5. Basic Concept Plan of the BRT

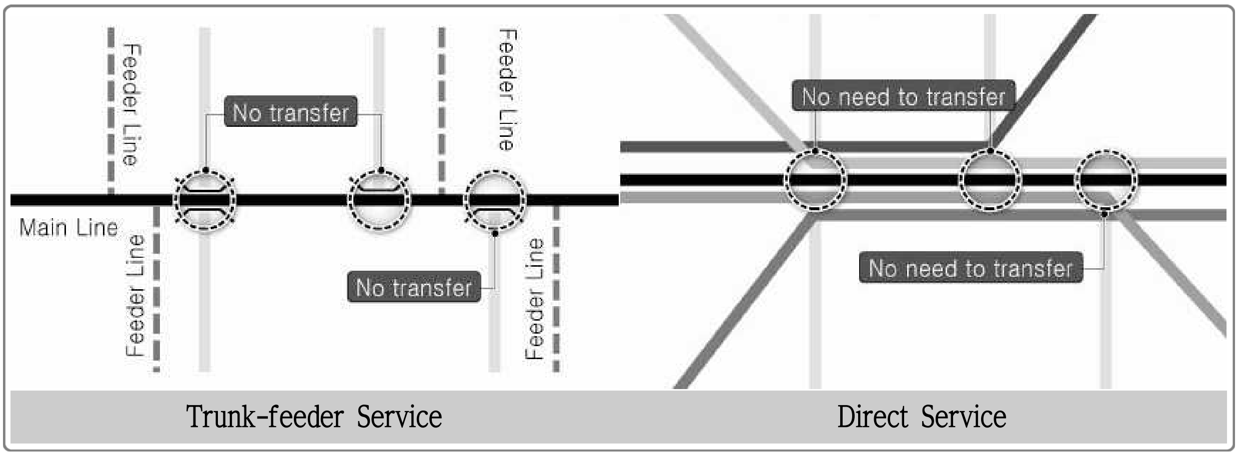
5.1. BRT Route

5.1.1. Route Alternatives for the BRT Line 5

- Prior to defining the route alternatives for the BRT line 5, it is reasonable to describe the characteristics of the outer ring road first which is the main corridor for BRT line 5.
- Functionally it connects with all the other 4 BRT lines and geographically it is located at the north eastern area which will be developed in the near future. Unlike the other 4 lines, this line does not connect to the CBD area. Instead, it is located on sparsely populated outskirt of Nairobi and has no fixed demand due to lack of special traffic-inducing facilities except the Jomo Kenyatta International Airport.
- In light of these unique circumstances, it is important to solve the problem of how to transfer to other lines and how to induce more potential demands for better execution of the BRT line 5. In order to do this, it is necessary to set a comprehensive direction that does not only minimize the inconvenience of passengers and maximize the accessibility of the BRT but also adjusts the route for the Matatus which is in a competitive relation.
- According to the "Feasibility study & Technical Assistance for Mass Rapid Transit System for the Nairobi Metropolitan Region(MOTI, 2011)" that proposed a future MRTS network of 9 MRTS corridors for the first time and is a basis for the current BRT line5 study, the outering road was defined as a single route of the nine MRTS corridors.
- However, the suggested service plan which runs narrowly only on the outering road cannot serve its function as a mass transit system properly considering its geographical scope and existing passenger travel pattern.
- In comparison with the existing matatu service, the condition that makes it have a competitive advantage must be presented in order to induce diverted travel demand from the passengers who are accustomed to using the existing transport option. It cannot be emphasized enough that securing proper demand is very important in that it is not only interrelated with economic feasibility but also system's sustainability.
- Prior to building a BRT infrastructure and buying the vehicles, we need to deliberate on the merits BRT has over the Matatus. Also, it is important to know the factor which caused the failure of the publicly managed bus system.
- When the BRT is implemented, the main benefit to be derived is that, total travel

time from origin to final destination will be greatly improved. Since it is hard to say that current average travel speed on the outering road is lower compared to the other roads in Nairobi, providing only BRT service on the outering road cannot improve total travel time for passengers significantly. This is because transferring activities to the final destination is inconvenient and actual travel time would be longer due to waiting and transferring.

- Such a kind of operation may stimulate the passengers' initial interest, but one can hardly expect that the BRT will replace the matatus in the long-term perspective. So in conclusion, for shortening total travel time, an appropriate service option for BRT line 5 should be suggested.
- In general, there are two types of service options to select from when providing transit service at the city level. These are namely trunk-feeder service and direct service. Each service has its pros and cons.
- The former provides fast mobility and regular headway, but passenger's accessibility is poor. Well distributed feeder lines and transfer facilities are very important to secure sufficient number of passengers.
- The latter does not require feeder lines and transfer facilities because BRT lines run on all roads. However, because it needs many drivers and buses, it hardly meets the economic and financial viability. Also, BRT buses can not actually operate on lower grade roads than minor arterial roads due to the narrow right-of-way.
- The illustration for these services are shown in figure below.



<Figure 5-1> Type of BRT route service

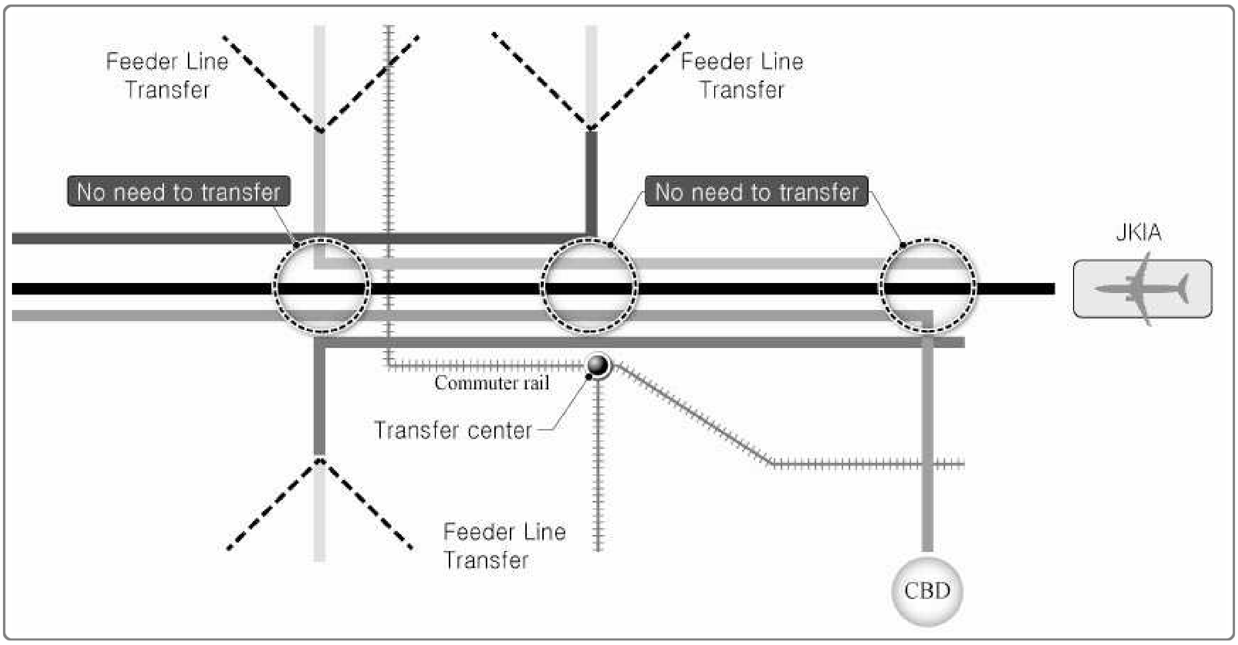
- A suitable condition for each service by multiple factors is shown in the table below.

<Table 5-1> Comparison of BRT route service

Factor	Trunk-feeder service	Direct Service
Population density	• When there is a large population density deviation between major arterial roads and residential areas	• When population density difference on all routes is not significant
service type	• Closed system with exclusive route license system	• Open system where all public transportation modes are available to use
ROW	• Median lane to avoid conflict with turning movements and to transfer along the corridor	• Roadside lane to operate feeder line
Vehicle type	• Major arterial - Coach • Branch road - Small Bus	• Considering the turning radius on the branch road
Travel time	• Optimized in-vehicle time, but wasteful transfer time	• Required transfer time is less, relatively high in-vehicle time
Volume	• Suitable for high-flow passengers handling more than 8,000 passengers per hour	• Reduced vehicle capacity, but flexible interval is possible depending on the actual demand
Travel distance	• When a total of the traveled distance is more than 10km, transfer impact is marginal	• When a traveled distance is short, it has an advantage

- Considering Nairobi's current traffic condition and geometric design of existing roads, it can be seen as applying inter-corridor route service which makes up for the weak points of the trunk-feeder service.
- Unlike the trunk-feeder service, this can operate several lines utilizing multiple surrounding corridors and not limiting to one line on one corridor. It can serve the high demand with efficient responsive route service and cover broader areas by operating a vehicle beyond the outer ring road to the near corridors.
- By so doing, few transfer facilities would be installed, and travel cost and time can be reduced by minimizing transfers. The extended service area can accommodate more travel demand onto our line. For your information, this service concept is in line with the ITDP's plan for the BRT line 1.
- In the course of the project, we will study to determine which type of route service is most suitable considering Nairobi's present circumstances, focusing on several influential factors such as travel demand pattern of existing public transport, terminal usage pattern, geometric design of intersection, operation plan of other BRT lines, etc.
- Through rigorous analysis, we will prioritize the alternatives than recommend the best route service.

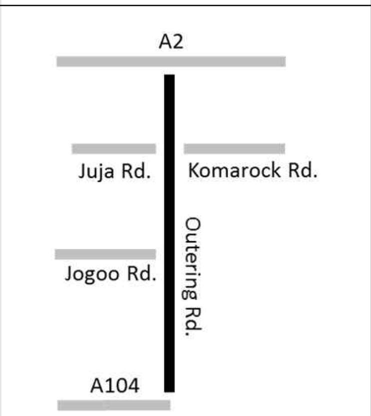
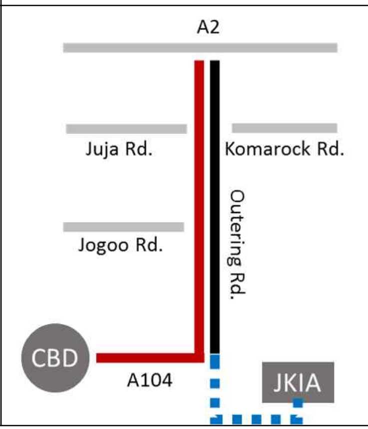
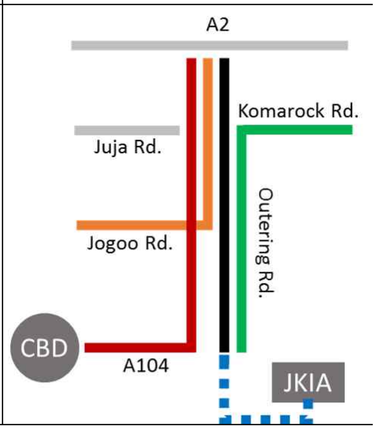
- The concept of the inter-corridor service is shown in the figure 5-2 below.



<Figure 5-2> Concept of the inter-corridor service

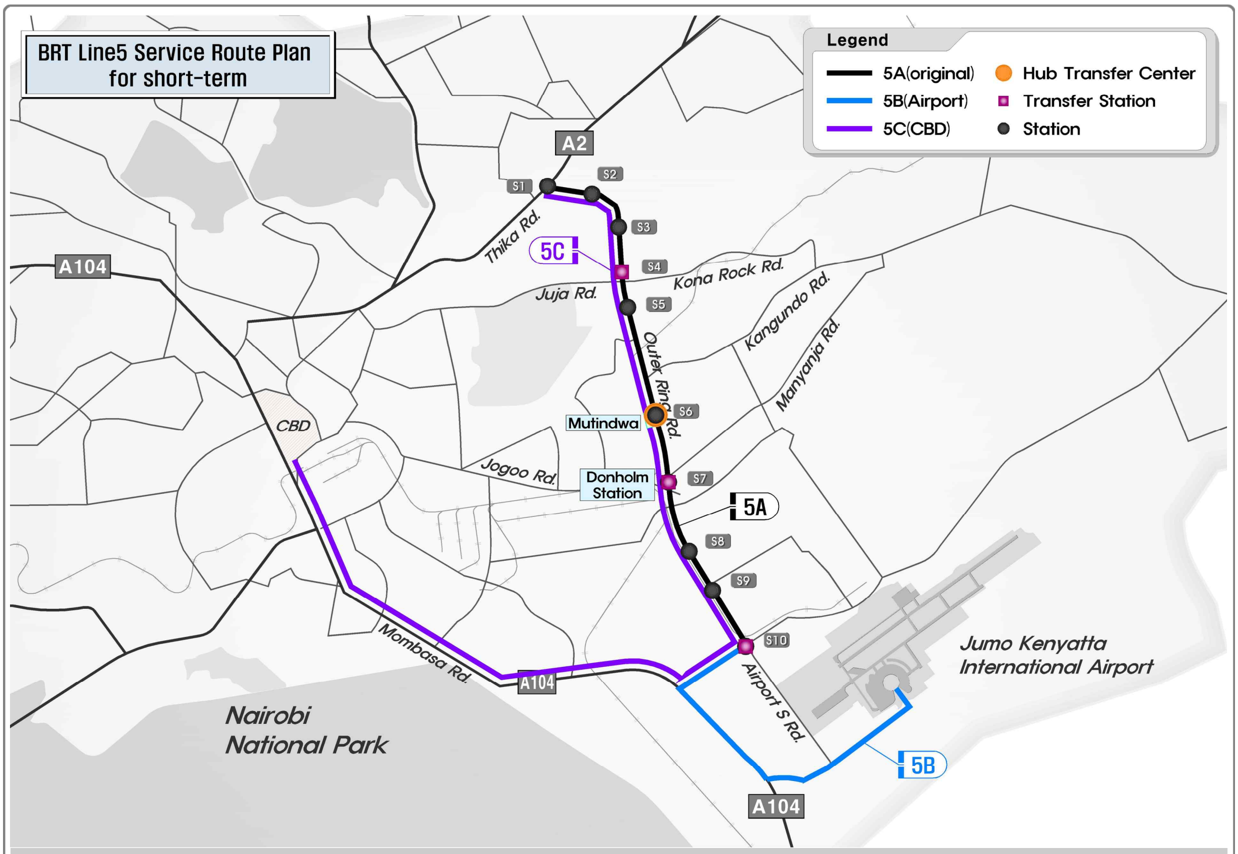
5.1.2. Scenarios of the BRT Route

- On the basis of the concept of the inter-corridor route service, a total of 3 service scenarios are developed as shown in Figure 5-3.
- The first scenario is the same as the original route proposed by the previous MRTS study. The second scenario adds the JKIA route to the first scenario.
- It is suggested that the 2nd scenario is considered as a short term solution which will add two routes to connect CBD and the Jommo Kenyatta International Airport and finally the 3rd scenario will be implemented in the long term.

Scenario	Scenario 1	Scenario 2	Scenario 3
Route	original route	scenario1 + CBD + JK International Airport	scenario 2 + Jogoo Rd.& Juja Rd. route
Concept			

<Figure 5-3> Proposed BRT route by scenarios

- Based on the proposed route scenarios, the service route plans for both short and long-term scenario are described as follows.
- In the short-term plan, besides the original route along the outering road, two more routes are added. The first route connects between outering road and CBD area by extending its original route to CBD via Mombasa road(A104) which is supposed to be the corridor for BRT line 1. Since almost all the traffic has a similar form of radial movement into CBD, it is imperative not only to achieve proper demand for the BRT line 5 but also to shorten the total travel time for most passengers.
- The second route connects to the Jommo Kenyatta International Airport from the end point of the outering road. Currently Nairobi does not have proper public transport service which connects the city and the airport. There is just one Matatu service route from the city stadium to the airport intermittently. A feeder line which starts from the end of the outering road, not the extended route of the original route, is suggested in order to secure frequent vehicle headway on this route.



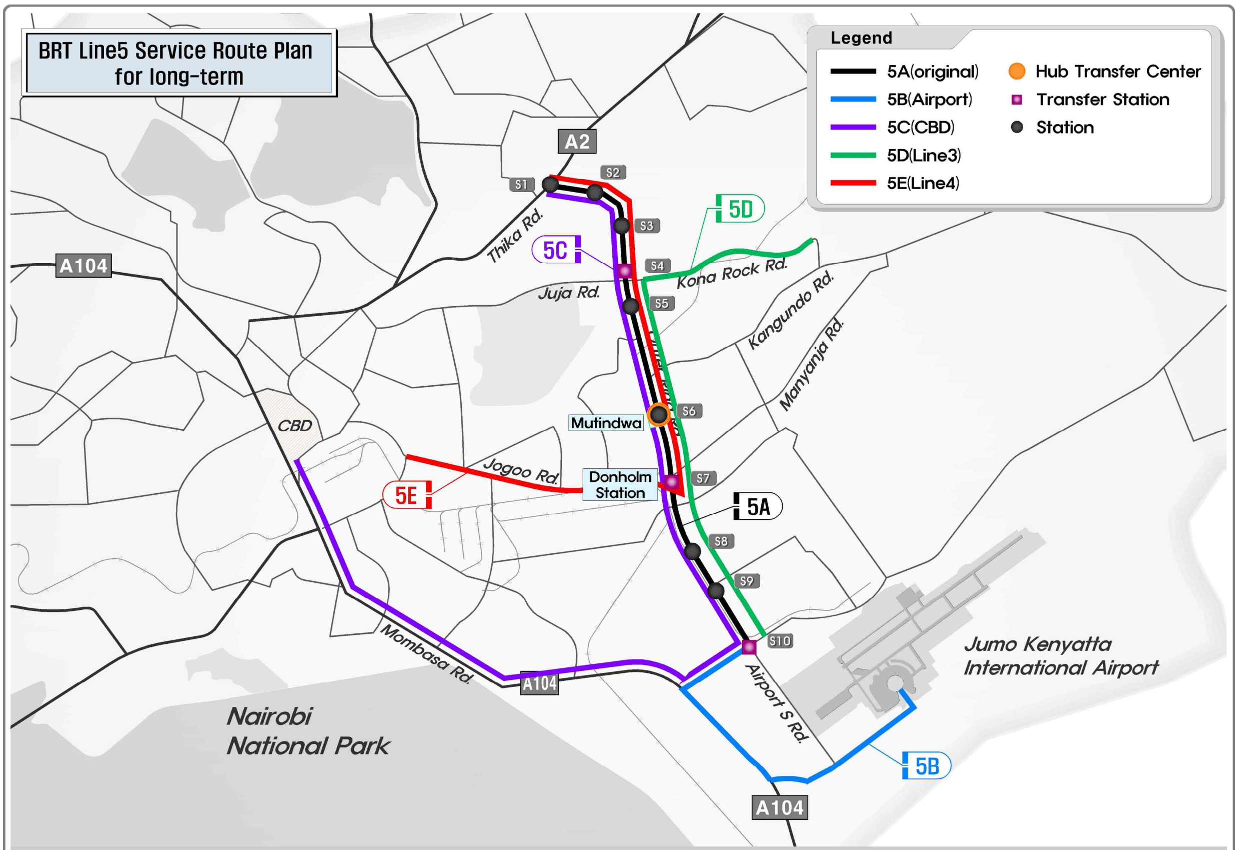
Suggested BRT line 5 route service plan for short-term

<Figure 5-4> Route service plan for short-term

- In the long term, BRT line 5 can be extended in more efficient way by interconnecting it with other BRT lines. Assuming that BRT line 3 and 4 are fully operated, more routes connecting with Jogoo and Juja roads will be established.

Ultimately, a total of 5 inter-corridor routes are expected to operate on BRT line 5 as part of a modern multi-modal public transport system.

- Detailed operation plan will be discussed in section 5.4. In the case of the long-term plan, it is very uncertain that an operation plan would be developed due to lack of related information about the other BRT lines. Hence, the operation plans for the original route and short-term are handled in this study.



Suggested BRT line 5 route service plan for long-term

<Figure 5-5> Route service plan for long-tem

5.1.3. Extension of BRT Line 5

- The extension of BRT Line 5 has been presented differently for each study. The first study, MRTS, planned 12.93 km from Balozi to Imara station, but the second study, the harmonization study, was modified to 10.2 km to reflect the extension of BRT 1 to JKIA. The most recent Nairobi Ndovu A104 BRT Service Plan (2015, ITDP) presents various route scenarios for BRT 1 and suggests extending to the Airport north road in most scenarios. Therefore, in this feasibility study, BRT 5 extension was set to 10.37 km within the ORR section to avoid redundancy with the BRT 1 alternative suggested in the harmonization study and the A104 BRT Service Plan.

5.2. BRT Station

5.2.1. Principles for Selection of BRT Stations

1) Station location

- Consideration for station location
- Currently, we plan to select a location after reviewing the utilization status of the bus stops, the presence of traffic demand facilities around the station, the problem of the geometry of the station, and the walking environment etc.

<Table 5-2> Determinants for selecting station location

Division		Review item
Ridership	Current Behavior	• Number of PSV lines, number of PSV passengers, current PSV stations
	Major facility	• Traffic induction facility (shopping mall, terminal, school, factory, government office, etc.)
	Connection with other PSV	• (Bridge, etc.) between railway stations and other BRT lines
Geometry	Route type of Line	• Examination of plan curve radius, end line type, etc. of bus platform candidate
	Distance from transport facilities	• Investigate the distance between the front and back facilities (entrance, intersection, platform) of the platform
Walking environment	Walking Connectivity	• Pedestrian accessibility/walking right (Spot investigation that minimizes user inconvenience and links main walking facilities)

2) Standard distance between stations

- The distance between the station is set by considering the appropriate service level (average travel speed) of BRT and BRT's design guidelines(Domestic, Overseas)
  - ✓ Installation distance standards of BRT station : Design criteria of domestic and overseas BRT the distance between stops is 0.5km ~ 1.0km, Seoul bus exclusive lane(median lane) is 0.5km ~ 0.8km.
  - ✓ Currently, the existing bus stop of the Outer Ring Road is maintained, and traffic system (railway station, bus terminal) around the bus stop is considered.

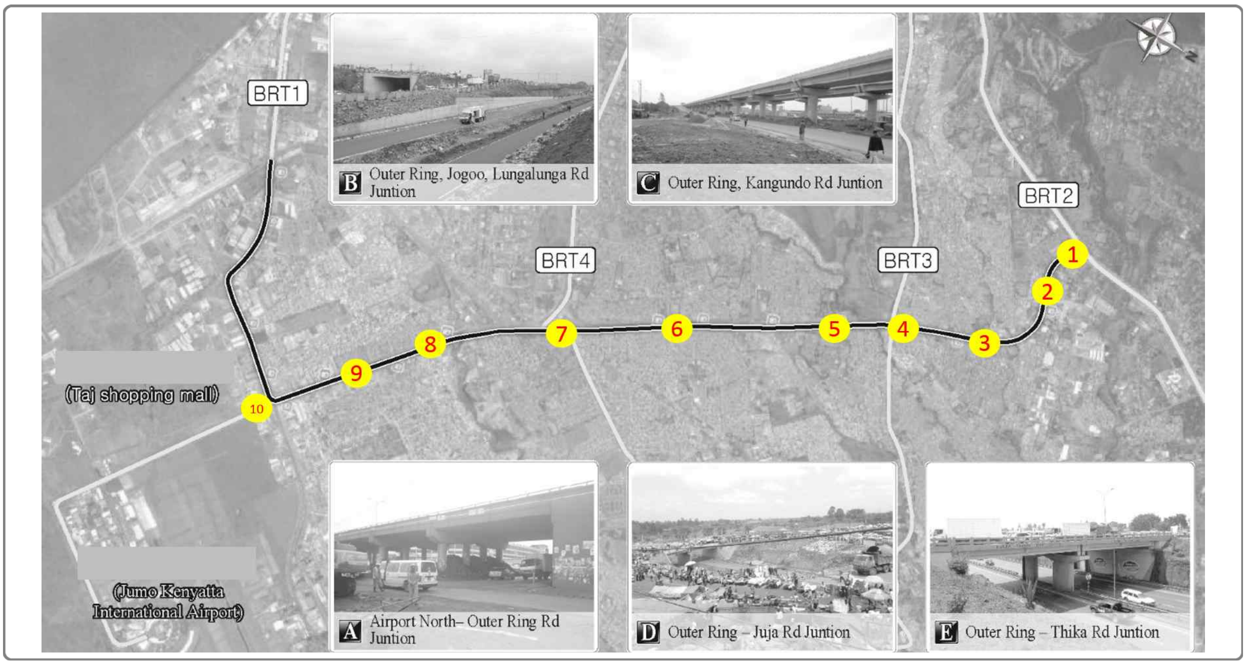
Region	Minimum distance(m)
Downtown	500
Urban	600
Sub-urban	800
Rular	1,000

Source : Bus Rapid Transit Design manual, 2010, MLTM(Korea)

5.2.2. Location of the Stations

1) BRT line 5 Station plan

- Distance between BRT station is determined by the type of roads, development density and the modality to reach a station. A BRT station needs to be located at a place where a high number of passengers are generated. Considering the traffic demand-inducing facilities around the project route, it is better to locate stations 1km apart. It is planned to have ten (10) stations on the Outer ring road section of BRT line 5.



