Service plan for public transport in Mombasa

Institute for Transportation and Development Policy

March 2020

Contents

1. Introduction 1
2. Existing public transport system 1
3. Importance of service planning 3
4. Travel demand surveys 3
   4.1 Frequency-occupancy survey 5
   4.2 Boarding-alighting survey 7
   4.3 Transfer survey 11
5. Public transport model preparation 12
   5.1 Network development 12
   5.2 Origin-destination matrix development 15
6. BRT corridor identification 22
7. Service plan 25
   7.1 BRT service design factors 25
   7.2 BRT services 26
   7.3 Modifications in regular services 42
8. Impacts of the BRT scenario 45
9. Implications for BRT corridor and station design 45
   9.1 BRT design principles 46
   9.2 Corridor cross sections 47
   9.3 Station sizing 51
   9.4 Intersections and interchanges 54
10. Conclusion & next steps 55
11. Appendix: Survey forms 57
   11.1 Frequency-occupancy survey form 57
   11.2 Transfer survey platform 58
   11.3 Boarding-alighting survey platform 59
   11.4 Fare system for existing services 59

1. Introduction

Mombasa County lies on the coast of Kenya and is the main gateway to landlocked countries in East and Central Africa via the Northern Corridor. The city is experiencing serious congestion due to increasing private car ownership and a lack of adequate public transport. Population growth and sprawl are contributing to an increasing challenge of providing well-organised, high-quality public transport.

Several major road corridors in Mombasa, including the A109 corridor, Magongo Rd, Nyali Bridge, and Mtwapa Road, are currently under expansion or are slated for improvements in the near future. There is an urgent need to ensure that the designs for these corridors include high-quality walking and cycling elements and also facilitate the operations of efficient public transport, including bus rapid transit (BRT). BRT is a high-quality bus-based public transport system that delivers fast, comfortable, and cost-effective services at metro-level capacities. Inclusion of dedicated lanes for BRT can significantly expand the passenger carrying capacity of major streets in Mombasa. Ongoing projects should consider the requirements of public transport services so as to avoid the need for costly infrastructure modifications in the future.

To develop a better understanding of mobility patterns in Mombasa, the Department of Transport, Infrastructure, and Public Works, Mombasa County Government (MCG), commissioned the Institute for Transportation and Development Policy (ITDP) and the United Nations Human Settlements Programme (UN-Habitat) to prepare a service plan for a potential BRT network Mombasa. 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. This report describes the service plan for the Mombasa and the implications for the design of road infrastructure projects in the city.

2. Existing public transport system

Existing modes of public transport in Mombasa include the matatus of various sizes as well as shared tuk-tuks. Matatus carry 36 percent of trips in the city.[1] Among matatus, 14-seat vehicles are the dominant model. There are 4,021 registered matatus in Mombasa per County Government records for December 2019. Matatus are privately owned, and the owner engages a driver and conductor who operate the vehicle. The current business model is based on the daily target system, in which the driver pays a fixed rent to the vehicle owner, ranging from around KES 3,500 per day for a 14-seater to KES 8,000 per day for a 33-seater. The driver then takes home whatever pay s/he earns after fuel and other expenses. This business model contributes to rash driving and road safety challenges.

As of December 2019, there are 8,027 registered three-wheelers, known as “tuk-tuks,” in Mombasa. Tuk-tuks offer both shared ride public transport services and door-to-door taxi services. In terms of road privileges, there are no restricted areas for tuk-tuks—they can operate anywhere other vehicles can travel. Tuk-tuks drivers typically rent the vehicle from an owner for KES 1,000 per day (or up to KES 1,200 for newer vehicles).

[1] Japan International Cooperation Agency. (2018, Mar). Project for Formulation of Comprehensive Development Master Plan in the Mombasa Gate City in the Republic of Kenya.

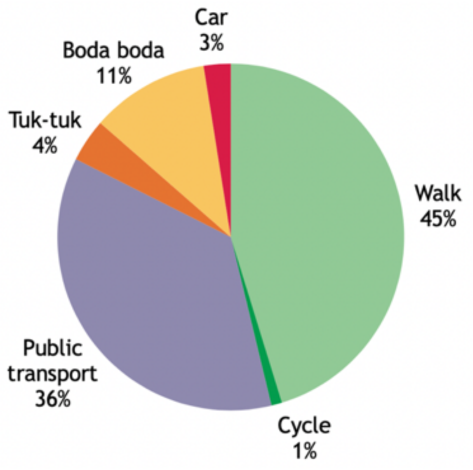


Figure 1. Mode split in Mombasa. (Source: JICA)

In the present public transport system in Mombasa, users face several challenges:

- **Slow speeds.** As discussed later in this report, speeds along key corridors, such as Mombasa-Malindi Rd, are as low as 5-10 km/h.
- **Lack of reliability.** Services are not scheduled, resulting in variable wait times. Frequent service is available at certain times, while at other times passengers must wait a long time for vehicles to fill up.
- **Lack of affordability.** High fares discourage the use of public transport.
- **Poor vehicle quality and comfort.** Vehicles are often overloaded, and awkward seating layouts make it difficult for passengers to board and alight.
- **Lack of weather protection and lighting at public transport stops.** Most roadside bus stops and terminals lack formal shelters, leaving passengers exposed to the elements.
- **Limited attention to last-mile access.** Pedestrian facilities are often lacking in the vicinity of public transport stops.

Urgent efforts are needed to address these challenges and develop a public transport system that offers convenient, reliable, and affordable services for all residents.

Figure 2: Matatus in Mombasa.

3. Importance of service planning

From a customer's perspective, some of the most important factors affecting the choice of travel mode are whether the service will take the passenger where s/he wants to go and the total travel time. Existing paratransit service patterns, developed in order to maximise operator profit and manage competition among operators, are not always optimal for passengers. Good service planning can help identify the most direct route that serves 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. A service plan also identifies locations where dedicated infrastructure for public transport (e.g., BRT facilities) can offer the greatest impact.

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. Next, 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 paratransit demand. Next, a set of service scenarios is defined to test different combinations of potential BRT and regular 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 matatu system in Mombasa was limited. Most services lack route numbers, formal itineraries, or defined stops. As a result, the survey process identified these services through primary data collection. The following surveys were conducted from Oct-Dec 2019:

- **Frequency-occupancy (FO) survey:** The FO survey records how frequently each matatu/bus or route runs and the approximate occupancy of each vehicle. Frequency-occupancy surveys were conducted at 39 bidirectional locations during the morning peak period and at 4 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 a vehicle at each stop along the route. BA surveys were conducted on 56 unique matatu 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. Transfer surveys were conducted on all major corridors in the city. Altogether, 2,135 effective samples were obtained.

MCG provided the survey team for the exercise. The following sections describe the survey procedures in more detail.

Table 1. Summary of travel demand surveys.

Survey	Details
Frequency-occupancy survey	39 bidirectional locations
Onboard boarding-alighting survey	56 routes
Transfer survey	2,135 effective samples

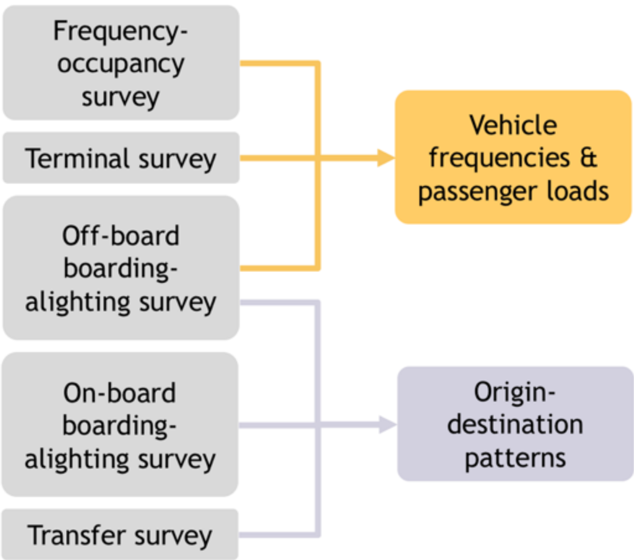


Figure 3. Information obtained from the surveys.

Figure 4. 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., “TT” for tuk-tuk, 11, 14, 33, 52+, etc.
- Route origin-destination
- 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 at 39 bidirectional locations across Mombasa City.

Figure 5. Surveyors recording frequency-occupancy data.

Figure 6. Frequency-occupancy survey locations.

The aggregate volumes of public transport passengers along major public transport corridors in Mombasa during the morning peak hour are displayed below. The graphics show the passenger volume per hour per direction (pphpd).

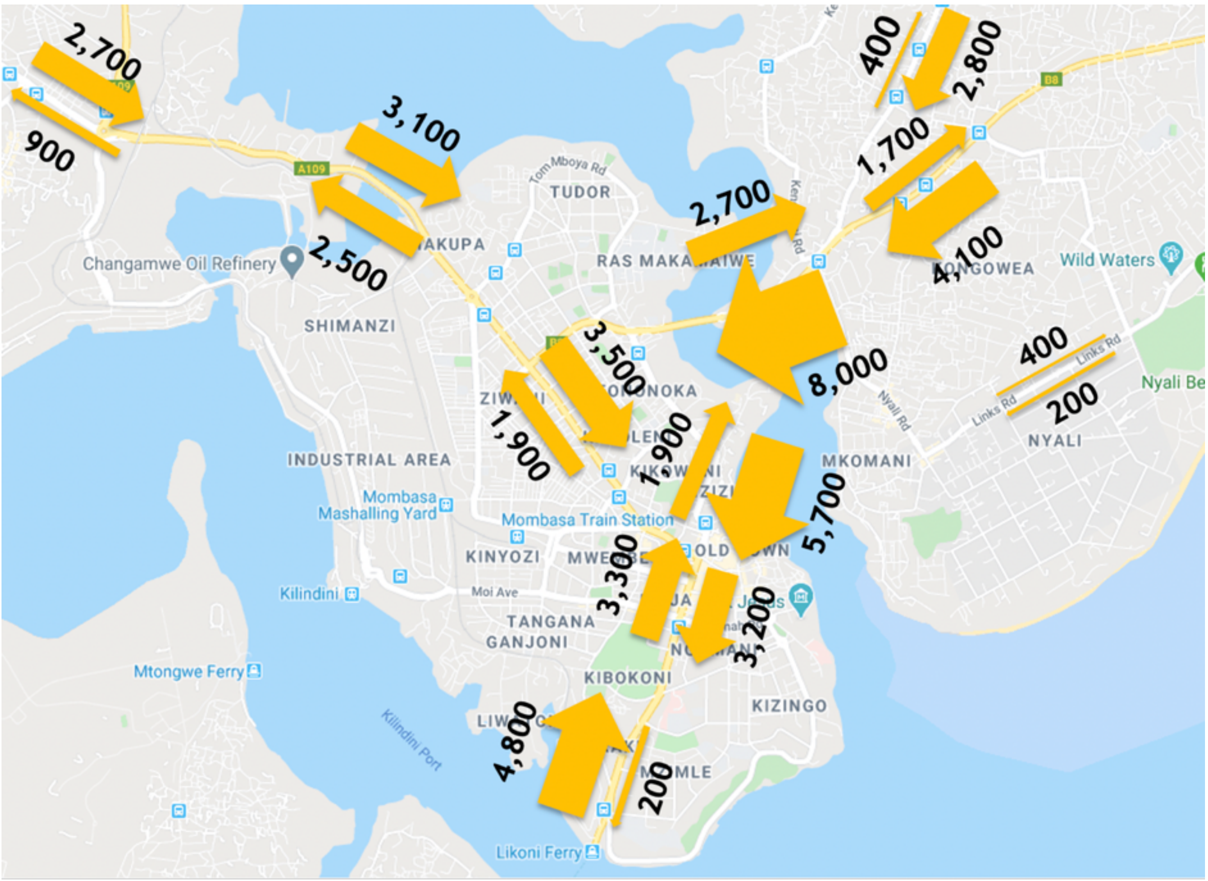


Figure 7. Peak hour passenger volumes (pphpd).

Based on the frequency-occupancy data, four 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. These were Nyali bridge, Makupa Causeway, Ferry terminal and across Likoni terminal. These locations were selected based on their strategic locations as they serve the main entrance points into the island from the north, west and south of Mombasa.

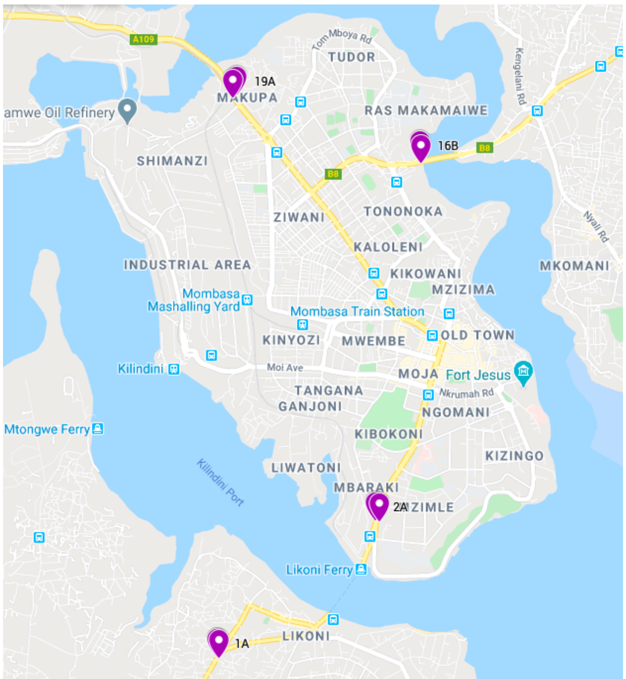


Figure 8. All-day frequency-occupancy survey locations.

4.2 Boarding-alighting survey

The boarding-alighting was carried out during the morning peak period on weekdays from October to November 2019. Surveyors rode on matatus, buses and ferries 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 O-D 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 56 routes.

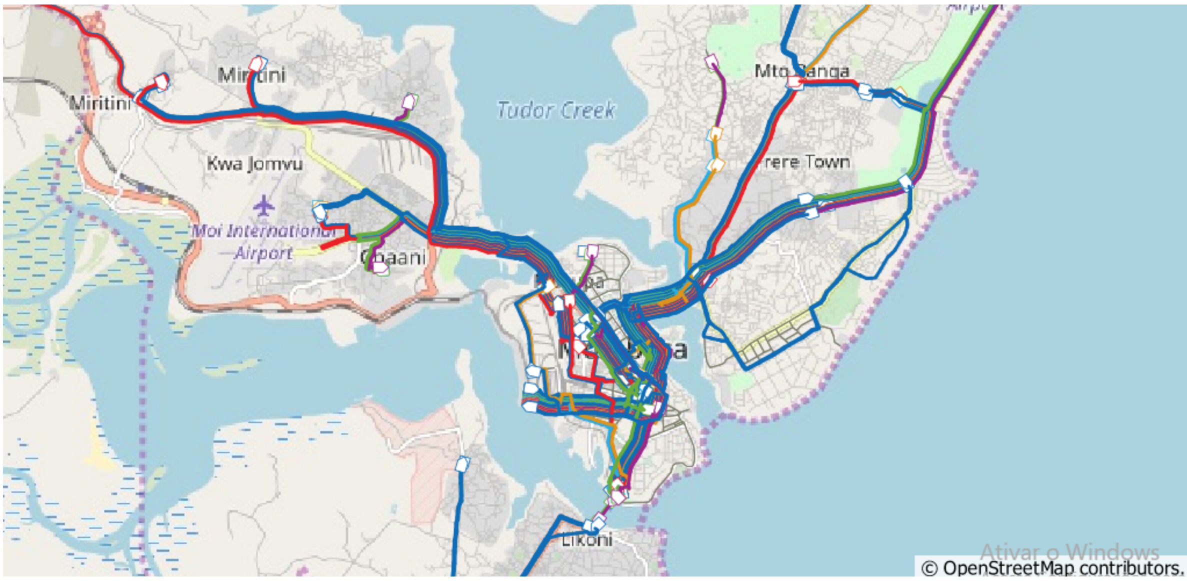


Figure 9. Public transport routes covered in the boarding-alighting survey.

The boarding-alighting survey revealed heavy boarding activity in the Mombasa CBD and along several radial corridors heading toward the city centre. Much of the demand for matatu services is concentrated along Kenyatta Ave and Digo Rd, with a large number of alightings occurring at Posta and Mwembe Tayari.

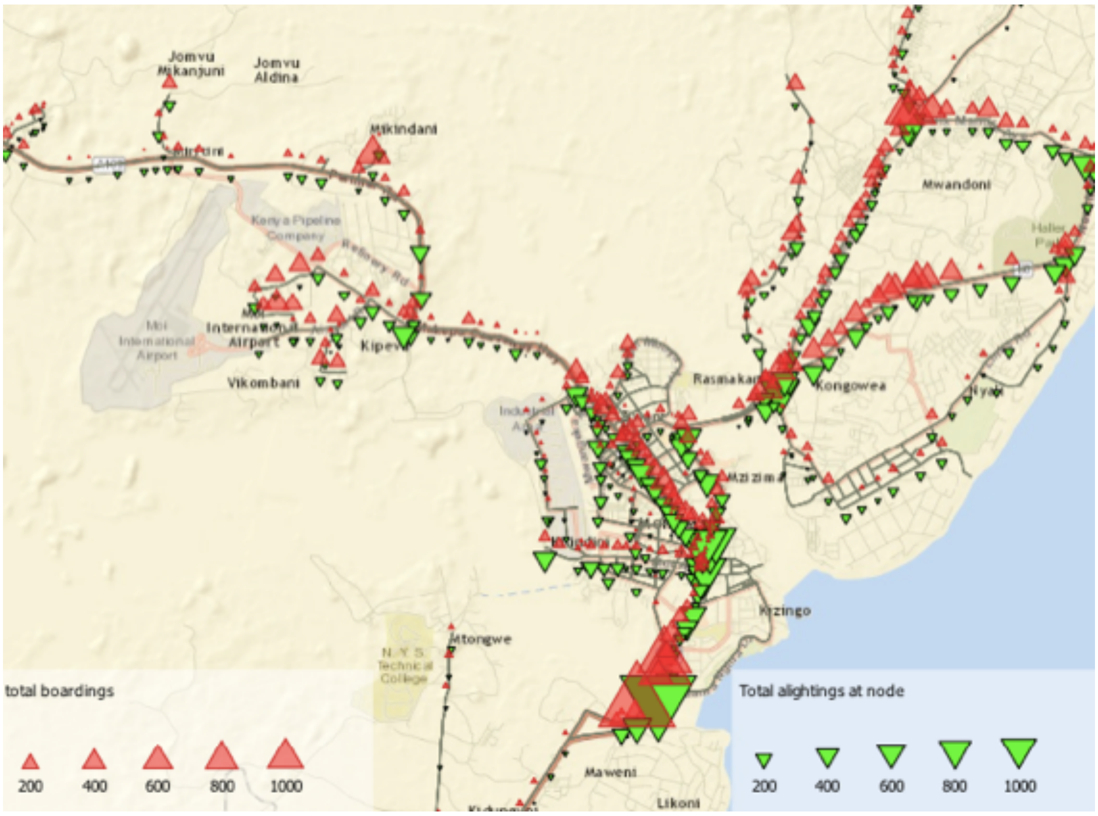


Figure 10. Passenger boarding and alighting patterns obtained through the BA surveys.

