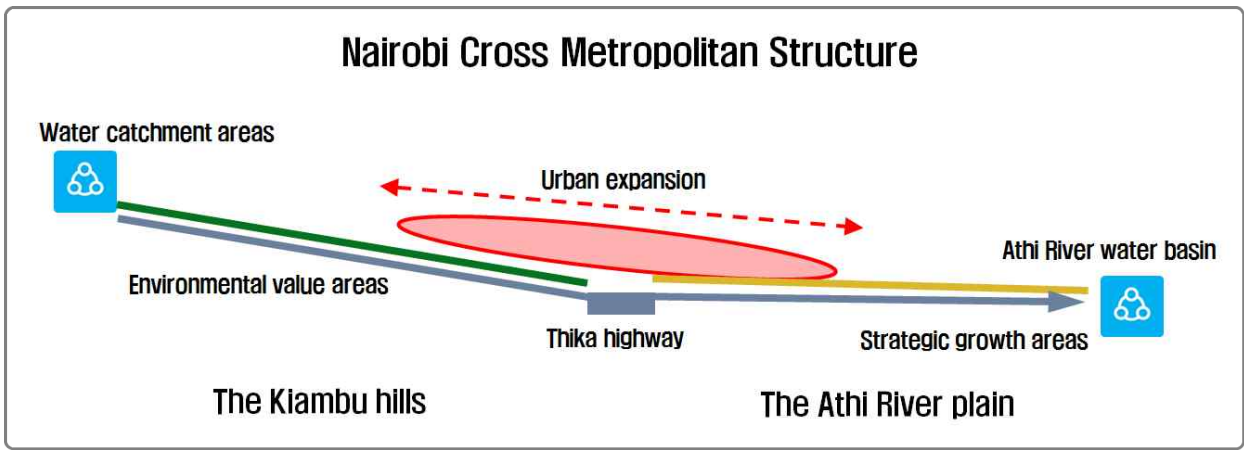
3.1. Urban Conditions

3.1.1. Urban Structure

1) Urban Characteristics

▪ Basic Urban Character

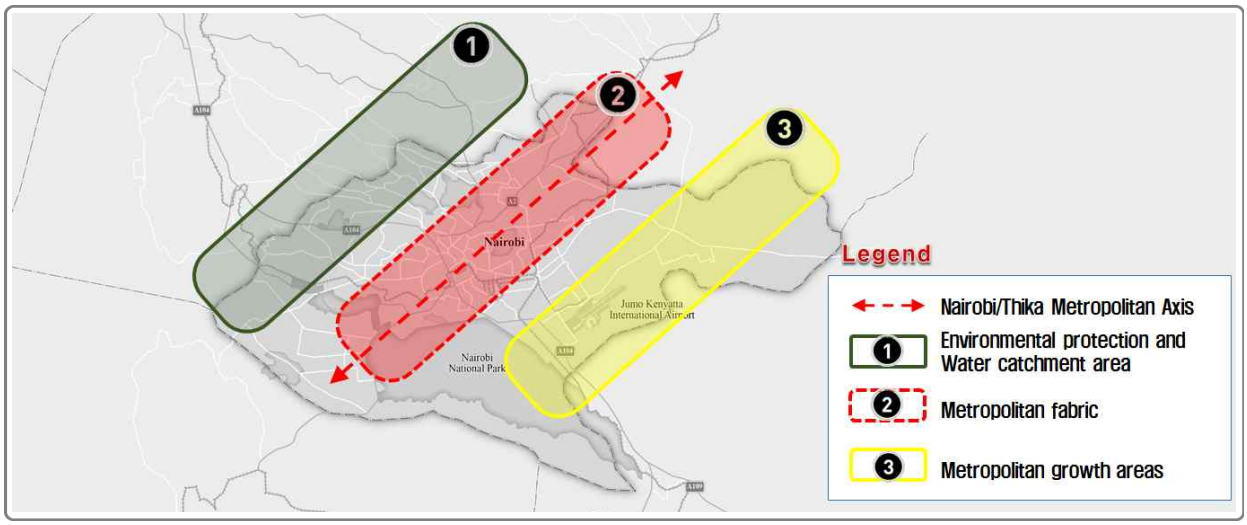
- Nairobi City's cross-sectional profile is shown in figure 3-1 below. Northeast to southwest axis is urban activity core areas. Northern and western areas are environmental value areas including agricultural activities. Eastern and southern parts are rapid urban growth areas.



Source : NaMSIP Consultant

<Figure 3-1> Cross-sectional Profile of Nairobi City

- This Urban profile can be simplified on a map as shown if Figure 3-2 below. Red color shows Nairobi Metropolitan fabic. Green color shows an environmental value area. And yellow color shows a metropolitan growth area.

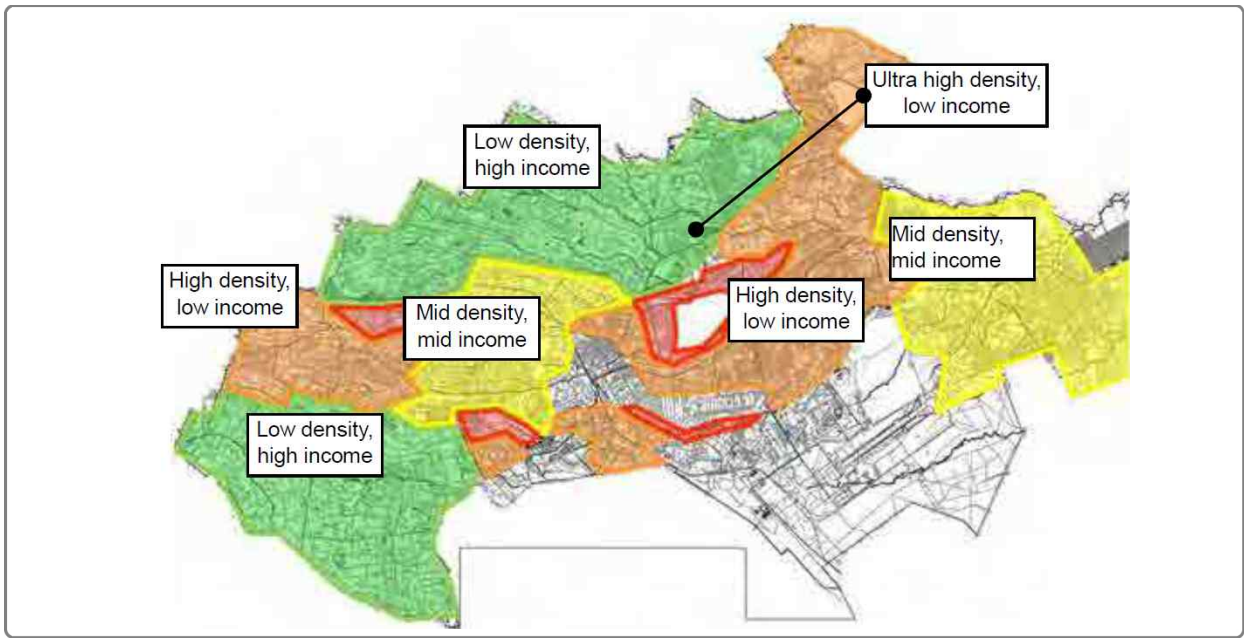


Source : NaMSIP Consultant

<Figure 3-2> Basic Urban Character

Population Distribution

- Basically, population distribution in Nairobi tends to be low density in the west and high density in the east. Extremely high density areas are mainly slums or informal settlements.



Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Reupublic of Kenya, 2014

<Figure 3-3> Land Availability in Some Areas

Major Obstacle for Urban Planning

- Nairobi City has several spatial obstacle for urban planning as shown in Table 3-1 below.

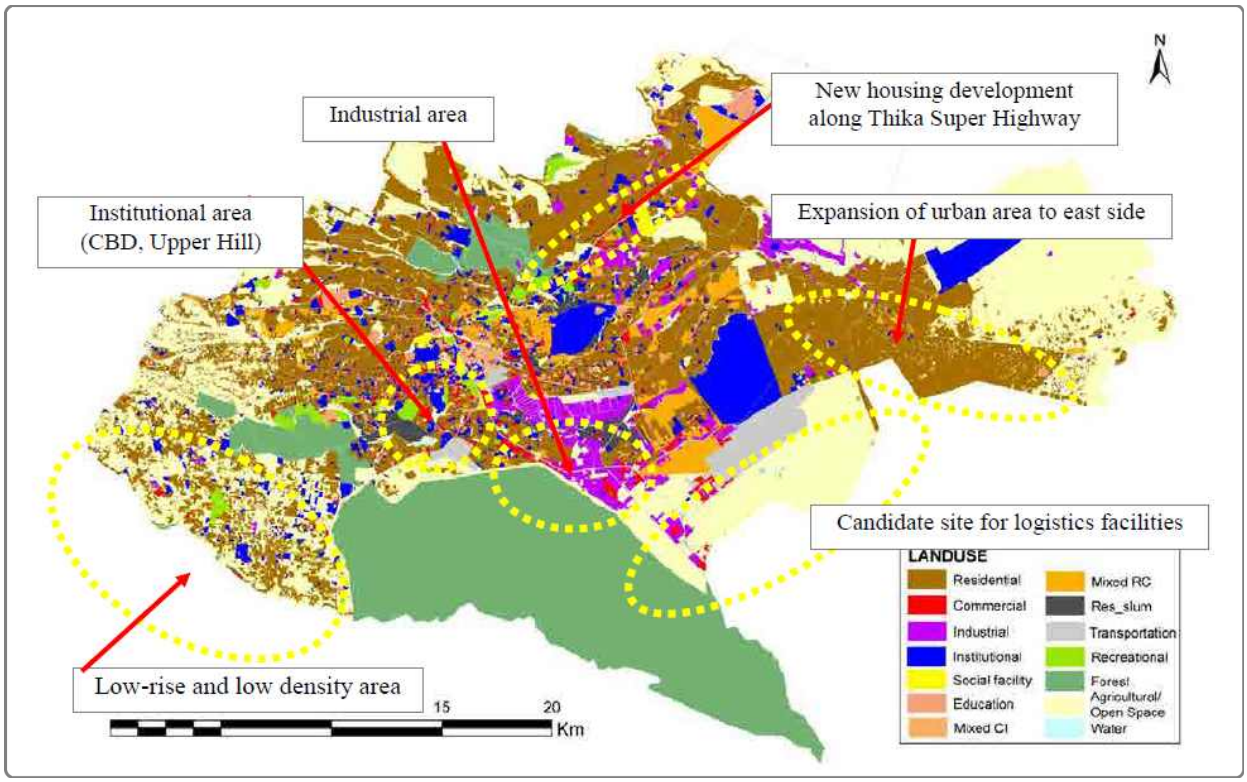
<Table 3-1> Major Obstacle for Urban Planning

Obstacle	Condition
Nairobi National Park	• Nairobi National Park occupies southern part of Nairobi City. Thus, almost all intercity traffic has to pass Mombasa Road and this causes heavy congestion on the road.
Kibera Slum to Ngong Forest	• There is no connection road between Mbagathi Way and Karen Road for about 10km. This causes severe traffic problem on Ngong and Langata Road.
Naironi Central Station	• Nairobi railway station and yard block CBD and southern industrial and business area. Thus, all traffic is concentrated on Mombasa and Jogoo Road.
KRC Land in Makadara	• 3.5km long and 400m wide strip of land is located between Jogoo Road and industrial area.
Airbase	• An airbase located at Eastland is now a land obstacle in this area, which is 3.5km×3.0km in size. This causes road congestion on Juja, Jogoo, Outer Ring Road and Eastleigh First Ave.
Rivers with informal settlements	• Several rivers flowing from west highland to east divide the lands without certain brige.

3.1.2. Land use patterns

1) Present Land Use and Buildings

- Majority of governmental institutions have their headquarters in the CBD and Upper Hill area. For this reason, the current land use of this area is mixed use with predominantly institutional and others.
- Some of the new office buildings for private companies, however, tend to be located outside CBD, principally along major roads, which are assumed to change the distribution of institutional use with in the city.
- Karen-Langata area which is located in the southwestern part of Nairobi City still keeps low-rise and low density residential profile with ample open space. On the other hand, housing developments in and around Ruai are conducted by private developers without a clearly defined comprehensive development concept to become high density and low open space area.
- Figure 3-4 shows the distribution of current land use of Nairobi City and their features.



Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014

<Figure 3-4> Current Land Use

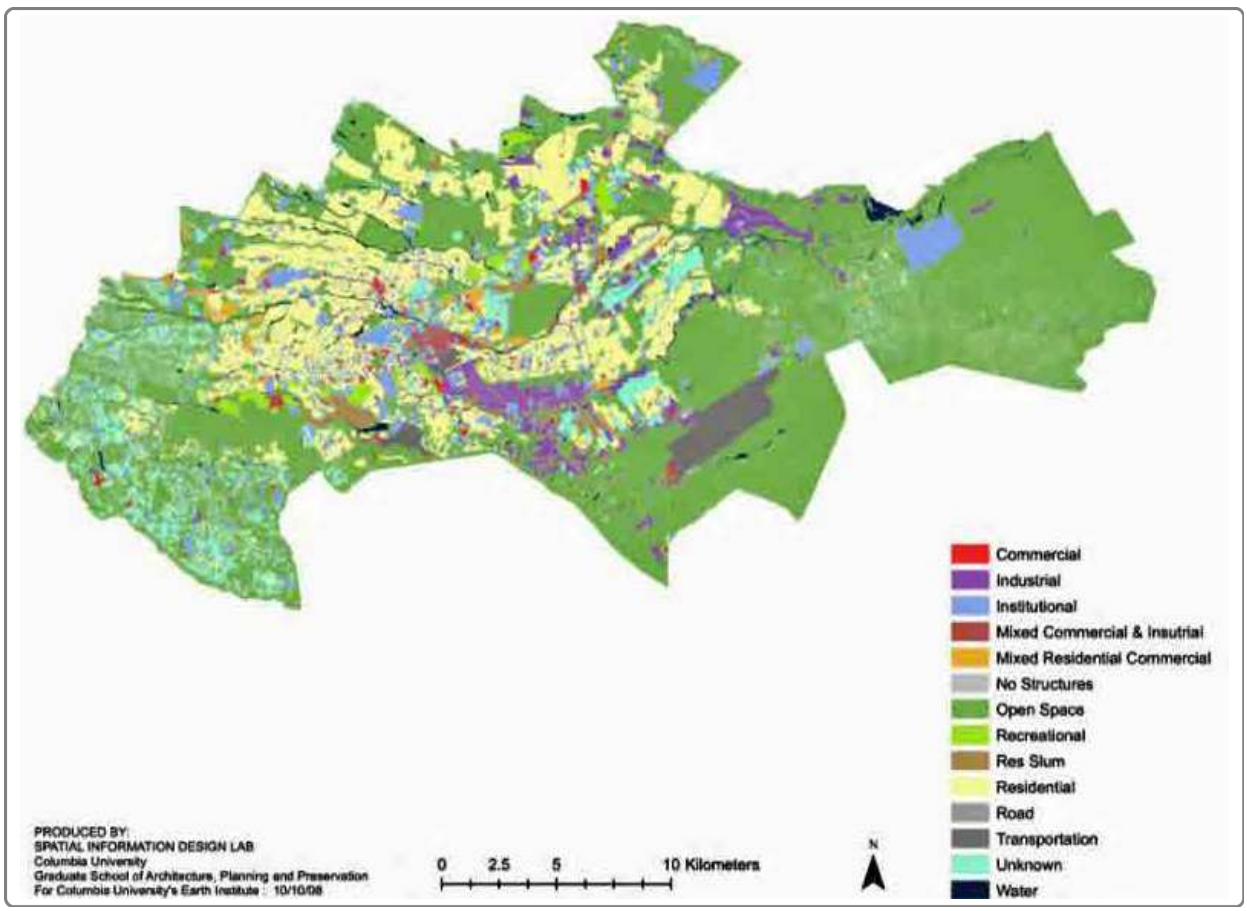
2) Land use Composition

- Land use surveys for the whole area of Nairobi City were conducted by the Centre of Sustainable Urban Development (CSUD) of Colombia University in collaboration with Nairobi University in 2005 and 2010.
- The land use map was developed from a combination of analysis o satellite images and ground surveys. The composition of land use is summarized as shown below.

<Table 3-2> Land Use Composition

Land Use	Area(Sq.km)	%	Land Use	Area(Sq.km)	%
Residential	105.2	15.1%	Commercial	5.9	0.8%
Industrial	22.2	3.2%	Mixed Commercial and industry	3.6	0.5%
Institutional	39.8	5.7%	Mixed residential and commercial	4.2	0.6%
No structures	0.3	0.0%	Open space	332.0	47.8%
Recreational	8.7	1.3%	Res slum	7.8	1.1%
Transportation	15.5	2.2%	Unknown	42.3	6.1%
water	10.9	1.6%	total	598.2	86.1
National Park	96.9	13.9%	Grand Total	695.1	100.0%

Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014



Source : The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya, 2014

<Figure 3-5> Land Use Map Done by Columbia University and Nairobi University

3) Land hold and land tenure

- A land hold (land ownership) and a land tenure are distinguished clearly in Kenya. About 80% of the lands in Nairobi City are owned by the government, but those lands are held by several types of users.
- About 41% of government lands (33% of total land) are alienated to private and other parties.

<Table 3-3> Land Use by Land Hold in Nairobi City

Category	Subcategory	Area(Sq.km)	%
Government land	1) Forest reserve	21	3.1
	2) Other government reserve	77	11.3
	3) Township	93	13.6
	4) Alienated land	225	32.9
	5) Un-alienated land	16	2.3
	6) National parks	117	17.1
	7) Open water	-	-
	Subtotal	549	80.3
Freehold land	8) Smallholder schemes	-	-
	9) Other	135	19.7
	Subtotal	135	19.7
Grand Total		684	100.0

Source : Statistics Abstract 2005

3.2. Socio-economic Status

3.2.1. Population

- Kenya's administrative districts consist of eight provinces (Nyanza, Western, Rift Valley, Central, Eatern, North Eastern, Coast and Nairobi), which are divided into 47 districts
- Kenya's population grew at an average annual rate of 2.3% from 38,610,097in 2009 to 44,156,600 in 2015, showing the average growth rate in African countries
- Kenya's capital, Nairobi, grew at an annual average rate of 5.1%, from 3,138,369 in 2009 to 4,232,100 in 2015, which is higher than Kenya's overall population growth rate
- Nairobi covers an area of 695 ㎢ of Kenya's total area of 581,313 km², which accounts for 0.1% of Kenya's population, but accounts for 9.6% of Kenya's population.
- The population density of Kenya is 76.0 person/㎢, but in Nairobi it is 6,089.4 person/㎢, which is 80 times higher than Kenya 's total population density

<Table 3-4> Population of Kenya by Region

Name	Area(㎢)		Population				Rate (%) (2009-2015)
			1989	1999	2009	2015	
Kenya	581,313	100.0%	21,443,636	28,686,607	38,610,097	44,156,600	2.3
Central	13,164	2.3%	3,116,703	3,724,159	4,383,743	4,947,400	2.0
Coast	82,893	14.3%	1,829,191	2,487,264	3,325,307	4,054,900	3.4
Eastern	153,404	26.4%	3,768,677	4,631,779	5,668,123	6,083,700	1.2
Nairobi	695	0.1%	1,324,570	2,143,254	3,138,369	4,232,100	5.1
North Eastern	126,852	21.8%	371,391	962,143	2,310,757	1,572,200	-6.2
Nyanza	12,613	2.2%	3,507,162	4,392,196	5,442,711	6,222,700	2.3
Rift Valley	183,383	31.5%	4,981,613	6,987,036	10,006,805	12,231,900	3.4
Western	8,309	1.4%	2,544,329	3,358,776	4,334,282	4,811,600	1.8

Source: http://citypopulation.de

<Figure 3-6> Population Trend of Kenya

3.2.2. Vehicle Registration

- The number of registered cars in Kenya is 2,963,130 as of 2017, showing an annual increase of 10.2% compared to 2013.
- The number of registered motor vehicles increased by 15.6% annually, followed by motor cars and Truck by 7.9% and 7.8%, respectively.

<Table 3-5> Total Number of Registered Vehicles

Unit	2013	2014	2015	2016	2017
Motor Cars	709,812	779,256	847,745	898,533	962,617
Utility Vans, Pick-Up	252,188	277,324	290,702	301,837	312,193
Lorries, Truckes & Heavy Vans	117,570	128,251	142,036	151,045	158,549
Buses and mini-Buses	95,644	98,067	100,990	103,125	104,795
Motor and Auto-cycles	738,219	853,670	993,090	1,110,195	1,320,576
Trailers	39,736	42,661	46,566	49,096	51,060
Others	58,803	31,678	36,549	43,793	53,340
Total	2,011,972	2,210,907	2,457,678	2,657,624	2,963,130

source: KNBS(Kenya National Bureau of Statistics) & NTSA(National Transport and Safety Authority)

- From 2013 to 2017, the number of newly registered vehicles has registered an average of 230,000 units annually, with more than 50% of them registered as Motor-cycles.
- Buses account for 1% of the average number of registered users, which means that the registration of private transportation means is higher than that of public transportation, thus providing traffic congestion

<Table 3-6> New Registration of Vehicles

Unit	2013	2014	2015	2016	2017
Motor Cars	65,005	69,444	68,489	50,788	64,084
Utility Vans, Pick-Up	9,819	12,568	13,878	11,135	10,356
Lorries, Truckes & Heavy Vans	9,570	10,681	13,785	9,009	7,504
Buses and mini-Buses	2,297	2,423	2,923	2,135	1,670
Motor and Auto-cycles	128,161	115,451	139,420	117,105	210,381
Trailers	3,973	2,925	3,905	2,530	1,964
Others	3,353	4,565	4,781	7,244	9,547
Total	222,178	218,057	247,181	199,946	305,506

source: KNBS(Kenya National Bureau of Statistics) & NTSA(National Transport and Safety Authority)

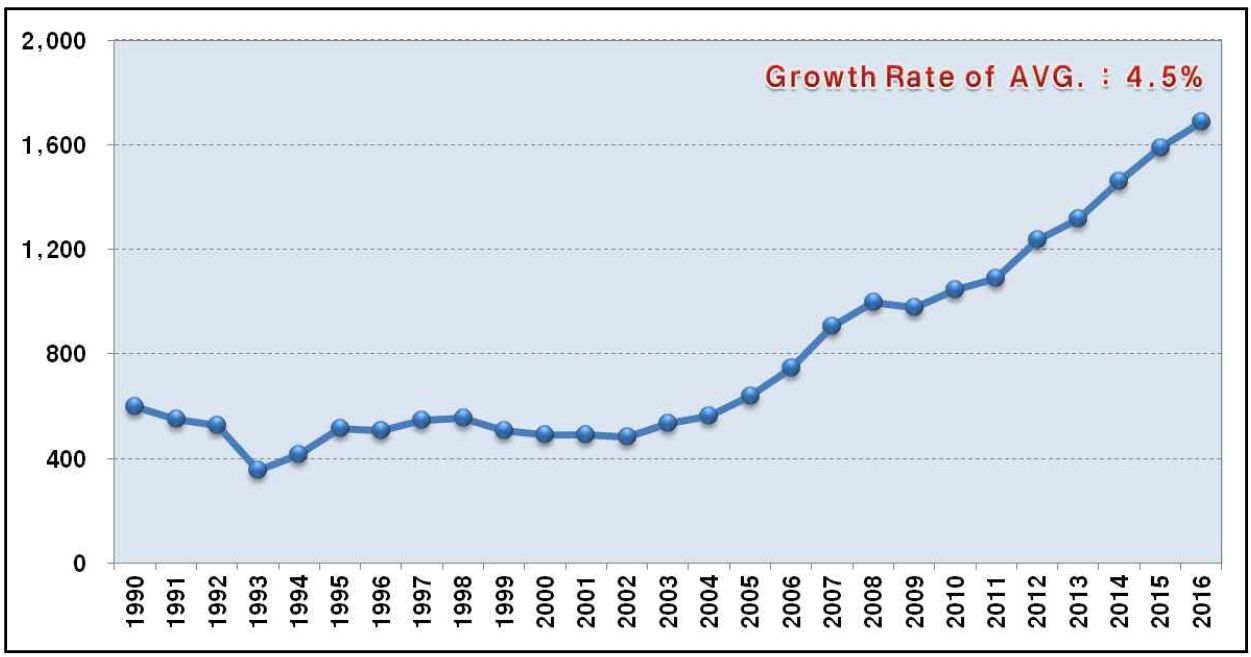
3.2.3. GDP

- The per capita GDP of Kenya is estimated to increase 2.8 times from 598 dolls in 1990 to 1,689 dolls in 2016.
- Looking at the per capita GDP of the 53 countries of Africa in 2016, Kenya is the 21st country.

<Table 3-7> GDP per capita table

Units	GDP per capita, current U.S. dollars	GDP per capita growth, %	Units	GDP per capita, current U.S. dollars	GDP per capita growth, %
1990	598.259	-	2003	535.568	10.8%
1991	548.014	-8.4%	2004	563.333	5.2%
1992	524.521	-4.3%	2005	638.485	13.3%
1993	354.787	-32.4%	2006	746.575	16.9%
1994	414.341	16.8%	2007	903.690	21.0%
1995	513.275	23.9%	2008	995.633	10.2%
1996	506.033	-1.4%	2009	978.448	-1.7%
1997	545.583	7.8%	2010	1,044.706	6.8%
1998	553.933	1.5%	2011	1,088.280	4.2%
1999	506.743	-8.5%	2012	1,237.503	13.7%
2000	488.318	-3.6%	2013	1,315.623	6.3%
2001	488.599	0.1%	2014	1,461.117	11.1%
2002	483.552	-1.0%	2015	1,587.640	8.7%
2003	535.568	10.8%	2016	1,689.776	6.4%

source: Statistical Abstract, 2016, KNBS



<Figure 3-7> GDP per capita from 1990 to 2016

3.3. Current Traffic Conditions

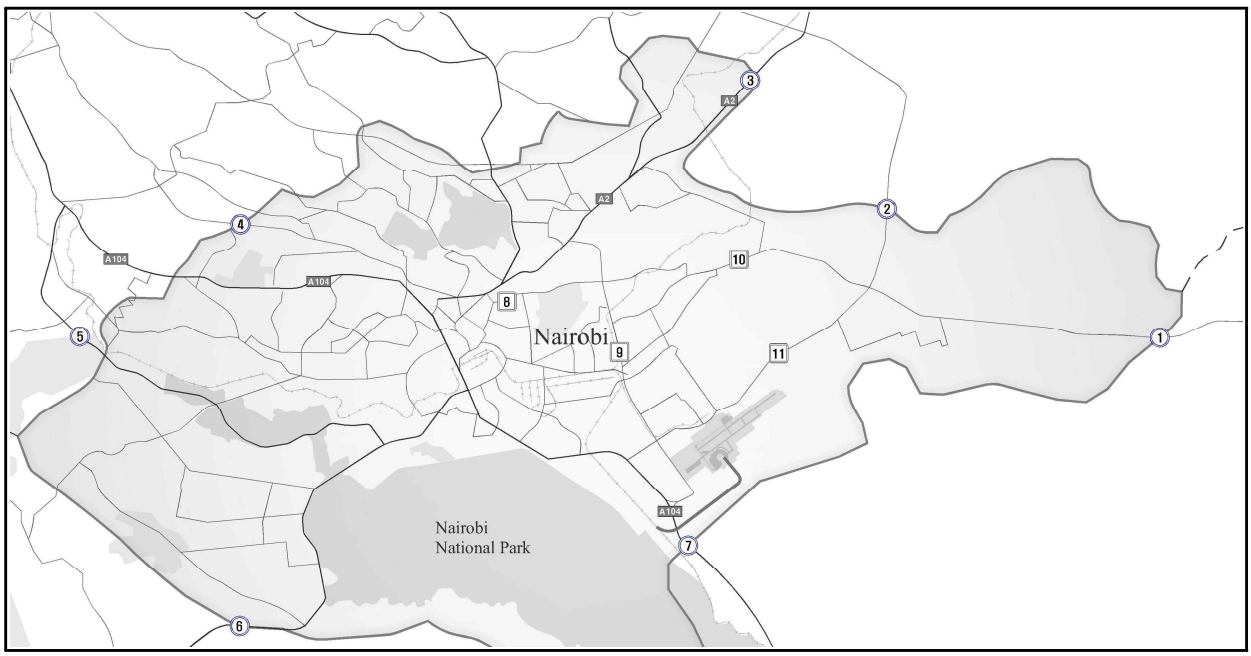
3.3.1. Field Survey

1) Survey Methods

- Field surveys conducted literature surveys and field surveys on traffic facility surveys, geometry surveys, traffic volume surveys, and public transportation surveys.
- The literature review examined existing feasibility and design reports, geotechnical Investigations Report, and master plan reports.
- The field survey was conducted using a local consultants, APEC.

Traffic Volume Survey

- The traffic volume survey was conducted through literature and on-site surveys, and a field survey was conducted by a local consultant APEC.
- The sub-consultancy service aims to conduct traffic counts survey(hereinafter called "the survey") in order to collect current traffic volume and understand existing traffic flows which are expected to utilize essential data for traffic demand forecast of Feasibility Study for KENYA Bus Rapid Transit System' Project.
- Traffic volume survey will be conducted 16hours (06:00 ~ 22:00) for 11spots.
  - ✓ Survey Location : 11 spots near the project site
  - ✓ Survey Date : one(1) day
  - ✓ Survey Time : 16 hours(06:00～22:00)



<Figure 3-8> Traffic Volume Survey Map

Public Transport survey

- The sub-consultancy service aims to conduct analyzing the characteristics and travel patterns of passengers using terminus and PSV stops etc. Two kinds of surveys would be conducted at the various terminus and bus stations. They are the passenger Interview and the PSV's operation surveys
- The public transportation survey will conduct an Origin-Destination(O/D) surveys and operations surveys for terminals at a local consultant, APEC.
- The source-destination survey will be conducted at 7spots for 100 users, and the public transportation operation survey will be conducted from 3spots for 14 hours (06: 00-20: 00).
  - ✓ Survey Location : Passemger Interview survey(8spots), PSV's operation survey(3spots)
  - ✓ Survey Date : one(1) day
  - ✓ Survey Time : Passemger Interview survey(100travelers per spot) spots, PSV's operation survey (14 hours)

<Figure 3-9> Public Transport Survey Map

- The results of both the traffic volume survey and public transport survey are mentioned below on 3.3.2 "the traffic condition of the outering road".

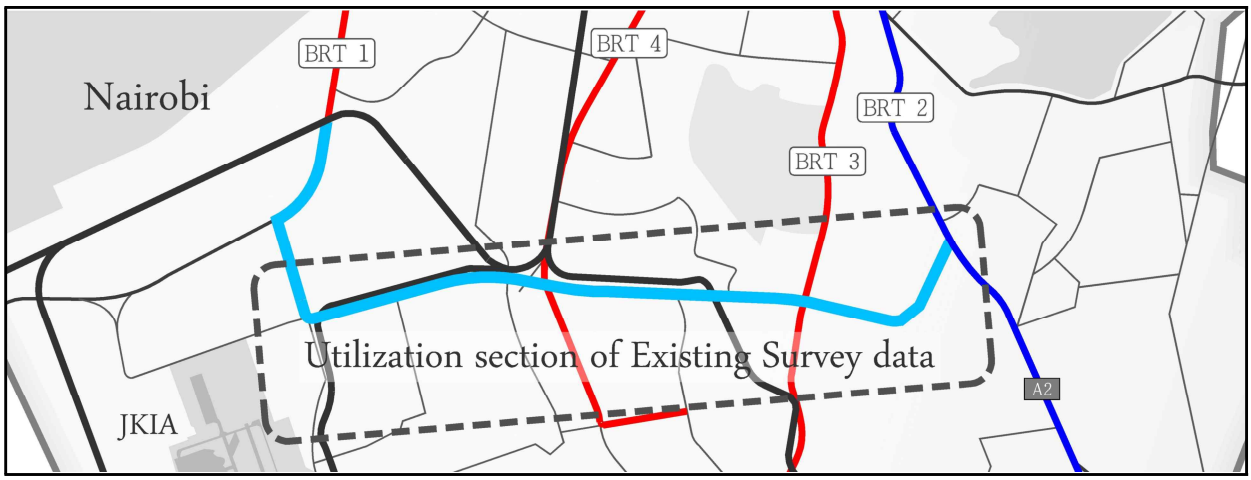
2) Geo-technical survey

Purpose of review

- The purpose of this review, based on the results of the first trip report and the existing data obtained on the feasibility study of the Kenya Rapid Transit Bus System Project(Geotechnical Investigations Factual Report for Outer Ring Road(C59) Improvement project), is to understand the current state of the ground related to the planned route, and review whether or not to carry out additional geotechnical survey.