<Figure 5-6> BRT line 5 Station plan

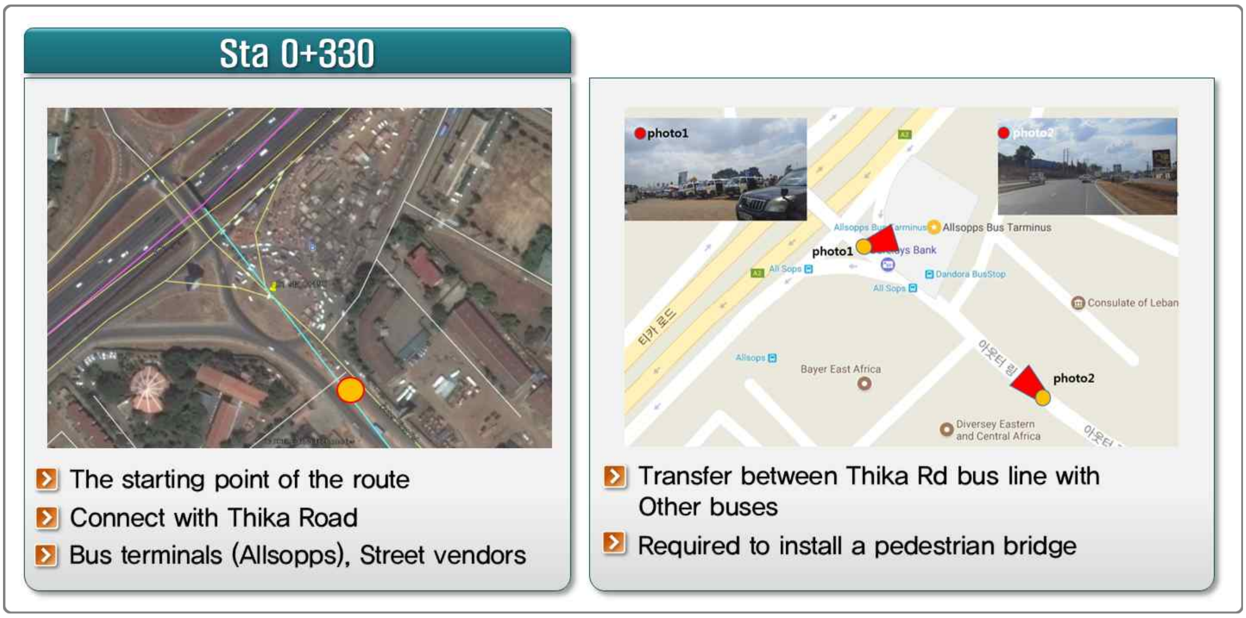
2) Distance between stations

- The maximum and minimum distance between stations is 2,160m and 620m respectively and the average distance is 990m.

<Table 5-3> Station spacing

Station number		Sta	Distance(m)	Remark
1		sta 0+400		
2		sta 1+020	620	
3		sta 1+890	870	
4		sta 2+790	900	
5		sta 3+500	710	
6		sta 5+660	2,160	
7		sta 7+000	1,340	
8		sta 8+475	1,475	
9		sta 9+350	875	
			1,010	
10	N	sta 10+360	75	
	S	sta 10+435		

- Bus stop 1 : Allsopps Bus Terminal is located at the starting point, and there are many street vendors in the vicinity ⇒ Improvement of existing facilities(Bus terminal), installation of a pedestrian bridge is required

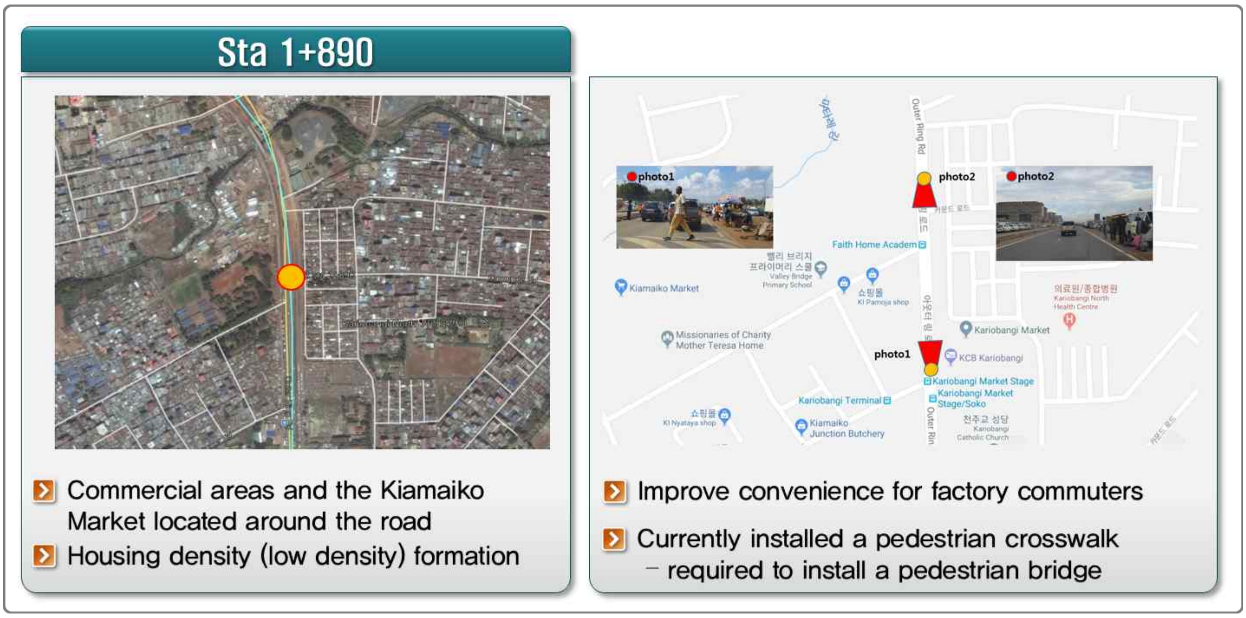


<Figure 5-7> Characteristics of BRT Stop 1

- Bus stop 2 : Improve convenience for factory commuters ⇒ Improvement of existing facilities, Review the existing pedestrian bridge construction plan

<Figure 5-8> Characteristics of BRT Stop 2

- Bus stop 3 : Improve convenience for factory commuters and visitors of the market
  ⇒ Improvement of existing facilities, Review the existing pedestrian bridge construction plan



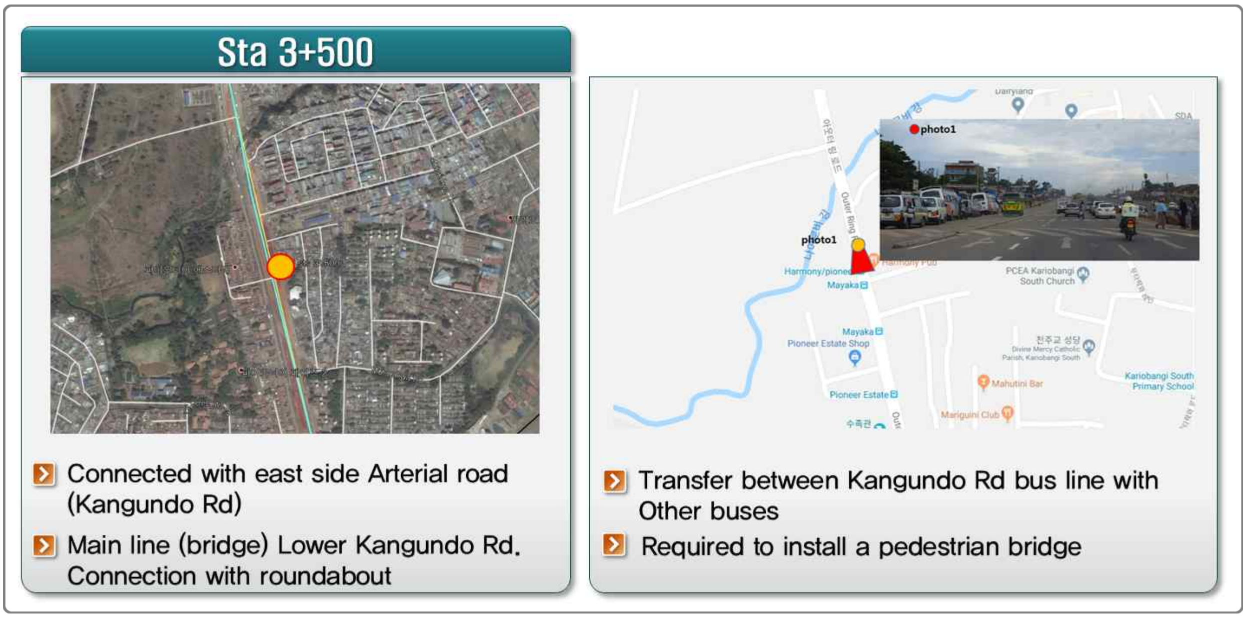
<Figure 5-9> Characteristics of BRT Stop 3

- Bus stop 4 : Improve convenience for transfer between Juja Rd bus with other buses
  - ✓ Traffic conflicts are expected due to the mix of buses and street vendors on the roundabout of Juja Rd
  - ✓ It is necessary to consider the installation limit of the bus stop on the outer ring road due to the facility’s features(bridge pier and ramp)

  ⇒ Improvement of existing facilities, installation of a pedestrian bridge is required

<Figure 5-10> Characteristics of BRT Stop 4

- Bus stop 5 : Review whether it is possible to install a bus stop within the section of a long bridge(over 1km) ⇒ Improvement of existing facilities, installation of a pedestrian bridge is required



<Figure 5-11> Characteristics of BRT Stop 5

- Bus stop 6 : Improve convenience for factory commuters and visitors of the street vendors ⇒ Improvement of existing facilities, Review the existing pedestrian bridge construction plan

<Figure 5-12> Characteristics of BRT Stop 6

- Bus stop 7 : Improve convenience for transfer between Jogoo Rd bus with other buses
  - ✓ Traffic conflicts are expected due to the mix of buses and street vendors on the roundabout of Jogoo Rd
  - ✓ It is necessary to consider the installation limit of the bus stop on the outer ring road due to facility's features(bridge pier and ramp)
  - ⇒ Improvement of existing facilities, installation of a pedestrian bridge is required

<Figure 5-13> Characteristics of BRT Stop 7

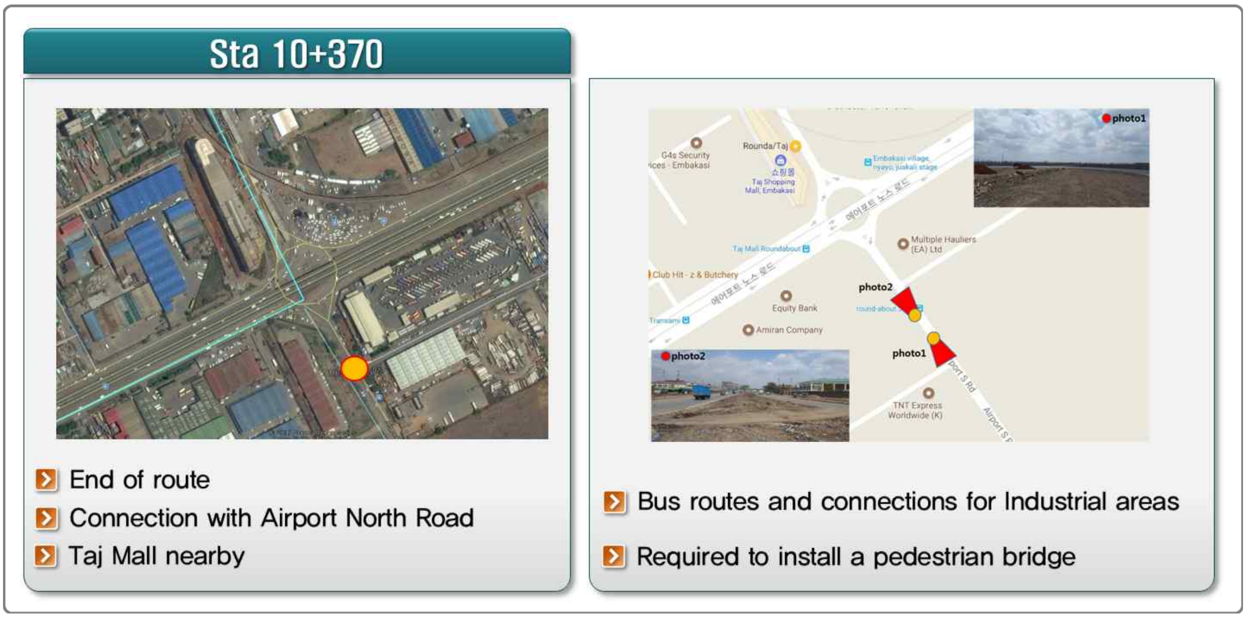
- Bus stop 8 : Improve convenience for factory commuters and visitors of the street vendors ⇒ Improvement of existing facilities, installation of a pedestrian bridge is required (need to review the existing pedestrian bridge construction plan)

<Figure 5-14> Characteristics of BRT Stop 8

- Bus stop 9 : Improve convenience for residents and visitors of of street vendors ⇒ Improvement of existing facilities, installation of a pedestrian bridge is required

<Figure 5-15> Characteristics of BRT Stop 9

- Bus stop 10 : Improve convenience for factory commuters and visitors of the Taj mall ⇒ Improvement of existing facilities, installation of a pedestrian bridge is required



<Figure 5-16> Characteristics of BRT Stop 10

b. Characteristics by station

<Table 5-4> Station characteristics

Station number	Characteristics	Function	Role
1	• The starting point of the route connects with Thika Road • Bus terminals (Allsopps), Street vendors	Connection and transfer	Transfer between Thika Rd bus line with Other buses
2	• A Industrial park located in the north • A commercial area and densely populated residential area in the south	-	Improve convenience for factory commuters
3	• Housing density (low density) formation • Commercial areas and the Kiamaiko market located around the road	-	Improve convenience for factory commuters
4	• Juja Rd roundabout on the flyover crossing the outer ring Rd • Markets and bus stops within the roundabout • Ramp section with bus stop	Connection and transfer (BRT 3 - to CBD)	Transfer between Juja Rd bus with Other buses
5	• Connected with east side Arterial road (Kangundo Rd) • Main line (bridge) Lower Kangundo Rd. • Connection with roundabout	-	Transfer between Kangundo Rd bus line with Other buses
6	• Residential area and commercial district • In the east (Umoja), in the west (Bourbour)	-	Connection for Use in Residential Areas
7	• Jogoo Rd Intersection on the flyover crossing the outer ring Rd • Bus transfer on roundabout • Market and industrial area in the west side of road	Connection and transfer (BRT 4 - to CBD)	Transfer between Kangundo Rd bus line with Other buses
8	• Railway Station(Stage mpya) on the west side of road • Densely populated residential area	-	Bus routes and connections for residential areas
9	• Commercial activities such as the market • And shopping streets around the roads • Densely populated residential area (dense residential)	-	Bus routes and connections for residential areas
10	• End of route • Connection with Airport North Road • Taj Mall nearby	Connection and transfer	Bus routes and connections for Industrial areas

5.3. Passenger Demand Forecasting of BRT Routes

5.3.1. Forecasting result of the BRT's modal

- This project assumes that four bus lines that set up four scenarios around the BRT Line5 are operated, and predicted transportation demand by route.
- As a result of estimating transportation demand for BRT Line 5 stops, it was estimated to be 2020 44,425 Trip/Day, 2030 55329 Trip/Day, and 2040 65,417 Trip/Day.
- Transport demand per km was estimated to be 2020 4,429 Trip/km, 2030 5,516 Trip/km, and 2040 6,522 Trip/km.

<Table 5-5> The number of BRT users

(Unit: Trip/Day, Trip/km)

Year	Length (km)	Number of user		Number of user/km	
		Boarding	Alighting	Boarding	Alighting
2020	10.43	44,425	46,287	4,429	4,615
2030	10.43	55,329	58,432	5,516	5,826
2040	10.43	65,417	69,015	6,522	6,881

- Running this scenario through the model yielded the following results.

<Table 5-6> Results of BRT Line 5 Service Plan

Route	veh type	Distance (km)	Run time (min)	Boarding	Pax km	Pax hours	Max volume
5-A	Std	10.43	29.7	2,689	13,657	20,232	1,566
5-B	Std	7.26	21.6	921	4,078	6,056	856
5-C	Std	21.29	64.2	2,123	17,651	26,610	1,166
TOTAL	-	38.58	115.5	5,732	35,386	52,898	3,588

5.3.2. Forecasting results for the number of boarding and alighting

1) 5-A route

- It is predicted that the 5-A route, which is the basic route of BRT, will increase 1.4 times from 30,912Trip/Day in 2020 to 43,898Trip/Day in 2040.

<Table 5-7> The total number of boarding and alighting (5-A route)

(Unit: Trip/Day)

Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
S01	333	6,317	0	398	7,549	0	473	8,971	0
S02	5,338	773	6,650	6,379	924	7,947	7,580	1,098	9,444
S03	1,795	1,132	12,761	2,145	1,353	15,250	2,549	1,608	18,122
S04	3,413	5,859	13,536	4,078	7,001	16,177	4,846	8,320	19,223
S05	6,747	2,780	13,427	8,063	3,322	16,046	9,582	3,948	19,067
S06	2,302	1,955	17,951	2,751	2,336	21,453	3,269	2,776	25,493
S07	1,483	687	16,505	1,772	821	19,725	2,106	976	23,439
S08	305	1,881	16,628	365	2,248	19,871	434	2,671	23,613
S09	459	788	17,995	549	941	21,505	652	1,119	25,555
S10	8,737	8,741	17,478	10,441	10,446	20,887	12,407	12,413	24,820
Total	30,912	30,912	132,931	36,941	36,941	158,859	43,898	43,898	188,776

<Figure 5-17> Forecasting result for BRT line 5-A route

- Analysis of number of boarding and alighting by direction on the 5-A route showed that the largest number of passengers boarded at 502station when moving from the north to the south, and the largest number of passengers at 510station when traveling from the south to the north.
- The highest number of people in the origin and destination of the route were alighting.

<Table 5-8> The number of boarding and alighting by direction (5-A route)

(Unit: Trip/Day)

Direction	N → S								
Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
501	333	0	0	398	0	0	473	0	0
502	5,338	0	333	6,379	0	398	7,580	0	473
503	958	239	5,671	1,145	286	6,777	1,361	340	8,053
504	1,458	2,736	6,390	1,743	3,270	7,636	2,071	3,886	9,074
505	4,857	611	5,112	5,804	730	6,109	6,897	867	7,260
506	840	1,389	9,358	1,003	1,660	11,184	1,192	1,973	13,290
507	972	513	8,809	1,162	614	10,527	1,381	729	12,509
508	136	241	9,268	163	287	11,075	194	342	13,161
509	171	594	9,164	204	709	10,951	242	843	13,013
510	0	8,741	8,741		10,446	10,446	0	12,413	12,413
Total	15,064	15,064	62,844	18,002	18,002	75,102	21,392	21,392	89,246

Direction	S → N								
Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
520	0	6,317	0	0	7,549	0	0	8,971	0
519	0	773	6,317	0	924	7,549	0	1,098	8,971
518	837	893	7,090	1,000	1,067	8,473	1,188	1,268	10,069
517	1,954	3,122	7,146	2,335	3,731	8,540	2,775	4,434	10,149
516	1,890	2,169	8,315	2,259	2,592	9,937	2,685	3,080	11,808
515	1,462	565	8,593	1,747	676	10,269	2,076	803	12,203
514	510	174	7,697	610	208	9,198	725	247	10,930
513	169	1,640	7,360	202	1,960	8,796	240	2,329	10,452
512	288	194	8,831	344	232	10,554	409	276	12,541
511	8,737	0	8,737	10,441	0	10,441	12,407	0	12,407
Total	15,848	15,848	70,086	18,939	18,939	83,757	22,506	22,506	99,530

2) 5-B route

- The 5-B route is the route linked to the airport and predicts the traffic volume considering the airport users, workers and others.
- Traffic was forecasted to be 10,582Trip/Day in 2020, 18,557Trip/Day in 2030 and 22,576Trip/Day in 2040.

<Table 5-9> The total number of boarding and alighting (5-B route)

(Unit: Trip/Day)

Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
S10	4,674	4,689	0	8,068	9,013	0	9,816	10,966	0
S11	532	647	9,363	644	783	17,082	783	953	20,782
S13	2,674	2,530	9,840	3,977	2,875	17,658	4,613	3,272	21,483
B1	2,702	2,717	5,419	5,868	5,885	11,753	7,364	7,386	14,750
Total	10,582	10,582	24,622	18,557	18,557	46,492	22,576	22,576	57,015

<Figure 5-18> Forecasting result for BRT line 5-B route

<Table 5-1> The number of boarding and alighting by direction (5-B route)

Direction	N → S								
Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
510	4,674	0	0	8,068	0	0	9,816	0	0
S11	371	191	4,674	449	231	8,068	547	281	9,816
S13	309	2,447	4,855	373	2,775	8,287	454	3,150	10,082
B1	0	2,717	2,717	0	5,885	5,885	0	7,386	7,386
Total	5,354	5,354	12,246	8,891	8,891	22,240	10,817	10,817	27,283
Direction	**S → N**								
Station	**2020**			**2030**			**2040**		
	Boarding	**Alighting**	**in-vehicle person**	**Boarding**	**Alighting**	**in-vehicle person**	**Boarding**	**Alighting**	**in-vehicle person**
511	0	4,689	0	0	9,013	0	0	10,966	0
S11	161	456	4,689	194	552	9,013	236	672	10,966
S13	2,365	83	4,985	3,604	100	9,371	4,159	122	11,401
B1	2,702	0	2,702	5,868	0	5,868	7,364	0	7,364
Total	5,228	5,228	12,376	9,666	9,666	24,252	11,759	11,759	29,731

3) 5-C route

- The 5-C route is estimated to be 24,397 Trip / Day in 2020, 28,484 Trip / Day in 2030, and 32,305 Trip / Day in 2040.