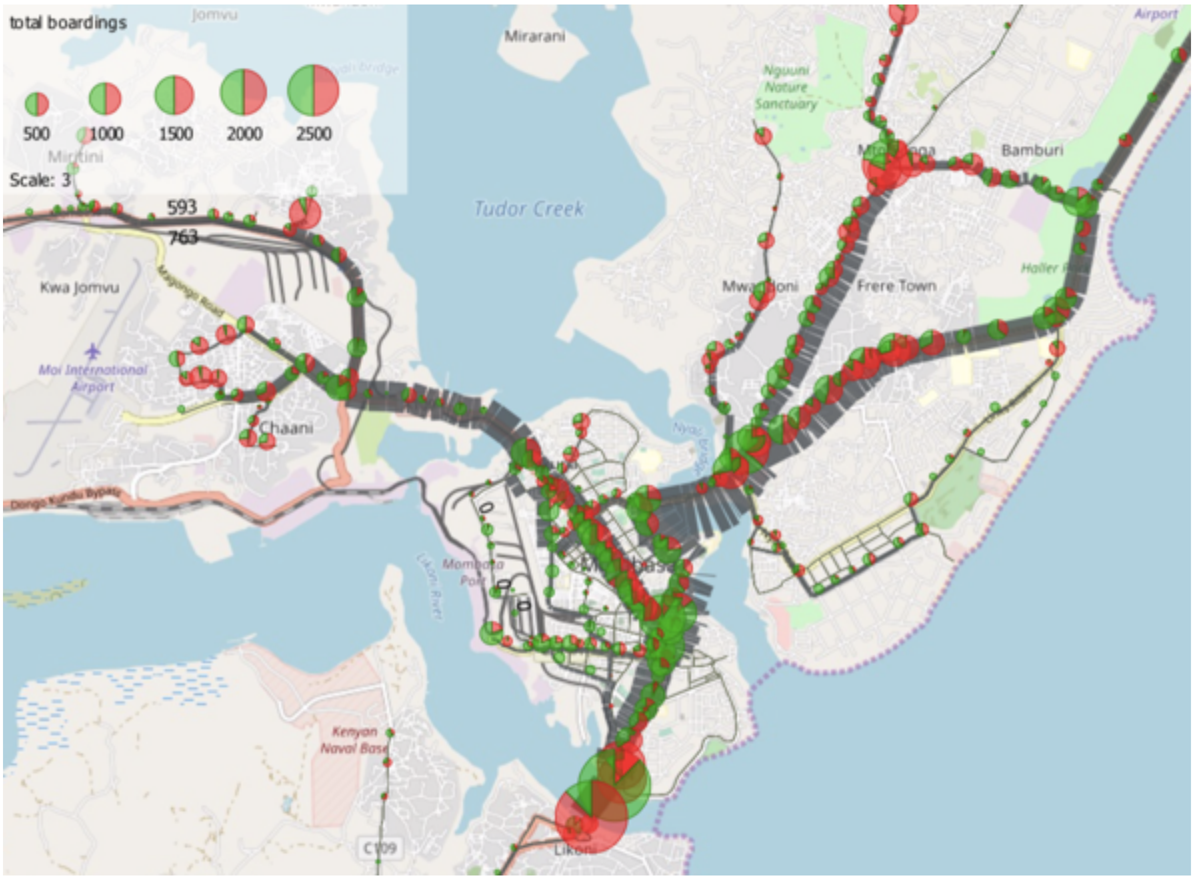


Figure 11. Modelled passenger boarding patterns obtained through the BA surveys.

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 Mombasa are as slow as 5-10 km/h, particularly on the approaches to the CBD along Mtwapa Rd, Links Rd, Old Malindi Rd and across Nyali bridge.

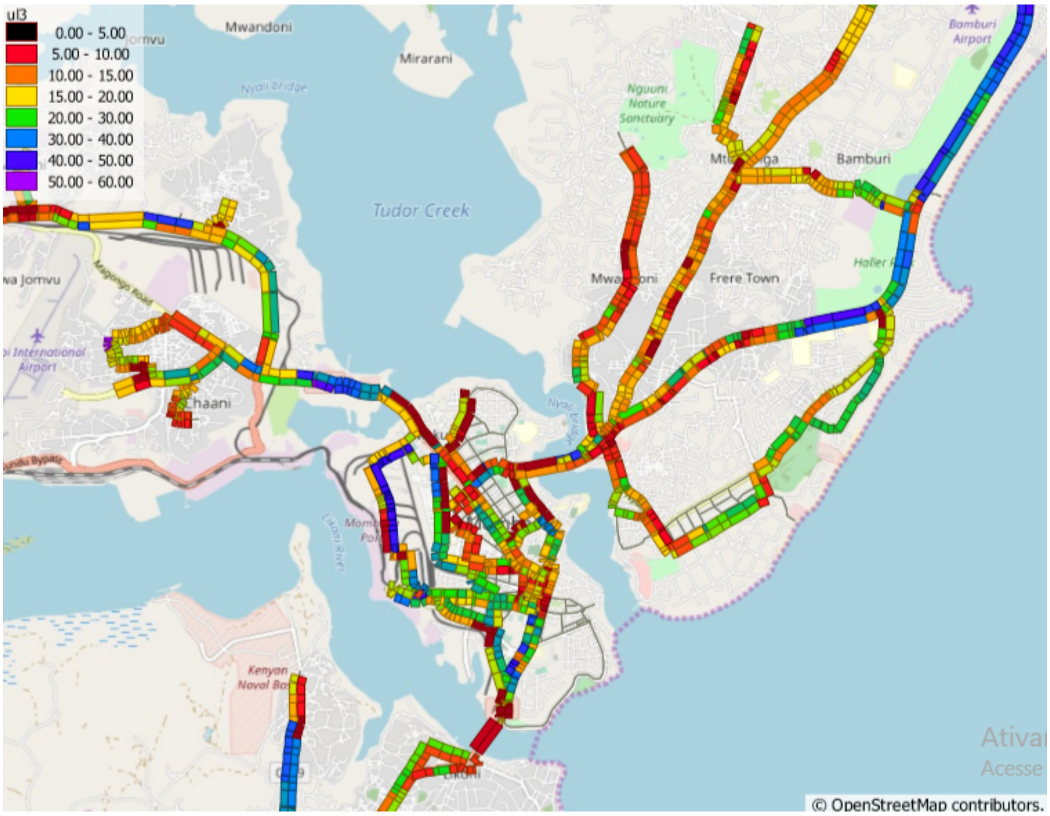


Figure 12. Public transport speeds derived from the BA surveys.

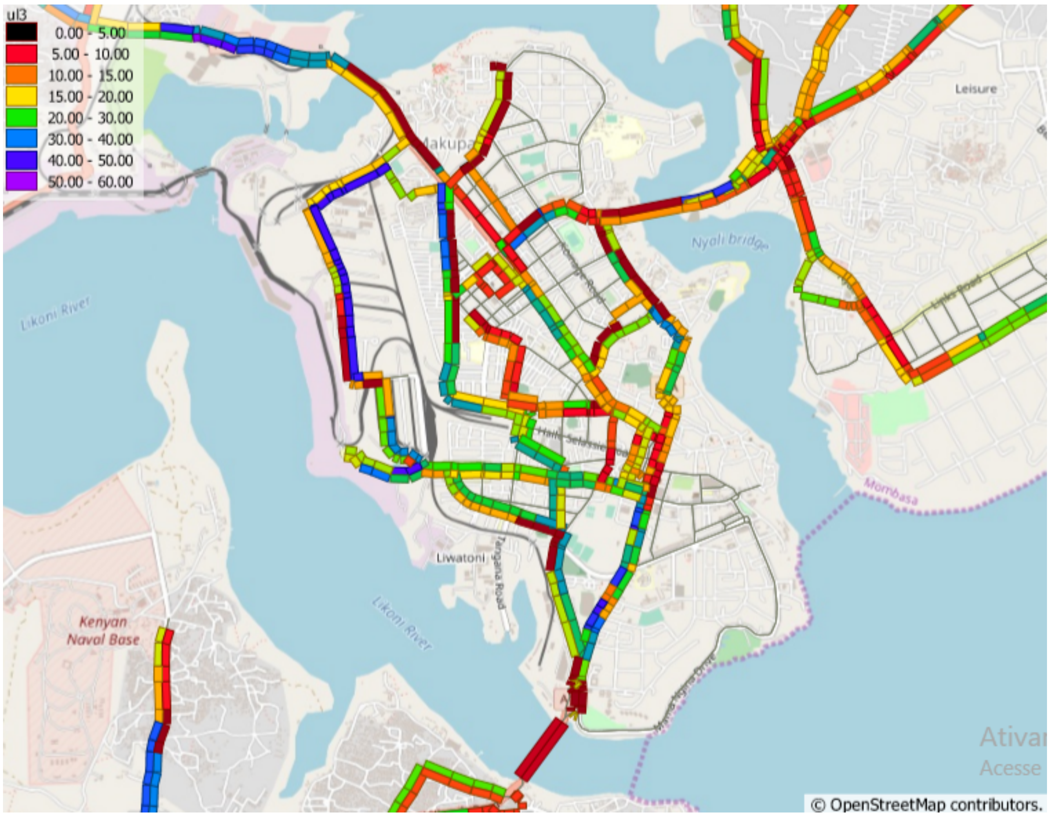


Figure 13. Public transport speeds derived from the BA surveys: Mombasa Island detail.

4.3 Transfer survey

The objective of the transfer survey is to identify trips consisting of more than one segment. The survey helps distinguish between passengers with origins near the transfer station, passengers who reached the transfer station after traveling on another route and passengers who will transfer to another route from the transfer station being surveyed. In this survey, surveyors interviewed passengers waiting to board at 5 major transfer stations in Mombasa namely Ferry, Posta, Lights, Sabasaba and Mwembe Tayari to gather details on the respondents' current trips. The survey took place during the morning peak period (6:00-10:00) on weekdays in December 2019.

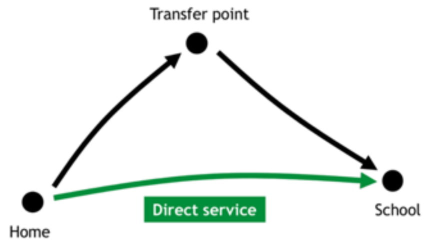


Figure 14. The transfer survey identifies trips with more than one segment (black). The introduction of new services (green) can help reduce the need for transfers.

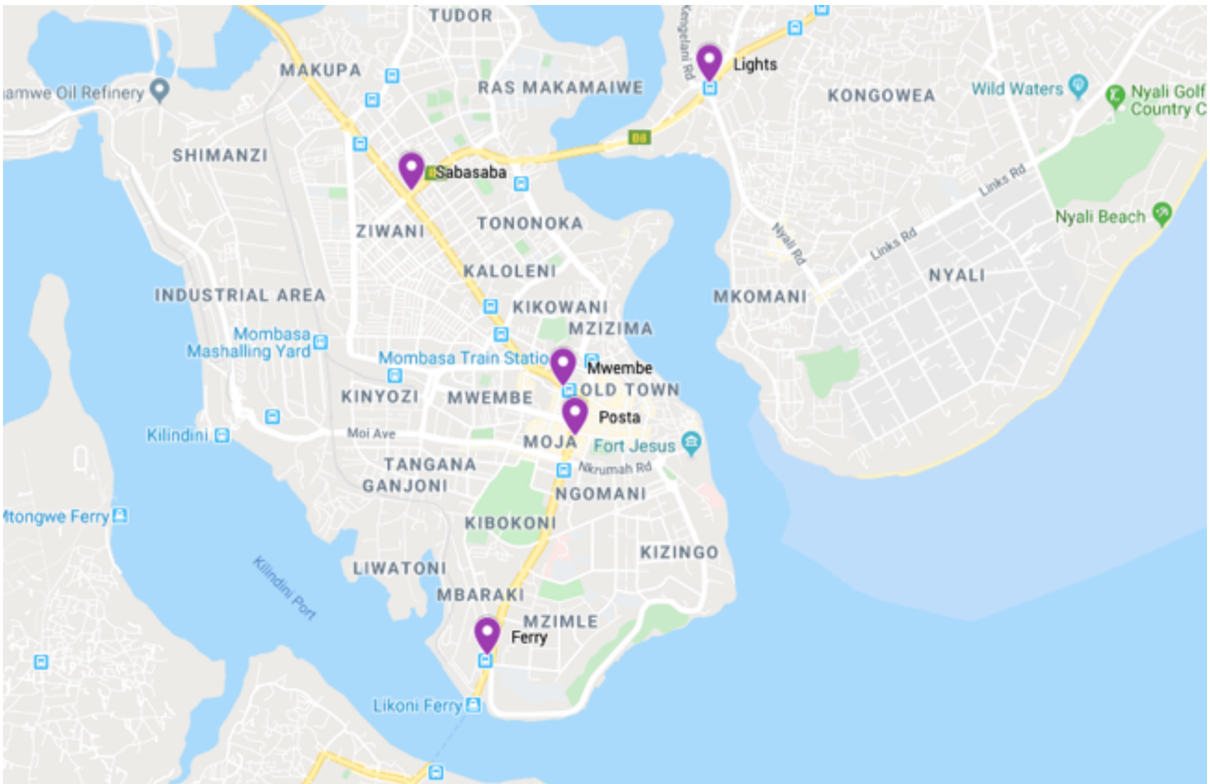


Figure 15. Transfer survey locations.

Data from the transfer survey indicate that a large number of passengers transfer one or more times to complete their journeys. Out of all journeys, 39.0 percent of passengers do not transfer, 55.2 percent of passengers transfer once, 5.1 percent transfer twice, and 0.8 percent transfer more than two times.

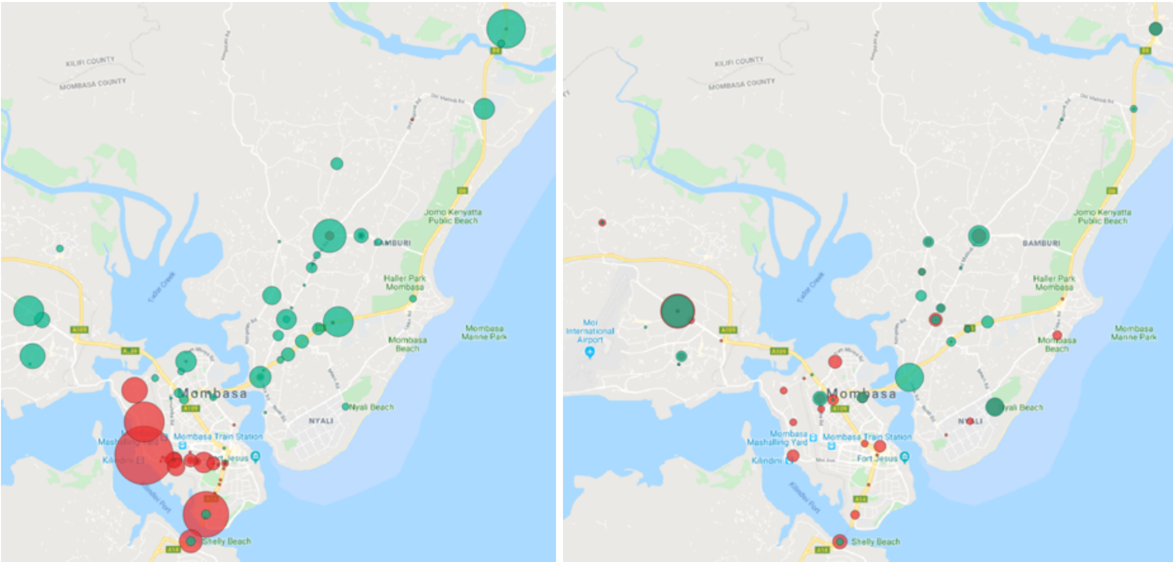


Figure 16. Transfer data: passengers transferring through Posta (left) and Lights (right): green = origins, red = destinations.

5. Public transport model preparation

A public transport model is a simplified representation of the public transport system that allows 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 public transport 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 Mombasa 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).

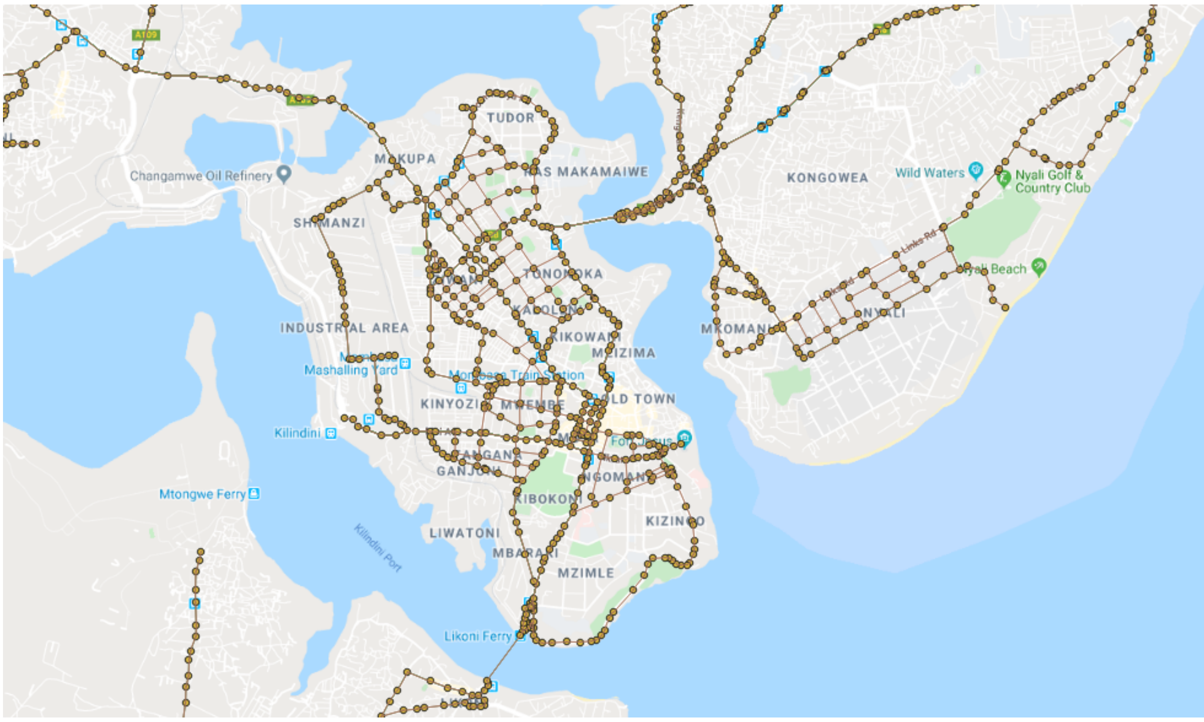


Figure 17. Existing street network represented as a set of links and nodes in the model.

5.1.2 Public transport lines

The geographic coordinates of over 5,580 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 340 locations that best represent 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.

