Service plan for Nairobi BRT Line 2

Institute for Transportation and Development Policy

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Contents

1. Introduction

Greater Nairobi is a rapidly growing metropolis characterised by daunting traffic jams at peak hours. A lack of sufficient public transport options and rapidly increasing ownership of private cars lead to daily traffic snarls on the roads that serve as the entry and exit points to the city centre. Responding to these issues, the Nairobi Metropolitan Area Transport Authority (NaMATA) is planning a bus rapid transit (BRT) system for the Nairobi Metropolitan Area (NMA). In the initial phase, the BRT network aims to provide improved connectivity along the Thika Rd corridor, known as Line 2.

When developing a high-quality BRT, many components must be planned in an integrated manner. A key element of this process is a service plan that identifies the most efficient way to deploy the bus fleet to serve passenger demand. The operational parameters determined through the service plan help define the infrastructure elements and required bus fleet needed. The following report describes the service plan for the Nairobi BRT Line 2 corridor.

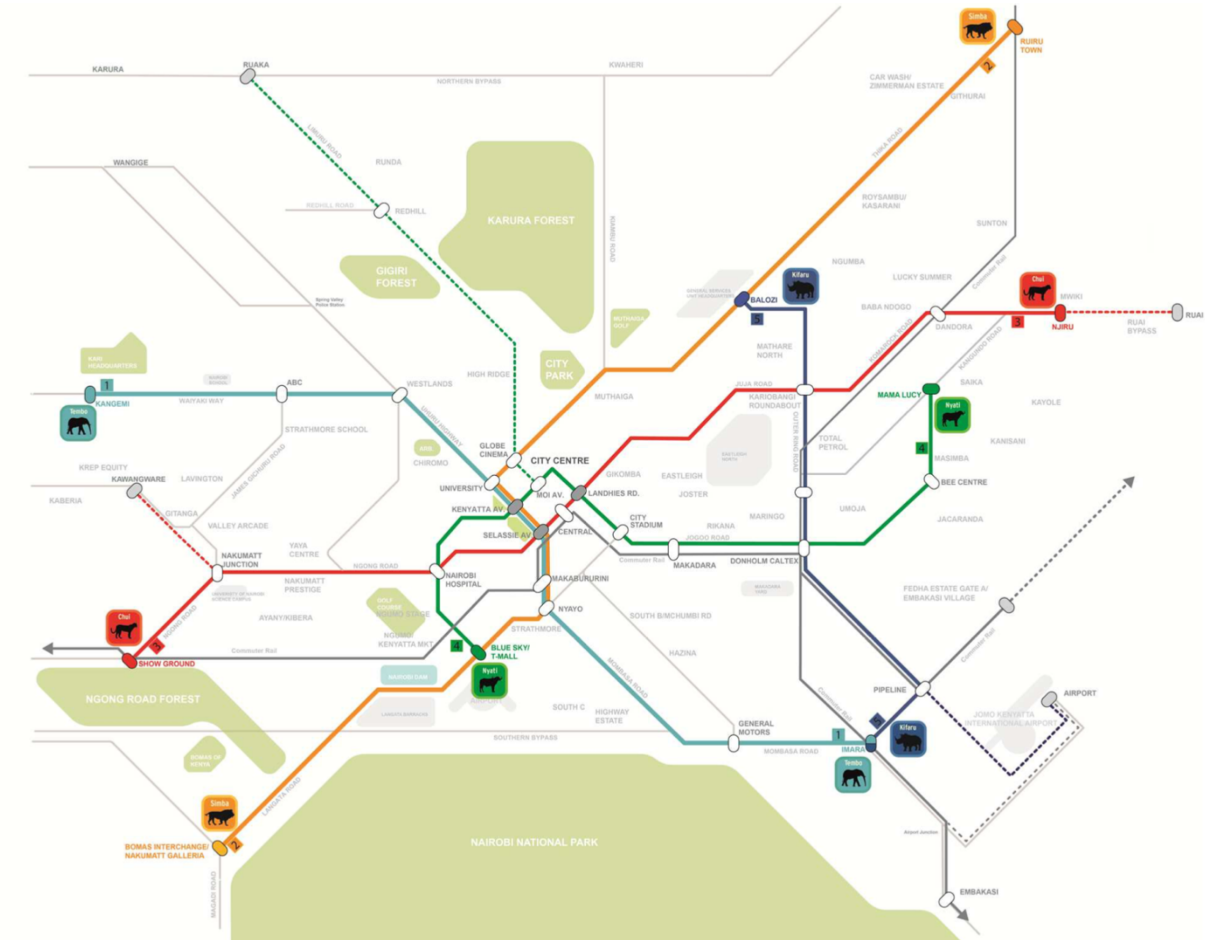

Figure 1. Out of the five lines of the planned BRT network in the NMA, NAMATA has prioritised the Line 2 BRT corridor along Thika Rd for implementation.

2. Key features of the Nairobi BRT system

In 2018, NAMATA adopted the BRT Design Framework to guide the design of BRT infrastructure. The BRT Design Framework outlines key features that enable BRT to offer high capacity, high speeds, and safe and convenient access for all users. These features facilitate the recovery of operating costs through farebox revenues, ensuring that the system can attract private investment in buses and other system elements. The basic design elements of a high-performance BRT system include dedicated median BRT lanes, platform level boarding at stations, off-board fare collection, and intersection treatments that avoid turns across BRT lanes. These elements along with other features outlined in the Nairobi BRT Design Framework form the basis for the service scenario described in this study.

Table 1: Basic features of high-performance BRT systems.

Design feature	 **Dedicated BRT lanes**	 **Median busway alignment**	 **Platform-level boarding**	 **Off-board fare collection**	 **Intersection treatments**
Impact on system performance and service quality	• Faster speeds because buses can bypass congestion in mixed traffic lanes.	• Faster speeds because of avoided interference with property entrances, side streets on-street parking, and pedestrian movements. • Improved safety due to reduced conflicts with mixed traffic.	• Faster speeds because of avoided delays during boarding and alighting. • Accessibility for all users, regardless of disability.	• Faster speeds because of multiple-door boarding and avoidance of queues for fare payment and/or validation. • Improved convenience for customers. • Reduced revenue leakage.	• Faster speeds due to reduction in signal phases if right turns across the busway are avoided. • Improved safety due to reduction in potential conflict points.

3. Importance of service planning

From a customer's perspective, some of the most important factors affecting the choice of travel modes are whether the service will take him/her where s/he wants to go and the total travel time. Good service planning provides the most direct route for the largest number of passengers in the most efficient way possible. This includes adjusting the frequency of buses based on demand and providing local and express services as necessary. A good service plan minimises the waiting time for passengers and the number of required transfers.

The service planning process begins with passenger demand surveys that help determine how frequently each existing route operates, how many people board and alight at each stop, current commercial speeds, and transfer locations. Afterward, the survey data are used to create a peak-hour origin-destination (OD) matrix for public transport services. Once an OD matrix has been created, the model is calibrated to ensure that the model accurately reflects the existing bus and paratransit demand in the base year. Next, a set of service scenarios is defined to test different combinations of potential BRT and regular bus services. The model provides various data for each scenario, including travel times for passengers, overall passenger volumes on each corridor, and the number of buses required for each route.

The result of the service planning exercise is a final operational design, incorporating a selected service scenario. The operational plan can then inform the design of corridor infrastructure, including the size and configuration of stations, the presence of passing lanes, and the design of road infrastructure. If infrastructure elements are designed around the operational parameters defined in the service plan, the system can avoid challenges such as overcrowding, customer queueing, and bus bunching during peak periods.

4. Travel demand surveys

A detailed assessment of current travel patterns is the first step in developing a service plan. Information on the existing transport system is limited, particularly with regard to informal microbus and minibus services. Some services lack route numbers, itineraries, or defined stops. As a result, the survey process identified these services from the following types of surveys:

- **Frequency-occupancy (FO) survey:** The FO survey records how frequently each bus or paratransit route runs and the approximate occupancy of each vehicle. Frequency-occupancy surveys were conducted at 92 bidirectional locations during the morning peak period and at selected locations throughout the entire day.
- **Boarding-alighting (BA) survey:** The BA survey is a count of how many passengers get on and off of the vehicle at each stop along the route. BA surveys were conducted on 131 unique routes.
- **Transfer surveys:** A transfer survey is helpful in order to get a better sense of full passenger trips, including trips that involve more than one segment linked by a transfer from one route to another. Transfer surveys were conducted on all major corridors in the city. Altogether, 4,621 effective samples were obtained.

MOTIHUD and NaMATA provided the survey team for the exercise. The following sections describe the survey procedures in more detail.

Table 2: Summary of travel demand surveys.

Survey	Details
Frequency-occupancy survey	92 bidirectional locations
Onboard boarding-alighting survey	131 routes
Transfer survey	4,621 effective samples

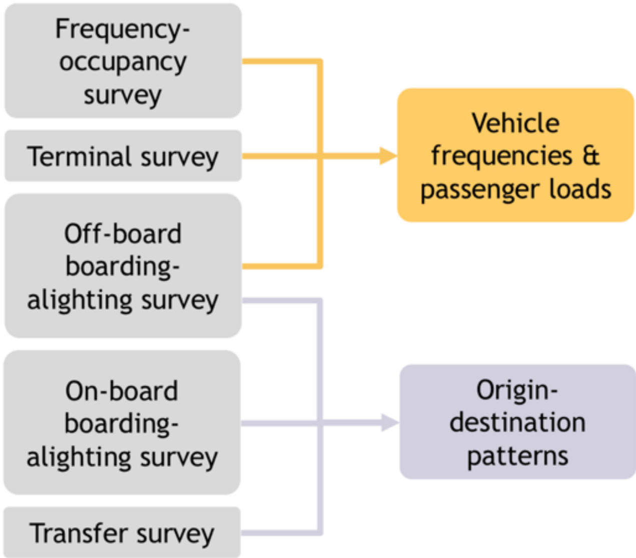

Figure 2. Information obtained from the surveys.

Figure 3. Surveyor training (left) and on-site trial survey (right).

4.1 Frequency-occupancy survey

In the frequency-occupancy survey, one to three surveyors recorded key details for all public transport vehicles that passed by in each direction:

- Vehicle type: Categorised by number of seats, e.g., 14, 33, 37, 52, etc.
- The route number (if present)
- Passenger occupancy
- Arrival time
- Direction (inbound or outbound)

The survey was conducted for four hours during the morning peak period of 6:00 to 10:00 and for three hours during the evening peak period of 16:00 to 19:00 at 92 bidirectional locations across the NMA.

Figure 4. Surveyors recording frequency-occupancy data.

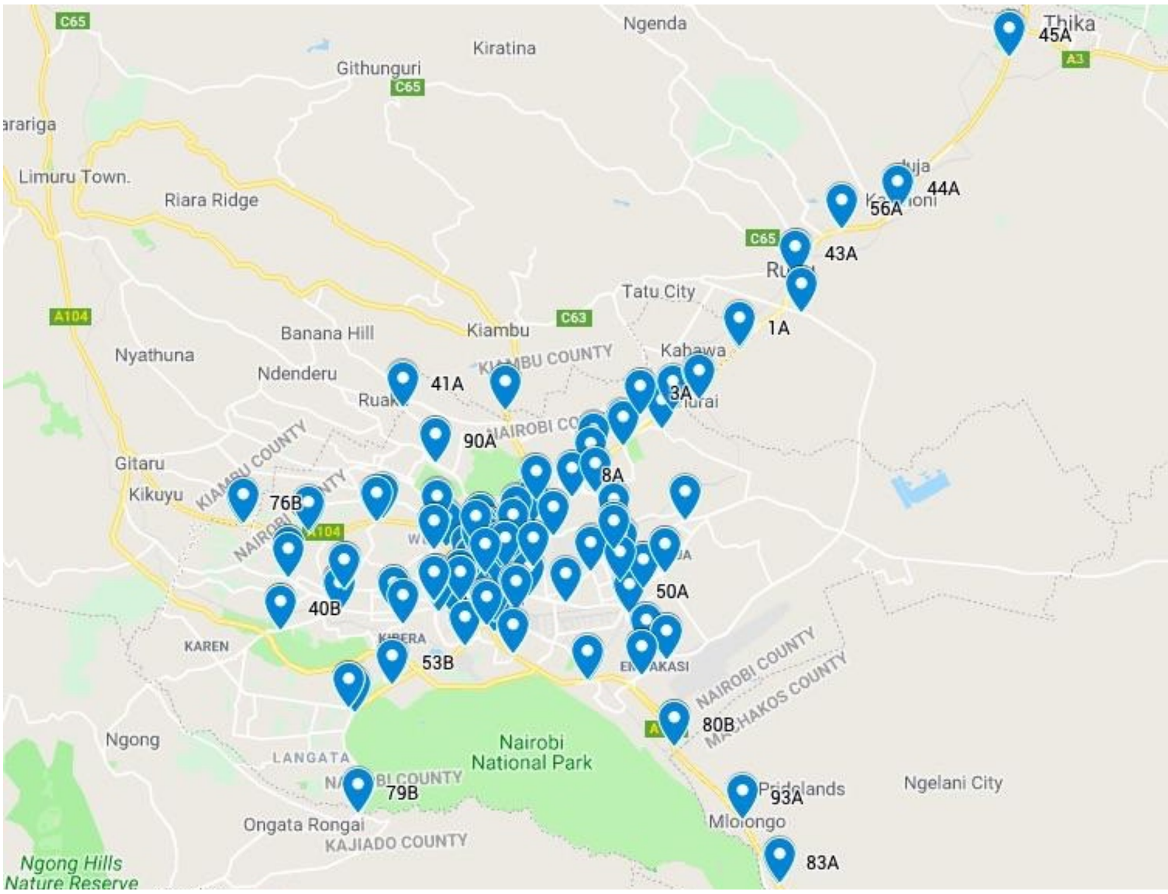

Figure 5. Frequency-occupancy survey locations.

The aggregate volumes of public transport passengers along Line 2 during the morning peak hour are displayed below. The graphics show the passenger volumes per hour per direction (pphpd).

Figure 6. Peak hour passenger volumes (pphpd): Witeithie, Juja Mall, and Toll Station.

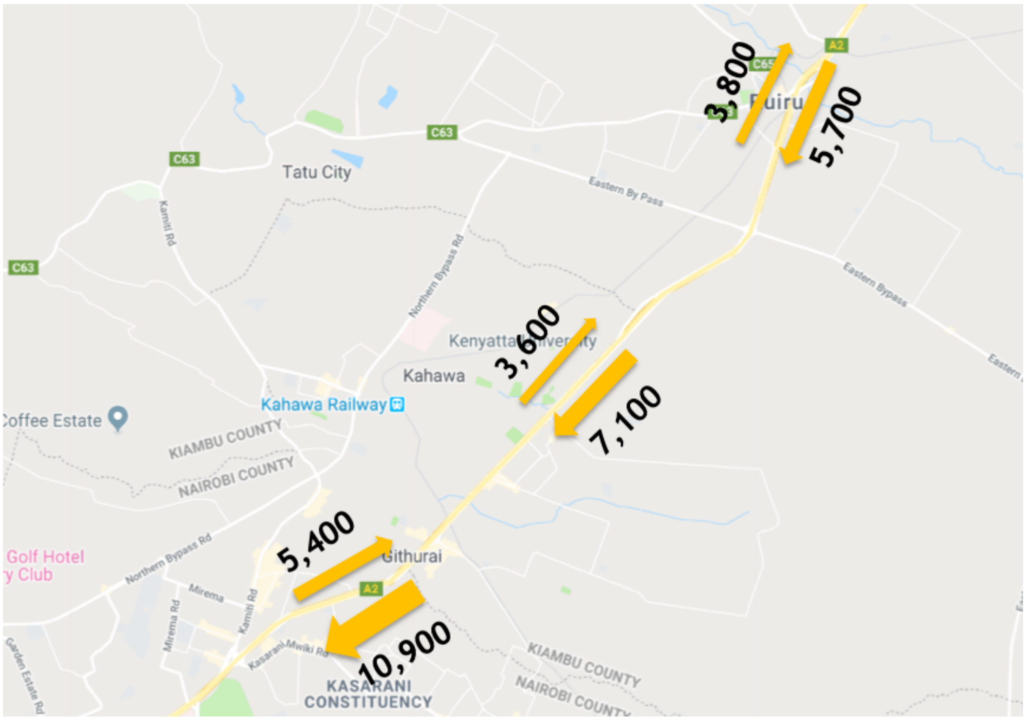

Figure 7. Peak hour passenger volumes (pphpd): Ruiru, Kenyatta University, and Clay Works.

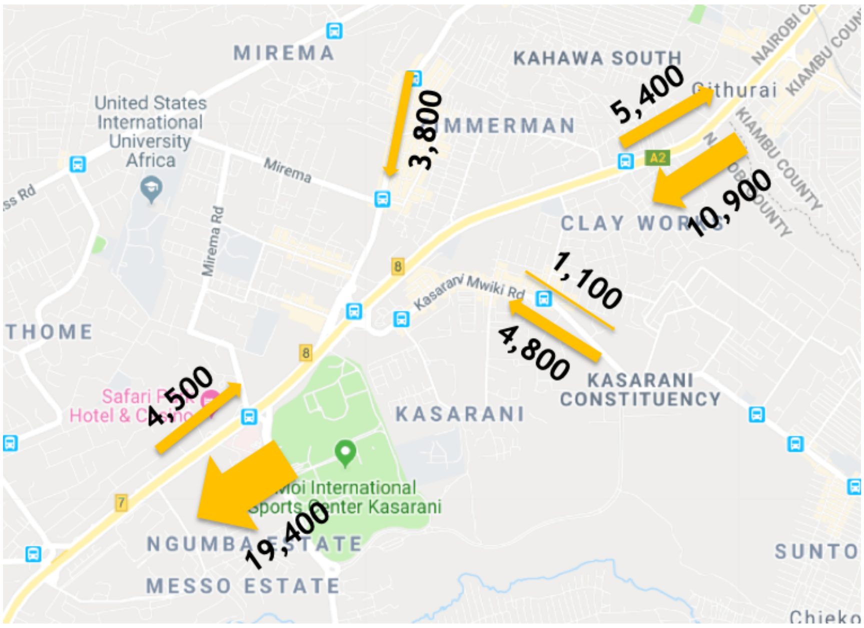

Figure 8. Peak hour passenger volumes (pphpd): Clay Works, Kasarani, Kahawa West, and Safari Park Hotel.

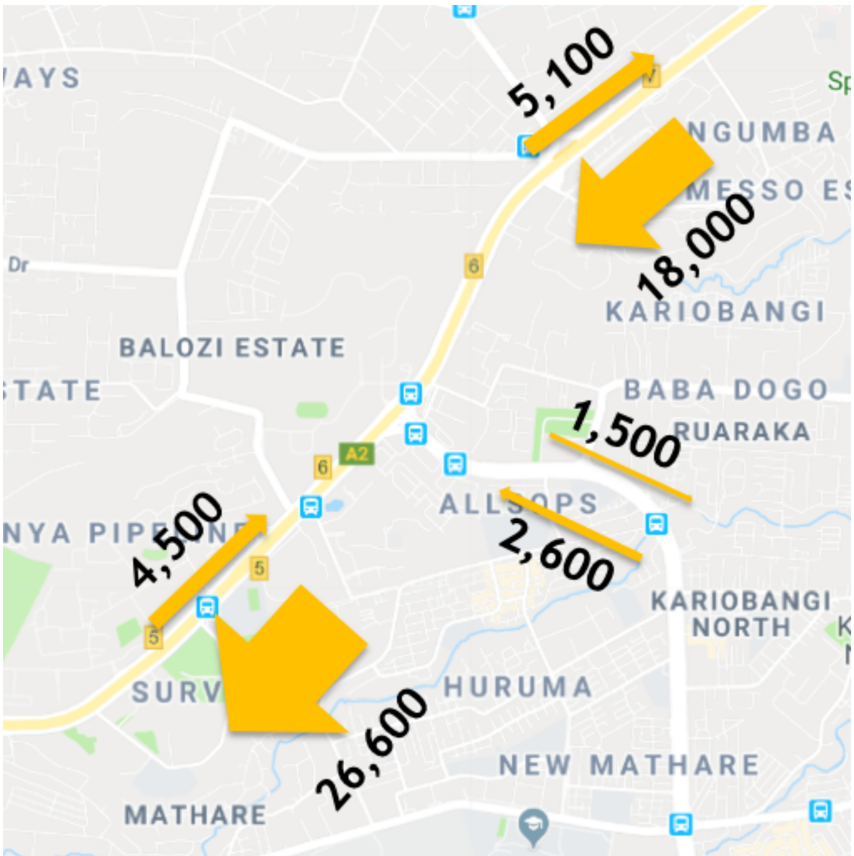

Figure 9. Peak hour passenger volumes (pphpd): Roasters, Outer Ring Rd, and Drive In.

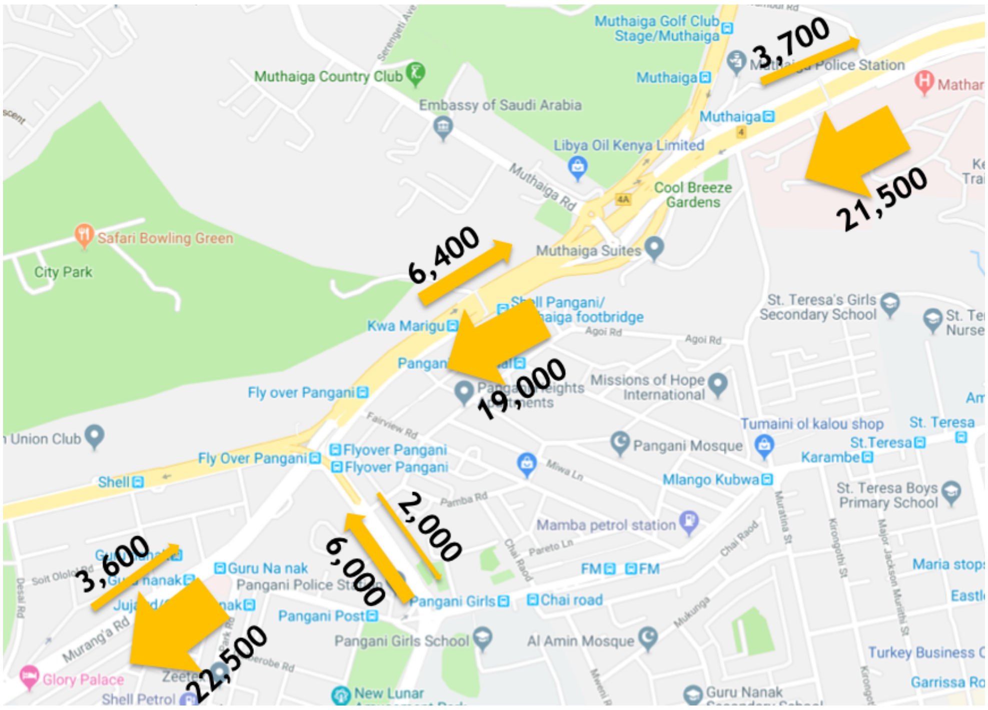

Figure 10. Peak hour passenger volumes (pphpd): Muthaiga Police, Shell Pangani, Pangani Girls, and Ngara Footbridge.