Analysis of Previous data

- Geo-technical Investigations Report
  - ✓ Length : about L=10.0km
  - ✓ Start point: THIKA ROAD near RUARAKA
  - ✓ End point : TAJ MALL
  - ✓ Project route



<Figure 3-10> Project route

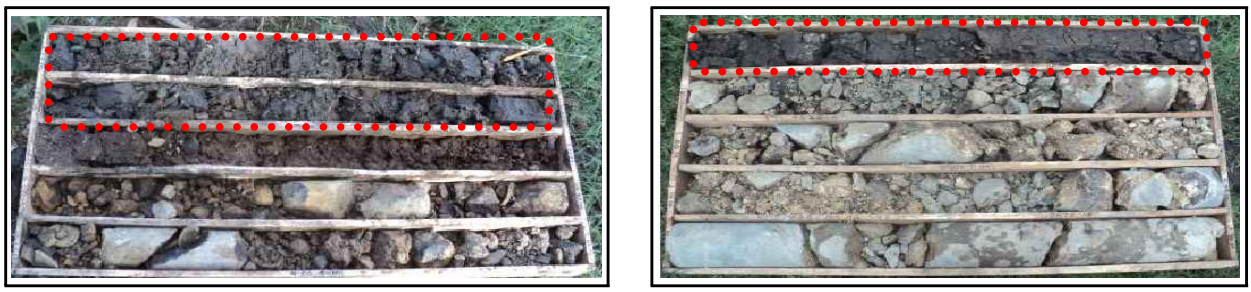
survey results and analysis

- The upper soil layer is consists of Black Cotton Soils in the undrained area and reddish brown clay alluvium in the drainage area, also, the lower bedrock is consists mostly of volcanic Welded Tuffs and Phonolites.
- The results of the boring survey are as follows: The soil is distributed in the range of 0.3 ~ 8.0m below the ground surface and bedrock in the lower part with thickness of 2.7~12.9m.

<Table 3-8> The result of the boring survey

Classification	Soil	Rock	Depth Drilled
Thickness(m)	0.3~8.0	2.7~12.9	5~15

- Overall, there is a soft clayey soil layer in the upper soil layer 0.3 to 5.2 m. It is confirmed that the soft ground is distributed as a result of checking the boring log.



<Figure 3-11> Nairobi River BH A1(left), ROB Bridge-LHS BH A2(right)

- Black Cotton Soil stratum has N value of 5 and then this can be classified as very soft clay.
- The result of uniaxial compressive strength test has generally high value to offer suitable stratum for the bridge footings.

<Table 3-9> Survey Item

Classification		Quantity	Note
Boring survey	Bridge & Embankment	39holes	Groundwater level measurement, Standard penetration test
Lab test	Basic properties	23times	Liquid·Plastic limit, Particle size distribution
	Uniaxial compression test	187times	Perform 1~10times by depth of boringhole
	Point load strength test	21times	
Chemical experiment		33times	pH, Organic Content, SO3, CL-

Review the results

- From the TAJ MALL to the end point, it is possible to utilize the existing geo-technical survey results. And L = 3.0km section from the start point to the TAJ MALL is already constructed, and it is not necessary to carry out additional ground survey. As a result of the analysis of the existing geotechnical survey, in general, soft ground is distributed at the upper part in this project section.
- The geological stratum conditions are as follows: the depth of the soft ground in the north side is at most 5.2m deep and within the depth of 2.0m at the south side.
- Overall, the thickness of the soil layer is up to 8 m, followed by the appearance of rocks and that is relatively good soil conditions.
- Considering that the embankment site is a soft ground, it is confirmed to have been replaced(through local field supervisors). And, considering the early appearance of the rocks in the Bridge foundation section, spread foundation may be applied, but caution is needed for interference with nearby bridges.

3) Environment Survey

■ Outline of project

- The feasibility study of KENYA Bus Rapid Transit System is conducted to build an economical, environment-friendly and sustainable BRT. This project aims to reduce the traffic congestion cost of about 186,133,000USD annually and improve the life quality of the Nairobi citizen by establishing BRT successfully.
- This project is expected to improve the life quality of the Nairobi citizen by ensuring mobility and stability of users and promote the development of Nairobi.
- The environmental impact analysis of this project is based on field surveys, data analysis, reports in various similar projects in KENYA and other developing countries, and environmental and social impact reports of the “Nairobi Outer-Ring Road Improvement Project, 2013, African Development Bank Group”.

■ Environmental Status

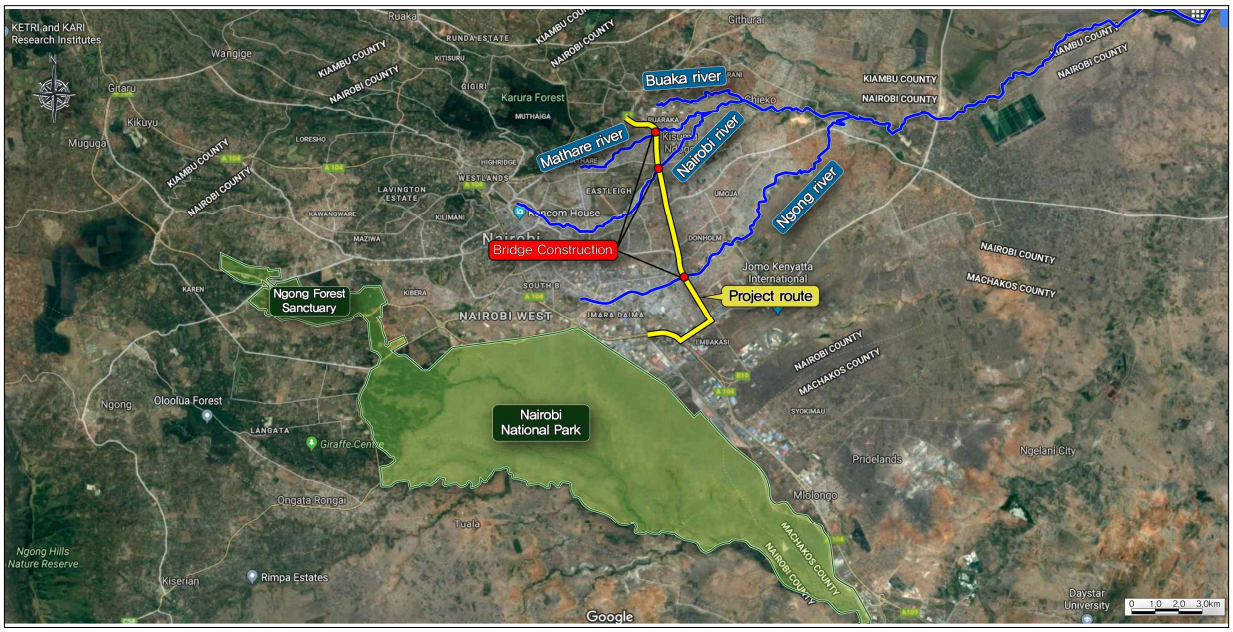
- Climate : In general, temperature is fairly uniform with the coolest months occurring from June to August while the hottest temperature typically occur from December to March. The main rainy season is from March to June and heavy showers often occurs from October to December. The mean of annual rainfall in Nairobi ranges between 800㎜ and 1,300㎜.

<Table 3-10> The mean of annual rainfall in Nairobi

	The mean of annual rainfall (㎜)
Nairobi	800 ~ 1,300

- Topography : The project area mainly has a flat terrain, and there are several rolling sections especially at bridge location.
- Surface Water Resources and Hydrology : The Mathare River, the Ngong River and the Nairobi River cross the project route from the west to the east, and the Buaka River is about 1.0㎞ away from the project route. Most of the project routes are on flat terrain but this area is well drained.
- ※ The Buaka, Mathare, Nairobi and Ngong River are usually dry rivers and have low flow rate.
- Flora :lawns and shrubs are located near the project route and residential areas are dominated by trees, shrubs, and ornamental plants. Population growth and development of this area have contributed to the destruction of flora due to negative impact on land resources, but there are planting materials to protect water resources along riverside.
- Fauna: The vicinity of the project line mainly consists of residential areas. The Nairobi National Park is separated by 1.4㎞, but the project route is in the urban

area that is under extensive economic activity, therefore there are already ecological breakdowns and notable wildlife is not found in the area.



<Figure 3-12> Environmental Status near Project route

Prediction of environmental impact

- The environmental impact from the implementation of the project is expected to occur directly or indirectly, but the impact of the project that widen and pave existing roads(2lanes→8lanes) is not expected to be significant. The environmental impact of this project is divided into construction period and operation period.
  - Construction period
- Noise and vibration : Noise and vibration effects can occur in the stationary areas such as Ruaraka, Umoja and Embakasi areas due to foundation and civil-engineering works using construction equipment.
  - Water quality
    · During bridge construction, the Mathare, the Nairobi and the Ngong River may be exposed by leaking out of the soil which may exacerbate the pollution of the river.
    · Depending on the operation of the construction equipment, it may cause contamination of riversand ground water when oil pollutants are leaked out.
    · The sewage is generated by the worker during construction.
  - Air quality
    · Pollutants such as scattered dust and NOx are generated due to the movement of construction vehicles and construction equipment during work.
  -Waste

· Municipal waste is generated by the worker at the construction site
· Waste oil is generated by the construction equipment
· Construction waste is generated when buildings are demolished

- Flora and fauna
  · Flora changes : Air pollutants(scattered dust and NOx) generated during construction are expected to affect the growth of flora temporarily.
  · Terrestrial fauna: As a result of the survey on the surrounding area, it is estimated that there is few animal near the project area, and the impact is expected to be insignificant.

• Operation period
  - Noise and vibration
    · Noise may affect stationary facilities in Ruaraka, Umoja and Embakasi area due to BRT in operation
  - Water quality
    · Influence of non-point pollutants in the Buaka, the Mathare, the Nairobi and the Ngong River during rainfall
  - Air quality
    · Occurrence of air pollutants due to exhaust gas of vehicles running on project route

Mitigation Plans

• Construction period
  - Noise and vibration
    · Limit vehicle speed when passing through residential area (less than 20km/hr)
    · Manage the schedule of the equipment effectively to minimize noise and vibration in noise-sensitive areas such as schools and hospitals.
    · Restrict on work time: Avoid noise-generation work in stationary area and perform daytime work as much as possible.
  - Water quality
    · Countermeasures to reduce soil runoff
  - Install drainage and grit chamber, and installs vinyl covers for slopes if necessary
  - Establish a construction plan avoiding rainy season
    · Regulate equipment maintenance and oil exchange in construction area
    · Establish appropriate treatment method of sewage by construction workers
  - Air quality
    · Periodic water spraying: The plan for operation of watering cars is necessary
    · NOx reduction plan: Effective management of construction equipment regulating

the use of aged equipment and unnecessary idling is necessary

· Restriction of construction vehicle: Restricted to the speed of 20 km/hr

· Installation of a temporary dust net if necessary: Install dust net considering local conditions and residents opinion

<Figure 3-13> An Example of grit chamber and dust net

- Waste

  · Disposal according to NEMA(National Environment Management Authority) waste management guidelines and local government approvals

  · Restoration of work area and field office when construction is completed

- Flora and fauna

  · To prevent the spread of air pollutants, periodic water spraying and installation of temporary dust net if necessary

• Operation period

- Noise and vibration

  · Install soundproof walls in the residential areas and stationary areas such as education facilities if necessary

- Water quality

  · Establishment of non-point pollution treatment facilities

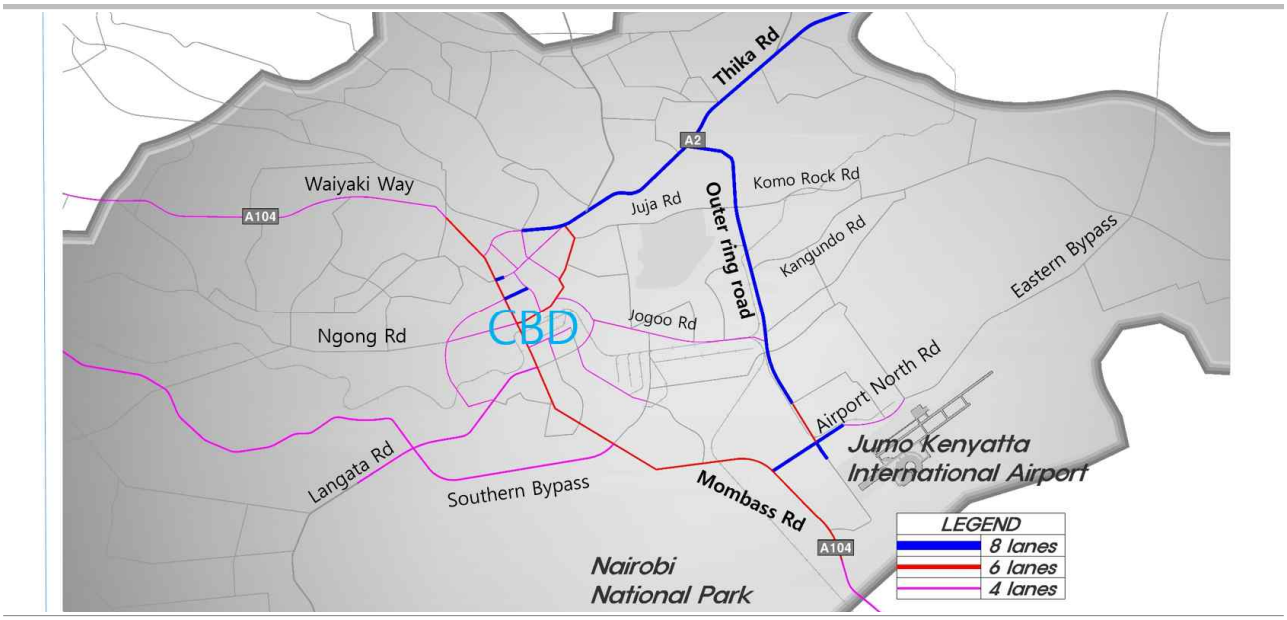
- Air quality

  · Periodic road cleaning and regular check of BRT vehicles

3.3.2. Outer ring Road

1) Road Networks

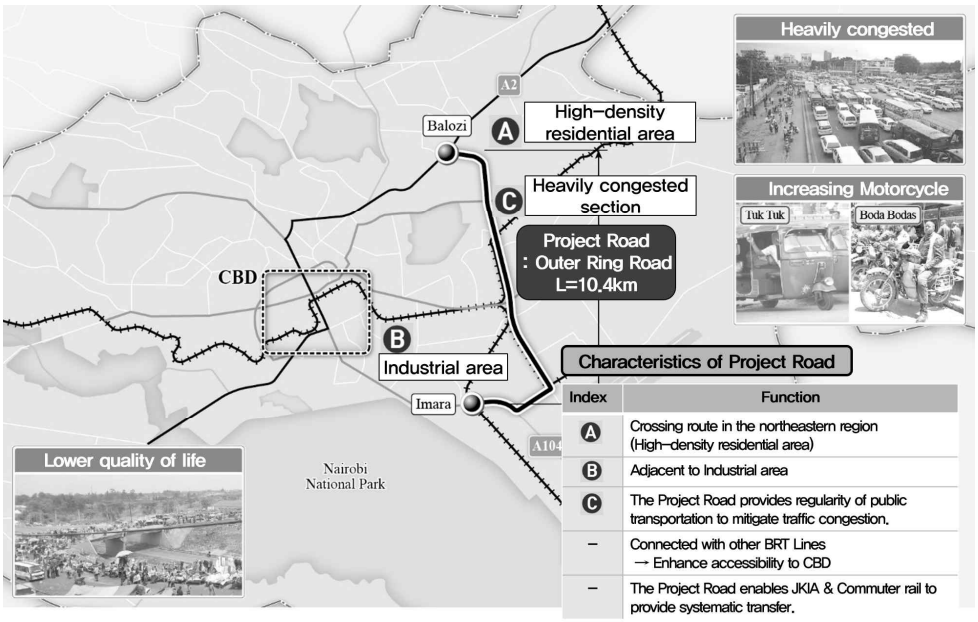
- The major trunk roads in the CBD have more than four(4) lanes, and especially Thika road and Airport North road have eight(8) lanes. And other roads in the city have two lanes.
- In particular, the Outer Ring Road (project road) is mainly composed of main roads with four(4) lanes and service roads with more two(2) lanes by each direction.



<Figure 3-14> Number of Lanes of Existing Road network

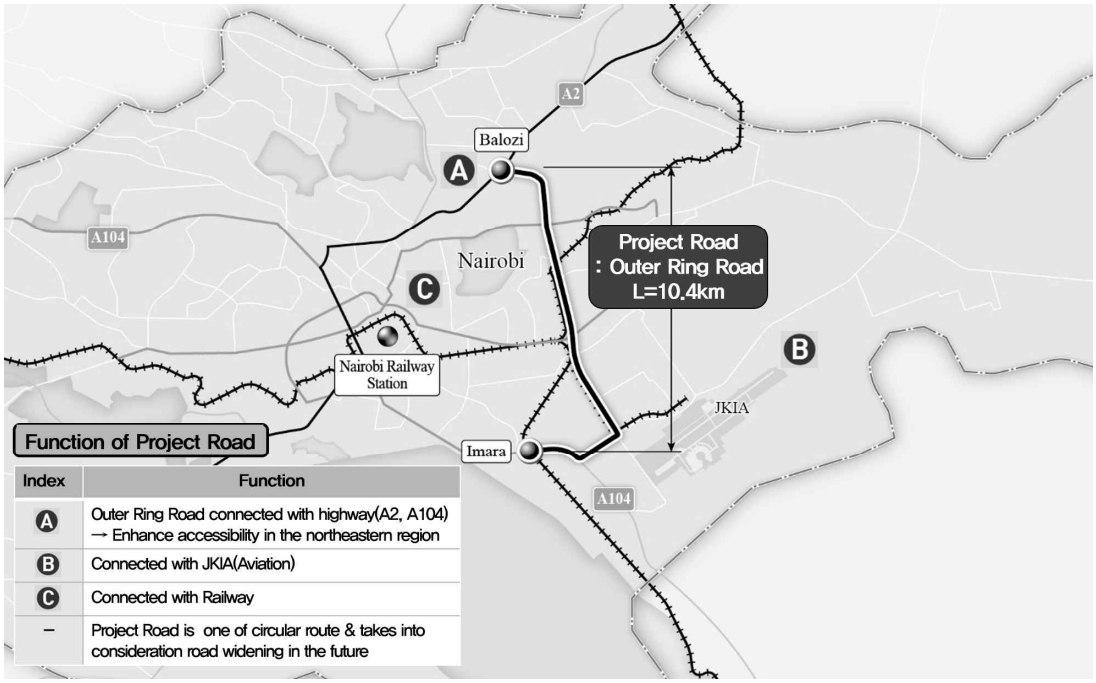
Project road

- The Outer Ring Road with six lanes is connected to main transportation facilities such as a/an airport, railway, and road A2 & A104 in the city.



<Figure 3-15> Traffic condition on outer ring road

- Although the surrounding area of project road is mainly covered by residential areas, the project area evidently requires public transportation infrastructures because it has high development potential as a growth corridor in the future according to the Urban Development Master Plan (NIUPLAN).



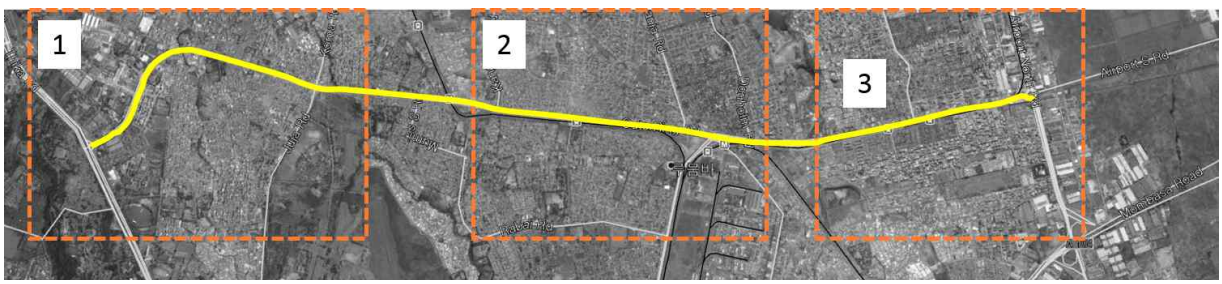
<Figure 3-16> Traffic condition on outer ring road

2) Transport Facilities

- The section has four(4) crosswalks. The crosswalks need to be changed to pedestrian overpass, u-turn needs to close at some sections.

<Table 3-11> Transport Facilities in Outer Ring Road

Transport Facility	Number of unit	Remark
Bus terminal, Railway station	each 1	Outer ring road
crosswalk	4	
Pedestrian bridge	2	Airport North road, A104



<Figure 3-17> Transfer facilities on outet ring road

<Figure 3-18> Transfer facilities on outer ring road

3) Traffic condition

■ Results of the traffic volume

- The traffic volume survey was conducted during Sep-Oct. in 2017 by using the traffic counter machines. The survey time is divided into 15 minutes
- A total number of spots which were surveyed are 7 as follows
  - 7 spots for 16 hours

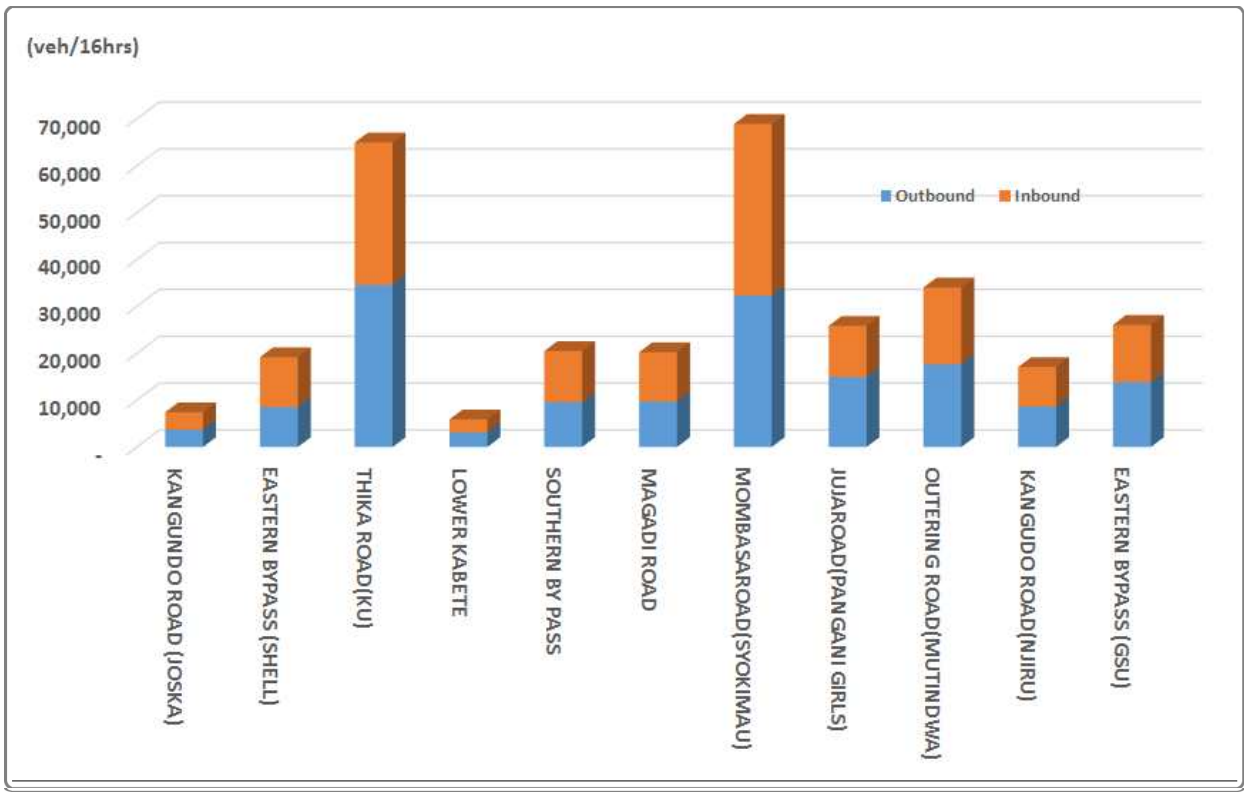
No.	Location Name	No.	Location Name
1	• Kangudo Rd	7	• Mombasa Rd
2	• Eastern Bypass	8	• Juja Rd
3	• Embu-Nairobi Hwy	9	• Outer Ring Rd
4	• Lower Kabete	10	• Kangundo
5	• Southern Bypass	11	• Eastern Bypass
6	• Magadi Rd		

Traffic volume for 16 hours

- Table 3-18 shows traffic volumes measured by the traffic volume survey. The result shows that Mombasaroad(syokimau) have a high traffic volume 68,968vehicles/16hours

<Table 3-12> Traffic volume on spot (16hrs)

No	Corridor(Road)	Outbound	Inbound	sum
1	KANGUNDOROAD(JOSKA)	3,693	3,738	7,431
2	EASTERNBYPASS(SHELL)	8,524	10,640	19,164
3	THIKAROAD(KU)	34,583	30,433	65,016
4	LOWERKABETE	3,083	2,815	5,898
5	SOUTHERNBYPASS	9,541	10,955	20,496
6	MAGADIROAD	9,715	10,523	20,238
7	MOMBASAROAD(SYOKIMAU)	32,340	36,628	68,968
8	JUJAROAD(PANGANIGIRLS)	14,935	10,936	25,871
9	OUTERINGROAD(MUTINDWA)	17,660	16,396	34,056
10	KANGUDOROAD(NJIRU)	8,641	8,450	17,091
11	EASTERNBYPASS(GSU)	13,853	12,220	26,073



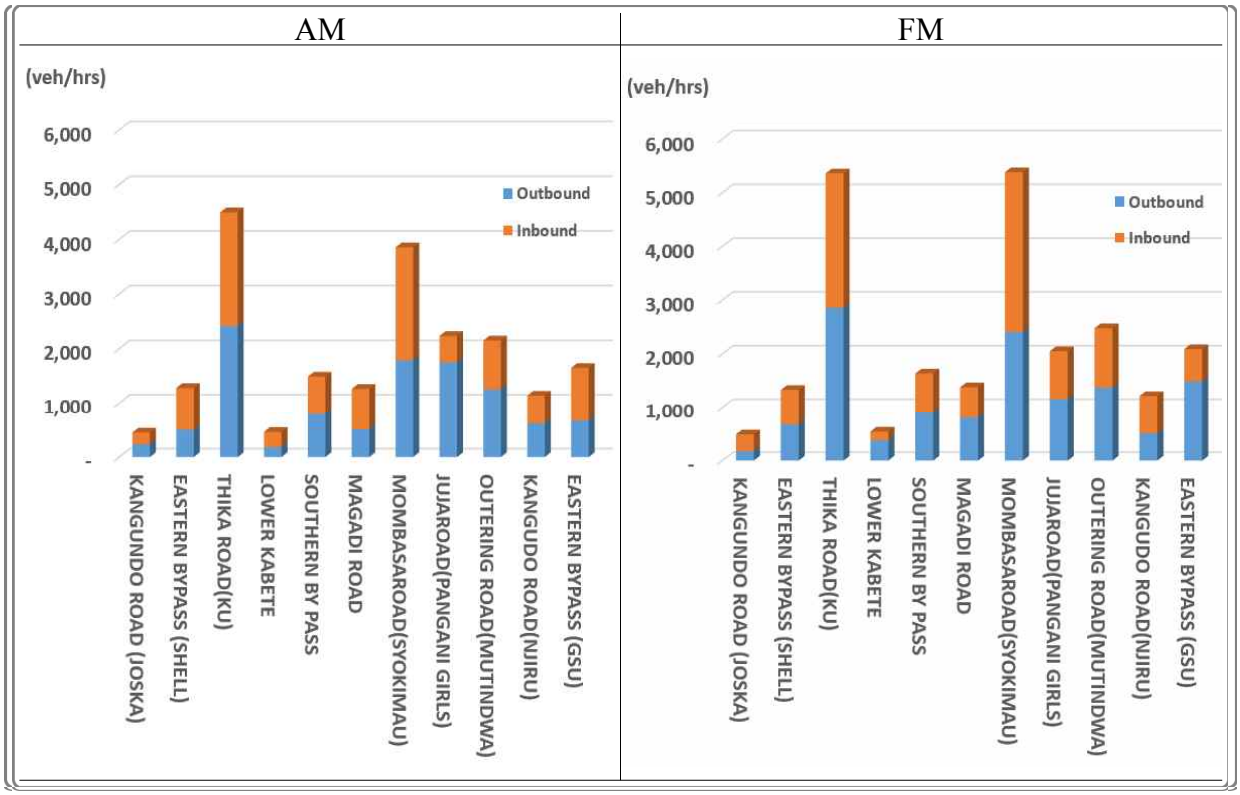
<Figure 3-19> Traffic Volume at peak time

Traffic Volume at peak time

- The traffic pattern shows that during the morning peak period, outbound is 52.4% and during the evening peak, outbound from Accra is 53.1%.

<Table 3-13> Traffic Volume at peak time

No	Corridor(Road)	AM			PM		
		Outbound	Inbound	sum	Outbound	Inbound	sum
1	KANGUNDOROAD(JOSKA)	232	216	448	176	312	488
2	EASTERNBYPASS(SHELL)	501	778	1,279	674	654	1,328
3	THIKAROAD(KU)	2,416	2,076	4,492	2,858	2,500	5,358
4	LOWERKABETE	181	280	461	376	163	539
5	SOUTHERNBYPASS	795	693	1,488	894	741	1,635
6	MAGADIROAD	512	750	1,262	806	572	1,378
7	MOMBASAROAD(SYOKIMAU)	1,785	2,067	3,852	2,410	2,970	5,380
8	JUJAROAD(PANGANIGIRLS)	1,748	483	2,231	1,156	894	2,050
9	OUTERINGROAD(MUTINDWA)	1,254	895	2,149	1,369	1,108	2,477
10	KANGUDOROAD(NJIRU)	618	519	1,137	507	706	1,213
11	EASTERNBYPASS(GSU)	673	973	1,646	1,483	606	2,089
SUM Ratio(%)		10,715 (52.4)	9,730 (47.6)	20,445 (100.0)	12,709 (53.1)	11,226 (46.9)	23,935 (100.0)



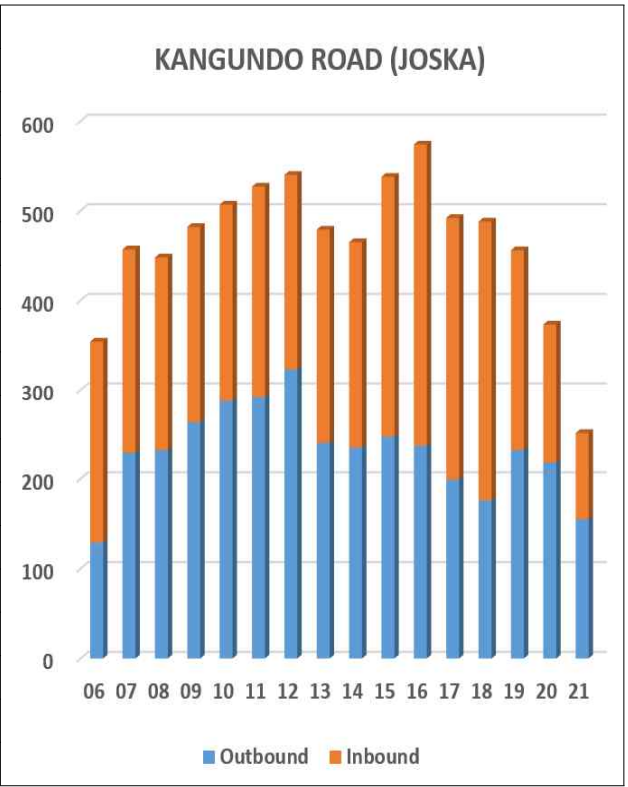
<Figure 3-20> Traffic Volume at peak time

Traffic volume by survey spot

- Traffic volume by survey spot/time is as follows.

