Nairobi MRTS Conceptualization: Transit-Oriented Development for Sustainable Transport

Bidhan Chandra Roy
RUPL, New Delhi, India
bcroy1944@gmail.com

Satyaki Bhattacharyya
Principal Track Engineer, DB Engineering & Consulting GmbH, Bengaluru, India
satyakib.backup@gmail.com

Abstract

Nairobi, famous for Nairobi National Park, the world's only game reserve found within a major city, started developing as a rail depot on the Uganda Railway. In 1963, Nairobi became the capital of the Republic of Kenya and showed phenomenal growth in terms of population ever since (from 11,500 in the year of 1906, to 3,138,369 by Year 2009, at growth rate of 4.1% a year). The city of Nairobi has experienced rapid urban sprawl. In 1970, average commuter distance was 0.8 km and increased to 25 km in 1998. Present commuter distance is over 40 km. The long commuter distances and heavy traffic congestion on the road has led to long travel time. At this rate, the difficulties commuting to the central business area is getting more and more complicated. The need of the hour is developing a world-class transport network, a combination of Road and Rail Based Mass Rapid Transit System (hereinafter mentioned as MRTS or MRT) technology. A comprehensive study was carried out in this direction to find out the feasibility of such MRTS in early 2000s. Based on the findings of the study, further study was conducted in 2013-2014 for developing the basis for a technical and financial harmonisation of measures. In 2019, the NMA Council gazetted 5 BRT and 7 Commuter Rail corridors vide Legal Notice No. 16 of 26th February 2019, which is outcome of all the efforts. This paper aims to put together the outcome of studies made so far.

Keywords: MRTS Planning; Nairobi MRTS

1 Introduction

The name Nairobi was derived from Enkare Nairobi, meaning "cool waters" in Maasai. In 1899, the Uganda Railway established a camp in what was then a swampy region that would become Nairobi. In 1905, the city served as the seat of government for both Kenya and the British East Africa Protectorate. The town was burnt down in the early 1900s and it had to be rebuilt, subsequent to spread of an infectious disease.

Nairobi's population reached above 15,000 in 1919, when it was officially recognised as a municipality with full corporate powers and a designated territory of 1.5 miles (3.9 Km). In 1950, Nairobi was officially recognised as a city, and its original 90 sq. km. expanded to include 690 sq. km. The colonial city's 1948 master plan called for a central business district (abbreviated as CBD) with easy access to the surrounding suburbs and industrial zone. Without any central planning, the town expanded along a gridiron layout of streets, and land use changed little in response to the prevailing racial dynamic (Africans, Asians and Europeans).

East of the main thoroughfare was where most African-American neighbourhoods were located. After

colonial limitations on Africans were lifted in 1963, migration into the city increased dramatically, catalysing rapid expansion. However, the city's public transportation infrastructure has not kept pace with its growth, leading to the chaos and stampedes that can be seen daily in the Central Business District.

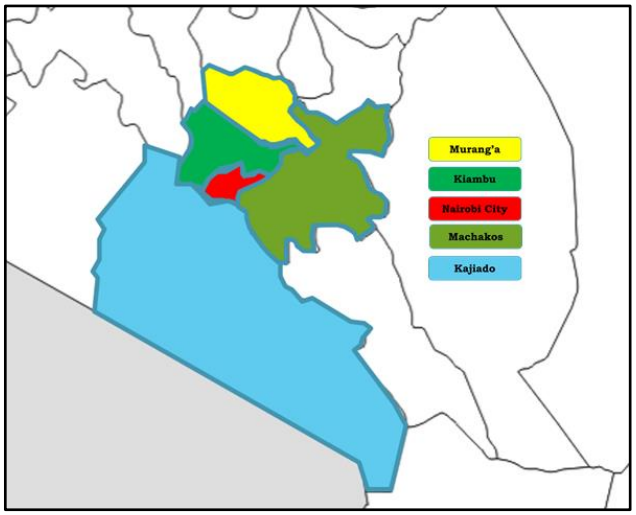

Fig. 1: Nairobi Metropolitan Area

Table 1: Population Distribution in NMR

COUNTY	Population (2019)	%	Area (KM^2)	%	Density (P/KM^2)
Nairobi	4,397,073	42.2%	694.9	2.1%	6,328
Kiambu	2,417,735	23.2%	2,449.2	7.5%	987
Kajiado	1,117,840	10.7%	21,292.7	65.1%	52
Machakos	1,421,932	13.7%	5,952.9	18.2%	239
Muranga	1,056,640	10.1%	2,325.8	7.1%	454
Totals	**10,411,220**	**100.0%**	**32,715.5**	**100.0%**	**318**