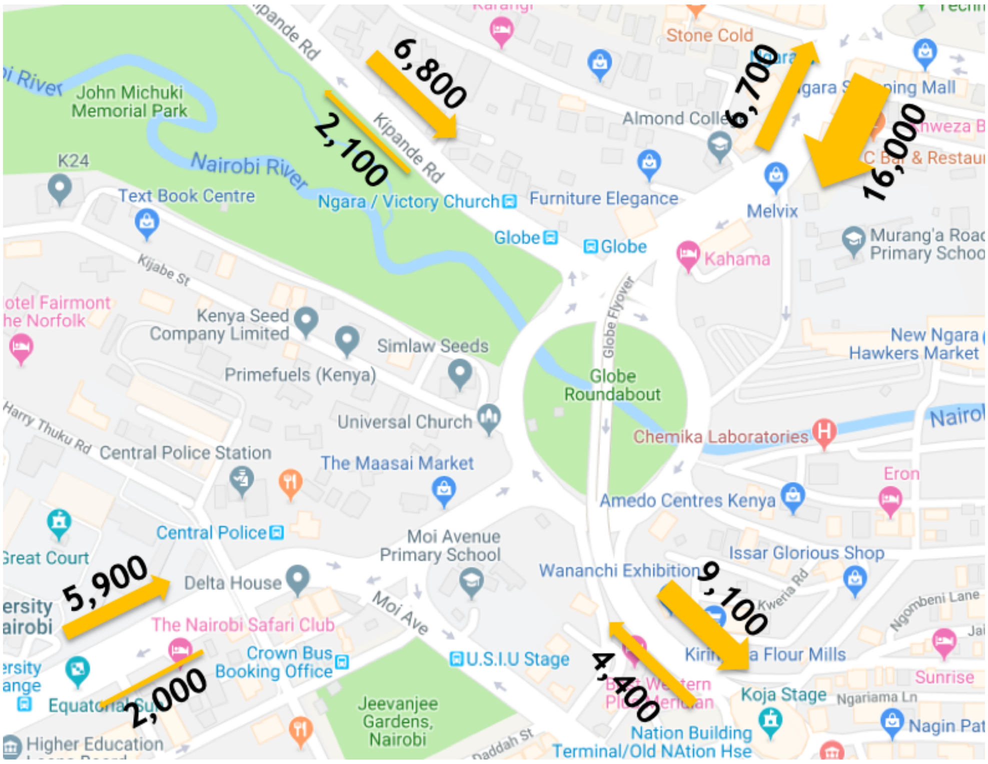

Figure 11. Peak hour passenger volumes (pphpd): Fig Tree, Kipande Rd, Koja, and University Way.

Based on the frequency-occupancy data, eleven locations with relatively high demand were selected for all-day (13-hour) surveys to determine the peak factor—the ratio of travel demand during the peak hour to that during the day as a whole.

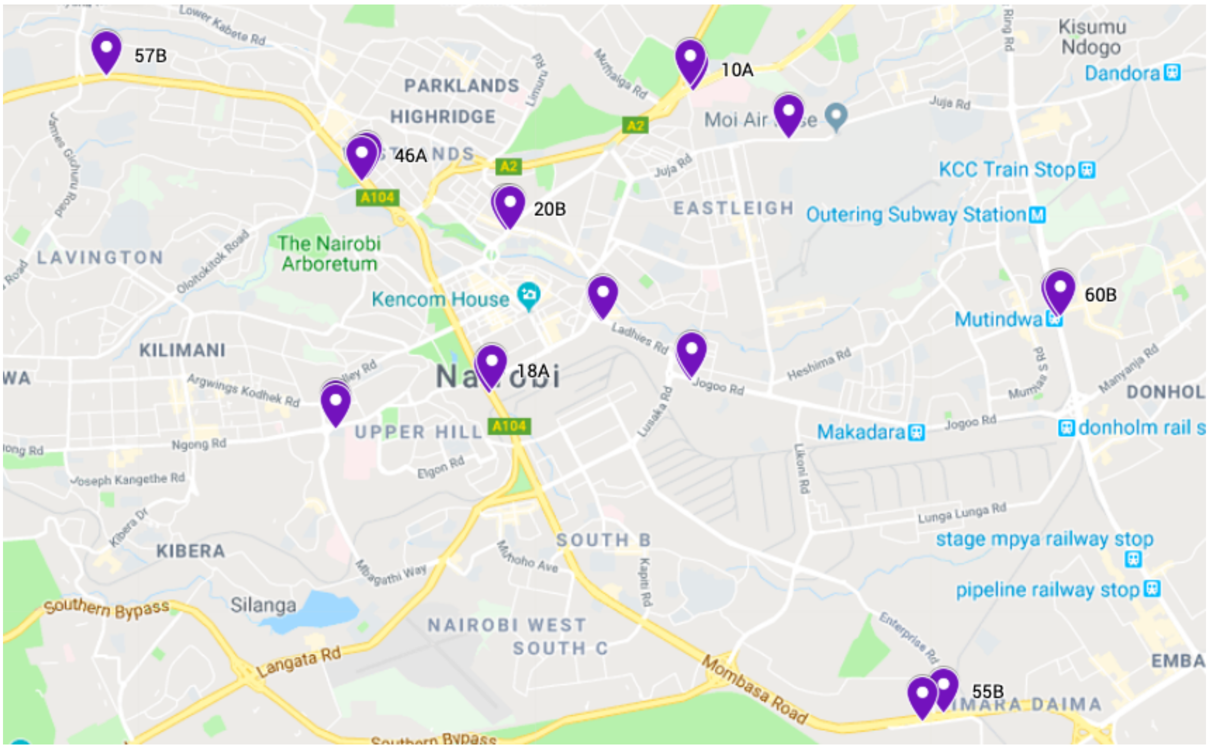

Figure 12. All-day frequency-occupancy survey locations.

4.2 Boarding-alighting survey

The boarding-alighting was carried out during the morning peak period on weekdays from September to October 2018 and April to June 2019. Surveyors rode on matatus and buses and recorded boarding and alighting information each time the vehicle stopped—at both official and unofficial stages. Using a GPS-enabled smartphone, surveyors recorded the following information at each stop:

- Route number boarded
- Stop name
- Number of passengers boarding
- Number of passengers alighting
- The fare paid for the trip
- The direction of the trip (inbound or outbound)

For each record, the app automatically stored the time and GPS coordinates of the stop location. Five samples for each route were required. In total, the team surveyed 131 routes.

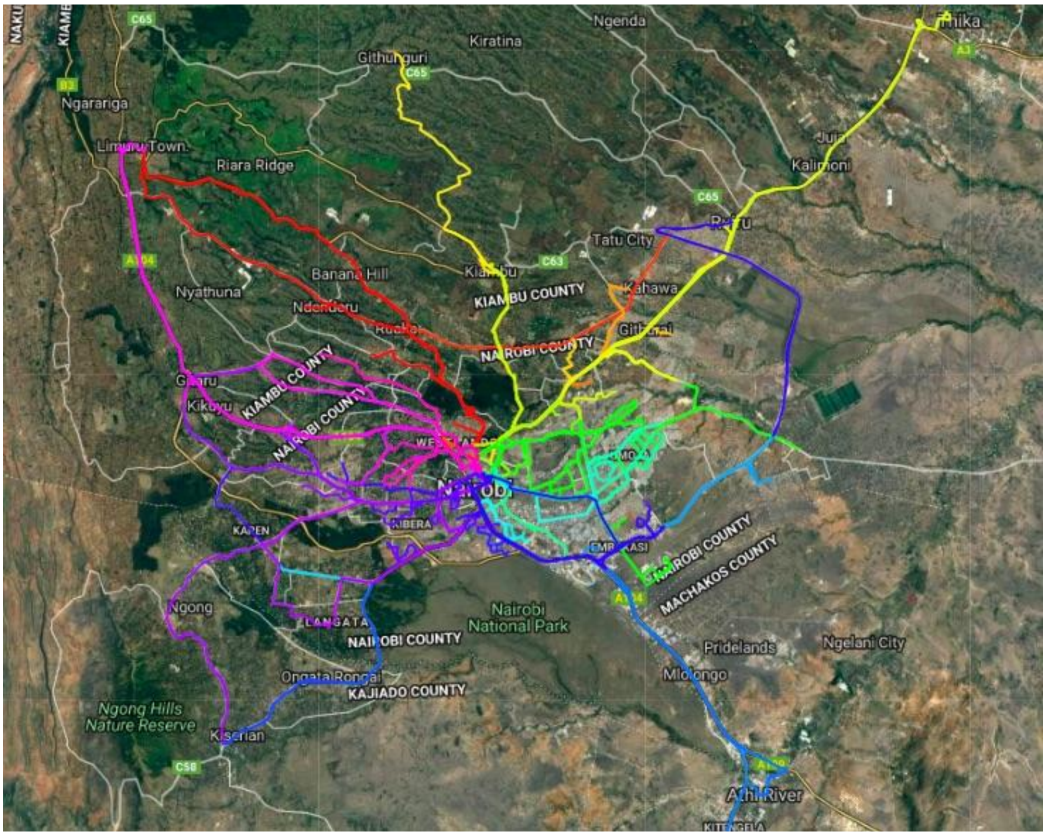

Figure 13. Public transport routes covered in the boarding-alighting survey.

The boarding-alighting survey revealed heavy boarding activity in the Nairobi CBD and along several radial corridors heading toward the city centre. Much of the demand for matatu services is concentrated in eastern Nairobi, including the Line 2 corridor.

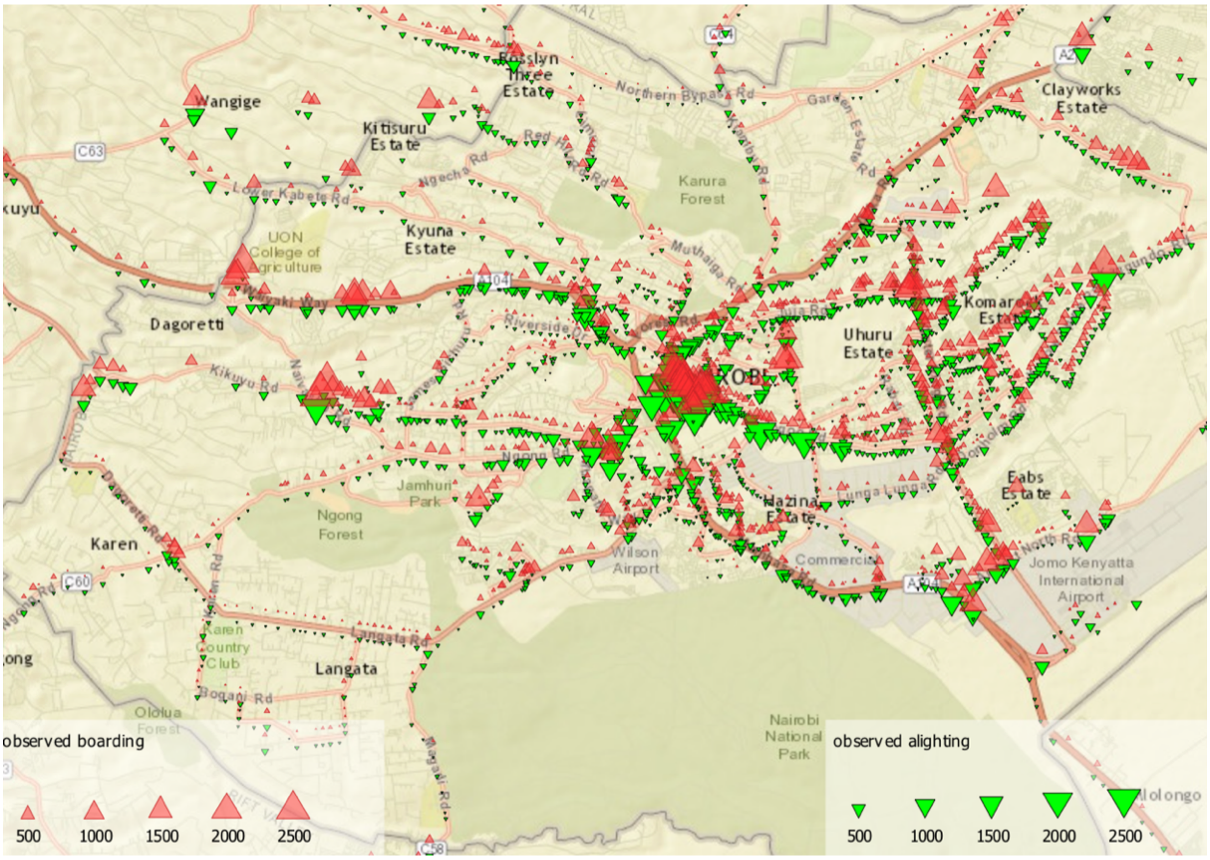

Figure 14. Passenger boarding patterns obtained through the BA surveys.

The global positioning system (GPS) tracks generated through the boarding-alighting survey also provide information on vehicle speeds. The speeds can help inform corridor selection and are used as inputs to the travel demand model. Bus speeds in Nairobi are slow, particularly on the approaches to the CBD along Thika Rd, Waiyaki Way, Juja Rd, Jogoo Rd.

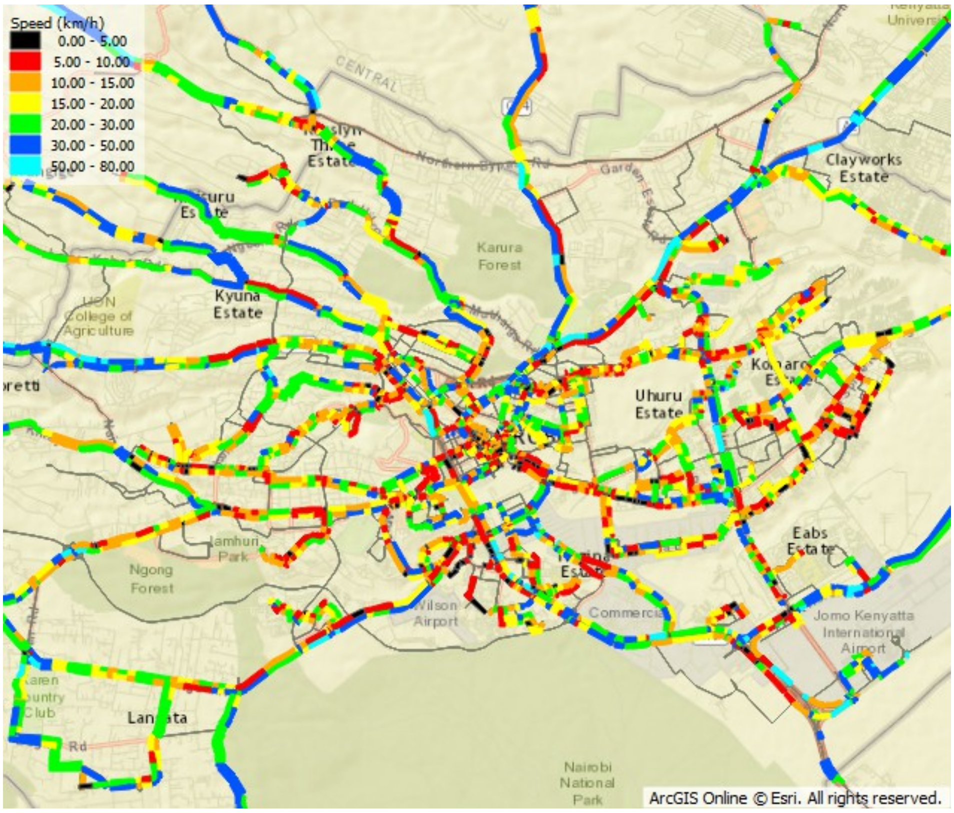

Figure 15. Bus speeds derived from the BA surveys.

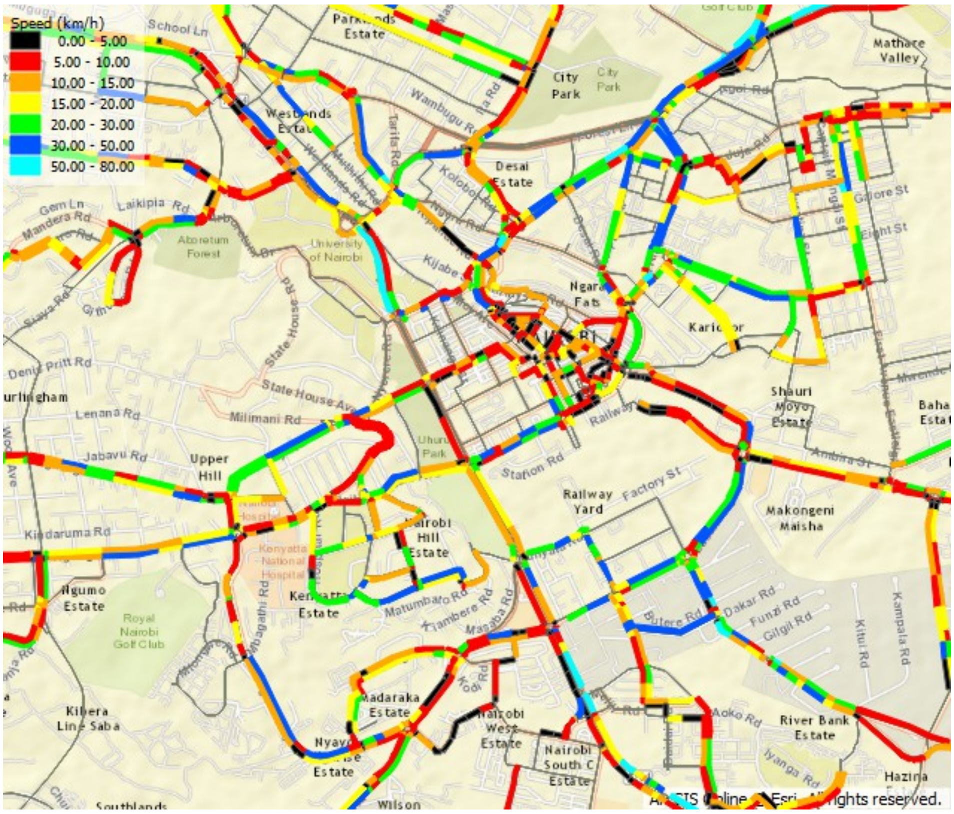

Figure 16. Bus speeds derived from the BA surveys: CBD detail.

4.3 Transfer survey

The objective of the transfer survey is to identify trips comprising f more than one segment. The survey helps distinguish between passengers with origins near the bus stop, passengers who reached the bus stop after traveling on another route and passengers who will transfer to another route from the route being surveyed. In this survey, surveyors boarded public transport vehicles and interviewed passengers to gather details on the respondents' current trips. The survey took place during the morning peak period (6:00-10:00) on weekdays in June 2019.

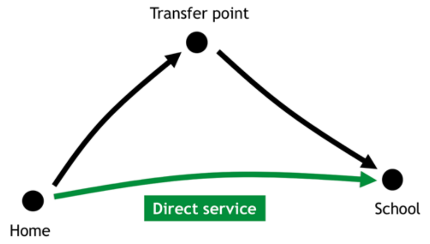

Figure 17. The transfer survey identifies trips with more than one segment (black). The introduction of new services (green) can help reduce the need for transfers.

Data from the transfer survey indicate that a large number of passengers transfer one or more times to complete their journeys. Forty two percent of the passengers transfer at least once to finish their trip. Out of all journeys, 35 percent of passengers transfer once, 7 percent transfer twice, and 0.3 percent transfer more than two times.

Figure 18. Transfer survey results for passengers boarding along the Line 2 corridor: green = origins, red = destinations.

5. Public transport model preparation

A public transport model is a simplified representation of the public transport systems that allow for the simulation of operations and projections of future conditions. It is a tool that provides planners with information to better gauge the impact of different future scenarios and aids in making critical operational decisions about the BRT system.

5.1 Network development

5.1.1 Road network

A geographical representation of the existing road network based on actual shapes observed in satellite imagery was plotted using QGIS, an open-source GIS software. The exercise focused on plotting the major streets that link different parts of Nairobi and carry public transport routes. The network layer is represented as a set of nodes and links. Nodes are locations, defined by latitude-longitude coordinates, where links start, end, or branch, while links are conduits that carry vehicles from one node to another. Each link has a set of attributes corresponding to actual features on the ground, such as length and direction of movement (i.e., one-way or bidirectional movement).

Figure 19. Existing street network represented as a set of links and nodes in the model.

5.1.2 Public transport lines

The geographic coordinates of over 12,000 official bus stops and popular informal stops captured during the BA survey were loaded onto the network. A large number of public transport vehicles pick and drop passengers at unofficial stops along each corridor, as demonstrated by the continuous string of stops along many streets. In order to simplify the information for modelling purposes, stops within a 50 m radius of each other were consolidated into discrete stops. This exercise reduced the number of stops to approximately 2,260 locations that best represent the location of major stops identified through the BA survey. New nodes were then introduced on the road network at each stop location to mark where riders can board and alight from a vehicle.

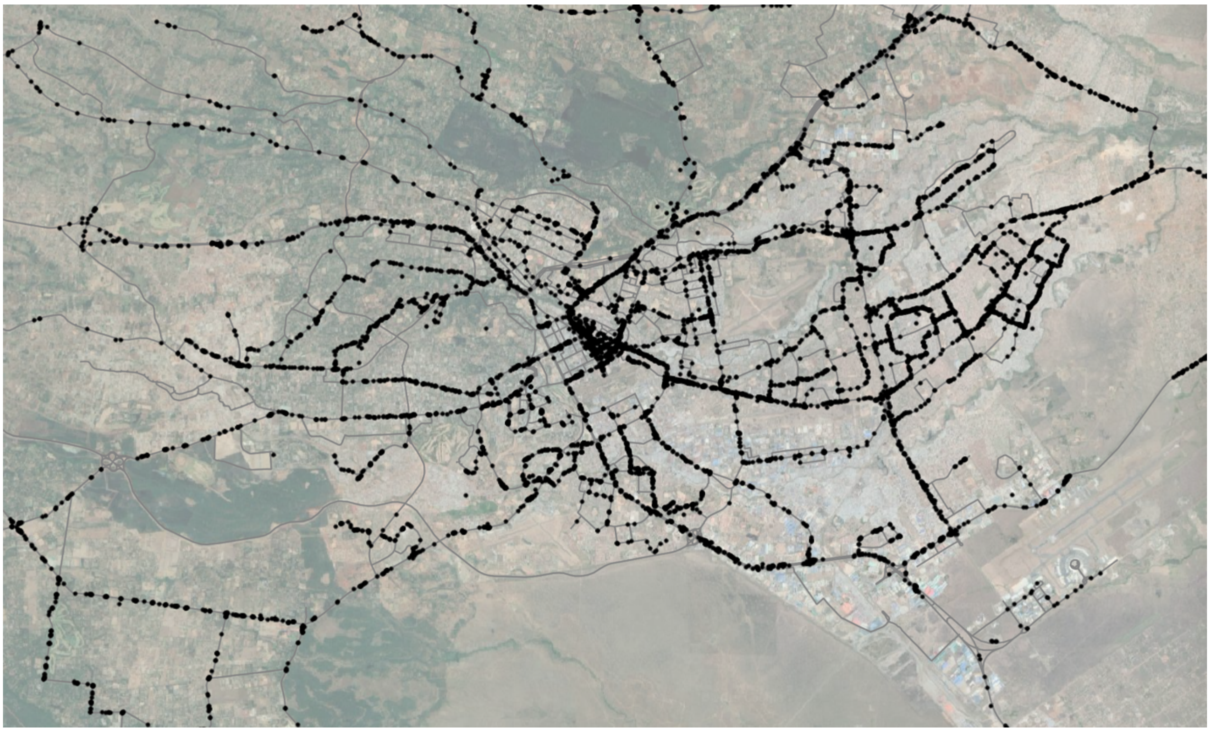

Figure 20. Boarding and alighting points captured during the BA survey.