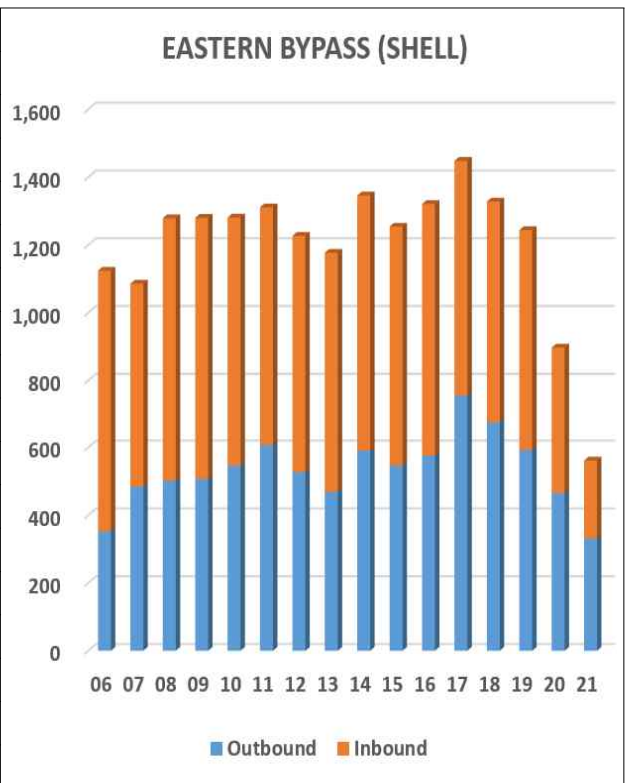
✓ spot 1. KANGUNDOROAD(JOSKA)

Time	Outbound	Inbound	sum
6:00~7:00	129	225	354
7:00~8:00	229	228	457
8:00~9:00	232	216	448
9:00~10:00	263	219	482
10:00~11:00	287	220	507
11:00~12:00	291	236	527
12:00~13:00	323	217	540
13:00~14:00	240	239	479
14:00~15:00	235	230	465
15:00~16:00	247	291	538
16:00~17:00	237	337	574
17:00~18:00	199	293	492
18:00~19:00	176	312	488
19:00~20:00	232	224	456
20:00~21:00	218	155	373
21:00~22:00	155	96	251
Total	3,693	3,738	7,431



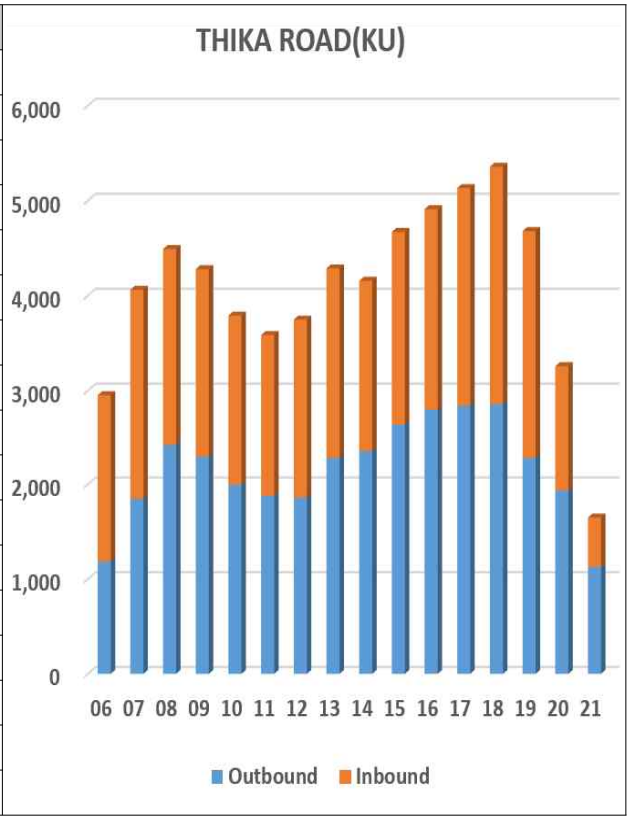
✓ spot 2. EASTERNBYPASS(SHELL)

Time	Outbound	Inbound	sum
6:00~7:00	352	772	1,124
7:00~8:00	484	602	1,086
8:00~9:00	501	778	1,279
9:00~10:00	507	773	1,280
10:00~11:00	546	735	1,281
11:00~12:00	607	704	1,311
12:00~13:00	527	700	1,227
13:00~14:00	469	708	1,177
14:00~15:00	590	756	1,346
15:00~16:00	547	707	1,254
16:00~17:00	576	745	1,321
17:00~18:00	756	692	1,448
18:00~19:00	674	654	1,328
19:00~20:00	592	652	1,244
20:00~21:00	465	432	897
21:00~22:00	331	230	561
Total	8,524	10,640	19,164



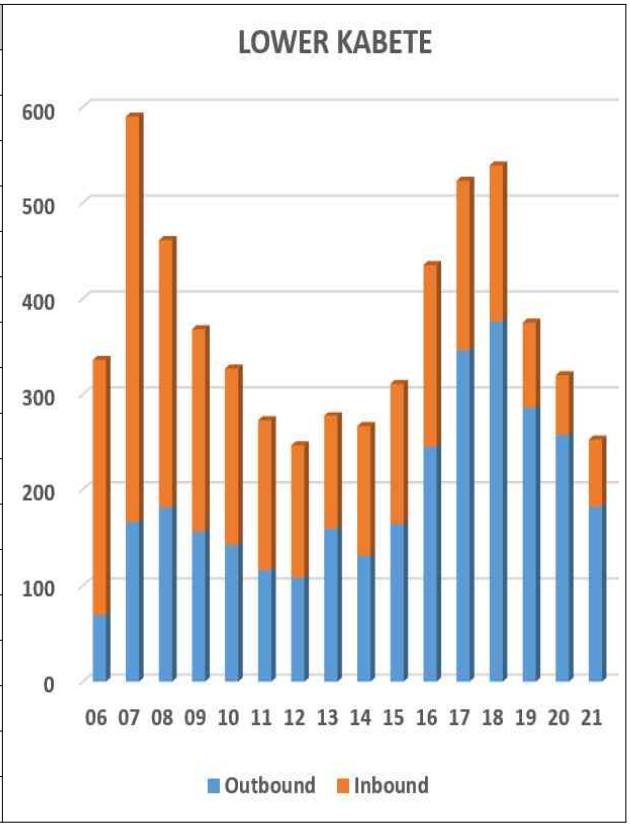
✓ spot 3. THIKAROAD(KU)

Time	Outbound	Inbound	sum
6:00~7:00	1,185	1,767	2,952
7:00~8:00	1,849	2,213	4,062
8:00~9:00	2,416	2,076	4,492
9:00~10:00	2,293	1,986	4,279
10:00~11:00	1,996	1,794	3,790
11:00~12:00	1,880	1,706	3,586
12:00~13:00	1,861	1,887	3,748
13:00~14:00	2,280	2,007	4,287
14:00~15:00	2,354	1,803	4,157
15:00~16:00	2,632	2,040	4,672
16:00~17:00	2,791	2,120	4,911
17:00~18:00	2,842	2,291	5,133
18:00~19:00	2,858	2,500	5,358
19:00~20:00	2,281	2,399	4,680
20:00~21:00	1,934	1,324	3,258
21:00~22:00	1,131	520	1,651
Total	34,583	30,433	65,016



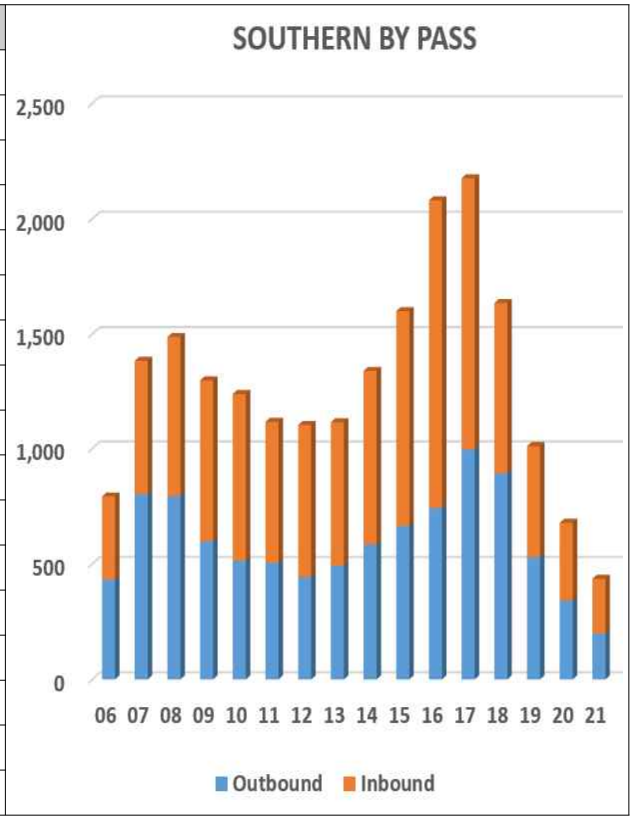
✓ spot 4. LOWERKABETE

Time	Outbound	Inbound	sum
6:00~7:00	69	267	336
7:00~8:00	166	424	590
8:00~9:00	181	280	461
9:00~10:00	156	212	368
10:00~11:00	142	185	327
11:00~12:00	116	156	272
12:00~13:00	108	138	246
13:00~14:00	159	118	277
14:00~15:00	131	135	266
15:00~16:00	164	147	311
16:00~17:00	244	191	435
17:00~18:00	346	177	523
18:00~19:00	376	163	539
19:00~20:00	286	89	375
20:00~21:00	257	63	320
21:00~22:00	182	70	252
Total	3,083	2,815	5,898



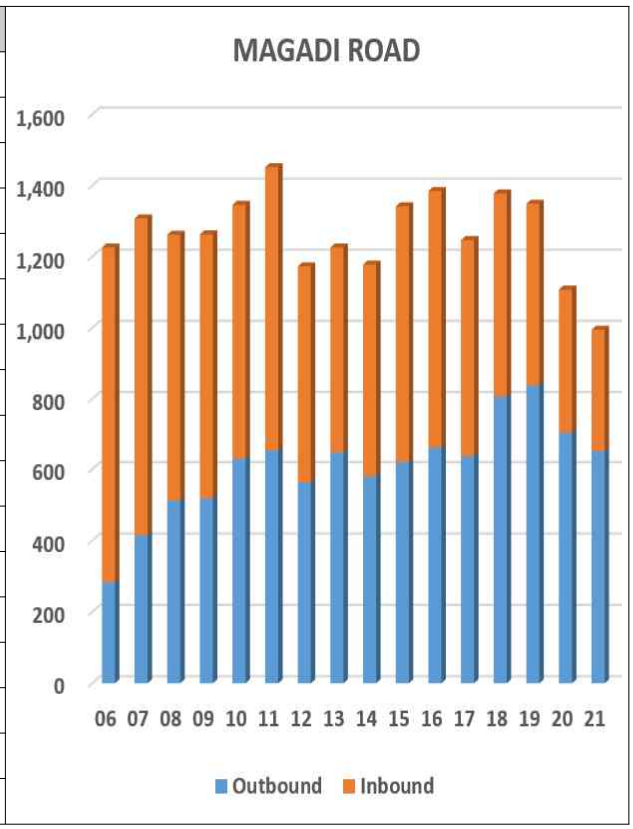
✓ spot 5. SOUTHERNBYPASS

Time	Outbound	Inbound	sum
6:00~7:00	433	359	792
7:00~8:00	803	582	1,385
8:00~9:00	795	693	1,488
9:00~10:00	598	702	1,300
10:00~11:00	514	727	1,241
11:00~12:00	505	611	1,116
12:00~13:00	445	657	1,102
13:00~14:00	493	621	1,114
14:00~15:00	585	756	1,341
15:00~16:00	665	935	1,600
16:00~17:00	742	1,338	2,080
17:00~18:00	997	1,179	2,176
18:00~19:00	894	741	1,635
19:00~20:00	531	480	1,011
20:00~21:00	342	337	679
21:00~22:00	199	237	436
Total	9,541	10,955	20,496



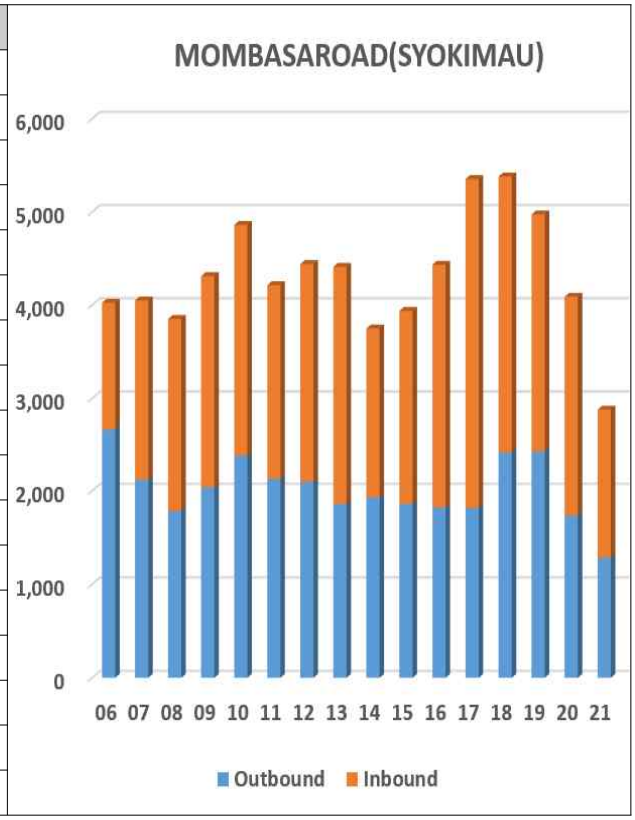
✓ spot 6. MAGADIROAD

Time	Outbound	Inbound	sum
6:00~7:00	283	943	1,226
7:00~8:00	415	893	1,308
8:00~9:00	512	750	1,262
9:00~10:00	518	745	1,263
10:00~11:00	630	716	1,346
11:00~12:00	652	800	1,452
12:00~13:00	563	610	1,173
13:00~14:00	647	579	1,226
14:00~15:00	580	598	1,178
15:00~16:00	620	722	1,342
16:00~17:00	661	724	1,385
17:00~18:00	637	610	1,247
18:00~19:00	806	572	1,378
19:00~20:00	838	511	1,349
20:00~21:00	702	406	1,108
21:00~22:00	651	344	995
Total	9,715	10,523	20,238



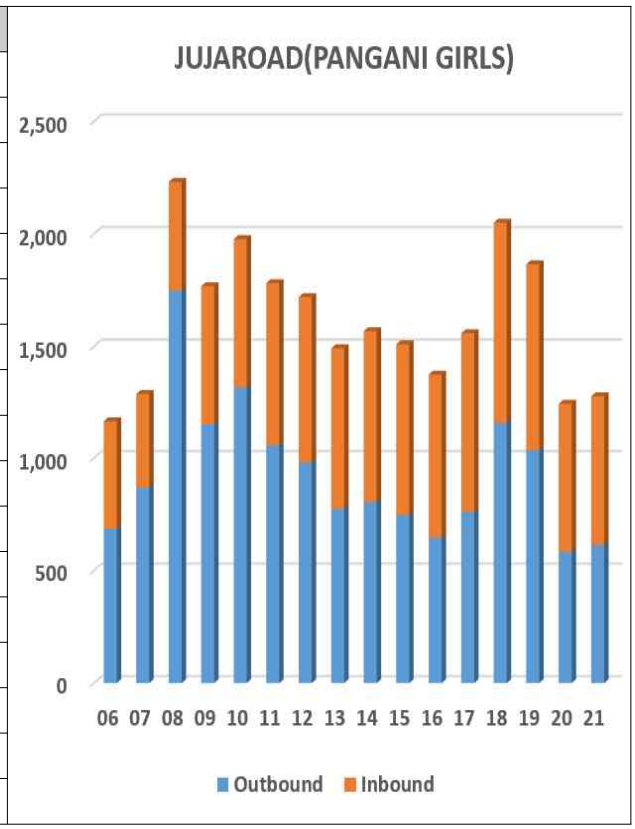
✓ spot 7. MOMBASAROAD(SYOKIMAU)

Time	Outbound	Inbound	sum
6:00~7:00	2,656	1,369	4,025
7:00~8:00	2,120	1,931	4,051
8:00~9:00	1,785	2,067	3,852
9:00~10:00	2,038	2,274	4,312
10:00~11:00	2,376	2,485	4,861
11:00~12:00	2,127	2,088	4,215
12:00~13:00	2,096	2,345	4,441
13:00~14:00	1,860	2,551	4,411
14:00~15:00	1,930	1,820	3,750
15:00~16:00	1,860	2,079	3,939
16:00~17:00	1,823	2,611	4,434
17:00~18:00	1,818	3,535	5,353
18:00~19:00	2,410	2,970	5,380
19:00~20:00	2,420	2,554	4,974
20:00~21:00	1,737	2,353	4,090
21:00~22:00	1,284	1,596	2,880
Total	32,340	36,628	68,968



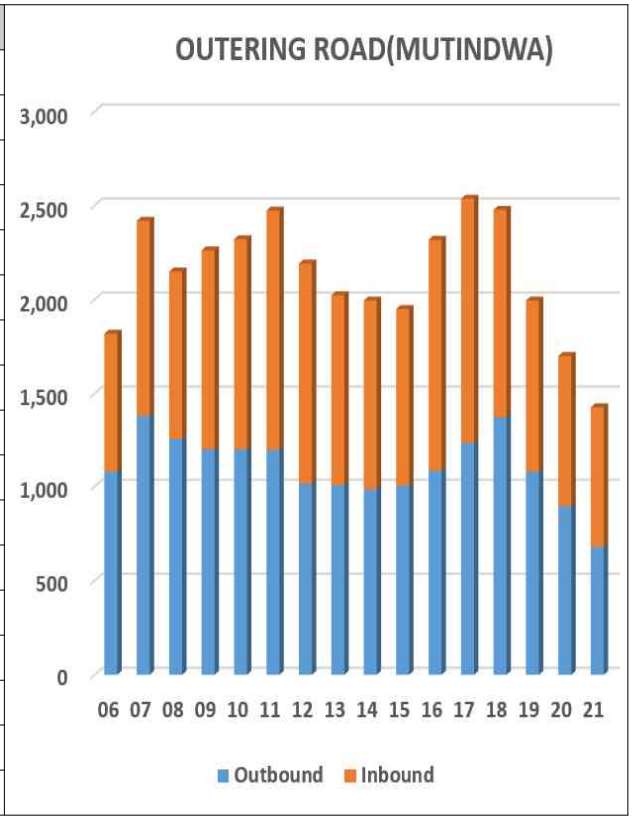
✓ spot 8. JUJAROAD(PANGANIGIRLS)

Time	Outbound	Inbound	sum
6:00~7:00	686	477	1,163
7:00~8:00	868	421	1,289
8:00~9:00	1,748	483	2,231
9:00~10:00	1,149	619	1,768
10:00~11:00	1,319	658	1,977
11:00~12:00	1,058	723	1,781
12:00~13:00	981	738	1,719
13:00~14:00	775	717	1,492
14:00~15:00	806	762	1,568
15:00~16:00	748	762	1,510
16:00~17:00	647	728	1,375
17:00~18:00	761	798	1,559
18:00~19:00	1,156	894	2,050
19:00~20:00	1,035	830	1,865
20:00~21:00	584	661	1,245
21:00~22:00	614	665	1,279
Total	14,935	10,936	25,871



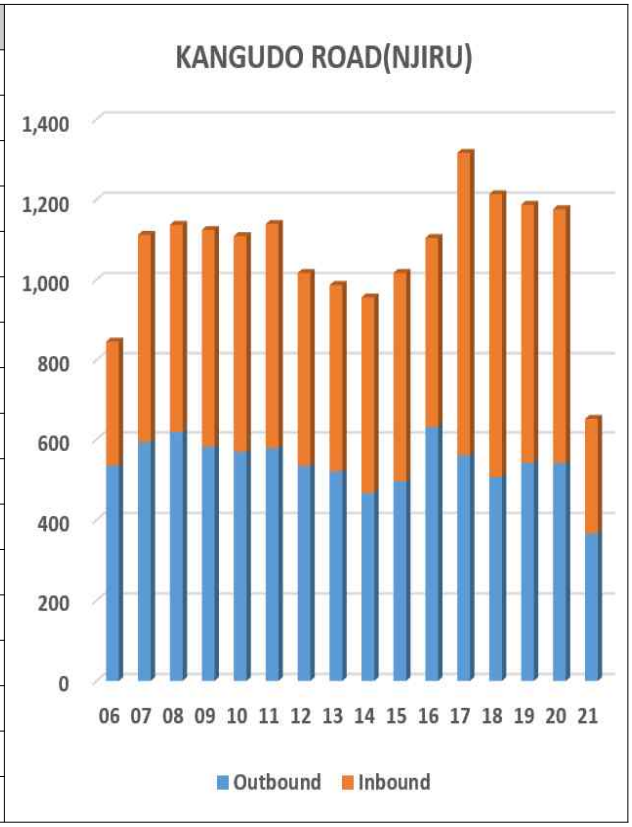
✓ spot 9. OUTERINGROAD(MUTINDWA)

Time	Outbound	Inbound	sum
6:00~7:00	1,080	739	1,819
7:00~8:00	1,376	1,043	2,419
8:00~9:00	1,254	895	2,149
9:00~10:00	1,199	1,063	2,262
10:00~11:00	1,198	1,123	2,321
11:00~12:00	1,196	1,277	2,473
12:00~13:00	1,016	1,176	2,192
13:00~14:00	1,008	1,015	2,023
14:00~15:00	986	1,009	1,995
15:00~16:00	1,005	945	1,950
16:00~17:00	1,085	1,233	2,318
17:00~18:00	1,232	1,304	2,536
18:00~19:00	1,369	1,108	2,477
19:00~20:00	1,079	916	1,995
20:00~21:00	897	803	1,700
21:00~22:00	680	747	1,427
Total	17,660	16,396	34,056



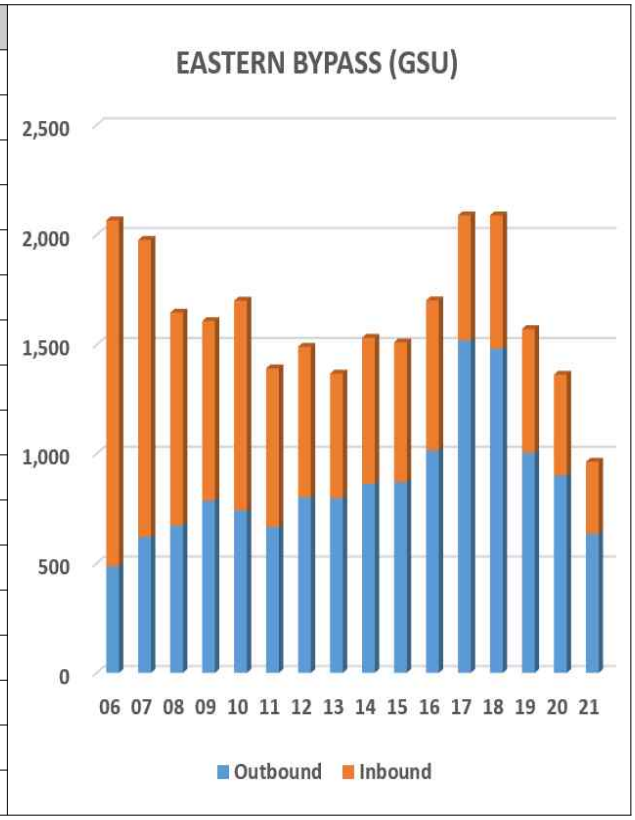
✓ spot 10. KANGUDOROAD(NJIRU)

Time	Outbound	Inbound	sum
6:00~7:00	535	311	846
7:00~8:00	593	519	1,112
8:00~9:00	618	519	1,137
9:00~10:00	582	542	1,124
10:00~11:00	569	540	1,109
11:00~12:00	578	561	1,139
12:00~13:00	534	483	1,017
13:00~14:00	521	466	987
14:00~15:00	467	489	956
15:00~16:00	496	521	1,017
16:00~17:00	631	473	1,104
17:00~18:00	561	755	1,316
18:00~19:00	507	706	1,213
19:00~20:00	542	645	1,187
20:00~21:00	541	635	1,176
21:00~22:00	366	285	651
Total	8,641	8,450	17,091



✓ spot 11. EASTERNBYPASS(GSU)

Time	Outbound	Inbound	sum
6:00~7:00	486	1,580	2,066
7:00~8:00	620	1,357	1,977
8:00~9:00	673	973	1,646
9:00~10:00	785	823	1,608
10:00~11:00	740	961	1,701
11:00~12:00	665	728	1,393
12:00~13:00	800	691	1,491
13:00~14:00	795	574	1,369
14:00~15:00	863	669	1,532
15:00~16:00	870	641	1,511
16:00~17:00	1,015	687	1,702
17:00~18:00	1,520	569	2,089
18:00~19:00	1,483	606	2,089
19:00~20:00	1,004	568	1,572
20:00~21:00	900	464	1,364
21:00~22:00	634	329	963
Total	13,853	12,220	26,073



Traffic volume by means of major roads

- Among main roads on the project road, Thika road has 17,760 vehicles, Juja road has 8,340 vehicles, and Jogoo road has 19,140 vehicles respectively. during the survey time from 07:30 to 08:30.

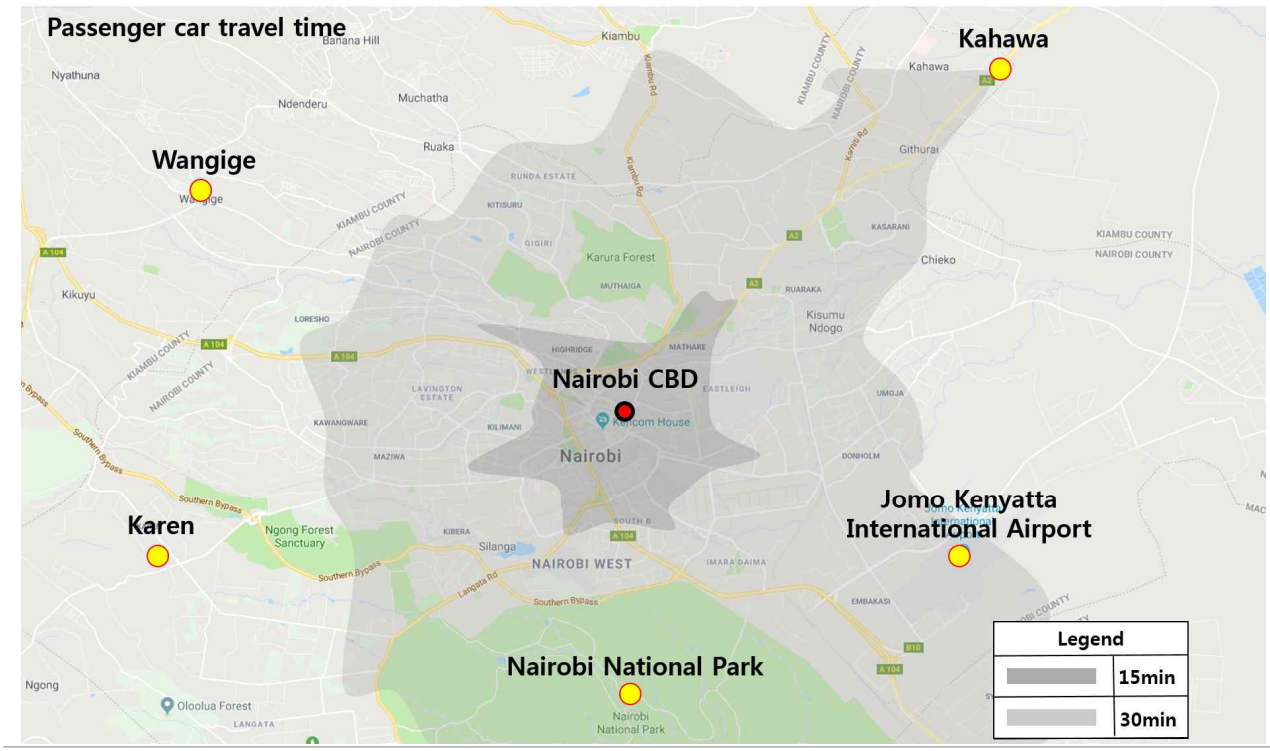
<Table 3-14> Traffic volume on major roads

Major Roads		Matatus	Buses	Lorries& Trucks	Private cars	Motor Bikes	Total
Arterial	ThikaRoad	7,500	3,480	180	6,000	600	17,760
	JujaRoad	1,140	1,500	240	4,980	480	8,340
	JogooRoad	1,920	3,300	540	11,820	1,560	19,140
	MombasaRoad	840	180	720	11,760	600	14,100
Collector	HaileSelasieAvenue	5,880	1,860	240	3,660	180	11,820
	KenyattaAvenue	300	1,680	60	12,840	480	15,360
	WaiyakiWay	660	480	660	15,420	480	17,700
	NgongRoad	960	360	360	2,820	300	4,800

source : "PSV demand, termini capacities and compliance level with TLB regulations In Nairobi metropolitan area" Ministry of Transport transport licensing board, Final report, Dec, 2012

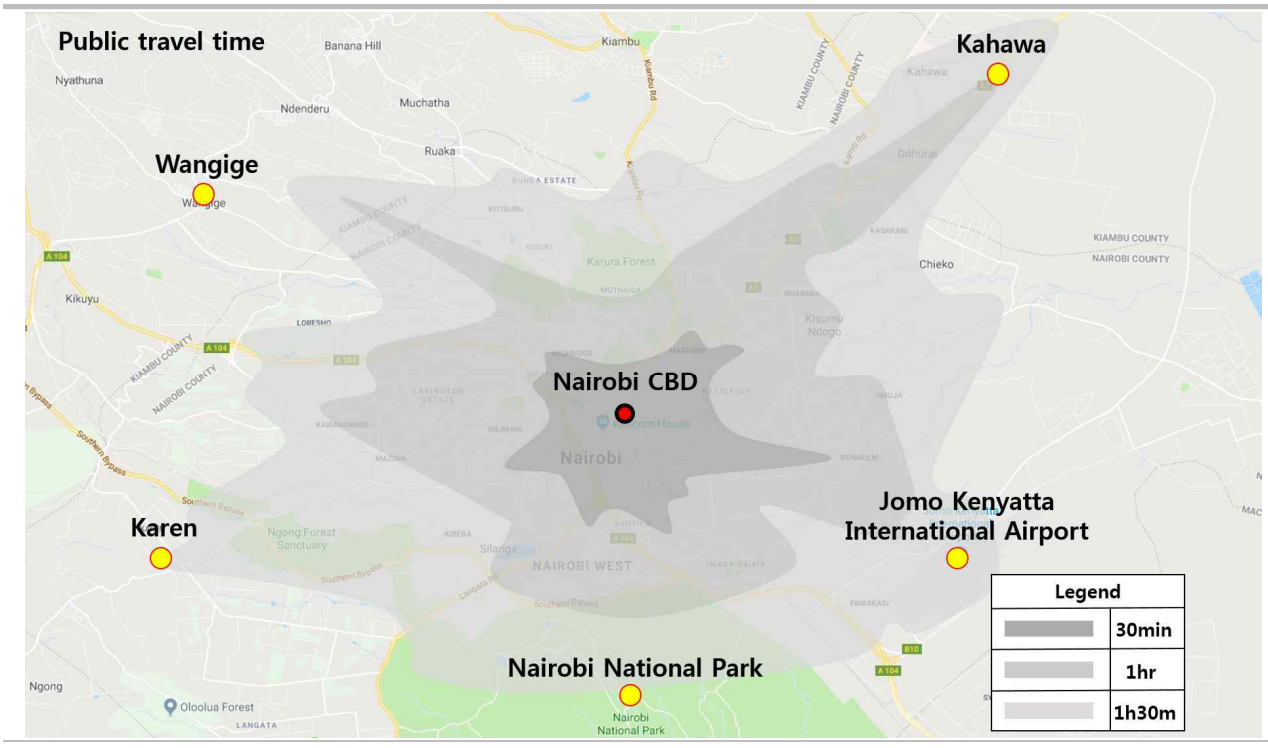
Travel time of Arterial Roads

- The passenger cars normally spend about 15 minutes to reach around the CBD, and 30 minutes to the major cities and facilities.



<Figure 3-21> Travel Time of Passenger Cars in A.M. Peak Period(07:00~08:30)

- Meanwhile, the public transport modes spend less than 30 minutes to the CBD, and 90 minutes to the major cities and facilities.