In 2009, 3.13 million people lived in Nairobi city, which covers 696 sq. km of the Nairobi Metropolitan Region (NMR); 47% of NMR residents. Nairobi's population density is 4509 people per sq.km. Compared to this, Kikuyu, Karuri, Thika, and Kangundo Town Councils had 1000–1500 people per sq.km; 400–600 people per sq.km live in Limuru, Kiambu, Ruiru, and Machakos Municipal Councils. The County Councils' population densities range from 18 in Kajiado to 437 in Kiambu.

Nairobi Metropolitan Region (NMR) begins at 2,300 m above sea level on the eastern side of the Rift Valley and progressively declines down to 1,400 m above mean sea level. The western and northern parts of NMR are hilly, whereas the eastern half has mild slopes. These districts' social-cultural zones are diversified, with urban areas having multi-ethnic groupings and rural areas having homogeneous ethnic groups like Kamba in eastern province, Kikuyu in central province, and Maasai in the Rift Valley.

2 Transportation Planning in Nairobi

2.1 History

In 1926, the Nairobi Municipal Council hired a town planning consultant team to reorganise the city (locate workers within walking distance to the CBD and industrial area). This was followed by a deal with a British transportation company (U.T.O.) to provide metropolitan public transportation services. This was the origin of the current bus services in Kenya. Prior to 1950, just 12 buses served predominantly Asian and European regions with good access roads to the town centre.

The CBD had ample open spaces before 1948. However, the master plan prevented spreading beyond Nairobi River in the North and the railway line in the South, and proposed a road system within the CBD with freedom of through traffic and easy exit for traffic into the city's suburbs and industrial area.

The 1970 Nairobi urban study group (N.U.S.G.) report, which led to the 1973 Nairobi Metropolitan expansion strategy, suggested decentralising industry to Dandora, Ruaraka, and Dagoretti in order to integrate work and housing zones. N.U.S.G. promoted exclusive bus ways, commuter rail transit, and staggered working hours, excluding the "Matatu" sector's role in public transport. Belgium Transurb consult group (1984) suggested three mass transit solutions for Nairobi-introduction of articulated

buses, light rail transit, and exclusive bus lanes.

2.2 Present Scenario

Because public transport is expensive and insufficient, most city journeys are made on foot. Nairobi's principal public transit is matatu and various private buses. Commuter train capacity is modest and limited to a few regions. Public transport cannot satisfy demand.

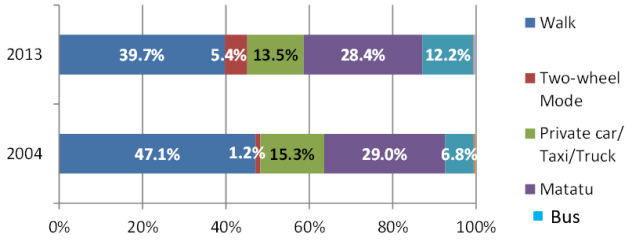

Fig. 2: Modal Split Changes

Fig. 3: Congestion in Central Business Area

Taxis are a well-liked means of transportation, not only among travellers but also among residents, and they are included in the category of intermediate public transport (IPT). Tuktuks are three-wheeled motor vehicles that can also function as an individual passenger transport (IPT). There are approximately 200 tuktuks that operate along the same lines as taxis but cater to shorter distances of travel. As part of the integrated public transport system, two-wheeled motor cycles known as boda bodas are used to transport passengers. Their primary route of operation is in the direction of and between the municipal towns. In the same vein, cycle taxis can also function as IPT in more remote locations.

Trains arrive and depart from Mombasa three times per week, making Nairobi reachable by rail. Only trains heading east to Mombasa are in operation. At the moment, Kenya Railway only runs one direction of intercity service per day from Nairobi Railway Station to each of (i) Embakasi Village (12.6 km), (ii) Kikuyu (31 km), (iii) Kahawa (24 km), and (iv) Ruiru (32 km). Normal speeds are around 12–20 kph. Despite being the more cost-effective public transportation option, most urban commuters avoid the commuter rail for a variety of reasons, including but not limited to: insufficient inter-modal transfer facilities; a lack of safety and comfort; and a lengthy distance between the station and their respective places of employment.