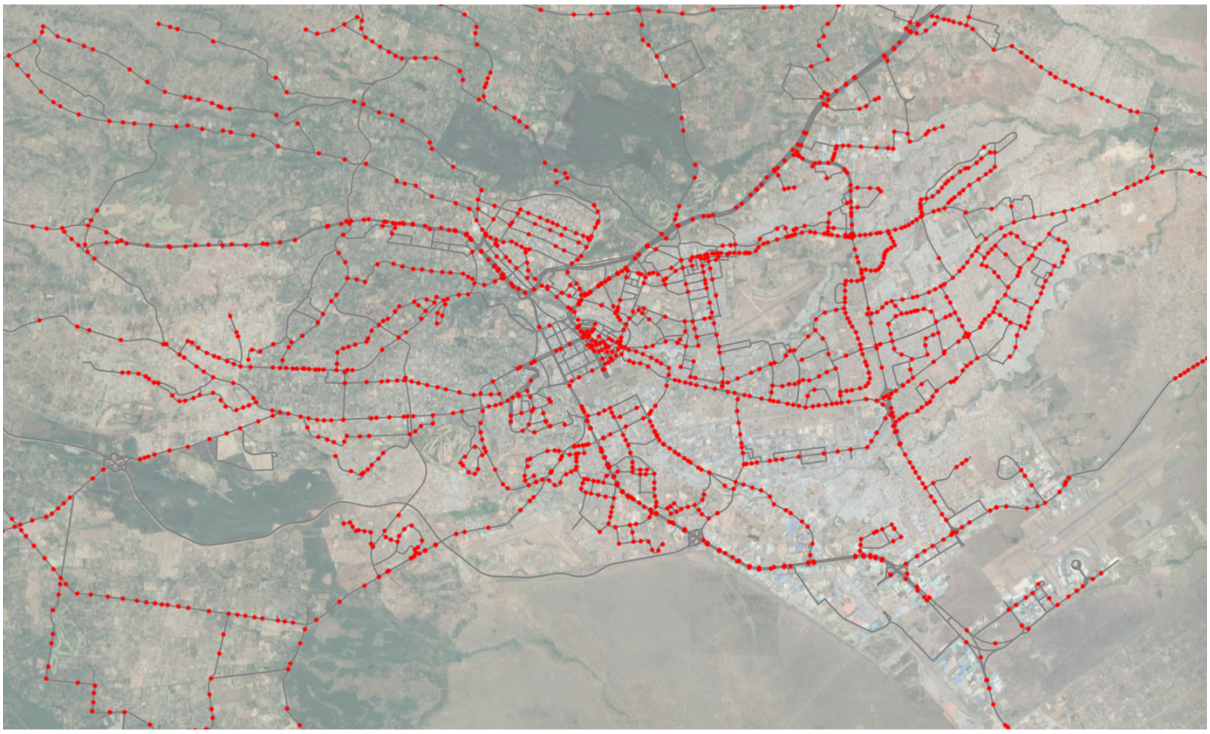

Figure 21. Consolidated stop locations in the model.

Most public transport services do not follow a fixed route. Itineraries can vary due to congestion, weather, and construction, amongst other factors. While this may make services seem chaotic and unpredictable, when itineraries from repeat BA surveys are mapped, patterns of regularity emerge. Almost all routes have a definite origin and final destination. In order to create routes that best fit BA survey observations, itineraries which appeared to be traced by most samples of each route, were plotted as a single line to represent the actual route followed by a particular service. Each route was plotted over the street network and assigned a corresponding route number. A collection of all routes and stops the routes trace over were stored as the route system.

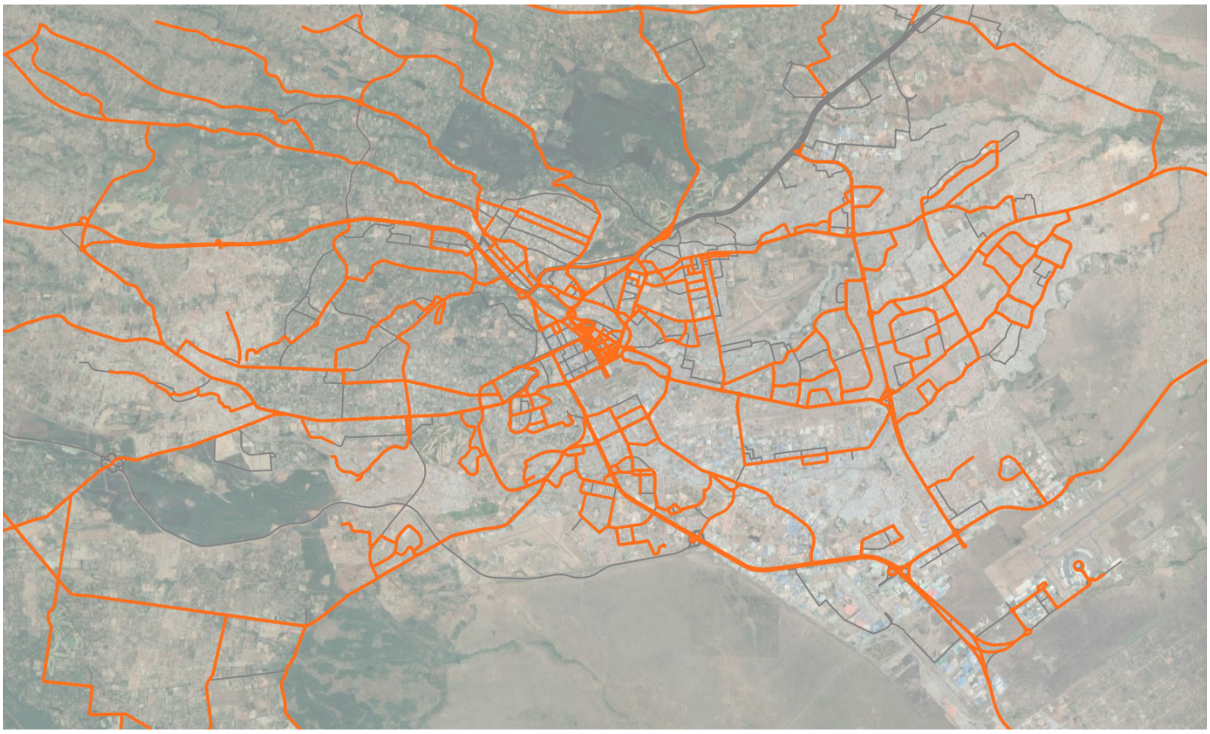

Figure 22. The 131 bus routes surveyed in the study.

5.2 Origin-destination matrix development

5.2.1 Modelling procedure

To develop a model capable of estimating future demand for a BRT system, the first step is to develop an accurate representation of existing travel patterns along the corridor. A key step in the process is to develop an origin-destination matrix indicating the number of passengers travelling from one bus stop in the city to every other bus stop. The matrix is prepared using data obtained during boarding and alighting survey, frequency-occupancy survey, and transfer survey. The following procedure was adopted:

- **Step 1: Determine the average route profile per direction.** Information from the onboard boarding and alighting survey is joined to determine the number of passengers boarding and alighting at each stop along the itinerary. The analysis is conducted for each sample and for both directions of the route. All of the samples for each route/direction are merged to obtain the average number of boardings and alightings at each stop for each route/direction. In boarding-alighting surveys, a small mismatch is typically observed in which the total boardings will not necessarily equal the total alightings. In such cases, a correction is introduced to systematically match the total number of boarding and alighting for each route/direction according to the maximum value (boarding or alighting).
- **Step 2: Get the route profile per direction per hour.** The model is built for morning peak hour (7:00 to 8:00). Data from the frequency-occupancy surveys is used to expand each route profile per the corresponding frequency observed in the survey. The database contains each route profile during the morning peak hour. At this step, the total boardings and alightings by stop are extracted from the database.

- **Step 3: Convert boardings/alightings into a stop-to-stop matrix for each route/direction.** Once boardings and alightings for all of the stops along each route itinerary are known, a distribution model (Fratar) is used to calculate a stop-to-stop matrix. At each stop, the boardings are distributed among the following stops according to the observed proportions of alightings. The process is iterative and seeks to match the total boardings and alightings at each stop. Some considerations are made regarding the probability to alight at the stops immediately following the boarding point, with the first stop after boarding having a very low probability of 0.1, the second stop having a probability of 0.4, the third stop, 0.7, and all of the other stops, 1.
- **Step 4: Adjust the stop-to-stop matrix using transfer data.** The transfer surveys are used to substitute the stop-to-stop matrix with the real origins and destinations identified in the survey. The transfer trips at each terminal are identified, including the first origin, last destination, and routes/direction used. The transfer survey sample is expanded to match the total number of boarding/alighting estimated in the stop-to-stop matrix. At the end of the process, each stop is associated with a zone in the model. Data from all of the bus routes are summed by zone to obtain the final origin-destination matrix.

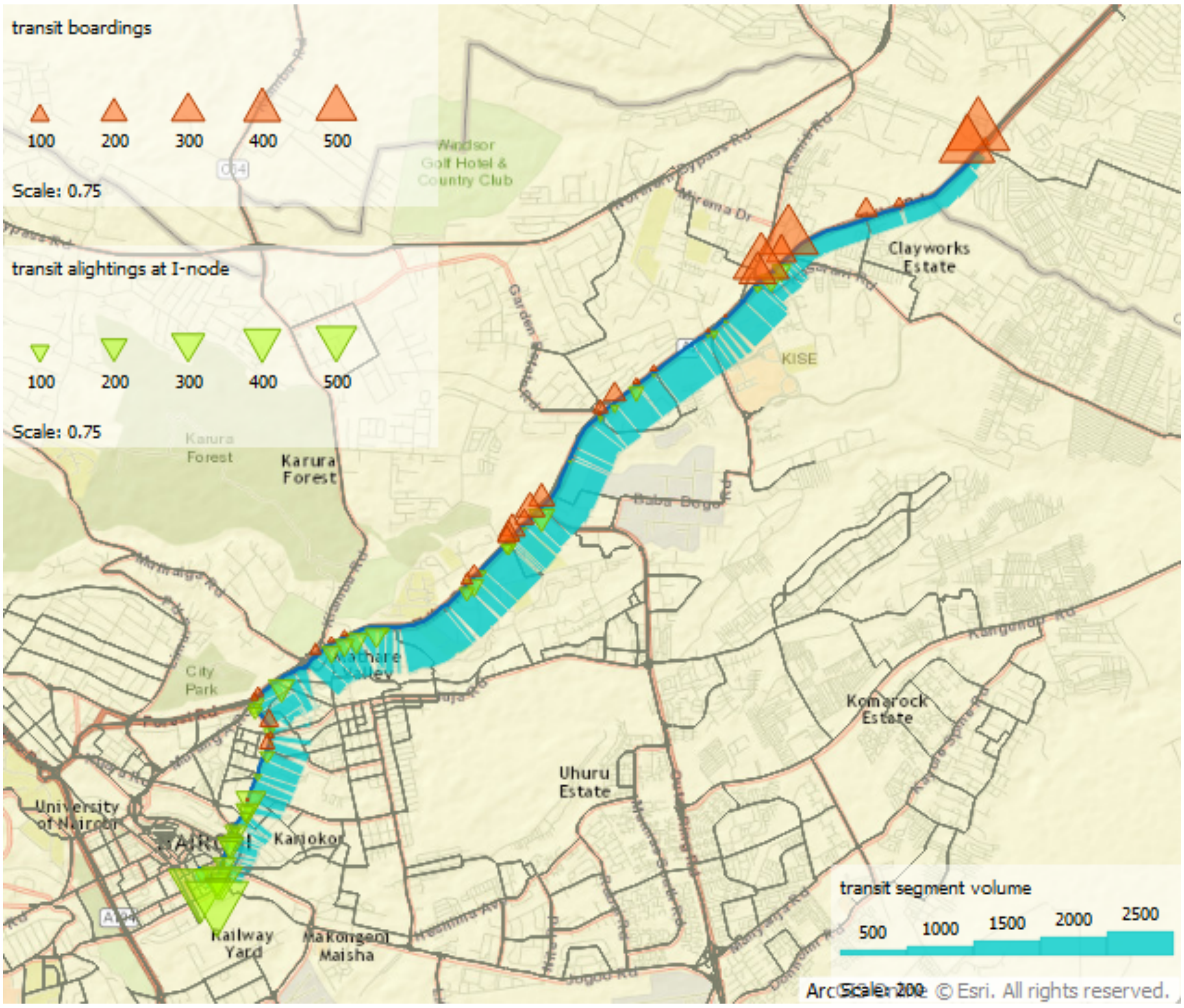

Figure 23. Sample route profile showing boarding and alighting during the morning peak hour.

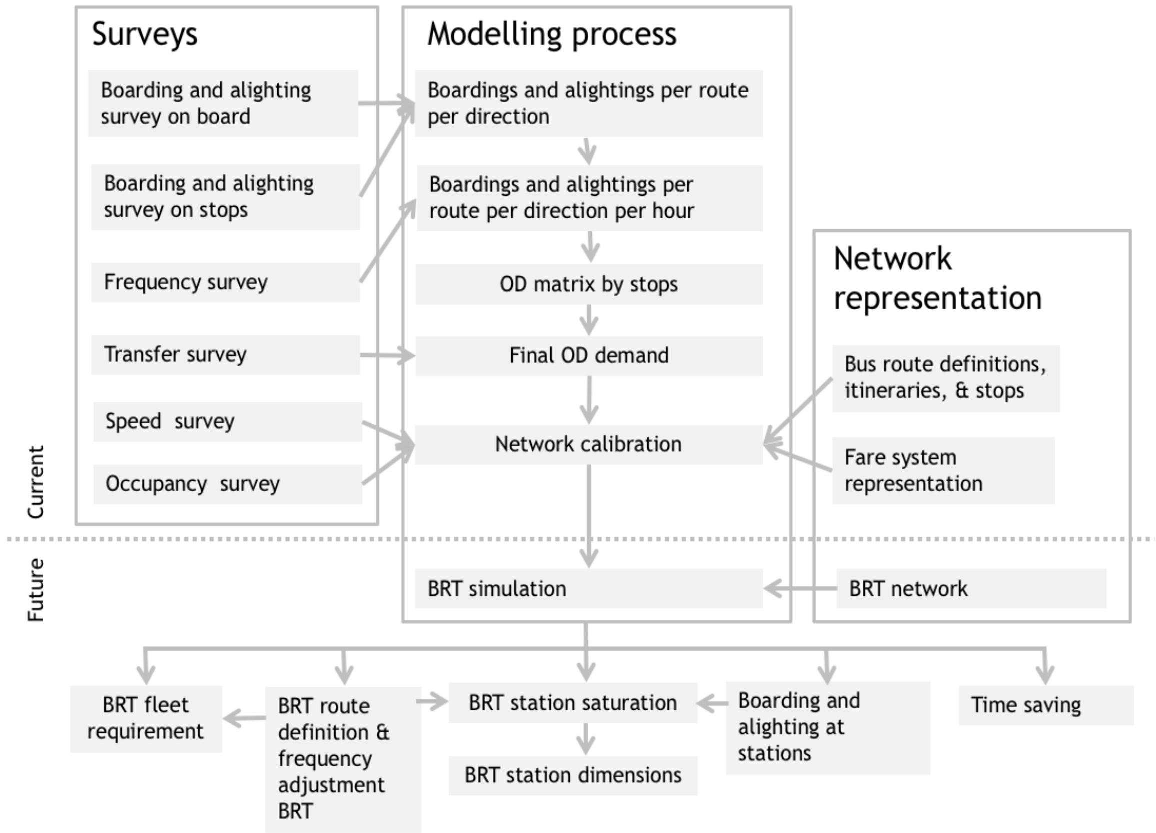

Figure 24. The planning process per the Nairobi BRT Design Framework. Data on travel patterns inform the selection of parameters such as bus route itineraries, frequencies, and fleet sizes.

5.3 Modelling assumptions

The following parameters are assumed in the model.

Impedance. The model considers various factors that influence a passenger's decision to take one transport service rather than another, including travel time components (e.g., walk time, waiting time, and in-vehicle time) and the fare. In the model, the algorithm for trip assignment is based on impedance (generalized cost) according to the formula:

$$I_{ij} = Tinv_{ij} + \alpha \cdot Twait_{ij} + \beta \cdot Twalk_{ij} + Tfare_{ij} + Ttransf_{ij}$$

Where:

- I_{ij} is the impedance from zone *i* to zone *j*.
- $Tinv_{ij}$ is the total in-vehicle time from *i* to *j*.
- $Twait_{ij}$ is the total waiting time from *i* to *j*.
- $Twalk_{ij}$ is the total walking time from *i* to *j*.
- $Tfare_{ij}$ is the fare equivalent in minutes from *i* to *j*, converted from currency to time using to value of time (see below).

- $Ttransf_{ij}$ is the total transfer time penalty from i to j. The transfer penalty, used to represent the perceived inconvenience of making a transfer, is assumed to be 5 minutes for regular buses and 3 minutes inside a BRT station.
- α and β are weights introduced in the calibration process, with $\alpha = 2$ and $\beta = 3$

For the modelling process, all of the parameters above are set up in a control panel and can be adjusted and tested for sensitivity analysis and elasticity.

Fare system. As seen in Figure 25, there is no global relationship between distance and fare. Instead, there is a wide range of fares that vary from route to route. Some routes operate with a flat fare and are represented accordingly in the model. The routes operating with a distance-based fare were separated in two groups:

- When the difference between the maximum and the minimum fare was below 25 percent, the routes were represented with a flat fare equal to the average of the minimum and maximum fares. For example, for route 114W, the minimum fare is KES 80, the maximum fare, KES 100, and a flat fare of KES 90 was adopted in the model.
- When the difference between the maximum and the minimum fare was higher than 25 percent, a specific linear function was estimated for each route, in the form:

$$y = a + bx$$

Where:

- x is the distance
- y is the fare
- a and b are estimated for each route.

The appendix presents the fare considered for each existing route.

For the BRT, the fare was defined as a flat fare of KES 50.

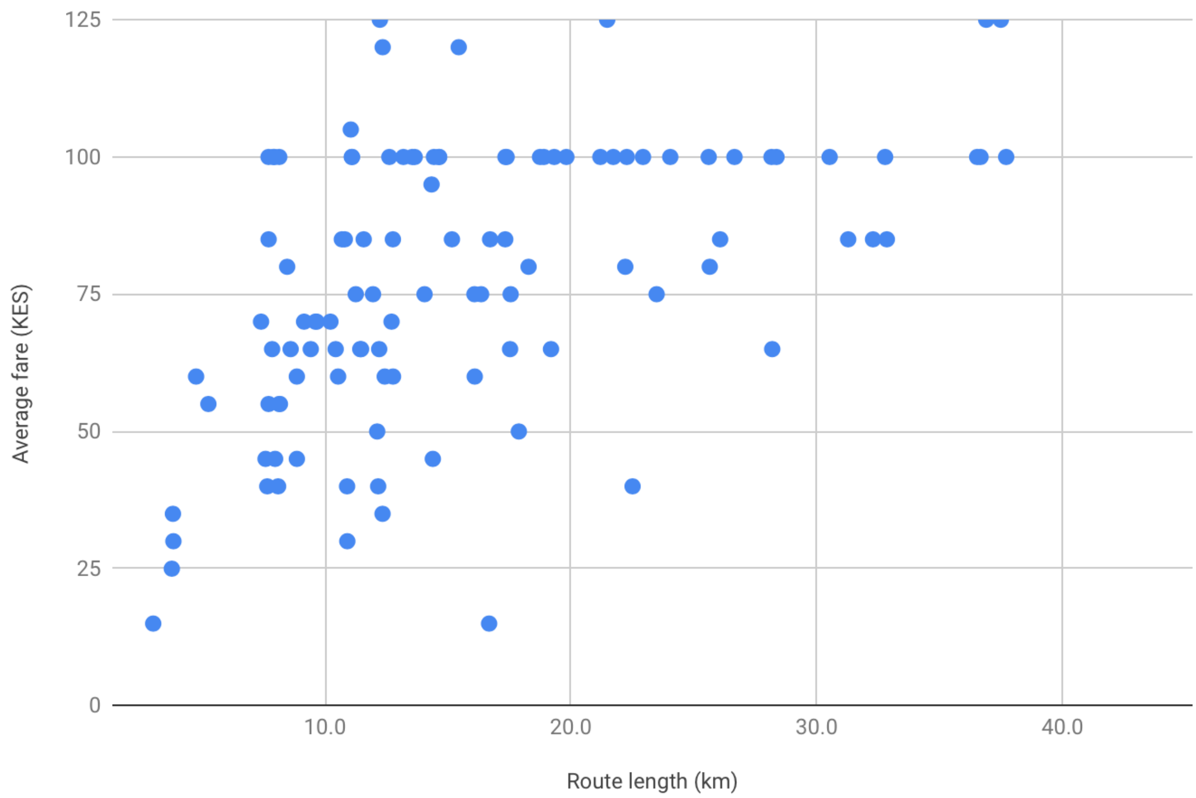

Figure 25. Relationship between fare and distance in Nairobi.

Value of time. In the modelling process, the fare paid by the users must be converted to time in order to calculate impedance. The value of time is estimated according to the average income per capita in Nairobi. In practice, the model should consider the average income for public transport users, which is lower than the average income of the population as a whole. However, information on public transport user incomes is not readily available.

According to the 2016 FinAccess household survey, the average income is estimated in KES 15,159 per month.[1] This is equivalent to KES 90.23 per hour, or 0.6649 minutes for 1 KES. This value is used in the model to convert the matatu fares to time. For example, a fare of KES 50 is equivalent to 33.25 minutes, a fare of KES 80 to 53.19 minutes, and so on.

Speeds. Speeds were collected using GPS as part of the on-board boarding and alighting surveys for all the routes surveyed. The speeds take into account all delays, traffic jams, intersection delays, and dwell time at stops. Accurate speeds are critical to the accurate modelling of real-world behaviour on the network. Speeds enable the model to:

- Display congested areas and bottlenecks under current conditions.
- Calculate in-vehicle travel times in the assignment procedure.

[1] Central Bank of Kenya, Kenya National Bureau of Statistics (KNBS), and FSD Kenya. (2016, Feb). 2016 FinAccess Household Survey. Retrieved from https://www.knbs.or.ke/download/finaccess-2016-survey-report/?wpdmdl=3256

- Get an accurate estimation of the cycle time for bus services, which in turn impacts the fleet size.
- Estimate the benefit of implementing BRT.

5.4 Calibration and baseline scenario

The calibration is the process of adjusting and checking the model to ensure that it represents reality. The main procedure is a matrix adjustment to match the observed passenger counts at principal frequency-occupancy survey locations. The origin-destination (OD) matrix used in the model is a partial matrix that captures information on routes surveyed in Nairobi. While the matrix does not capture all trips in the city, the passenger counts captured through the frequency-occupancy survey include all trips. As a result, some adjustments were made to account for the difference between the total number of passengers traveling on each corridor and those represented in the OD matrix.

The calibration is checked by linear regression between the observed passengers at road sections and the passengers assigned, represented by the following equation:

$$y = a + bx$$

Where:

- x is the number of observed passengers
- y is the number of modelled passengers
- a is the y-intercept
- b is the slope (should be close to 1)

The regression yielded the following values:

- a = -140.226
- b = 1.00714
- Regression coefficient, r^2 (should be close to 1) = 0.955011
- Root mean square error relative to data value (RSME) = 999.264

For the present situation, the model produces results including boardings and alightings by route, passenger loads, route profiles, cycle times, fleets, trip times, and fare by origin-destination.