<Table 5-10> The total number of boarding and alighting (5-C route)

(Unit: Trip/Day)

Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
S01	1,268	2,768	0	1,481	3,232	0	1,679	3,666	0
S02	642	337	4,036	750	394	4,713	851	447	5,345
S03	646	407	5,016	754	476	5,857	855	539	6,642
S04	653	667	5,273	762	779	6,156	865	883	6,982
S05	484	955	6,067	565	1,115	7,083	641	1,265	8,033
S06	634	803	6,946	740	938	8,110	839	1,064	9,198
S07	605	265	7,346	706	310	8,576	801	351	9,727
S08	628	991	7,702	733	1,158	8,992	831	1,313	10,199
S09	850	666	8,756	992	778	10,223	1,125	882	11,594
S10	2,429	2,826	9,333	2,836	3,299	10,897	3,217	3,742	12,358
S11	2,076	1,329	9,279	2,424	1,552	10,834	2,749	1,760	12,287
S12	2,103	2,007	12,683	2,455	2,343	14,807	2,785	2,658	16,794
C1	1,991	1,080	13,406	2,325	1,261	15,652	2,637	1,431	17,751
C2	1,519	1,009	12,808	1,774	1,178	14,954	2,012	1,336	16,960
C3	796	672	12,721	929	785	14,852	1,053	890	16,845
C4	762	622	12,240	890	727	14,291	1,009	824	16,208
C5	612	241	11,788	714	281	13,763	810	319	15,609
C6	649	458	11,507	758	535	13,435	860	607	15,237
C7	811	527	11,185	947	615	13,059	1,074	697	14,811
C8	4,239	5,764	10,002	4,949	6,729	11,678	5,612	7,632	13,244
Total	24,397	24,397	178,094	28,484	28,484	207,931	32,305	32,305	235,824

<Figure 5-19> Forecasting result for BRT line 5-C route

<Table 5-11> The number of boarding and alighting by direction (5-C route)

(Unit: Trip/Day)

Direction	N → S								
Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
501	1,268	0	0	1,481	0	0	1,679	0	0
502	642	0	1,268	750	0	1,481	851	0	1,679
503	374	127	1,911	437	148	2,231	495	168	2,530
504	435	45	2,158	508	52	2,519	576	59	2,857
505	342	138	2,548	399	161	2,975	453	183	3,374
506	290	175	2,752	339	205	3,213	384	232	3,644
507	480	132	2,867	561	154	3,347	636	175	3,796
508	397	52	3,215	463	60	3,754	526	69	4,257
509	506	126	3,560	591	147	4,157	670	166	4,714
510	1,410	1,636	3,941	1,647	1,910	4,601	1,868	2,166	5,218
S11	2,076	1	3,715	2,424	1	4,338	2,749	1	4,920
S12	1,381	971	5,791	1,612	1,134	6,761	1,829	1,286	7,668
C1	617	460	6,200	720	537	7,239	817	609	8,210
C2	631	420	6,357	737	490	7,422	836	556	8,418
C3	179	358	6,568	209	418	7,669	237	474	8,697
C4	190	346	6,389	222	404	7,460	252	458	8,460
C5	183	138	6,233	214	161	7,278	242	183	8,254
C6	198	263	6,278	231	307	7,330	262	349	8,313
C7	27	476	6,213	31	556	7,254	36	630	8,227
C8	0	5,764	5,764	0	6,729	6,729	0	7,632	7,632
Total	11,628	11,628	83,728	13,576	13,576	97,756	15397	15397	110869

Direction	S → N								
Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
520	0	2,768	0	0	3,232	0	0	3,666	0
519	0	337	2,768	0	394	3,232	0	447	3,666
518	272	281	3,106	317	328	3,626	360	372	4,112
517	218	622	3,115	255	726	3,636	289	824	4,124
516	142	817	3,519	166	954	4,108	188	1,082	4,659
515	343	628	4,194	401	733	4,897	454	831	5,554
514	125	133	4,479	146	155	5,229	165	176	5,930
513	231	940	4,487	270	1,097	5,239	306	1,244	5,941
512	344	540	5,196	401	631	6,066	455	716	6,880
511	1,019	1,190	5,392	1,189	1,389	6,296	1,349	1,576	7,140
S11	0	1,328	5,564	0	1,551	6,496	0	1,759	7,367
S12	722	1,036	6,892	843	1,209	8,047	956	1,371	9,126
C1	1,374	620	7,206	1,605	724	8,413	1,820	821	9,541
C2	888	589	6,451	1,037	688	7,532	1,176	780	8,543
C3	616	314	6,153	720	367	7,184	816	416	8,147
C4	572	276	5,851	668	323	6,831	758	366	7,747
C5	429	102	5,555	500	120	6,485	568	136	7,355
C6	452	195	5,229	527	228	6,105	598	258	6,923
C7	784	51	4,972	916	59	5,805	1,038	67	6,584
C8	4,239	0	4,239	4,949	0	4,949	5,612	0	5,612
Total	15,848	15,848	70,086	14,908	14,908	110,175	16,908	16,908	124,954

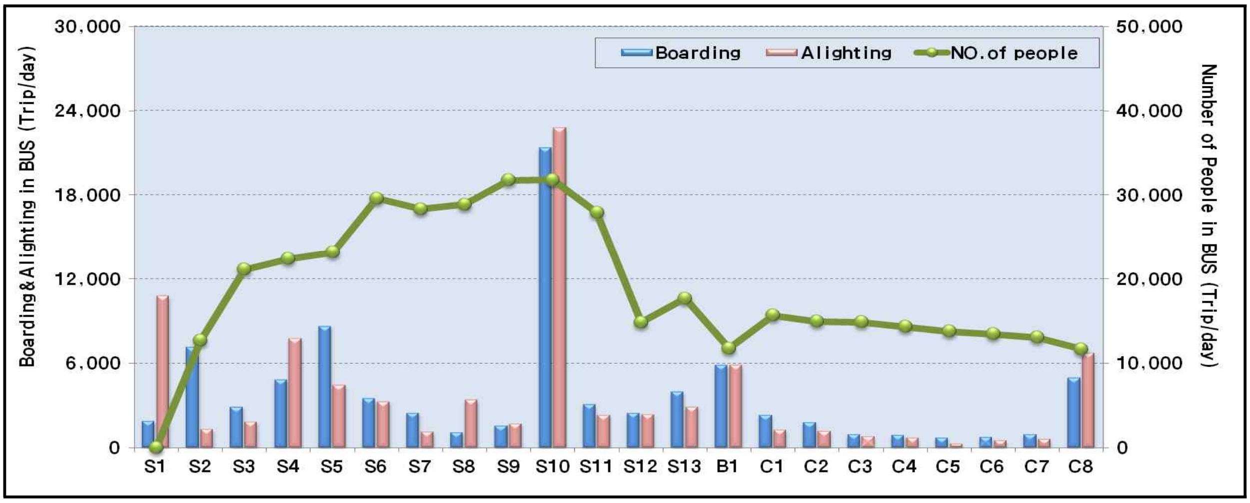
4) BRT line5 service route

- The BRT Line5 demand will increase 1.5 times from 2020 65,891Trip/Day to 2040 98,779Trip/Day. The number of boarding and alighting passengers are as follows:

<Table 5-12> The total number of boarding and alighting

(Unit: Trip/Day)

Station	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
S1	1,601	9,085	0	1,878	10,781	0	2,152	12,637	0
S2	5,980	1,110	10,686	7,129	1,318	12,660	8,431	1,544	14,789
S3	2,441	1,540	17,777	2,899	1,829	21,107	3,404	2,147	24,764
S4	4,066	6,526	18,809	4,841	7,780	22,333	5,711	9,203	26,205
S5	7,231	3,735	19,494	8,629	4,437	23,129	10,223	5,212	27,101
S6	2,935	2,758	24,898	3,490	3,274	29,563	4,108	3,840	34,691
S7	2,088	953	23,851	2,479	1,131	28,301	2,907	1,327	33,166
S8	933	2,872	24,330	1,098	3,405	28,863	1,265	3,984	33,812
S9	1,309	1,454	26,751	1,540	1,719	31,727	1,777	2,000	37,149
S10	15,841	16,255	26,811	21,346	22,758	31,783	25,440	27,120	37,179
S11	2,608	1,976	18,642	3,068	2,335	27,915	3,532	2,712	33,069
S12	2,103	2,007	12,683	2,455	2,343	14,807	2,785	2,658	16,794
S13	2,674	2,530	9,840	3,977	2,875	17,658	4,613	3,272	21,483
B1	2,702	2,717	5,419	5,868	5,885	11,753	7,364	7,386	14,750
C1	1,991	1,080	13,406	2,325	1,261	15,652	2,637	1,431	17,751
C2	1,519	1,009	12,808	1,774	1,178	14,954	2,012	1,336	16,960
C3	796	672	12,721	929	785	14,852	1,053	890	16,845
C4	762	622	12,240	890	727	14,291	1,009	824	16,208
C5	612	241	11,788	714	281	13,763	810	319	15,609
C6	649	458	11,507	758	535	13,435	860	607	15,237
C7	811	527	11,185	947	615	13,059	1,074	697	14,811
C8	4,239	5,764	10,002	4,949	6,729	11,678	5,612	7,632	13,244
Total	65,891	65,891	335,646	83,982	83,982	413,282	98,779	98,779	481,614



<Figure 5-20> Vehicle Assignment Result (2030)

<Table 5-13> The number of boarding and alighting

(Unit: Trip/Day)

Station	N → S								
	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
501	1,601	0	0	1,878	0	0	2,152	0	0
502	5,980	0	1,601	7,129	0	1,878	8,431	0	2,152
503	1,332	366	7,581	1,582	434	9,008	1,856	508	10,583
504	1,893	2,781	8,548	2,251	3,322	10,156	2,647	3,945	11,932
505	5,199	749	7,660	6,204	891	9,084	7,350	1,050	10,634
506	1,130	1,565	12,110	1,342	1,865	14,397	1,577	2,205	16,934
507	1,453	646	11,675	1,723	768	13,874	2,017	904	16,305
508	533	292	12,483	626	348	14,829	719	410	17,418
509	677	719	12,724	795	856	15,108	912	1,009	17,727
510	6,085	10,376	12,681	9,715	12,355	15,046	11,684	14,579	17,631
S11	2,448	192	8,390	2,873	232	12,406	3,296	282	14,736
S12	1,381	971	5,791	1,612	1,134	6,761	1,829	1,286	7,668
S13	309	2,447	4,855	373	2,775	8,287	454	3,150	10,082
B1	0	2,717	2,717	0	5,885	5,885	0	7,386	7,386
C1	617	460	6,200	720	537	7,239	817	609	8,210
C2	631	420	6,357	737	490	7,422	836	556	8,418
C3	179	358	6,568	209	418	7,669	237	474	8,697
C4	190	346	6,389	222	404	7,460	252	458	8,460
C5	183	138	6,233	214	161	7,278	242	183	8,254
C6	198	263	6,278	231	307	7,330	262	349	8,313
C7	27	476	6,213	31	556	7,254	36	630	8,227
C8	0	5,764	5,764	0	6,729	6,729	0	7,632	7,632
Total	32,046	32,046	158,819	40,469	40,469	195,098	47,606	47,606	227,398

Station	S → N								
	2020			2030			2040		
	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person	Boarding	Alighting	in-vehicle person
520	0	9,085	0	0	10,781	0	0	12,637	0
519	0	1,110	9,085	0	1,318	10,781	0	1,544	12,637
518	1,108	1,174	10,196	1,317	1,395	12,099	1,548	1,640	14,181
517	2,172	3,745	10,261	2,590	4,458	12,177	3,064	5,258	14,273
516	2,032	2,986	11,834	2,425	3,546	14,045	2,873	4,162	16,467
515	1,805	1,193	12,787	2,148	1,409	15,166	2,531	1,634	17,757
514	635	307	12,175	756	363	14,427	890	423	16,860
513	400	2,580	11,847	472	3,057	14,034	546	3,573	16,393
512	632	734	14,027	746	863	16,620	864	991	19,421
511	9,756	5,879	14,129	11,631	10,403	16,737	13,756	12,542	19,548
S11	161	1,784	10,253	194	2,103	15,509	236	2,430	18,333
S12	722	1,036	6,892	843	1,209	8,047	956	1,371	9,126
S13	2,365	83	4,985	3,604	100	9,371	4,159	122	11,401
B1	2,702	0	2,702	5,868	0	5,868	7,364	0	7,364
C1	1,374	620	7,206	1,605	724	8,413	1,820	821	9,541
C2	888	589	6,451	1,037	688	7,532	1,176	780	8,543
C3	616	314	6,153	720	367	7,184	816	416	8,147
C4	572	276	5,851	668	323	6,831	758	366	7,747
C5	429	102	5,555	500	120	6,485	568	136	7,355
C6	452	195	5,229	527	228	6,105	598	258	6,923
C7	784	51	4,972	916	59	5,805	1,038	67	6,584
C8	4,239	0	4,239	4,949	0	4,949	5,612	0	5,612
Total	33,845	33,845	176,827	43,513	43,513	218,184	51,173	51,173	254,216

5.4. BRT Operation Plan

- The operation plan is studied to facilitate two alternative scenarios which are the original scenario along the outering road, referred to as scenario 1, and the multi-route scenario which expands its original route to CBD and the airport, referred to as scenario 2.

5.4.1. BRT Vehicle

- The BRT vehicle type does not only influence operation speed and capacity of the system but also has high effect on environmental and passenger convenience aspects. Furthermore, the recognition and image of the BRT will be determined by the vehicle type which is critical.
- Hence, in order to revitalize the use of public transport by means of establishing the BRT system, it is essential that the vehicle should be selected, and designed, for the type of services offered and the nature of markets served.
- The type of vehicles are classified by body type and propulsion system. The available types of vehicles for BRT are discussed below.

1) Low floor bus

- Regular buses are the most standard mode of public transportation used. Whereas the floor of regular buses is 80~90 cm above ground, low floor buses are built as low as 25~40 cm above ground.
- some vehicles can additionally lower the height by using hydraulics during stops. Thus, they have the advantage of being much more convenient for the disabled and facilitate in transporting people who use wheelchairs. Cost-wise, they have the disadvantage that they are nearly twice as expensive as regular buses.

2) Articulated bus

- Articulated bus is operated by connecting two or more vehicles and were developed to handle large numbers of passengers. There are bi-articulated buses, which connects 3 vehicles into one, and double-decker buses, which are operated in cities such as London, Hong Kong and Singapore.
- An articulated bus is more difficult to manufacture than regular buses and are not mass-produced. Therefore, an articulated bus is about 5.2 times more expensive than the regular bus. Even though both articulated and regular buses use the same engines, articulated buses have reduced speed due to increased weight, and they easily get overheated and malfunction frequently in hilly cities.

- An articulated bus has larger minimum radius of rotation (12.0m) than the regular bus (9.4m) and are thus limited by curve radii in rotation at both entry and exit points. Therefore, a BRT vehicle with high operating effect relative to cost should be selected by taking into consideration the characteristics of the BRT route, passenger demand, operation interval, and boarding facilities.

3) Bimodal tram

- A bimodal tram adopts an electromagnetic exclusive lane and operates on roads like buses, combining the function of two modes of transportation (trains and buses).
- The appearance of a bimodal tram is closer to that of buses but its operation is unmanned. It is possible to use on exclusive roads, and is easy to secure high transport loads by increasing the number of units. A bimodal tram can run continuously on exclusive and regular roads. They are a novel public transportation system that utilizes a hybrid driving system that combines CNG engines and motors.
- However, a bimodal tram has not been commercialized yet and costs more than other transportation modes.
- In the case of construction costs, 1 km of regular BRT exclusive lane costs approximately 173,900 USD, whereas 1km of bimodal tram exclusive lane is about 15 times the cost of constructing a regular BRT exclusive lane (approximately 1,165,200 USD). Cost of purchase of a bimodal tram vehicle is also around 10 times more expensive than the cost of regular BRT buses. A regular BRT bus costs about 90,800 USD per vehicle while a bimodal tram costs 1,086,957 USD per vehicle (2 units).
- Like articulated buses, a bimodal tram (18m) is longer than regular buses and have greater radius of rotation (12.0m), and are thus restricted in rotation during crossroad entry and exit.

<Table 5-14> Dimension by type of BRT vehicles

(Unit : m, USD)

Dimension	Low floor bus	Articulated bus	Bimodal tram
Length/Height	12.0/3.2	18.0/3.2	18.0/3.4
Capacity	55 pax (25seats)	150+ pax (45seats)	130 pax (30seats)
Turning radius	9.4	12.0	12.0
Fuel	CNG, Diesel, Electric	CNG	CNG-hybrid
Price	approx. 170,000	approx. 487,000	approx. 1,087,000
Image			

4) Suggested vehicle type

- A comparative review on the three vehicle types; low-floor bus, articulated bus and bimodal tram, was conducted and has been identified that each type has its own advantages and disadvantages.
- The major advantage that a low-floor bus has over the other types is that it is cost-effective and universal. Also, compared to a general standard bus, it offers improved accessibility in the form of a step-less boarding system for both people with disabilities and the elderly. However, considering the exterior appearance, this bus can hardly be differentiated from a standard bus, hence it is not easy to drag attention from people for the system.
- The advantage of an articulated bus is that it can accomodate the largest number of passengers at peak time and the congestion rate of the vehicle is reduced during off peak times. However, the bus has many demerits which deters it from move along narrow streets especially when turning due to its wide turning radius.
- Although a bimodal tram is the cutting edge among them and the riding quality is very superior, it is not yet commercially proven and the capital cost is extremely high. Furthermore, the maintenance cost is also very high due to the customized nature of the vehicle.
- Consequently, a low-floor CNG bus can be considered the most suitable BRT vehicle type for Nairobi in the short-term. The other alternatives also have a benefit of more capacity and better image, however the economic efficiency is too low and the smooth movement is restricted depending on the road geometry. In the long term, the CNG bus can be substituted by an electric bus which is more convenient, eco friendly and of better fuel efficiency.

<Table 5-15> Comparison of BRT vehicles

Type	Pros	Cons	Suggested
Low-floor bus	• Low capital and operation cost • Widely used and verified in many revenue services • Easy to procure spare parts	• Relatively high noise and GHG emission when using diesel • Lack of distinctive identity	◎
Articulated bus	• Much larger passenger capacity especially at peak time • Better vehicle image than standard bus	• Limited operation in poor geometric and pavement condition • 4 times higher capital cost than that of low-floor bus	
Bimodal tram	• Superb riding quality • Relatively high capacity • Future-oriented vehicle image	• Not yet commercialized and proven • Extremely high capital cost	

5.4.2. Operation Time

- Operation time for BRT Line 5 is assumed to be between 05:00 AM and 22:00 PM, taking into consideration the transport pattern of urban passengers and current matatu operation times (05:00-21:30) in Nairobi.
- Based on the maximum demand in the most congested section during the peak time, a detailed operation time per each time window was established. For the rest of the time windows, operation times were established flexibly by considering the convenience of passengers.

<Table 5-16> Plan on Operation Time

<table>
<tr><th colspan="3">Contents</th><th colspan="2">Operation time</th><th>Remarks</th></tr>
<tr><td rowspan="3">Weekday</td><td rowspan="2">Peak</td><td>Morning</td><td>06:30-09:00</td><td>2.5 hours</td><td rowspan="2">6 hours</td></tr>
<tr><td>Evening</td><td>16:30-20:00</td><td>3.5 hours</td></tr>
<tr><td colspan="2">Off-peak</td><td>05:00-06:30
09:00-16:30
20:00-22:00</td><td>1.5 hour
7.5 hours
2.0 hours</td><td>11 hours</td></tr>
<tr><td colspan="3">Saturday</td><td>05:00-22:00</td><td>17 hours</td><td>17 hours</td></tr>
<tr><td colspan="3">Sunday</td><td>05:00-22:00</td><td>17 hours</td><td>17 hours</td></tr>
</table>

5.4.3. Operation Speed

- The average values of acceleration and deceleration speeds are generally used to set up an operation plan since they affect passengers' safety and comfort.
- Scheduled speed is the speed that takes into consideration variables such as travel time (operation time of a bus), stoppage time at bus stations, and acceleration/deceleration of the bus.

Scheduled speed (km/h) = bus route length (km) / total operation time including stop time (h)

- Time for boarding, alighting, and loading at bus stations are flexible depending on operation conditions, methods, bus station types and facilities and attitude of passengers. However, they were assumed to be consistent for convenience of analysis. The scheduled speed on the outering road was estimated at 22.3km/h for scenario 1 and 24.75km/h, 25.87km/h, 24.83km/h for scenario 2 on routes 5A, 5B, 5C respectively.

<Table 5-17> Service frequency per day

Category		route distance (km)	no. of stations	boarding time(sec)	round trip(hr)	commercial speed(km/h)
scenario1		22.3	20	15	54.06	24.75
scenario2	5A	22.3	20	15	54.06	24.75
	5B	16.8	8	15	38.96	25.87
	5C	46.3	40	15	111.86	24.83

※ Operation speed is assumed to be 30km/h considering deceleration when approaching and departing the stations

5.4.4. Service Frequency and Vehicle Headway

- From the estimation of the service frequency per day based on peak and off-peak hours during daily operation hour (17 hours), service frequency was found to be 200~580times per day for weekdays and 170~340 times per day for weekends by service plans.

<Table 5-18> Service frequency per day

Category		Weekdays			Weekends
		Sum	Peak	Off-peak	
Service Plan 1	Headway	-	4 min	6 min	6 min
	Frequency	200 times	90 times	110 times	170 times
Service Plan 2	Headway	-	3 min	5 min	5 min
	Frequency	252 times	120 times	132 times	204 times
Service Plan 3	Headway	-	2 min	4 min	4 min
	Frequency	345 times	180 times	165 times	255 times
Service Plan 4	Headway	-	1 min	3 min	3 min
	Frequency	580 times	360 times	220 times	340 times

- The maximum number of passengers served by a 'Low-floor CNG Bus' was estimated to be 66 persons with a congestion rate of 120%. Considering the total service frequency per day, the maximum number of passengers carried per day was estimated.
- Vehicle headway and service frequency(required number of vehicle per hour) was calculated by using the maximum demand on the most congested stop at peak hours and the planned vehicle capacity. See the formula as below

The required number of BRT vehicles per hour = peak hour demand at the most congested stop ÷ (passenger capacity x 120 %)

The required number of BRT vehicles per hour = 60 min ÷ Scheduled BRT Headway

- When the bus operates on 5A routes of the ORR, 990~3,960 persons can be conveyed per hour.
- Considering the fact that the capacity of a standard bus is 75 persons according to the BRT Design Framework(2017, NaMATA), the proper headway should be approx. 3 minutes at peak time in proportion to the load factor in 2020.

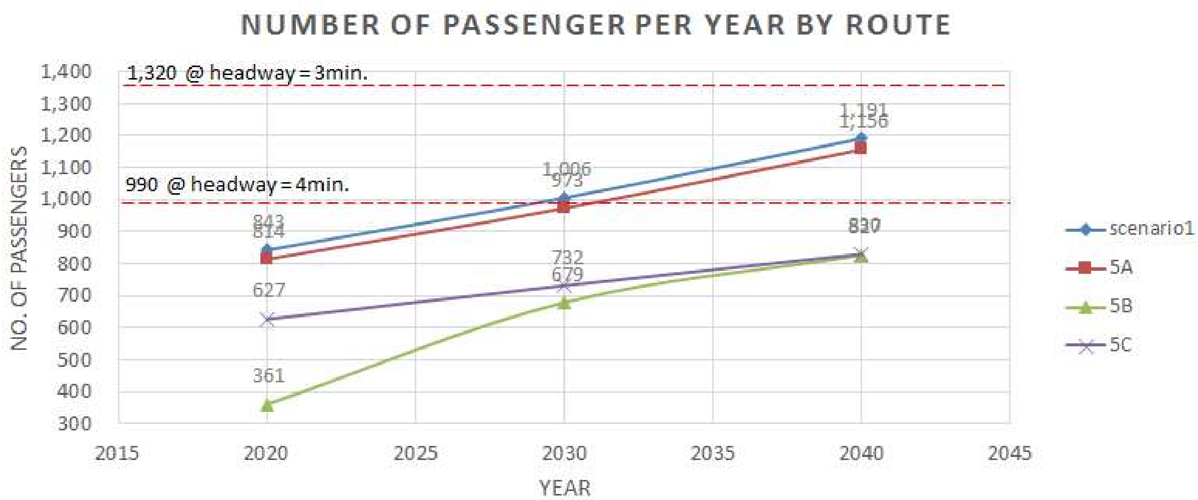
<Table 5-19> Maximum capacity of a BRT route

Service Plan	Bus Capacity (person/veh)	Service frequency (times/hour)	BRT Capacity (person/hour)	No. of passengers (person/hour)	Load Factor
Plan 1	55 X 120% = 66 persons	15	990	843	.85
Plan 2		20	1,320		.64
Plan 3		30	1,980		.43
Plan 4		60	3,960		.21

- Based on the estimated headway for scenario 1, the required headways for the other scenario and future years are estimated. The following table shows the number of required vehicles and headway based on the maximum capacity and the graph illustrates the relationship.

<Table 5-20> Maximum capacity of a BRT route

Scenario		Maximum capacity (person/hour)			No. of required operating vehicles			required vehicle headway (min.)		
		2020	2030	2040	2020	2030	2040	2020	2030	2040
Scenario1		843	1,006	1,191	16	19	23	4.6	3.7	3.2
Sce-nario2	5A	814	973	1,156	16	18	22	4.6	4.0	3.3
	5B	361	679	827	7	13	16	10.0	5.5	4.6
	5C	627	732	830	12	14	16	6.0	5.0	4.6



<Figure 5-21> Number of expected capacity by route

- The optimum vehicle headway and service frequency for each route are suggested in the table 5-11. Results from analysis shows that vehicle headway for scenario1 at peak and off-peak times are 3 and 5 minutes respectively in the opening year.

<Table 5-21> Optimum headway and service frequency

Scenario			Maximum capacity (person/hour)			optimum vehicle headway (min.)			Service Frequency (times/hour)		
			2020	2030	2040	2020	2030	2040	2020	2030	2040
Scenario1		Peak	843	1006	1191	4	3	3	15	20	20
		Off	422	503	595	6	6	5	10	10	12
Scena-rio2	5A	Peak	814	973	1156	4	3	3	15	20	20
		Off	407	486	578	6	6	5	10	10	12
	5B	Peak	361	679	827	10	5	4	6	12	15
		Off	257	482	586	10	7	6	6	9	10
	5C	Peak	627	732	830	5	4	4	12	15	15
		Off	314	366	415	10	8	8	6	7.5	8

※ A peak hour rate of 8.7% is applied on a basis of empirical analysis

5.4.5. Annual Traveled Miles

- Annual travel distance serves as the basis for the estimation of operation cost. It is calculated by multiplying the service frequency by the length of the extended route.