The bus system in Kenya is generally dependable, however it is insufficient. Nairobi serves as the hub of the country's bus system, and a number of bus companies offer services to and from the country's other major cities. Approximately 4% of all passenger trips in NMR are made on buses, which operate on approximately 67 routes and are projected to carry approximately 0.35 to 0.40 million passengers per day. The vast majority of buses compete with the Matatus for passengers on the same routes.

Commuters and tourists alike utilise Matatus (public minibuses) to get from the city centre to the outskirts of Nairobi. The smallest Matatus are the size of a van and seat capacity of 14, while the largest may hold up to 50 passengers. In the event of an accident, Matatus frequently have more passengers than seatbelts. Matatus are typically driven recklessly due to the lack of licence requirements, including passing on the sidewalk, exceeding the speed limit, and weaving in and out of traffic.

Transportation costs in the city are prohibitive for most residents due to high prices and low wages. The typical bus fare during rush hour is Ksh 50 in the central 0-10 km zone, and Ksh 100 in the 10-20 km zone. When compared to the minimum wage of Ksh 7, 334 (GOK, 2011) per month, which is roughly Ksh 200-300 per day, the expense of public transportation is quite high.

This necessitates the creation of a brand-new, cutting-edge mass transit system that is at once dependable, committed, and affordable. Consulting Engineering Services (India) Pvt. Ltd. conducted a feasibility study on the topic between 2009 and 2013 in order to find a workable solution for the ambitious Nirobi Mass Rapid Transit System. A second international consulting bid was issued to conduct a harmonisation study of the available alternatives and find the optimal way to improve traffic flow.

3 Outcome of Feasibility Study by CES & APEC (Ref 1)

3.1 Field Studies and Mode Selection Method

In order to determine the level of interest in travelling within the NMR, the research area was divided into 74 traffic analysis zones (TAZ). Simulation of the travel demand pattern between TAZs in NMR was carried out with the use of a four-stage urban transport-planning model. Based on the projections of the demand for transportation, it appears as though certain corridors in NMR may require the high capacity Metro Rail. On other lines, medium-capacity modes of transportation such as bus rapid transit systems (BRTS), light rail transit systems (LRT), and monorail will be sufficient. The level of demand, as shown by peak hour peak direction traffic (PHPDT), is the primary factor that determines which of these systems will be selected.

Corridors with a peak hour passenger demand threshold (PHPDT) of fewer than 5,000 passengers have not been evaluated for a new MRTS technology, and the same number of passengers can be fed by the present bus service. In areas with a PHPDT of more than 5,000 passengers, BRTS has been proposed as an alternative. Between these two options, the Bus Rapid Transit System (BRTS) is the one that has been deemed to be more suitable for Nairobi due to the fact that it would make the transition into a system with a higher capacity less cumbersome. There have been discussions about installing LRT in areas with a PHPDT of more than 12,000 passengers and installing Metro Rail in corridors with a PHPDT of more than 30,000 passengers (not envisaged in Scenario at present).

The following is a prediction of future travel demand on the specified MRTS corridors for the year 2030 based on low growth scenarios:

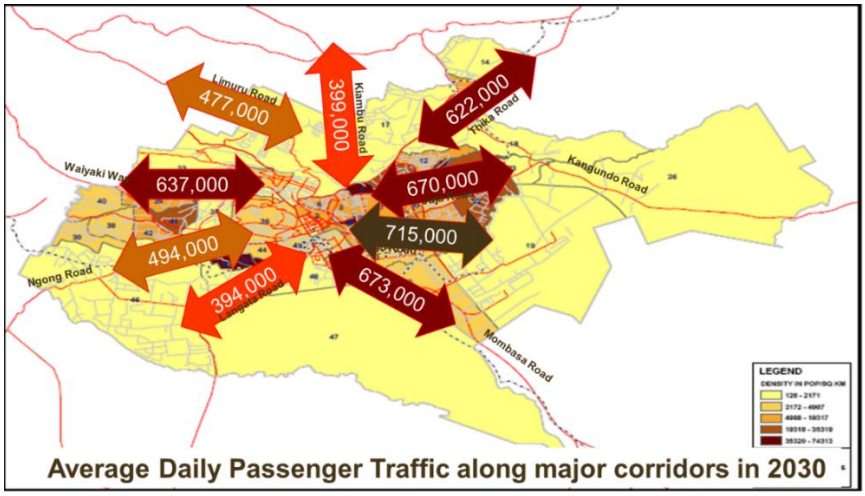

Figure 4: Travel Demand in the City of Nairobi

3.2 Study Outcome

A transit hub at NRS (Nairobi Railway Station) and connecting the entire city to this, with sufficient transit interchanges so that any commuter can bypass the Transit hub at NRS in case, would satisfy the movement demand of most commuters in the city, as most travel in Nairobi is directed toward NRS.

Fig. 5: Concept of Transit Hub

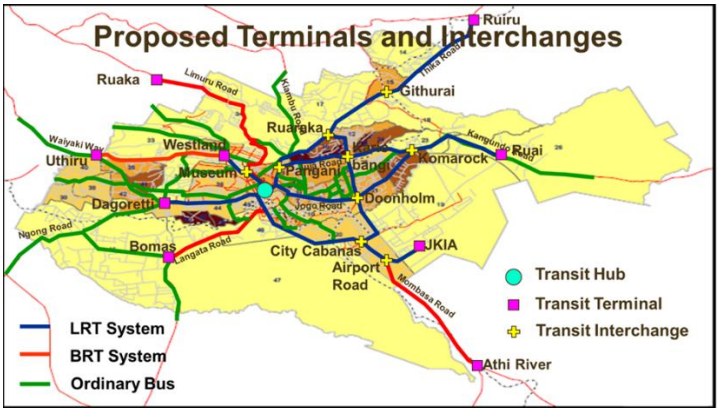

Fig. 6: Nairobi MRTS Corridors

The current Nairobi Railway Station and its adjacent yards might be repurposed into the Central Hub Terminal of the Nairobi Mass Rapid Transit System (MRTS), complete with sleek, environmentally friendly architecture. This terminal would be the starting point and final destination for all lines. This would make it simple to switch between different lines, shortening the time it takes to travel between different parts of the region/city.

In a perfect world, demand control strategies would complement the availability of public transportation options. Critical areas such as the Central Business District, proposed District Centres, Nodal Terminals, MRTS/BRTS proposed stations/stops, and corridors should be prepared for transit oriented development around rail stations, road terminals, and along the corridors/lines up to one km on either side, first for the construction stage of MRTS and then for the operation stage on a continuous basis.

3.3 Economic Viability

Economic viability study was done in all the corridors, and the project was found to be economically viable. The difference in the economic instances "without" and "with" the project is used to calculate the benefits of the project. The circumstance known as "without project" is referred to as the "base" case or the "do-nothing" case. In this scenario, the predicted development scenario is superimposed over the transport network that is already in place. The 'with project' case illustrates a potential future development scenario for the integrated multi-modal transport network following the successful completion of the MRTS project.

MRTS would reduce carbon emissions, travel time, and vehicle costs, in addition to reducing the amount of carbon emissions. The wage rate method was utilised in order to arrive at an estimation of the value of time (VOT) for passengers. The Consultants for PT consumers' Stated Preference Survey determined passengers' average monthly income. A carbon footprint software model was utilised to assess carbon emission decrease.

Table 2: Economic Viability Table

#	Corridor Name	Approx. Length kms	EIRR (%)	Technology Proposed
1	Thika Road	40.47	33.13	LRT/BRT
2	Juja Road	13.82	21.94	LRT
3	Jogoo Road	12.79	24.77	LRT

#	Corridor Name	Approx. Length kms	EIRR (%)	Technology Proposed
4	Ngong Road	20.30	24.44	LRT/BRT
5	Limuru Road	13.8	25.75	BRT
6	Mombasa Road	26.62	63.43	BRT
7	Outer Ring Road	12.93	25.10	LRT
8	Waiyaki Way	18.71	14.29	LRT
9	Langata Road	7.64	28.65	BRT

3.4 Financial Viability and Viability Gap Funding

Discounted cash flow (DCF) analysis estimates the Financial Internal Rate of Return (FIRR). Capital and operating costs were stated earlier. Each route's average daily ridership estimates revenue. This research assumes KSH 2.5 for BRTS and KSH 4 for LRTS per passenger-kilometre. The Phase 1 MRTS sections' Project FIRR and Equity FIRR were estimated. The Project FIRRs, or returns on total investment, were lower than the EIRRs, as is typical for such projects. With debt and equity financing and Viability Gap Funding (VGF), projects can be made feasible with Equity FIRRs of 18%.