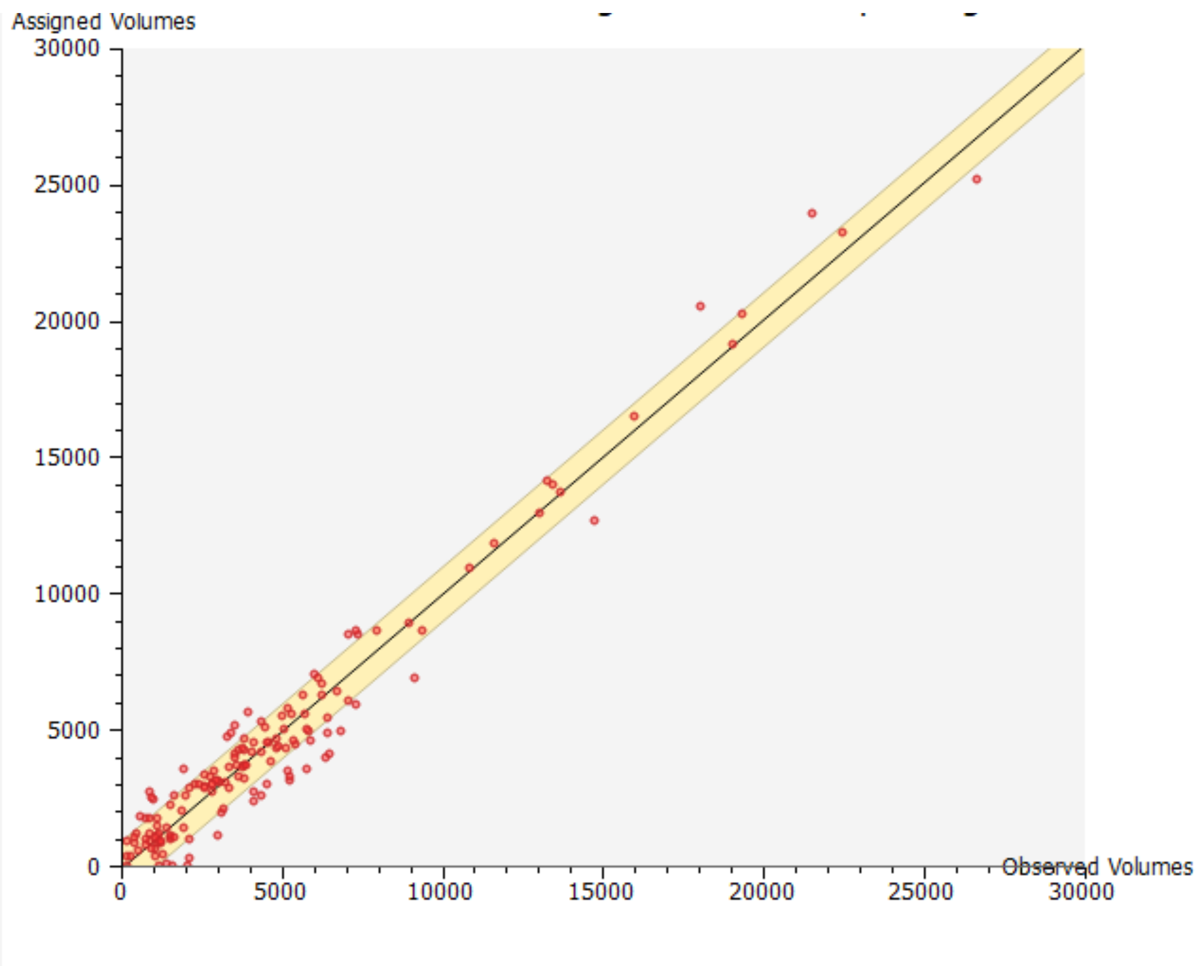

Figure 26. Linear regression between observed and modelled passengers at road sections

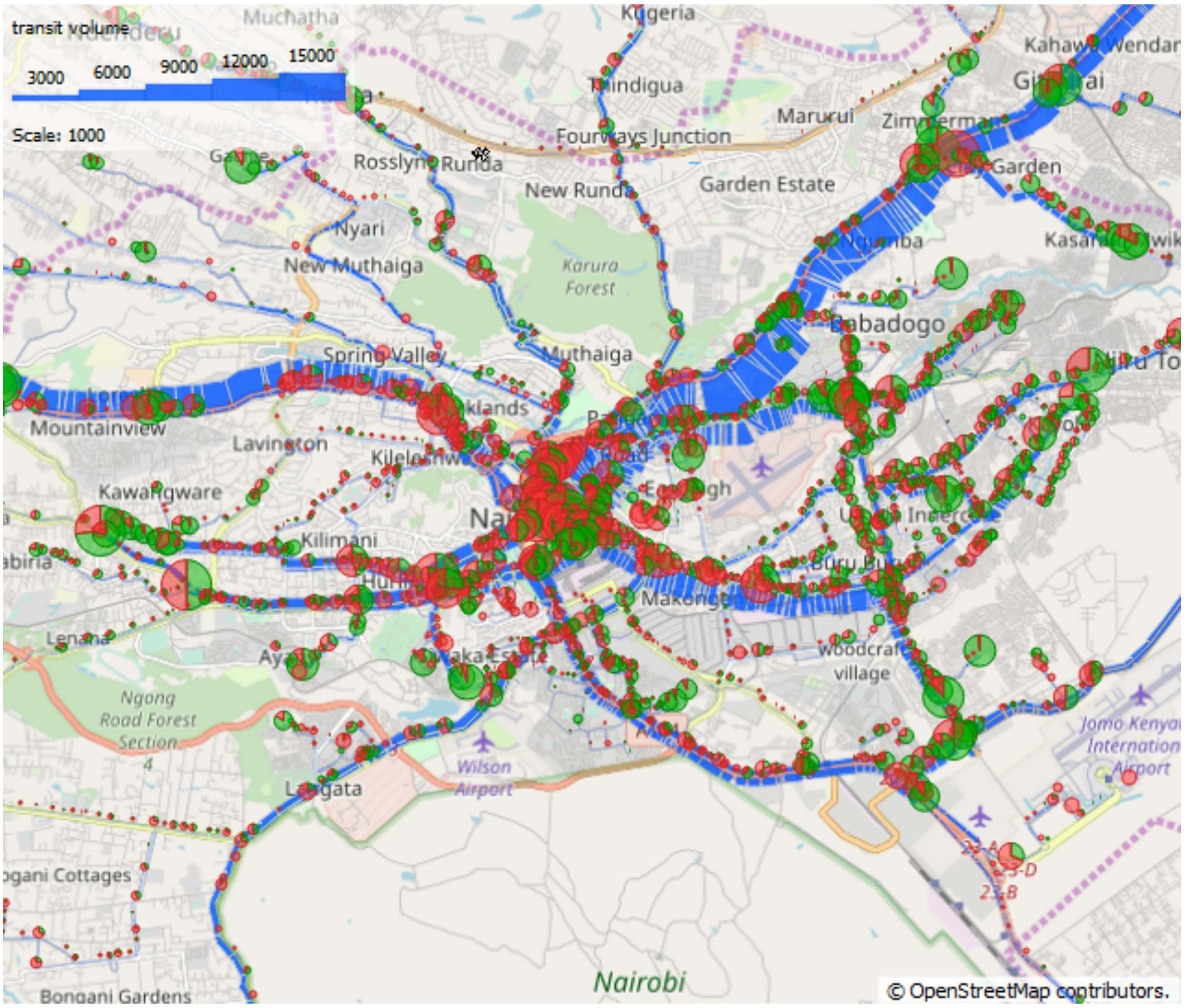

Figure 27. Estimate of existing loads (blue) and passenger boardings and alightings (green/red) during the morning peak hour following calibration of the travel demand model.

6. BRT service plan

6.1 BRT design factors

An efficient BRT service plan can improve customer experiences, reduce the need for transfers, prevent bottlenecks at stations, and prevent delays along BRT corridors. Given that many passenger trips will include origins and destinations beyond a single BRT corridor, the following types of services were considered for the Nairobi BRT network:

- **Trunk services that operate along BRT corridors.** Some services may operate entirely within the dedicated BRT infrastructure, with feeder services used to bring passengers from nearby neighbourhoods to the BRT stations.
- **Services that begin in a BRT corridor and then exit the BRT lanes to provide direct services.** Such services prevent the need for time-consuming transfers for trips with origins and destinations not immediately located within the catchment area of BRT corridors.

- **Express services that skip some stations.** Express services offer faster commercial speeds than all-stop services and reduce congestion at stations. The stops along express services are selected to provide optimum connectivity for the greatest number of passengers.

For the Thika Rd corridor, a direct service typology was determined to be the most effective way to serve the corridor demand for the following reasons:

- Most existing matatu routes on Thika Rd provide express-style service from residential areas to central Nairobi. Compared to other corridors in the city, there is less passenger renovation along the corridor itself.
- In most cases, existing routes typically pick up passengers off the corridor and then join the highway. If passengers who currently enjoy a one-seat journey to the CBD need to transfer from feeders to trunk services, the BRT will be less competitive.
- Due to the geometry of interchanges, it is difficult to develop transfer stations or terminals directly at intersections with adjoining streets. For example, at intersections such as Kasarani, Outer Ring Road, and Githurai, stations will need to be constructed away from existing grade separators.

The following diagram displays the proposed service structure for the Thika Rd corridor. A core trunk corridor offers a dedicated right-of-way for 16 km along Thika Rd, freeing buses from the congestion experienced near the city centre. Direct services will pick up passengers from residential areas adjacent to the dedicated corridor and will extend along Thika Rd to communities such as Ruiru, Thika, and Juja. In the city centre, direct services will extend to Westlands and Upper Hill, thereby allowing passengers to reach their destinations without making a transfer in the CBD.

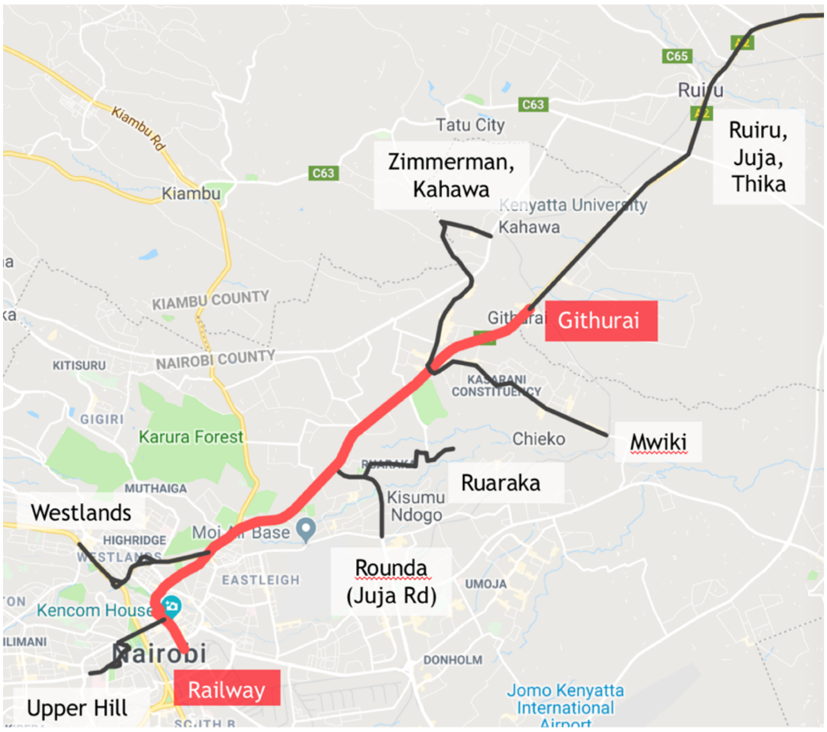

Figure 28. Dedicated corridor (red) and service extensions (black).

While service typologies may differ from corridor to corridor, the design of physical infrastructure in the BRT system should permit flexible operations. In particular, system designs should incorporate the following elements:

- **Buses with doors on both sides.** Buses providing direct services will require doors on the left side to facilitate level boarding at median stations as well as doors on the right side that can be used for service extensions.
- **Provision for BRT turning movements at intersections.** Intersection designs should allow for turning movements of BRT buses at the intersection of key corridors.

In addition to the services described above, the other public transport services will interact with the BRT corridor. It is important that the corridor provides convenient transfer opportunities for passengers who still need to transfer following the introduction of the BRT.

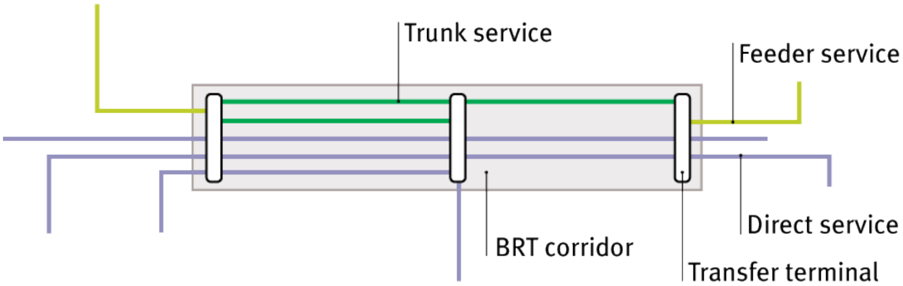

Figure 29. The Nairobi BRT will incorporate a variety of services to improve efficiency and minimise passenger transfers, including direct services that extend beyond the dedicated BRT corridors to outlying areas.

6.2 BRT services

Many scenarios have been tested to reach a configuration with a limited number of transfers and an optimal fleet. The following images display the final routes that were selected.

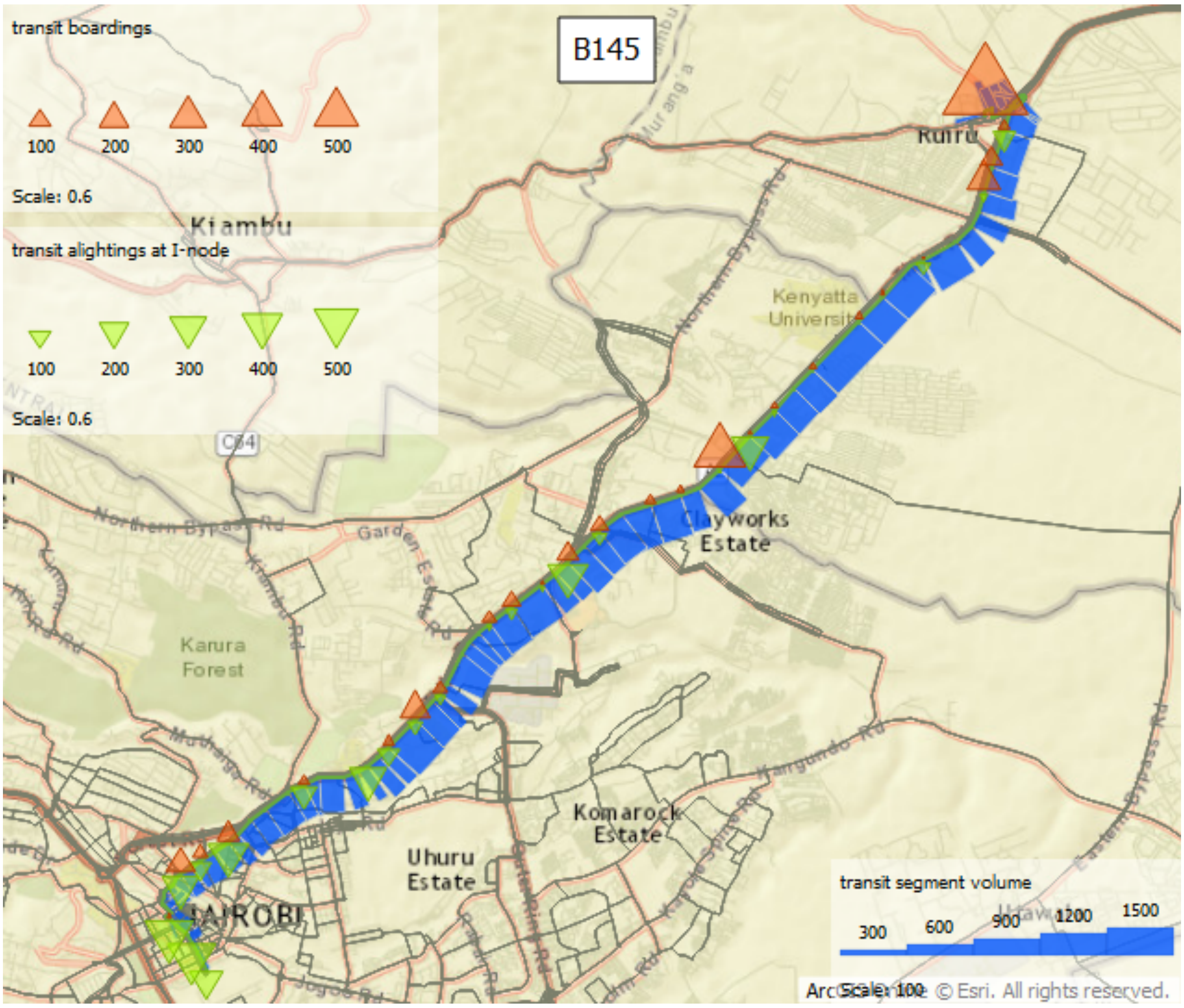

Figure 30. Boarding pattern and passenger load on route B145: Ruiru to Railways.

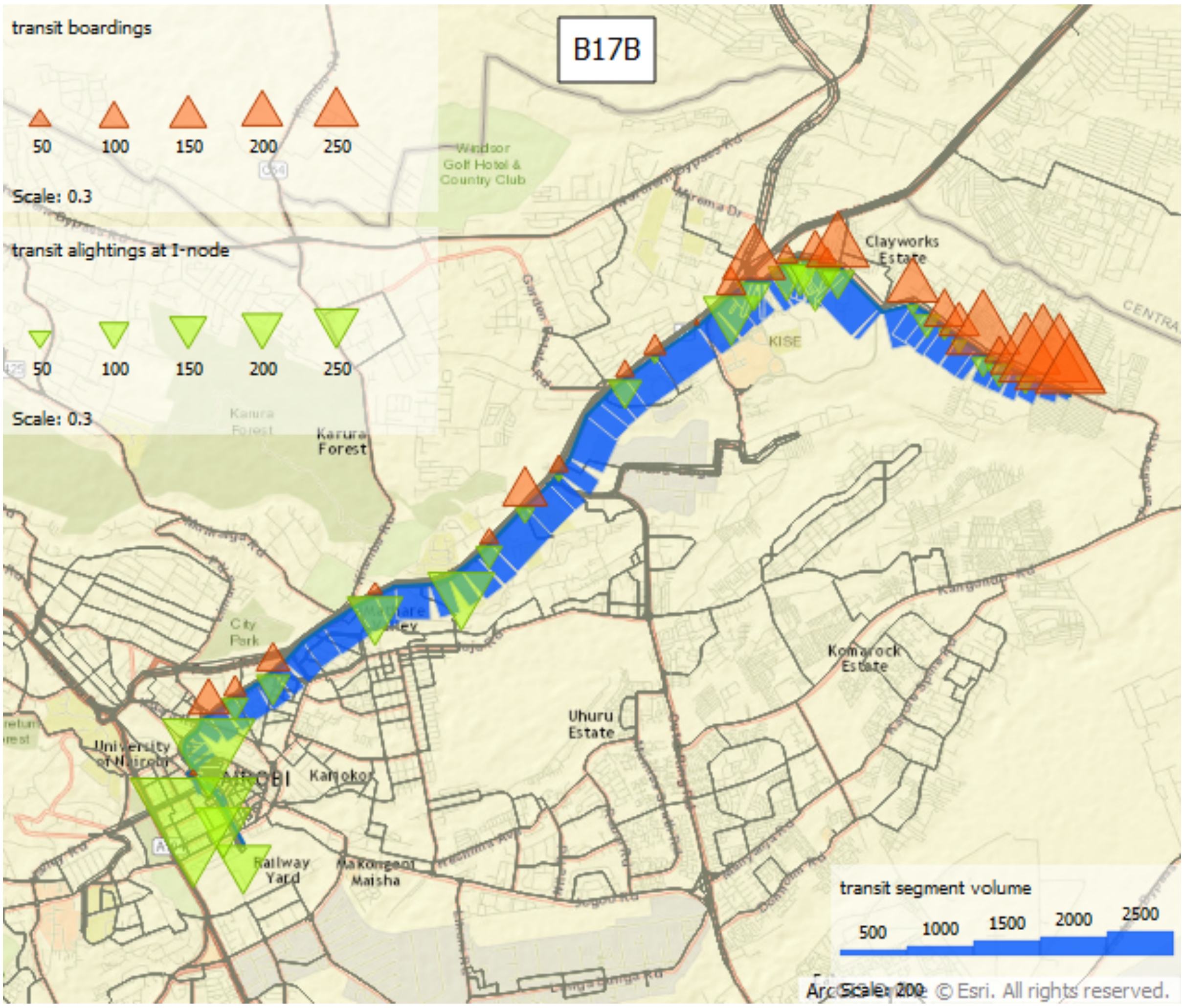

Figure 31. Boarding pattern and passenger load on route B17B: Mwiki to Railways.

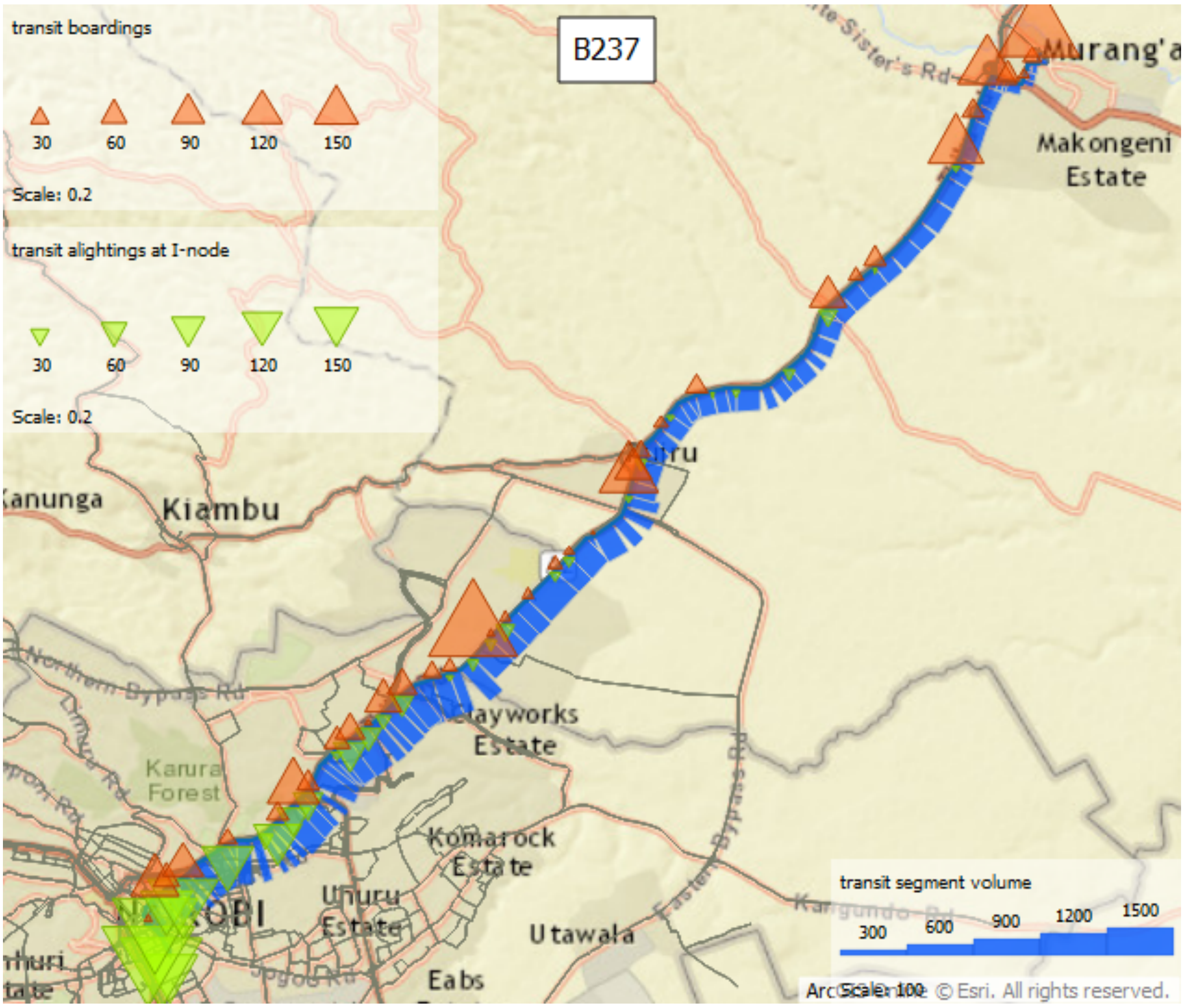

Figure 32. Boarding pattern and passenger load on route B237: Thika to Railways.