Annual travel distance (km/year) = The length of route (km) × ((Weekday service frequency × 261days) + (Weekends service frequency × 104 days))

<Table 5-22> Annual traveled distance

(Units: km)

Category			Scenario1	5A	5B	5C
route length			22.3	22.3	16.8	46.3
2020	weekdays	peak	453,983.4	453,983.4	157,852.8	725,058.0
		off	448,163.1	448,163.1	192,931.2	664,636.5
	weekends		275,984.8	275,984.8	118,809.6	409,292.0
	Total		1,178,131.3	1,178,131.3	469,593.6	1,798,986.5
2030	weekdays	peak	558,748.8	523,827.0	289,396.8	870,069.6
		off	512,186.4	512,186.4	385,862.4	797,563.8
	weekends		315,411.2	315,411.2	237,619.2	491,150.4
	Total		1,386,346.4	1,351,424.6	912,878.4	2,158,783.8
2040	weekdays	peak	663,514.2	628,592.4	342,014.4	942,575.4
		off	640,233.0	576,209.7	434,095.2	930,491.1
	weekends		394,264.0	354,837.6	267,321.6	573,008.8
	Total		1,698,011.2	1,559,639.7	1,043,431.2	2,446,075.3

5.4.6. Number of Fleet

- The required number of vehicles is affected by the operating speed, round trip time by route length, and circulation time. The scheduled vehicle headway for scenario 1 is 3 to 5 minutes and the length of extended round trip route is 22.3 km.
- The required number of vehicles was estimated using the following formula:

Required number of vehicles = round trip time / service interval during peak hours

Number of spare buses = Required number of vehicles × spare rate (20%)

- The analysis indicates that the total number of vehicles in the opening year will be 18 including 3 spare vehicles for scenario1. For scenario2, the required number of vehicles is 40, 56, 60 in 2020, 2030, 2040 respectively.

<Table 5-23> Required number of buses

Category			Route length (km)	Round trip time (min)	peak hours vehicle headway (min)	Required number of vehicles(veh)		
						Number of operating buses	Number of spare buses	Total number of buses
2020	Scenario 1		22.3	54.06	4	15	3	18
	Scenario2	5A	22.3	54.06	4	15	3	18
		5B	16.8	38.96	10	7	1	8
		5C	46.3	111.86	5	12	2	14
2030	Scenario 1		22.3	54.06	3	20	4	24
	Scenario2	5A	22.3	54.06	3	19	4	23
		5B	16.8	38.96	5	13	2	15
		5C	46.3	111.86	4	15	3	18
2040	Scenario 1		22.3	54.06	3	20	4	24
	Scenario2	5A	22.3	54.06	3	20	4	24
		5B	16.8	38.96	4	15	3	18
		5C	46.3	111.86	4	15	3	18

Note: Assuming that the layover/schedule recovery time equals 10% of the total round-trip running time

5.4.7. Service Frequency

- Estimation of service frequency per day based on peak and off-peak hours during daily operation hours (17 hours) shows that, service frequency for scenario 1 is 252 times per day on weekdays and 204 times per day on weekends in the opening year.

<Table 5-24> Service frequency per day

Category			weekdays(times)			weekends (times)
			sum	peak	off-peak	
2020	Scenario 1		200	90	110	170
	Scenario2	5A	200	90	110	170
		5B	102	36	66	102
		5C	138	72	66	102
2030	Scenario 1		230	120	110	170
	Scenario2	5A	230	120	110	170
		5B	171	72	99	153
		5C	173	90	83	128
2030	Scenario 1		252	120	132	204
	Scenario2	5A	252	120	132	204
		5B	200	90	110	170
		5C	178	90	88	136

5.5. BRT Fare Collection

5.5.1. Fare Structure

- Fare system should be determined reasonably by considering service level, market demand, and other various social and economic conditions. It should consider both BRT supplier and user to determine an appropriate pricing level. The selection of a transport made by a passenger is affected by the pass price which is levied on. It has a close relationship with transportation structure and level, Hence, it is required to set an appropriate level of fare systems depending on the features of the transportation mode.
- In general, policy target to set the fare system is offset in most cases. When the fare system is reviewed, it would help analyze trade-off closely between conflicting goals. For example, if its main target is to increase revenue, it can do so by simply increasing fare but eventually it may become a burden to passengers and discourage them from using it. Therefore, two goals have to complement each other.

<Table 5-25> Policy goal on fare system

Revenue increase	• Increase total fare revenue through setting fares at reasonable levels
Fair price	• Fair price and structure for facility user
Easy use	• Easy use for facility user and simple and reasonable system on fare collection process
Minimized fare	• Minimized expense during fare collection process

2) Review on fare system

- BRT fare structure may be consolidated and operated with other transportation systems, like Matatus, or it may run independently. In particular, it may be consolidated with general bus service, and have a united fare structure which is easier to understand by passengers and has more advantage to transit, BRT and other transportations like linked bus, etc.
- Considering the fare structure of public transportation, there are several systems: ① equal fare system, which imposes a certain level of price regardless of driving distance, ② proportional rate on distance, which levies a fare as a proportion of passing distance, ③ traveling section system, which levies fares proportional to distance by setting a certain distance, and ④ zone system, which levies fares by predetermined number of sections.
- The following table 5-9 is about the overview and features of respective methods

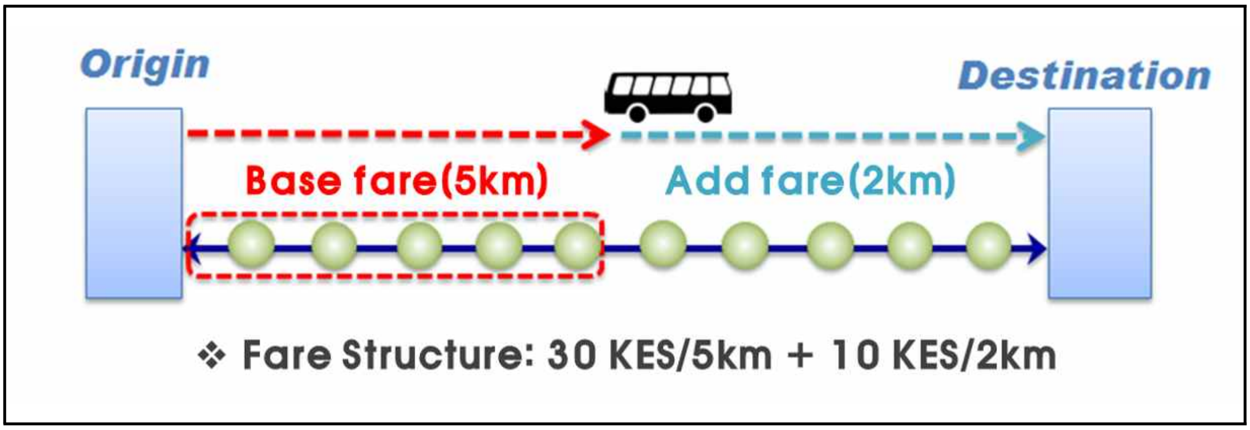
discussed. Its feature can be divided by operational convenience, economic feasibility or equal opportunity to user.

<Table 5-26> **Characteristics of fare structure on public transit**

Category	Overview	Feature
Equal fare system	- Same fare regardless of customer's travel distance - It is appropriate for short route.	- Convenient use - Save service facility and personnel expense - Unfair fare system
Proportional on distance	- Proportional fare by travel distance - For long route	- Improve equality - Many fare types make it complex for management and operation.
Moving section system	- In a certain interval unit, same fare in proportion with travel distance by setting a section. - Fare system which is close to fare system proportional to distance	- Improve equality - Many fare types make it complex for management and operation.
Section system	- All driving routes are divided into several sections and each section has its unit price. Passengers pay depending on how many sections he or she moves.	- Section is fixed and passenger easily knows fare. - Unfair fare - Hard to confirm section.

5.5.2. Method of the Fare Collection

- The basic rate for route 5-A on BRT Line 5 will be considered based on the present Matatu fare system. In order to avoid the inconvenience caused by an unfamiliar fare system, it would be reasonable to follow the current fare system of the Matatus which is close to the moving section system.
- Another alternative is to apply a proportional fare system based on distance where the basic rate is charged by a certain travel distance and additional fare is charged in proportion to a travel distance. The fare structure is rational and many advanced systems adopt it. Usage of an electronic transport card is a prerequisite. Since the PSV currently accepts cash only, it is required to amend the regulation and establish appropriate systems for applying this fare collection method.
- The total round-trip distance of route 5A is 22.3 km starting from Thika road junction to Airport North road junction. The anticipated rate for the longest distance on this route based on the Matatus fare system is 100 Kenya shillings.
- The basic rate for the BRT is 30 Kenyan shillings per 10 km and additional fare will be charged according to the travel distance (10 shillings/2km).



<Figure 5-22> The fare system of Arterial Bus

- From results of the applied fare system for the major stations on route 5-A, the basic fare, moving southbound from S1 at Thika road junction to S5 near Umoja district which has a distance of 3.3 km is 30 Kenyan shillings and the last 10th station at the end of the outering road is 60 Kenyan Shillings for 10.4km.

<Table 5-27> The fare for major stations on route 5-A for BRT Line 5

(unit: KES)

Bus Stop	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1	0	30	30	30	30	40	40	50	60	60
S2	30	0	30	30	30	30	40	50	50	60
S3	30	30	0	30	30	30	30	40	50	50
S4	30	30	30	0	30	30	30	40	40	50
S5	30	30	30	30	0	30	30	30	40	40
S6	40	30	30	30	30	0	30	30	30	30
S7	40	40	30	30	30	30	0	30	30	30
S8	50	50	40	40	30	30	30	0	30	30
S9	60	50	50	40	40	30	30	30	0	30
S10	60	60	50	50	40	30	30	30	30	0

5.6. Priority Policies of the BRT Operation

5.6.1. Permitted Vehicles

- The types of vehicles which are allowed to use the BRT lane influence the speed of the BRT vehicle, its operation etc. If many vehicles are using the BRT lane, the speed of the BRT vehicle is lowered and the time spent in driving is increased. Hence, the vehicle using the BRT lane should be determined considering the capacity of lane, speed of BRT lane, ensuring punctuality etc.
- In Bogota and Curitiba, only BRT vehicles are allowed to use the BRT lanes to improve the speed and ensure punctuality.
- Most countries allow emergency vehicles (ambulance and fire truck) to use the BRT lane. Therefore, citizens can get a positive image about the BRT
- Some other countries allow official vehicles with various applications based on the level of the vehicles
- If there is stable and smooth traffic flow on the BRT lanes (below 105 vehicles per hour: 「Transit Capacity and Quality of Service Manual (2nd Edition), TRB, 200 3」), operation of Matatus with 23 or more passenger seats which have AFC system might be temporarily allowed. For the detailed operational plan, it is advised to have in-depth discussions with Matatus Saccos, local governments and the Government of Kenya at the basic and detailed design stages.

Source: www.chinabrt.org

<Figure 5-23> Emergency vehicles on BRT lane

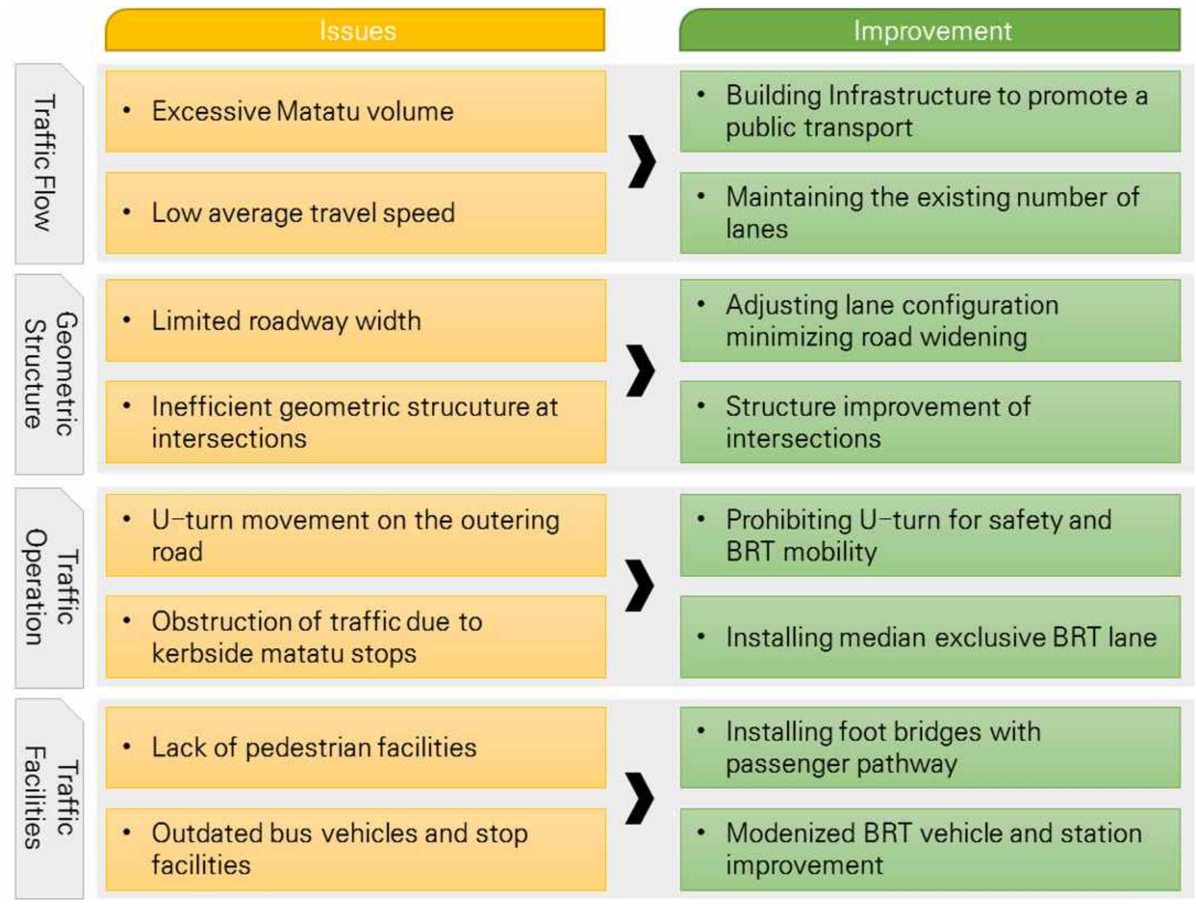
5.6.2. Initial control of the BRT exclusive lane

- In order to implement the BRT system successfully in a certain area where the system has never been introduced, a specialized control measure is imperative. Control of the exclusive lane is to confirm and remove obstacles to efficiently run the BRT system. An appropriate control should be carried out because control of cars, motorcycles, etc. except the BRT vehicles, largely affects the operation of the BRT system.
- To increase the control efficiency, various control strategies can be utilized if necessary and the strategies can be carried out by classifying the type of road, local characteristics, type of infringement, etc.
- To maximize effectiveness, long term and practical controls should be carried out and various technologies (such as, field controls and the Vehicle Enforcement System) can be used.
- In particular, control staff should be positioned in all the trial axis sections to maintain a stable BRT system. They would provide supervision and control in the initial stage of the BRT introduction.

5.7. Infrastructures of the BRT System

5.7.1. Comprehensive Direction for Infrastructure design

- Prior to developing infrastructure based on the requirements of the BRT system, the improvement direction is predetermined by reviewing problems pertaining to traffic flows, geometric structures, traffic operations and traffic facilities. As a result, design criteria are prepared to materialize the direction.



<Figure 5-24> General direction for infrastructure design

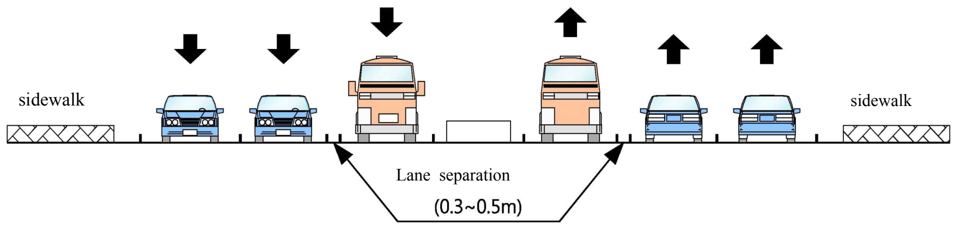
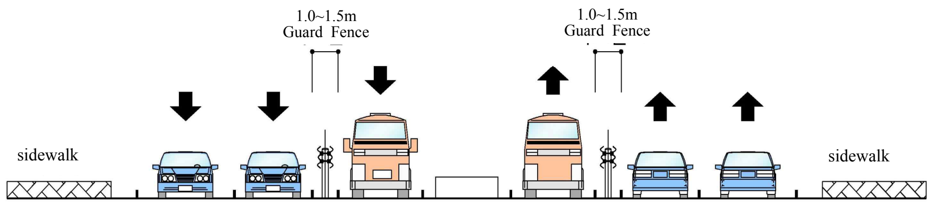
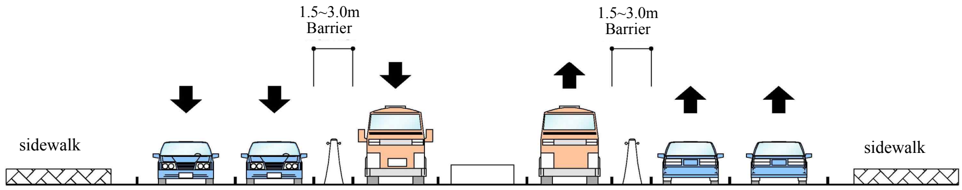
1) Design criteria on road section

- The design speed is set at 60km/h on the BRT lane and a safe width of 25~50m is selected. The chosen width of the BRT lane must be at least the value indicated in the table below which is in line with the "Design Manual for Roads and Bridges (Ministry of Roads, 2009)" and the “BRT Design Framework (NaMATA, 2017)".
- Physical lane barriers must be installed on the BRT route and the road surface should be marked to separate it from the general traffic lane.

<Table 5-28> **Standard of BRT corridor width**

Classification		Specifications
Width	BRT lane	• One-way lane: 3.5 ~ 4.0m • Two-way lane: 7.0 ~ 7.5m
	Buffer	• 0.5m ~ 1.0m
	Pedestrian refuge	• 1.0m
	Carriageway	• Mixed traffic lane : 3.0 ~ 3.5m

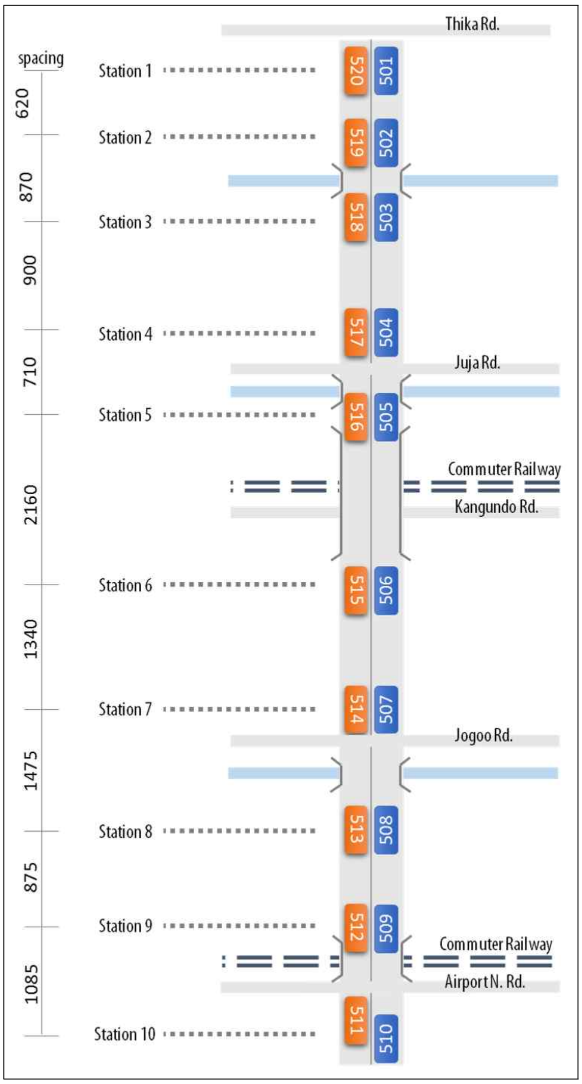
- Separating the BRT exclusive lane can done in 3 ways; separation with lane markings, installation of guard fence, and installation of barriers. Under the condition where the roadway width is restricted like the outering road and the possibility of private car drivers trying to use the BRT lane is high, installing a guard fence higher than 300mm is recommended.

Classification		Content	Recom mend
Lane separa-tion	Layout		
	Pros	•Easy to install it if the width of roadway is restricted •Effective if entering and exiting can be controlled	
	Cons	•Easy to access of mixed traffic into the exclusive BRT lane	
Install guard fence	Layout		○
	Pros	•Relatively small width required for the installation of guard fence	
	Cons	• BRT movement may be negatively affected by car crash with fence	
Install barrier	Layout		
	Pros	•Complete and physical separation between exclusive lane and general lane •Prevent the second accident between vehicles and the BRT vehicles	
	Cons	•Require wide road width due to the installation of barriers	

<Figure 5-25> **Comparison of lane separation**

2) Station design criteria

- When deciding a location of the BRT station, the followed points should be considered.
  - ✓ The location of existing bus and/or matatus stops
  - ✓ the distance between intersections and facility locations such as railway, bridge, etc.
  - ✓ Adjacent land use and pedestrian accessibility
- Generally, appropriate spacing between stations is known to 500m in order to ensure that the stations are easy to access from adjoining neighborhoods. In cases where close placement of stations is not suitable or is not necessary due to local passenger demand, wider spacing of up to 1km is acceptable.
- When it comes to estimating the width of station, the BRT design framework from NaMATA recommends at least 4.0m for median stations that serves both directions of BRT services. However, since the reserved width for the BRT ROW in the outering road is not enough to apply the standard, 3m width of station with a staggered arrangement is applied. The applied width is consists of platform, passenger refuge, divider, shelter wall, bus border transition kerb, and so on.



<Figure 5-26> Location of BRT stations

<Table 5-29> Average distance between BRT stations in overseas

case	Bogota (TransMileno)	Curitiba	Beijing	Kunming	Jakarta (TransJakarta)	Seoul
Distance	500m	540m	940m	500m	860m	750m

Source : Bus Rapid Transit Planning Guide, 2007.6

- The length of station is composed of station space, extra length (5m@2) and connection length to the pedestrian access. With Regard to the length of the bus bay, the number of bay has been determined based on the method indicated in the 『Transit Capacity and Quality of Service Manual 2nd』.

5.7.2. Run way Plan

- Route 5-A for BRT Line 5 was originally proposed to be used as the same route along the outering road proposed by the MRTS harmonization study in 2014. The original line terminates at the end of the northern outering road which intersects the Thika road and transfers to BRT Line 1 on the Mombasa road.
- Route 5-A is composed of 3 roads; mainly the Outering road, Airport north road, and Mombasa(A104) road. It should be noted that the BRT Line 5 will be operated on these roads but the detailed run way plan will be developed after analyzing the field survey results. A description of each road is discussed in the following section.

1) Outering Road

- Outering Road is an important road connecting Thika Rd(A2) and Mombasa Rd(A104) trunk roads. The road starts at the junction of GSU along Thika Road and ends at the Eastern bypass road. The road is under construction to enhance smooth traffic flow and improve traffic movement linkages with major corridors including Thika and Mombasa highway and the construction work will be done by February 2018.
- The road traverses through an intense development of industrial establishments from GSU to Mathare River Crossing, at Jogoo Road and Outering Junction up to Ngong River and after Tassia Estate.
- The total length of the road is approximately 13km, comprising of a 2 lane main carriageway and a 2 lane service road in each direction. Along the road, about 9m of the central median has been reserved for the BRT system.

<Figure 5-27> Outering road layout

2) Airport North Road

- Airport North Road which connects with south end of Outering road is located in the northern area from the Jomo Kenyatta International Airport. The length of The road is composed of a 2 lane main carriageway and another 2 lane service road in each direction. Assuming that The BRT carriageway will use the median space, an adjustment of the lane composition will be required.

<Figure 5-28> Airport N. Road layout

3) Mombasa Road (A104)

- Mombasa Road, as the main highway between Nairobi and Mombasa which is the largest port city in Kenya. It plays an important role by moving more than 50 percent of all goods traded in East African Community.
- This road is composed of a 3 lane main carriageway in each direction and the median landscape will be used as BRT carriageway.