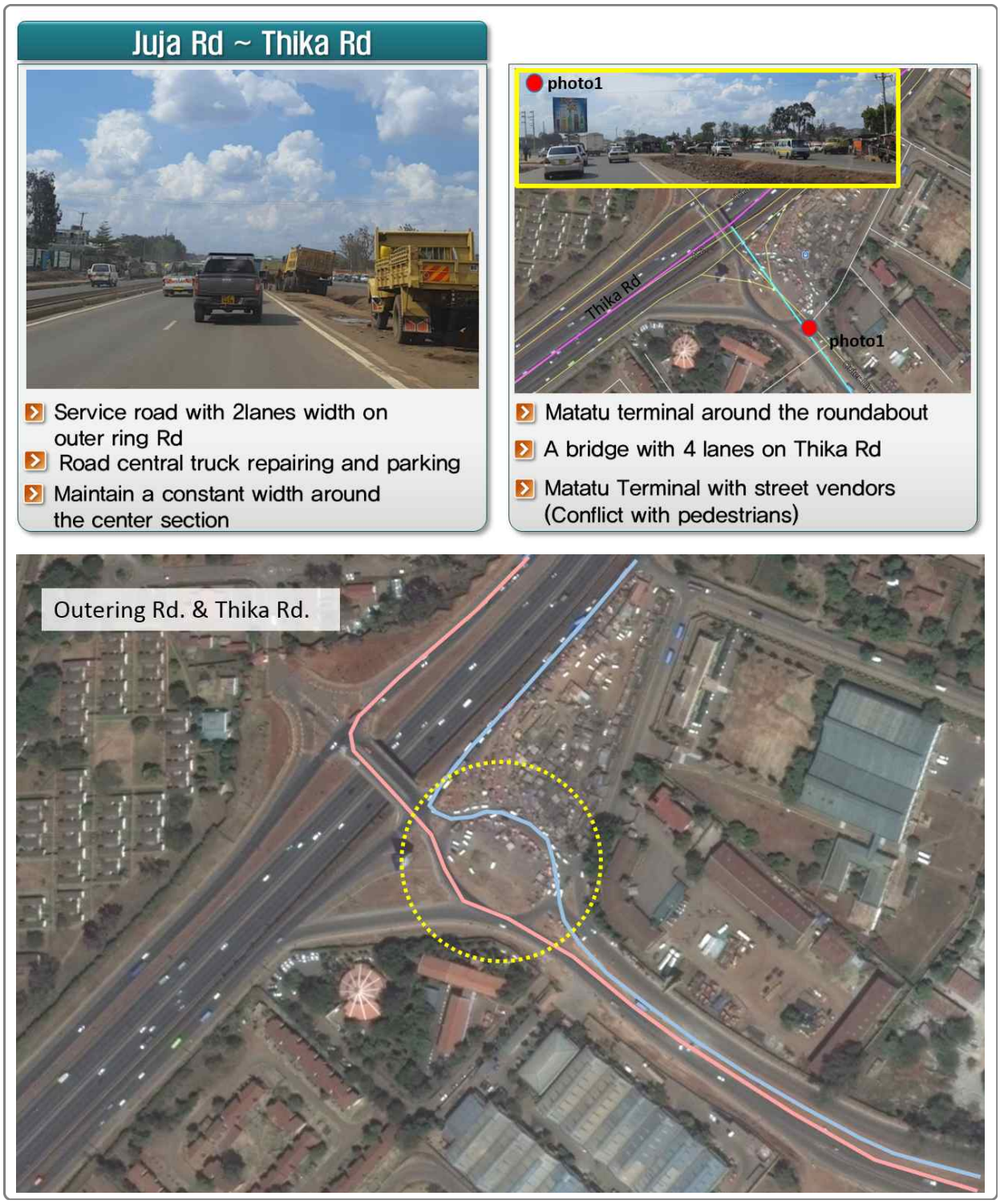


<Figure 3-22> Travel Time of Public Transport Modes in A.M. Peak Period(07:00~08:30)

Traffic characteristics

a. Juja Rd ~ Thika Rd

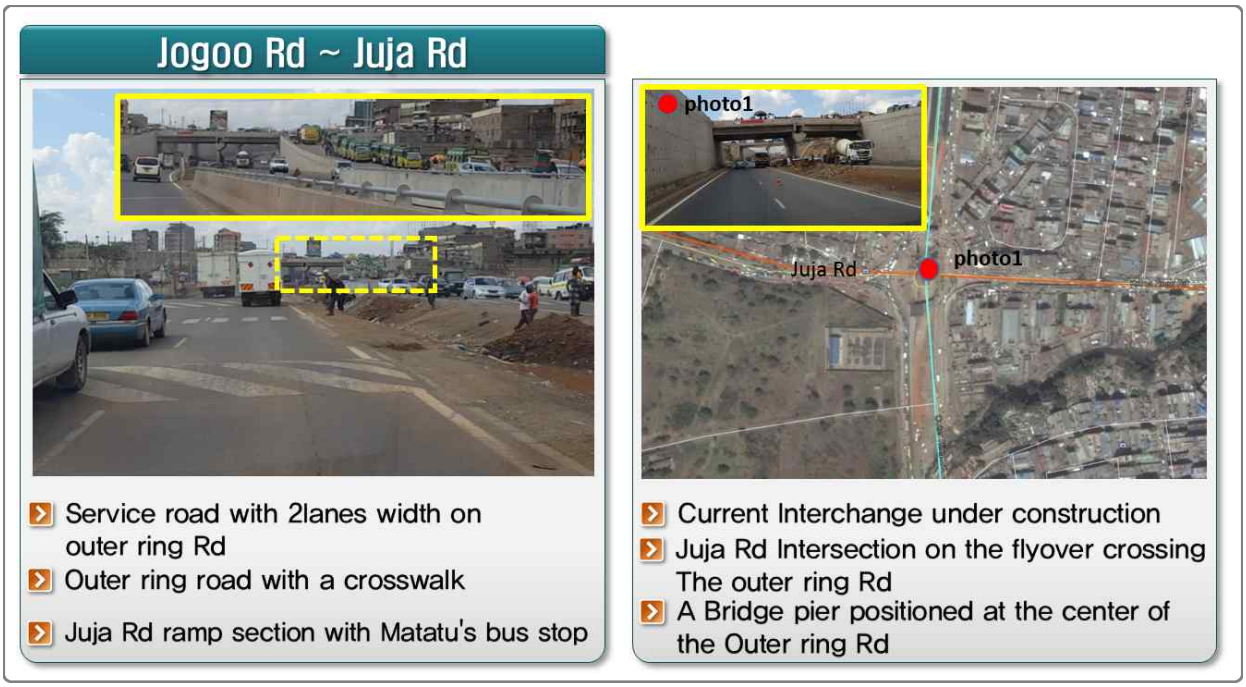
- This section has the service road with 2 lanes width on outer ring Rd, and is occupied by truck repairing and parking in the road central.
- The Matatu terminal is located nearby the roundabout



<Figure 3-23> Juja Rd ~ Thika Rd

b. Jogoo Rd ~ Juja Rd

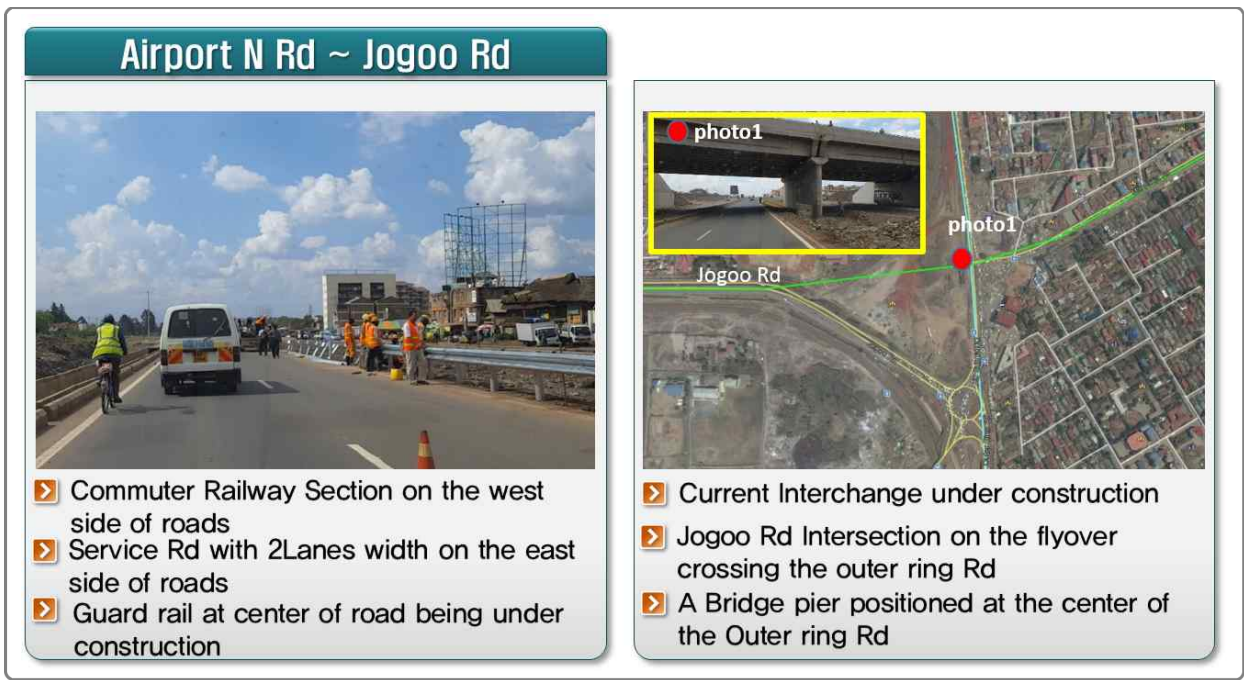
- This section has the service road with 2 lanes width on outer ring Rd, and a crosswalk.
- The ramp section of Juja Rd has Matatu's bus stops.



<Figure 3-24> Jogoo Rd~Juja Rd

c. Airport North Road ~ Jogoo Road

- This section has commuter railway on the west side of the road, and the service road with 2 lanes width on its east side.
- And, its guard rails are under construction in the center of the road.



<Figure 3-25> Airport North Road ~ Jogoo Road

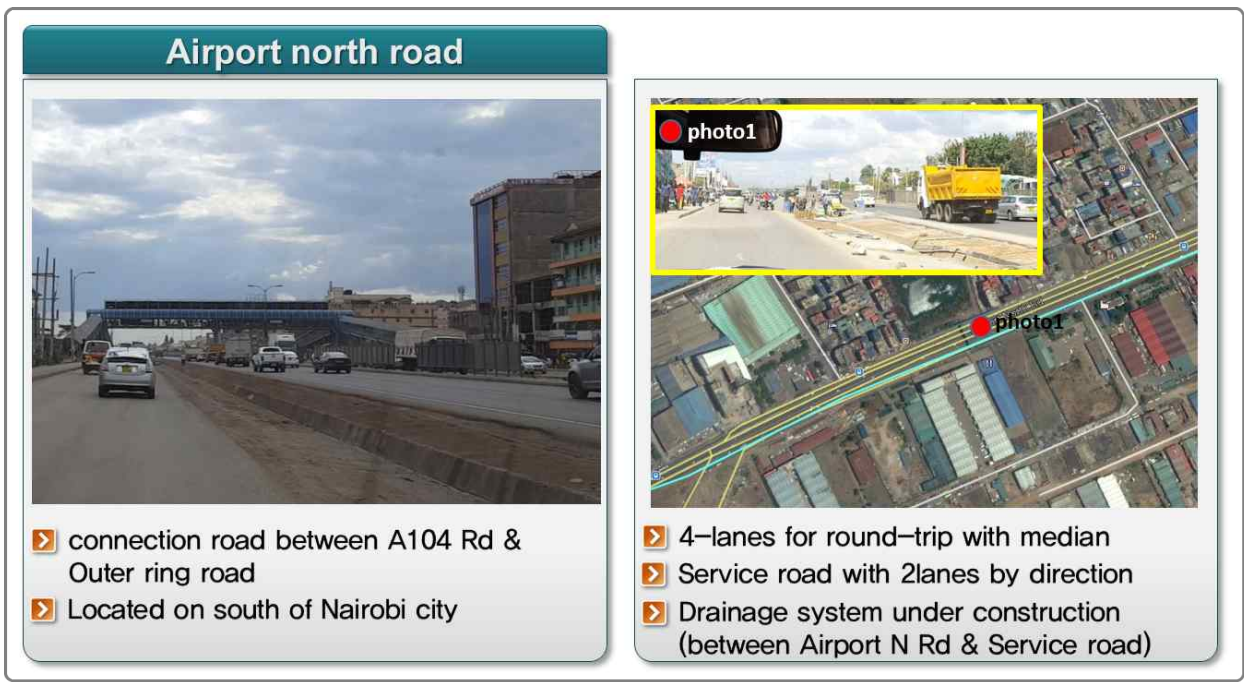
d. Outer ring road ~ Airport north Road

- The Taj intersection is located under the overpass of Airport North Road
- This section has struggled by traffic congestion due to a mix of matatu and general vehicles, and its insufficient road capacity due to waiting for matatu.

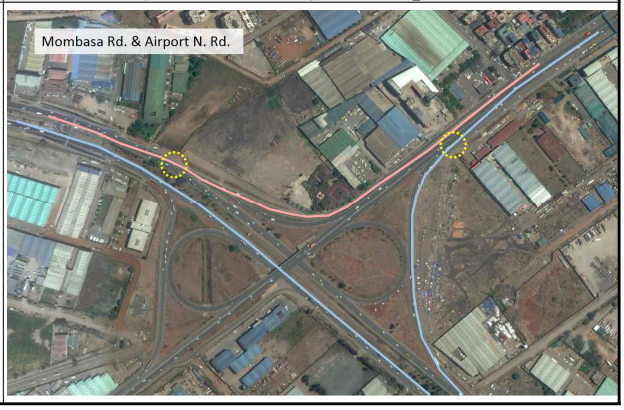
<Figure 3-26> Outer ring road ~ Airport north Road

e. Airport North road

- This road is under construction to rehabilitate drainage system(between Airport north road & service road)



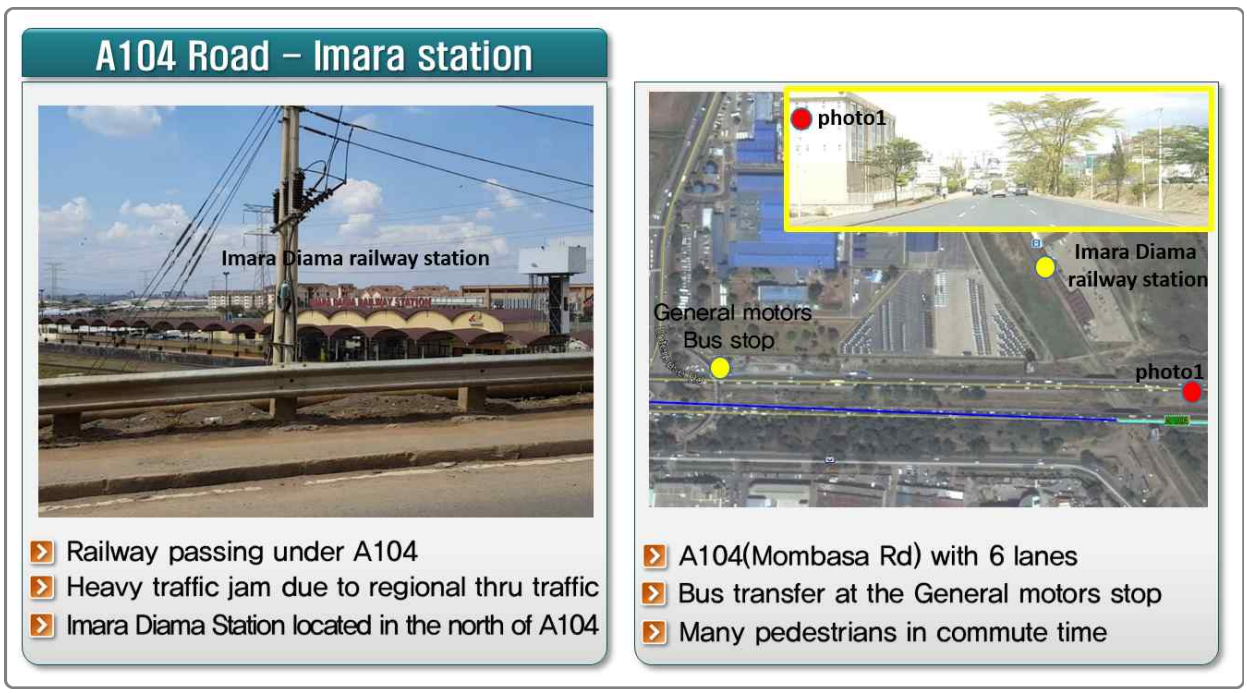
<Figure 3-27> Airport North road

Outerring Rd & Airport N. Rd	A104(Mombasa Rd) & Airport N. Rd
	

<Figure 3-28> Outering Rd & Airport N. Rd, A104(Mombasa Rd) & Airport N. Rd

f. A104 Road – Imara Station

- This section has heavy traffic congestion due to regional thru traffic.
- And, it is playing a role of bus transfer service at the general motors stop for many pedestrians in commuter time.



<Figure 3-29> A104 Road – Imara Station

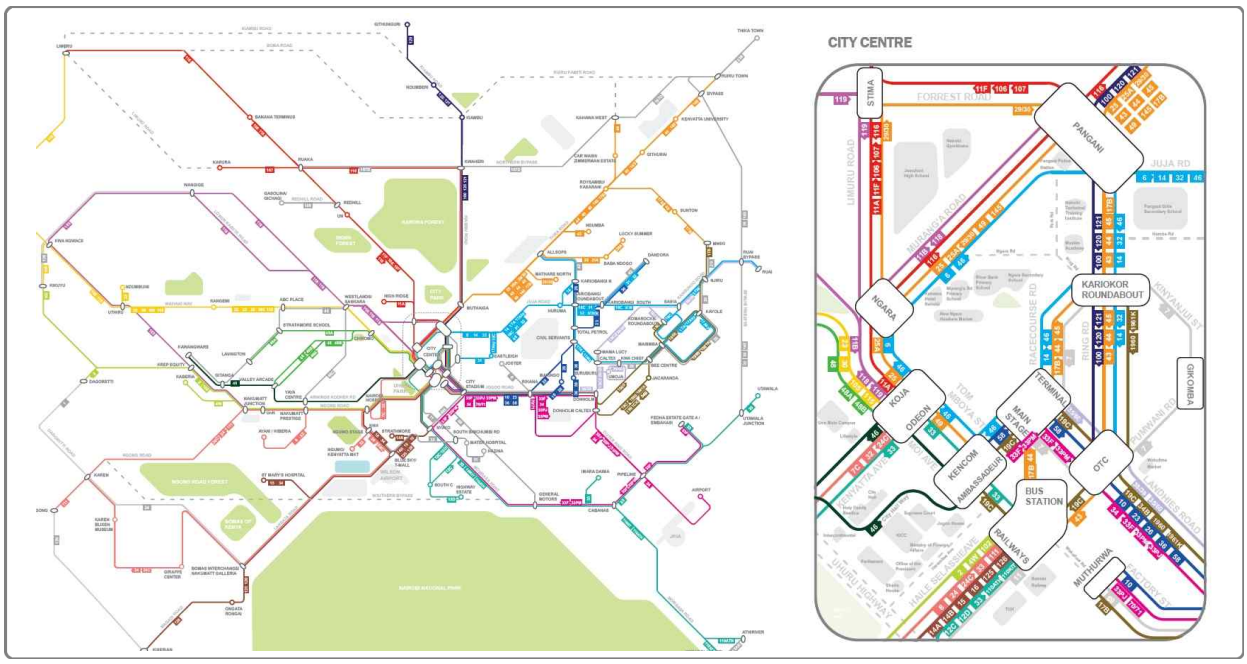
4) Public Transport Condition

- Public service vehicles (PSV) is composed of Matatus, KBS (Kenya Bus Services) and City Hoppa. Most of them are operated by private enterprises and individuals. And, most of the bus lines are concentrated in CBDs, and the city has many isolated areas without public transportation service for this reason.
- However, in the case of CBD, the bus lines are concentrated around bus terminals and stations.

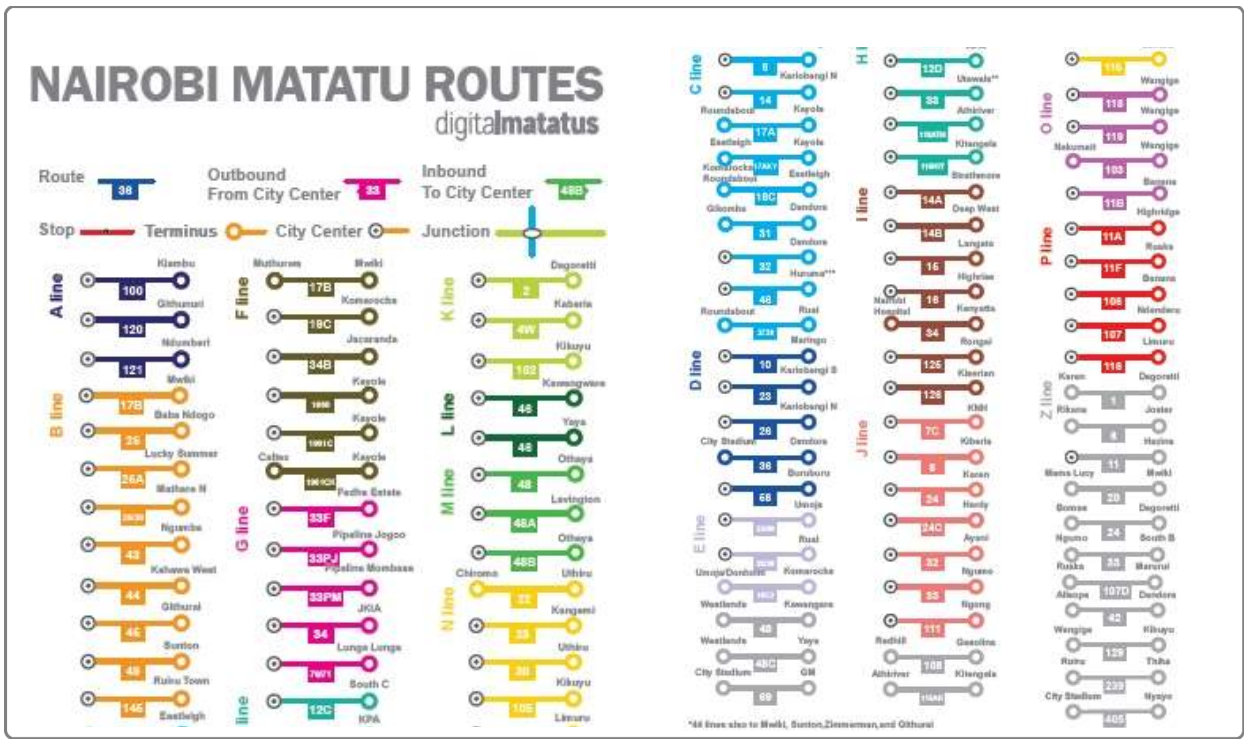
<Figure 3-30> Photo of the PSV

Matatu Routes

- According to the Digital Matatus Route Map in 2014, 134 routes are in operation.
- Most of the Matatu Routes are concentrated in the CBD.
- The Matatus Routes through this project road are Route 14, Route 26, Route 36, Route 42, etc.



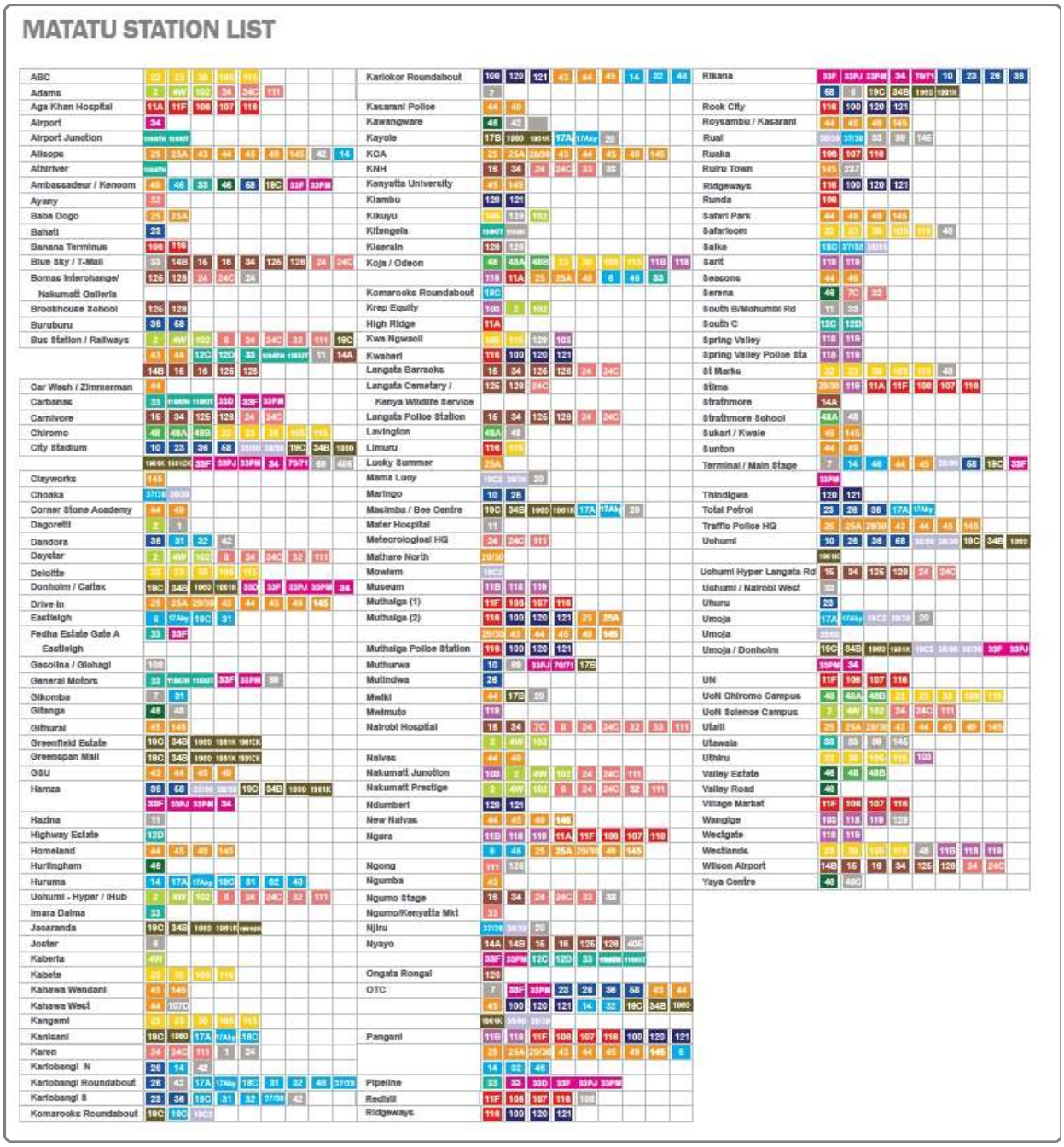
<Figure 3-31> Matatus route map from the Digital matatus



<Figure 3-32> Matatus route display(from the Digital matatus)

Station

- According to the Digital Matatus Route Map in 2014, there are over 2,481 stops.
- Tha Matatus station located on this project road are Allsops, Kariobangi, Total Petrol, Civil Servants Donholm, etc.



<Figure 3-33> Matatu station list

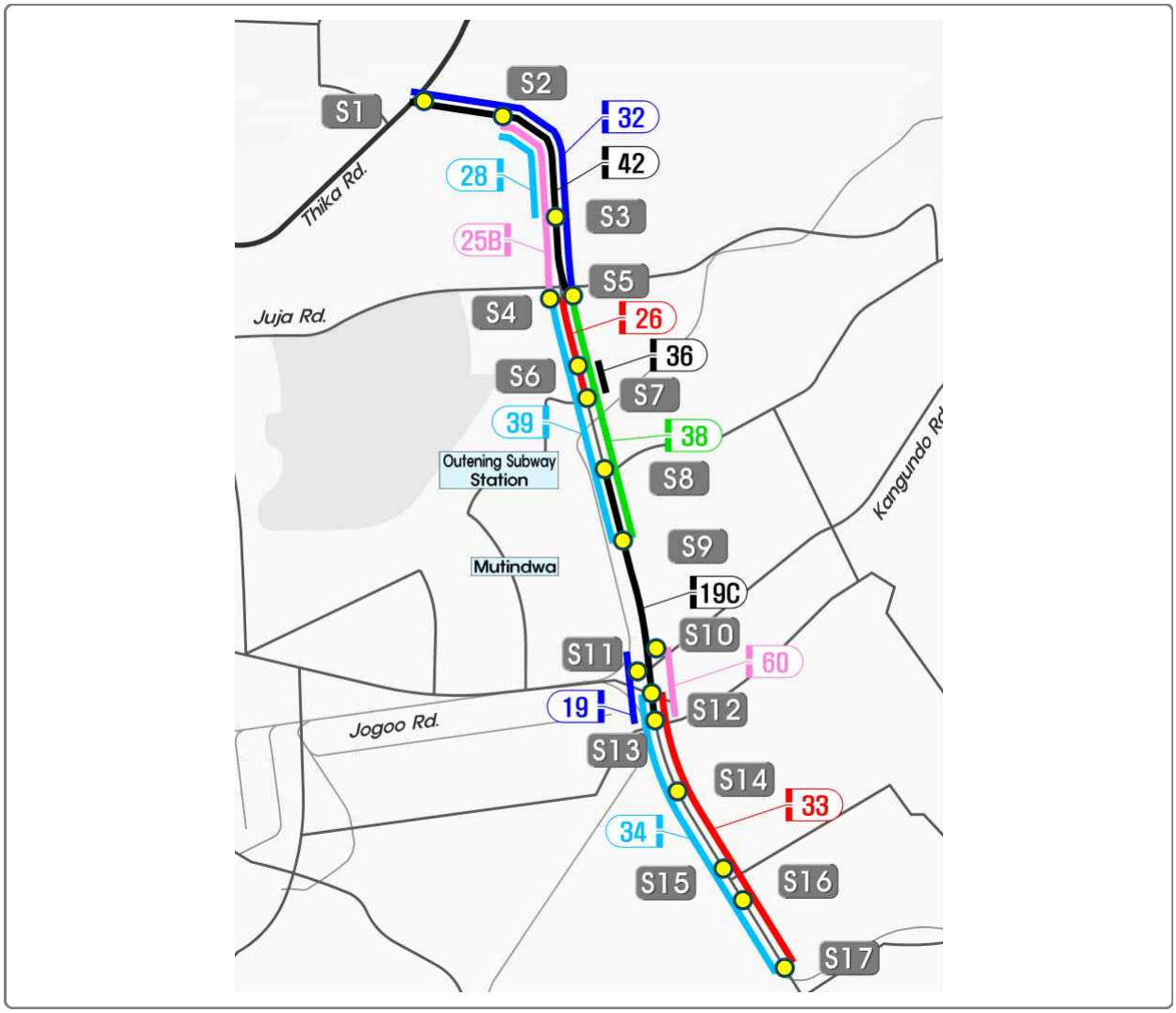
Bus routes

- The Outer Ring Road has 17 bus stops as shown in the following table.

<Table 3-15> Bus Routes

Bus stop name		MATATU NUMBER				
1	Allsops Bus stop	25	32/42		City Hoppa	Embassava
2	Baba Ndogo Junction	25B	28	32/42	25B	
3	Kariobangi mkt stage/ Huruma road	14	32/42	18	25B	28
4	Juja road	237	25B	18C	42/32	Forward Sacco
		46				
5	Koma rocks road	46	38/39	20	18 C	Forward
		32/42	26			
6	Mutarakwa road	26	ROG	36	Forward	
7	Mumias south road	39	36	26		ROG Sacco
8	Kangundo road	39	38	34	19C	Umoiner Sacco
		20				
9	Mutindwa bus stage	38/39	19C	38/39	38B	Ummoiner Sacco
10	Manyanja Road	19/60	35/60			
11	Donholm Roundabout					
	Jogoo Road	39	19C	26		
12	Lunga Lunga Road	33	34	19/60	71	35/60
13	Caltex Donholm Bus Stop	34	33		19 (Double M)	Embassava Sacco
14	Kwale Bus Stop	35	34	33		Embassava Sacco
15	Tassia Bus Stop	34	33			Embassava Sacco
16	Pipeline Stage	33	34			Embassava Sacco
17	Tajmall Round about	33	34			Embassava sacco

source : field survey(2017.11)

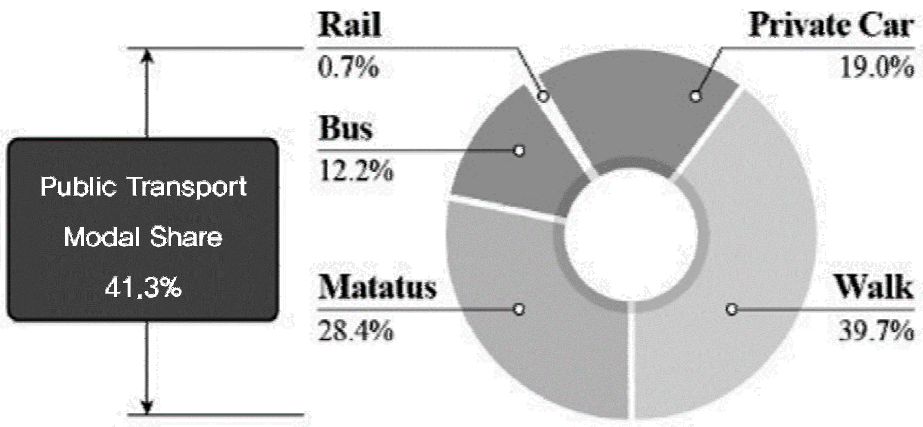


<Figure 3-34> Bus Routes

The proportion of public transportation

- The proportion of public transportation is very high (67.3%) except for 41.3% in 2013 (Matatus 28.4%, Bus 12.2%, Rail 0.7%) and walk 40%

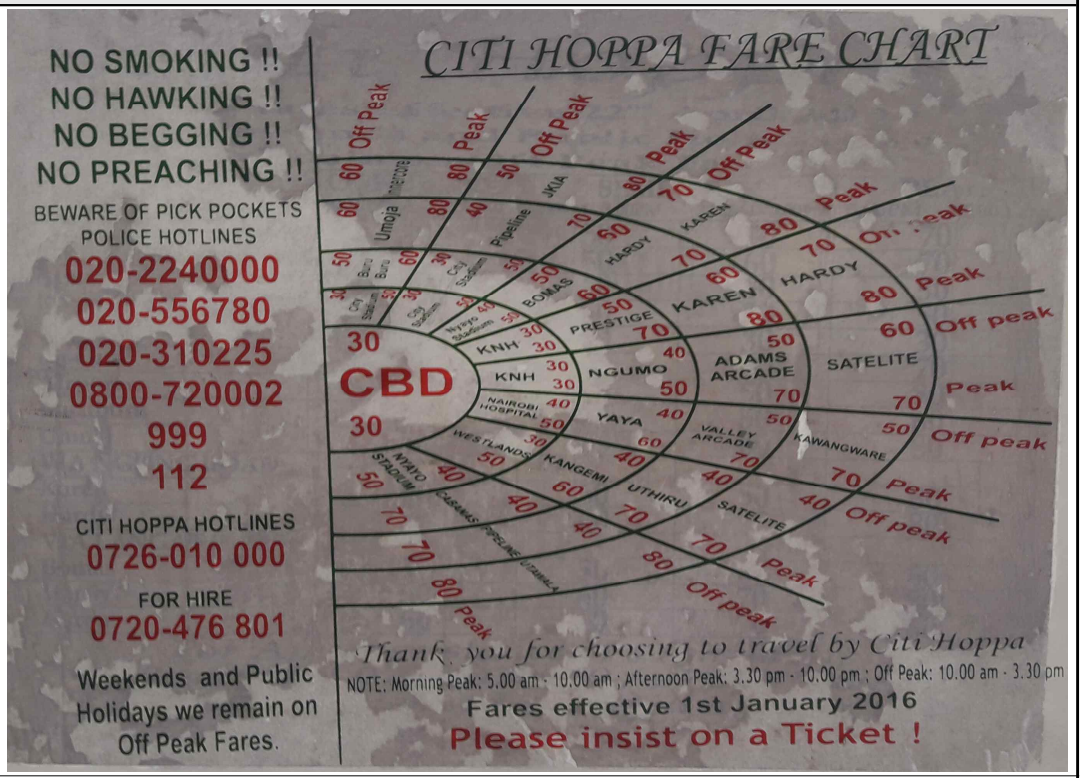
Proportion of public transportation[1)]



<Figure 3-35> Modeshare of Nairobi transport

4) Fare

- The fare system has differently operated by zone and time.
- The lowest fare is 30 Kenya Shillings as a base fare, with a difference between peak and non-peak hours(am 11:00 ~ pm 3:00).
- In addition, some buses require an extra charge (2-3 times) in case of rain.