Figure 33. Boarding pattern and passenger load on route B237e: Thika to Railways (express).

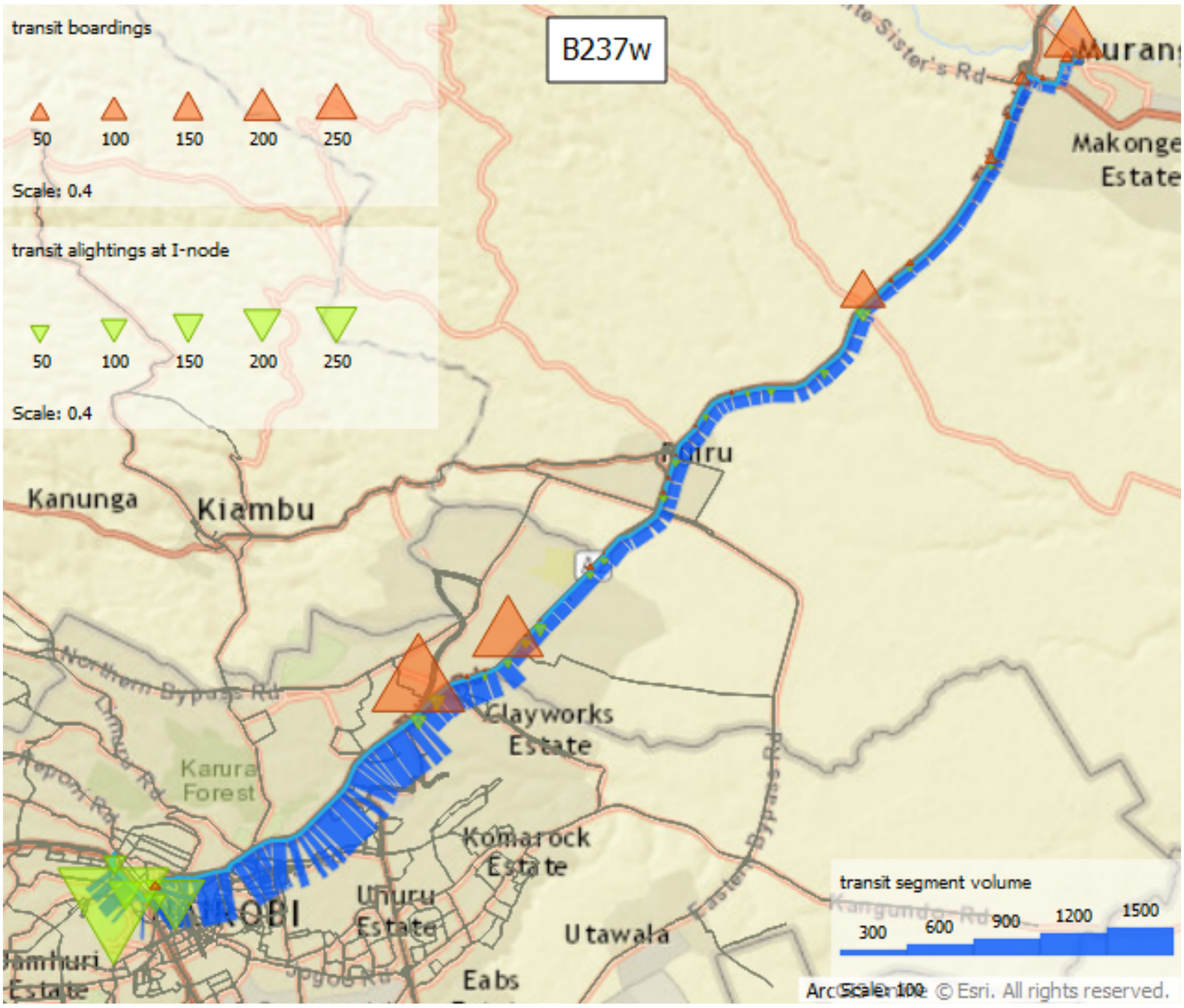

Figure 34. Boarding pattern and passenger load on route B237w: Thika to Westlands.

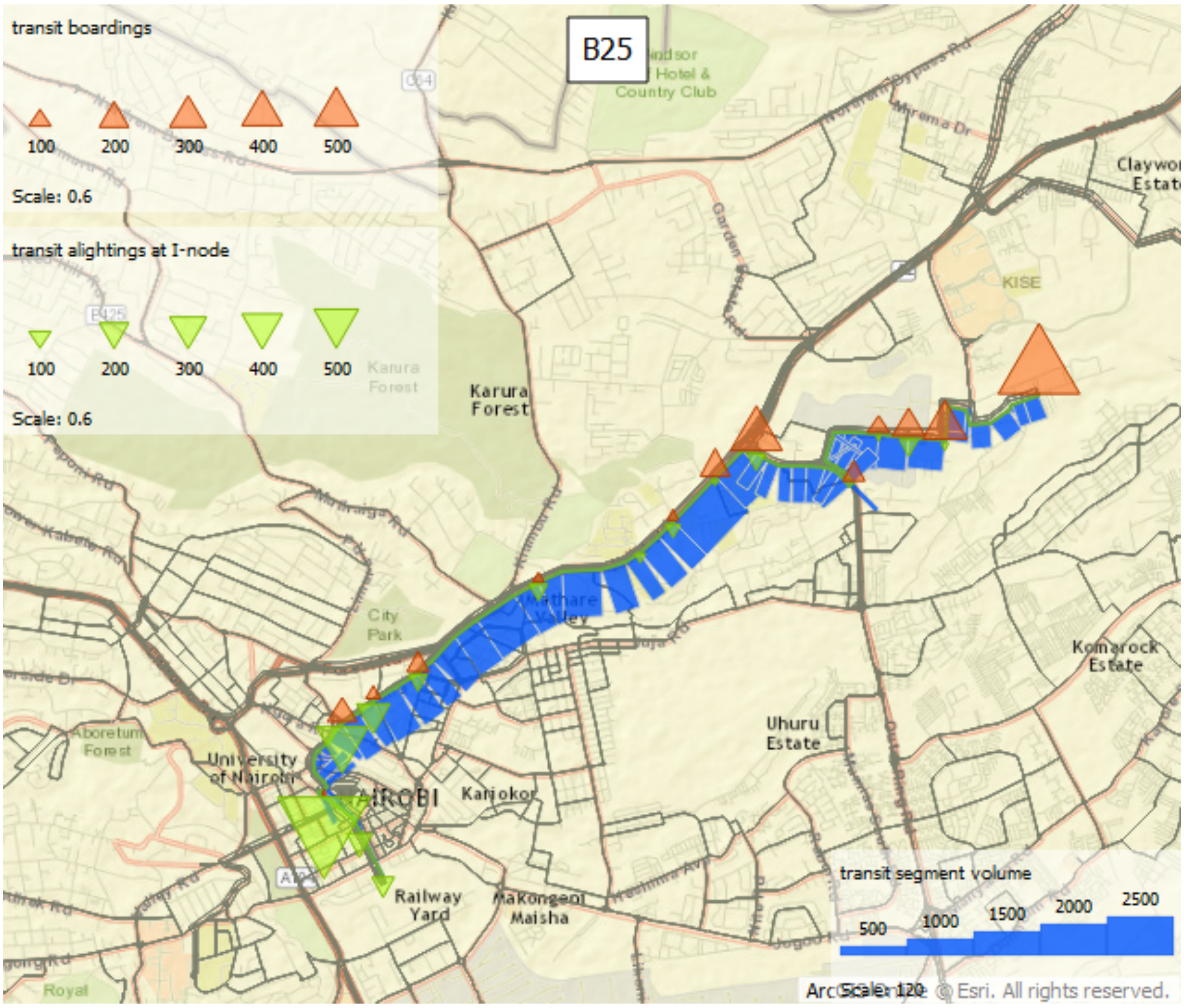

Figure 35. Boarding pattern and passenger load on route B25: Ruaraka/Lucky Summer to Railways.

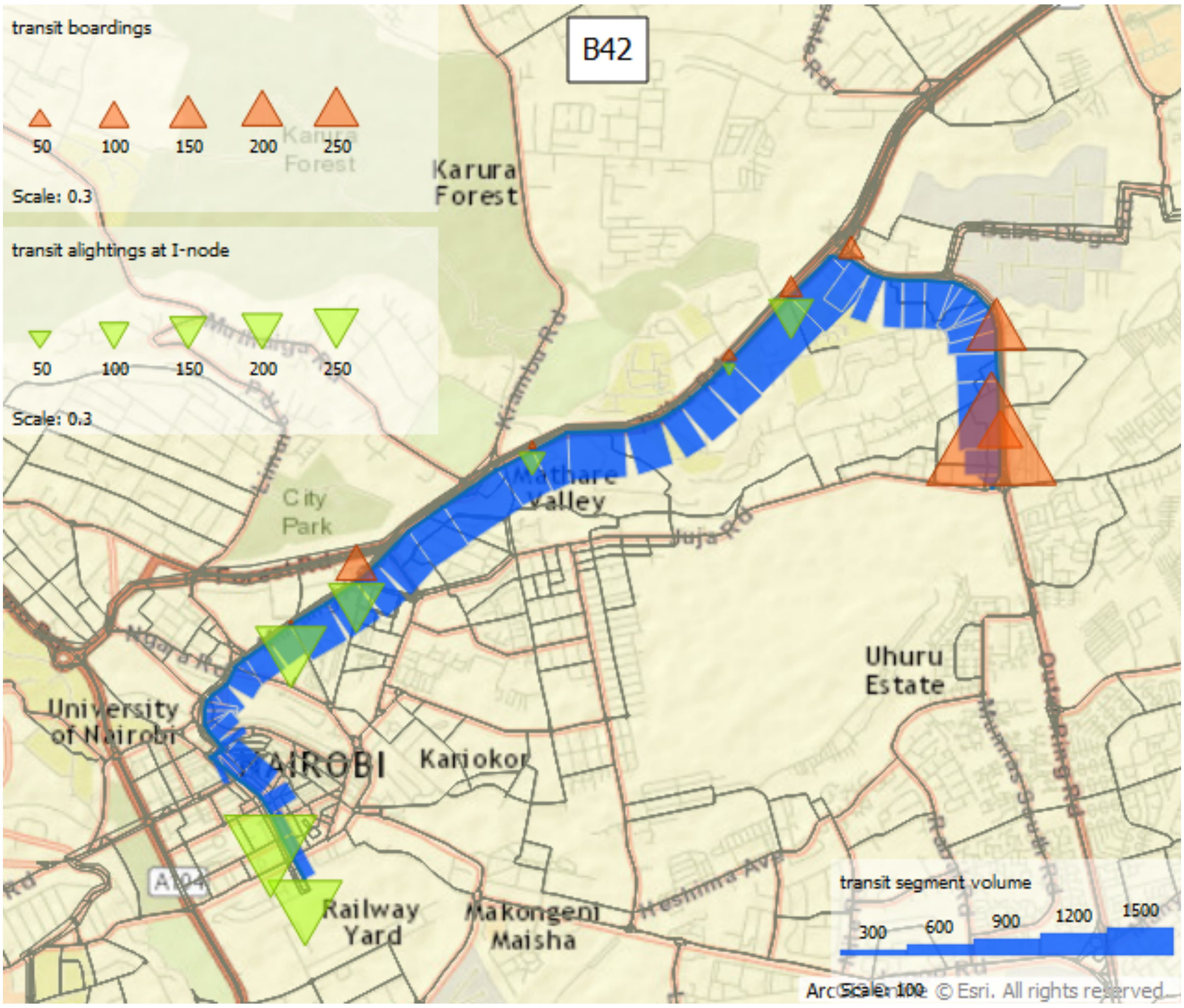

Figure 36. Boarding pattern and passenger load on route B42: Rounda (Juja Rd x Outer Ring Road) to Railways.

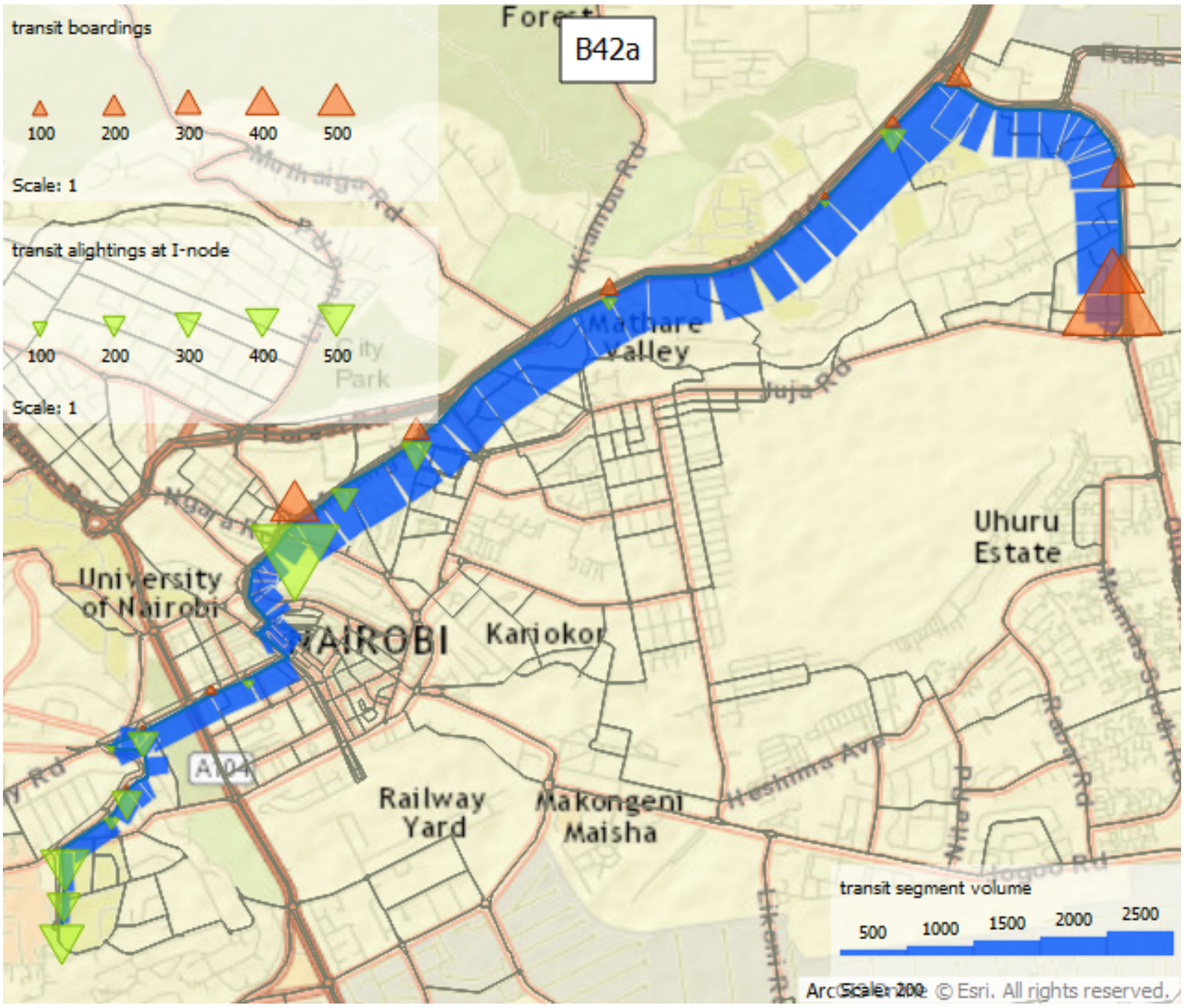

Figure 37. Boarding pattern and passenger load on route B42a: Rounda (Juja Rd x Outer Ring Road) to Upper Hill.

Figure 38. Boarding pattern and passenger load on route B42b: Rounda (Juja Rd x Outer Ring Road) to Westlands.

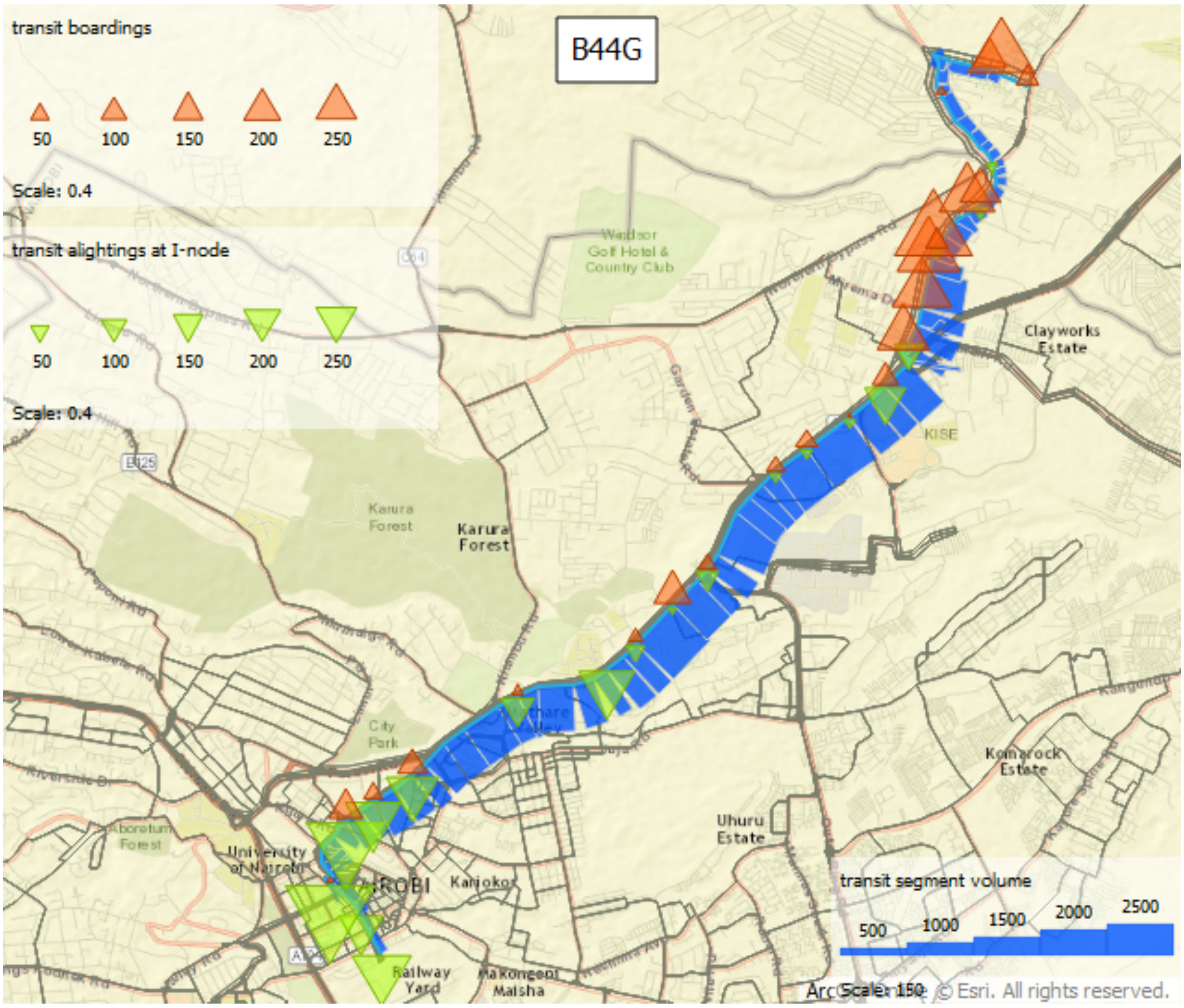

Figure 39. Boarding pattern and passenger load on route B44G: Kahawa/Zimmerman to Railways.

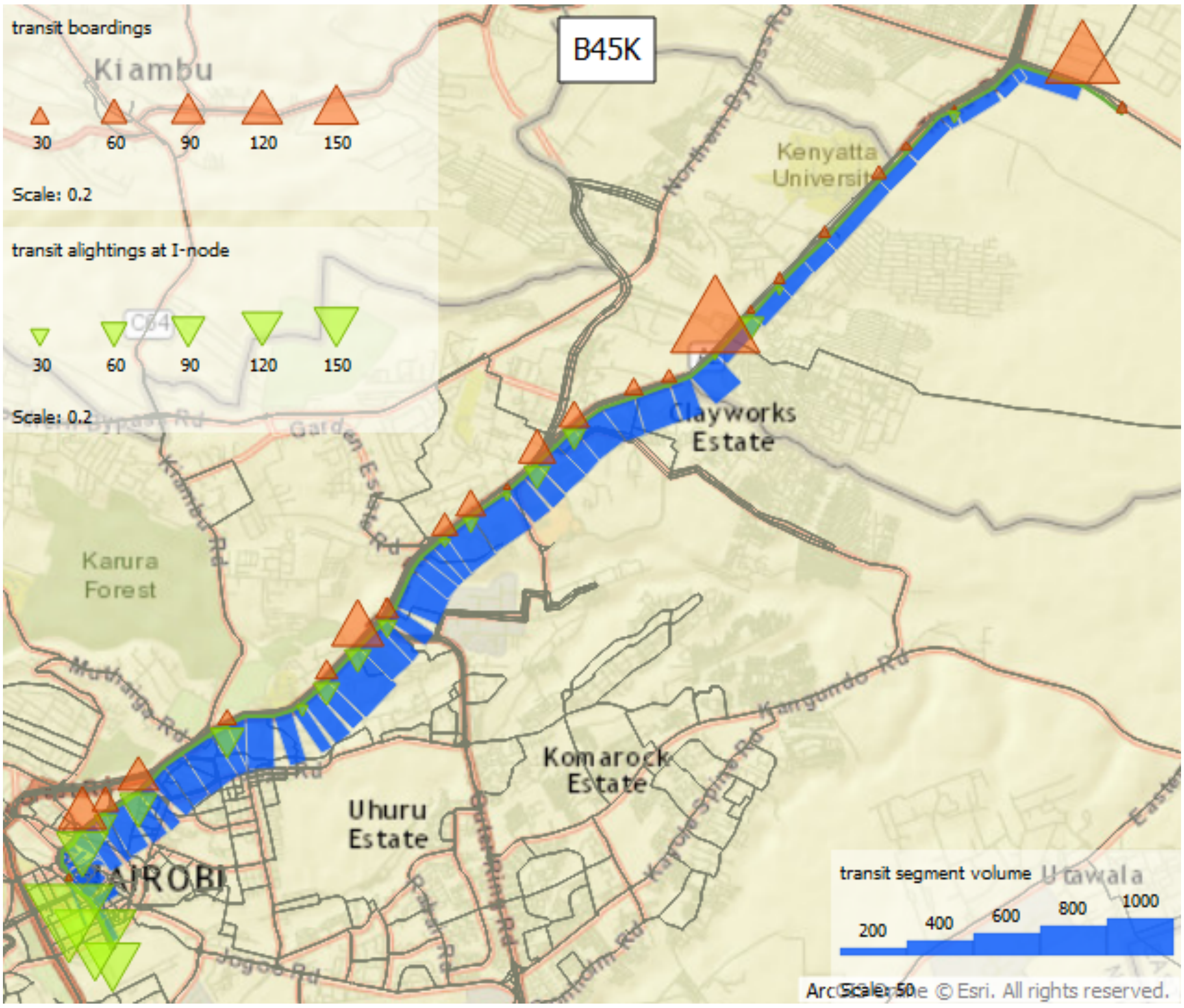

Figure 40. Boarding pattern and passenger load on route B45K: Eastern Bypass to Railways.