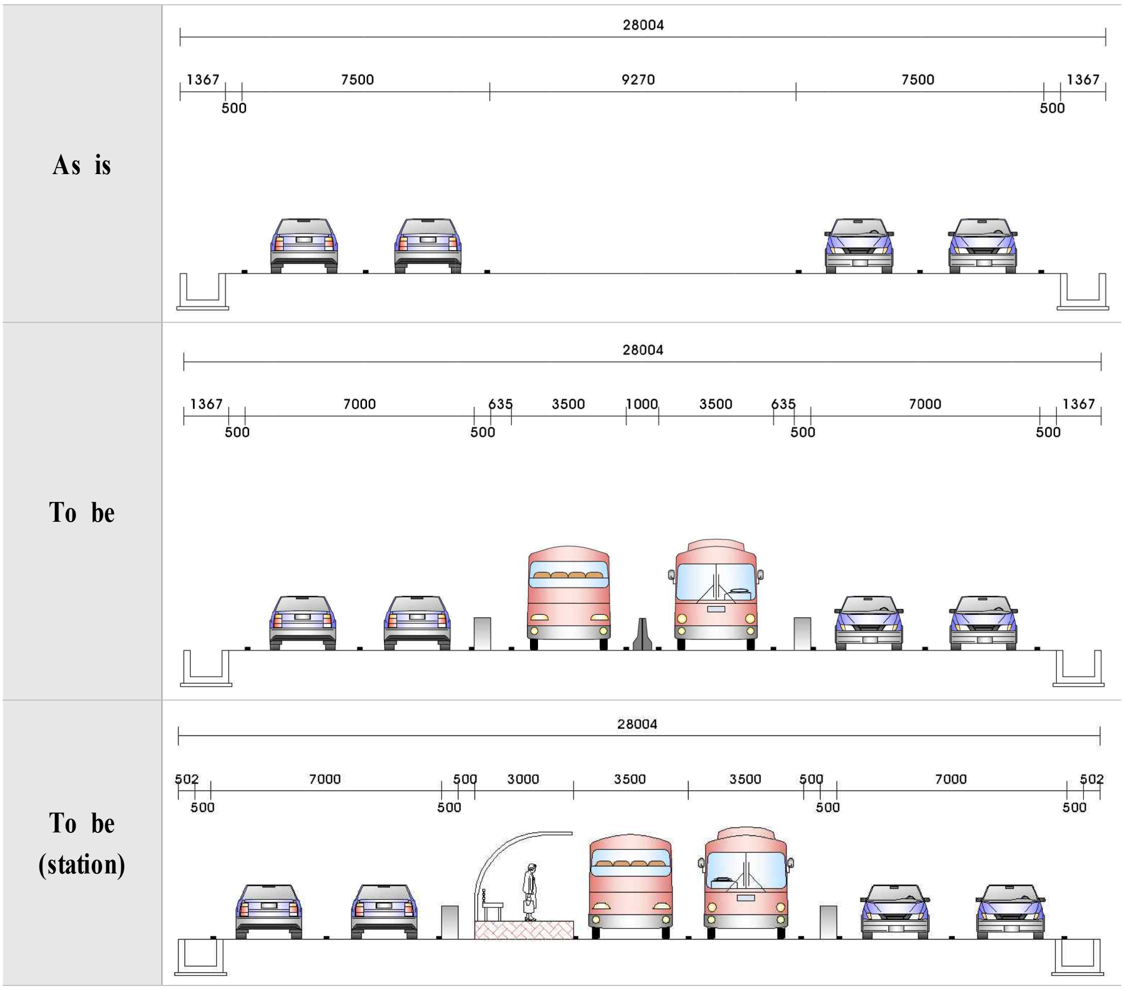
<Figure 5-29> Mombasa Road(A104) layout

- The alignment of the original BRT line 5 corridor along the outering road is shown below.

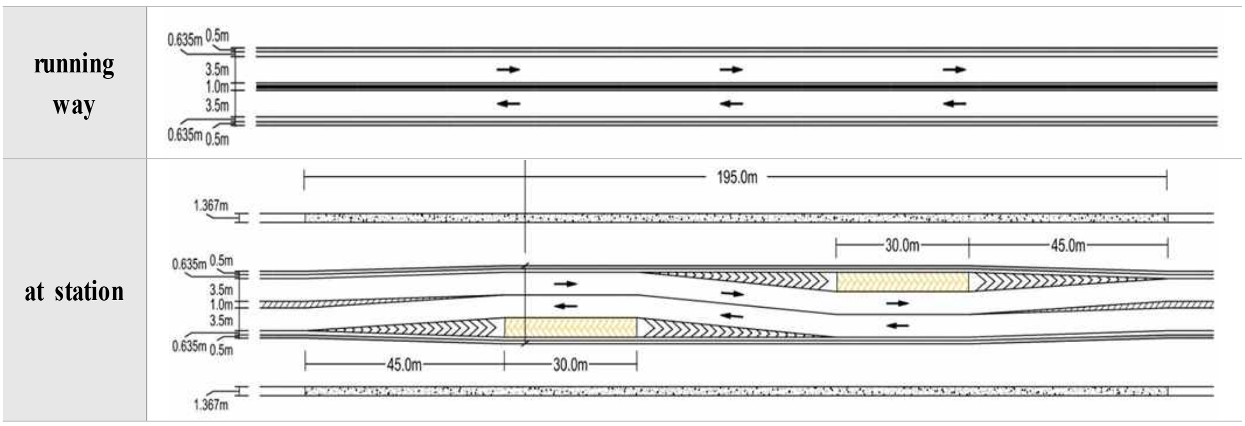
<Figure 5-30> The alignment of the entire outering road

5.7.3. Road Section Plan

- Typical cross section proposed in the study is illustrated as shown below. The width of BRT section at the station based on ground area is 9.27m consisting of one passing lane(3.5m), one bus stoppage lane(3.5m), a platform(3m), two passenger refuges (0.5m×2), and two spaces for a barrier structure(0.5m×2). The total width excluding sidewalks becomes 28m in case of two-lane carriageway for both sides. Due to limited road space, the station area will have a from of staggered arrangement.



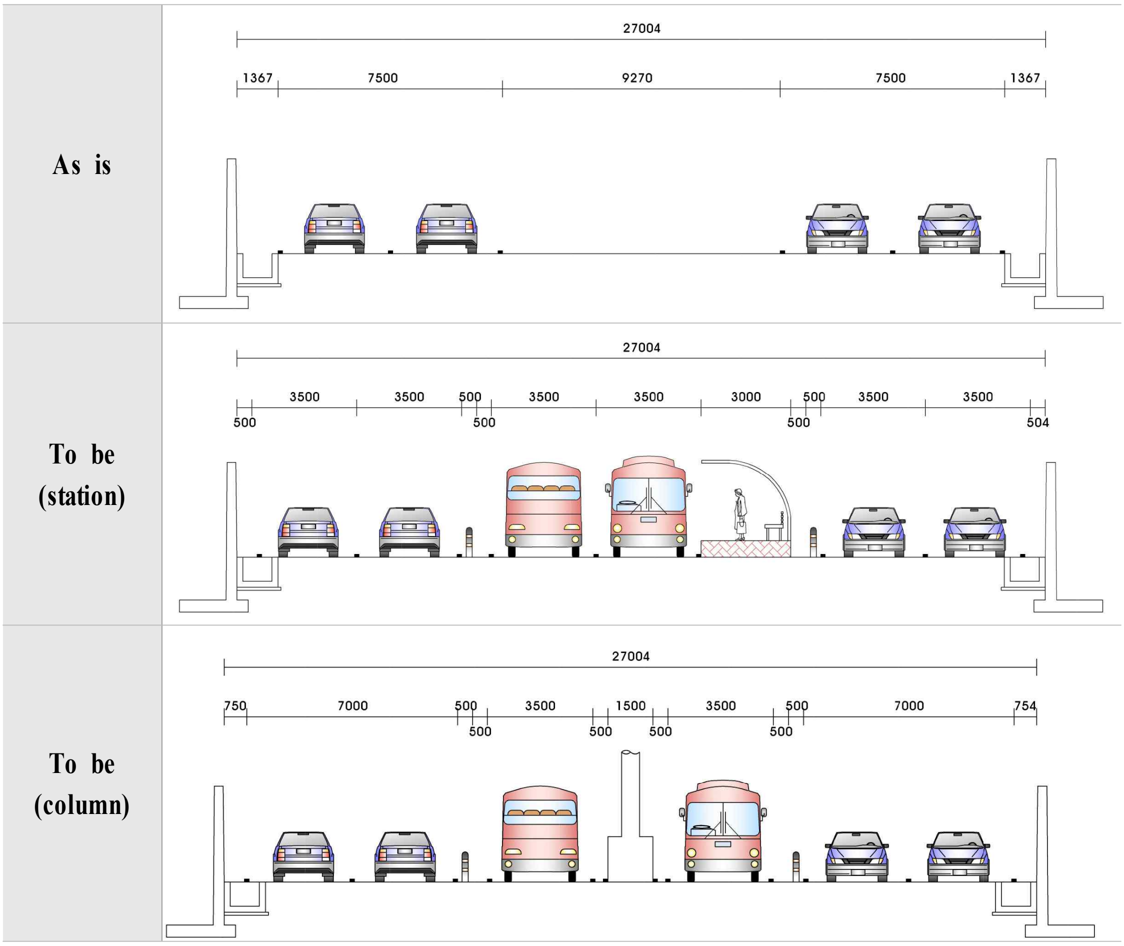
<Figure 5-31> Typical cross-section at ground area



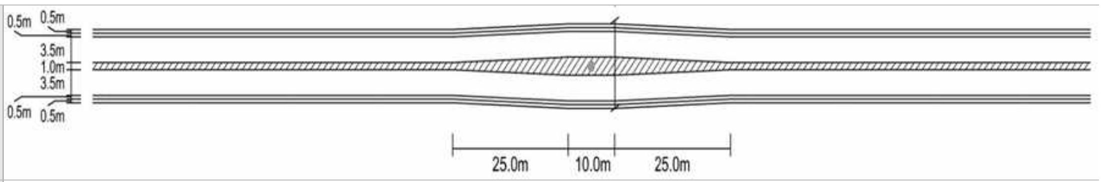
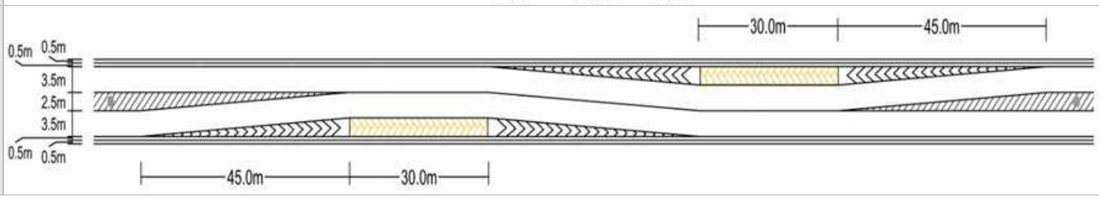
<Figure 5-32> Typical floor plan at ground area

- The allowed space for BRT carriageway on underground area is more restricted than the ground. The width of the reserved median space for BRT is 9.27m. However, it is very difficult to widen a roadway and adjust a lane configuration due to the fact that the end of the road on each side is blocked with retaining walls. Furthermore, some columns of traversed bridges interrupts BRT's movements when placed at the median space.
- Inevitably, we have planned that the existing 2 lane roadway is offset to the opened drainage section on each side of the road in order to secure a marginal site for station area.
- Along the outering road, a total of 6 columns of the traversed bridges are located in the middle of the BRT ROW. Suggestions for the layout of the cross section of the road, taking into account the columns in the median are shown in the figure below.

<Figure 5-33> Column at proposed BRT lane

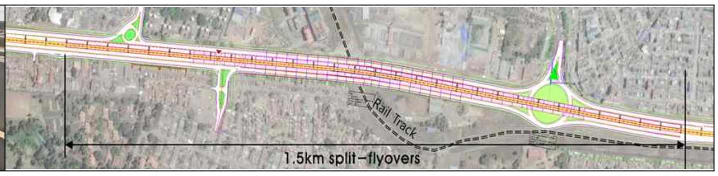


<Figure 5-34> Typical cross-section at station on underpass area

running way	
at station	

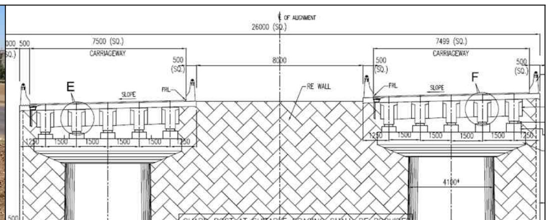
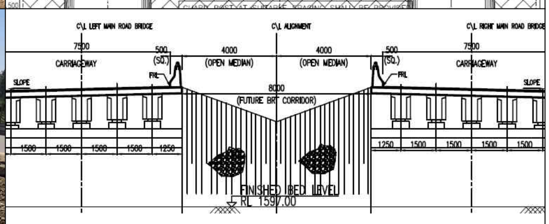
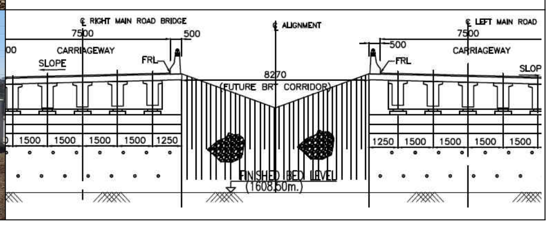
<Figure 5-35> Typical floor plan at underpass area

- Along the outering road, a total of 4 flyovers are proposed for construction. At the Kangundo bridge section, the reserved width between the split flyovers is 9.7m only and this width is not enough for installation of a station. So, there will be no station in all the areas with flyovers. The cross-section for the area with this phenomenon is shown below.

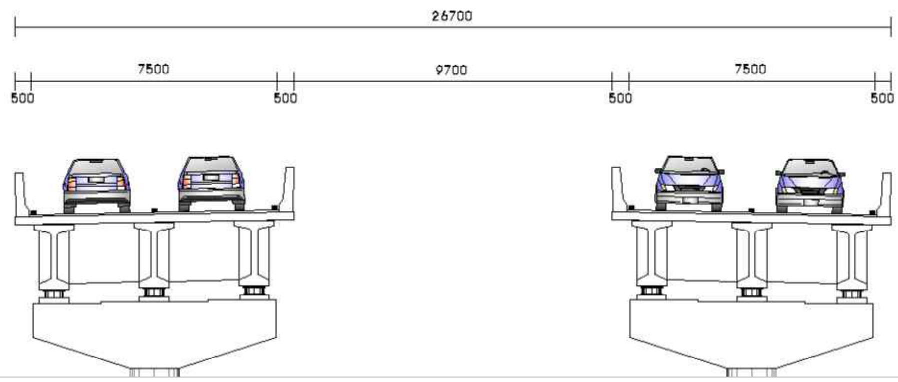
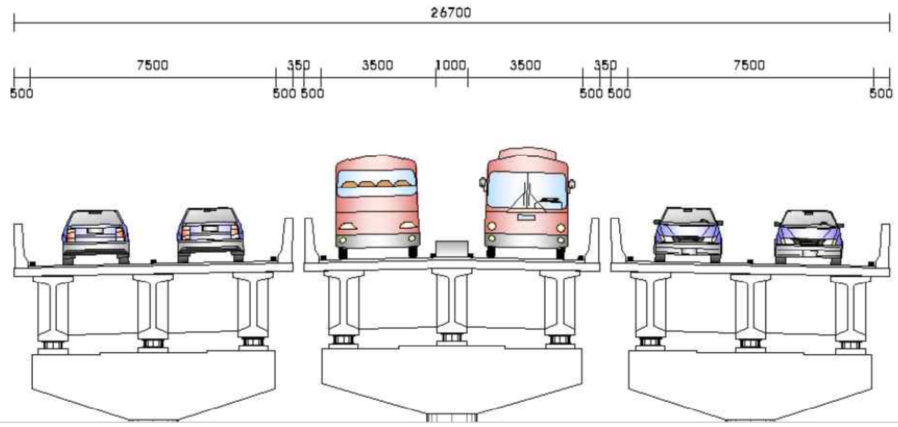
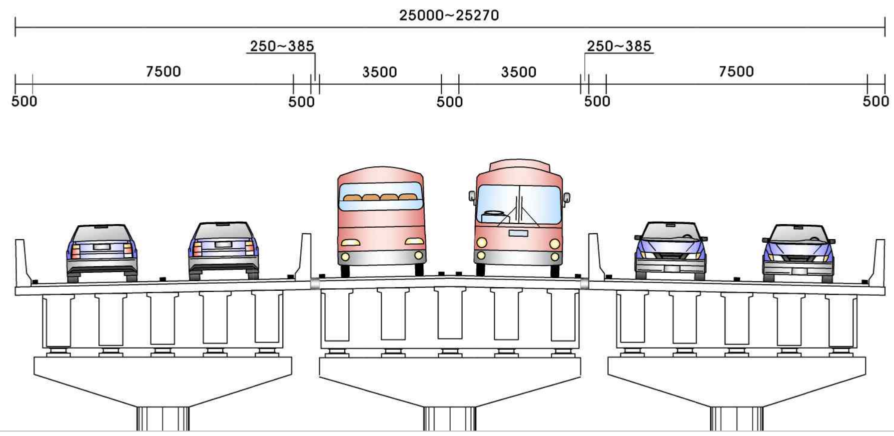


<Figure 5-36> Field investigation(left) and floor map(right) of the Kangundo bridge(sta. 4+500)

- And worse, from field investigations, it was discovered that the reserved width at the three short bridges namely Mathari, Nairobi and Ngong bridges were less than 8.27m. These sections cannot allow for a typical bridge construction but a joint-based construction can be an alternative. Their cross sections are shown below.

Mathari Br. (sta.1+500)		
Nairobi Br. (sta.3+200)		
Ungong Br. (sta.7+900)		

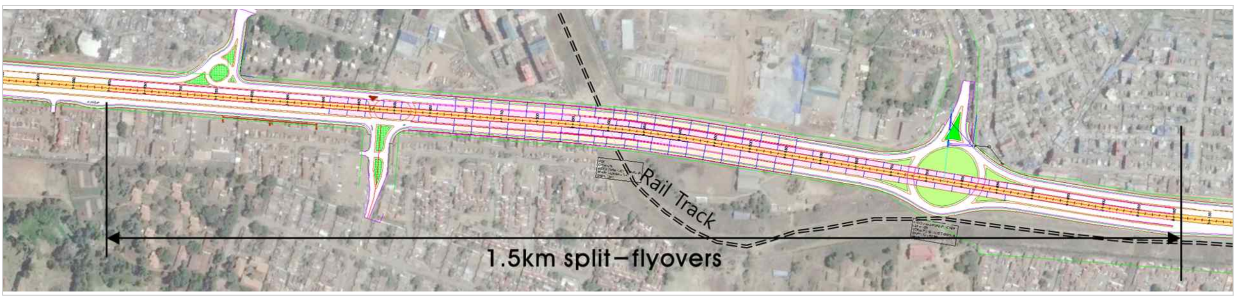
<Figure 5-37> Field investigation(left) and detailed drawings(right) of the short bridges

As is	
To be (reserved width is 9.7m)	
To be (reserved width is less than 8.27m)	

<Figure 5-38> Typical cross-section on overpass area

5.7.4. Grade Separation (Flyover)

- Since the reserved ROW for BRT Line 5 is not sufficient, we need to find a way to secure the BRT corridor in tight settings without disturbing the existing context.
- Underground or elevated BRT corridors may make sense for short segments where there is little option for connectivity. This is plausible in that BRT vehicles can negotiate slope changes within relatively short distance in comparison to other mass transit modes. However, grade separation for longer distance may lose its economic merits in comparison to other technologies.
- Grade separation is a viable option in the following circumstances:
  - ✓ Roundabouts
  - ✓ Congested/complex intersections
  - ✓ Obstacles to avoid necessarily (river, rail track, etc.)
- Closely examining the condition of our project, it can be seen that there are 4 sections where flyovers are installed on the outering road. Among them is a section where two split flyovers with more than 1.5km length are placed 9.7 meters apart from each other passing over the commuter rail track and the Kangundo road. To place a BRT corridor in this section, two kinds of alternatives can be considered.
- The first one is to place the same flyover as the existing flyovers so that the BRT vehicle can avoid conflicts with crossing roads. On the contrary, spacing with next station has to be far away and the passengers from the junction at Kangundo road should walk more to the proposed BRT station.
- The latter is that the BRT corridor is lowered to the ground after passing over the track in order to place a station near the junction on the Kangundo road. Then, the BRT corridor again rises to meet the elevation at the abutment section. Due to too much variation in the vertical alignment, the construction will be burdensome and some delays will be expected at the junction.
- After considering the geometric design and adjacent land use, it is evident that placing a flyover at this section is technically and operationally adequate.



<Figure 5-39> Ground plan at the split-flyover section

- Including the Kangundo flyover, a total of 5 bridges for the BRT line 5 will be installed along the outering road. Among them, 3 bridges will cross the river in a few spans. The bridge at the end of the outering road near Taj mall will be 350m long and will cross two service roads and a commuter railway. The specifications of the expected 5 bridges are described below in Table 5-19

<Table 5-30> Specification of the bridges

No.	Bridges	Chainage	Length of span(m)	width(m)	Lane configuration
1	**Mathari Br.**	Sta.1+500	70	8.0	• 2 BRT lanes, 1 median separator, 2 joints
2	**Nairobi Br.**	Sta.3+200	25	8.0	• 2 BRT lanes, 1 median separator, 2 joints
3	**Kangundo Br.**	Sta.3+920	950	9.0	• 2 BRT lanes, 1 median barrier, 2 crash barriers
4	**Ungong Br.**	Sta.7+900	44	8.3	• 2 BRT lane, 1 median separator, 2 joints
5	**Taj mall Br.**	Sta.9+810	375	8.4	• 2 BRT lanes, 1 median separator, 2 joints
Total length of span			1,464	-	-

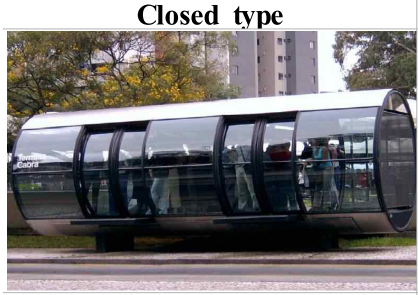
5.7.5. Earthworks

- As at the time writing, civil work for the outering road improvement scheduled to be done by December 2019 is in its finishing stage. The median space reserved for the BRT corridor has a width of 9.27m. Finishing works including covering it with turf and installation of crash barriers on each side in order to prevent illegal u-turns are still in progress. Street lights and foot bridges will be installed in the near future.
- With regards to the BRT line 5, there will be a high possibility that street lights and crash barriers will be removed or replaced due to pavement works and proper BRT operation.
- In sections where the station is proposed it will be necessary to replace an existing subassembly with a new one and the entire width of the road could be slightly expanded.

5.7.6. Station Dimensions and Configuration

1) General Overview

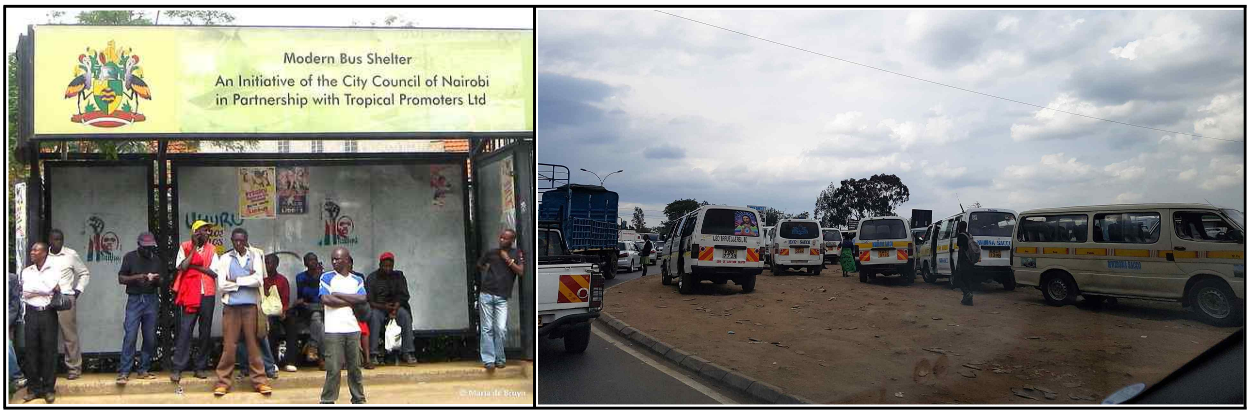
- Stations are classified into three types: open type, semi-open type and closed type.
- The open type is frequently used along streets and at bus stops. The closed type is a concept that has a close meaning to the railway station type, which is run to provide high-quality station service in some countries that run a high-end BRT system.
- If a high-level BRT service is provided, it will be reasonable to operate a closed type or semi-open type of station that makes use of a station pay-type fare collection system, but is flexible enough to run by considering user demand, quantity of stations, or limits on facility installation.
- Open type (paid by car): It is a basic form of shelter that is installed at a general bus stop. It has facilities such as a roof (which helps passengers avoid snow or rain), simple bench, and information guide or signboard.
- Semi-open type: It is a combination of the open and closed station types that utilizes features from both forms. This basic type of shelter for an open station installs a certain boundary line for the station in order to provide user safety. It can be used when the station pay system is applied to the open station type.
- Closed type (pay at station): This is a type of improved station that offers a safer and more pleasant rest area since the shelter is closed. Ticket gates are installed at shelter entrances and the pay-type fare system can be used. By installing a screen door at the bus platform, passengers can be directed to correct boarding places.