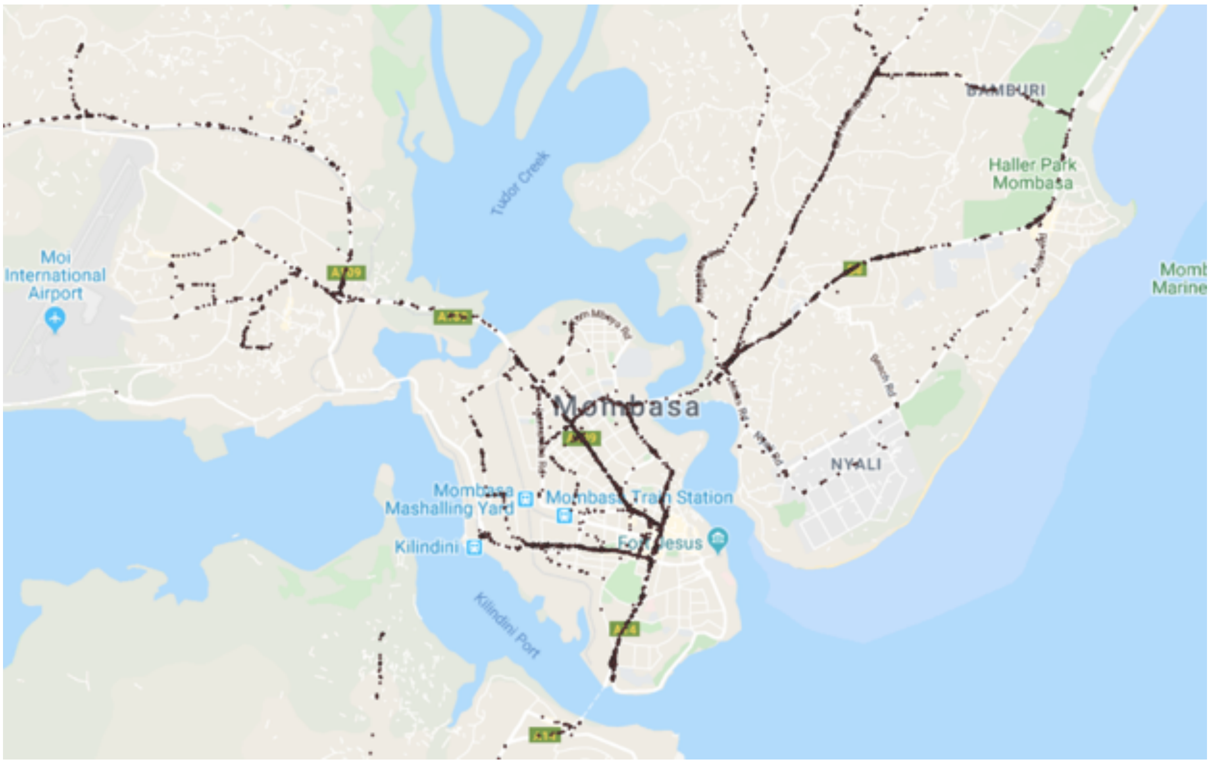


Figure 18. Boarding and alighting points captured during the BA survey.

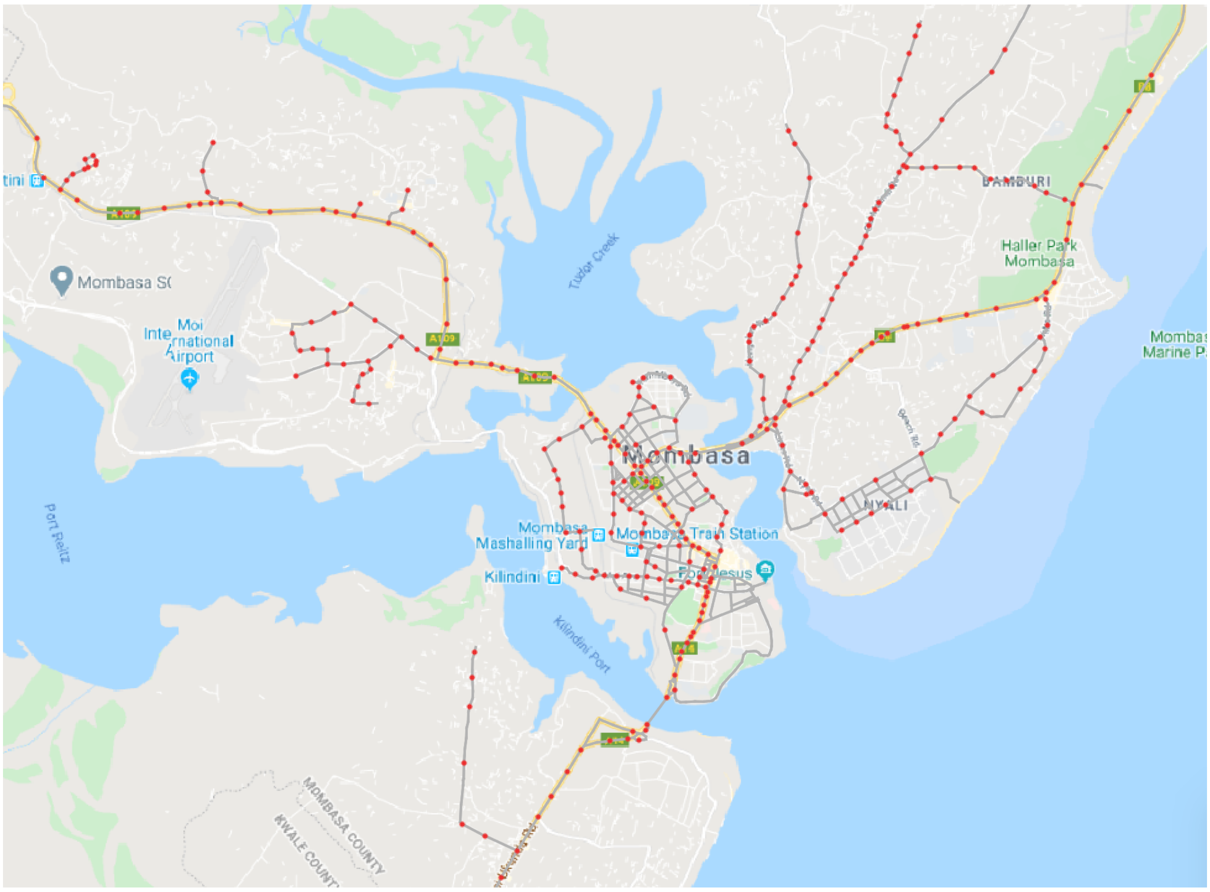


Figure 19. Consolidated stop locations in the model.

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 the BA survey observations, itineraries followed by most samples were plotted as a single line to represent the main itinerary 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 were stored as the route system.

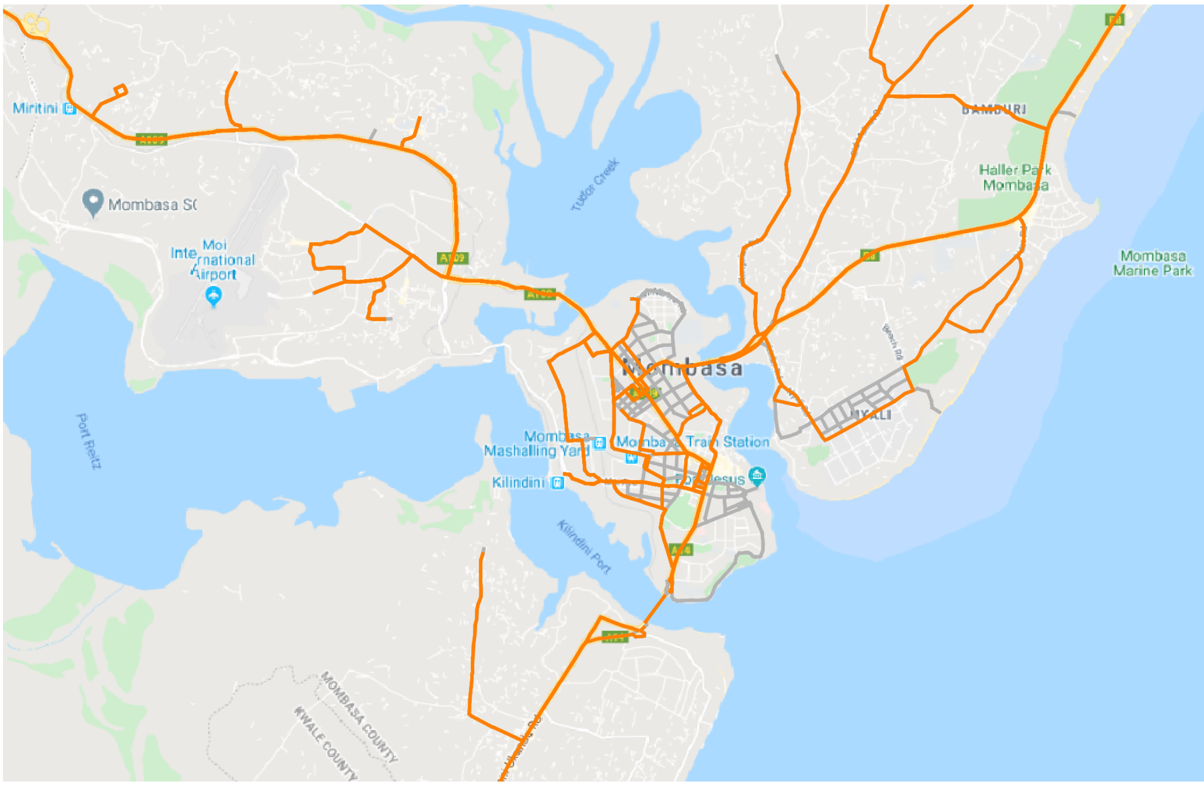


Figure 20. The matatu routes as coded in the model.

5.2 Origin-destination matrix development

5.2.1 Modelling procedure

To develop a model capable of estimating future demand for a public transport system, the first step is to develop an accurate representation of existing travel patterns. 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 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.** The database contains boardings and alightings for all of the stops along each route itinerary. 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 combined by zone to obtain the final origin-destination matrix.

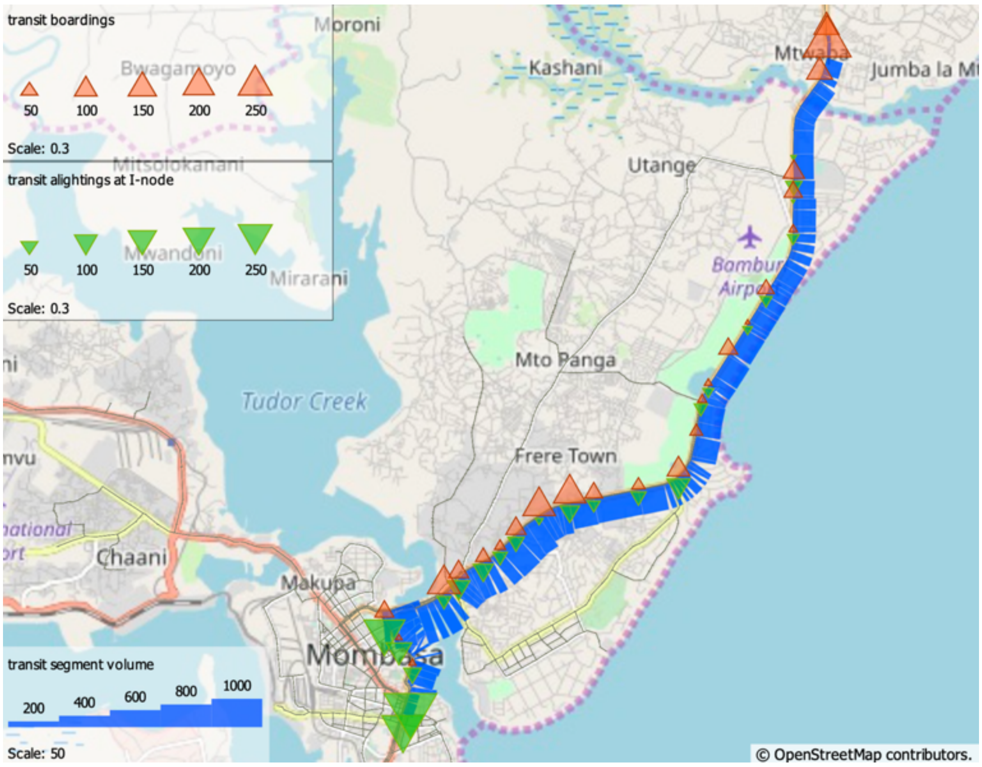


Figure 21. Sample route profile showing boarding and alighting during the morning peak hour.

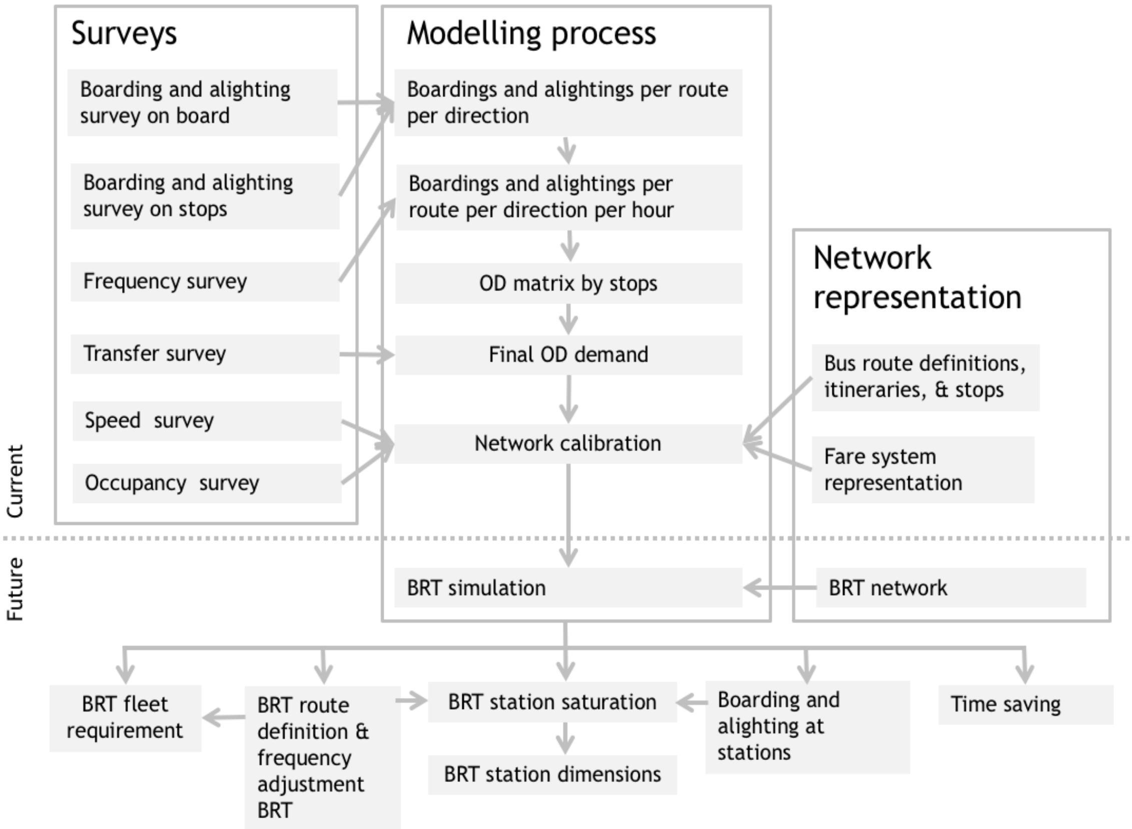


Figure 22. The BRT planning process. Data on travel patterns inform the selection of parameters such as bus route itineraries, frequencies, and fleet sizes.

5.2.2 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. There is no global relationship between distance and fare. Instead, matatu services have 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. Out of 99 directional routes, 25 operate with a flat fare, mainly the shortest routes. The other 74 routes operate with a distance-based fare, which is represented in the model through a linear function of 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 60.

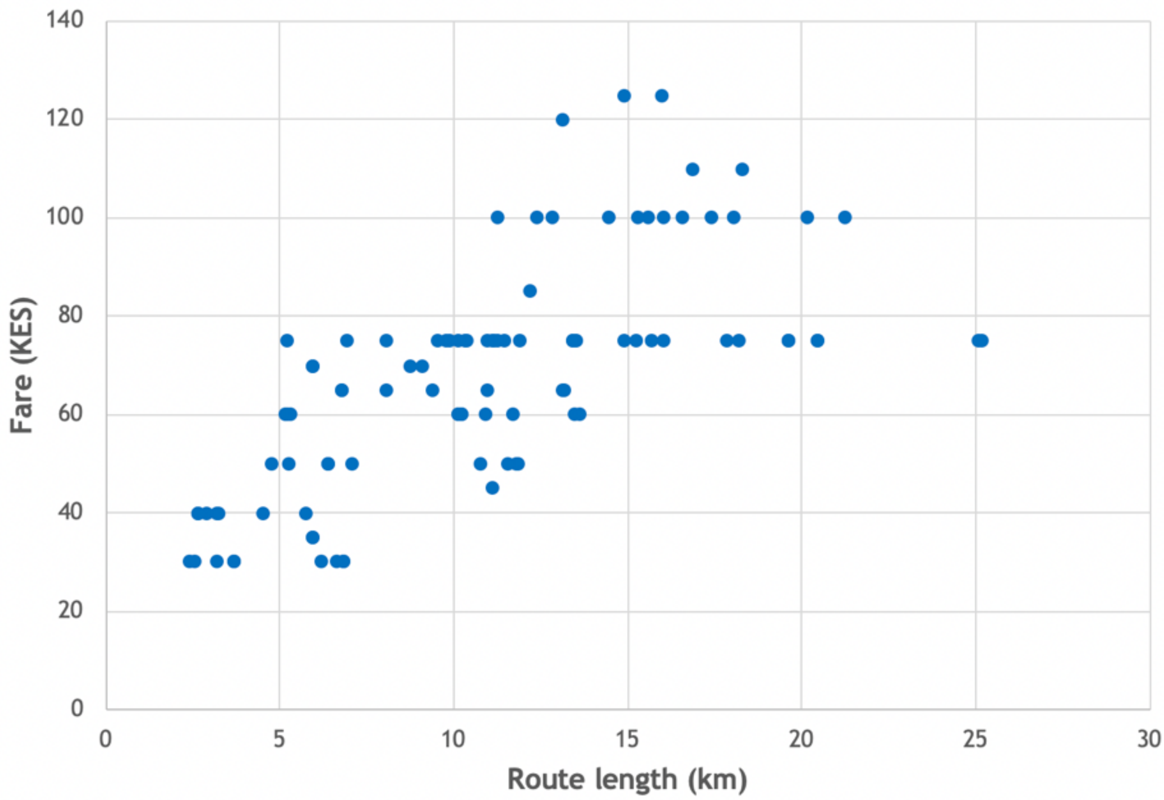


Figure 23. Relationship between route length and fare for existing matatu services.

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 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.[2] 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 consider 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.

[2] 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.

5.2.3 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 Mombasa. 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 = 25.03
- b = 0.9711
- Regression coefficient, r^2 (should be close to 1) = 0.98365
- Root mean square error relative to data value (RSME) = 178.942

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.