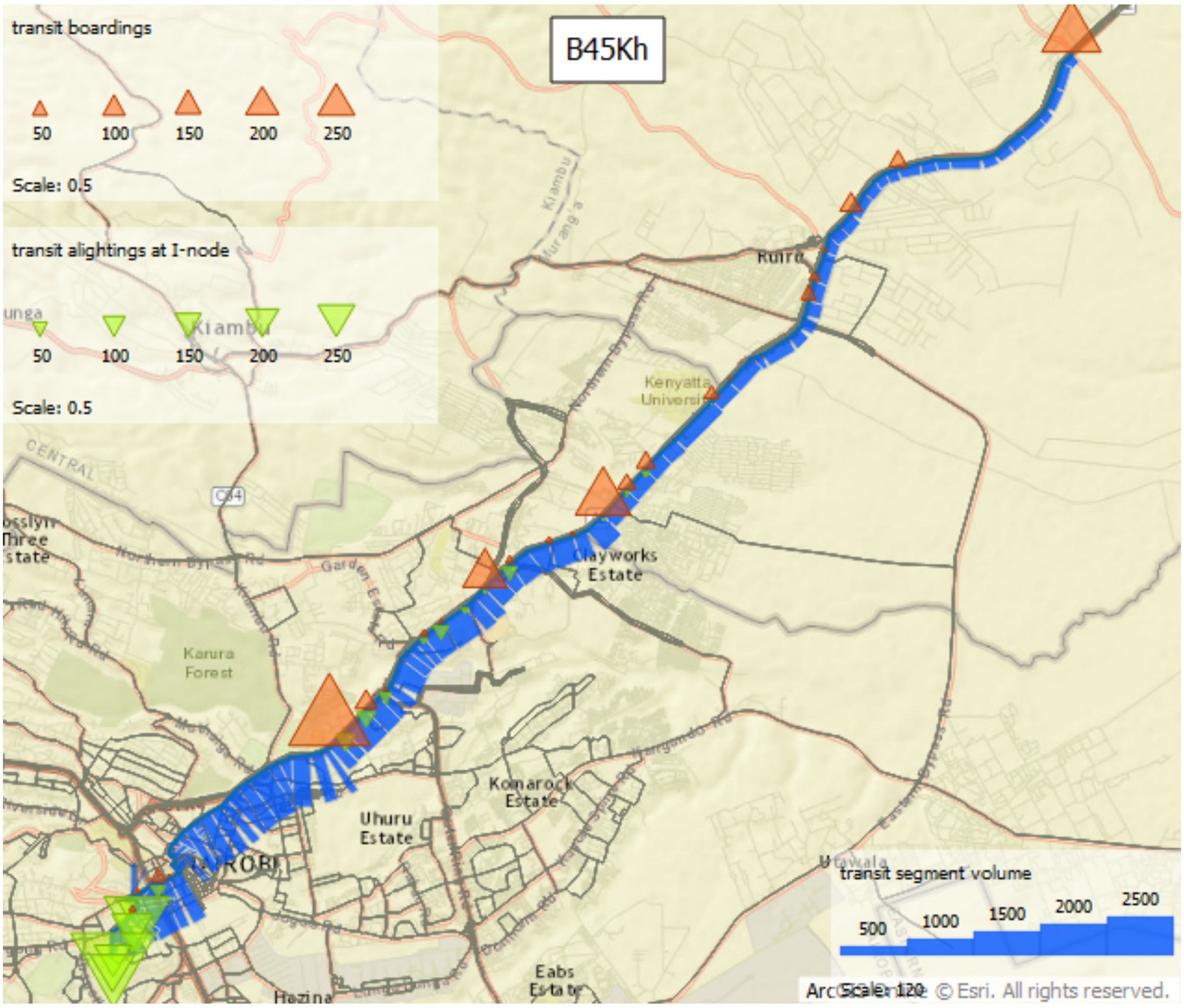

Figure 41. Boarding pattern and passenger load on route B45Kh: Juja to Upper Hill.

The BRT fleet is comprised of articulated buses shown in Figure 42, with a capacity of 140 passengers per bus. A layover of 2 minutes per one-way trip is assumed for each route. The operational fleet needed to operate the system is estimated to be 555 articulated buses, corresponding to a total fleet of 611 buses with a 10 percent reserve. The average speed for local BRT service inside the corridor is 24.5 km/h. Factoring in the express services, the average speed for the system is 28 km/h.

Figure 42. An articulated bus.

Table 3 displays the passenger demand, headway, and required fleet size for each BRT service.

Table 3. BRT service characteristics.

Line	Length (km)	Max load (pphpd)	Boardings, peak hour	Boardings, daily	Headway (min)	Fleet size (no reserve)
B145N	24.1	307	929	8,361	3.7	16
B145S	25.6	2,288	3,783	34,047	3.7	17
B17BE	17.7	364	675	6,075	1.9	32
B17BW	17.3	4,538	6,583	59,247	1.9	32
B237N	44.3	644	1,489	13,401	3.3	29
B237S	43.4	2,560	3,513	31,617	3.3	29
B237eN	44.3	1,634	2,386	21,474	2.8	32
B237eS	43.4	3,052	3,204	28,836	2.8	31
B237wN	44.4	2,273	3,097	27,873	3.1	33
B237wS	44.1	2,741	2,982	26,838	3.1	34
B25E	12.6	234	576	5,184	2.7	16
B25W	13.2	3,088	3,716	33,444	2.7	18
B42E	10.9	206	232	2,088	3.1	11
B42W	10.7	2,683	2,974	26,766	3.1	10
B42aE	12.9	1,998	2,227	20,043	1.5	30
B42aW	12.6	5,449	6,873	61,857	1.5	29
B42bE	11.0	203	207	1,863	8.0	6
B42bW	11.4	1,051	1,065	9,585	8.0	6
B44GN	18.6	437	1,197	10,773	2.0	31
B44GS	18.5	4,204	5,269	47,421	2.0	31

Line	Length (km)	Max load (pphpd)	Boardings, peak hour	Boardings, daily	Headway (min)	Fleet size (no reserve)
B45KE	23.7	326	976	8,784	5.8	10
B45KW	23.6	1,452	2,156	19,404	5.8	10
B45KhE	34.0	693	1,102	9,918	2.6	31
B45KhW	33.9	3,291	3,625	32,625	2.6	31
Total	596		60,836	547,524		555

6.3 Modifications in regular services

The bus route restructuring plan modified the original matatu and bus routes along the Line 2 corridor as follows:

- A set of seven existing bus routes with a high percentage of the itinerary length overlapping the corridor were converted into BRT routes. These routes are:
    - 145
    - 17B
    - 237: Split into 3 routes: regular, express to Railways, and express to Westlands
    - 25
    - 42: Split into 3 routes: regular, express to Westlands, and express to Upper Hill
    - 44G
    - 45K: Split into 2 routes: regular and express to Upper Hill
- Other existing bus routes with a high percentage of itinerary length overlapping the corridor and itineraries that are similar to the seven routes already included (see above) were removed. The removed routes are:
    - 49
    - 45G
    - 44Z
    - 43
    - 29-3
    - 25A
- The routes along Kiambu Rd were retained as matatu services because there is only a short stretch of overlap between these services and Thika Rd.

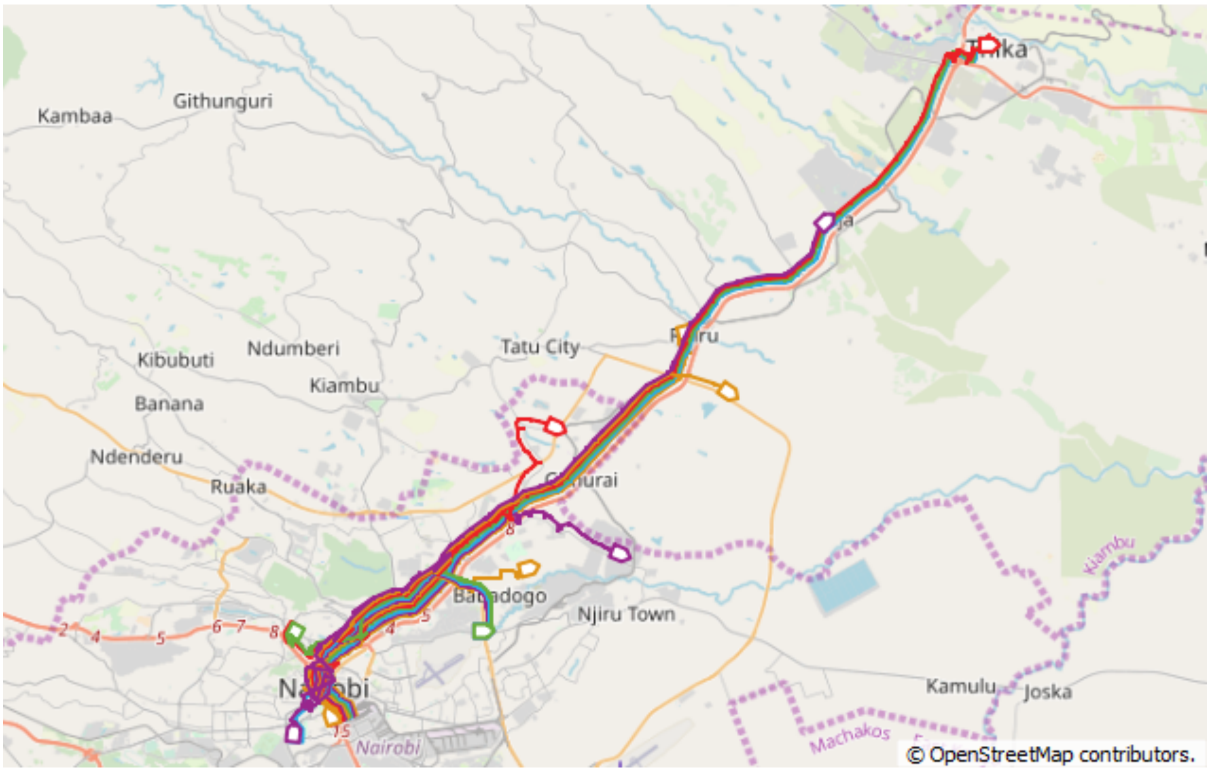

Figure 43. The 12 BRT services.

Figure 44. Six existing routes removed.

7. Impacts of the BRT scenario

Passengers using the BRT will benefit from significant time savings. The BRT, operating in a segregated right-of-way, will be able to transport people more efficiently than existing public transport services. It will offer a very high quality of service for users and will help to reduce urban congestion. In terms of time spent riding in public transport vehicles, the average benefit for passengers from Thika to downtown is 22 minutes per trip. From Ruiru to downtown the average benefit is 18 minutes. Residents will save many hours each year that they otherwise would have spent sitting in traffic, thereby improving their quality of life. The dedicated lanes will give the BRT system a speed advantage over vehicles operating in congested mixed traffic lanes. A BRT system that offers quicker journeys and provides convenient access to popular destinations can compete with competing modes, including private cars and taxis.

The monetary cost of a journey also will fall, with an assumed BRT fare set at KES 50 compared to a current average fare of KES 70 for passengers travelling from Thika to town. The "generalised cost" of travel—a representation of all of the costs including time and direct monetary costs—is an indicator to estimate the overall benefit of the system. Considering the average value of time, KES 20 is equivalent to 13 minutes. Passengers from Thika will experience a benefit equivalent to 35 minutes considering both travel time and fare. In Ruiru, with a current average fare of KES 55, the combined benefit considering time and fare savings is the equivalent of 21 minutes. The direct services to Westlands and Upper Hill generate a large benefit, with fares dropping drastically compared with the existing situation where passengers need to pay twice and loose time waiting and walking for their transfers. The global generalised cost benefit is an average equivalent of 25 minutes for BRT users, which represent a benefit of 145,000 hours per day.

The BRT also will have a significant impact on overall road space usage. The BRT will shift passengers from a large number of small paratransit vehicles to a smaller number of articulated buses, all of which will travel in the dedicated bus lanes. As a result, the vehicle volumes in mixed traffic lanes along the BRT corridor will fall significantly.

8. Implications for BRT corridor and station design

Designs for the Line 2 BRT corridor need to have sufficient capacity to handle anticipated ridership and should offer a safe, comfortable space that eases the wait. The corridor designs should incorporate the following critical elements:

- **All stations require passing lanes.** The passing lanes will make it possible to operate express services and will reduce station congestion.
- **An appropriate number of sub-stops for bus docking.** Multiple sub-stops increase the number of buses that can dock at a station without causing congestion. They also permit different types of services to operate from the same station.
- **Stations must be long enough to allow the sub-stops to function independently** of one another. The distance between the independent sub-stops should be 1.8 times the bus length (i.e., 32 m for an articulated bus) to enable buses to manoeuvre easily.
- **BRT stations should be designed with room for expansion**. Space should be reserved in the median for the addition of new sub-stops based on the future growth in passenger demand.

The following sections explain these design parameters in more detail.

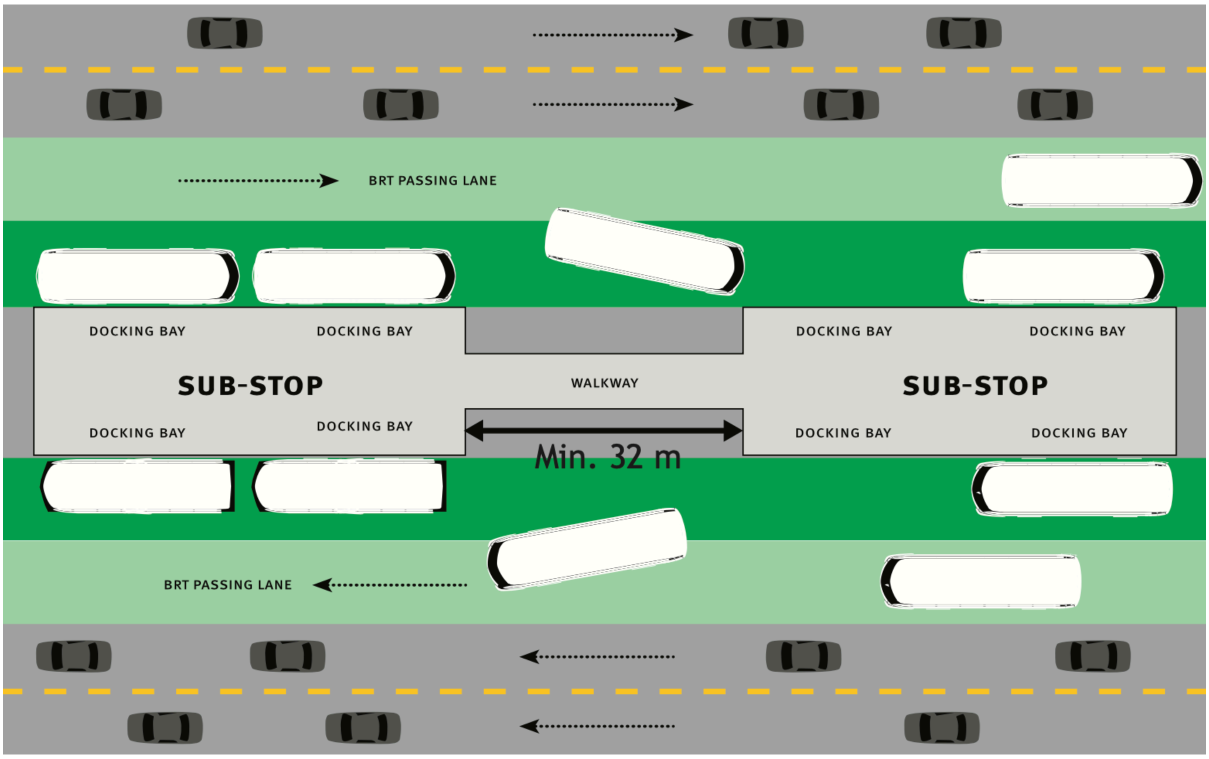

Figure 45: Sub-stops function independently, thereby increasing the capacity of the station. The minimum gap between sub-stops is 1.8 times the bus length, or 32 m for articulated buses.

8.1 Corridor cross sections

The Thika Rd corridor has sufficient right-of-way to accommodate a high-quality BRT. Standard sections were prepared for each section with a unique ROW, drawing on the following assumptions:

- Along Thika Rd and Murang'a Roads, the off-station cross section would remain largely the same as the existing design. Modifications would be limited to the sections with stations in order to minimise implementation costs.
- Staggered stations will be designed for Thika Rd and the 40 m wide section of Murang'a road to reduce mixed traffic lane displacement.
- Along Moi Avenue, the stations take up most of the length of the stretch so this portion of the corridor will require more extensive modifications.
- After modifications on Moi Avenue, the section between Biashara Street and City Hall Way will be limited to BRT, cyclists, and pedestrians.
- Special stretches like the segment between Muthaiga and Pangani interchange that differ from the standard cross sections and will require further detailing.

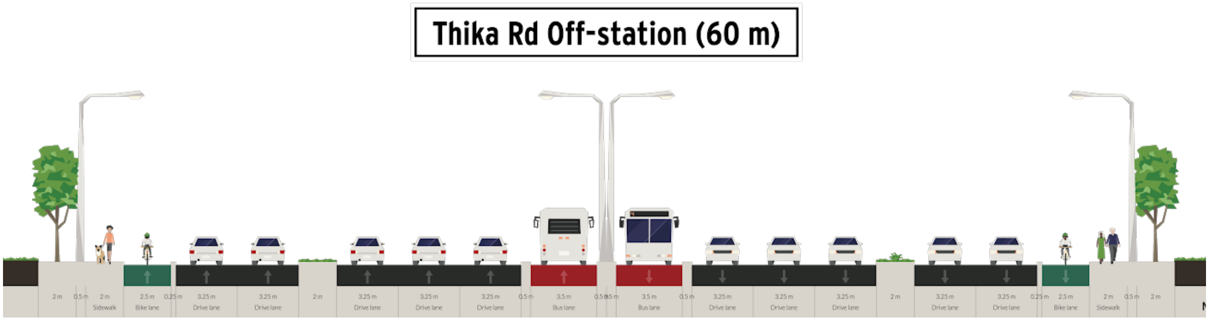

Figure 46. Thika Rd off-station (60 m).

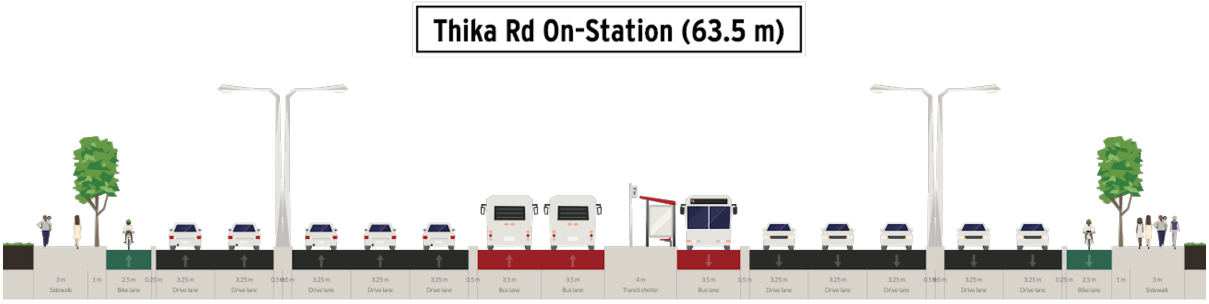

Figure 47. Thika Rd on-station (63.5 m).

Figure 48. Representative design for BRT on Thika Rd near Muthaiga Police Station.

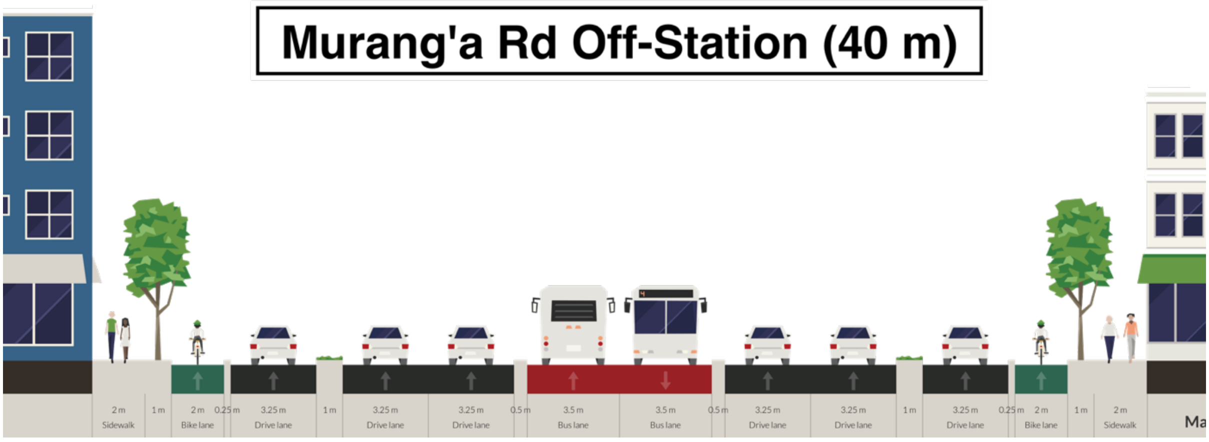

Figure 49. Murang’a Rd off-station (40 m).

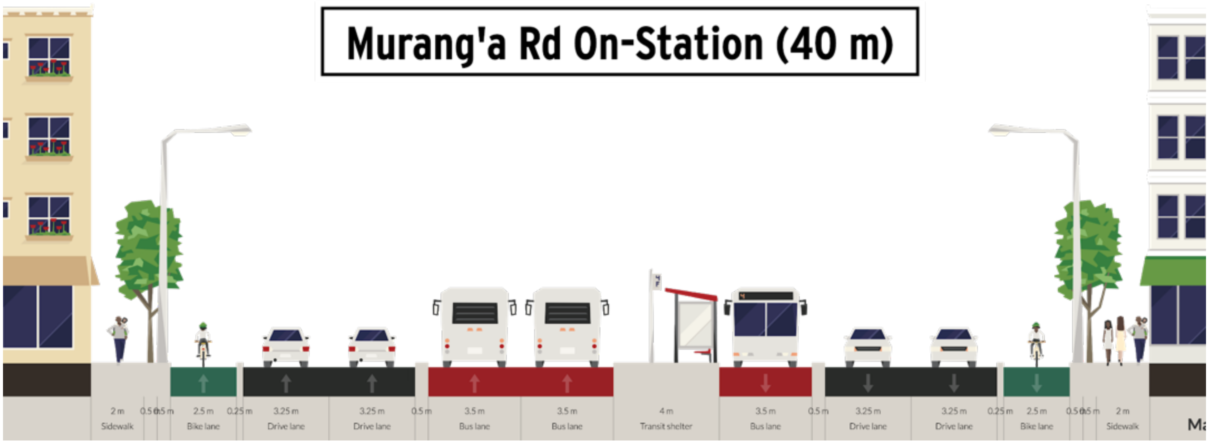

Figure 50. Murang’a Rd on-station (40 m).