Table 3: Project FIRR and VGF

Corridors	Name	Project FIRR (%)	VGF in Ml. Kshs
LRT-2(1)	Thika Corridor (NRS - Githurai)	4.33	37,713
LRT-3	Juja Corridor	7.61	36,669
LRT-4	Jogoo Corridor	7.70	29,864
LRT-6	Ngong Corridor	3.01	32,326
BRT-1	Limuru Road (NRS To Ruaka)	0.79	15,793
BRT-3	Mobassa (Athi River)	5.84	27,652
			1,80,017

It is envisaged that funding for the MRTS project will come from a public-private partnership (PPP), which will make use of the resources and core skills offered by the private sector. Building public and partner confidence will require a significant contribution from the government, which must take the lead in this endeavour.

Table 4: Recommended Sources for VGF

Sources	Amount (mn Ksh)	Percentage
Property development by Private Investors	9,000	5%
Soft Loan from Multilateral agencies	126,000	70%
Share of GoK (from Budgetary resources)	45,000	25%
Total	1,80,000	

3.5 Project Capital Cost

A period of approximately 15 years would be required for the implementation of the complete 170 kilometres of projected MRTS within Nairobi. The following is a summary of the estimated capital costs of all of the corridors at their pricing in 2010-2011:

Table 5: Project Capital Cost

Corridor	Financial Cost (mill Kshs)	Economic Cost (mill Kshs)
MRTS 1 : Waiyaki Way	54,864	45,770
MRTS 2 : Thika Road	108,115	89,361
MRTS 3 : Juja Road	63,207	52,414
MRTS 4 : Jogoo Road	43,183	35,938

Corridor	Financial Cost (mill Kshs)	Economic Cost (mill Kshs)
MRTS 5 : Outer Ring Road	42,021	34,953
MRTS 6 : Ngong Road	44,411	37,364
MRTS 7 : Limuru Road	17,357	15,100
MRTS 8 : Langata Road	9,120	7,934
MRTS 9 : Mombasa Road /Athi River	27,075	23,555

The cost estimate for the infrastructure was derived from the costs of similar works being performed as part of the ongoing Thika Road Improvement Project. The cost of BRT/LRT systems and rolling stock is determined based on the knowledge gained from previous projects of a similar nature that were carried out in India. We will assume that the cost of government land is zero. One percent of the total cost of the civil project is allocated to R&R and social impact.

3.6 Social and Environmental Viability

All MRTS corridors are planned on highways with right of way over 30 metres, enough for elevated LRT structures at the road centre. Construction, depots, and yards would require more land. Reduce project-affected persons. Transportation-related water quality factors need intensive monitoring. Some streams have 0.235mg/l of oil and grease, above the Water Quality Regulation's zero limit. Due to fewer public transport vehicles in major corridors, the high-capacity MRTS should reduce oil and grease in waterways. Sulphur, nitrogen, and carbon monoxide levels in Nairobi's ambient air are low. Carbon dioxide and particulate matter, the most common metrics, are low outside the city. These make the project socially and environmentally viable.

4 Implementation

Following the results of the feasibility study, additional research was conducted to lay the groundwork for a technical and financial harmonisation of measures aimed at improving the traffic situation and increasing the efficiency of the various transport networks in the Kenyan capital. This research included conducting a detailed traffic analysis and developing models, as well as formulating a concerted strategy for the implementation of an integrated transport solution (Ref: Harmonization of Public Transport done by H.P. Gauff Ingenieure GmbH consortium & inputs available in Nairobi Metropolitan Area Transport Authority Website https://namata.go.ke/mrts).

During this, a few corridors identified was merged together and mode converted to BRTS instead of providing a combination of BRT & LRT as proposed earlier, for the first phase. In later stage, some of the corridors are proposed for conversion to LRT.