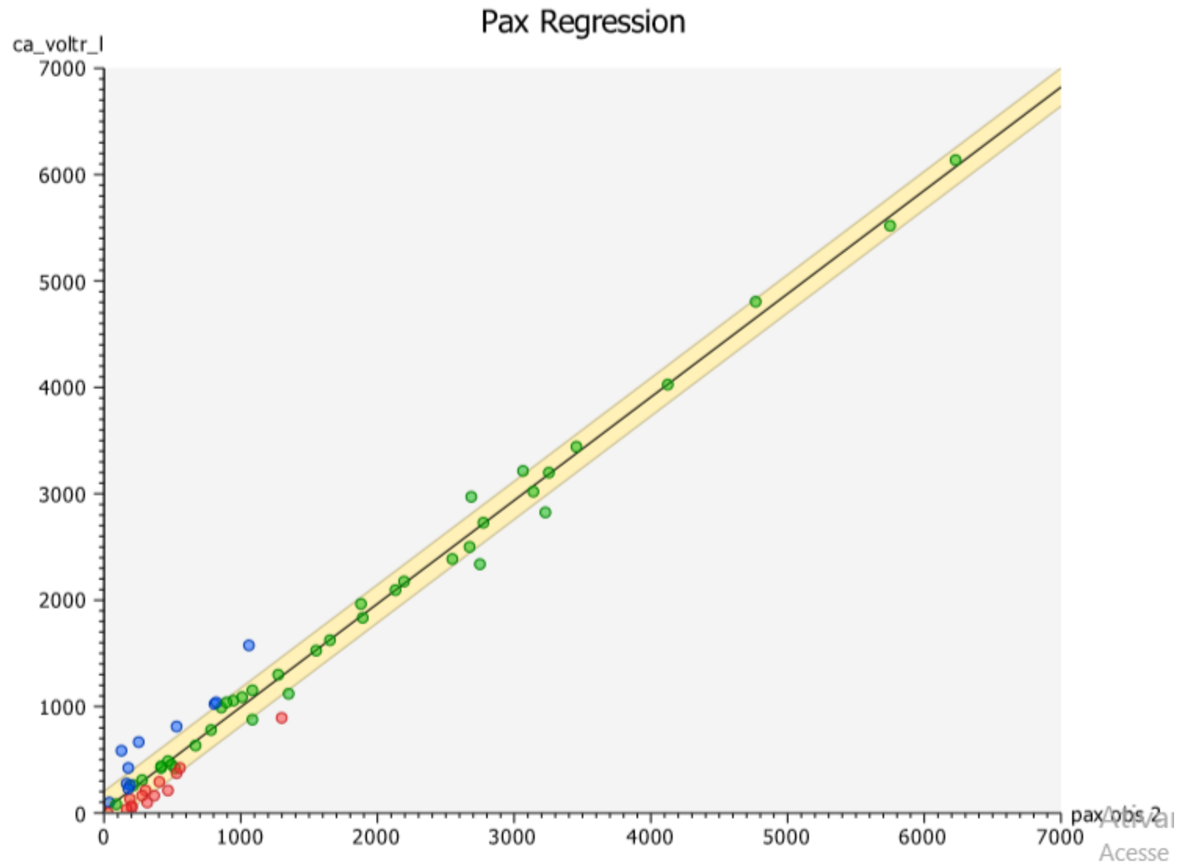


Figure 24. Linear regression between observed and modelled passengers at road sections.

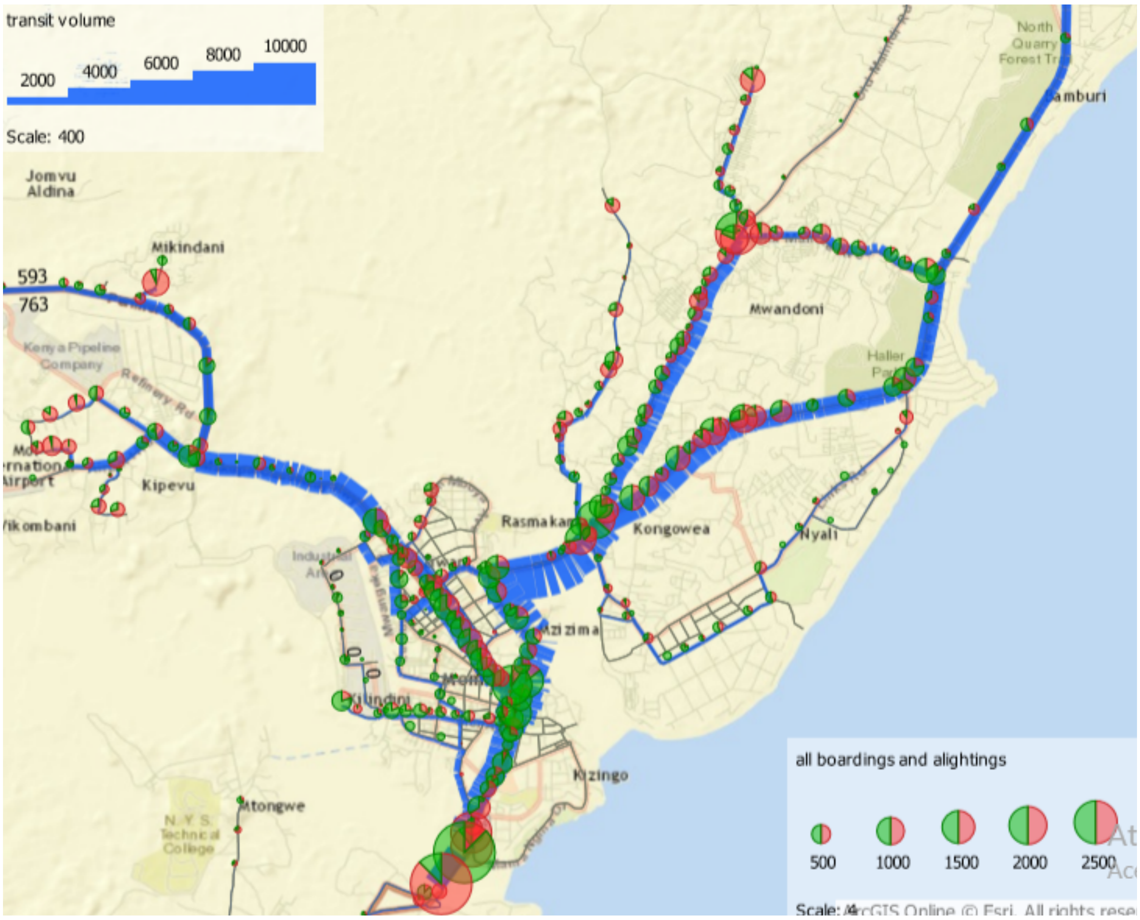


Figure 25. Estimate of existing loads (blue) and passenger boardings and alightings (green/red) during the morning peak hour following calibration of the travel demand model.

6. BRT corridor identification

As shown above, key corridors in Mombasa experience slow public transport speeds during peak commuting hours. Urgent solutions are required to provide convenient, reliable access to employment and educational opportunities in the city. Past experience has shown that simply expanding roads is not a sustainable solution to increasing congestion. Larger roads simply attract more traffic. The only viable long-term solution for ensuring mobility is to build high quality facilities for public transport and non-motorised transport (NMT). Public transport can carry large numbers of passengers without an exponential increase in road space requirements.

To make public transport service competitive with personal motor vehicles, major corridors in Mombasa require dedicated road space for public transport in the form of bus rapid transit (BRT). BRT is a high quality bus-based public transport system that delivers fast, comfortable and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service. [3] An efficient BRT can accommodate 4,000 to 45,000 people per hour per direction and typically costs 10 to 20 times less

[3] https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt/

than a metro system. Thus, BRT can significantly increase the passenger carrying capacity of the major roads in Mombasa.

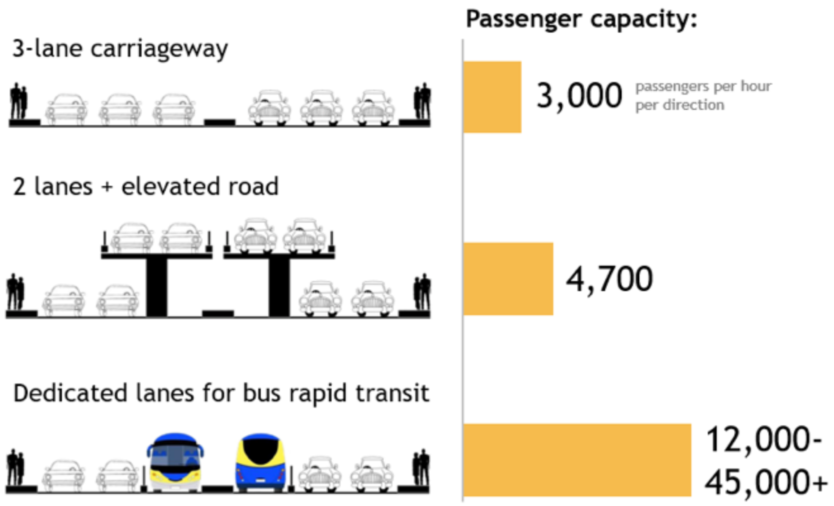


Figure 26: To increase passenger carrying capacity, major roads in Mombasa should incorporate dedicated lanes for public transport.

The introduction of BRT also presents an opportunity to bring about a transition of the affected part of the matatu industry from individual informal operators to modern, competitive companies operating under contract to the government. Many of the best BRT systems in developing economies emerged out of weakly regulated and informal sector-dominated private transport services.

Figure 27. The DART BRT system in Dar es Salaam incorporates best practice features such as dedicated median bus lanes and level boarding from central stations.

Figure 28. BRT can have the largest impact on corridors experiencing serious traffic congestion and high public transport passenger volumes.

The selection of the corridors for BRT should consider several factors:

- **Public transport passenger volumes**. Opening the first phases of the BRT areas with high demand will help demonstrate the ability of BRT to benefit a large number of commuters.
- **Speeds for public transport passengers**: Sections with low existing speeds have the greatest potential for speed improvements if BRT is implemented.
- **Ability to connect main trip generation and attraction areas** with services that are as direct as possible.
- **Presence of sufficient right-of-way (ROW)** for median-aligned lanes and stations.

Based these factors, two major corridors in Mombasa should be considered for BRT:

- **Phase 1: Malindi Rd to the CBD and ferry terminal.** An efficient connection is required between city centre and the northern catchment areas of Bamburi, Mtwapa, Kisauni, and Mshomoroni. The volume on this corridor reaches 8,000 pphpd at Nyali Bridge, the highest volume in the city, so this corridor should be prioritised. Within the island, BRT infrastructure should be extended to major destinations including Posta, Mwembe Tayari, and the ferry terminal.
- **Phase 2: Mariakani Rd.** In the second phase, a corridor extension can be developed from Sabasaba to the western areas of Magongo and Miritini through Jomo Kenyatta Ave and the Makupa Causeway. A volume of 3,100 pphpd was recorded on the Makupa Causeway.

This report discusses service scenarios for phase 1, with infrastructure along the Mombasa-Malindi Rd up to the CBD and the ferry terminal. Services from both the northern and western parts of Mombasa can utilise the phase 1 BRT infrastructure, as described below.

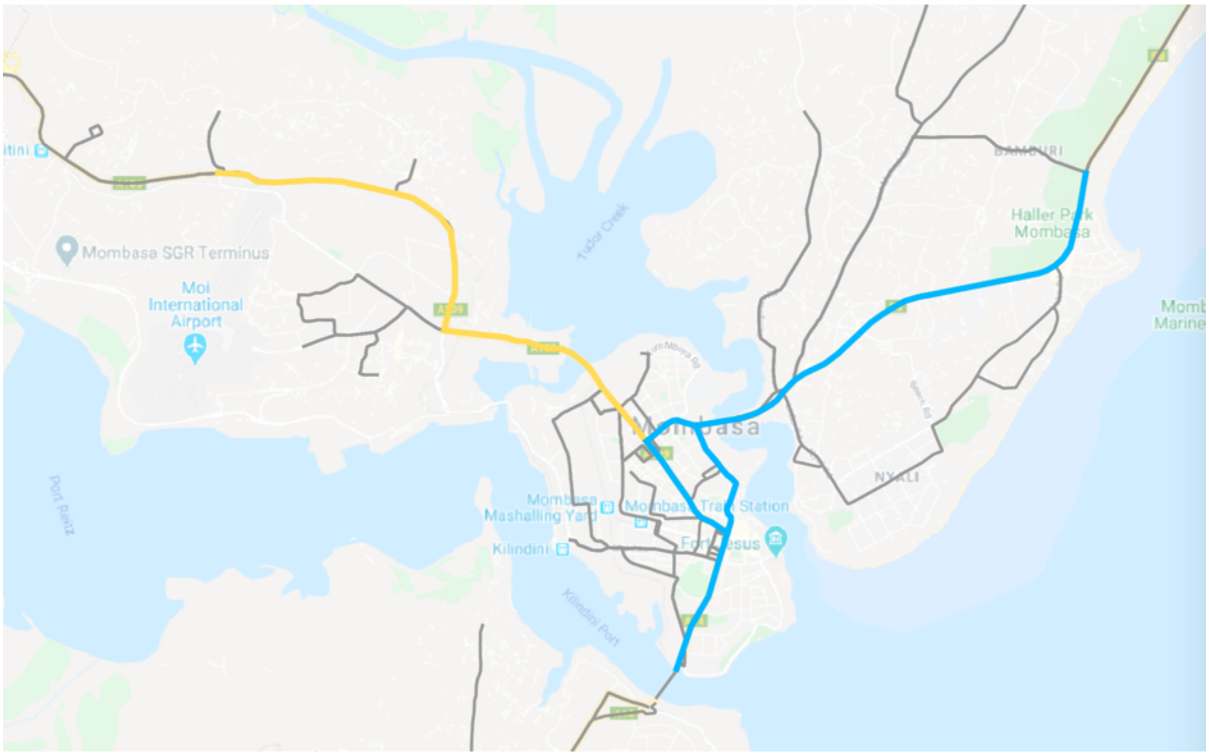


Figure 29. Corridors identified for BRT infrastructure in Mombasa (blue = phase 1; yellow = phase 2; BRT service extensions and matatu routes = grey).

7. Service plan

A citywide service plan was developed to determine the set of routes that best accommodate passenger trips while optimising the use of the bus fleet. The modelling process assumes that future routes operating on the identified BRT corridors (Figure 29) will travel at higher speeds than existing services. The service plan includes two scenarios: service scenario 1, where services from northern Mombasa access the infrastructure, and service scenario 2, where both northern and western routes enter the phase 1 BRT infrastructure.

7.1 BRT service 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 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.

For the Mombasa BRT service, 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 in Mombasa provide direct service from residential areas of Bamburi, Tudor, Bombolulu, and Mshomoroni to the CBD and ferry terminal.
- Many existing routes pick up passengers from residential areas off the corridor and then join the main roads to the CBD. 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.

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 to facilitate the operation of direct services.

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.

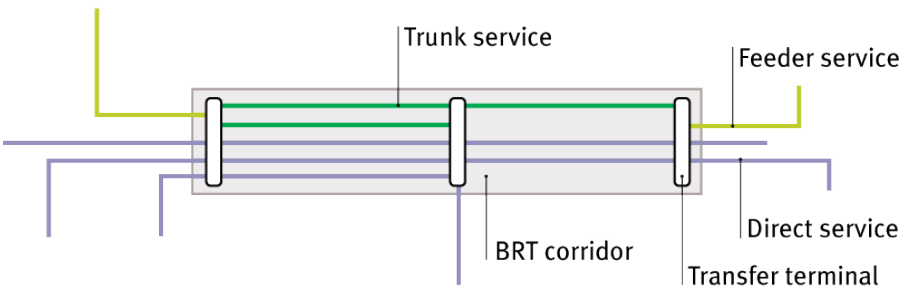


Figure 30. The Mombasa BRT will incorporate a variety of services to improve efficiency and minimise passenger transfers, including direct services that extend beyond dedicated BRT corridors to outlying areas.

7.2 BRT services

Many scenarios were tested to reach a configuration with a limited number of transfers and an optimal fleet. The testing considered two services operating in the phase 1 BRT infrastructure (blue corridor in Figure 29):

- **Service scenario 1:** Services operating to the north along Malindi Rd, Old Malindi Rd, and Kengeleni Rd are converted to BRT services, while matatu routes in western Mombasa continue to operate as non-BRT services.
- **Service scenario 2:** In addition to the northern lines, several routes in western Mombasa become BRT services. They operate in mixed traffic up to Sabasaba where they enter the BRT infrastructure.

The following images display the final routes that were selected for each scenario.

7.2.1 Service scenario 1: BRT services on Malindi Rd

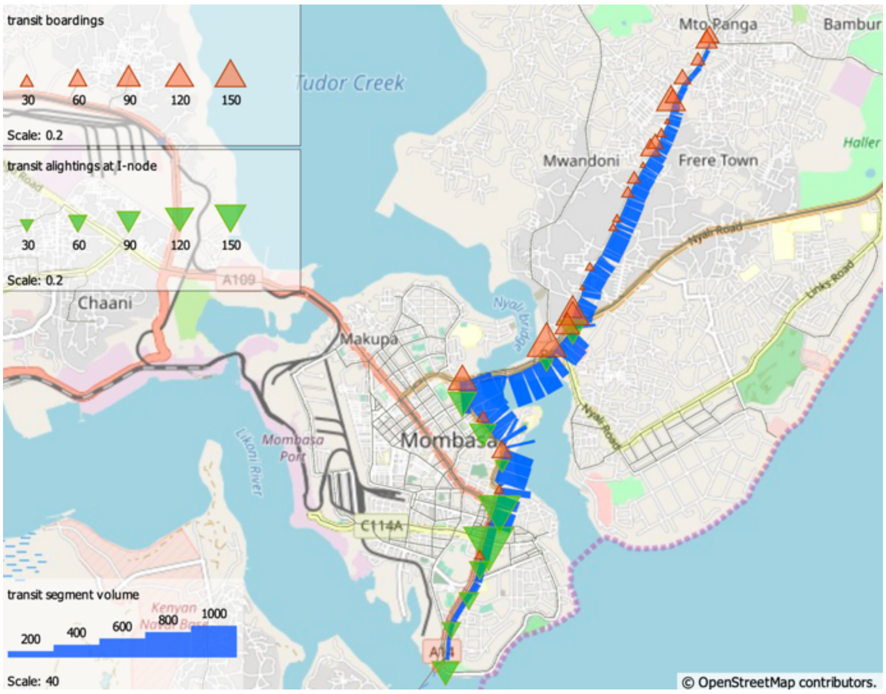


Figure 31. Boarding pattern and passenger load: Ferry-Buxton-Kisauni-Bamburi (BR03).