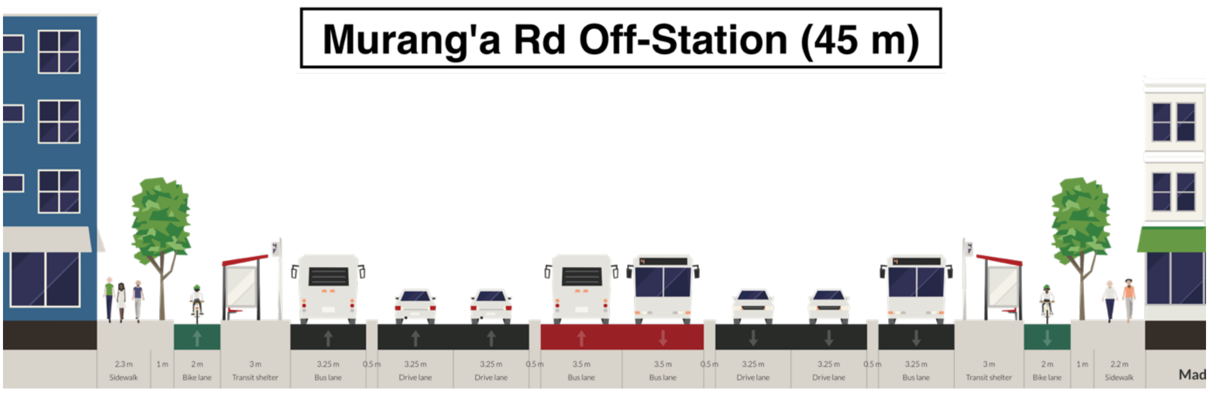

Figure 51. Murang’a Rd off-station (45 m).

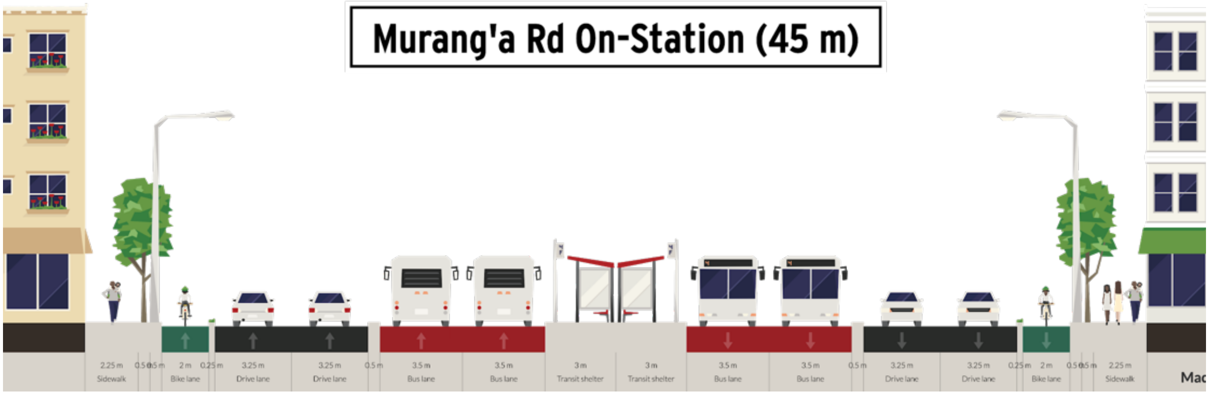

Figure 52. Murang’a Rd on-station (45 m).

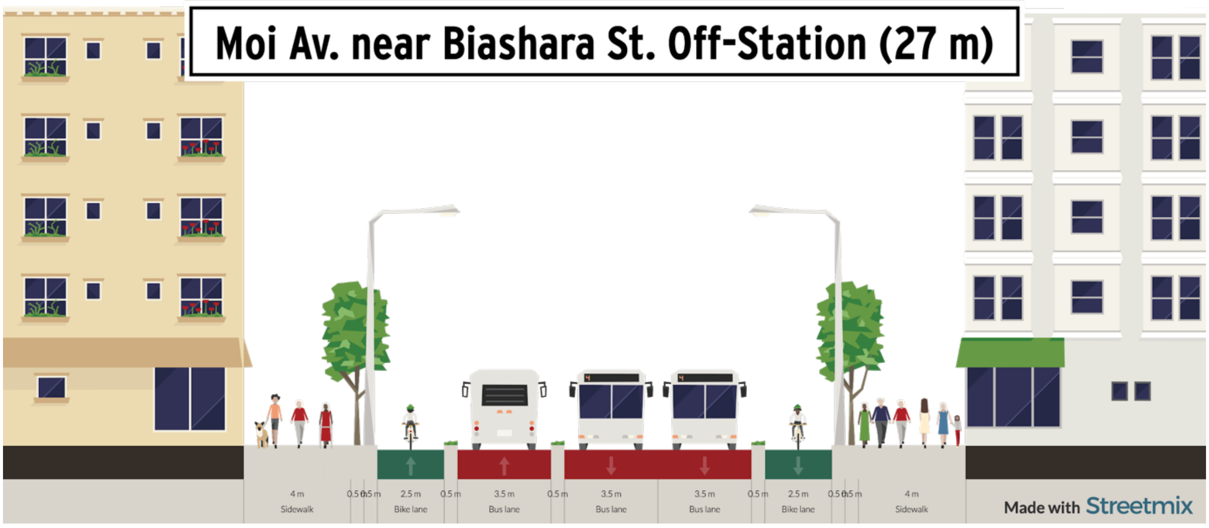

Figure 53. Moi Ave near Biashara St off-station (27 m). A separate southbound right turn lane is provided near the intersection with Kenyatta Ave for Upper Hill-bound buses.

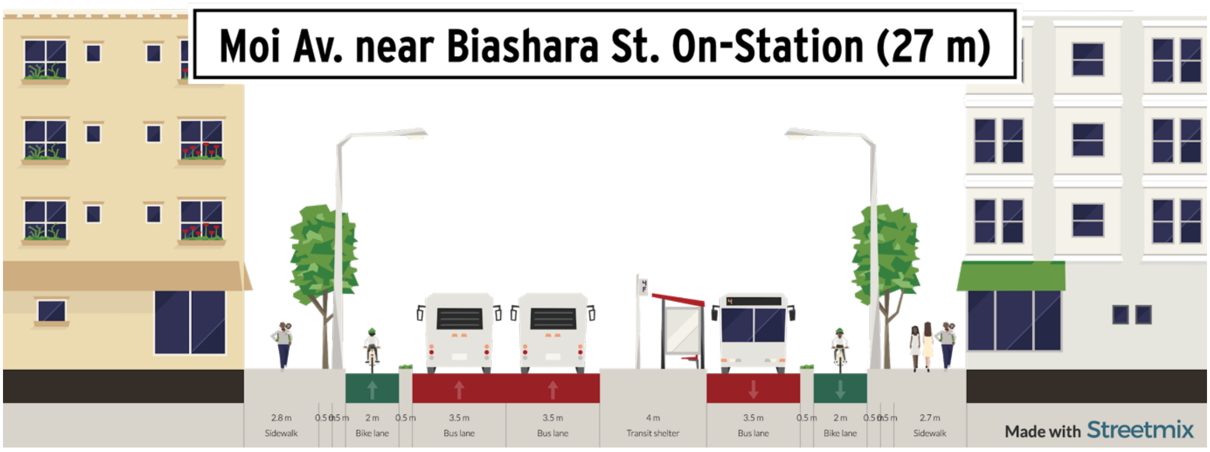

Figure 54. Moi Ave near Biashara St on-station (27 m).

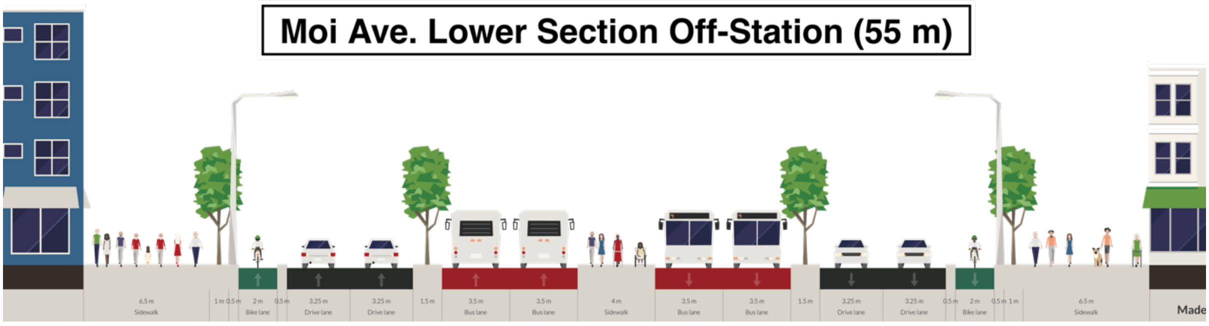

Figure 55. Moi Ave from City Hall Way to Haile Selassie off-station (55 m).

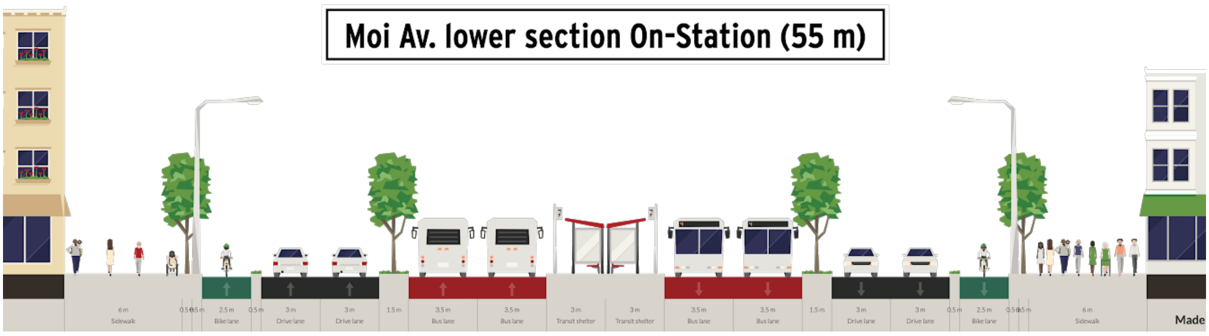

Figure 56. Moi Ave from City Hall Way to Haile Selassie on-station (55 m).

Figure 57. Representative design for Moi Ave near Kencom.

8.2 Station sizing

BRT station positions were identified considering existing passenger boarding and alighting patterns. There are a total of 20 stations, including 4 stations along Moi Ave and 16 stations outside of the CBD. The size of a station depends on the level of "saturation," which depends on the bus frequency and level of passenger demand. Stations with higher saturation require multiple independent docking bays to handle demand without reducing commercial speeds. In literal terms, saturation refers to the percentage of time that a vehicle stopping by at a BRT station is occupied and is calculated using the following formula:

$$s = \alpha \cdot F + \beta \cdot B + \gamma \cdot A$$

Where:

- s = Saturation
- F = Bus frequency
- B = Number of passengers boarding
- A = Number of passengers alighting
- α = minimum dwell time (i.e., 15 seconds for an articulated bus)
- β = Time per boarding passenger (i.e., 0.5 sec)
- γ = Time per alighting passenger (i.e., 0.5 sec)

Based on empirical evidence, BRT systems perform best when the saturation level is below 40 per cent at each station. Above this level, BRT systems run the risk of congestion and system breakdown. Therefore, it is desirable to keep saturation levels as low as possible. According to passenger volumes and bus frequency, the following sub-stops are required by station:

- 3 sub-stops: 3 stations: CBD-1, CBD-2, Thika Rd-1
- 2 sub-stops: 10 stations: CBD-3, CBD-4, Thika Rd-2 to Thika Rd-7, Thika Rd-12, Thika Rd-16
- 1 sub-stop: remaining 7 stations

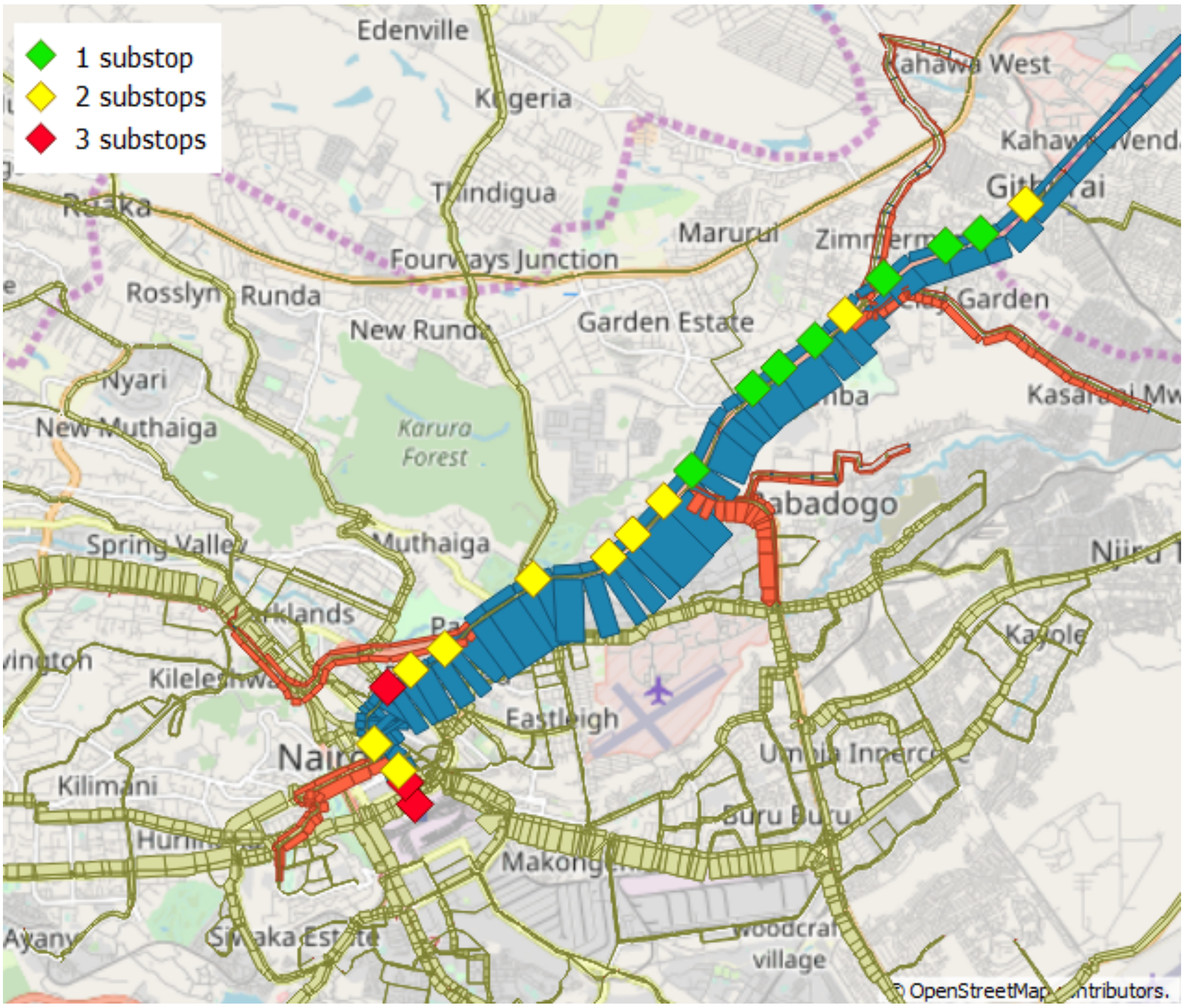

Figure 58. Required number of sub-stops at BRT stations.

Table 4. Saturation and required sub-stops at stations.

	Boardings		Alightings		Frequency		Saturation		Sub-stops	
Station	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound
CBD										
1	0	1,885	4,322	0	68	68	0.88	0.54	3.00	2.00
2	0	0	4,608	0	73	73	0.94	0.30	3.00	1.00
3	0	1,413	3,108	0	66	66	0.70	0.47	2.00	2.00
4	35	743	4,198	279	51	51	0.80	0.35	2.00	1.00
Murang'a Rd/Thika Rd										
1	475	111	6,550	541	46	46	1.17	0.28	3.00	1.00
2	657	15	2,515	322	57	57	0.68	0.28	2.00	1.00
3	1,108	195	2,043	207	55	55	0.67	0.29	2.00	1.00
4	808	278	1,290	565	81	81	0.63	0.45	2.00	2.00
5	687	266	378	214	66	66	0.42	0.34	2.00	1.00
6	828	97	970	263	69	69	0.54	0.34	2.00	1.00
7	2,032	753	781	440	90	90	0.77	0.54	2.00	2.00
8	775	17	561	388	40	40	0.35	0.22	1.00	1.00
9	822	98	362	67	40	40	0.33	0.19	1.00	1.00
10	686	53	362	27	59	59	0.39	0.26	1.00	1.00
11	73	96	88	103	46	46	0.22	0.22	1.00	1.00
12	2,211	271	1,109	741	70	70	0.75	0.43	2.00	2.00
13	213	15	207	40	38	38	0.22	0.17	1.00	1.00
14	99	0	0	0	36	36	0.16	0.15	1.00	1.00
15	59	15	10	0	36	36	0.16	0.15	1.00	1.00
16	3,249	62	28	1,404	69	69	0.74	0.49	2.00	2.00

8.3 Intersections and interchanges

Along Thika Rd, the BRT will operate along the median of the existing express lanes. These lanes are grade separated and the BRT can operate without signals along this stretch. Once the BRT reaches the city centre, the corridor will shift to an urban street typology with signals at major intersections.

The Nairobi BRT Design Framework calls simplified signal cycles to avoid delays at intersections and minimise disruption of BRT movements. Right turns across BRT lanes should be avoided in order to reduce delay and improve safety. The Design Framework identifies a set of alternative movements to avoid right turns across the busway, as displayed in Figure 59. The following sections introduce representative two-phase signal cycles for the intersections along the CBD segment. Further traffic analysis is required to validate these signal designs and inform the geometric design of each intersection.

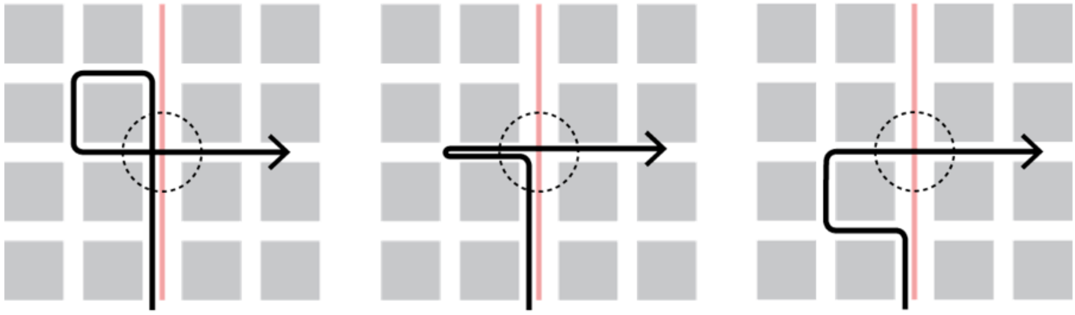

Figure 59. Alternatives to avoid right turns across BRT lanes.

Figure 60. A sign prohibiting a right turn across a BRT lane in Dar es Salaam.

8.3.1 Koja

At this section, the traffic will operate on two phases where the inbound BRT buses take a right turn to access Moi Avenue via River Road. Outbound mixed traffic will be stopped at intervals to enable the BRT buses to access Moi Avenue. The intersection will operate with two phases. Inbound mixed traffic from the Globe Flyover will continue to operate without a signal. Mixed traffic will be removed from this section of River Road in order to facilitate BRT movements.

Figure 61. Signal phasing at Koja (red = BRT; grey = mixed traffic).

8.3.2 Kenyatta Ave x Moi Ave

The intersections of Kenyatta Ave/Mondlane St and Cabral St can operate as part of a single coordinated signal cycle to avoid conflict and reduce delays for BRT buses. Due to the limited ROW available on this stretch, mixed traffic movement on Moi should be limited to the northbound traffic moving from Cabral St to Kenyatta Ave. The intersection will operate with two phases.

Some BRT buses providing direct services will turn right from Moi Ave onto Kenyatta Ave. A separate southbound BRT lane should be provided to accommodate these vehicles. The turns can happen once all northbound buses have cleared the intersection.

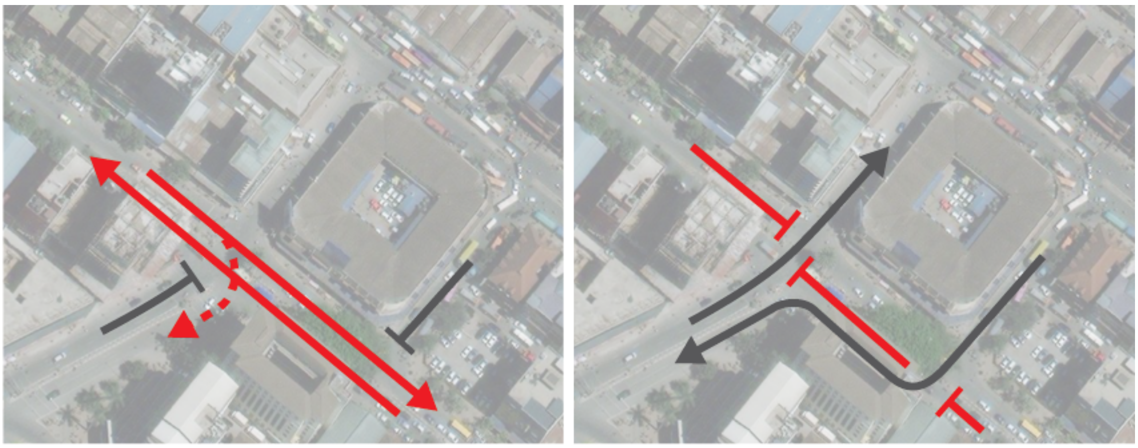

Figure 62. Signal phasing at Kenyatta and Moi (red = BRT; grey = mixed traffic).

8.3.3 City Hall Way x Moi Ave (Kencom)

Moi Ave has a limited ROW from Koja to the intersection with City Hall Way. To accommodate BRT movements while maintaining the popular public space in front of the National Archives, mixed traffic should be removed from the stretch of Moi Ave between Mama Ngina St and City Hall Way. Existing right turning movements from Mama Ngina St onto Moi Ave can be routed further south to City Hall Way. Vehicles can then turn right from City Hall Way onto Moi Ave. To accommodate these movements, the section of City Hall Way near Kencom will become a two-way street. Traffic at the intersection will operate in two phases.

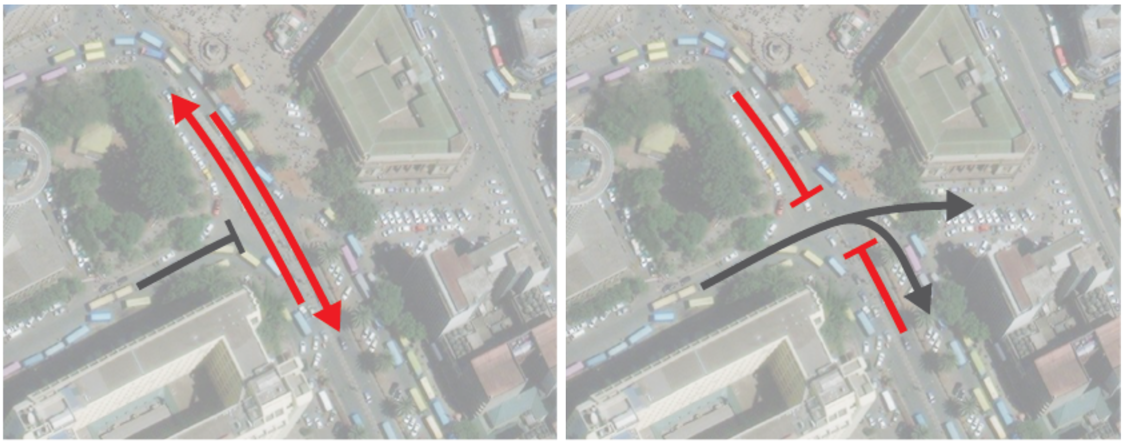

Figure 63. Signal phasing at City Hall Way and Moi (red = BRT; grey = mixed traffic).