Closed type	**Semi-open type**	**Open type**
		
Historical architecture type	**Semi-open box type**	**Tube box type**
		

<Figure 5-40> Examples of BRT station facility type

2) Components of BRT Station Facility

- Most general stations in Nairobi are established as following the open type. In fact, some points where many Matatus gather has been naturally formed and used as a station by necessity, and accordingly no one can find any signs or facilities



<Figure 5-41> Current condition of stations in Nairobi

- A BRT station has to at least possess some basic factors (listed below) and provide services to passengers. For a station that has relatively high user demand, the establishment of additional factors has to be made. A facility which needs review from the system perspective (i.e. station pay type fare systems or information guide facility), should be linked with systems such as ITS etc in other areas.

▪ Basic factors:

- Shelter: Install structures with roof and simple chairs (for closed type, it is not included.)
- Portable and convenient facility for disabled people: Blind and wheelchair user's moving line should be provided. Install information guide which provides braille and voice guide. Raised spots around the station should be lowered.
- Information facility: It provides real-time bus location, which bus will arrive next at station, and the expected arrival time.
- Proper space: Within a station, minimize installation of vending machines, outdoor advertisements, unnecessary plantings etc. Planting may be done for beautification of the station only if it will not cause any inconvenience to users.
- Station design: A unique station design should be used so that corresponding BRT routes can express originality.

▪ Additional factor:

- Heating and cooling system: Installing heating facilities (fan heater, infrared rays, etc.) and cooling facilities in the closed type station can help maintain appropriate temperature throughout the year. Restroom: A restroom should be installed for people waiting for longer periods. However, this consideration is limited to cases where additional space can be acquired in the station.

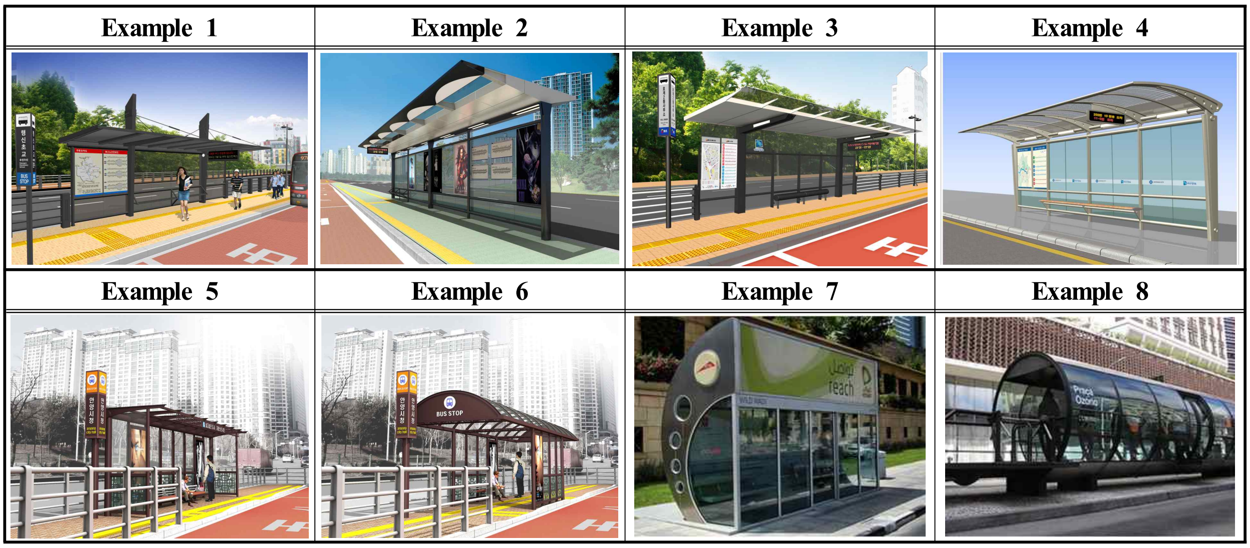
- Lighting system: For reading and preventing accidents in entering and exiting the platform, more than 200lx of bright interior light should be installed.
- Station pay fare system: By installing ticket gates at entrance, payment is received before passengers get on the bus. However, the local fare system and operating condition should be considered.

3) Review of BRT Station Facility

- BRT stations should plan to have their own image to differentiate themselves from existing bus stops. For passenger convenience and comfort, design, rain protection, etc. should be considered during installation. In addition, characteristics of BRT vehicles or the possibility to acquiring a station site should be considered in the selection process along with vehicle operation plan and local conditions.
- In this project, we devised and reviewed an alternative that selects and applies depending on demand and regional characteristics, and an alternative that applies one type to all stations as a package.
- By considering the symbolic and economic feasibility of the road constructions, a strategy which will help select and apply a station form depending on regional characteristics should be developed. When facility levels differ by direction, maintenance of uniformity should be considered for same station facilities and harmony between high and level facilities should be promoted.
- Considering the limited space reserved for the BRT ROW, it is not easy to install the closed type platform. Fortunately, since Nairobi is a city that has the benefit of good climate all year round, it is not imperative to install the closed type platform.

<Table 5-31> Alternatives for station facility

Category	Alternative 1 (Optional apply by region's characteristics)	Alternative 2 (One type will be applied as package)
Pros.	• Cost-saving by applying closed type station facility optionally • Introduction of various types of stations by living area	• Provide uniformity of BRT station as central road for public transportation • Advantageous from perspective of symbol and user convenience
Cons.	• Initial adaptation period for user is recommended. • Disadvantageous in terms of principle of equity by living area	• As closed type, its expense increases when it is used as batch.
Review	• As it is optionally adopted by region, it can simultaneously satisfy cost-saving effect and symbolic effect as central road for public transportation	• When it is used as batch closed type, it may emphasize road's symbolic and united feature but its cost increases.

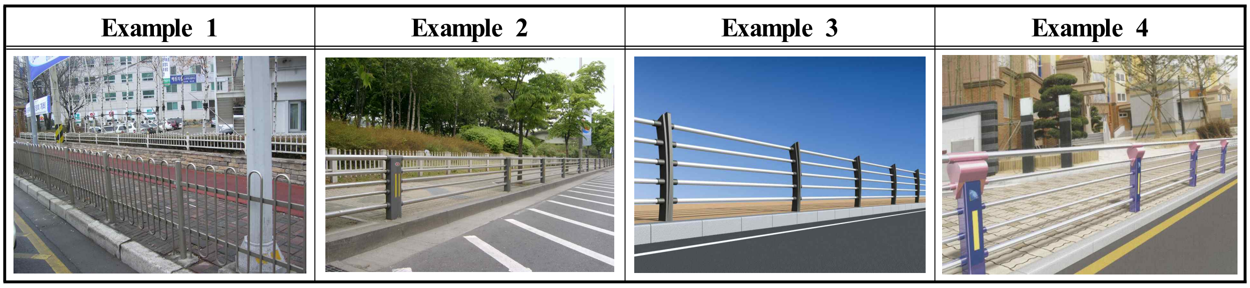


<Figure 5-42> Example of station shelter installation

- Inside the station, installation of unnecessary facilities should be minimized and the actual station size maximized to increase passenger convenience. In addition, in order to improve passenger service, characteristics of operation method should be considered. Additional facilities may be installed within the station.
- BRT station should specifically establish a protection wall for pedestrians depending on roads and conditions of traffic to protect pedestrians and discourage jaywalking.
- Installation type should be determined by tailoring basic design and implementation to regional characteristics in Nairobi. It is desirable that the installation should be within 200 meters of a platform to prevent jaywalking. Concrete installation should reflect site conditions.

<Table 5-32> Standard of pedestrian protection fence

Contents	Installing place
Where to install	• A section that prohibits pedestrian from crossing road • A section that is highly prone to possible car accidents due to jaywalking • Downtown road that has low speed of traffic
If BRT exclusive lane is used	• Near central station (including station and accelerated/ reduced speeding area) - Possible for jaywalking on 2 - 3 lane road. • If there are many jaywalkers, it should be installed. - Since buses use central lane, jaywalking will surely result in an accident.



<Figure 5-43> Example of pedestrian protective fence

5.7.7. Transfer Facilities

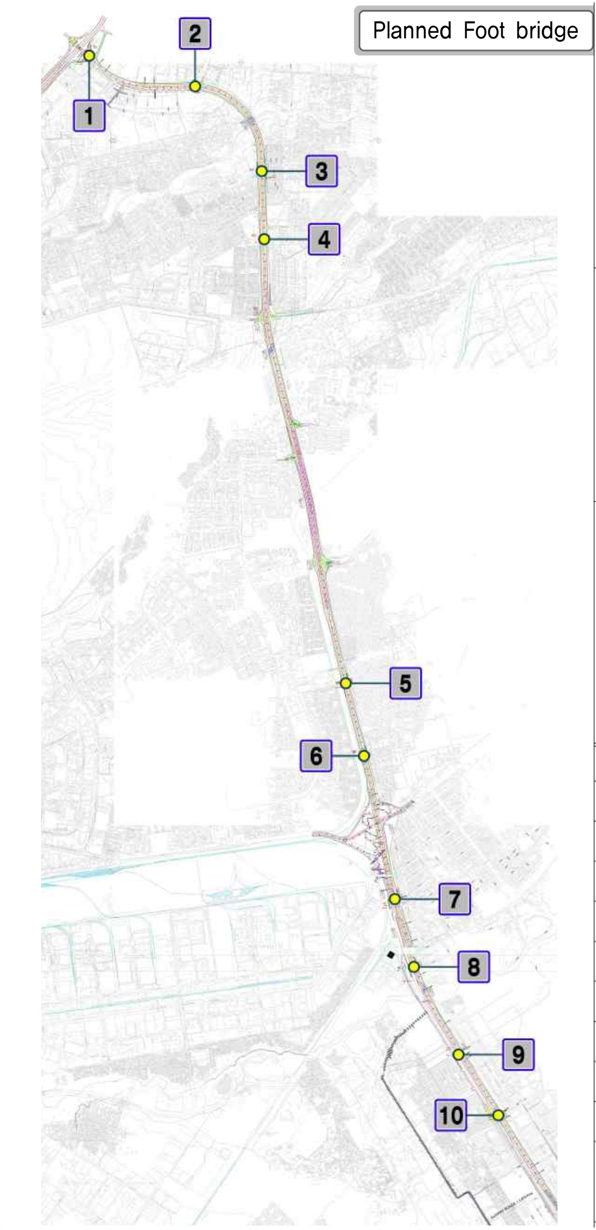
1) Basic concept

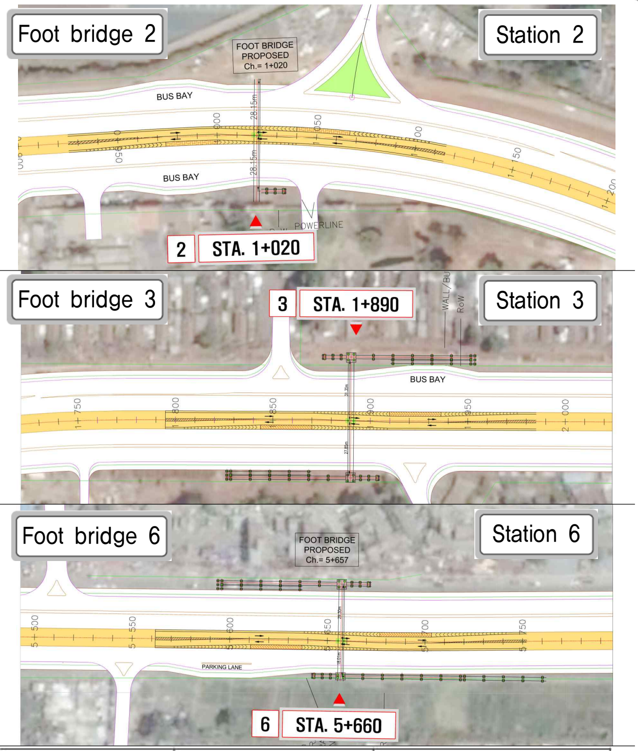
- BRT station is installed at the shortest distance, time.
- Installing sidewalk for pedestrians
- Pedestrian overpass installation
- Pedestrian protection fence(Considering the safety of the user during standby time)
- Station shelter installation(Sufficient waiting space)

2) Plan of Transfer Facilities

- Foot Bridges are planned on the Outer Ring Road.
- The foot bridge adjacent to the planned BRT station in this project are used as a transfer facility.
  - Station 2, 3, 6 : Total 3 Stations
- If the foot bridge is not adjacent to the BRT station, an additional transfer facility will be planned.
  - Station 1, 4, 5, 7, 8, 9, 10 : Total 7 Stations

<Figure 5-1> Planned Foot bridge & Plan for Transfer facilities

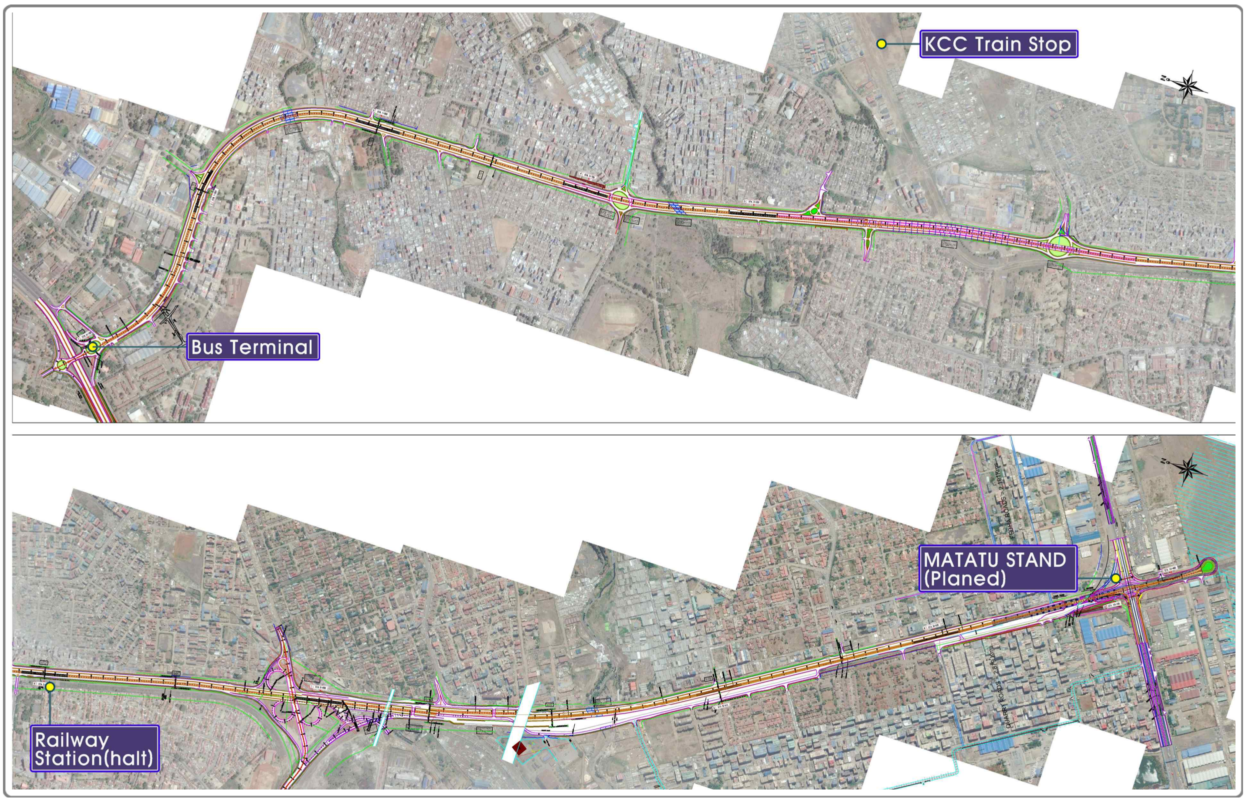




Sta. No		Location	Foot bridge
1		sta 0+400	New
2		sta 1+020	Foot bridge (Planed)
3		sta 1+890	Foot bridge (Planed)
4		sta 2+790	New
5		sta 3+500	New
6		sta 5+660	Foot bridge (Planed)
7		sta 7+000	New
8		sta 8+475	New
9		sta 9+350	New
10	N	sta 10+360	New
	S	sta 10+435	

- According to the study, three(3) foot bridges are enabled to use in this project because they have same locations with the previous plan. However, the consultant calculated construction cost of ten(10) foot bridges in this study because there still remain discussion with related agencies and whether foot bridges actually installed or not.

- Currently, there are one(1) bus terminal and two(2) train stops on the ORR route, and one(1) Matatu stand is planned to be installed.

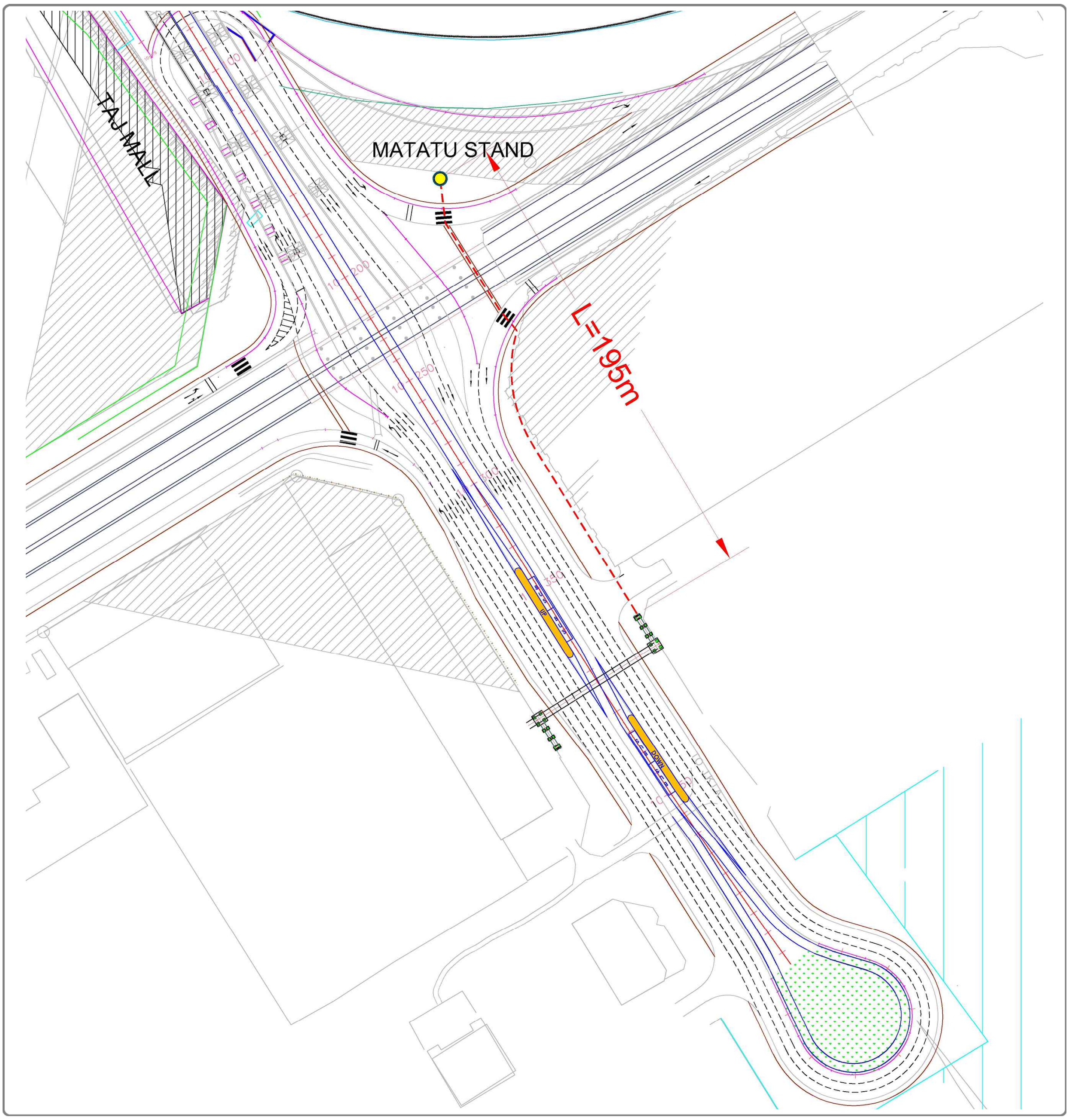


<Figure 5-44> Transferring Point for Public Transport on the ORR Route

- The KCC trains stop has excessive separation distance (more than 700m) with the ORR route, and it is limited to take into consideration any structure installation at the moment.

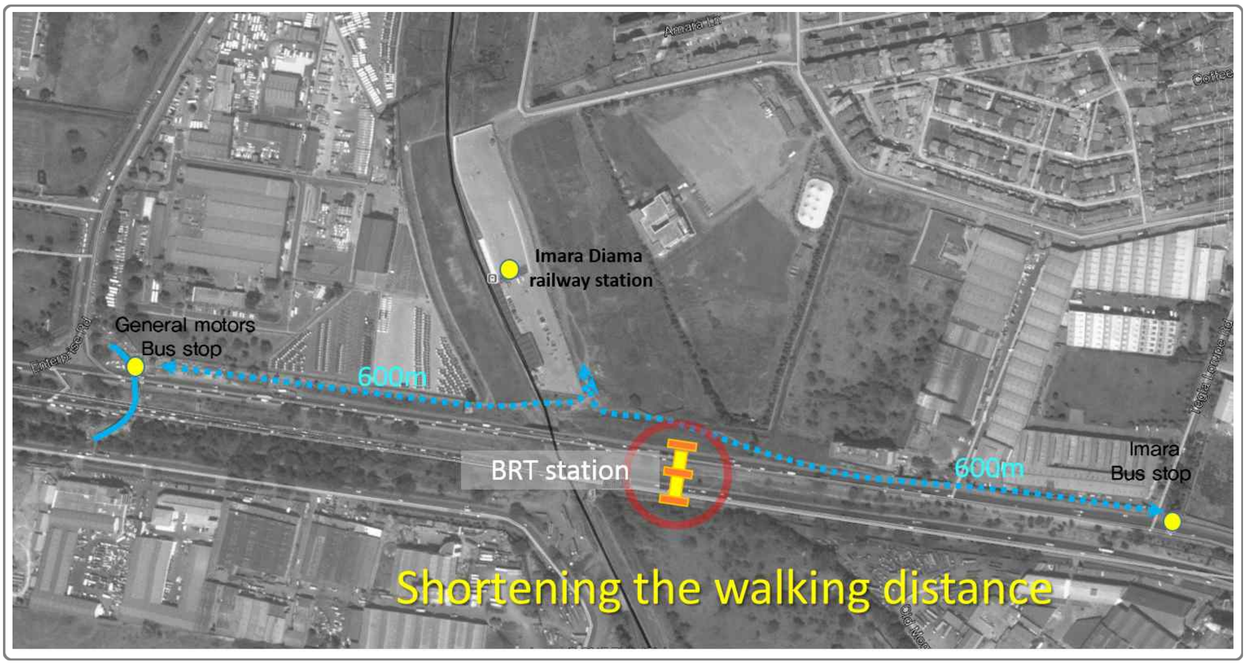
<Figure 5-45> Transferring Point for Public Transport on the ORR Route

- The bus terminal is located within 150m from the BRT station, and it enables users to transfer with both foot bridges which are previously planned and expected to be installed at BRT stops.
- The Matatu stand is located at the point of 195m which is directly accessible from the BRT station #10 by sidewalks and crosswalks. If additional transfer facilities are installed for the overpass of Airport North Road and access roads in the future, the height of the structure should be planned as a facility which enables pedestrians to walk.