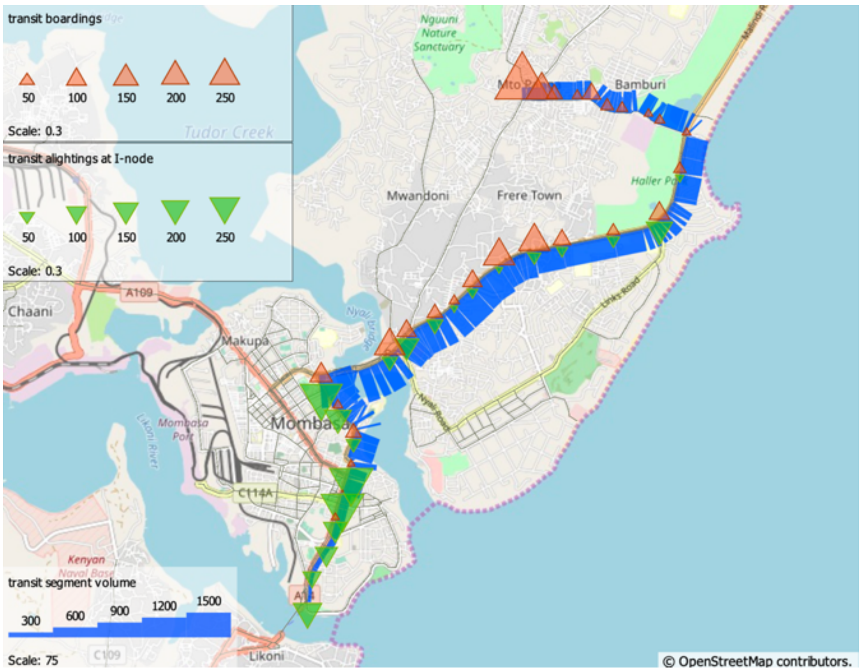


Figure 32. Boarding pattern and passenger load: Ferry-Buxton-Mtamboni-Bamburi (BR04).

Figure 33. Boarding pattern and passenger load: Posta-Sabasaba-Mtamboni-Bamburi (BR05).

Figure 34. Boarding pattern and passenger load: Posta-Sabasaba-Bombolulu (BR07).

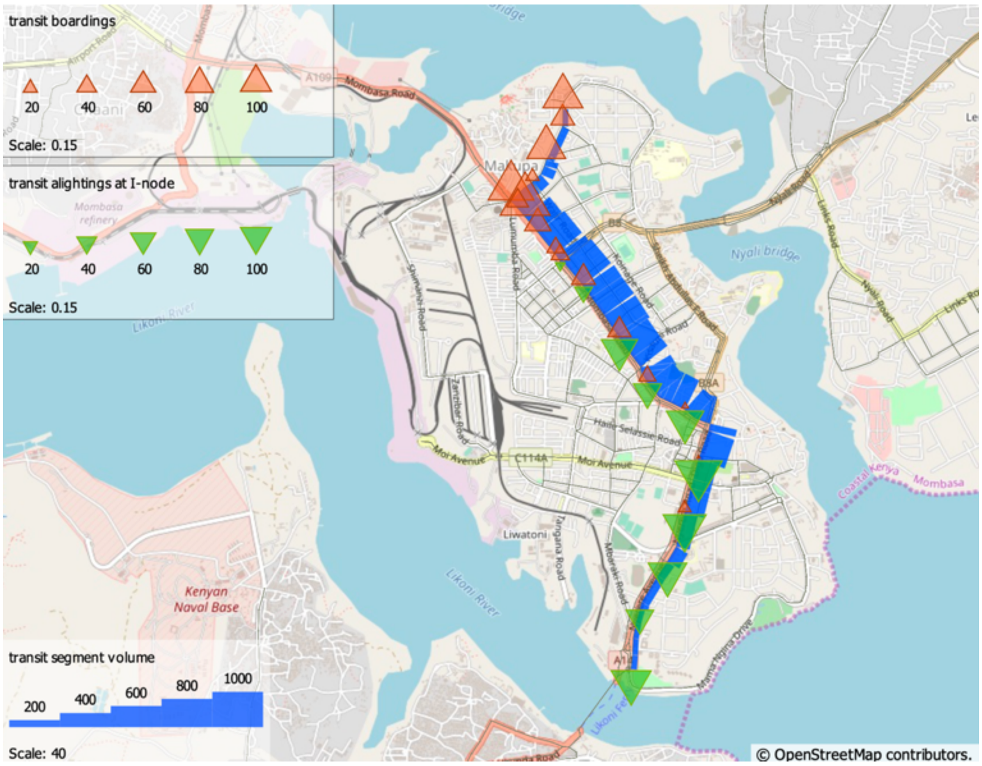


Figure 35. Boarding pattern and passenger load: Tudor-Ferry (BR08).

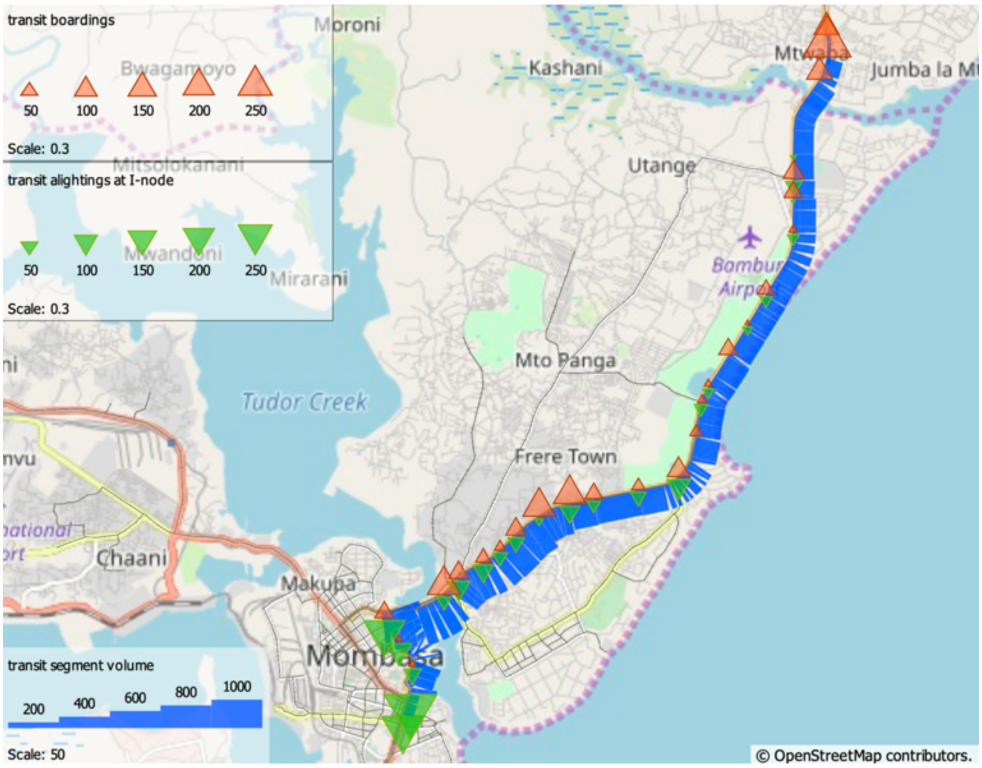


Figure 36. Boarding pattern and passenger load: Posta-Buxton-Mtwapa (BR13).

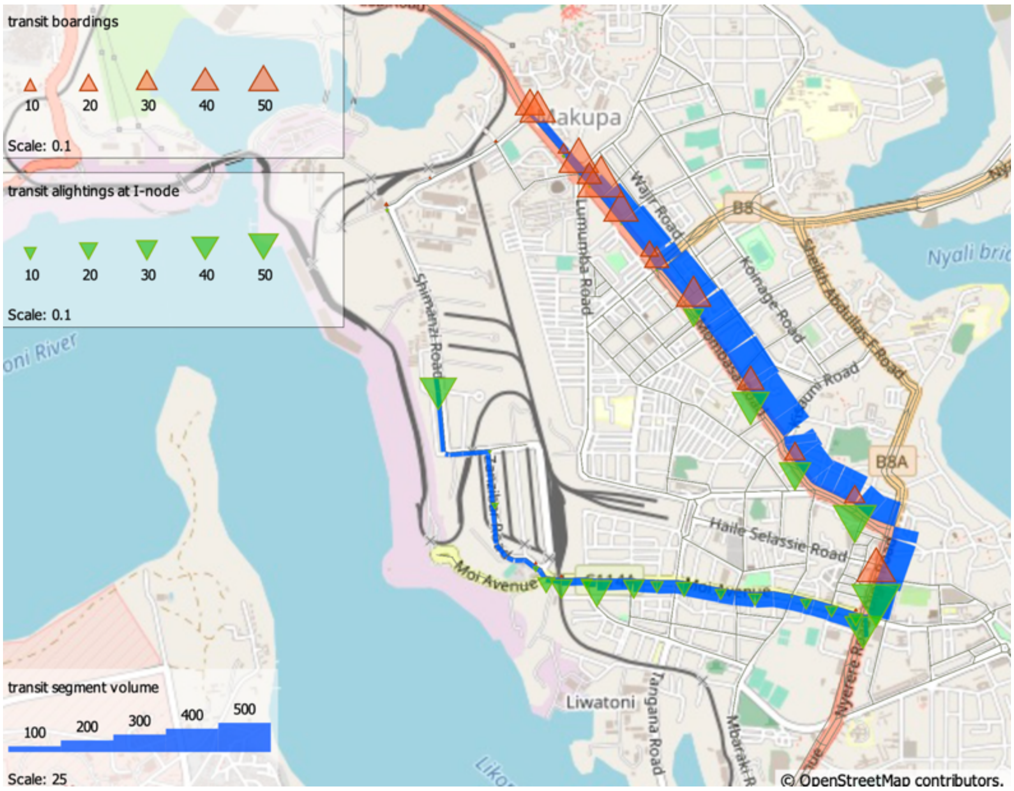


Figure 37. Boarding pattern and passenger load: Shimanzi-Posta-Makupa (BR14).

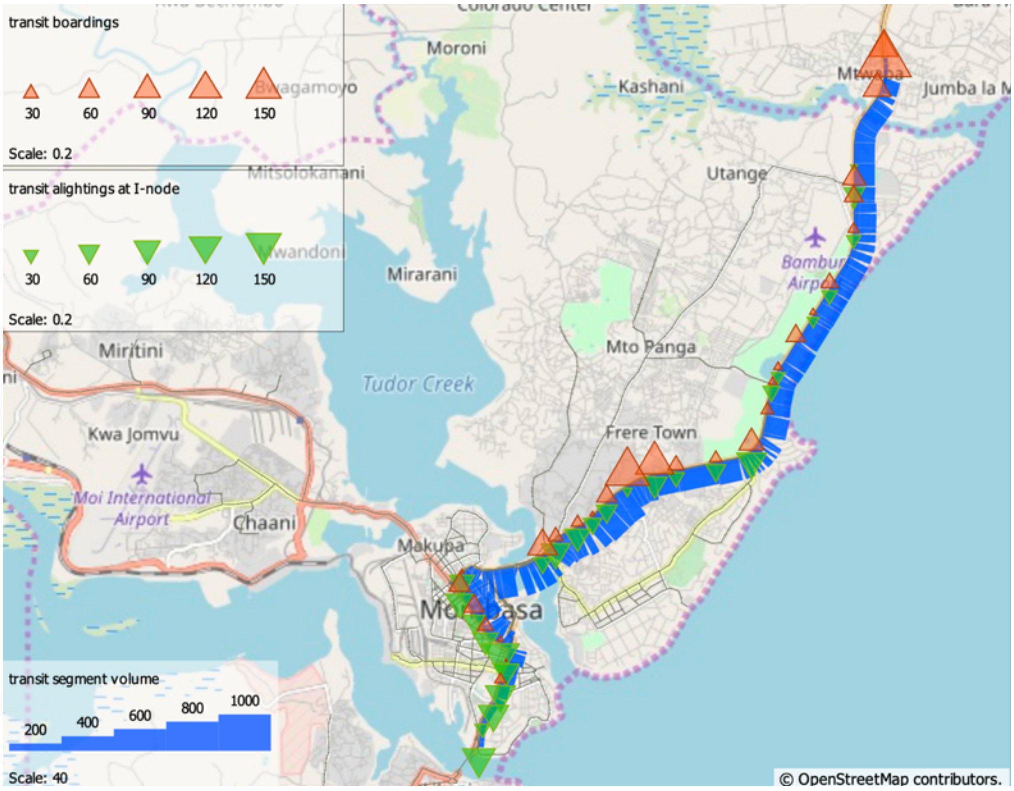


Figure 38. Boarding pattern and passenger load: Ferry-Sabasaba-Mtwapa (BR17).

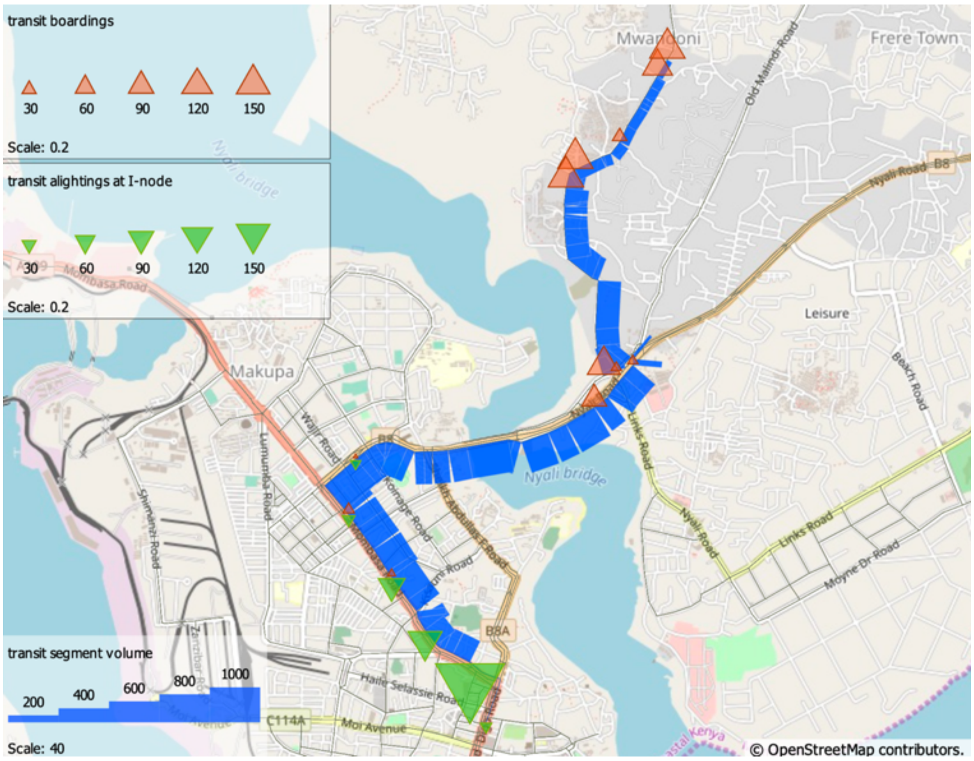


Figure 39. Boarding pattern and passenger load: Posta-Sabasaba-Mshomoroni (BR20).

The final BRT fleet for service scenario 1, with BRT services extending to the north within the Mombasa-Malindi Road basin, requires an operational fleet of 160 buses (all 12 m vehicles), corresponding to a total fleet of 176 buses with a 10 percent reserve. Table 2 displays the passenger demand, headway, and required fleet size for each of the 9 BRT services.

Table 2. BRT service characteristics: Infrastructure phase 1; service scenario 2.

Line	Origin-destination	Length (KM)	Max load (pphpd)	Boardings (peak hour)	Boardings, daily	Headway (min)	Fleet size (no reserve)
BR03n	Ferry-Kisauni-Bamburi	10.3	810	1,098	9,882	5.2	9
BR03s	Bamburi-Kisauni-Ferry	10.3	1,034	1,455	13,095	5.2	10
BR04n	Ferry-Mtamboni-Bamburi	15.1	889	1,501	13,509	2.7	18
BR04s	Bamburi-Mtamboni-Ferry	15.0	2,028	2,952	26,568	2.7	18
BR05n	Posta-Saba-Mtamboni-Bamburi	14.0	363	645	5,805	5.4	8
BR05s	Bamburi-Mtamboni-Saba-Posta	14.0	1,006	1,530	13,770	5.4	9

Line	Origin-destination	Length (KM)	Max load (pphpd)	Boardings (peak hour)	Boardings, daily	Headway (min)	Fleet size (no reserve)
BR07n	Posta-Sabasaba-Bombolulu	7.9	189	258	2,322	11.1	2
BR07s	Bombolulu-Sabasaba-Posta	7.9	488	651	5,859	11.1	2
BR08n	Tudor-Ferry	5.9	841	997	8,973	5.1	4
BR08s	Ferry-Tudor	6.0	1,049	1,198	10,782	5.1	8
BR13n	Posta-Mtwapa	17.9	661	1,133	10,197	3.9	12
BR13s	Mtwapa-Posta	17.8	1,370	2,282	20,538	3.9	14
BR14n	Shimanzi-Posta-Makupa	8.6	139	162	1,458	9.1	3
BR14s	Makupa-Posta-Shimanzi	8.7	596	814	7,326	9.1	6
BR17n	Ferry-Sabasaba-Mtwapa	20.7	1,036	2,216	19,944	5.2	11
BR17s	Mtwapa-Sabasaba-Ferry	20.7	920	1,793	16,137	5.2	12
BR20n	Posta-Mshomoroni	7.9	232	241	2,169	5.8	8
BR20s	Mshomoroni-Posta	7.9	930	960	8,640	5.8	6
Total				21,886	196,974		160

7.2.2 Scenario 2: BRT services on Malindi Rd and Mariakani Rd

Figure 40. Boarding pattern and passenger load: Ferry-Sabasaba-Miritini (BM07).

Figure 41. Boarding pattern and passenger load: Posta-Sabasaba-Migadini (BM08).

Figure 42. Boarding pattern and passenger load: Posta-Buxton-Mikindani (BM10).

Figure 43. Boarding pattern and passenger load: Posta-Buxton-Kwa Jomvu-Miritini (BM11).

Figure 44. Boarding pattern and passenger load: Lights-Sabasaba-Magongo (BM15).

Figure 45. Boarding pattern and passenger load: Migadini – Lights (BM16).

Figure 46. Boarding pattern and passenger load: Posta-Buxton-Magongo (BM17).

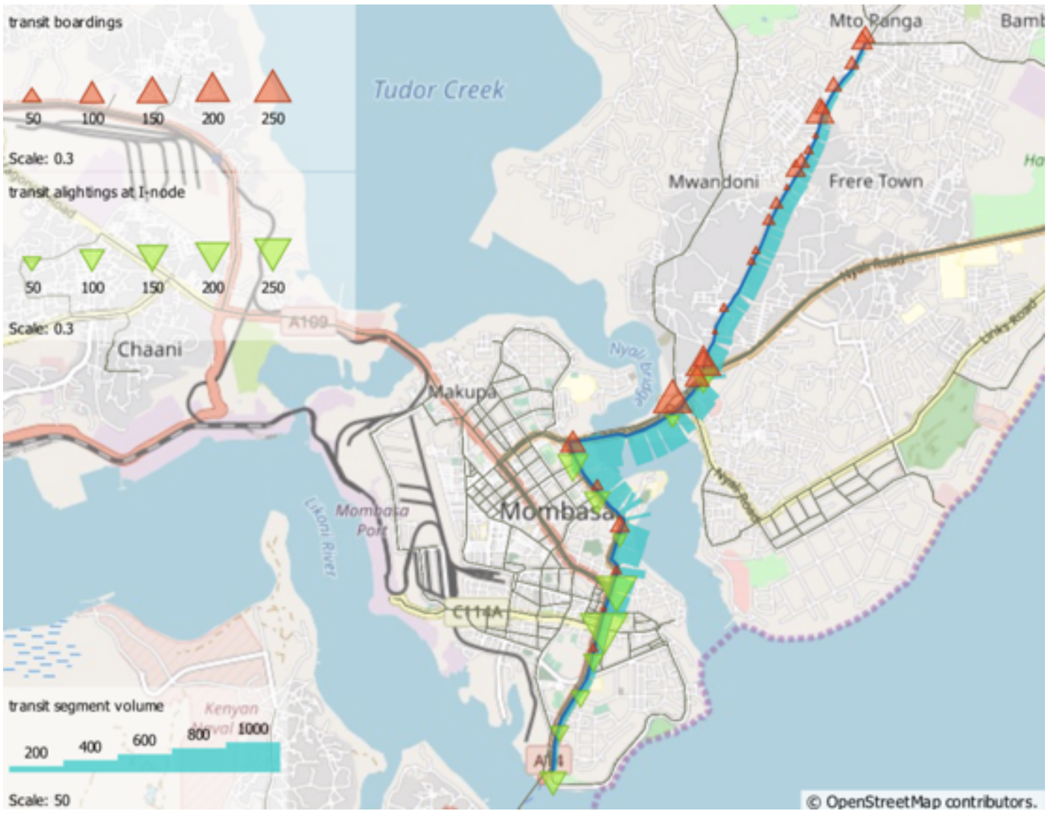


Figure 47. Boarding pattern and passenger load: Ferry-Buxton-Kisauni-Bamburi (BR03).