Fare	Fare chart
Citi Hoppa fare chart	
Express connections LTD (Offpeak am11~pm3 fare)	

<Figure 3-36> Fare chart

5) Public demand

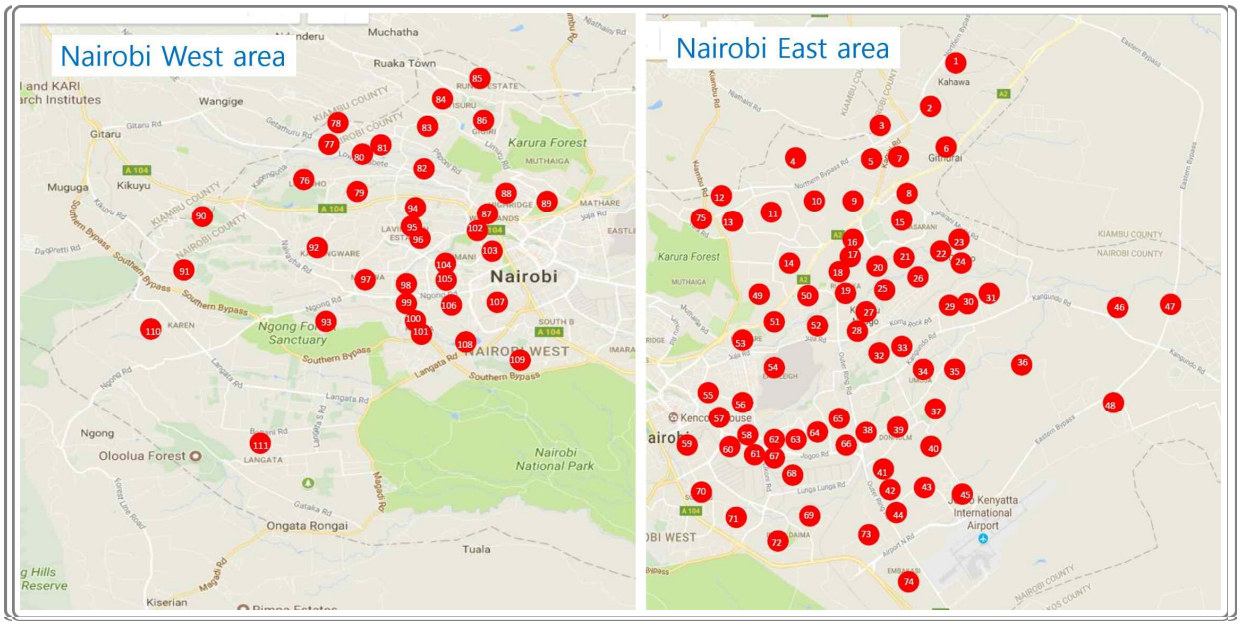
Introduction

- In order to understand the traffic characteristics and travel patterns, the major terminals were surveyed in Nairobi.
- In this chapter, the results of analysis will be shown for the survey which was conducted at 8 terminals
- Two kinds of surveys were conducted at the various terminals. They are the passenger Interview and the vehicle frequency surveys.
- Table 3-16 shows the effective samples obtained from the survey.

<Table 3-16> Passenger interview and Traffic volume survey : Origin-Destination Survey point

Classification		Survey point	Investigation contents
Nairobi central	Railway	① Nairobi Railway station	Passenger interview survey
	Bus terminal	② Nairobi bus station	Passenger interview and Traffic volume survey
		③ koja bus station (Nation building terminal, koja etc)	
Project route	Bus terminal	④ Allsopps bus tarminus (Allsops, Dandora bus stop etc)	
	Railway	⑤ Imara Diama Railway Station	Passenger Interview survey
	Bus station	⑥ Doni bus stop (Donholm roundabout bus stop)	
	Shopping Mall	⑦ Taj Shopping Mall, Embakasi village, nyayo, juakali stage	
	Bus station	⑧ Juja Outering Junction	

<Figure 3-37> Origin-Destination Survey point



<Figure 3-38> Origin and Destination (OD) Interview Survey Zone code number

<Table 3-17> ORIGIN AND DESTINATION (OD) INTERVIEW SURVEY ESTATE CODE NUMBER

1	Kahawa
2	Kongo Estate
3	Kamiti
4	Marurui
5	Mirema
6	Githurai
7	Zimmerman
8	Clay works
9	Roysambu
10	Thome
11	Garden Estate
12	Thindigua
13	Ridgeways
14	Balozi Estate
15	Kasarani
16	Ngumba Estate
17	Messo estate
18	Kariobangi
19	Ruaraka
20	Gathecha village
21	lucky summer
22	Gituamba
23	Sunton
24	Chieko
25	Ngomongo village
26	Dandora
27	Kisumu Ndogo
28	Nyayo Village
29	Saika
30	Obama Estate
31	Njiru
32	Kariobangi South
33	Mowlem
34	Umoja
35	Sabasaba
36	Quarry
37	Soweto
38	Tena
39	Donholm

40	Baraka Estate
41	Savannah
42	Tassia
43	Nyayo Estate
44	Fedha Estate
45	Simba Villas
46	Chereni
47	Ruai
48	Mihango
49	Kenya Pipeline Estate
50	All sopps
51	Survey
52	Huruma
53	Mathare
54	Eastleigh
55	Kariokor
56	Pumwani
57	Gikomba
58	Shauri Moyo
59	CBD
60	Kaloleni
61	Makingeni
62	Bahati
63	Maringo
64	Jericho
65	Buruburu
66	Lumumba
67	MbotelA
68	Industrial Area
69	Viwandani
70	South B
71	River Bank Estate
72	Imara Daima
73	Kwa Njenga
74	Embakasi
75	Runda Evergreen
76	Loresho
77	Mitini
78	Getathuro

79	Kyuna Estate
80	Lower Kabete
81	Kitisuru
82	Spring Valley
83	Nyari
84	Rosslyn
85	Runda Estate
86	Gigiri
87	Westlands
88	Highridge
89	City Park Estate
90	Uthiru
91	Mutuini Estate
92	Kawangware
93	Jamhuri
94	Muthangari
95	Lavington
96	Kileleshwa
97	Valley Arcade
98	Kilimani Estate
99	Woodley Estate
100	Karanja Road Estate
101	Kibera Slum
102	Chiromo
103	Estate Fanusi
104	Caledona Estate
105	Hurlingham Estate
106	Golf Course Estate
107	Nairobi Upper Hill
108	Nairobi Dam Estate
109	Nairobi West
110	Karen
111	Langata
112	Others

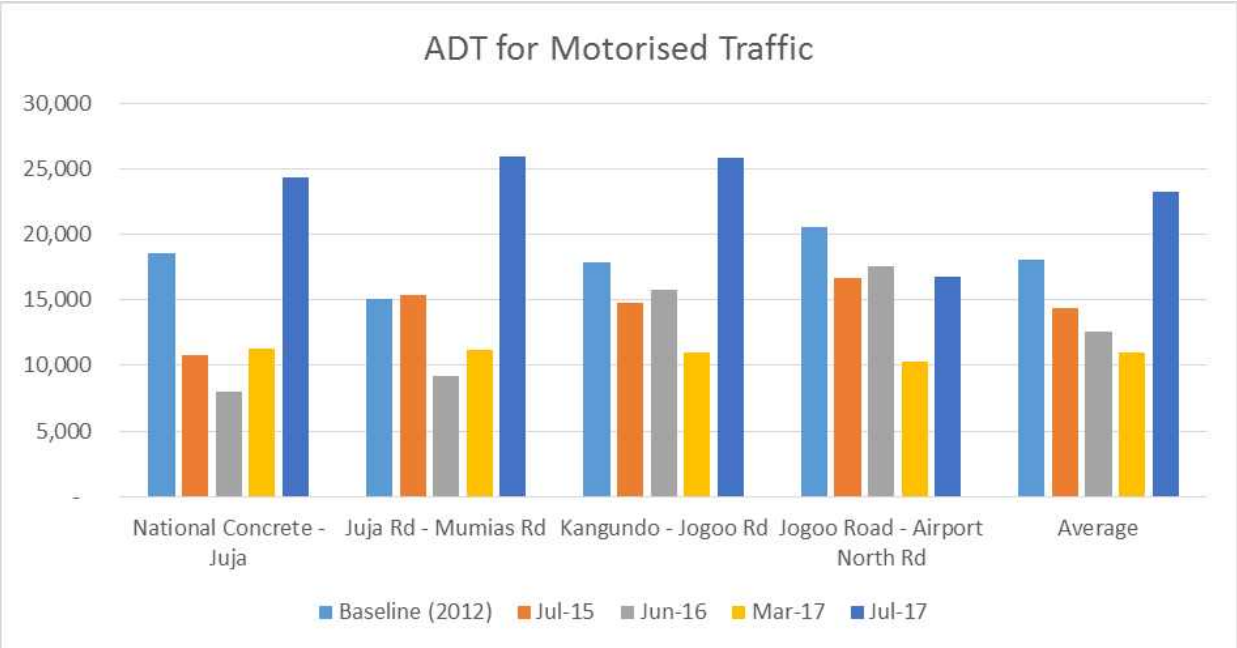
Traffic volume of the PSVs

- The traffic monitoring was carried out 5 day 12-hr counts and 2-day 24 hour counts in July 2017 by the engineering team on the outering road improvement project. the counts were carried out for traffic along the outering road at the following locations

<Table 3-18> Location of the traffic monitoring

Chainage	Location
2+300	• Before junction with Juja Road / Dandora Road
3+300	• After junction with Juja Road / Dandora
6+300	• Before junction with Jogoo Road
8+000	• After junction with Jogoo Road

- As a result of the 5-times phased traffic monitoring, it is indicated that the traffic volumes has been increased significantly in July 2017 compared to the previous counts. This pattern should be caused by the progress of the construction at which the main carriageway was fully open to traffic as well as the service roads.



source: Traffic monitoring report no.4 on outer ring road improvement project (KURA, 07.2017)

<Figure 3-39> Comparison of the ADT for motorised traffic on outering road

- The study team are focused on the traffic volume of the PSVs and the results was utilized as the baseline data for estimating the peak hour rate which is calculated at 8.7%.
- The following table shows the daily traffic volume of the PSVs including matatus and buses on weekdays.

<Table 3-19> 24hours Traffic volume of PSVs on outering road

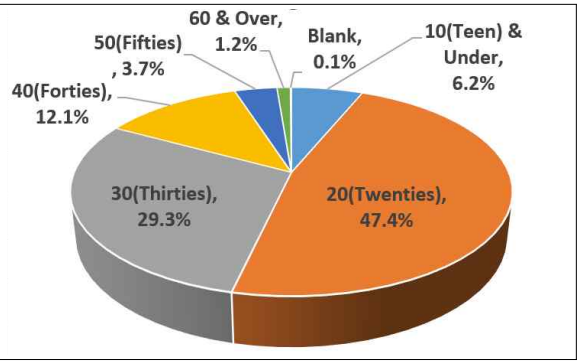
hour	Thika -> Taj					Taj -> Thika				
	RHS MCW	LHS MCW	RHS SR	LHS SR	Total	RHS MCW	LHS MCW	RHS SR	LHS SR	Total
7:00 AM	40	62	8	15	125	33	56	82	125	296
8:00 AM	0	130	20	14	164	43	49	63	25	180
9:00 AM	0	83	9	13	105	33	37	44	29	143
10:00 AM	0	131	23	19	173	37	47	40	15	139
11:00 AM	0	171	35	9	215	63	51	51	6	171
12:00 PM	45	78	46	41	210	35	36	58	8	137
1:00 PM	24	75	81	50	230	27	58	47	12	144
2:00 PM	25	70	43	22	160	38	47	45	6	136
3:00 PM	22	65	29	10	126	41	35	31	5	112
4:00 PM	47	112	33	11	203	36	37	30	21	124
5:00 PM	42	0	63	6	111	51	56	49	13	169
6:00 PM	36	67	49	85	237	70	73	39	30	212
7:00 PM	20	98	26	22	166	82	106	48	32	268
8:00 PM	10	116	16	51	193	92	83	36	19	230
9:00 PM	16	86	19	39	160	76	65	45	20	206
10:00 PM	14	60	3	95	172	42	44	13	12	111
11:00 PM	13	32	5	39	89	27	21	11	10	69
12:00 AM	10	22	0	27	59	12	15	0	3	30
1:00 AM	5	13	2	12	32	7	19	0	6	32
2:00 AM	5	19	4	5	33	2	21	4	15	42
3:00 AM	12	14	0	34	60	26	17	6	15	64
4:00 AM	51	33	16	214	314	46	15	18	20	99
5:00 AM	32	40	8	176	256	30	50	53	55	188
6:00 AM	37	58	15	99	209	42	26	23	16	107
Peak hour rate	8.3%					**8.7%**				

Passenger Survey

- The analysis of this survey was made based on an effective sample of 1,106 passengers.
- The survey was conducted on a one on one basis. Data was collected on the origin and destination of the trips, waiting and travel times, trip purpose, transport fares, transfer frequency and profile of each passenger.
- Socio-Economic Profile
  - ✓ The socio-economic profile of the respondents in this survey is shown in the Figure 5-24, 5-22, 5-22
  - ✓ Majority of the respondents were between the ages of 20 and 30 of which males were 76.7% and male were 55.7%. Most of them were office workers (22.2%), labourers (18.30%) and students(12.8%).

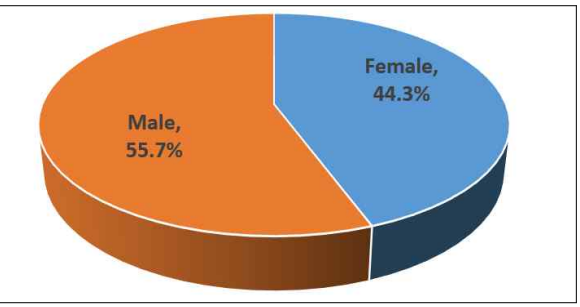
<Table 3-20> Profile of surveyed public transport passengers (age)

Age	Count	%
10(Teen)&Under	69	6.2%
20(Twenties)	524	47.4%
30(Thirties)	324	29.3%
40(Forties)	134	12.1%
50(Fifties)	41	3.7%
60&Over	13	1.2%
Blank	1	0.1%
Total	1,106	100.0%



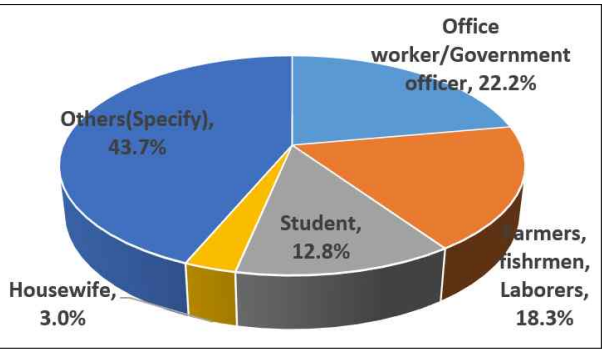
<Table 3-21> Profile of surveyed public transport passengers (sex)

Sex	Count	%
Female	488	44.3%
Male	613	55.7%
Blank	1	-
Typing error	4	-
Total	1,106	100.0%



<Table 3-22> Profile of surveyed public transport passengers (occupation)

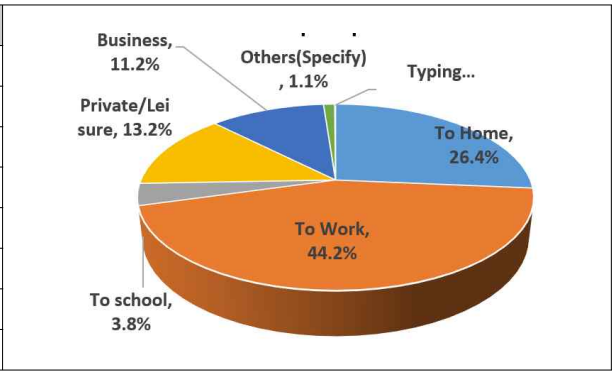
Occupation	Count	%
Office worker / Government officer	218	22.2%
Farmers, fishrmen, Laborers	180	18.3%
Student	126	12.8%
Housewife	30	3.0%
Others(Specify)	430	43.7%
Total	984	100.0%



- Trip purpose
  - ✓ A large percentage of the trips were made to work (44.2%), home (26.4%) and then for private purposes (13.2%).

<Table 3-23> Trip prupose

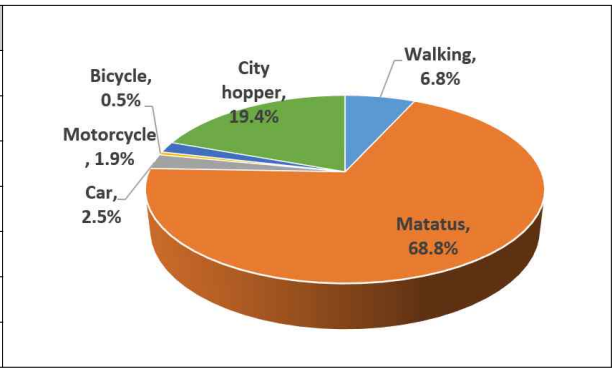
Trip Purpose	Count	%
To Home	292	26.4%
To Work	489	44.2%
To school	42	3.8%
Private / Leisure	146	13.2%
Business	124	11.2%
Others(Specify)	12	1.1%
Typing error	1	0.1%
Total	1,106	100.0%



- Access Mode
  - ✓ 95.1% of commuters arrived at the terminals by walking or by making a transit using matatus and city hopper. Others, as labelled below are those who arrived at the terminals by walking.

<Table 3-24> Access Mode of surveyed public transport passengers

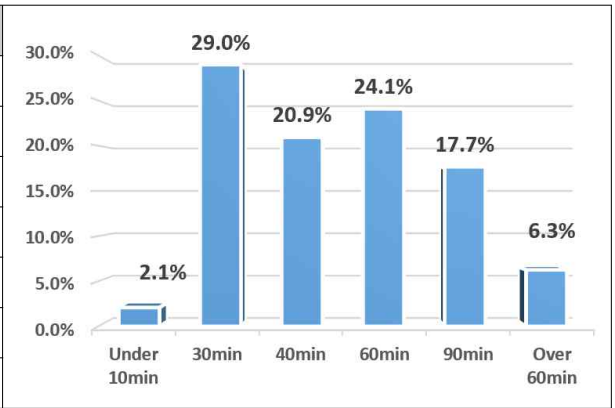
Access Mode	Count	%
Walking	75	6.8%
Matatus	761	68.8%
Car	28	2.5%
Bicycle	6	0.5%
Motorcycle	21	1.9%
City hopper	215	19.4%
Total	1,106	100.0%



- Waiting time
  - ✓ A lot of the passengers waited for 10~30 minutes. Also, 24.10% and 20.9% of the passengers waited for 40~60 minutes and 30~40 minutes respectively before the left the terminal.

<Table 3-25> Waiting time of surveyed public transport passengers

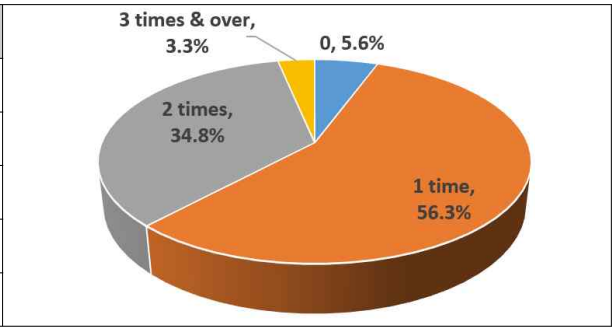
Travel Time	Count	%
Under 10min	23	2.1%
10~30min	320	29.0%
30~40min	231	20.9%
40~60min	266	24.1%
60~90min	195	17.7%
Over 60min	69	6.3%
Total	1,104	100.0%



- Transfer Frequency
  - ✓ Majority of the passengers made just one transfer (56.3%). 34.8% of the passengers made two transfers and this came in second.

<Table 3-26> Transfer frequency of surveyed public transport passengers

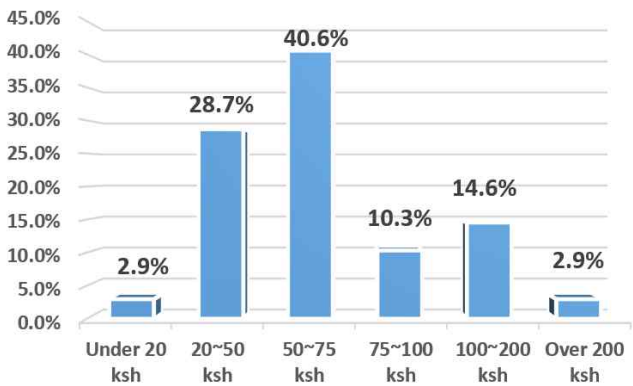
Transfer Frequency	Count	%
0	62	5.6%
1time	620	56.3%
2times	383	34.8%
3times & over	36	3.3%
Total	1,101	100.0%



- Transport Fare
  - ✓ Majority of the passengers paid a fare of 50~70 ksh (40.6%) which is the highest recorded, whilst 28.7% of them paid a fare of 20~50 ksh which came in second.

<Table 3-27> Transport Fare of surveyed public transport passengers

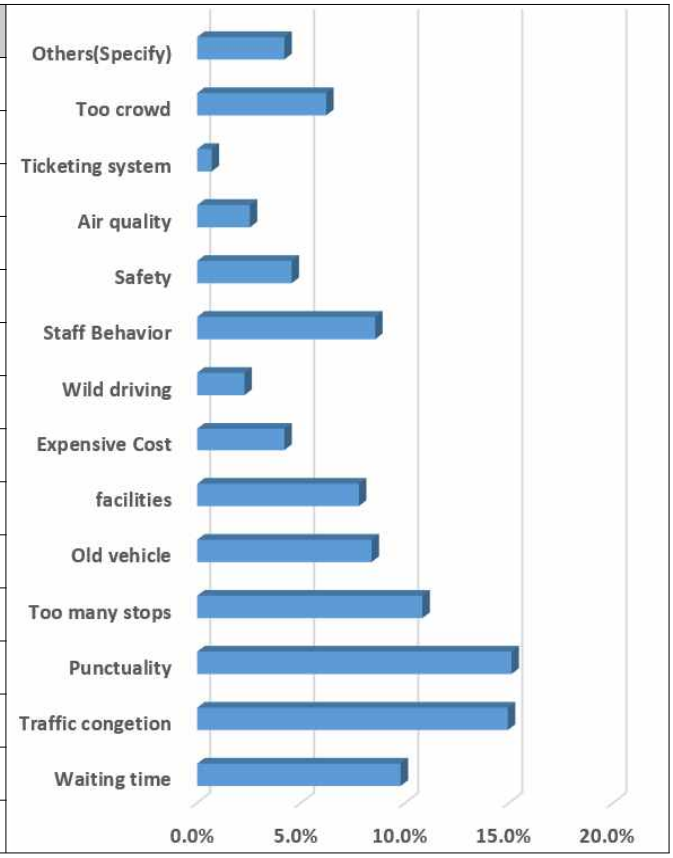
Transport Fare	Count	%
Under 20ksh	32	2.9%
20~50ksh	311	28.7%
50~75ksh	440	40.6%
75~100ksh	112	10.3%
100~200ksh	158	14.6%
Over 200ksh	32	2.9%
Total	1,085	100.0%



- Assessment
  - ✓ Average Assessment Score obtained from the survey is 5.7(perfect score is 10).
  - ✓ Majority of the reasons for this score was based on Punctuality (15.1%), high traffic congestion (14.9%), Too many stops (10.8%), waiting time (9.8%), and old vehicles (8.4%) in the system.

<Table 3-28> Assessment of Public Service Vehicle

Reasons	%
Waiting time	9.8%
Traffic congetion(speed)	14.9%
Punctuality	15.1%
Too many stops	10.8%
Old vehicle	8.4%
Bus stop/terminal facilities	7.8%
Expensive Cost	4.2%
Wild driving	2.3%
Staff Behavior	8.6%
Safety on board & alight	4.5%
Air quality	2.5%
Ticketing system	0.7%
Too crowd(too many passengers)	6.2%
Others(Specify)	4.2%
Total	100.0%



- Pictures of Field survey

<Figure 3-40> Pictures of surveyed public transport passengers (PSV Operation Survey-Koja)

<Figure 3-41> Pictures of surveyed public transport passengers (Passenger Interviews-Bus Station)

<Figure 3-42> Pictures of surveyed public transport passengers (PSV Operation Survey-Bus Station, Passenger O/D-Allsopps)

<Figure 3-43> Pictures of surveyed public transport passengers (Passenger O/D-Allsopps, Passenger O/D-Imara Daima)

<Figure 3-44> Pictures of surveyed public transport passengers(PSV Operation Survey-Allsopps, PSV Operation Survey-Allsopps)

<Figure 3-45> Pictures of surveyed public transport passengers (Passenger O/D-Taj Mall, Passenger O/D-Taj Mall)

<Figure 3-46> Pictures of surveyed public transport passengers (PSV Operation Survey-Koja Bus Station, Passenger O/D-Allsopps)

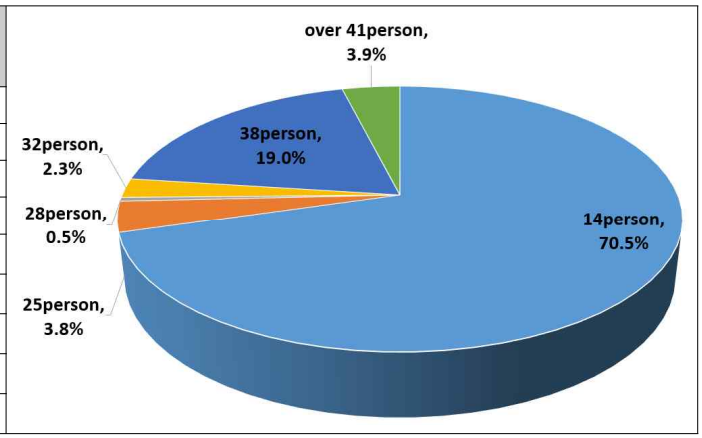
<Figure 3-47> Pictures of surveyed public transport passengers (PSV Operation Survey-Donholm, PSV Operation Survey-Allsopps)

Vehicle Frequency Survey

- Analysis on this survey was made based on an effective sample of 2,383 vehicles.
- In this survey, two surveyors worked at a given time as they stand at the exit of the terminal. One surveyor asks the driver about the destination as the other notes the destination, departure time, plate number and capacity of the vehicle.
- Capacity (for persons)
  - ✓ Majority of the vehicle have capacities of 14 persons respectively and this formed 70.5% of the vehicles that used

<Table 3-29> Capacity of surveyed public transport vehicle frequency

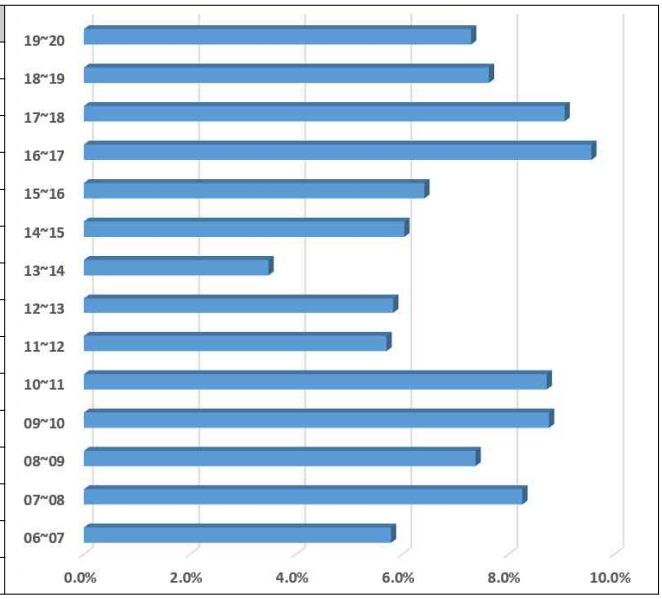
Capacity (for persons)	count	%
14 person	1,679	70.5%
25 person	90	3.8%
28 person	11	0.5%
32 person	56	2.3%
38 person	453	19.0%
41 person	13	0.5%
45 person	19	0.8%
51 person	62	2.6%
Total	2,383	100.0%



- Hourly frequency
  - ✓ From Table 5-23, it can be seen that the morning and evening peak hours are between 07:00 and 10:00 and between 15:00 and 18:00, respectively.
  - ✓ Meanwhile, it can be seen clearly that the busiest hour is between 16:00 and 18:00. This is because a lot of people use the terminals after work.

<Table 3-30> Hourly frequency of surveyed public transport vehicle frequency

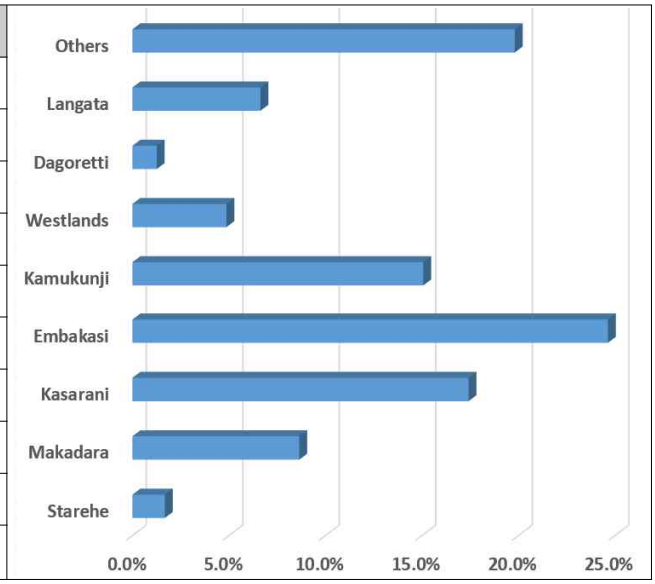
Time	count	%
06~07	138	5.8%
07~08	197	8.3%
08~09	176	7.4%
09~10	209	8.8%
10~11	208	8.7%
11~12	136	5.7%
12~13	139	5.8%
13~14	83	3.5%
14~15	144	6.0%
15~16	153	6.4%
16~17	228	9.6%
17~18	216	9.1%
18~19	182	7.6%
19~20	174	7.3%
Total	2383	100.0%



- Destination (Whole)
  - ✓ From Table 5-24, 24.6% of the passengers were going to Embakasi, followed by Kasarani (17.4%).