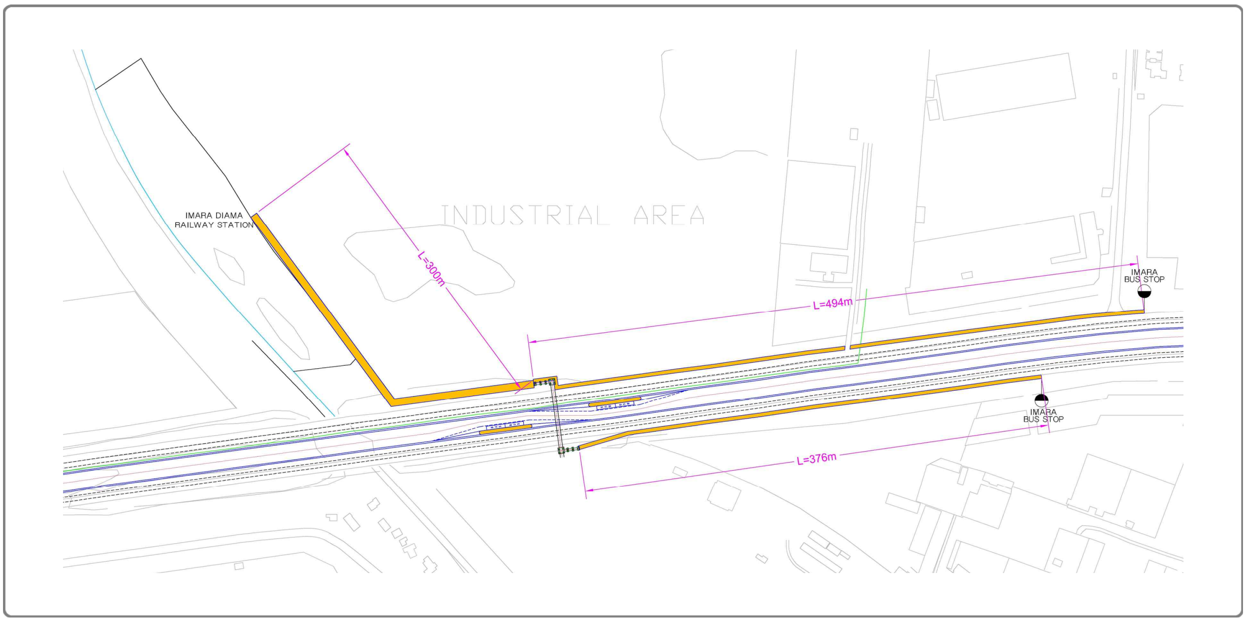
<Figure 5-46> Distance for transferring between Matatu stand and BRT station #10

- Imara Diama Railway station which are connected with BRT Line No. 1 and 5 has two bus stops(General motors and Imara) on Mombass road, and the station is 600m far from both bus stops.



<Figure 5-47> Public Transport Facilities of Imara Diama railway station

- If transfer facilities are planned for BRT system and Imara Diama Railway station, the location of BRT station should be positioned to shorten transfer time of pedestrians, and pedestrians bridges is suggested to be installed as access transport facilities as shown below.



<Figure 5-48> Example transfer Pedestrian bridge location

5.7.8. BRT Depot Plan

- A plan for BRT depot should be considered as follows: accessibility of the BRT routes, easiness to secure site, characteristic of route etc.

1) Facilities for the BRT depot

- The size of the depots will be adjusted depending on the number of buses to accomodate, integration with the other BRT lines, bus operation system(public or private), etc.
- Given the size requirements of the depots, the major consideration will be identification of available and sufficient land, and the property acquisition cost. Cost and land constraints will need to be compromised over operational efficiencies of depot sites in close proximity to the corridor, and may lead to preference for sites towards the end where land may be more easy to come by and less costly than within the city.
- The bus depot includes the general facilities to operate the 'BRT vehicles' well composing of exit and entrance of the vehicle, parking, storing, oil change, car wash, maintenance facilities, office facilities for management etc.
- An exit and entrance should be installed for the vehicles at places where line of sight distance can be secured. Traffic lines should also be maintained for easy turning of vehicles. Also, a leading lane should be secured to lead the exit and entrance of the vehicles.
- In the facilities, the BRT vehicles should move forward towards the exit and entrance with no moving backward and they should be widespread and well operated.
- Additionally, supplementary facilities such as management offices, maintenance facilities, car wash and fuel facilities should be provided.

3) Review on cases of BRT depot

- The installation of BRT depots in Korea had been reviewed in order to estimate an optimal size of a BRT depot for Nairobi.
- Size of BRT depot is estimated by considering the parking lot, administration buildings, car wash, maintenance facility, oil supply and change, green zone etc.
- The size of a parking lot was estimated to be 112.2㎡ based on the results of the review of BRT depots in Korea

<Table 5-33> Unit area of parking lot

Public Bus Depot	Total	Parking Lot	
		Area (㎡)	Number of Vehicle
Eunpyeong	49,138	33,815	310
Gangdong	32,968	27,174	244
Songpa	55,635	47,612	444
Yangchon	50,347	37,387	319
Jungnang	47,593	41,092	351
Average	**-**	**Average area/stored number of unit=112.2㎡**	

Source: Operation case of public bus depot in Seoul, Korea

- Additionally, supplementary facilities should be secured.
- The size of supplementary facilities estimated per unit area based on the case of the installation of the public bus depot in Korea.

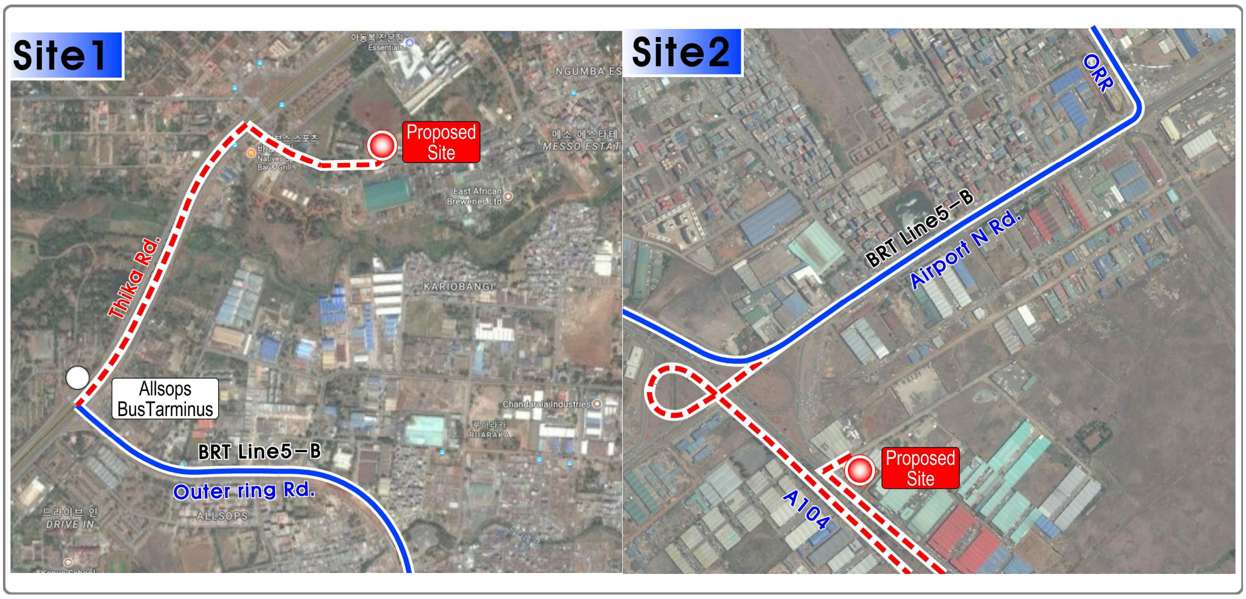
<Table 5-34> Unit area of supplementary facilities

Public Bus Depot	No. of Vehicle	Supplementary facilities				
		Total (㎡)	Office (㎡)	Maintenance (㎡(docks))	Car wash (㎡(units))	Oil facility (㎡(units))
Jungnang	351	5,512	3,284	1,298 (8)	710 (4)	220 (4)
Gangdong	244	2,658	1,839	421 (5)	222 (2)	122 (3)
Songpa	444	3,929	1,762	1,042 (4)	726 (4)	306 (7)
Yangchon	319	5,270	3,150	1,074 (3)	688 (3)	261 (4)
Eunpyeong	310	4,551	2,043	1,218 (10)	744 (4)	137 (4)
Sangam	77	1,392	947	382 (1)	63 (1)	-
Dobong	189	3,074	1,321	996 (2)	604 (2)	153 (4)
Namdong	100	517.6	249.6	120 (2)	60 (1)	38.5 (1)
Kwaneum	85	1,024.5	225	225 (2)	228 (2)	346.5 (2)
Nangwoul	180	2,263	1,780	-	366 (2)	117 (6)
Wonnae	100	327	327	-	-	-
Sindae	215	2,258	2,062	726 (5)	726 (2)	436 (6)
Average	**1**	**-**	**7.3**	**178.6 (1)**	**190.3 (1)**	**52.1 (1)**

Source: Public bus depot Operation case in Seoul, Korea

3) Candidates for BRT depot

- The depot will be the BRT's operation base. It will provide parking space, servicing and maintenance facilities for vehicles, administrative function, and facilities for staff.
- When deciding on an appropriate location for the depot site, many considerations such as nearby land use, urban development pattern, guidelines and regulations for installing related facilities, easiness of securing the site, accessibility to the corridor, easiness of vehicle turning, and so on, should be reviewed.
- An ideal location of the depot for vehicle parking and maintenance will be near the starting and/or end point of the outering road in order to facilitate rapid and cost-effective entry of the vehicles into the depot.
- On ways to developing the project, some alternative sites for the depot have been suggested from our side. One of the previous alternative sites we suggested which is located on JKIA site on Airport South road was rejected by the project executing agency, KURA, due to security issues. The replaced site which is located on A104 road near the junction with Airport North road has been selected and the adequacy as the depot site will be determined soon after a consultation with KURA.
- The following figure shows the 2 proposed site for the depot located at the start and end point of the route respectively. The first option which is located at the north of the outering road can be accessed through Thika service road and the property is privately owned by Kenya Brewery Company. The second option which is located next to A104 road on the way to the JKIA airport.



<Figure 5-49> Location of the candidates for Bus depot

4) Size of BRT depot

- The estimated BRT depot size is about 7,600㎡ of which a larger area is made up of a parking lot and the smallest area is occupied by the fuel facility. This is shown in the table.

<Table 5-35> Estimation result of facility size for the BRT depot

Arterial Bus Lines		Total	Parking lot Area (㎡)	Supplementary facilities			
				Office	Maintenance	Car wash	Oil facility
Unit area	Units	-	1 buses	1 buses	1 dock	1 unit	1 unit
	Area (㎡)	-	112.2	7.3	178.6	190.3	52.1
BRT depot	Quantity	60 buses	60 buses	60 buses	1 dock	1 unit	1 unit
	Area (㎡)	7,591	6,732.0	438.0	178.6	190.3	52.1

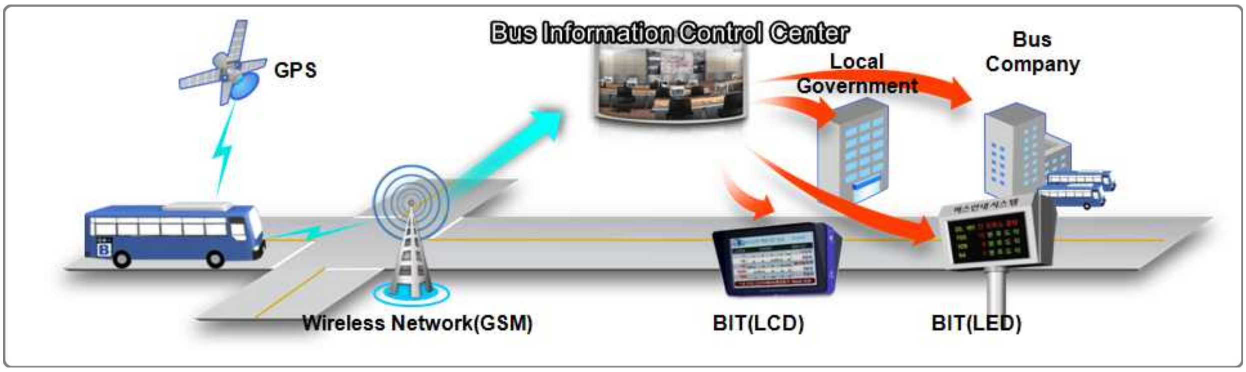
5.7.9. Intelligent Transport System (ITS)

- Bus Information System(BIS) is one that provides information on bus management and operation and relates information in real time about the running status of buses to passengers, drivers and decision-makers through various media. by doing this, it maximizes convenience for passengers, promotes bus use, and offers a more regulated bus schedule as well as systematic and efficient bus policies.

Basic direction	• In this project, only subsystems such as AFCS, ATMS, BIMS, and VES are planned - Kenya does not currently have an ITS system. It is not advisable to establish an ITS system plan for Nairobi as a whole in this project. • It is desirable to build only the core subsystems necessary for the operation of BRT Line 5 • Currently, Korea Export-Import Bank is promoting "Kenya ITS / public transportation support project" as KSP. Our Plan is to have a consistent plan in conjunction with KSP

BIMS(Bus Information & Management System)

- BIMS will enable authorities to conduct real-time monitoring of operating status of each bus and provide passengers with accurate expected arrival time of the next bus.
- Improved bus services supported by BIMS will make bus transportation more convenient and popular among passengers, resulting in increased use of bus service and traffic congestion relief.
- Criteria to select the installation site
  - ✓ Bus stops where there are passengers more than a certain number
  - ✓ Bus stops where the routes overlay more than a certain number
  - ✓ Bus stops which are adjacent to a main building such as city hall, major road, hospital and school, etc.
  - ✓ OBU (on board unit) for buses will be used in all the buses & Matatus in Nairobi
- Considerations in design of BIMS
  - ✓ Collecting accurate information of bus location
  - ✓ Increasing correctness of information through stable network
  - ✓ BIMS should have a compatibility for the future expansion or connection to the other systems.
  - ✓ Providing the passengers with not only bus information but also other social issues such as political campaign
  - ✓ Durability and visibility against any circumstance
  - ✓ Remote monitoring function over BIMS operation and easy error control



<Figure 5-50> Concept of the Bus Information Control Center

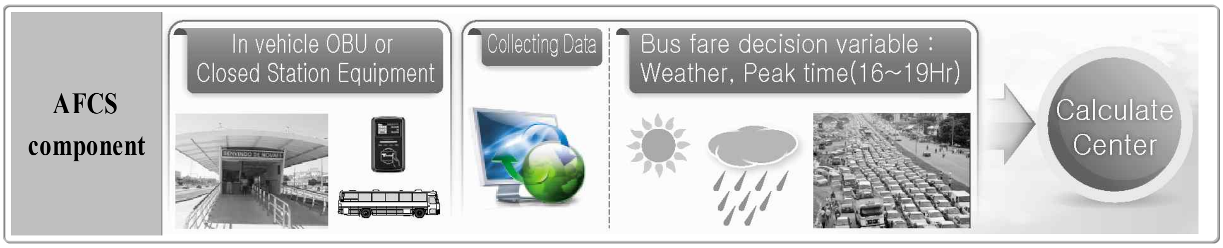
- The main functions of BIMS include bus-related information collection & management, information generation & management, information communication, supervision & adjustment of bus operation

<Table 5-36> Function of BIMS components

Category	Main Functions
Bus-related data collection & management	• Collect location and schedule data of buses and transmit it to database • Establish and maintain database of city bus operation
Information generation & management	• Monitor traffic situations in real time • Offer expected arrival time • Generate (static/dynamic) travel information • Review actual operation status against planned schedule
Information communication	• Transmit bus schedule data and expected arrival time to the Traffic Information Center • Transmit traffic condition data to the Traffic Information Distribution Center • Transmit (static/dynamic) travel information to public/personal terminals
Bus-related data collection/communication & facility management	• Automatically detect and repair malfunctions of detectors & public terminals
Bus operation data collection & management	• Establish and maintain a database of real time bus operation information • Identify information of incidents and passenger safety violations
Supervision & adjustment of bus operation	• Supervise bus operation and make necessary adjustment
Instruct city bus operation	• Order adjustment
Incidents/passenger safety data & response	• Respond to incidents or passenger safety violations
Information sharing with Traffic Information Center	• Transmit all information regarding bus operation to the Traffic Information Center, exchanging incident report data, and update database • Receive traffic and road information and transmit bus schedule data

AFCS(Automated Fare Collection System) plan

- The nature of the Outer Ring Road, which has the north-south axis trunk function, is expected to secure economical efficiency by transforming existing Matatu users into BRT customers through transit with the branch line(Matatus) in order to secure proper BRT demand.
- Automatic fare collection system (AFCS) must be established, as it is necessary to establish a transfer plan in order to secure sustainability.
- As an example of the failure of the electronic payment system in Kenya in the past (Bebapay in 2013), a flexible fare system that reflects differentiated rates by weather and time frame is also considered as an alternative.



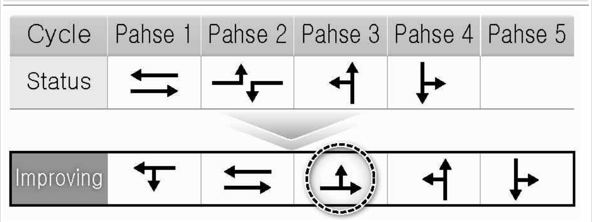
ATMS(Advanced Traffic Management System - BRT Priority signal system)

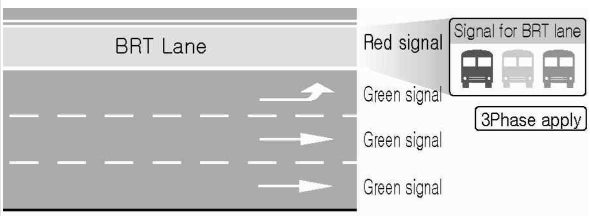
- The ATMS is a signaling system applied to smoothen traffic processing of BRT vehicles at intersections, applying a step-by-step signaling system (reviewing the application of priority signals in the short term and in the mid to long term).
- BRT Priority Signal System Applicable intersections : Six priority intersections at Airport North Rd, Fedha Rd, Donholm Rd, Manyanna Rd, Kangundo Rd, Juja Rd etc.

BRT Bus-only signal

- Separate signaling system between BRT bus and general vehicle in case of left turn of general vehicle on intersection to alleviate congestion of BRT buses.

Dedicated Signal Strategy

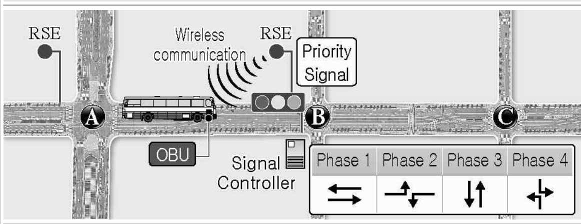




BRT Bus priority signal

- A method of preferentially assigning the signal of the bus to the traffic light to pass the BRT bus in order to minimize the delay at the intersection.

Priority Signal Strategy



- Green Time Extension: Extends 1-phase signal time when bus arrives with phase 1 in progress
- Early signal on: When the BRT bus is detected while phase 2, 3, 4 signal is in progress, the signal is terminated early and phase1 is set to light early.

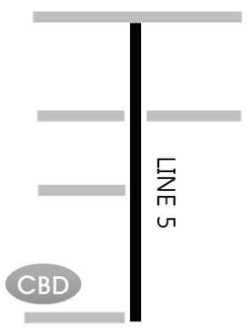
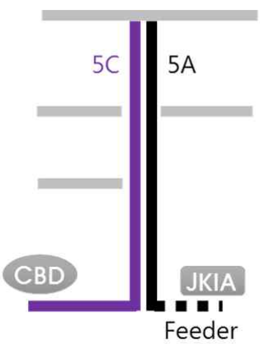
5.8. Scenarios of BRT Implementation

- A systematic implementation strategy is needed for a BRT project to be successfully established. Although there are many factors to consider in establishing the implementation strategy, the BRT route, the running way, the BRT network, the fare structure, the operation and the infrastructure are considered as important items in this project.

5.8.1. BRT Route Scenario for short term

- There are relatively high density residential complexes around the ORR and neighborhood facilities on the roads, so BRT transportation demand will not be low. However, considering that the traffic pattern of Nairobi residents is concentrated in the CBD, it is doubtful whether the BRR routes of the ORR, which serve only the suburbs, can secure enough transportation demand for justifying their feasibility.
- In order to overcome the limitations of these outer routes, various BRT routes are required to be excavated. Therefore, three scenarios that can be implemented in the short term are analyzed as follows.

<Table 5-37> Scenarios of BRT routes

Item	Scenario 1	Scenario 2	Scenario 3
Schematic Diagram			
Route	·Only Route 5A	·Route 5A+5C+Feeder	·Route 5A+5B+5C
Pros	·Convenient operation by single route ·Maintain short headway ·Required minimum BRT fleets ·Required minimum depot	·Reduced travel time and increased passenger demand with direct connection to CBD ·JKIA service available via feeder line	·Reduced travel time and increased passenger demand with direct connection to CBD and JKIA ·No transfer to other routes
Cons	·Decrease in demand due to unconnected CBD ·Increase of transfer time with other routes	·Expansion of dispatch interval by route ·Increase BRT fleet number ·Increase BRT depot area	·Expansion of dispatch interval by route ·Increase BRT fleet number ·Increase BRT depot area
Reviewed result	·Even though JKIA passenger should be transferred to feeder, but it is desirable to execute Scenario 2 which maximizes passenger demand because it is possible to connect to CBD without transfer to other line.		

5.8.2. BRT Run way Scenario

- An exclusive BRT lane must be installed to ensure punctuality and free mobility of the BRT buses. A few run way scenarios should be considered even though it might be an unnecessary process since the ROW for the BRT run way is already secured in the median of the ORR.

<Table 5-38> Scenarios of BRT run way

Item	Scenario 1	Scenario 2
Type		
Location	Median lane	Curb lane
Pros	• No conflict with other vehicles • BRT bus punctuality and mobility are secured by preventing other vehicles from encroaching the exclusive lane	• Good accessibility of passengers • No need for an island platform at BRT station • In the case of bridges, it could be designated as a mixed section without expanding it to reduce the project cost
Cons	• Need to install a foot bridge for pedestrian access • Additional platform space required • In the case of the platform installation section, there is no room for the reserved ROW • No space for installing a platform in a long bridge section	• Conflicts with parking and turning vehicles • Additional civil works for installing roadside facilities will be needed • BRT bus punctuality and mobility are not secured due to encroachment by other vehicles
Reviewed result	• Scenario 1 will be desired in order to secure the mobility and punctuality of the BRT because the ROW of the BRT is already secured at the center of ORR	

5.8.3. BRT Network Scenario

- In addition to the BRT Route plan, an important factor to consider is to decide whether to operate the BRT lane as a closed or open system.
- An open network system does not require subsidies from the PEA and NCCG. However, in order for BRT to be recognized as a new, advanced and fancy public transport for Nairobi citizens, it is necessary to adopt a closed system.

<Table 5-39> Scenarios of BRT Network System

Scenario	Scenario 1	Scenario 2
Type	• Closed Network	• Open Network
Pros	• Position BRT as a new and fancy public transport • Maintain a proper LOS of BRT network service	• PEA only provide BRT Network and leave the BRT infrastructure operation to the private sector
Cons	• If BRT operation frequency is low, matatu operators will demand for BRT infra usage	• Impossible to maintain a proper LOS for BRT network service due to many PSVs
Reviewed result	• Scenario 1 will be desired in order to secure the proper LOS, mobility and punctuality of BRT service	

- On the other hand, when operating an open BRT network system, it is generally not advisable to operate BRT fleet. But most cities that operate BRT fleet have adopted the closed system.
- By default, most BRT systems have their own fleets and brands. Even though all PEAs still do not have a clear plan for operating the Nairobi's BRT, all BRTs to be operated in Nairobi in the future should be unified with the same brand and the same fleet in the long run.

5.8.4. BRT Fare Scenario

- As described above, it is reasonable to apply the distance-based system to the BRT fare structure. However, matatu operators set their fares differently depending on peak and off-peak seasons. It is necessary to consider whether the BRT might be applicable to the add-on fare system based on demand / supply principles, as used in the matatus's fare system.

<Table 5-40> Scenarios of BRT Fare structure

Item	Scenario 1	Scenario 2
Type	• distance-based	• distance-based + peak time fare
Pros	• Simple fare structure • Secure the public nature	• Maximize the profit by the demand-response • Similar fare structure with matatus
Cons	• Different fare structure with matatus • Constrained to profit maximization	• Undermined the BRT's public nature • No clue about setting peak time • Increase civil complaints due to additional fare
Reviewed result	• Scenario 1 will be desired in order to secure public demand for the BRT, reducing the burden on citizens' when it comes to high fares, and preventing confusion due to complex fare structures	

- Transfer discount by using AFC is essential to maximize BRT's passenger demand. Although the organization operating the BRT has not been decided yet, it is expected that Nairobi's BRT will be run by one institution, so the transfer discount between BRT routes will be implemented naturally.
- However, transfer discounts with matatus are expected to be challenging. First of all, it is important to make matatus use a feeder BRT line rather than a competitive route, but it is expected that it will not be easy to obtain consent because there are many stake-holders involved. Even if it is agreed to use the feeder line, installing an AFC on matatus will also require a lot of review.
- Transfer discount has the advantage of increasing public transport share and reducing the fare burden on citizens, while the operators have the disadvantage of decreasing the fare revenue. In order to overcome these problems, most developed countries have implemented a policy which will reduce the financial burden of PSV operators by subsidizing the money lost to the transfer discounts.