Figure 48. Boarding pattern and passenger load: Ferry-Buxton-Mtamboni-Bamburi (BR04).

Figure 49. Boarding pattern and passenger load: Posta-Sabasaba-Mtamboni-Bamburi (BR05).

Figure 50. Boarding pattern and passenger load: Posta-Sabasaba-Bombolulu (BR07).

Figure 51. Boarding pattern and passenger load: Ferry-Tudor (BR08).

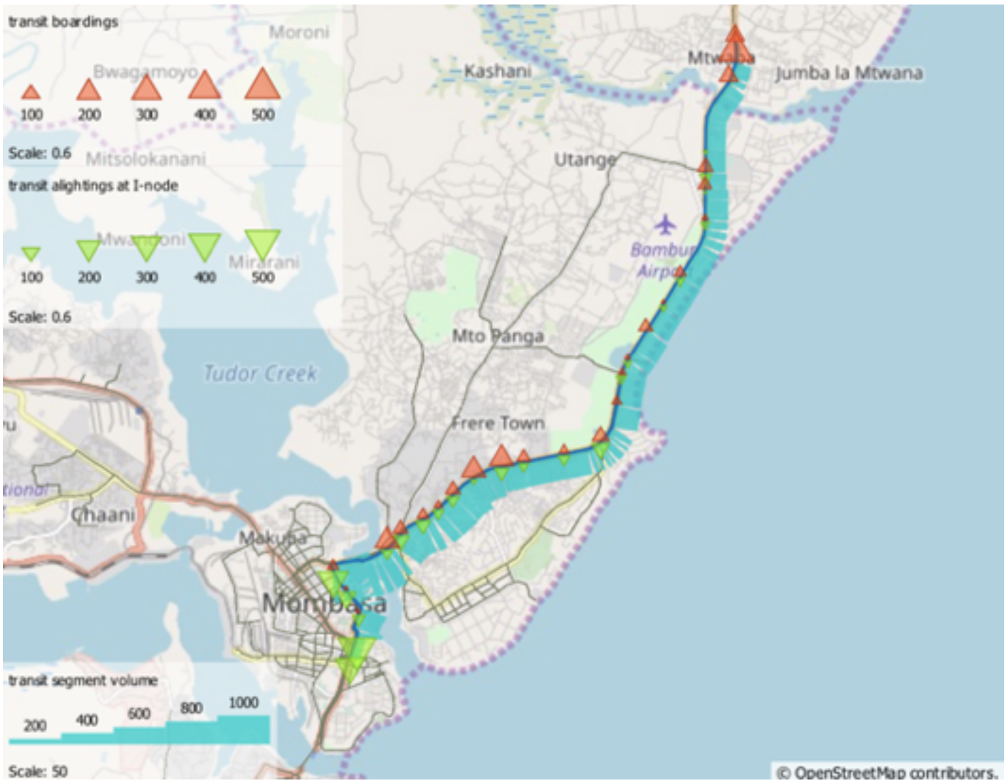


Figure 52. Boarding pattern and passenger load: Posta-Buxton-Mtwapa (BR13).

Figure 53. Boarding pattern and passenger load: Shimanzi-Posta-Makupa-Shimanzi (BR14).

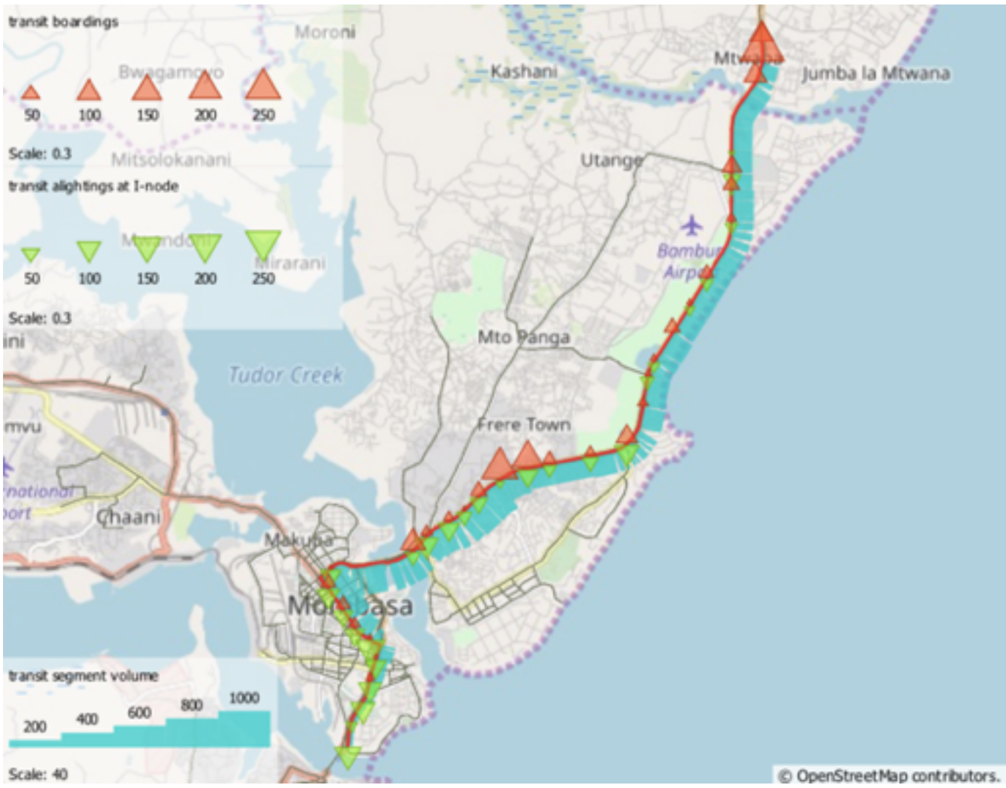


Figure 54. Boarding pattern and passenger load: Ferry-Sabasaba-Mtwapa (BR17).

Figure 55. Boarding pattern and passenger load: Mwembe-Sabasaba-Mshomoroni (BR20).

The final BRT fleet for service scenario 2, with BRT services on Malindi and Mariakani Roads, requires an operational fleet of 232 buses, corresponding to a total fleet of 256 buses with a 10 percent reserve. The average speed for BRT service inside the corridor is 24 km/h. Table 3 displays the passenger demand, headway, and required fleet size for each of the 16 BRT services.

Table 3. BRT service characteristics: Infrastructure phase 1; service scenario 2.

Line	Origin-destination	Length (KM)	Max load (pphpd)	Boardings (peak hour)	Boardings, daily	Headway (min)	Fleet size (no reserve)
BM07e	Miritini-Ferry	14.6	513	806	7,254	6.6	11
BM07w	Ferry-Miritini	14.6	813	1,354	12,186	6.6	9
BM08e	Migadini-Posta	9.2	865	935	8,415	6.2	9
BM08w	Posta-Migadini	9.0	377	447	4,023	6.2	7
BM10e	Mikindani-Posta	10.6	308	370	3,330	17.5	4
BM10w	Posta-Mikindani	10.3	82	120	1,080	17.5	3
BM11e	Miritini-Posta	14.8	304	561	5,049	11.6	11
BM11w	Posta-Miritini	14.7	465	621	5,589	11.6	6
BM15e	Magongo-Lights	9.2	272	332	2,988	19.9	3
BM15w	Lights-Magongo	9.1	164	207	1,863	19.9	2
BM16e	Migadini-Lights	9.8	230	277	2,493	23.5	3
BM16w	Lights-Migadini	8.9	139	181	1,629	23.5	2
BM17e	Magongo-Posta	10.1	490	566	5,094	11.0	6
BM17w	Posta-Magongo	9.8	116	171	1,539	11.0	4
BR03n	Ferry-Kisauni-Bamburi	10.3	762	1,051	9,459	5.1	9
BR03s	Bamburi-Kisauni-Ferry	10.3	1,063	1,448	13,032	5.1	11
BR04n	Ferry-Mtamboni-Bamburi	15.1	841	1,444	12,996	2.7	18
BR04s	Bamburi-Mtamboni-Ferry	15.0	2,032	2,921	26,289	2.7	18
BR05n	Posta-Saba-Mtamboni-Bamburi	14.0	361	627	5,643	5.4	8
BR05s	Bamburi-Mtamboni-Saba-Posta	14.0	1,008	1,520	13,680	5.4	9
BR07n	Posta-Sabasaba-Bombolulu	7.9	173	240	2,160	11.1	2

Line	Origin-destination	Length (KM)	Max load (pphpd)	Boardings (peak hour)	Boardings, daily	Headway (min)	Fleet size (no reserve)
BR07s	Bombolulu-Sabasaba-Posta	7.9	488	639	5,751	11.1	2
BR08n	Tudor-Ferry	5.9	641	750	6,750	8.4	3
BR08s	Ferry-Tudor	6.0	589	710	6,390	8.4	5
BR13n	Posta-Mtwapa	17.9	662	1,124	10,116	3.9	12
BR13s	Mtwapa-Posta	17.8	1,376	2,252	20,268	3.9	14
BR14n	Shimanzi-Posta-Makupa	8.6	69	85	765	14.7	2
BR14s	Makupa-Posta-Shimanzi	8.7	368	497	4,473	14.7	4
BR17n	Ferry-Sabasaba-Mtwapa	20.7	842	1,988	17,892	5.9	10
BR17s	Mtwapa-Sabasaba-Ferry	20.7	921	1,744	15,696	5.9	11
BR20n	Mwembe-Mshomoroni	7.9	216	223	2,007	5.6	8
BR20s	Mshomoroni-Mwembe	7.9	965	986	8,874	5.6	6
Total				27,197	244,773		232

7.3 Modifications in regular services

In the service plan scenarios, existing matatu services to reviewed to identify opportunities for improved efficiency through consolidation, re-routing, and other modifications to the service itineraries. For service scenario 2, the restructuring plan modified the original matatu routes as follows:

- A set of 16 existing routes with a high percentage of the itinerary length overlapping the corridor were converted into the 16 BRT services. These routes are: N03, N04, N05, N07, N08, N13, T14c, N17, N20, M07, M08, M10, M11, M15, M16, M17
- Other existing bus routes with a high percentage of itinerary length overlapping the corridor and itineraries that are similar to the 16 routes already included (see above) were removed. The removed routes are: B05, N01, N09, N10, N12, N16, N19, N26, N77, T02, T03, T04, T05, T08.
- 21 routes continue to operate as matatu services.

Table 4. Matatu routes converted to BRT routes.

Route	Route Description
M07	Miritini - Ferry
M08	Kwa Hola - ferry
M10	Mikindani - Ferry
M11	Miritini - Ferry
M15	Magongo - Kongowea
M16	Migadini - Kongowea
M17	Magongo - Ferry
N03	Bamburi – Kisauni – Ferry
N04	Ferry – Mtamboni – Bamburi
N05	King'orani – Bamburi
N07	Bombolulu – Docks
N08	Ferry – Bombolulu
N13	Mtwapa - Docks
N17	Mtwapa - Ferry
N20	Mshomoroni - Sabasaba
T14c	Shimanzi - Posta - Shimanzi

Table 5. Matatu routes removed in the final scenario.

Route	Route Description
B05	Bamburi - Barclays
N01	Bamburi - Kisauni - Docks
N09	Bombolulu -Mwembe Tayari
N10	Bamburi - Mtamboni - Posta
N12	Mtamboni - Docks
N16	Mtamboni - Ferry
N19	Kongowea - Ferry
N26	Mtwapa - Posta
N77	Bombolulu - Sabasaba
T02	Docks - Mwembe

Route	Route Description
T03	Posta - Shimanzi
T04	Docks - Makupa
T05	Tudor - Docks
TO8	Tudor - Ferry

Figure 56. Routes converted to BRT services in the island and mainland north in scenario 1.

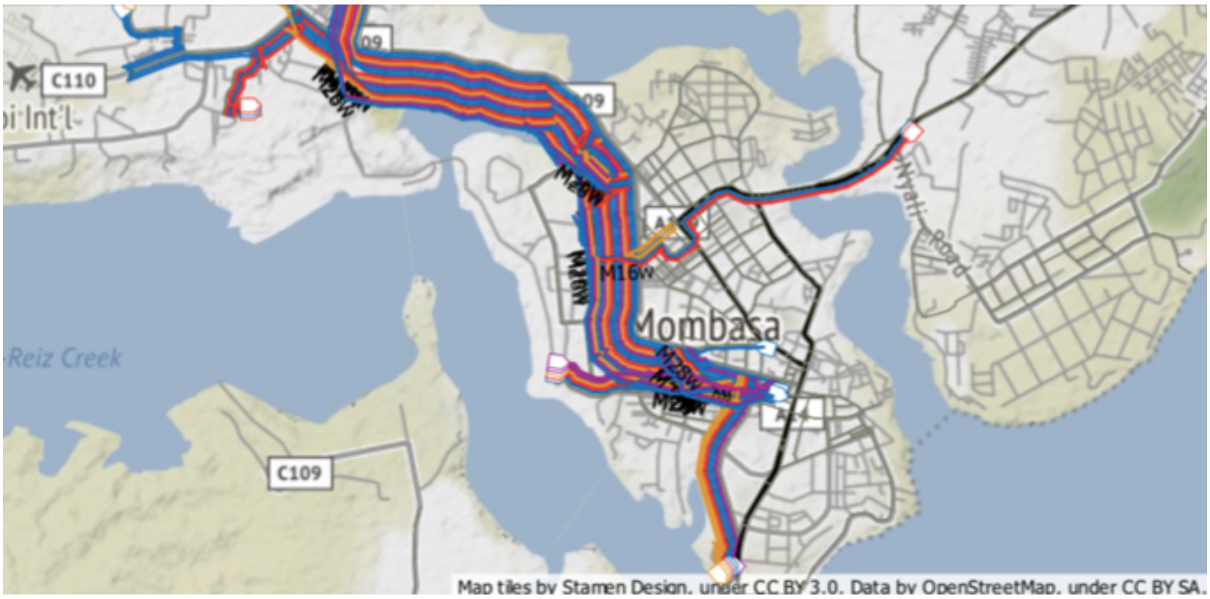


Figure 57. Routes in the island and west of Mombasa converted to BRT services in scenario 2.

8. 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, BRT users will experience a reduction in average travel time from 35.8 to 21.0 minutes, or 41 percent. In terms of generalised cost, considering both time and monetary expenditure, the benefit to commuters is the equivalent of 47,500 hours per day. 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 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.

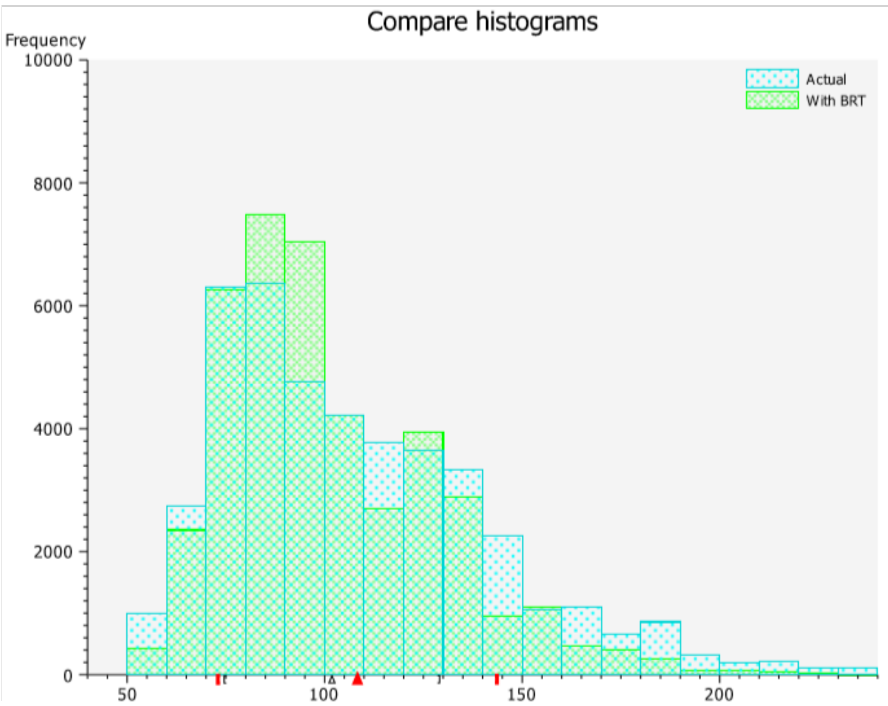


Figure 58. Comparison of travel time histograms with (green) and without (blue) BRT.

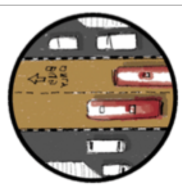
9. Implications for BRT corridor and station design

In order to address the ever increasing congestion challenges in Mombasa, the city requires an efficient and reliable public transport system combined with high-quality NMT facilities. Given the significant potential benefits of BRT, all major road projects should incorporate facilities for public transport and NMT.

9.1 BRT design principles

Several key infrastructure elements enable BRT systems 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 form the basis for the service scenario described in this report.

Table 6. 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 performanc e 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.

Designs for the Mombasa 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:

- **Passing lanes at stations with high demand.** Passing lanes will make it possible to operate express services and will reduce station congestion. These will be provided at locations with two or more sub stops. However, due to the limited ROW, some stations can be staggered with passing lanes on either side.
- **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. Sub-stops will be provided at Ferry, Posta, Mwembe, Kengeleni, Lights, Bombolulu and Workshop.

- **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.