<Table 3-31> Destination of surveyed public transport vehicle frequency(Whole)

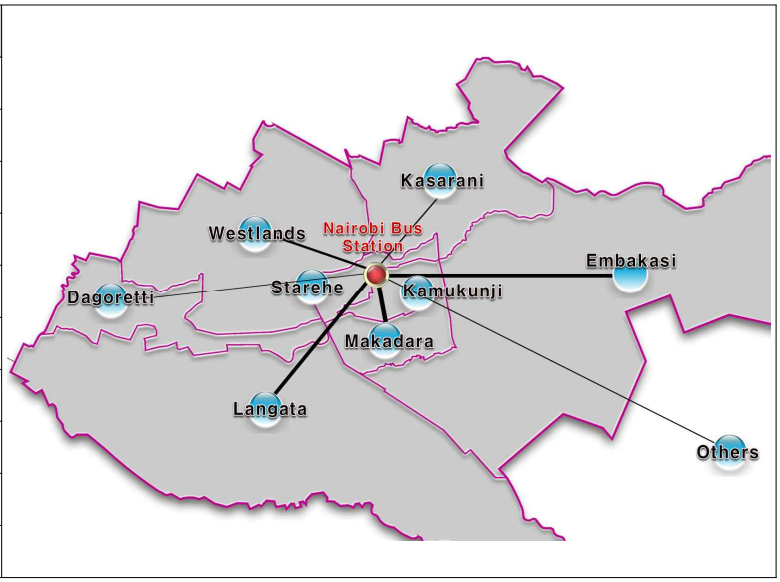
No	Location	Count	%
1	Starehe	40	1.7%
2	Makadara	206	8.6%
3	Kasarani	415	17.4%
4	Embakasi	587	24.6%
5	Kamukunji	359	15.1%
6	Westlands	116	4.9%
7	Dagoretti	30	1.3%
8	Langata	158	6.6%
9	Others	472	19.8%
Total		2383	100.0%



- Destination by terminal
  - ✓ NAIROBI BUS STATION
    - · 33.4% of passengers left this terminal to Makadara which is the highest. It was followed by Langata which has 26.9% of passengers.

<Table 3-32> Destination of surveyed public transport vehicle frequency(NAIROBI BUS STATION)

No	Location	Count	%
1	Starehe	0	0.0%
2	Makadara	195	33.4%
3	Kasarani	1	0.2%
4	Embakasi	151	25.9%
5	Kamukunji	0	0.0%
6	Westlands	0	0.0%
7	Dagoretti	30	5.1%
8	Langata	157	26.9%
9	Others	50	8.6%
Total		584	100.0%

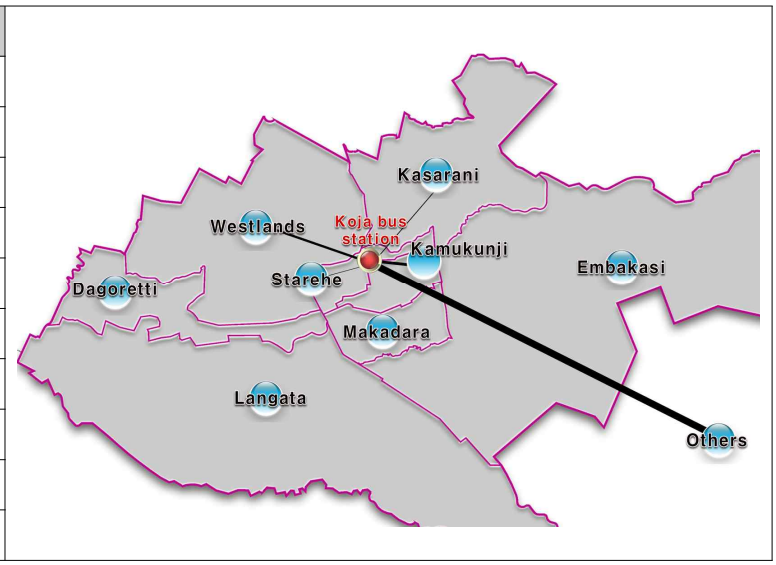


✓ KOJA BUS STATION

· 21.4% of passengers left this terminal to Kamukunji which is highest. Next is Westlands which has 16.7%.

<Table 3-33> Destination of surveyed public transport vehicle frequency(KOJA BUS STATION)

No	Location	Count	%
1	Starehe	16	2.3%
2	Makadara	0	0.0%
3	Kasarani	33	4.7%
4	Embakasi	0	0.0%
5	Kamukunji	149	21.4%
6	Westlands	116	16.7%
7	Dagoretti	0	0.0%
8	Langata	0	0.0%
9	Others	382	54.9%
Total		696	100.0%

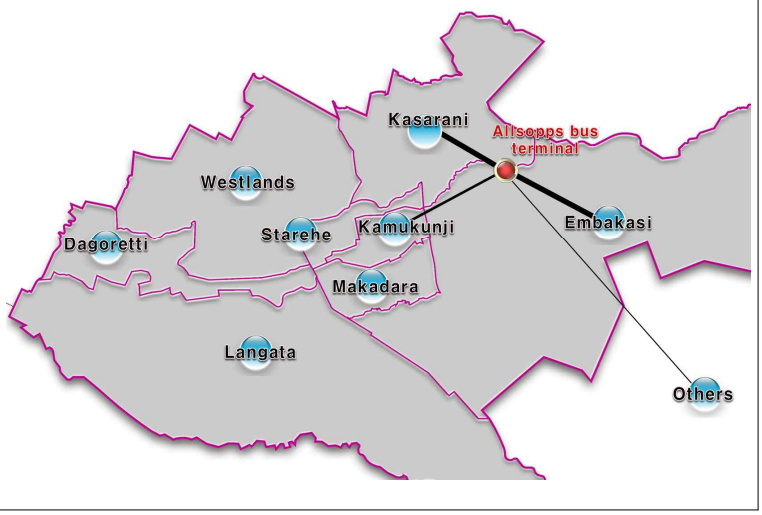


✓ ALLSOPS

· 39.3% of passengers left this terminal to Kasarani which is highest. Next is Embakasi which has 39.2%.

<Table 3-34> Destination of surveyed public transport vehicle frequency(ALLSOPS)

No	Location	Count	%
1	Starehe	0	0.0%
2	Makadara	0	0.0%
3	Kasarani	308	39.3%
4	Embakasi	307	39.2%
5	Kamukunji	139	17.8%
6	Westlands	0	0.0%
7	Dagoretti	0	0.0%
8	Langata	0	0.0%
9	Others	29	3.7%
Total		783	100.0%

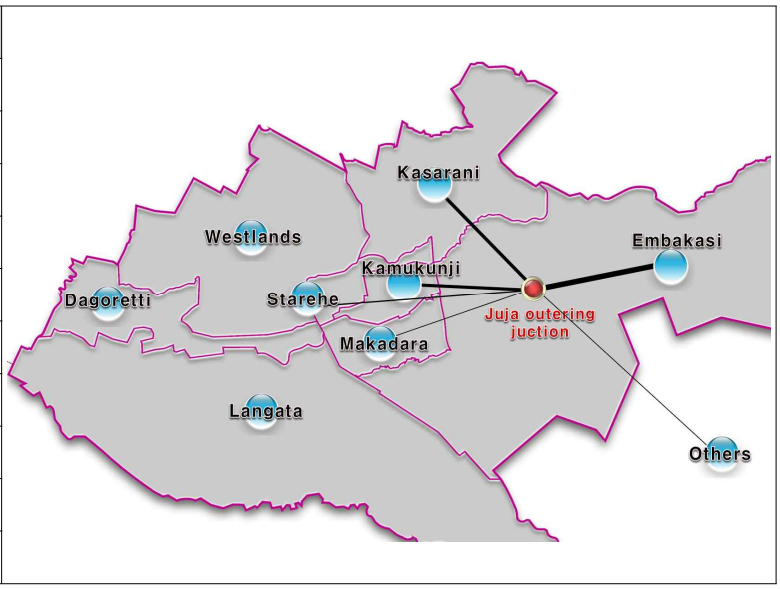


✓ JUJA OUTERING JUNCTION

· 40.3% of passengers left this terminal to Embakasi which is highest. Next is Kasarani which has 22.8%.

<Table 3-35> Destination of surveyed public transport vehicle frequency(JUJA OUTERING JUNCTION)

No	Location	Count	%
1	Starehe	24	7.5%
2	Makadara	11	3.4%
3	Kasarani	73	22.8%
4	Embakasi	129	40.3%
5	Kamukunji	71	22.2%
6	Westlands	0	0.0%
7	Dagoretti	0	0.0%
8	Langata	1	0.3%
9	Others	11	3.4%
Total		320	100.0%



Problems of current PSV

- Nairobi's PSV is playing a role as the main transport for citizens, but it has many problems as follows.
  - ✓ PSV vehicles are mostly cramped, uncomfortable, old-dated, and poorly managed.
  - ✓ All PSVs are owned and operated by the private sector and can not play a role as public transport modes.
  - ✓ All routes are concentrated in the city center, resulting in inefficient route overlaps and serious traffic congestion in CBD.
  - ✓ At the starting point and ending point, PSV drivers do not operate until when all the seats are filled, which causes unnecessary and excessive waiting time for the user.
  - ✓ PSV drivers frequently operate illegal and abusive driving to earn the daily lease fee of the fleet, so passengers are always exposed to traffic accidents.
  - ✓ Because of the concentration of routes in the city center, there are many vacant service areas, citizens have to transfer with additional fare or to walk on foot.
  - ✓ Although distance-based fare systems are in operation, they are receiving additional charges on peak hours and rainy days, imposing a heavy burden on citizens.
- The current traffic situation in Nairobi is very serious, and if it does not solve the problem of public transport immediately, it will be a stumbling block to Kenya's economic growth.

3.3.3. Railways and Aviation

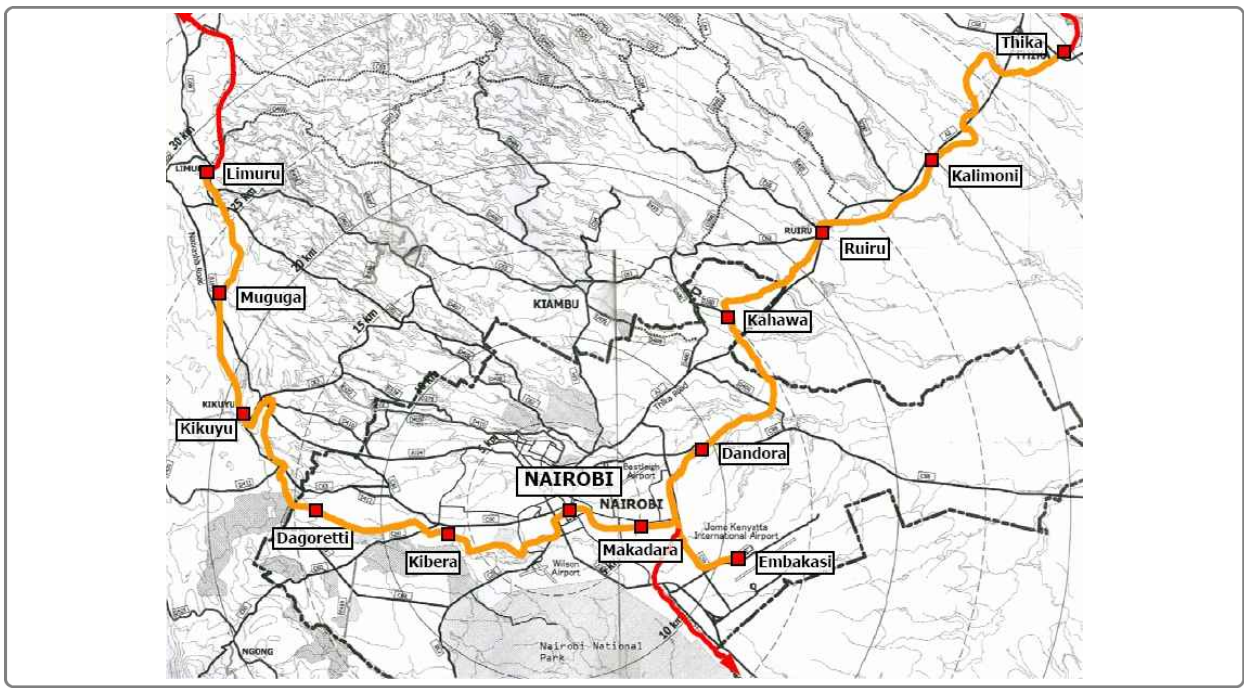
1) Railways

- In the past 10 years (2006), Nairobi metropolitan areas like now have four commuter routes, It consists of the Thika and Kahawa routes in the northeast direction, the Limuru in the northeast direction, and the Embakasi route in the south direction centered on Nairobi Central Station. It is basically a one-day round trip to each of the routes. In the morning, it runs in the direction of Nairobi city and in the afternoon it runs in the suburbs in Nairobi.

<Table 3-36> Commuter rail network

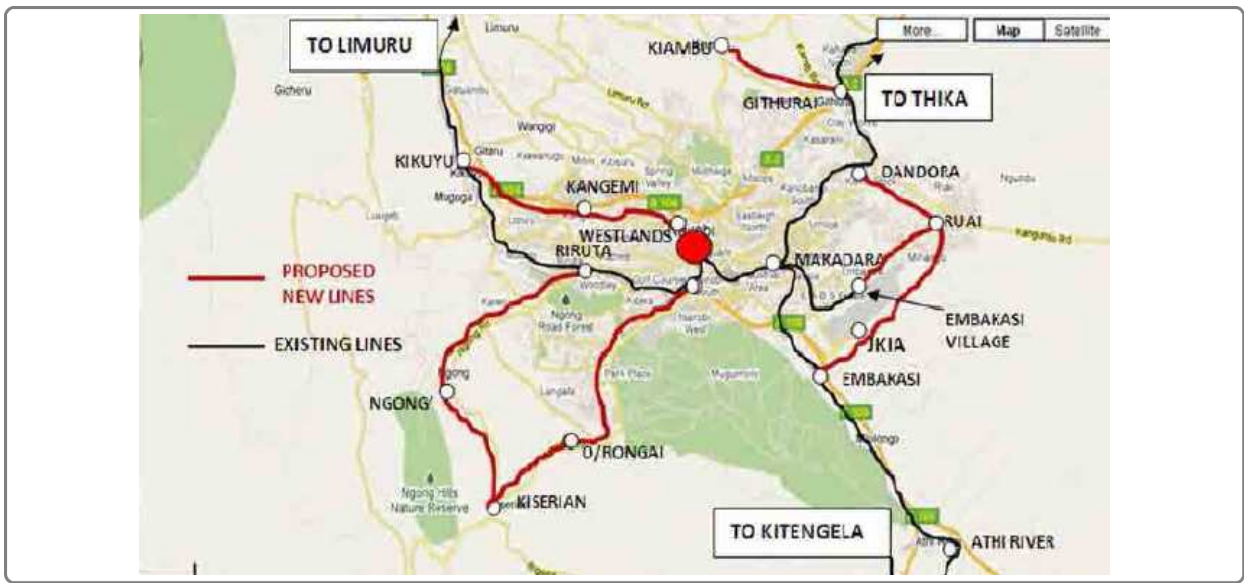
Route		Distance from Nairobi(km)	Current rate(ksp)	No. of coaches	Morning		Evening		Current Matatu Faires
					dep	arrival	dep	arrival	
Thika	NRB-TKA	56.75	20	20	5:30am	7.45am	5.30pm	7.55pm	60
	NRB-RUI	31.63	20						50
	NRB-KAA	24.03	20	20	5:45am	6.47am	6.10pm	7.15pm	30
	NRB-DDA	12.1	15						20
	NRB-UMOJA	-	15						20
	NRB-MKR	5.16	15						20
	NRB-DON	-	15						20
Embakasi	NRB-EKV	14.28	15	5	6.30am	7.05am	5.05pm	5.30pm	30
	NRB-MKR	5.16	10				6.25pm	6.55pm	20
	NRB-DONHM	-	10						20
Limuru	NRB-LMU	46.86	20	14	5.40am	7.40am	5.40pm	7.45pm	50
	NRB-KYU	30.62	20						30
	NRB-KBE	9.93	10						20

Source : The Study on Master Plan for Urban Transport in the Nairobi Metropolitan area in the republic of kenya, March 2006, JICA



<Figure 3-48> commuter rail network

- KRC is now planning to strengthen commuter train services by providing new lines as indicated in red on the following figure. The planned new line from Nairobi to Kikuyu shown on the map is overlapping with the planned LRT line, proposed in the MRTS report in 2011
- There are two approaches for the development of rail-based mass transit system in Nairobi City; namely, 1) the utilisation of the existing KRC facilities, and 2) the construction of new LRT/mass rapid transit (MRT) lines.



<Figure 3-49> Kenya Railways Corporation (KRC) Existing and Planned Lines

- Kenya Railway Corporation (KRC) operates four lines of lines
- Four lines account for 6,185 persons/day in the AM of 2017. Also, Four lines acount for 9,645 persons/day in the PM of 2017.

<Table 3-37> Railway Operation Status

(Unit : persons/day)

AM	2014	2015	2016	2017
RUIRU - NAIROBI	2,671	2,157	2,964	3,341
KAHAWA - NAIROBI	853	294	0	0
EMBAKASI - NAIROBI	2,867	2,348	2,449	2,199
DANDORA - NAIROBI	889	528	0	0
KIKUYU - NAIROBI	1,109	777	532	645
TOTAL MORNING	8,390	6,103	5,946	6,185
PM	**2014**	**2015**	**2016**	**2017**
NAIROBI - RUIRU	2,034	1,709	1,809	1,707
NAIROBI - KAHAWA	1,648	1,440	0	0
NAIROBI - EMBAKASI	1,168	866	1,151	1,070
NAIROBI - KIKUYU	670	510	489	684
TOTAL EVENING	5,519	4,524	3,448	3,461
DAYS TOTAL	13,910	10,627	9,394	9,645

Source : Kenya Railway Corporation, 2017

2) Aviation

- Kenya's aviation industry has recorded a 17.5 percent cargo decline between 2012 to 2016 besides maintaining a positive growth trend posting a 6.2 per cent increase in passenger traffic.

※ Source : Kenyan Aviation Sector Records 17.5pc Decline in Cargo Volume. jan 19,2017

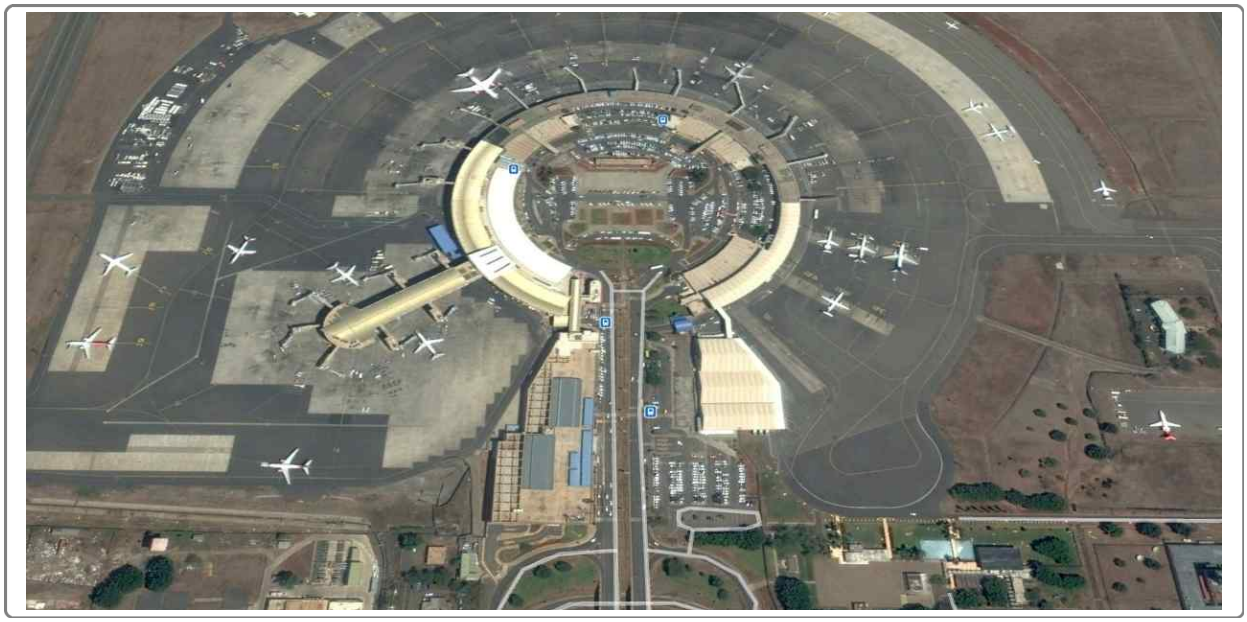
- Nairobi has the domestic Wilson Airport and Jomo Kenyatta International Airport (JKIA)
- Data from Kenya Civil Aviation Authority (KCAA) shows that Jomo Kenyatta International Airport registered 255 tonnes in 2016 compared to 309 tonnes in 2012. The aircraft traffic movement (ATM) at JKIA increased to reach over 322,504 aircraft as of 2016 compared to 306,366 in 2012 resulting into 5.3 percent increase. The safety compliance level has constantly remained at 78.40 percent in the entire period.

※ Source : Kenyan Aviation Sector Records 17.5pc Decline in Cargo Volume. jan 19,2017

- Wilson Airport is located to the South of Nairobi and immediately to the South of Langata Road, some 2km southwest of the junction with Mombasa Road. Wilson Airport is one of the busiest airports in terms of aircraft movement in East and Central Africa. Domestic flights constitute 90% of the total flights from the Airport with international flights accounting for 10%. Destinations served from the Airport include Maasai Mara, Mombasa, Amboseli, Lamu, Kilimanjaro Diani, Lokichogio and Nanyuki. It is also a modern hub of General Aviation in East and Central Africa.

- JKIA is Africa's premier hub and ideal gateway into and out of East and Central Africa. JKIA is the flagship airport of The KAA. The airport boasts of over 40 passenger airlines and 25 cargo airlines. Jomo Kenyatta International Airport, formerly called Embakasi Airport and Nairobi International Airport, is Kenya's largest aviation facility, and the busiest airport in East Africa. It's importance as an aviation center makes it the pace setter for other airports in the region. Jomo Kenyatta International Airport (JKIA) is located in Nairobi in the Mid-Northern Region of Kenya at an altitude of 1,625 meters above mean sea level.

■ Jomo Kenyatta International Airport (JKIA)



<Figure 3-50> Jomo Kenyatta International Airport (JKIA)

a. Landside

- JKIA is the largest airport in East and Central Africa and the 6th busiest airport in Africa, which was handled over 5.5 million passengers and 70,000 aircraft operations in 2010. At present, the length of a existing runway is 4,117m and is 45m wide. Runway orientation is 06 – 24 and the airport is operating CAT-I. Currently the capacity of JKIA is 25 operations per hour for 06 runways.
- The existing passenger terminal facility, its associated vehicle parking areas, accesses, a series of administrative buildings and other related facilities cover a great portion of landside area, with vehicular access to/from the highway connecting to Nairobi City.

b. Access Road Network

- The airport is served by two main access roads. The southern 6 lane dual carriageway connects the main security monitored gate with Mombasa road into the passenger terminal. The second 4-lane dual carriageway road on the northern side joins the cargo terminal from the outer ring road.

c. Curbside

- JKIA terminal frontage roads distribute vehicles directly to terminal buildings; domestic and international. Since considerable merging from through lanes to and from the curb front occurs on these roadways, two lanes are provided adjacent to the curb at the airport. JKIA also has re-circulator road along the terminal to facilitate recirculation of vehicles to the passenger terminal and is linked to the ingress and egress lanes of the access road.

d. Vehicular Parking

• Surface access vehicular parking area has around 1,800 classified space.

<Figure 3-51> Location of Vehicle Parking in JKIA

<Table 3-38> Vehicle Parking Details

Parking name	Category	Capacity	Remark
Passenger Terminal 1A to D	General vehicle	450	Including JKIA staff and registered
	Taxi	12	
	Bus	3	
Passenger Terminal 1E	General vehicle	88	JKIA Staff parking
	Taxi	15	-
	Bus	5	-
Multi-storey Car Park	General vehicle	1100	Original capacity is 1,500. currently, rooftop is used as office space.
Passenger Terminal 2	General vehicle	100	-
	Taxi	6	-
	Bus	2	-
Temporary Parking	General vehicle	110	-
	Taxi	120	-
	Bus	20	-
※ Cargo Terminal	General vehicle	300	

Source : Pre-feasibility Study for New Terminal Development Project at Jomo Kenyatta International Airport in the Republic of Kenya. February 2017, The Ministry of Economy, Trade and Industry

e. Historical Air Traffic

- JKIA currently accounts for 6.8 million annual passengers. As can be seen in below Table, most of the growth since the mid-1990''s has been in domestic and transit traffic.

<Table 3-39> Air Traffic Data of JKIA(1996-2015)

Year	Terminal Passengers			Total	
	Intern.	Domestic	Total	Transit*	Total
1996	2,023,764	331,772	2,355,536	323,154	2,678,690
1997	1,935,134	361,890	2,297,024	253,948	2,550,972
1998	1,689,961	448,917	2,138,878	211,241	2,350,119
1999	1,907,407	546,079	2,453,486	214,731	2,668,217
2000	2,245,474	488,634	2,734,108	211,044	2,945,152
2001	2,274,540	506,942	2,781,482	186,941	2,968,423
2002	2,426,378	500,652	2,927,030	126,895	3,053,925
2003	2,706,067	606,503	3,312,570	138,544	3,451,114
2004	3,287,482	712,229	3,999,711	-	3,999,711
2005	2,706,601	629,326	3,335,927	903,020	4,238,947
2006	2,871,174	635,230	3,506,404	942,628	4,449,032
2007	3,060,469	850,085	3,910,554	951,152	4,861,706
2008	2,754,834	893,725	3,648,559	977,481	4,626,040
2009	2,727,911	940,380	3,668,291	1,004,404	4,672,695
2010	3,421,004	963,598	4,384,602	1,101,169	5,485,771
2011	3,526,958	1,054,185	4,581,143	1,091,395	5,672,538
2012	3,657,767	1,123,185	4,780,952	1,117,475	5,898,428
2013	3,828,724	1,213,363	5,042,087	1,151,560	6,193,464
2014	3,997,937	1,302,620	5,300,557	1,185,297	6,485,854
2015	4,186,775	1,402,230	5,589,005	1,222,947	6,811,952

Source : Pre-feasibility Study for New Terminal Development Project at Jomo Kenyatta International Airport in the Republic of Kenya. February 2017, The Ministry of Economy, Trade and Industry

4. Travel Demand Forecasting

4.1. Traffic Analysis Zone

4.1.1. Zoning System

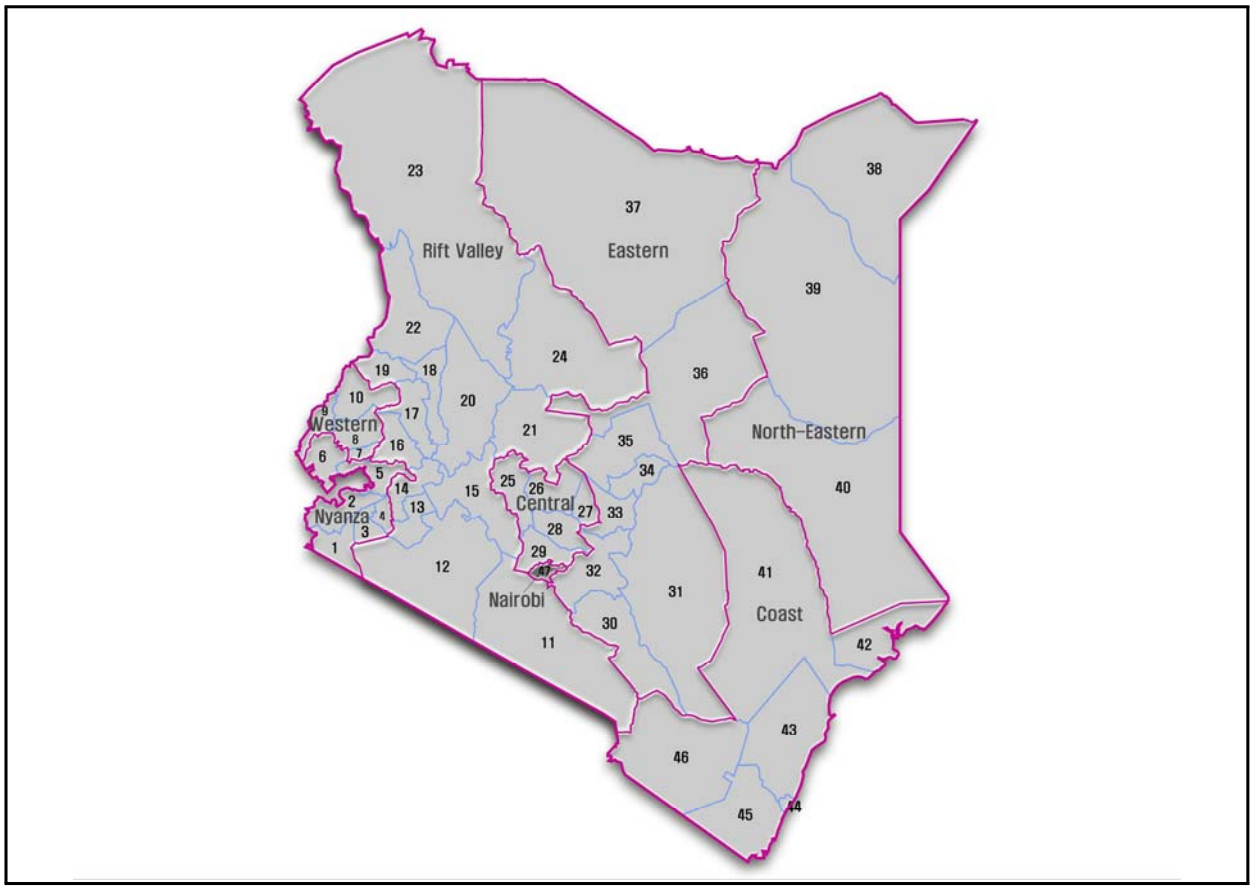
- Kenya's administrative districts are comprised of eight provinces (Nyanza, Western, Rift Valley, Central, Eastern, North Eastern, Coast and Nairobi), which are divided into 47 district.
- This project is to establish BRT in Outer Ring road which is the main road in Nairobi. In order to distribute rational traffic to Nairobi, the administrative district is divided into subdivisions to form a zone system.
- Nairobi has been subdivided into 95 zones based on the Nairobi parliamentary election district for subdivision of the zone.
- The zone system of this study consists of 95 zones in Nairobi and 46 zones in the outskirts. The zone contents are as shown in the table below.