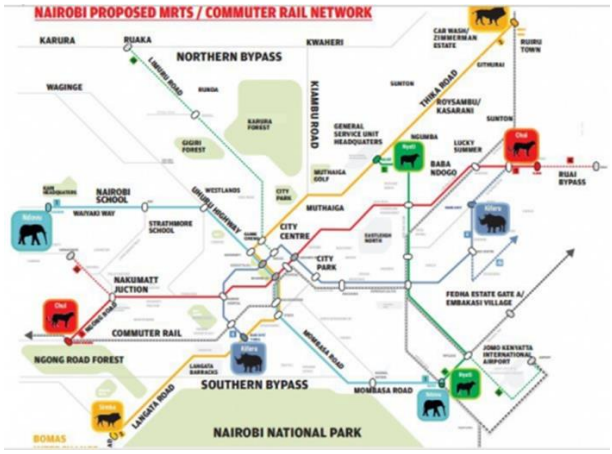

Fig. 7: Nairobi MRTS Schematic

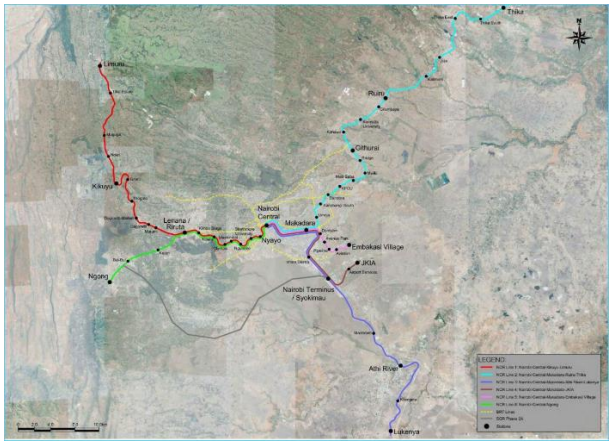

Fig. 8: Commuter Rail Master Plan

The proposed plan calls for a Bus Rapid Transit (BRT) system to be the primary mode of transportation in the first phase of the project, with five interconnecting lines named after Kenya's Big Five animals: Ndovu (elephant), Simba (lion), Chui (leopard), Kifaru (rhino), and Nyati (buffalo).

5 Conclusion

In order to meet the demand for transportation in the Nairobi Metropolitan Area, the MRTS Harmonisation Study of 2014 recommended the construction of Commuter Rail and five BRT lanes (NMA). Through the publication of Legal Notice No. 16 on February 26, 2019, the NMA Council officially designated the following 5 BRT lines and 7 Commuter Rail corridors for the year 2019:

One ticket gets a traveller from Kangemi to Imara Daima on Ndovu line. The Waiyaki Way and Mombasa Road line will contain drop-off and pick-up stations at ABC Place, Westlands, University Way, Kenyatta Avenue, Haile Selassie Avenue, Makaburini, Nyayo Stadium, and near General Motors. Some stations connect to other lines. This project is a proposed addition to the Expressway project that is currently being developed by KeNHA.

Simba Line will transport passengers from Bomas Interchange at the Bomas of Kenya to Ruiru town via the city. The 27-kilometer project follows Thika Superhighway from Ruiru to Kenyatta National Hospital through Nairobi CBD. The STECOL Corporation-SMEDI project began on August 4, 2020.

Chui Line passengers can take one bus from Njiru in Embakasi to Jamhuri Showground. Dandora, Kariabangi, and Gikomba market would be significant stops on the Ngong Road, Juja Road, and Komarock Road route. The MRTS will reach Ruai and Kawangware in Phase II. Detail Design of this corridor is being carried out at present.

Kifaru Line will connect Mama Lucy Hospital to T-Mall via the CBD in Nairobi's densely populated Eastlands. Donholm, City Stadium, Bee Centre, Nairobi Hospital, and Moi Avenue are prominent stops along Jogoo Road.

Nyati, the shortest of the five lines, will connect Balozi Estate near GSU headquarters to Imara Daima through Outering Road. Phase II extends the railway to Jomo Kenyatta International Airport (JKIA). This stretch is being developed under Korea Funding Plan.

In addition, the following Commuter Rail Lines are also given go-ahead for implementation:

a. Nairobi - Limuru Town
b. Nairobi - Ngong Town
c. Nairobi - Kenol, Murang'a
d. Nairobi - Kiambu Town
e. Nairobi - Ruai Town
f. Nairobi - Jomo Kenyatta International Airport
g. Nairobi – Konza

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