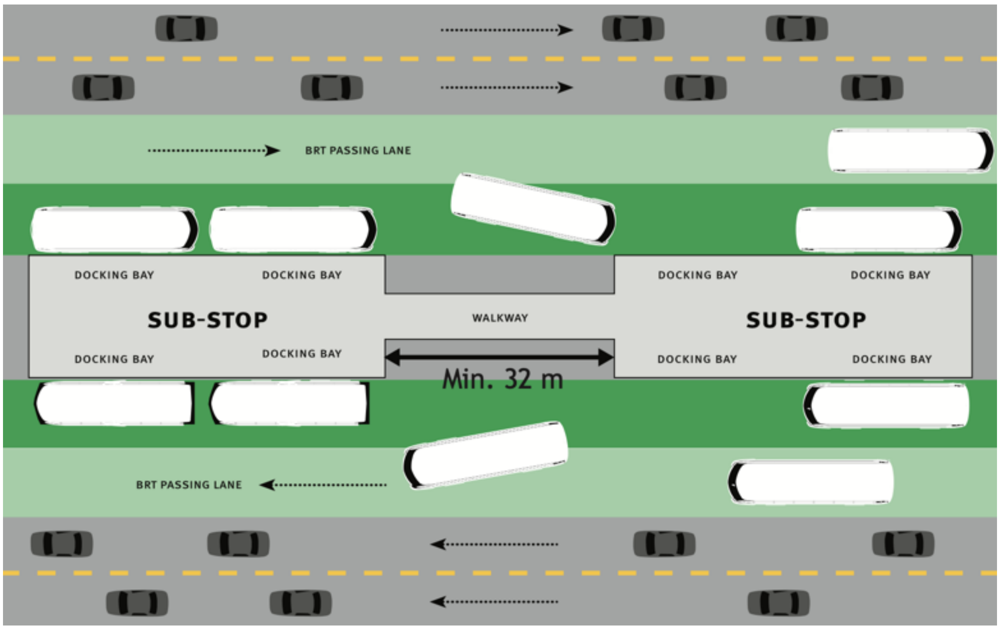


Figure 59. Sub-stops function independently, thereby increasing the capacity of the station. The minimum gap between sub-stops is 1.8 times the bus length, or 32 m for articulated buses.

9.2 Corridor cross sections

Most roads in Mombasa have sufficient ROW to accommodate high-quality BRT. Most of the roads in the island have a ROW of at least 30 m. The available ROW increases to 36-40 m along Malindi road and 50 m at Lights stage.

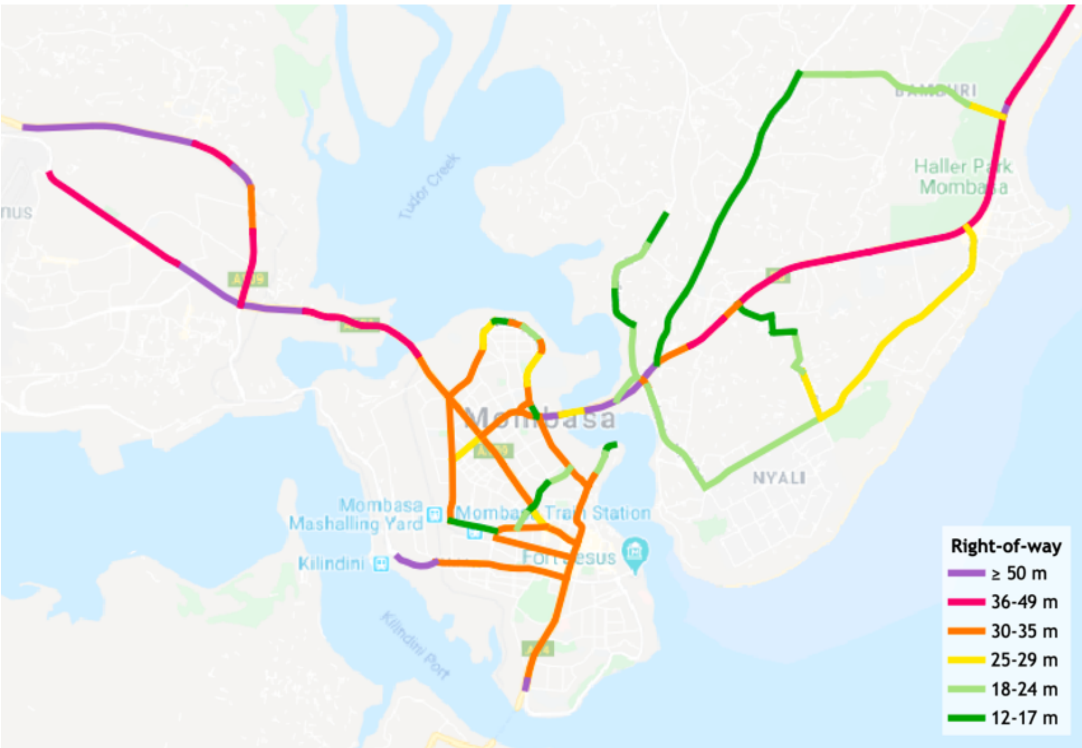


Figure 60. Available right-of-way along streets in Mombasa.

Considering the available road widths, standard sections were prepared for each section with a unique ROW, drawing on the following assumptions:

- Most CBD segments will share the same cross section where the ROW is 30 m.
- Posta and Mwembe Tayari require multiple sub-stops and passing lanes. To accommodate the additional width required for BRT, mixed traffic will be in one direction, in the inbound direction. Outbound traffic at Posta will be diverted via Msanifu Kombo road and join Digo road via Haile Selassie Road. Outbound traffic at Mwembe station will be diverted via Msanifu Kombo road and Join Kenyatta Avenue via KFA.
- A standard 37 m cross section can be adopted for Malindi Rd, consistent with the ROW identified in the ongoing KeNHA project. To accommodate passing lanes, a staggered station design is used. At Bombolulu and Workshop, two sub-stops will be required.
- For service scenario 1, stations with two sub-stops will be Ferry, Posta, Kengeleni, Lights, Bombolu, and Workshop. All the other stations will have one sub-stop.
- For service scenario 2, additional substops are needed in the CBD. Posta will have three substops while a second substop will be added at Mwembe Station. Space should be left for expansion of these stations in future.

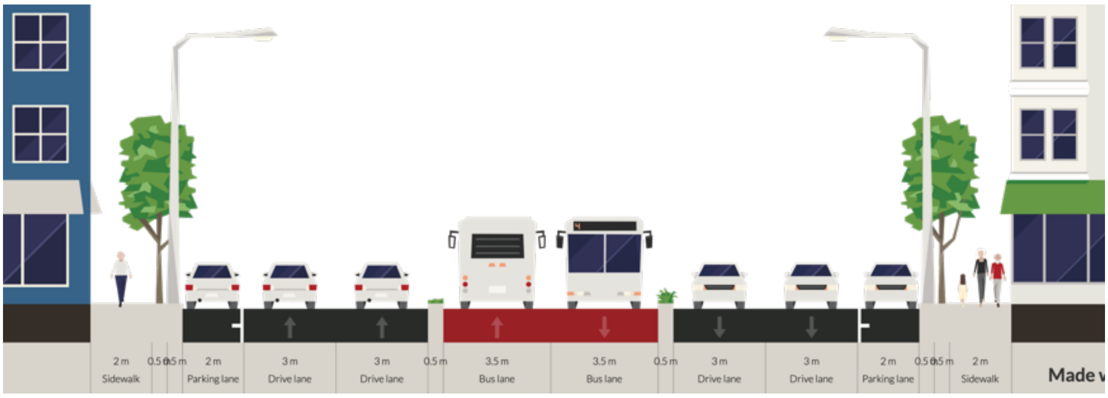


Figure 61. CBD off-station (30 m).

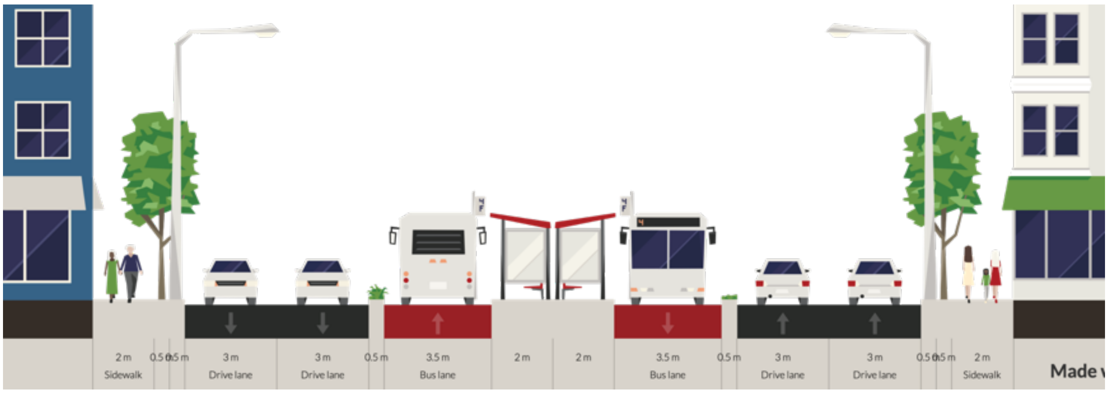


Figure 62. CBD on-station (30 m).

Figure 63. Representative design for BRT on along Kenyatta at Kanisani near the Mash Booking office.

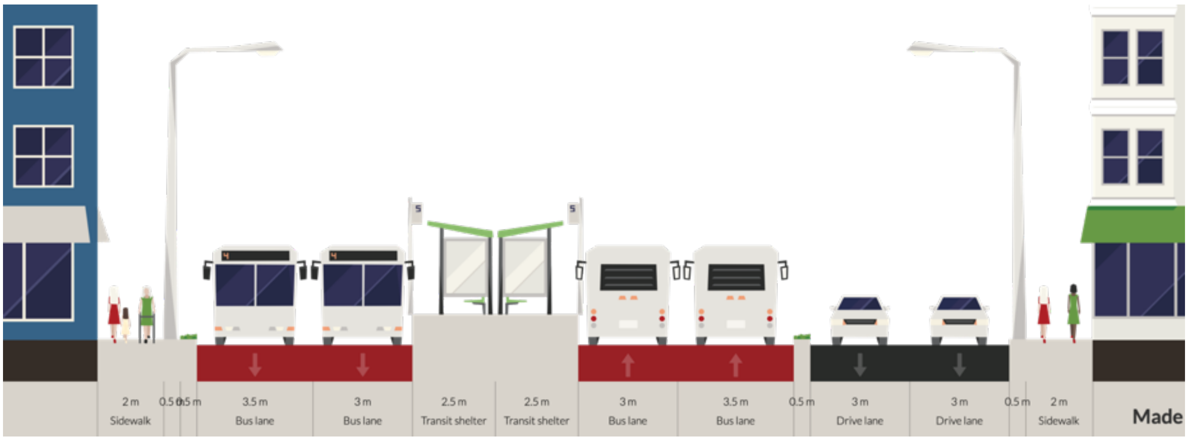


Figure 64. Posta and Mwembe Tayari on-station (30 m).

The Kenya National Highways Authority (KeNHA) is currently rehabilitating the Mombasa-Malindi Rd. The African Development Bank and European Union-financed project was initially designed as a high-speed highway with four traffic lanes per direction and basic footpaths on either side (Figure 65).[4] The planned cross section omits critical urban street elements, including dedicated space for public transport, bus shelters, cycle tracks, and street trees. Figure 66 and Figure 67 display preferred cross sections for the Mombasa-Malindi Rd incorporating adequate provisions for walking, cycling, and public transport. The cross sections are shown for 37 m, the same ROW as the original Mombasa-Malindi Rd cross section. Where additional ROW is available, footpaths, cycle tracks, and landscaping street elements can be expanded accordingly.

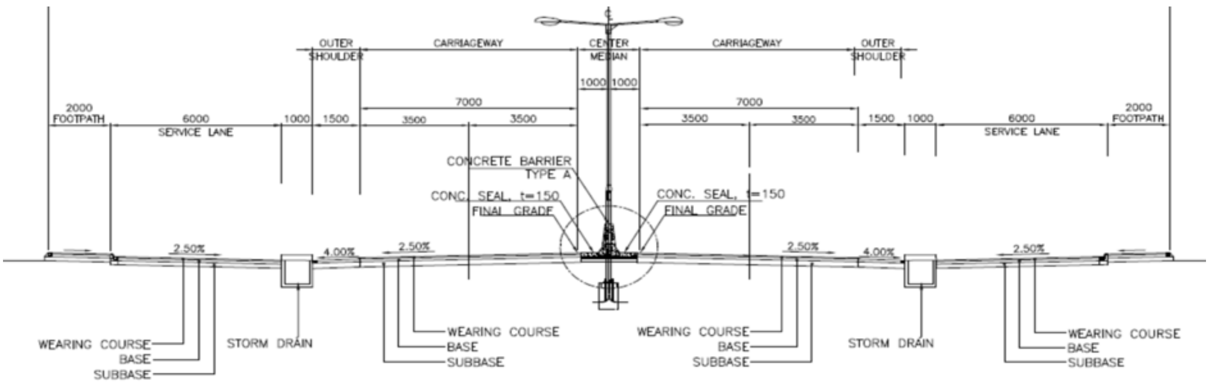


Figure 65. Original cross section for Malindi Rd (37 m). (Source: AfDB)

[4] African Development Bank. (2019, May). ESIA Summary for the Proposed Upgrading of Mombasamtwapa [sic]-Kwa Kadzengo-Kilifi (A7) Section, Kenya. Retrieved from https://www.afdb.org/en/documents/document/multinational-malindi-lunga-lunga-tanga-bagamoyo-road-corridor-development-esia-summary-for-the-proposed-upgrading-of-mombasa-mtwapa-kwa-kadzengo-kilifi-a7-section-kenya-109342

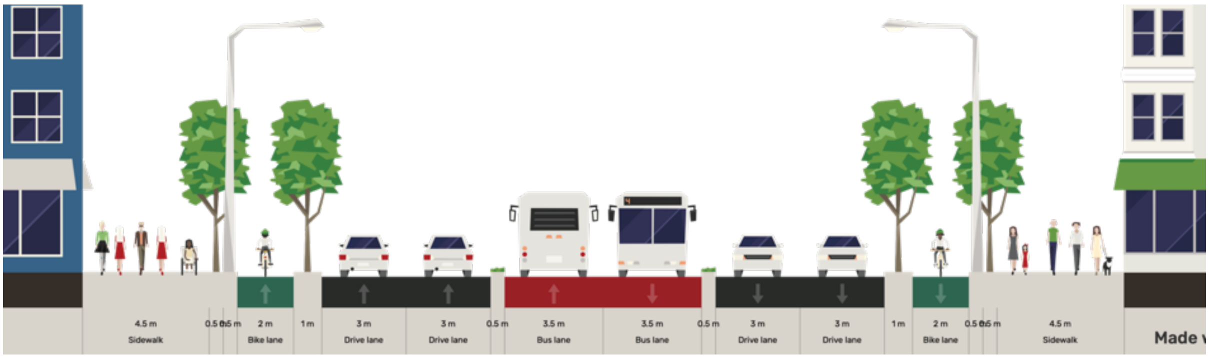


Figure 66. Malindi Rd off-station (37 m).

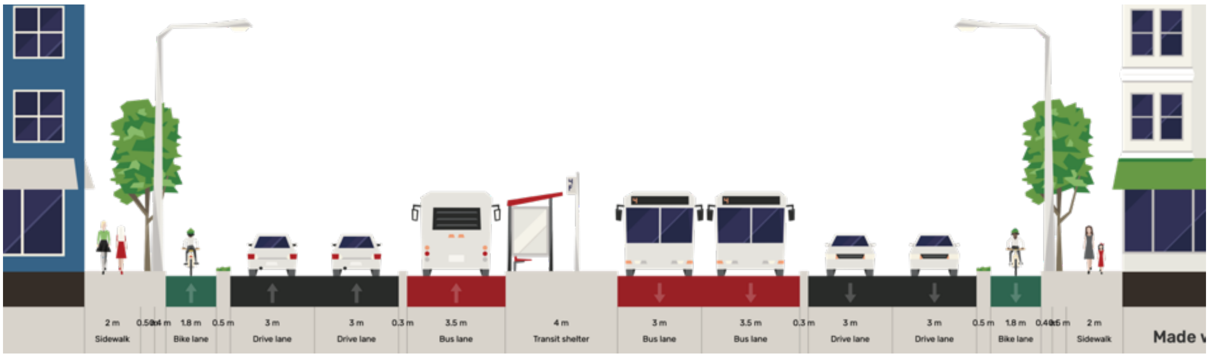


Figure 67. Malindi Rd at staggered station (37 m).

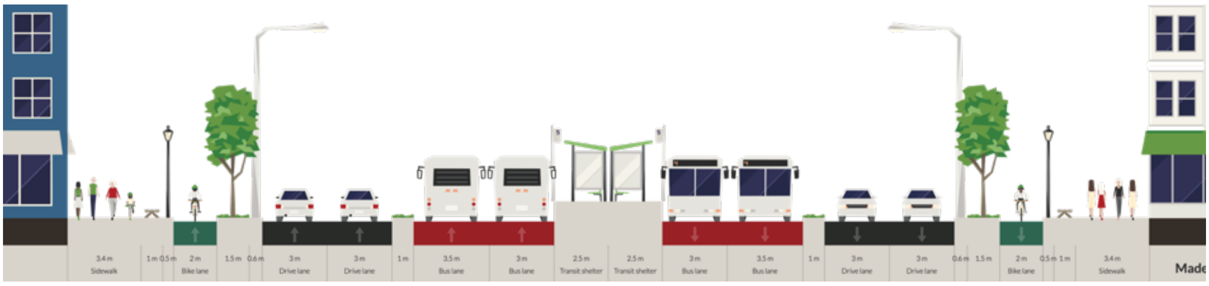


Figure 68. Lights on-station (50 m).

9.3 Station sizing

BRT station positions were identified considering existing passenger boarding and alighting patterns. There are a total of 26 stations proposed along the BRT corridor. 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 sizes are required for service scenario 1, with BRT services operating to the north:

- 2 sub-stops: 6 stations: Ferry, Posta, Kengeleni, Lights, Bombolulu, Workshop.
- 1 sub-stop: Remaining 20 stations: Bombay, Pandya, Biashara, Marikiti, Bondeni, Coast General, Buxton, Mwembe, Mash, Kanisani, Majengo, Sabasaba, Makuti, Leisure, VOK, Sheikh Khalifa, KESRA, Kenol, Baobab, Pirates.

Service scenario 2, with services covering the northern and western catchment areas, will increase passenger demand in the CBD. Additional sub-stops should be provided as below:

- 3 sub-stops: 1 station at Posta.
- 2 sub-stops: 1 station at Mwembe.

Figure 69. Required number of sub-stops at BRT stations for service scenario 1.

Figure 70. Additional sub stops required for service scenario 2, at Posta and Mwembe stations.

Table 4. Saturation and required sub-stops at stations: service scenario 2.