<Table 4-1> Zoning System

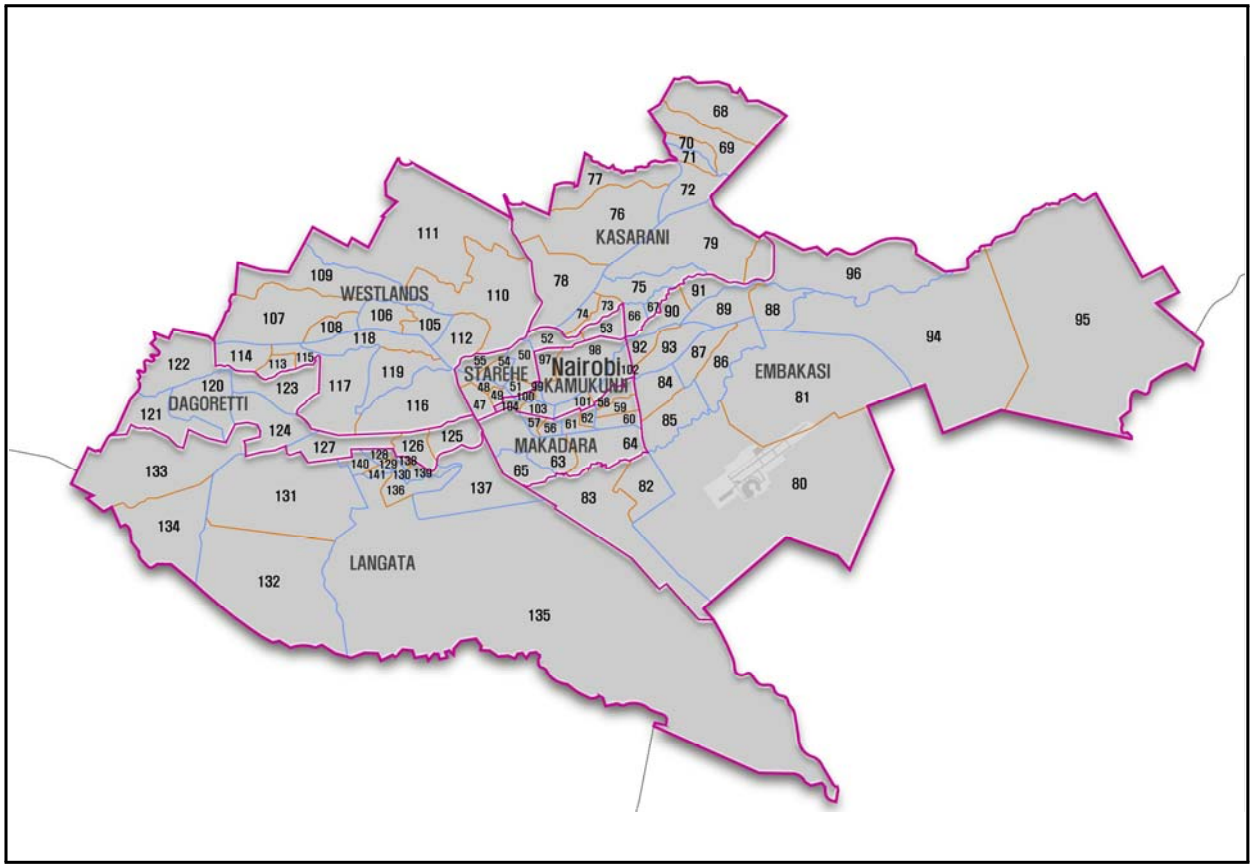
Provinces	Location	Zone Code	Provinces	Location	Zone Code
Nyanza	Migori	1	Rift Valley	Samburu	24
	Homabay	2	Central	Nyandarua	25
	Kisii	3		Nyeri	26
	Nyamira	4		Kirinyaga	27
	Kisumu	5		Muranga	28
	Siaya	6		Kiambu	29
Western	Vihiga	7	Eastern	Makueni	30
	Kakamega	8		Kitui	31
	Busia	9		Machakos	32
	Bungoma	10		Embu	33
Rift Valley	Kajiado	11		Tharaka	34
	Narok	12		Meru	35
	Bomet	13		Isiolo	36
	Kericho	14		Marsabit	37
	Nakuru	15	North-Eastern	Mandera	38
	Mandi	16		Wajir	39
	Uasin Gishu	17		Garissa	40
	Elgeyo-Marakwet	18	Coast	Tana River	41
	Trans Nzoia	19		Lamu	42
	Baringo	20		Kilifi	43
	Laikipia	21		Mombasa	44
	West Pokot	22		Kwale	45
	Turkana	23		Taita Taveta	46

Region	Location		Sub-location	Zone Code
Nairobi	Starehe	Starehe	City Centre	47
			City Square	48
			River Road	49
		Kariokor	Pangani	50
			Ziwani / Kariokor	51
		Mathare	Mathare	52
			Huruma	53
		Ngara	Ngara East	54
			Ngara West	55
	Makadara	Makongeni	Makongeni	56
			Kaloneni	57
		Makadara	Harambee	58
			Lumumba	59
			Hamza	60
		Maringo	Mbotela	61
			Ofafa	62
		Viwandani	Landi Mawe	63
			Lunga Lunga	64
		Nairobi South	Nairobi South	65
	Kasarani	Kariobangi	Kariobangi North	66
		Korogocho	Korogocho	67
		Kahawa	Kiwanja	68
			Juakali	69
			Kongo Soweto	70
		Githurai	Kamuthi	71
			Githrai	72
		Ruaraka	Mathare 4A	73
			Utalii	74
			Baba Dogo	75
		Roysambu	Roysambu	76
			Njathaini	77
			Garden Estate	78
		Kasarani	Kasarani	79
	Embakasi	Embakasi	Embakasi	80
			Mihang'o	81
		Mukuru	kwanjenga	82
			Imara Daima	83
		Umoja	Umoja	84
			Savannah	85
		kayole	Kayole	86
			Komarock	87
		Njiru	Niuru	88
			Maili Saba (Saika)	89
		Dandora	Dandora 'A'	90
			Dandora 'B'	91
		Kariobangi South	Kariobangi South	92
			Moulem	93
		Ruai	Ruai	94

Region	Location		Sub-location	Zone Code
Nairobi	Embakasi	Ruai	Ngundu	95
			Nwiki	96
	Kamukunji	Eastleigh North	Eastleigh North	97
		Eastleigh South	Eastleigh South	98
		Punwani	Majengo	99
			/ Gorofani / Bondeni	100
		Bahati	Kimathi	101
			Uhuru	102
		Kamukunji	Shauri Moyo	103
			Muthurwa	104
	Westlands	Parklands	Upper parklands	105
			Spring Valley	106
		Kitisuru	Loresho	107
			Kyuna	108
			Kitsyru	109
		Highridge	Muthaniga	110
			Karura	111
			Highidge	112
		Kangemi	Gichagi	113
			Mountain View	114
			Kangemi	115
		Kilimani	Kilimani	116
			Masiwa	117
		Lavington	Muthangari	118
			Kileleshwa	119
	Dagoretti	Waithaka	Waithaka	120
		Mutuini	Mutuini	121
		Uthiru / Ruthmitu	Ruthimitu / Uthiru	122
		Kawanggware	Kawangware	123
		Riruta	Riruta	124
		Kenyatta / Golf Course	Kenyatta	125
			Golf Course	126
			Woodley	127
	Langata	Kibera	Makina	128
			Kibera	129
			Lindi	130
		Langata / Karen	Langata	131
			Hardy	132
			Karen	133
			Lenana	134
		Mugumoini	Mugumoini	135
			Bomas	136
		Nairobi West	South 'C'	137
		Laini Sahbaa	Laini Sahbaa	138
			Nyayo Highrise	139
		Sarangombe	Gatikira	140
			Olympic	141



<Figure 4-1> Zone map outside the city of Nairobi



<Figure 4-2> Zone map inside the city of Nairobi

4.2. Network

4.2.1. Road Network

4.2.1.1 Building Network's Baseline

- An analysis network was constructed using Google map for Kenya's entire road network.
- In order to construct a detailed analysis network, the road network was constructed in detail to the main arterial roads of Nairobi and the roads below the main roads, and the outskirts of Nairobi was built around the main road network.
- The network properties such as turn-penalty, number of lanes, distance, VDF, centroid and the connector of the categorized zones which are important elements that could have an effect on the route choice was modified and complemented via field surveys.

<Table 4-2> Network Building Process

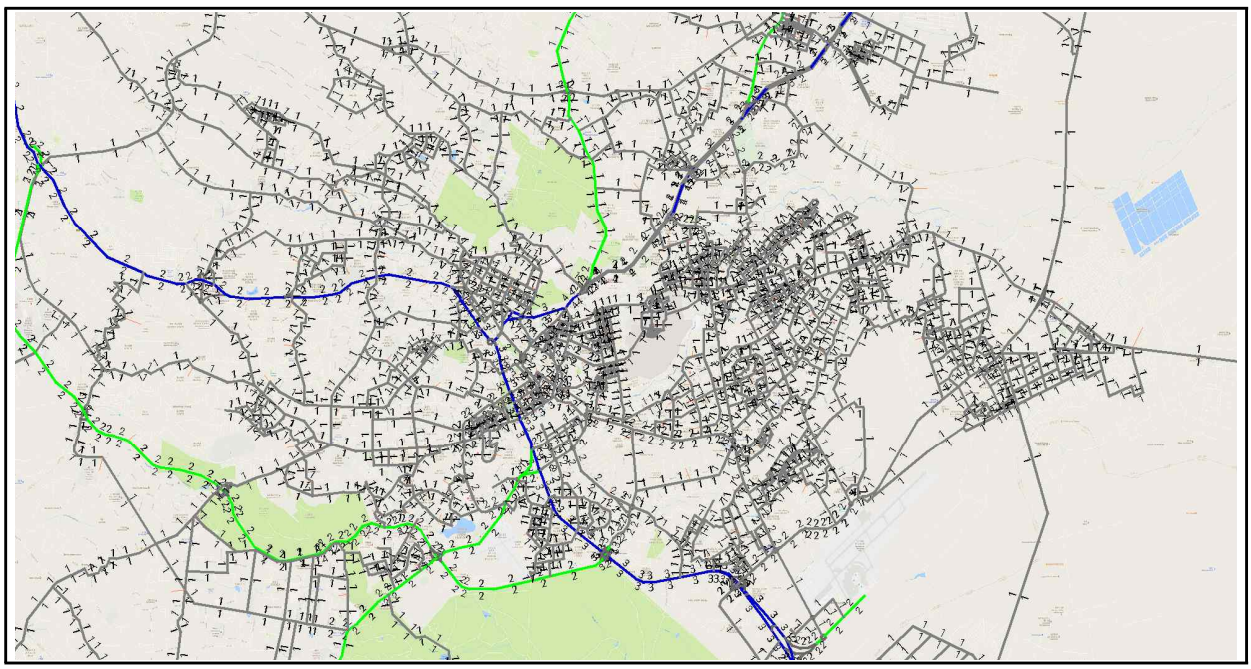
Steps & Items			Contents
Step 1	Highway Network Establishment		• Utilizing Google Map for Nairobi
Step 2	Turn Penalty		• Applying Turn-Penalty on the established network
Step 3	Link Property	NO of Lanes	• Applying the field survey data
		Distance	• Applying the link length obtained from digital map or Google Map
Step 4	Volume-Delay Function (VDF)		• Applying NIUPLAN VDF function by reviewing and checking its accordance with reality within travel speed and highway capacity
Step 5	Positioning Centroid and Connector		• Positioning each zonal centroid • Positioning the access point of the centroid connector

1) Turn Penalty

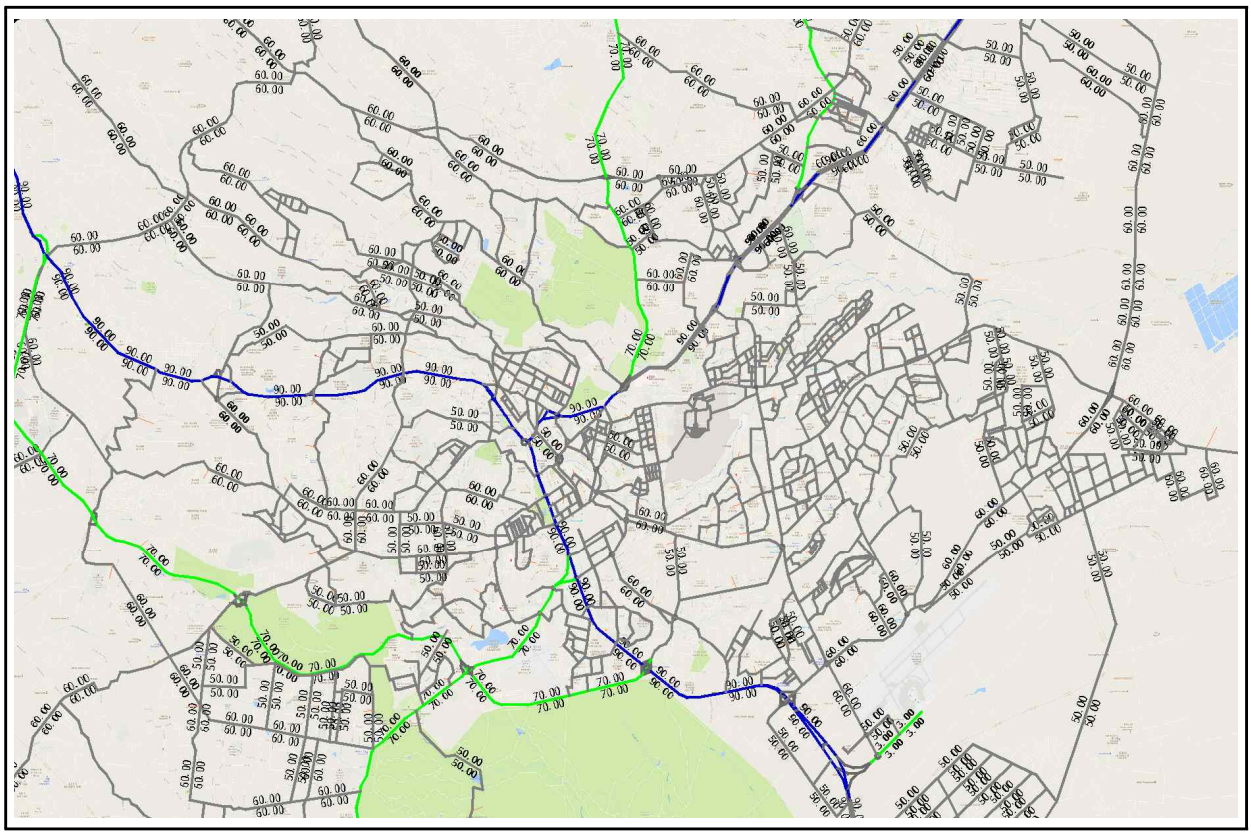
- Since the turn penalty is an important element which has an effect on the route choice during traffic assignment, the highway network was complemented by reviewing the turn penalties which are operated through the literature review and the field surveys.

2) Link Properties

- Since the number of lanes, distance, lane capacity and link speed are important elements which have an effect on the route choice during trip distribution, these were modified and complemented via field surveys.



<Figure 4-3> Number of Lanes



<Figure 4-4> Travel Speed

3) Volume-Delay Function (VDF)

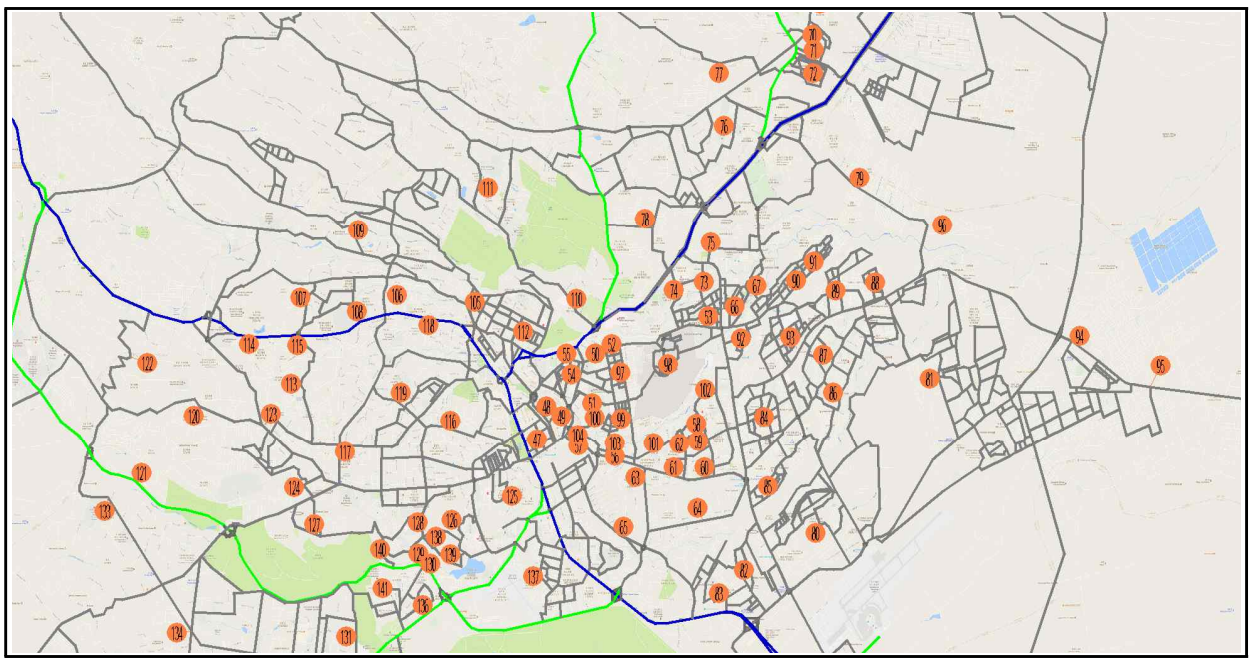
- BPR function, which was developed by the Bureau of Public Roads, was applied to VDF, and the roads were classified into seven categories. Different VDFs were applied to each link type as shown in Table 4-3.

<Table 4-3> Volume-Delay Function (VDF)

Class	Road Type	Lane Division	α	β	Free Flow Speed (kph)	Capacity (pcphpl)
1	Expressway	-	0.150	4.000	90	1,900
2	National Road	1 lane	0.150	4.000	70	1,200
3		more than 2 lanes	0.150	4.000	70	1,200
5	Arterial Highway	-	0.150	4.000	60	800
6	Etc.	-	0.150	4.000	50	700
7	Lamp Connector	-	0.150	4.000	40	1,000
4	centroid	-	0.150	4.000	20	9,999

4) Zone Centroid and Connector

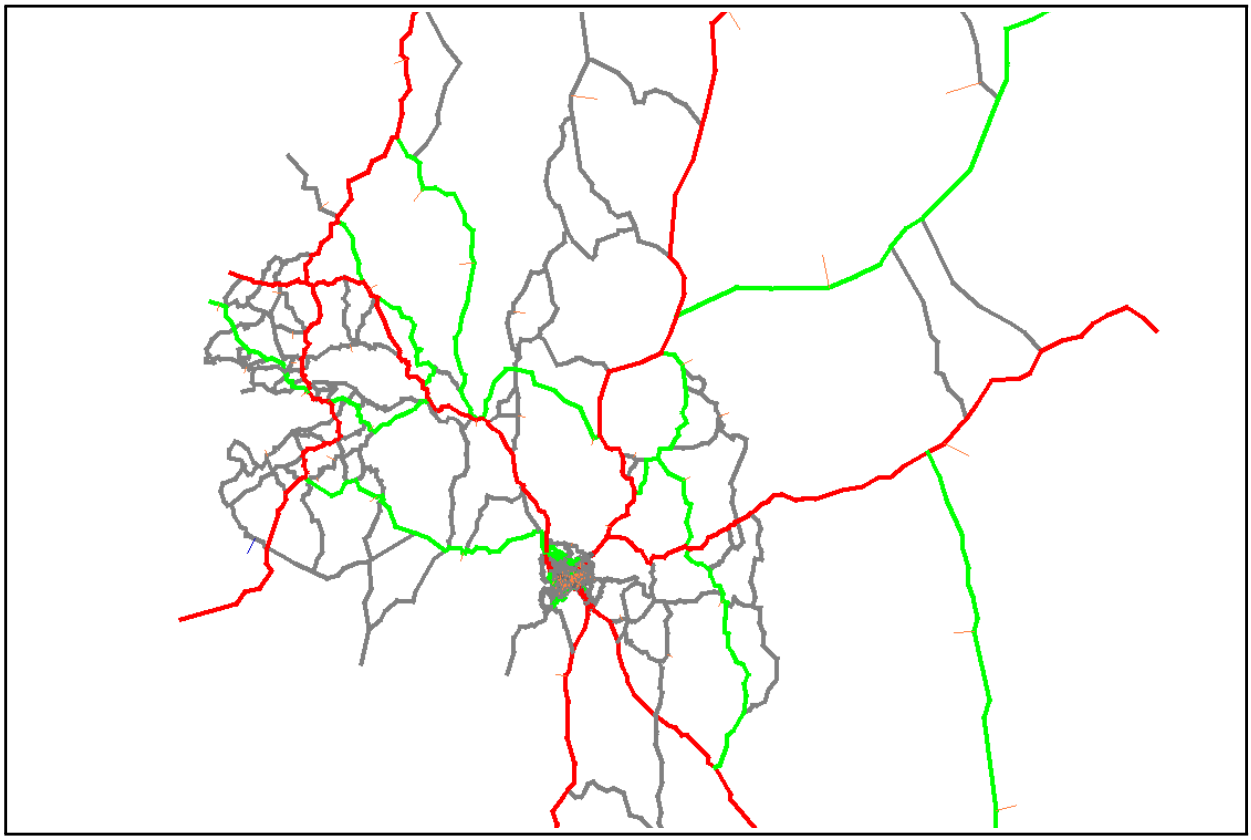
- With the traffic analysis model, the demand analysis was carried out based on an assumption that all trips were generated from the zone centroid. At this time, all input/output from the zone were connected with other links through the zone centroid.
- If the centroid connector which connects to the zone centroid and the link, are not enough or the connector is inappropriate, it would create an excessive traffic jam in that specific link. In the current project, the location of the centroid was set in the geographical center or the population density center.



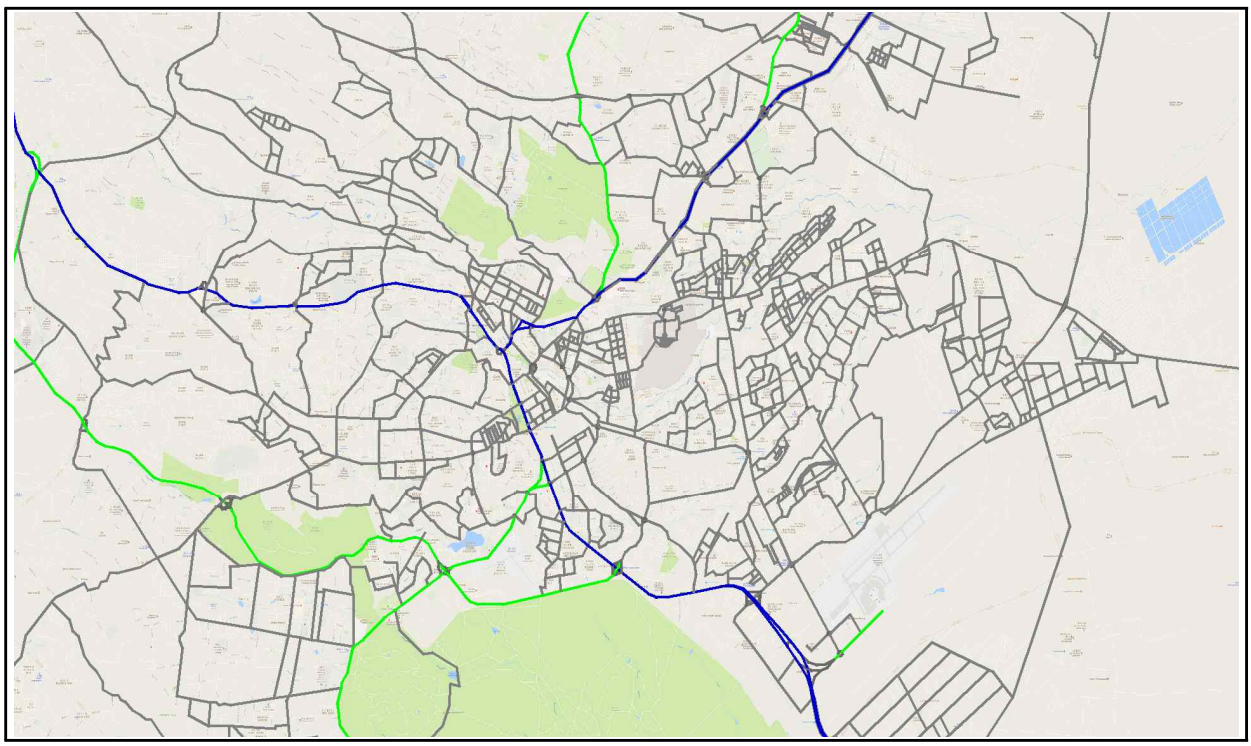
<Figure 4-5> Nairobi Zone Centroid

5) Establishment of the Road Network

- The analysis network constructed through the above procedure is shown in the following figure.



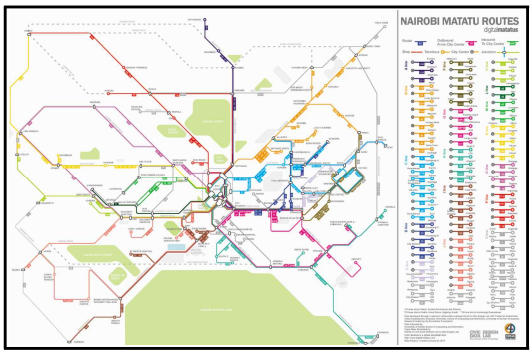
<Figure 4-6> Road network of Kenya



<Figure 4-7> Road network of Nairobi

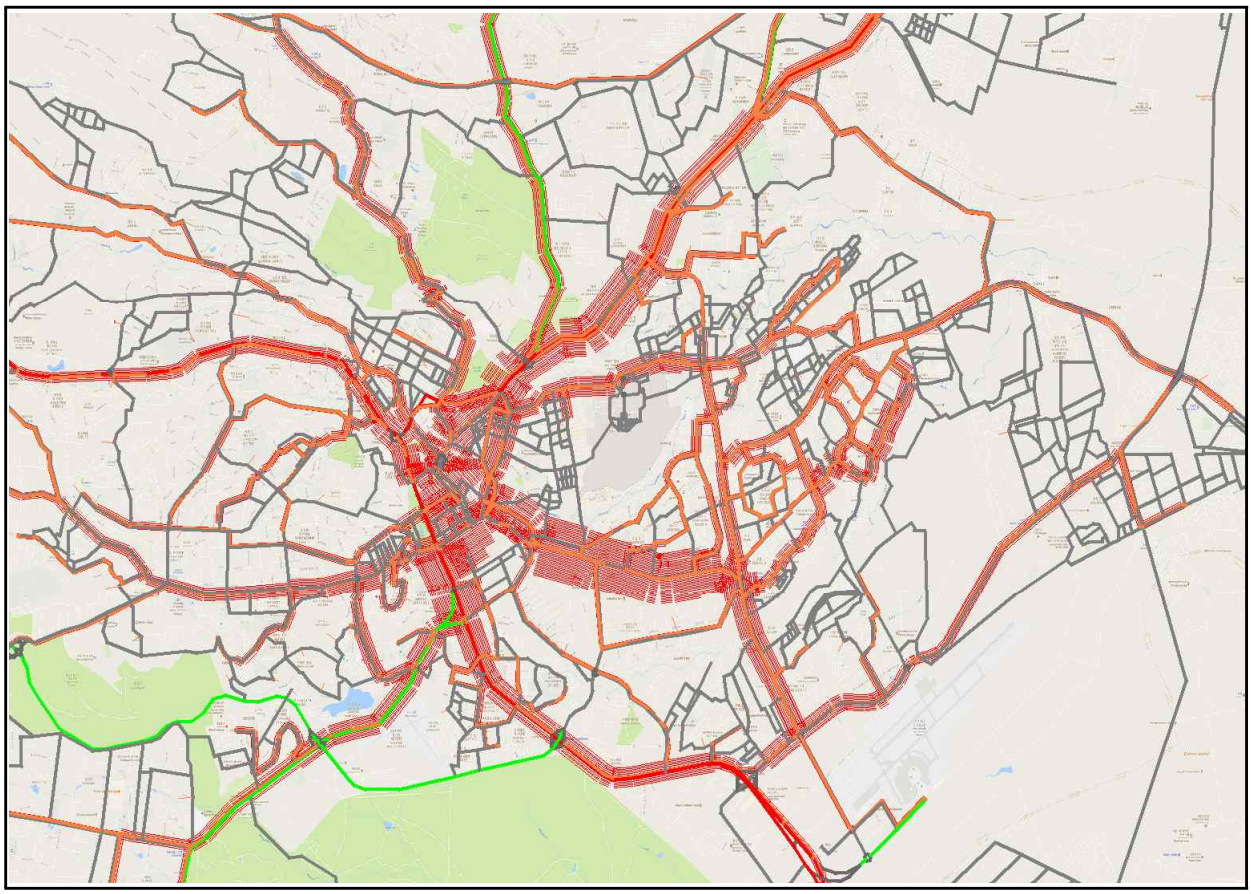
4.2.2. Transit Network

- Nairobi's public transport information is provided by Digital Matatus with information on 134 routes and 2,481 stops.
- Digital Matatus is constantly supplementing and updating its network to reflect realistic traffic system.
- Digital Matatus expresses the Matatu route of Nairobi as shown on the right, and provides GIS data.



<Figure 4-8> Map of Nairobi's matatu services(Source: Digital Matatus)

- Traffic analysis network is basic data for effective establishment, implementation and evaluation of various traffic plans together with traffic volume.
- As the utilization and importance of network for analysis are increasing, reliable and high - quality data is needed because it is required to construct more accurate and highly utilized data.
- In this work, reliability was improved based on the data of Digital Matatus, which provides public transportation information, in order to construct public transportation network for analysis.

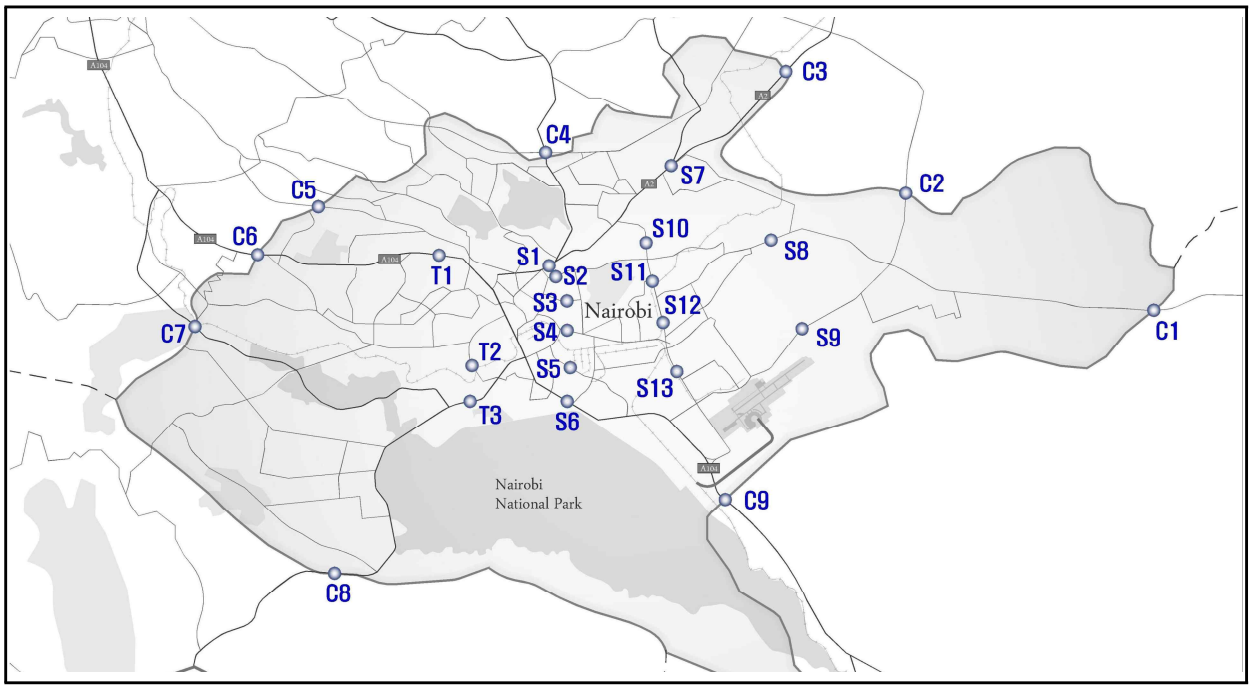


<Figure 4-9> Transit network of Nairobi

4.3. O/D Building

4.3.1. Cordon and Screen Line

- The estimated O/D should be verified by comparing with field surveyed data. A few screen lines were selected which could be checked with the surveyed traffic volume. The criteria for selection of guidelines are as follows:
  - ✓ The lines having geometrical and physical obstacles which could divide the travel pattern between the areas
  - ✓ The lines which cross over a few roads as possible
  - ✓ The lines which have many intra zonal trips
- In this study, three lines of screen lines were set around the Nairobi border and the codon line and Nairobi main road. In addition, the outer ring road corresponding to this task line additionally set four major points.



<Figure 4-10> Cordon and Screen Lines for verify the estimated O/D

- The simple error rate method is used for O/D verification and the method is as follows.