8.3.4 Ronald Ngala St x Moi Ave

Traffic at this intersection will operate at two phases with a direct right turn from Ronald Ngala St onto Moi Ave.

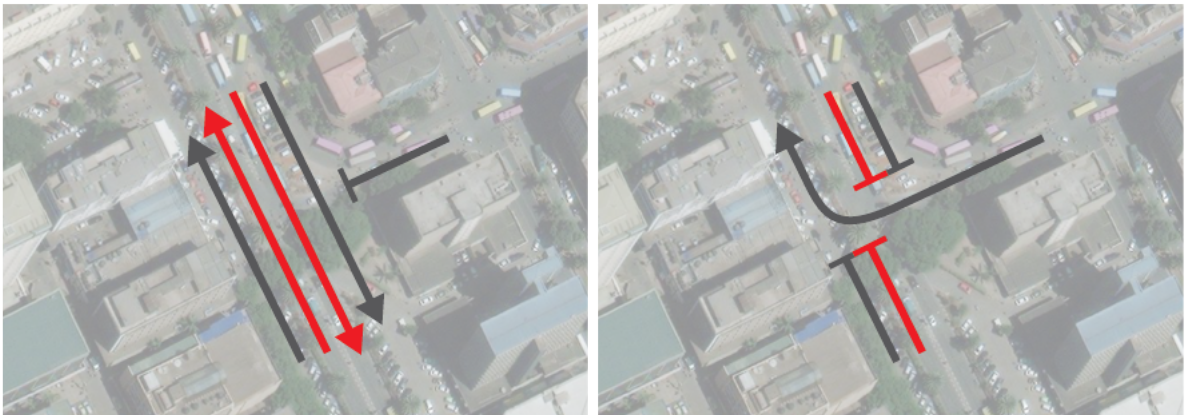

Figure 64. Signal phasing at Ronald Ngala and Moi (red = BRT; grey = mixed traffic).

8.3.5 Harambee Ave x Moi Ave

The right turn from Harambe Avenue onto Moi Avenue will be removed. Traffic making this movement can be rerouted to City Hall Way or exit to Tumbo Avenue and consequently make a left turn to Haile Selassie Ave.

8.3.6 Haile Selassie Ave x Moi Ave

This intersection will have traffic operating at two phases with priority given to BRT movements from Moi Ave toward the final BRT terminal at Railways. All right turns at this intersection are barred to enable smooth operations as the intersection experiences high volumes of traffic from Landhies Road, Ring Road Ngara, Uhuru Highway, Ngong Road, and Mombasa Road. The right turns can be accommodated in the network to reduce conflict and disruption for BRT buses.

Figure 65. Signal phasing at Haile Selassie and Moi (red = BRT; grey = mixed traffic).

9. Conclusion

Efficient BRT systems are designed around service plans that get the most people to where they want to go through the fastest means possible. BRT infrastructure is then designed to ensure fast operations by avoiding bottlenecks for buses and passengers. Many scenarios have been tested to reach a configuration for the services along the Nairobi BRT Line 2 corridor with a limited number of transfers and an optimal fleet. The final service plan proposes twelve routes along the corridor. The corridor has a critical load of 34,000 pphpd and around 260 buses per hour along Thika Road. The system will carry around 550,000 passengers per day.

Implementing the Nairobi Line 2 BRT corridor will yield significant benefits for city residents. BRT passengers will enjoy a benefit of 25 minutes per trip. In addition, the system has the potential to improve traffic by shifting trips from numerous small trips to large vehicles in a dedicated lane. The shift of trips from polluting vehicles to high-capacity BRT buses will reduce local air and noise pollution, leading to significant public health benefits. A well-designed BRT can also contribute to a reduction in road fatalities, especially for pedestrians, the most vulnerable road users. The BRT can improve social equity by providing affordable and accessible mobility for the poorest residents, the elderly, women, and people with disabilities.

10. Appendix: Survey forms

10.1 Frequency-occupancy survey form

Thika Road Public transport survey

Frequency-occupancy survey

Date:	Location number:
Surveyor:	Location landmark:
Supervisor:	Direction:

Vehicle type	Route/ Sacco	Cross country (Y,N)	Occupants	Time	
				HH	MM
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
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7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					

Vehicle type	Route/ Sacco	Cross country (Y,N)	Occupants	Time	
				HH	MM
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
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7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					
7 11 14 19 26 29 33 37 42 52 B 120					

10.2 Transfer survey form

Nairobi public transport survey

Transfer survey

Date:	Route number:
Surveyor:	Boarding Location:
Supervisor:	Alighting Location: Sheet No:

#	Hr	Min	Origin	Mode	Destination	Cost (KES)	Walk time (min)	Purpose	M/F
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	
				W CY BB TT TX C 14 B R				W E S R M A O	

10.3 Boarding-alighting survey platform

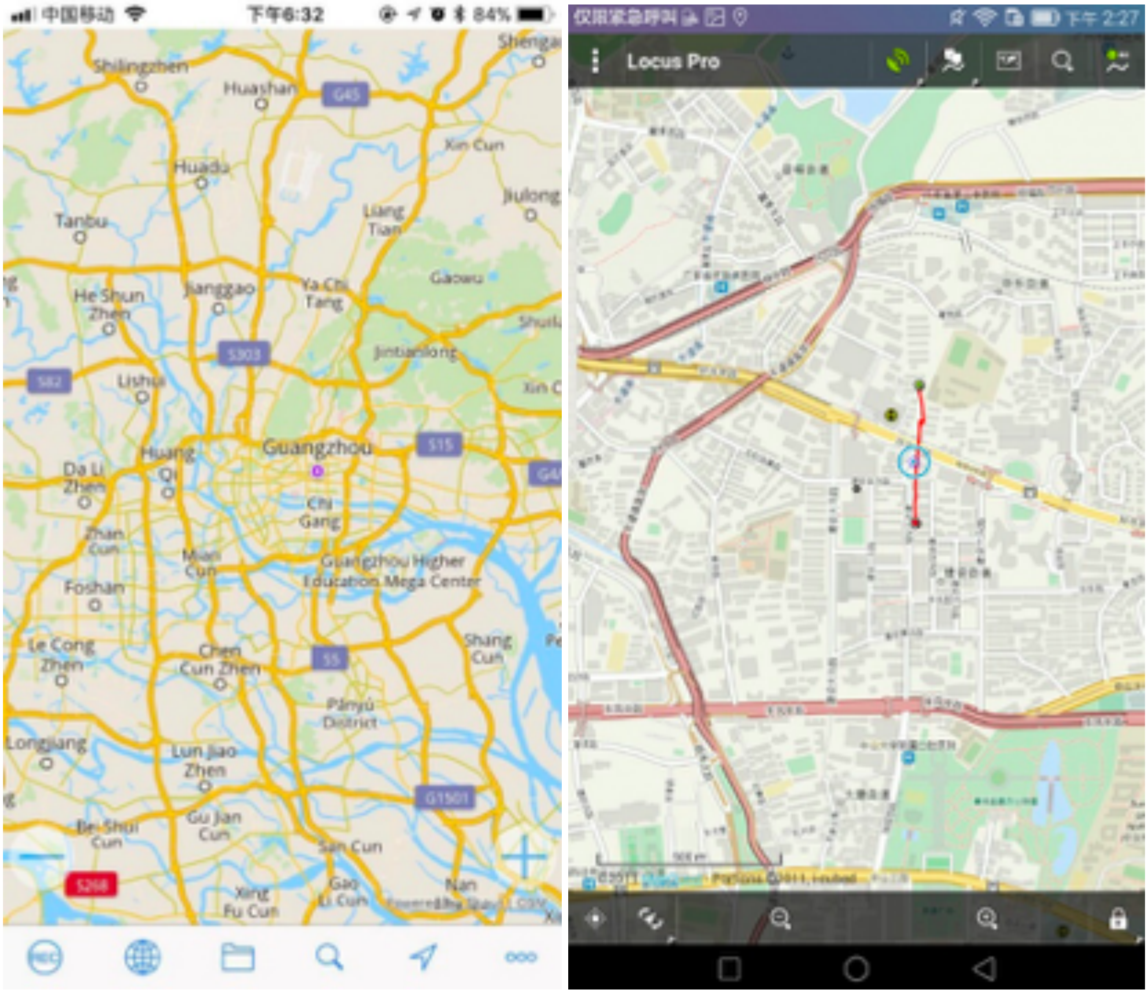

Figure 66. Screenshots from the boarding-alighting survey platforms: MyTracks for iOS (left) and locus for Android (right).

11. Appendix: Fare system for existing services

Route	Route length (km)	Fare type	Constant fare (a)	Variable fare (b)
100AN	14.27	Distance-based	42.4	3.6
100AS	15.07	Distance-based	42.4	3.7
100N	16.35	Distance-based	42.4	3.6
100S	16.07	Distance-based	42.4	3.7
102E	22.33	Distance-based	26.9	1.1
102W	22.5	Distance-based	26.9	1.1
103N	20.51	Flat fare	100.0	0.0
103S	14.06	Flat fare	100.0	0.0
105E	22.27	Flat fare	100.0	0.0
105W	22.21	Flat fare	80.0	0.0
106N	17.55	Distance-based	42.4	3.4
106S	17.33	Distance-based	65.4	2.1
107DE	26.65	Flat fare	100.0	0.0
107DW	26.39	Flat fare	80.0	0.0
107E	22.21	Distance-based	53.9	2.1
107W	19.19	Distance-based	19.3	4.3
108E	13.64	Flat fare	100.0	0.0
108W	13.18	Flat fare	100.0	0.0
10E	6.32	Flat fare	50.0	0.0
10W	6.42	Flat fare	75.0	0.0
11-2N	7.54	Flat fare	80.0	0.0
11-2S	7.7	Distance-based	65.4	4.6
110AKN	6.92	Flat fare	100.0	0.0
110AKS	7.21	Flat fare	100.0	0.0
110ATN	31.49	Flat fare	100.0	0.0
110ATS	31.61	Flat fare	60.0	0.0
110N	30.52	Flat fare	100.0	0.0
110S	30.73	Flat fare	60.0	0.0
111E	24.04	Flat fare	100.0	0.0
111W	22.93	Flat fare	100.0	0.0
114RE	32.78	Flat fare	100.0	0.0
114RW	32.85	Distance-based	65.4	1.1
114WE	36.53	Flat fare	90.0	0.0
114WW	38.35	Flat fare	100.0	0.0
115E	36.52	Flat fare	100.0	0.0
115W	37.7	Flat fare	100.0	0.0
116E	36.66	Flat fare	100.0	0.0
116W	37.72	Flat fare	100.0	0.0

Route	Route length (km)	Fare type	Constant fare (a)	Variable fare (b)
118E	17.34	Flat fare	100.0	0.0
118W	17.44	Flat fare	90.0	0.0
119AE	13.54	Flat fare	100.0	0.0
119AW	14.43	Flat fare	100.0	0.0
119E	15.43	Distance-based	93.9	3.1
119W	17.97	Flat fare	90.0	0.0
11AN	5.25	Distance-based	22.4	11.3
11AS	7.84	Distance-based	19.3	10.6
11BN	4.75	Distance-based	33.9	10.0
11BS	4.58	Flat fare	75.0	0.0
11CN	5.52	Flat fare	60.0	0.0
11CS	4.04	Flat fare	60.0	0.0
11N	8.16	Distance-based	22.4	7.3
11S	8.14	Distance-based	35.4	4.4
120N	36.89	Distance-based	92.4	1.6
120S	37.48	Distance-based	92.4	1.6
121N	19.32	Flat fare	100.0	0.0
121S	21.2	Flat fare	100.0	0.0
125N	21.47	Distance-based	92.4	2.8
125S	19.81	Flat fare	100.0	0.0
126E	28.16	Flat fare	100.0	0.0
126NN	9.83	Flat fare	100.0	0.0
126NS	9.94	Flat fare	100.0	0.0
126RE	11.09	Flat fare	100.0	0.0
126RW	11.09	Flat fare	100.0	0.0
126W	28.36	Flat fare	100.0	0.0
129E	7.68	Flat fare	100.0	0.0
129W	7.99	Flat fare	100.0	0.0
12CN	6.65	Flat fare	80.0	0.0
12CS	9.6	Flat fare	80.0	0.0
12DN	8.31	Flat fare	80.0	0.0
12DS	10.25	Flat fare	80.0	0.0
135E	37.02	Flat fare	100.0	0.0
135W	38.18	Flat fare	100.0	0.0
145BN	23.09	Flat fare	60.0	0.0
145BS	23.67	Flat fare	50.0	0.0
145N	23.86	Flat fare	55.0	0.0
145S	25.64	Distance-based	53.9	1.9
145xN	21.58	Flat fare	50.0	0.0
145xS	20.33	Flat fare	50.0	0.0
145yN	17.26	Flat fare	50.0	0.0

Route	Route length (km)	Fare type	Constant fare (*a*)	Variable fare (*b*)
145yS	17.5	Flat fare	50.0	0.0
145zN	39.32	Flat fare	100.0	0.0
145zS	38.55	Flat fare	100.0	0.0
14AN	5.84	Flat fare	60.0	0.0
14AS	6.32	Flat fare	55.0	0.0
14BN	7.1	Flat fare	75.0	0.0
14BS	5.8	Flat fare	80.0	0.0
14E	10.71	Flat fare	50.0	0.0
14W	10.94	Flat fare	70.0	0.0
15E	12.58	Flat fare	75.0	0.0
15W	12.65	Flat fare	75.0	0.0
16-6E	16.67	Distance-based	8.5	0.7
16-6W	19.3	Flat fare	50.0	0.0
16-7E	10.89	Distance-based	26.9	2.2
16-7W	10.53	Distance-based	33.9	4.5
16E	7.43	Flat fare	70.0	0.0
16S	8.11	Flat fare	50.0	0.0
17AE	9.61	Distance-based	30.8	7.4
17AW	10.22	Distance-based	30.8	7.0
17AkE	14.33	Distance-based	49.3	5.8
17AkW	12.1	Flat fare	55.0	0.0
17B-E	4.26	Flat fare	30.0	0.0
17B-W	4.54	Flat fare	50.0	0.0
17BE	17.04	Flat fare	40.0	0.0
17BW	16.71	Distance-based	65.4	2.1
18CE	11.29	Flat fare	80.0	0.0
18CW	14.51	Flat fare	80.0	0.0
1960E	14.61	Flat fare	80.0	0.0
1960W	12.87	Flat fare	80.0	0.0
1961DE	5.98	Flat fare	80.0	0.0
1961DW	6.65	Flat fare	90.0	0.0
1961KE	14.82	Flat fare	90.0	0.0
1961KW	13.57	Flat fare	90.0	0.0
19C2E	7.56	Flat fare	90.0	0.0
19C2S	6.39	Flat fare	90.0	0.0
19CdE	14.04	Distance-based	42.4	4.2
19CdW	15.15	Flat fare	90.0	0.0
1N	12.43	Distance-based	46.9	1.9
1S	12.2	Distance-based	45.4	2.9
2030N	2.85	Flat fare	20.0	0.0
2030S	3.01	Distance-based	8.5	3.9

Route	Route length (km)	Fare type	Constant fare (a)	Variable fare (b)
20N	11.95	Distance-based	42.4	5.0
20S	11.43	Distance-based	19.3	7.3
236N	32.28	Flat fare	50.0	0.0
236S	32.51	Flat fare	60.0	0.0
237N	44.63	Flat fare	70.0	0.0
237S	44.8	Flat fare	70.0	0.0
23KGE	11.46	Distance-based	19.3	7.2
23KGW	10.9	Distance-based	3.9	4.4
23KSE	9.94	Flat fare	70.0	0.0
23KSW	10.86	Flat fare	75.0	0.0
23WN	4.38	Flat fare	30.0	0.0
23WS	4.86	Flat fare	30.0	0.0
24BKE	7.93	Flat fare	100.0	0.0
24BKW	7.9	Flat fare	100.0	0.0
24CE	31.65	Flat fare	90.0	0.0
24CW	15.2	Flat fare	80.0	0.0
24E	25.6	Flat fare	100.0	0.0
24W	26.07	Distance-based	65.4	1.4
24xE	15.16	Distance-based	65.4	2.3
25AE	11.97	Flat fare	75.0	0.0
25AW	12.61	Flat fare	100.0	0.0
25E	12.34	Distance-based	15.4	2.9
25W	12.7	Distance-based	30.8	5.6
26N	7.54	Flat fare	60.0	0.0
26S	6.93	Flat fare	70.0	0.0
26SN	6.09	Flat fare	60.0	0.0
26SS	5.58	Flat fare	70.0	0.0
28E	7.7	Distance-based	22.4	7.7
28W	9.14	Distance-based	30.8	7.8
29-3E	8.85	Distance-based	25.4	4.0
29-3W	7.32	Flat fare	75.0	0.0
29-3xW	7.4	Distance-based	30.8	9.6
2E	18.9	Flat fare	100.0	0.0
2W	18.74	Flat fare	100.0	0.0
30E	16.09	Distance-based	33.9	3.0
30W	14.89	Flat fare	50.0	0.0
32AE	8.09	Distance-based	26.9	2.9
32AW	14.38	Distance-based	25.4	2.5
32DE	12.16	Distance-based	26.9	2.0
32DW	11.31	Flat fare	70.0	0.0
33AE	14.28	Flat fare	70.0	0.0

Route	Route length (km)	Fare type	Constant fare (a)	Variable fare (b)
33AW	14.71	Flat fare	80.0	0.0
33BE	16.52	Flat fare	80.0	0.0
33BW	20.24	Flat fare	80.0	0.0
33CE	12.76	Distance-based	65.4	2.8
33CW	15.68	Flat fare	90.0	0.0
33DCN	6.29	Flat fare	85.0	0.0
33DCS	6.44	Flat fare	85.0	0.0
33DPE	12.12	Distance-based	23.9	3.9
33DPW	10.68	Distance-based	65.4	3.3
33FEE	18.72	Flat fare	80.0	0.0
33FEW	19.26	Flat fare	80.0	0.0
33GTE	11.72	Flat fare	95.0	0.0
33GTW	14.63	Flat fare	100.0	0.0
33HE	15.25	Flat fare	80.0	0.0
33HW	15.13	Flat fare	80.0	0.0
33IME	12.47	Flat fare	80.0	0.0
33IMW	12.88	Flat fare	90.0	0.0
33JE	16.85	Flat fare	80.0	0.0
33JW	15.18	Flat fare	80.0	0.0
33MKE	12.23	Flat fare	70.0	0.0
33MKW	14.56	Flat fare	90.0	0.0
33NGE	8.26	Flat fare	80.0	0.0
33NGW	6.4	Flat fare	80.0	0.0
33SBE	7.3	Flat fare	80.0	0.0
33SBW	6.33	Flat fare	80.0	0.0
33TPE	13.87	Flat fare	80.0	0.0
33TPW	11.39	Flat fare	80.0	0.0
33UTE	26.46	Flat fare	80.0	0.0
33UTW	28.24	Flat fare	80.0	0.0
34BE	11.25	Distance-based	42.4	5.3
34BW	11.28	Flat fare	90.0	0.0
34JE	23.84	Flat fare	80.0	0.0
34JW	28.18	Distance-based	19.3	2.9
34LN	11.04	Distance-based	59.3	7.5
34LS	11.57	Distance-based	65.4	3.1
35-6E	12.34	Distance-based	54.7	9.6
35-6W	12.23	Distance-based	66.3	8.7
3560N	3.77	Distance-based	18.5	3.2
3560S	4	Flat fare	30.0	0.0
36E	12.76	Distance-based	7.8	7.4
36W	13.2	Flat fare	80.0	0.0

Route	Route length (km)	Fare type	Constant fare (*a*)	Variable fare (*b*)
3738E	14.4	Flat fare	90.0	0.0
3738W	14.61	Flat fare	90.0	0.0
38-3E	31.27	Distance-based	65.4	1.1
38-3W	32.28	Distance-based	65.4	1.1
39SKE	14.64	Flat fare	100.0	0.0
39SKW	15.5	Flat fare	90.0	0.0
3NE	3.56	Flat fare	50.0	0.0
3NW	2.7	Flat fare	50.0	0.0
3U-3E	7.27	Flat fare	50.0	0.0
3U-3W	7.66	Flat fare	50.0	0.0
405E	2.17	Flat fare	60.0	0.0
405W	2.26	Flat fare	60.0	0.0
41E	10.85	Flat fare	60.0	0.0
41W	10.8	Distance-based	65.4	3.3
42E	7.58	Distance-based	25.4	4.7
42W	7.65	Distance-based	26.9	3.1
43E	10.23	Flat fare	50.0	0.0
43W	9.65	Distance-based	56.9	2.5
44GN	17.88	Distance-based	36.9	1.3
44GS	17.52	Distance-based	19.3	4.7
44KN	5.79	Flat fare	50.0	0.0
44KS	5.79	Flat fare	50.0	0.0
44ZN	18.27	Distance-based	53.9	2.6
44ZS	17.38	Flat fare	100.0	0.0
45GE	15.01	Flat fare	50.0	0.0
45GW	14.58	Flat fare	50.0	0.0
45KE	21.99	Flat fare	50.0	0.0
45KW	23.48	Distance-based	55.4	1.5
45PE	8.78	Flat fare	50.0	0.0
45PW	8.72	Flat fare	50.0	0.0
46BE	9.26	Flat fare	30.0	0.0
46BW	9.42	Distance-based	45.4	3.8
46HE	8.85	Distance-based	7.8	10.7
46HW	9.16	Flat fare	70.0	0.0
46KE	10.43	Distance-based	45.4	3.4
46KW	11.23	Flat fare	45.0	0.0
46YE	4.93	Flat fare	30.0	0.0
46YW	5.21	Flat fare	30.0	0.0
48AE	9.75	Flat fare	80.0	0.0
48AW	8.85	Flat fare	70.0	0.0
48BE	11.25	Flat fare	80.0	0.0

Route	Route length (km)	Fare type	Constant fare (a)	Variable fare (b)
48BW	9.17	Flat fare	80.0	0.0
48CE	6.05	Flat fare	80.0	0.0
48CW	7.99	Flat fare	80.0	0.0
48KE	9.33	Flat fare	80.0	0.0
48KW	7.89	Flat fare	55.0	0.0
48OE	11.19	Flat fare	80.0	0.0
48OW	8.6	Distance-based	45.4	4.1
49E	21.76	Flat fare	50.0	0.0
49W	21.72	Flat fare	100.0	0.0
4WE	12.86	Flat fare	4.0	0.0
4WW	12.79	Flat fare	40.0	0.0
53N	3.56	Flat fare	40.0	0.0
53S	3.29	Flat fare	40.0	0.0
56E	11.79	Flat fare	80.0	0.0
56W	11.28	Flat fare	80.0	0.0
58E	8.85	Flat fare	55.0	0.0
58W	9.71	Flat fare	65.0	0.0
5E	8.71	Flat fare	80.0	0.0
5W	7.89	Flat fare	80.0	0.0
69N	8.13	Flat fare	100.0	0.0
69S	7.7	Flat fare	100.0	0.0
6E	4.89	Flat fare	45.0	0.0
6EN	1.98	Flat fare	50.0	0.0
6ES	1.84	Flat fare	50.0	0.0
6W	4.9	Flat fare	45.0	0.0
6xE	6.19	Flat fare	50.0	0.0
6xW	5.61	Flat fare	50.0	0.0
70-7E	8.03	Flat fare	50.0	0.0
70-7W	8.46	Distance-based	53.9	5.6
7CE	3.81	Distance-based	28.5	3.1
7CW	8.04	Flat fare	40.0	0.0
7E	3.31	Flat fare	40.0	0.0
7W	3.83	Distance-based	16.9	6.2
7xE	3.77	Flat fare	40.0	0.0
7xW	3.7	Flat fare	40.0	0.0
8E	7.97	Distance-based	25.4	4.5
8W	6.96	Flat fare	60.0	0.0