		Boardings		Alightings		Frequency		Saturation		
No.	Name	In-bound	Out-bound	In-bound	Out-bound	In-bound	Out-bound	In-bound	Out-bound	Sub-stops
Sheikh Farsy / Adel Naseer										
1	Buxton	342	194	999	258	59	59	0.40	0.27	1
2	Kenya Medical	60	70	431	219	59	59	0.28	0.25	1
3	Bondeni	141	34	154	238	59	59	0.25	0.25	1
4	Marikiti	31	324	1272	148	59	59	0.39	0.28	1
New Malindi / Kenyatta / Nyerere										
1	Pirates	59	3	0	0	59	59	0.22	0.21	1
2	Baobab	116	3	39	41	59	59	0.24	0.22	1
3	Kenol	389	149	593	571	59	59	0.35	0.31	1
4	KESRA	119	4	176	158	59	59	0.26	0.24	1
5	Sheikh Khalifa	237	131	137	74	65	65	0.29	0.26	1
6	Workshop	1007	415	245	293	65	65	0.41	0.33	2
7	Bombolulu	1200	273	49	196	65	65	0.41	0.30	2
8	VOK	330	126	176	154	65	65	0.30	0.27	1
9	Leisure	71	331	121	100	65	65	0.26	0.29	1
10	Makuti	169	221	339	63	65	65	0.30	0.27	1
11	Lights	399	570	597	287	82	82	0.43	0.42	2
12	Kengeleni	1289	1	266	433	93	93	0.55	0.40	2
13	Sabasaba	18	336	300	23	52	52	0.23	0.24	1
14	Majengo	250	300	619	245	73	73	0.38	0.34	1
15	Kanisani	184	466	599	289	73	73	0.37	0.37	1
16	Mash	88	464	621	222	73	73	0.36	0.36	1
17	Mwembe	35	247	1559	275	73	73	0.48	0.33	2
18	Posta	146	232	2860	514	131	131	0.89	0.58	3
19	Biashara	69	36	477	375	88	88	0.39	0.37	1
20	Pandya	0	197	470	230	88	88	0.38	0.38	1
21	Bombay	0	325	250	0	88	88	0.35	0.36	1
22	Ferry	0	3518	714	0	88	88	0.42	0.81	3

9.4 Intersections and interchanges

In BRT systems, simplified signal cycles can help prevent delays at intersections and minimise disruption of bus movements. Right turns across BRT lanes should be avoided in order to reduce delay and improve safety. Several alternative movements can help prevent right turns across the busway. The following sections introduce representative two-phase signal cycles for the intersections along the corridor. Further traffic analysis is required to inform the geometric design of each intersection.

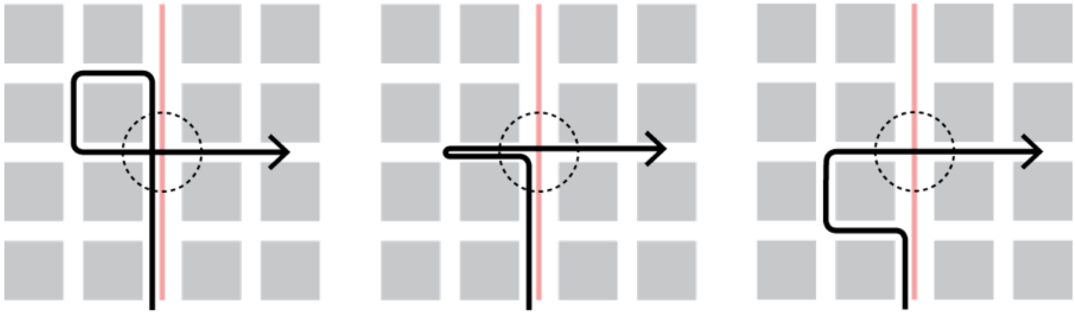


Figure 71. Alternatives to avoid right turns across BRT lanes.

Figure 72. A sign prohibiting a right turn across a BRT lane in Dar es Salaam.

10. Conclusion & next steps

Streets in Mombasa should prioritise efficient, sustainable modes of transport, namely walking, cycling, and public transport. BRT infrastructure can help ensure fast public transport operations by avoiding bottlenecks for buses and passengers. It also can help make public transport service accessible to more Mombasa residents. Based on an analysis of existing passenger travel patterns and matatu services, the present study identified a BRT network including a first-phase corridor linking Posta, Mwembe Tayari, and the ferry terminal with the northern catchment areas of Bamburi, Mtwapa, Kisauni, and Mshomoroni. This corridor has the highest passenger volumes in the city and experiences low commercial speeds.

Efficient BRT systems are designed around service plans that bring people where they want to go through the fastest means possible. Many scenarios have been tested to reach a configuration for BRT services in Mombasa with a limited number of transfers and an optimal fleet. The final service plan proposes 16 routes along the BRT corridor serving key destinations including Ferry, Posta, Mwembe Tayari, Buxton, Kongowea, Bombolulu, and Bamburi, plus additional direct services to Magongo and Miritini. The BRT corridor has a critical load of 7,800 pphpd and around 93 buses per hour along

Nyali Bridge. The system will benefit 245,000 passengers per day, or around 39 percent of public transport passengers in the city.

Implementing BRT in Mombasa will yield significant benefits for city residents. BRT passengers will see significant travel time savings, reducing the time spent on the vehicle for a one-way commute by 41 percent. In addition, the system has the potential to improve traffic flow by shifting trips from numerous 14-seat matatus 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 corridor also can contribute to a reduction in road fatalities, especially for pedestrians, the most vulnerable road users. BRT can improve social equity by providing affordable and accessible mobility for the poorest residents, the elderly, women, and people with disabilities.

The following next steps can help facilitate the introduction of BRT:

- **Incorporate provisions for BRT in all road development projects in Mombasa** to avoid unnecessary reconstruction of road infrastructure, land acquisition costs, and compensation of affected persons in the future. Specifically, the planned improvements along the Mombasa-Malindi Road should incorporate provisions for BRT and NMT.
- **Prepare a financial model and business plan** to assess the level of profitability of improved public transport services and identify what elements of the services should be contracted out, how many operators would be required, and how payments to the operators would be determined. The business plan will include recommendations on the fare collection system and revenue management.
- **Engage with the existing public transport industry** to begin the transition to formal public transport operations. The government must decide on a policy on how to handle the affected industry and then begin the engagement process. Initial steps include registering operators on the affected routes, assisting them in company formation, and working with them to develop qualified management teams.
- **Implement NMT improvements** to enhance safety and convenience for pedestrians and cyclists and improve access to the future BRT corridors.

11. Appendix: Survey forms

11.1 Frequency-occupancy survey form

Mombasa Public Transport Survey

Frequency-Occupancy Survey

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

Vehicle type	Origin	Destinati on	Cross country (Y,N)	Occu pants	Time	
					HH	MM
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						

Vehicle type	Origin	Destinati on	Cross country (Y,N)	Occu pants	Time	
					HH	MM
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						
TT 11 14 33 52+						

11.2 Transfer survey platform

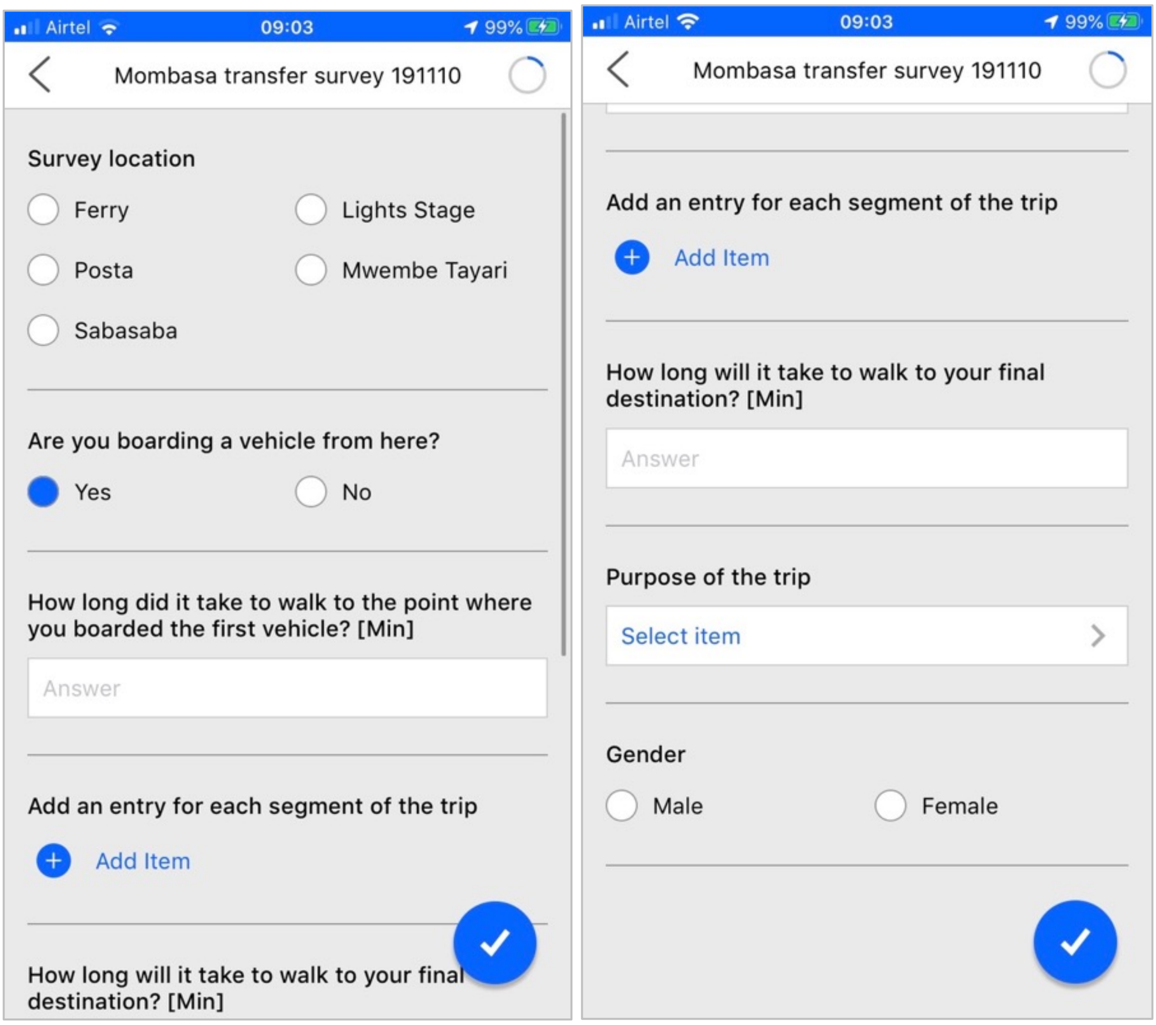


Figure 73. Screenshots from the transfer survey platform: Device Magic

11.3 Boarding-alighting survey platform

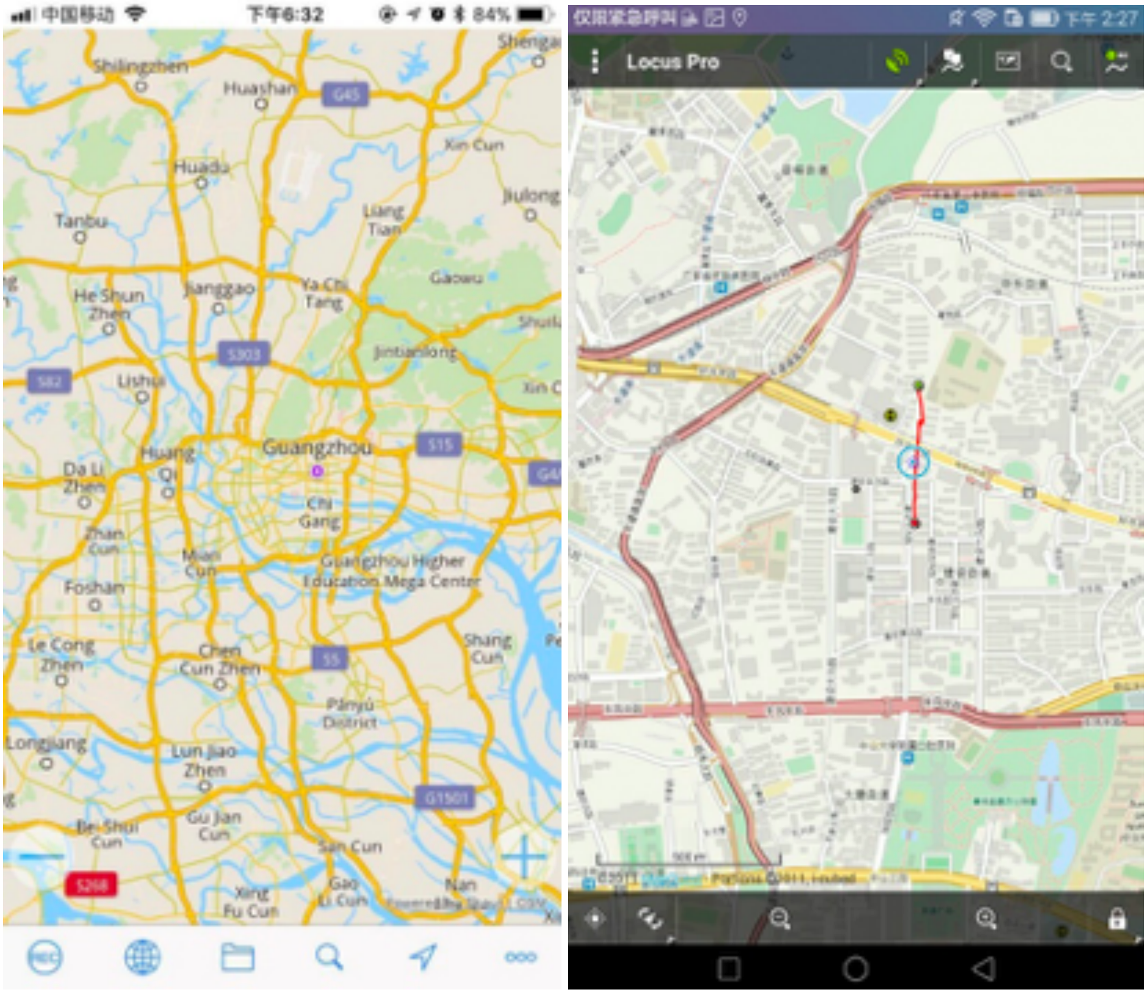


Figure 74. BA survey app in iOS (left) and locus for Android (right).

11.4 Fare system for existing services

Number	Description	Length (km)	Fixed fare	Variable fare
B01n	BAM-SHA	6.4	50.0	0.0
B01s	SHA-BAM	6.4	50.0	0.0
B02n	LIT-CON	5.2	42.4	11.4
B02s	CON-LIT	5.2	46.9	4.6
B03n	LIT-KIE	6.8	45.4	5.2
B03s	KIE-LIT	6.8	45.4	5.2
B07n	LIT-MSH	3.7	30.0	0.0
B07s	MSH-LIT	3.7	30.0	0.0
L01e	MTO-LIK	6.8	30.0	0.0

Number	Description	Length (km)	Fixed fare	Variable fare
L01w	LIK-MTO	6.8	30.0	0.0
L02n	UKU-LIK	25.1	42.4	2.4
L02s	LIK-UKU	25.1	42.4	2.4
M04e	MAG-DOC	11.7	46.9	2.0
M04w	DOC-MAG	13.6	46.9	1.7
M05e	MIG-DOC	11.2	42.4	5.3
M05w	DOC-MIG	11.9	42.4	5.0
M06e	MIK-DOC	11.3	34.7	10.5
M06w	DOC-MIK	12.8	34.7	9.2
M07e	JOM-FER	14.5	34.7	8.2
M07w	FER-JOM	15.6	34.7	7.6
M08e	MAG-FER	10.9	46.9	2.2
M08w	FER-MAG	13.2	45.4	2.7
M09e	MIG-FER	11.1	42.4	5.3
M09w	FER-MIG	11.5	42.4	5.2
M10e	MIK-FER	11.3	42.4	5.3
M10w	FER-MIK	12.4	34.7	9.6
M11e	MIR-FER	16.6	34.7	7.2
M11w	FER-MIR	18.3	31.7	7.8
M12e	JOM-DOC	15.3	34.7	7.8
M12w	DOC-JOM	16	34.7	7.4
M14e	JOM-MWE	12.2	39.3	6.8
M14w	MWE-JOM	13.1	28.6	12.7
M15e	MAG-KON	9.8	42.4	6.1
M15w	KON-MAG	10.4	42.4	5.7
M16e	MIG-KON	10.3	42.4	5.7
M16w	KON-MIG	10.1	42.4	5.9
M17e	MAG-FER	10.7	50.0	0.0
M17w	FER-MAG	11.9	50.0	0.0
M26e	MIR-DOC	16.9	31.7	8.4
M28e	MIR-MWE	14.9	27.1	12.0
M28w	MWE-MIR	16	27.1	11.1
N01n	DOC-BAM	10.9	42.4	5.4
N01s	BAM-DOC	11	45.4	3.2
N02n	DOC-BAM	16	42.4	3.7
N02s	BAM-DOC	15.7	42.4	3.8

Number	Description	Length (km)	Fixed fare	Variable fare
N03n	FER-BAM	10.1	46.9	2.3
N03s	BAM-FER	10.1	46.9	2.3
N04n	FER-BAM	15.2	42.4	3.9
N04s	BAM-FER	14.9	42.4	4.0
N05n	KIN-BAM	10.2	46.9	2.3
N05s	BAM-KIN	10.2	46.9	2.3
N06n	BAR-MTW	17.4	34.7	6.8
N06s	MTW-BAR	18.1	34.7	6.6
N07n	DOC-BOM	9.9	42.4	6.0
N07s	BOM-DOC	9.6	42.4	6.2
N08n	FER-BOM	9.1	43.9	5.2
N08s	BOM-FER	8.7	43.9	5.4
N09n	MWE-BOM	7.1	50.0	0.0
N09s	BOM-MWE	6.9	42.4	8.5
N12n	DOC-MTA	13.5	42.4	4.4
N12s	MTA-DOC	13.5	42.4	4.4
N13n	DOC-MTW	20.4	42.4	2.9
N13s	MTW-DOC	20.4	42.4	2.9
N16n	FER-MTA	13.4	42.4	4.4
N16s	MTA-FER	13.4	42.4	4.4
N17n	FER-MTW	19.6	42.4	3.0
N17s	MTW-FER	19.6	42.4	3.0
N19s	KON-FER	5.8	40.0	0.0
N20n	SAB-MSH	5.2	46.9	4.6
N20s	MSH-SAB	9.4	45.4	3.8
N26n	POS-MTW	18.2	42.4	3.3
N26s	MTW-POS	17.9	42.4	3.3
N28n	MWE-NYA	11.8	50.0	0.0
N28s	NYA-MWE	11.5	50.0	0.0
N77n	SAB-BOM	5.2	50.0	0.0
N77s	BOM-SAB	5.3	46.9	4.5
T01e	DOC-FER	3.2	30.0	0.0
T01w	FER-DOC	3.2	40.0	0.0
T02e	DOC-MWE	2.9	40.0	0.0
T02w	MWE-DOC	3.2	40.0	0.0
T03e	DOC-POS	2.4	30.0	0.0

Number	Description	Length (km)	Fixed fare	Variable fare
T03w	POS-DOC	2.6	30.0	0.0
T04n	DOC-SAB	4.8	50.0	0.0
T05n	DOC-TUD	6.2	30.0	0.0
T05s	TUD-DOC	6.6	30.0	0.0
T06n	FER-TUD	4.5	40.0	0.0
T07n	FER-SHI	5.9	30.8	12.0
T07s	SHI-FER	5.9	30.8	12.0
T08n	FER-TUD	6	28.5	2.0
T08s	TUD-FER	5.9	28.5	2.0
T14c	SHI-SHI	11.1	25.4	3.2
B05n	MWE-BAM	8.1	45.4	4.4
N10s	BAM-POS	13.1	45.4	2.7
N10n	POS-BAM	13.5	46.9	1.8
B04n	BAM-KIE	2.6	40.0	0.0
B05s	BAM-MWE	8.1	42.4	7.4
B04s	KIE-BAM	2.6	40.0	0.0
M03e	MAZ-MWE	20.2	34.7	5.9
M03w	MWE-MAZ	21.3	34.7	5.6