Method	Calculating Process
Simple Error Rate	Simple Error Rate (%) $= 100 \times \frac{\int_l^{est} - \int_l^{obs}}{\int_l^{obs}}$ Where, $\int_l^{est}$ = Estimated traffic of link, $\int_l^{obs}$ = Observed traffic of link

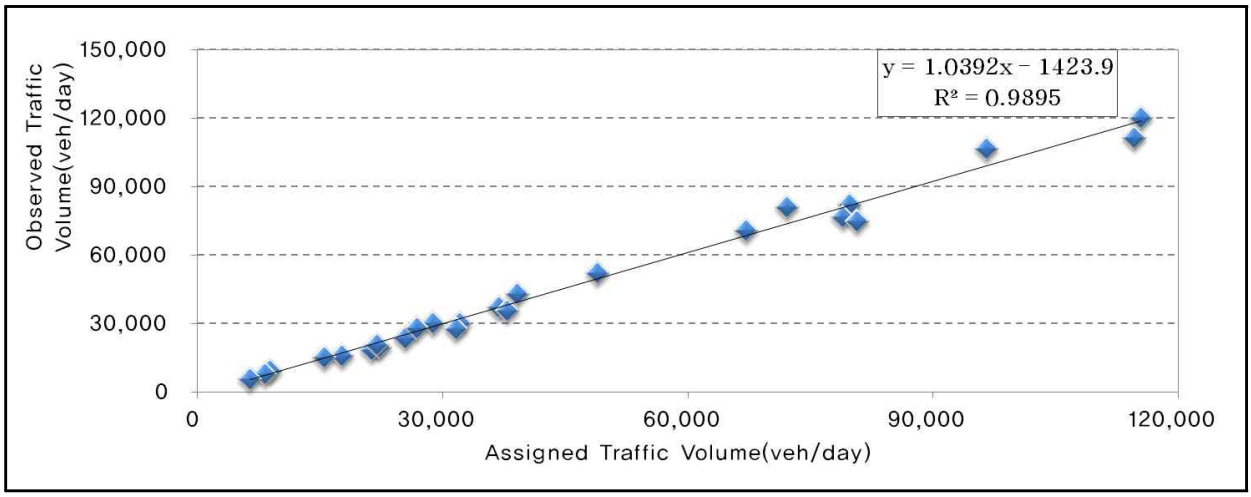
4.3.2. Adjusting Estimated O/D

1) Process

- Step 1: calculate the adjusting factor which is the observed volume divided by the estimated volume
- Step 2: re-estimate O/D by multiplying the adjusting factor to the 1st estimated O/D
- Step 3: check the %RMSE and repeat step 1 if it is not within the permitted range
- Step 4: select the proper adjusting factors within the permitted range (under Error ratio 20%)

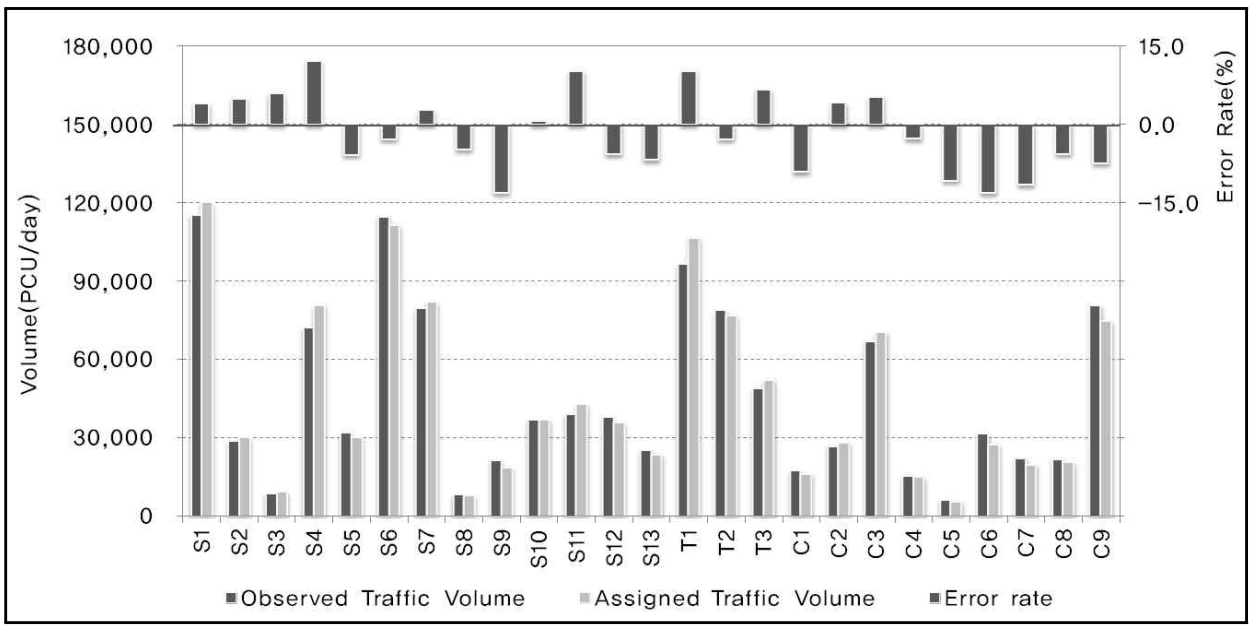
2) Result after applying the adjusting factors

- The surveyed volumes and the estimated volumes were plotted on a 2-dimensional graph and calculated the coefficient of correlation by regression analysis. It was thought that he result is sufficiently good since the coefficient of correlation is over 90%.



<Figure 4-11> Coefficient of correlation between observed and estimate traffic volume

- It was thought that the estimated O/D is reliable because the Simple Error Rate is between −11.65% and 12.32%

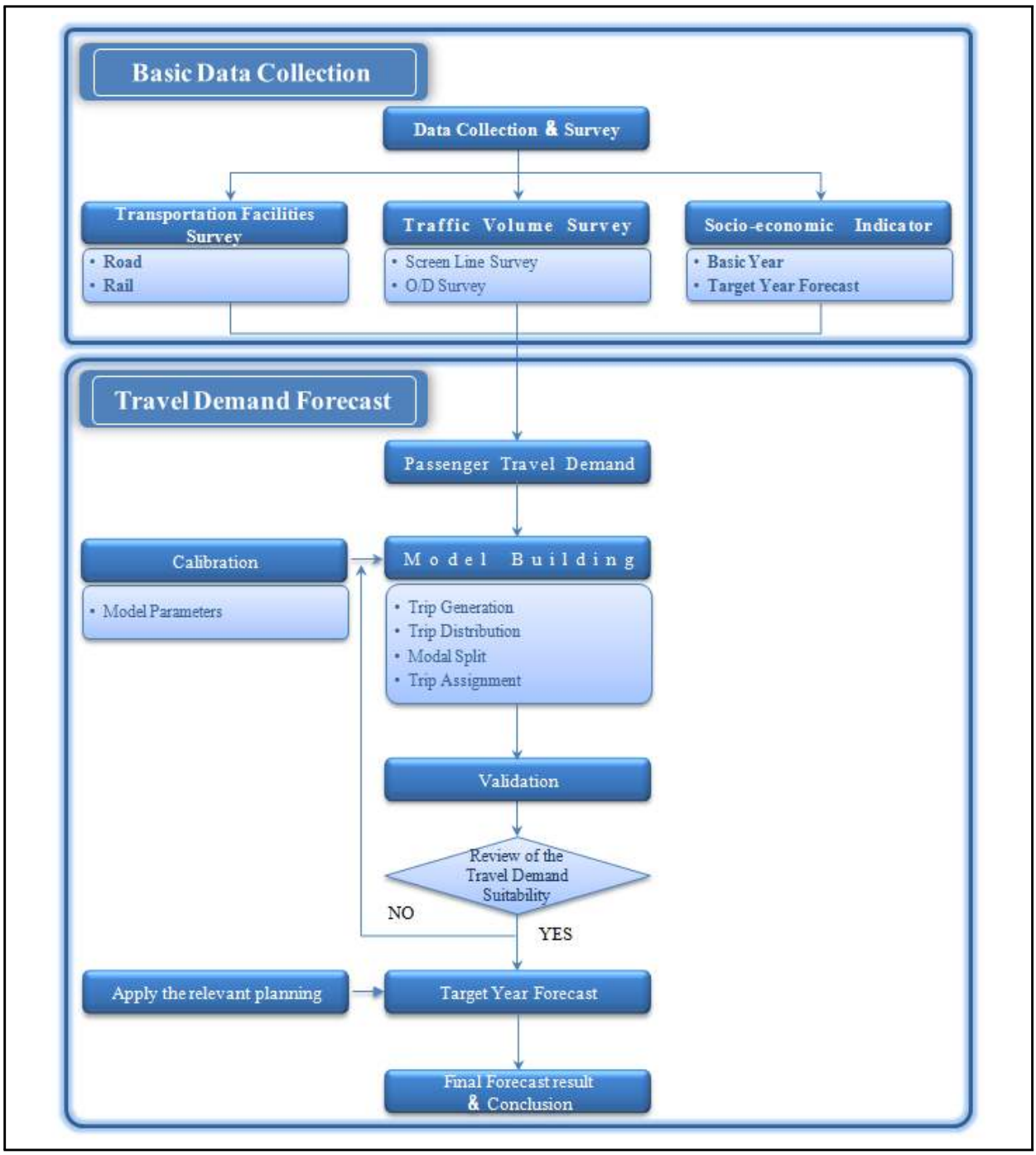


<Figure 4-12> Error Rate and Traffic volume

4.4. Travel Demand Forecasting

4.4.1. Methodology

- The four step model which is commonly used, has been applied to the travel demand forecast of the current project. This model's steps are trip generation, trip distribution, modal split and trip assignment.
- The first step is to review and apply the data of the "Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya (NIUPLAN)".



<Figure 4-13> Travel Demand Forecast Process

4.4.2. Trip Generation

1) Trip Generation Model

- The trip generation model utilized a regression analysis, (which is generally applied when forecasting the traffic volume) since the functional expression of the causal relationship between independent and dependent variables is mathematically easy to interpret.
- In order to estimate the trip generation, the amount of traffic was calculated by using the person trip shown in "The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Repulic of Kenya (NIUPLAN)".
- The population of Nairobi is 1.88 trips / pop with 6.8 million passengers in 2013 and 1.92 trips / pop with 10 million passengers in 2030.
- The increase in traffic was projected to be greater than the increase in population.
- The proposed Nairobi person trips include walking trips, and the other cities shown in the table below have an average of 1.87 traffic per trip excluding walking trips.

<Table 4-4> Review of Person trips

Unit	2004	2013	2018	2023	2030
Population (persons)	2,656,997	3,601,351	4,174,952	4,677,671	5,212,500
Total trip generation (person trips)	4,815,457	6,769,861	7,832,087	8,858,349	10,017,678
Trip/pop.	1.81	1.88	1.88	1.89	1.92

Source: The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Repulic of Kenya, 2014, JICA

<Table 4-5> Person Trip Unit by country (All Motorized & MMT Modes)

Country		GDP per capita (USD,1996)	Person trip
Colombia	Bogota	2,609.0	1.56
Mexico	Mexico City	4,088.5	2.07
Chile	Santiago	5,167.6	1.50
Brazil	Sao Paulo	5,107.8	1.50
Egypt	Cairo	1,088.6	1.41
Morocco	Casa Blanca	1,505.0	1.43
Tunisia	Tunis	2,155.0	2.00
Senegal	Dakar	566.6	1.58
China	Beijing	703.1	2.44
China	Guangzhou	703.1	2.30
Thailand	Bangkok	3,054.8	2.61
India	Delhi	1,410.8	2.72
India	Mumbai	1,410.8	1.24
Average		2,274.7	1.87

Source: Millenium Database(UITP, 1996)

- Each Region's trip generation is calculated by multiplying the ith population by person trip rate.

$$Y_i = P_i \times \theta$$

Where, Y_i : i^{th} trip generation

P_i : i^{th} population

θ : person trip ($\frac{Y_n}{P_n}$), Y_n : Total trip generation, P_n : Total population

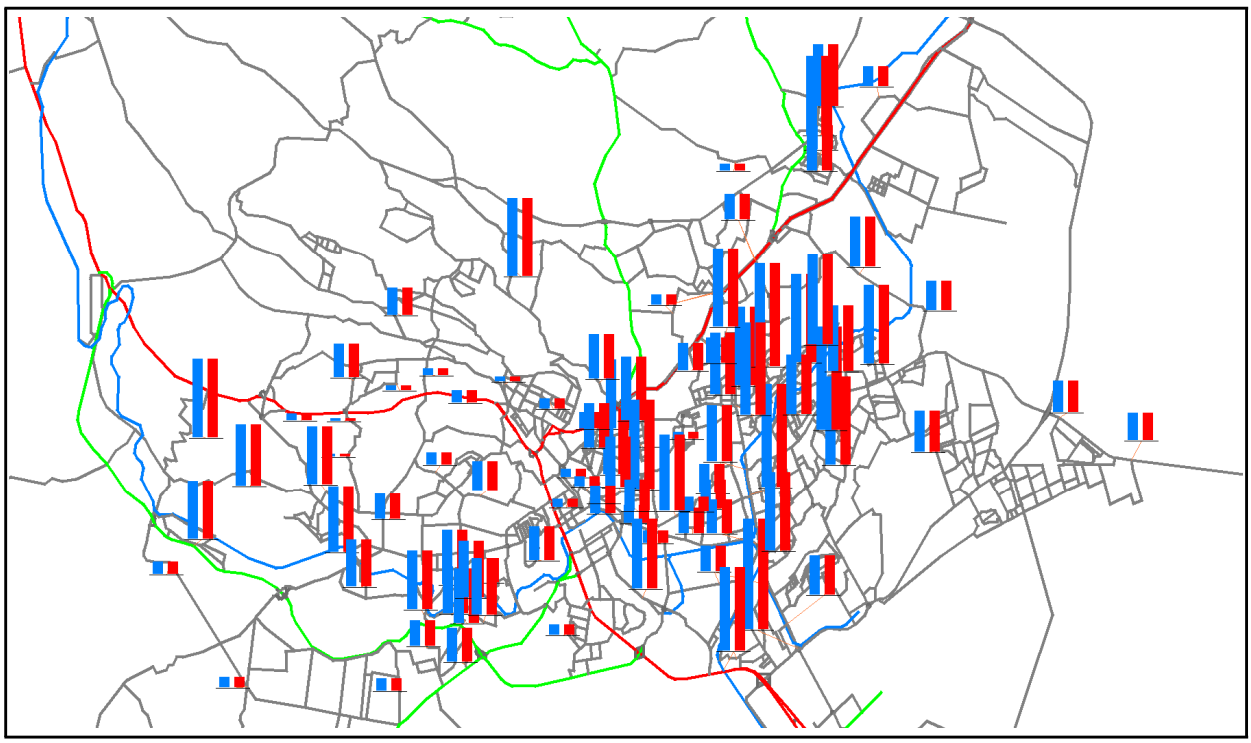
2) Trip Volume Forecast

- The target year of the task is set as the base year of 2017, and the middle target year is set as 2020, 2030, and the final target year is 2040.
- The trip volume forecast of this task predicts the trip volume of 2040, which is the final target year, based on the population and traffic trend of existing data presented until 2030.
- Nairobi city estimated by region is allocated according to the population and area of each administrative district, and the allocated traffic is shown in the following figure.

<Table 4-6> Person trips in Nairobi

Unit	2017	2020	2030	2040
Population (persons)	4,053,352	4,369,208	5,212,500	5,761,491
Total trip generation (person trips)	7,608,284	8,227,495	10,017,678	12,330,328
Trip/pop.	1.88	1.88	1.92	2.14

Source: The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Repulic of Kenya, 2014, JICA



<Figure 4-14> Trip generation by Zone(2040)

4.4.3. Trip Distribution

1) Trip Distribution Model

- There are a few methods to deduce the estimated O/D such as the Growth Factor Model and Gravity Model. The Gravity Model were selected, which is most widely used.
- There are four types of Gravity Models. These are the Total Flow Constrained Gravity Model, Production Constrained Gravity Model, Attraction Constrained Gravity Model, doubly Constrained Gravity Model by number of constraints. A Doubly Constrained Gravity Model was applied, which could be calculated using both total production and attraction constraints.
- The doubly constrained gravity model which fits the constraint condition formula is;

$$Xij = K * Oi^{a} * Dj^{\beta} / Lij^{\gamma}$$

$$Xij = Ri * Oi$$

$$Ri = Xii / Oi$$

Where, Xij: Interzonal trip distribution zone i to j

Xii: Intrazonal trip distribution in zone i

Oi: Trip generation in zone i

Dj: Trip attraction in zone j

Lij: Travel length from zone i to j (km)

Ri: Intra trip rate

K, a, β, γ: Model parameters

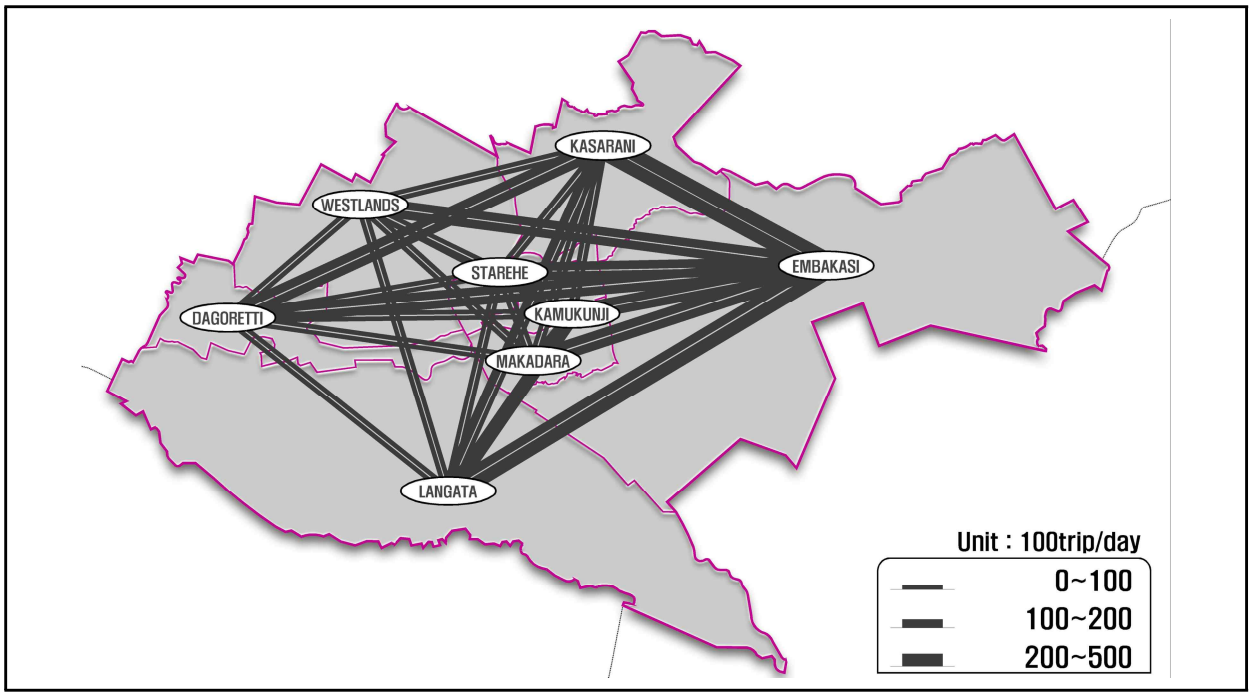
- The parameter values of the trip distribution are compared with the estimated values of each zone in NIUPLAN and the parameter values of the model are applied
- The total trip generation and attraction volume for each zone is converged according to trip generation and attraction volume of the zone.
- The parameter values of trip distribution are as follows.

<Table 4-7> Trip Distribution Model Parameters

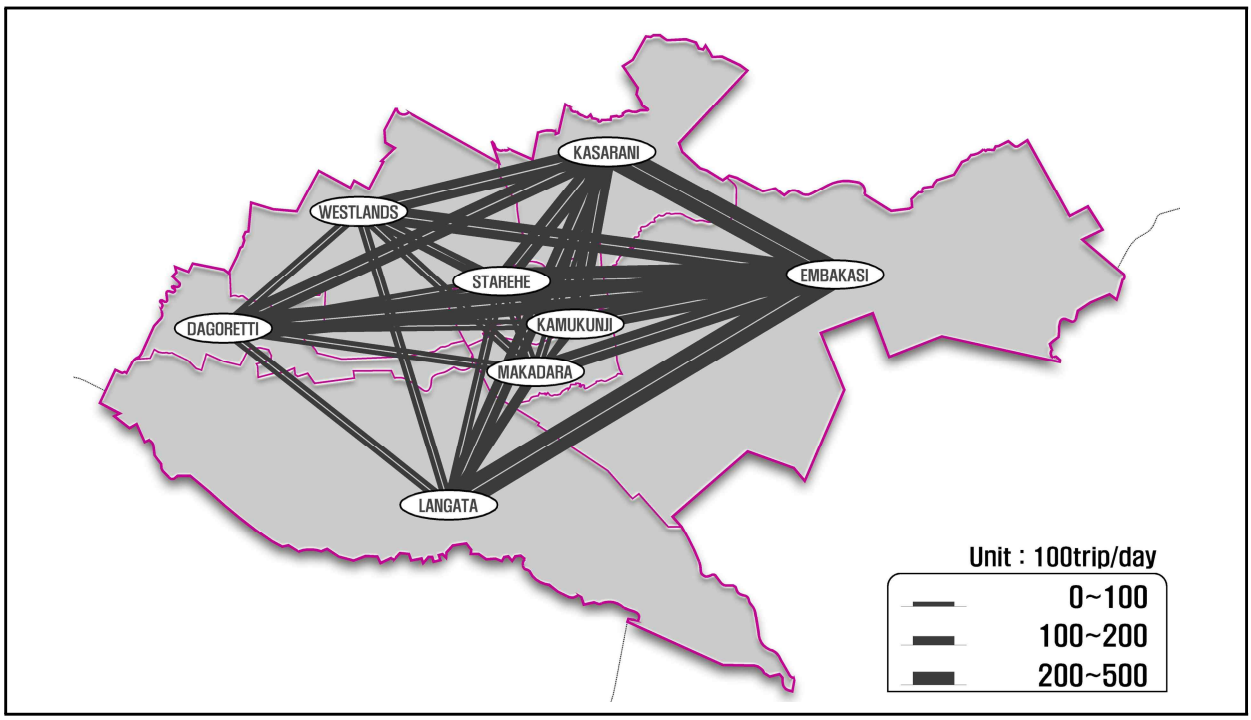
Trip Purpose	α	β	γ	Log(K)	R-squared
Home	0.91945	0.5702	-0.75966	-1.82231	0.74090
Work	0.53011	0.67989	-0.68057	-2.31429	0.78405
School	0.11171	0.42457	-0.43606	0.73126	0.68236
Others	0.30109	0.55044	-0.59065	-0.22105	0.77531

2) Trip Distribution Forecast

- The distribution of Nairobi traffic based on the results of the 2017 and 2030 traffic distribution is shown in the following figure. This figure shows the traffic volume connected to each zone.
- The traffic volume in the east-west direction is expected to increase more than the traffic volume in the north-south direction, and traffic to the city center is expected to increase further.



<Figure 4-15> Trip Distribution of Total trips(2017)



<Figure 4-16> Trip Distribution of Total trips(2030)

4.4.4. Modal Split

1) Modal Split Model

- The Multinomial Logit Model was selected to estimate the modal spilt because it makes it possible to apply the Utility function.

$$P(K) = \frac{e^{U_K}}{\sum_{i}^{n} e^{U_i}}$$

Where, $P(K)$: Choice probability of K

U_K : Utility of modal K

U_i : Utility of modal i

n : the number of modals

- The modal split model composed of the multinomial logit model of 4 modals (car, bus, matatu, train), and the utility function was used in this project. This is as follows;

$$U_{ijm} = \beta_0 + \beta_1 TIME_{ijm} + \beta_2 COST_{ijm} + \epsilon_i$$

Where, $TIME_{ijm}$: Travel time of modal m between zone i zone j

$COST_{ijm}$: Travel cost of modal m between zone i zone j

$\beta_0, \beta_1, \beta_2$: Parameters

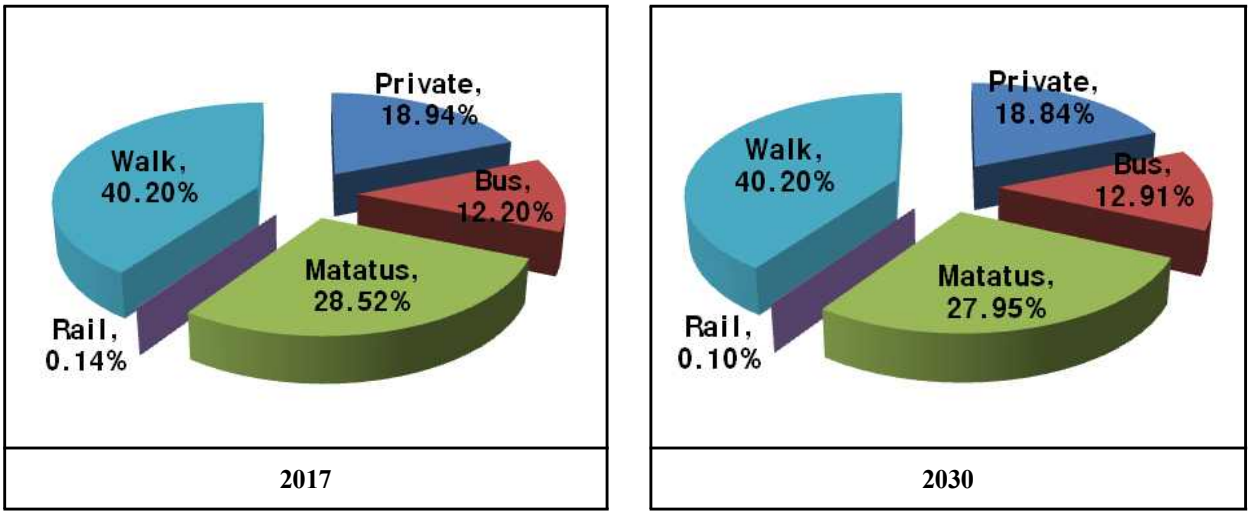
ϵ_i : Unobserved utility of modal m

2) Modal Split Forecast

- The future modal split of nairobi was forecasted by using the Multinomial Logit Model.
- In 2035, the mode share is forecasted to be as follows; private 19.70%, bus 12.50%, matatus 28.60%, rail 0.13%, walk 39.70%.
- Imatatus is a mass transit system that transports passengers in Nairobi, and due to irregular dispatch intervals and route selection, the quality of service is lower, but traffic is expected to continue to increase.
- Nairobi has seen a lot of economic development, but the increase in infrastructure and commuting costs make up more than 40% of the total traffic.

<Table 4-8> Future Modal Split Rate

Classification		Private	Bus	Matatus	Rail	Walk	Total
Trip (Trip/day)	2017	1,440,756	928,150	2,170,233	10,616	3,058,528	7,608,284
	2020	1,549,584	1,060,204	2,301,372	8,882	3,307,453	8,227,495
	2030	1,886,948	1,293,461	2,800,047	10,115	4,027,106	10,017,677
	2040	2,324,312	1,589,152	3,448,804	11,272	4,956,789	12,330,329
Split Rate (%)	2017	18.94%	12.20%	28.52%	0.14%	40.20%	100.00%
	2020	18.83%	12.89%	27.97%	0.11%	40.20%	100.00%
	2030	18.84%	12.91%	27.95%	0.10%	40.20%	100.00%
	2040	18.85%	12.89%	27.97%	0.09%	40.20%	100.00%



<Figure 4-17> Modal Split rate

4.4.5. Trip Assignment

1) Trip Assignment Model

▪ Model Estimation

- The user equilibrium, (which is the Wardrop's first principle of route choice that users seek to minimize their travel time, regardless of other users' selection of the trip route) was utilized in the current project.
- The user equilibrium assignment is as follows:

$$\min \sum_a \int_o^{V_a} C_a(V_a)dx$$

$$V_a = \sum_i \sum_j \sum_r P_{ijr} S^a_{ijr} T$$

Where, $C_a(V_a)$: Function of traffic costs for link "a"

P_{ijr} : Trip using route "r" when traveling from origin "i" to destination "j"

S^a_{ijr} : 1 if it is route "r" connecting origin "i" and destination "j", all others "0"

T : Total number of trips

▪ Traffic Cost Function (BPR)

- The BPR function developed by the Bureau of Public Roads was used in the traffic cost function, and the road division grouped into 6 types and applied.

$$\text{BPR} = t_0(1+\alpha(\frac{V}{C})^\beta)$$

Where, t_0 : Free flow travel time of link

V : Traffic volume of link

C : Capacity of link

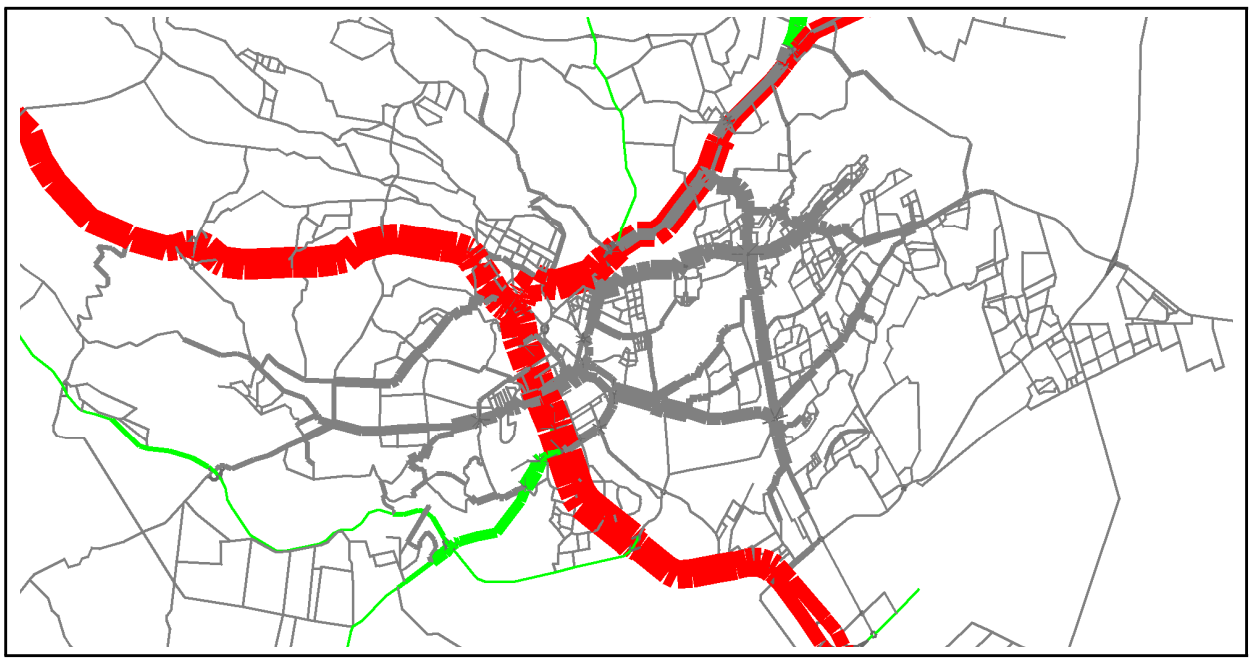
α, β : Parameter

<Table 4-9> Traffic Cost Function (BPR)

Class	Road Type	Lane Division	α	β	Free Speed (kph)	Capacity (pcphpl)
1	Express way	-	0.150	4.000	90	1,900
2	National Road	1 lane	0.150	4.000	70	1,200
3		more than 2 lanes	0.150	4.000	70	1,200
5	Arterial Highway	-	0.150	4.000	60	800
6	Etc.	-	0.150	4.000	50	700
7	Lamp Connector	-	0.150	4.000	40	1,000
4	centroid	-	0.150	4.000	20	9,999

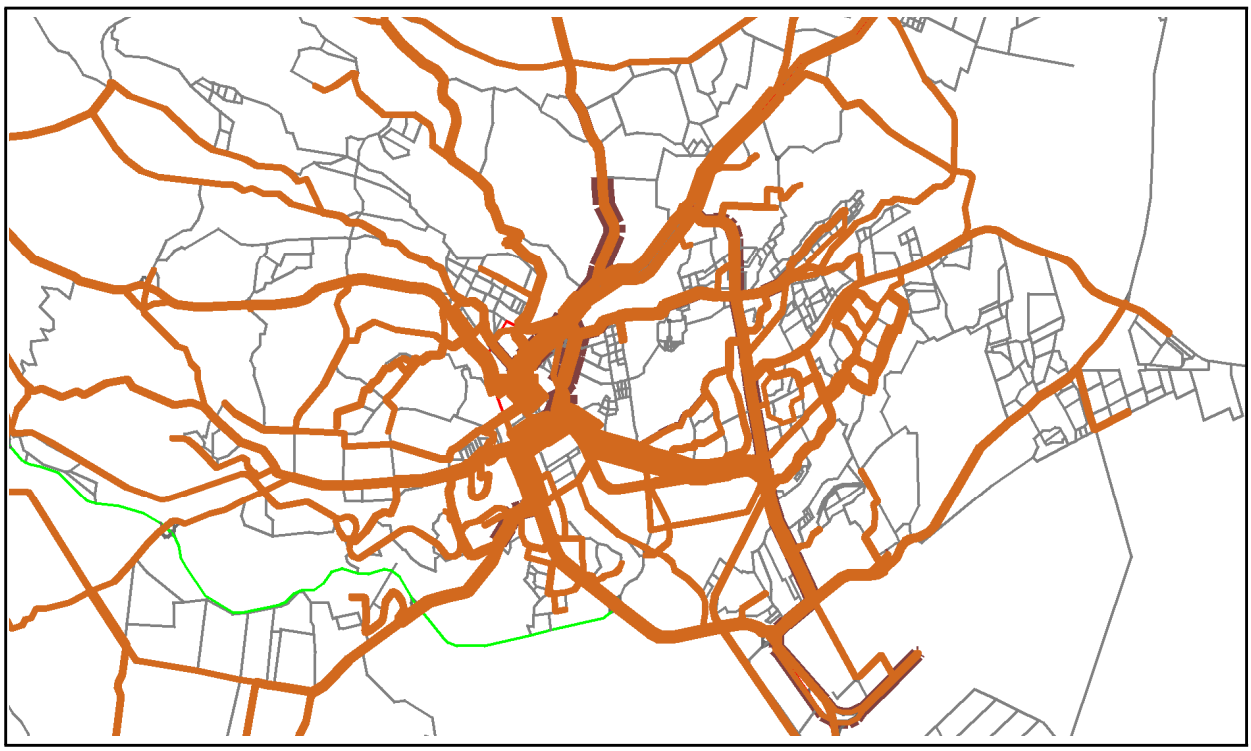
2) Trip Assignment Results

- If you look at the traffic distribution centered on Outer Ring Road, which is the main line of business, traffic is concentrated around Outer Ring Road on north-south axis, Juja Road on east-west axis, and Jogoo Road connection point.



<Figure 4-18> Vehicle Assignment Result (2030)

- As a result of assigning public transport routes, the traffic volume of both main roads was high, especially in the Nairobi CBD, rather than in the outer area.



<Figure 4-19> Public Transport Assignment Result (2030)