<Table 5-41> Scenarios of Fare Discount for Transfer

Item	Scenario 1	Scenario 2
Type	• Discount-fare for transfer	• No discount-fare for transfer
Pros	• Reduce the fare burden on citizens • Increase public transport market share	• Install AFC on only BRT fleet • No subsidies for PSV
Cons	• Install AFC on all PSV • Provide subsidies to PSV for discounted fare	• Increase the fare burden on citizens • Difficult to secure the economic feasibility due to insufficient passenger demand
Reviewed result	• Transfer discounts are absolutely necessary for the ultimate goal of installing and operating the BRT to promote public transport usage • In short-term, install AFC system on BRT and feeder line for the transfer discount • In the mid to long term, AFC is installed in all PSVs to establish a complete transfer system	

5.8.5. BRT Infrastructure Scenario

- The BRT infrastructure has a very high proportion of the total cost of the project, which is a factor affecting the economic feasibility of the project.
- First is the flyover plan which is the most expensive in terms of cost. The ORR has two long flyovers and two short flyovers. In the short section, we recommend that the exclusive BRT flyover should be the same height as the existing two flyovers.
- However, in the case of the long flyovers, if the BRT bridge is constructed to have the same length as the existing bridge, there will be a disadvantage in terms of accessibility for BRT users. On the other hand, when the bridge is divided into two such that we have two small bridges so that the BRT bus can connect other PSVs of the cross road, the end slope of the bridges becomes poor and it is difficult to treat the intersection crossing.

<Table 5-42> Scenarios of BRT flyover

Item	Scenario 1	Scenario 2
Type	• similar bridge with exiting ORR bridge	• divide into two small bridges
Pros	• Easy civil work and reduced construction cost • Good mobility and punctuality thanks to the separation from the road crossing	• Passenger convenience by securing proper spacing of the BRT stations • Direct connection with BRT 3 and BRT 4
Cons	• Poor accessibility due to long spacing of the BRT station • Direct connection with BRT 3 and BRT 4 is not possible	• Difficult civil work and increased construction cost • Poor mobility and punctuality due to level crossing with roads
Reviewed result	• Although direct connection with BRT 3 and 4 is impossible and long BRT station causes poor accessibility, scenario 1 is desirable in that a construction is relatively easy and more reliable BRT service can be provided	

- The second is the platform installation plan. The types of BRT platforms vary, but can mainly be divided into open and closed.
- As described above, an open platform is more advantageous than the closed type since the maximum ROW of the BRT platform on the ORR is only 3.0m. Fortunately, Nairobi's climate is one of the best in the world and hence there is little inconvenience to the user even if the open type is installed.

<Table 5-43> Scenarios of BRT Station

Item	Scenario 1	Scenario 2
Type	• open type	• closed type
Pros	• Reduced construction cost and easy construction • Flexible installation is possible at narrow space • Maintenance cost can be decreased thanks to renting billboard space	• Positive urban landscape by classy design • Perfectly keeping out rain in bad weather • Taking advantage of security issues
Cons	• Relatively poor exterior design • Insufficient protection from rain by shelter only • Vulnerable to security and equipment demage	• High construction cost • Many restrictions on installation at narrow space • High maintenance cost
Reviewed result	• Although it has a disadvantage of urban landscape and passengers' convenience, scenario 1 is more desirable considering the good climate of Nairobi and the possibility of installing in narrow spaces	

- The third is a VES(Vehicle Enforcement System) plan for vehicles encroaching into the BRT lane. When the BRT is first installed, many unauthorized vehicles will invade the BRT lanes until the citizens' compliance spirit is matured. If a vehicle that encroaches into a BRT lane is left unattended, the BRT system may become obsolete, necessitating strong interception at the beginning.
- The enforcement types can be divided into the way of installing and operating a VES as an ITS subsystem or controlling by the policeman. In the former case, installation and operation of the VES is not difficult and hence would be easy to install in Nairobi. However, it will be difficult to punish the offenders until vehicle registration and electronic fine ticketing systems are introduced.
- It is better to check encroaching vehicles by using the policeman in the case of BRT line 5 in the short term period until vehicle registration and electronic fine ticketing systems are established.

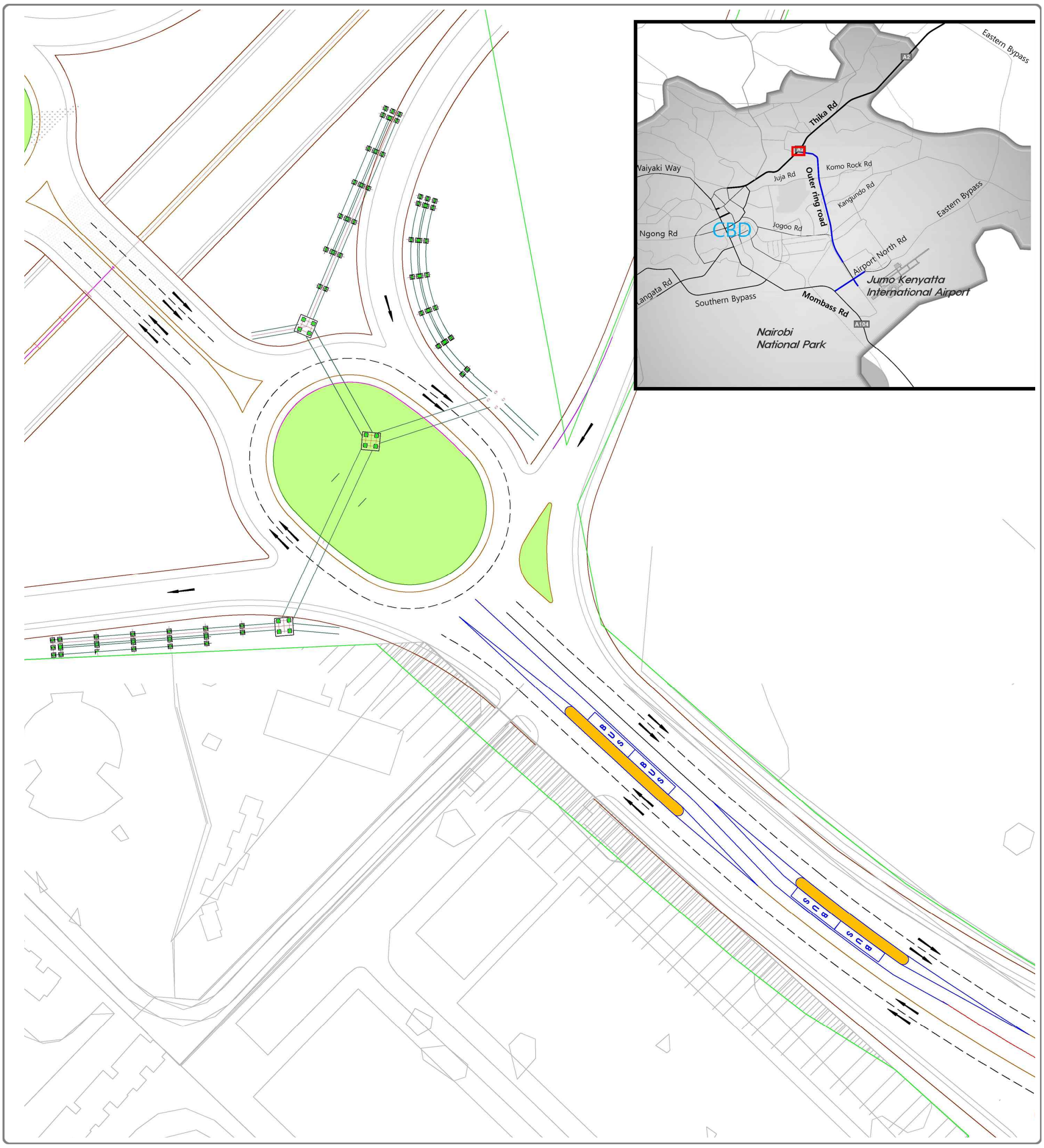
<Table 5-44> Scenarios of Enforcement System

Item	Scenario 1	Scenario 2
Type	• Policeman	• VES(Vehicle Enforcement System)
Pros	• Immediate enforcement • Strong enforcement	• Constant enforcement • No room for corruption
Cons	• Permanent enforcement is impossible • Corruption might be a problem	• Since there's no electronic vehicle registration and electronic fine ticketing system, immediate usage is impossible
Reviewed result	• In a short term, manual enforcement system by policeman will be appropriate. • In case of establishing electronic vehicle registration system and electronic fine ticketing system, Vehicle Enforcement System can be used.	

5.8.6. Additional Improvement for BRT on Intersection

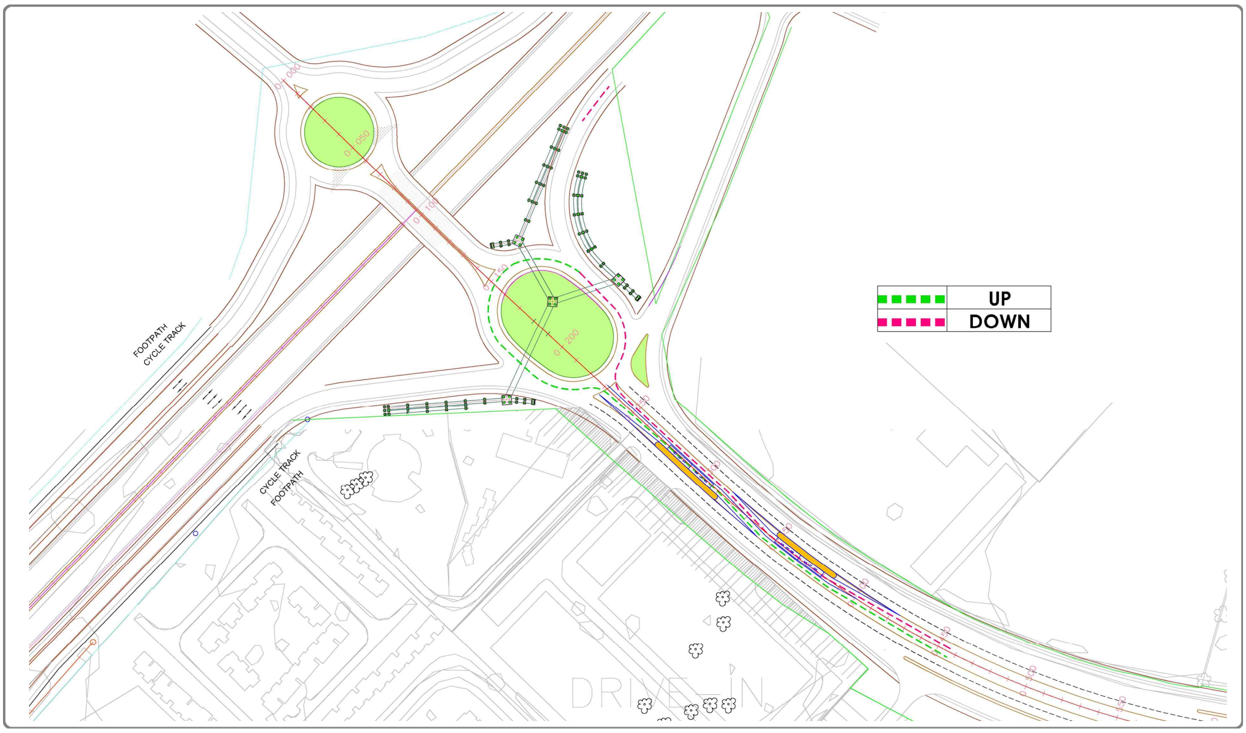
▌Intersections at starting and ending points

- For the intersection on the starting point of ORR route, entry and exit lanes of the BRT station are clearly separated for approaching system of roundabouts.



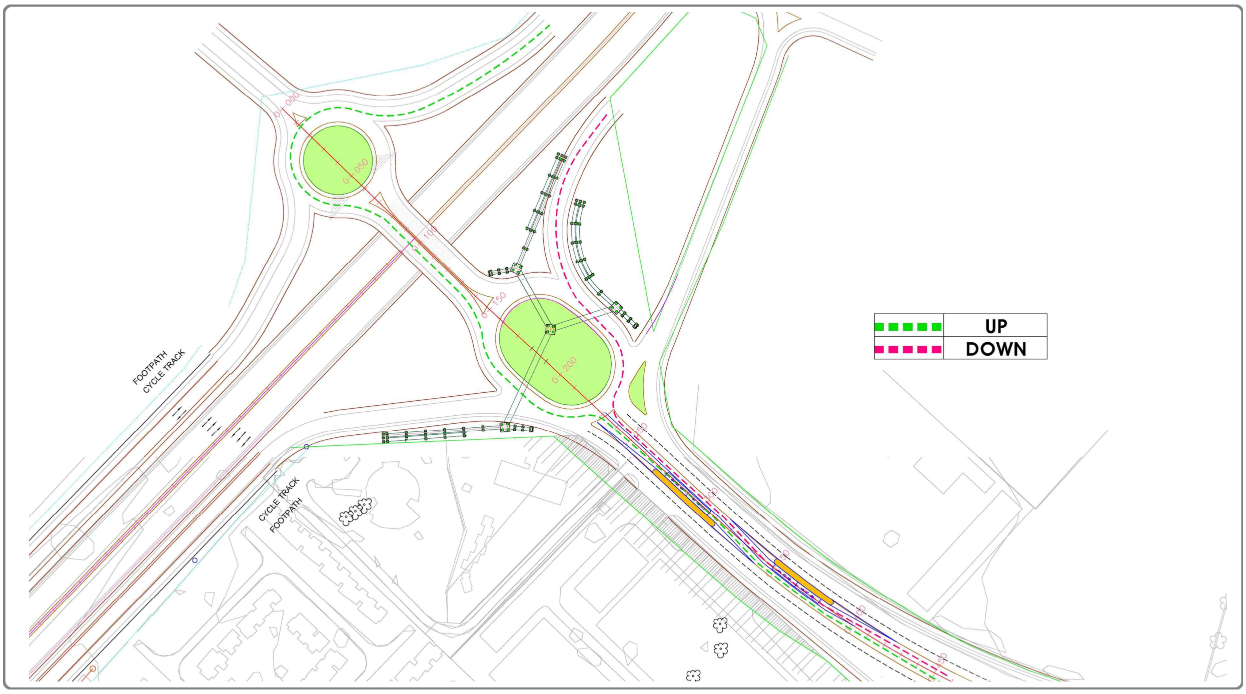
<Figure 5-51> Traffic Improvement Plan for the Starting point of ORR route

- If only ORR route is operated, its traffic flow pattern is shown below.



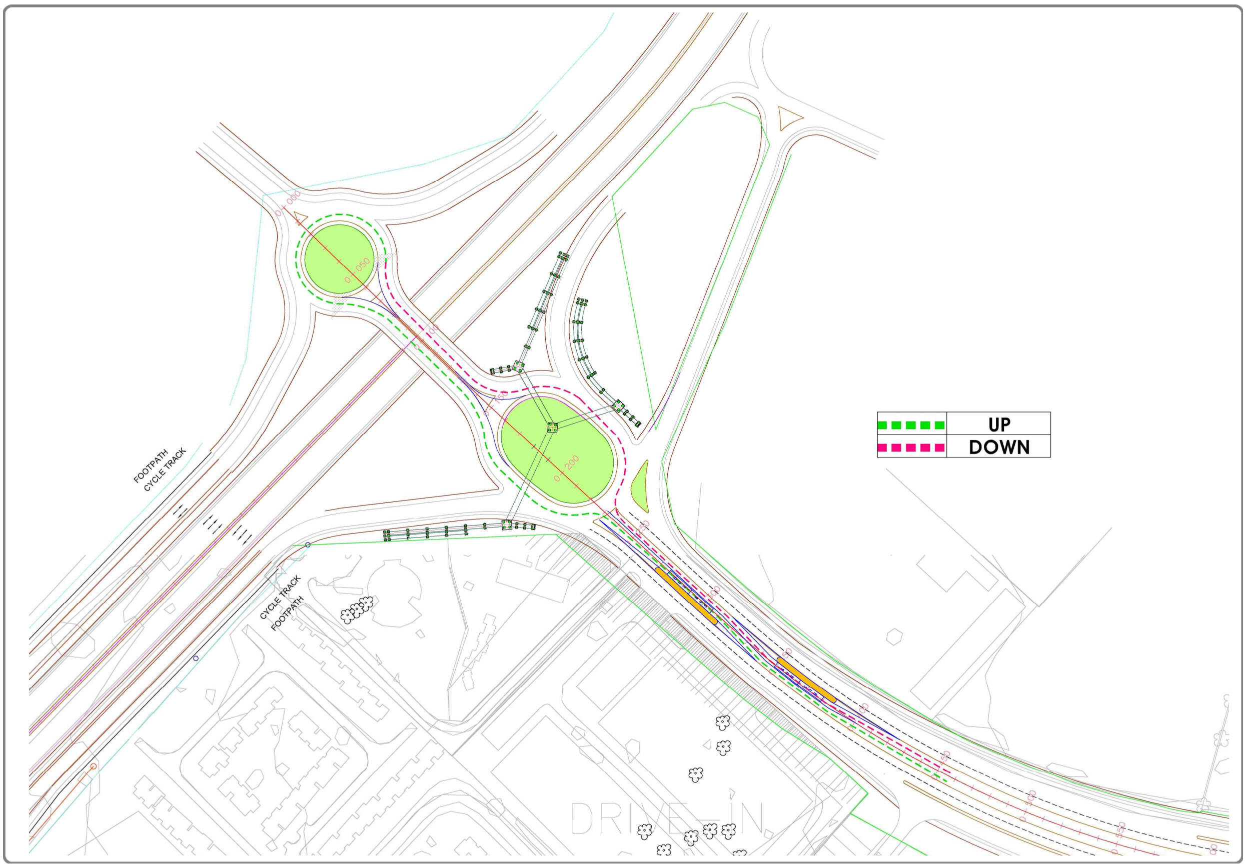
<Figure 5-52> ALT.1 of Traffic Flow Pattern on the Starting point of ORR

- If the Depot of BRT line No.5 are located on the side of Thika road, traffic flow pattern are shown below



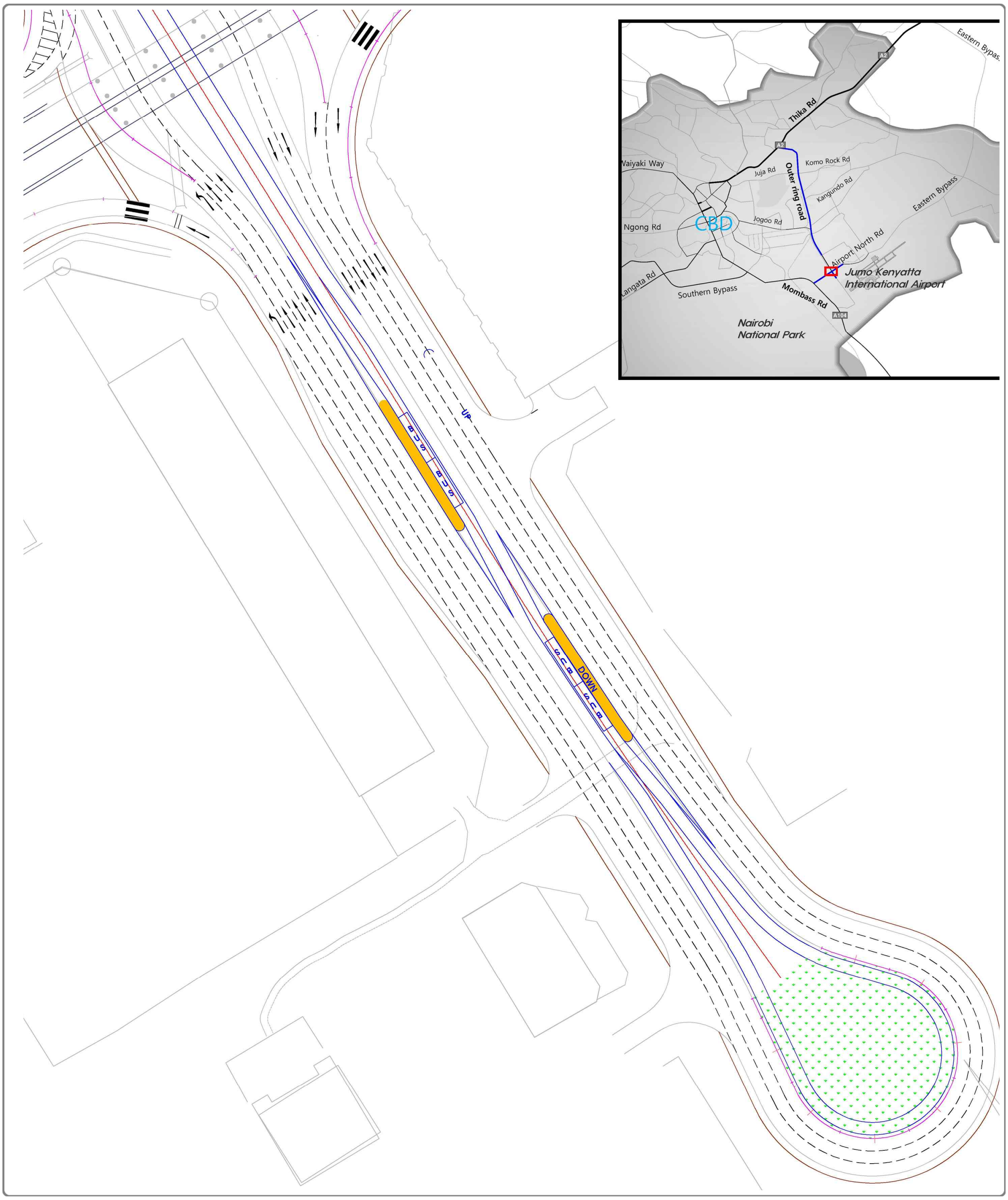
<Figure 5-53> ALT.2 of Traffic Flow Pattern on the Starting point of ORR

- In order to improve efficiency of two roundabouts next to each other, the following traffic flow pattern is suggested as shown below.



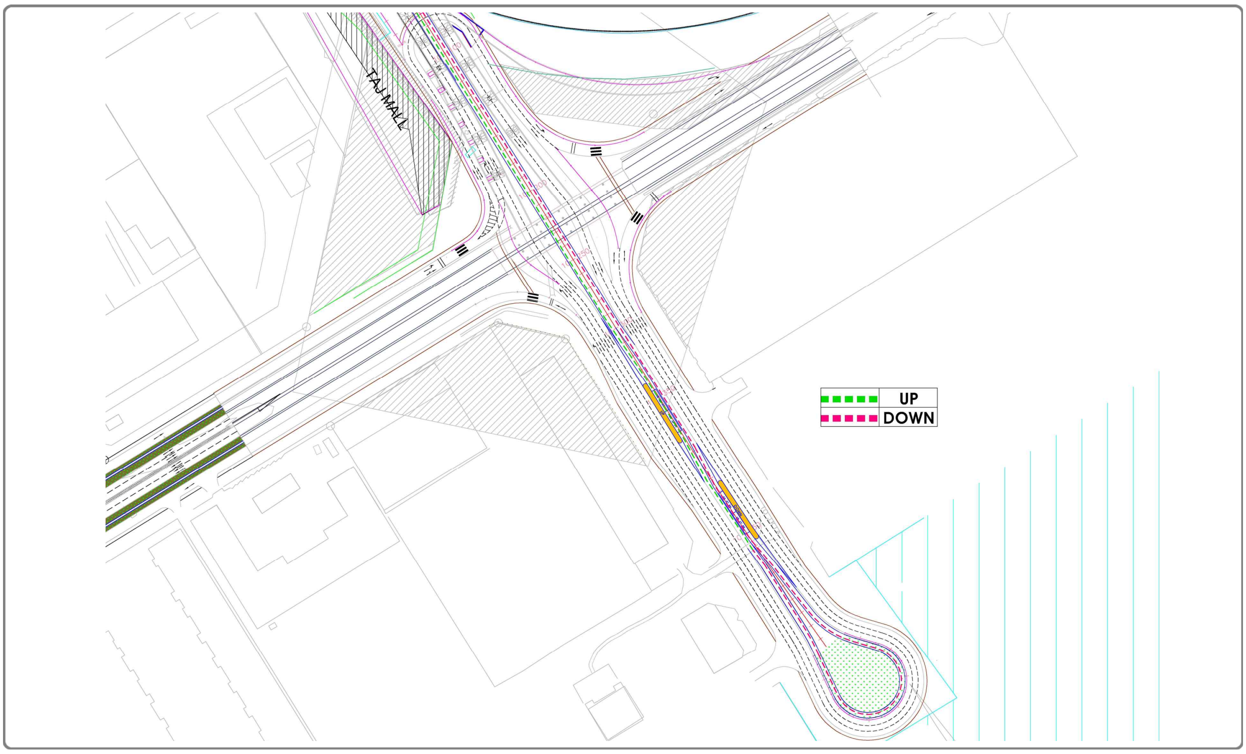
<Figure 5-54> Traffic Flow Pattern on the Starting point of ORR with a Roundabout

- The ending point of ORR route has one way with type of cul-de-sac, and the location of BRT stations are positioned in order to operate both stations on each direction taking into consideration the overpass of Airport North Road.



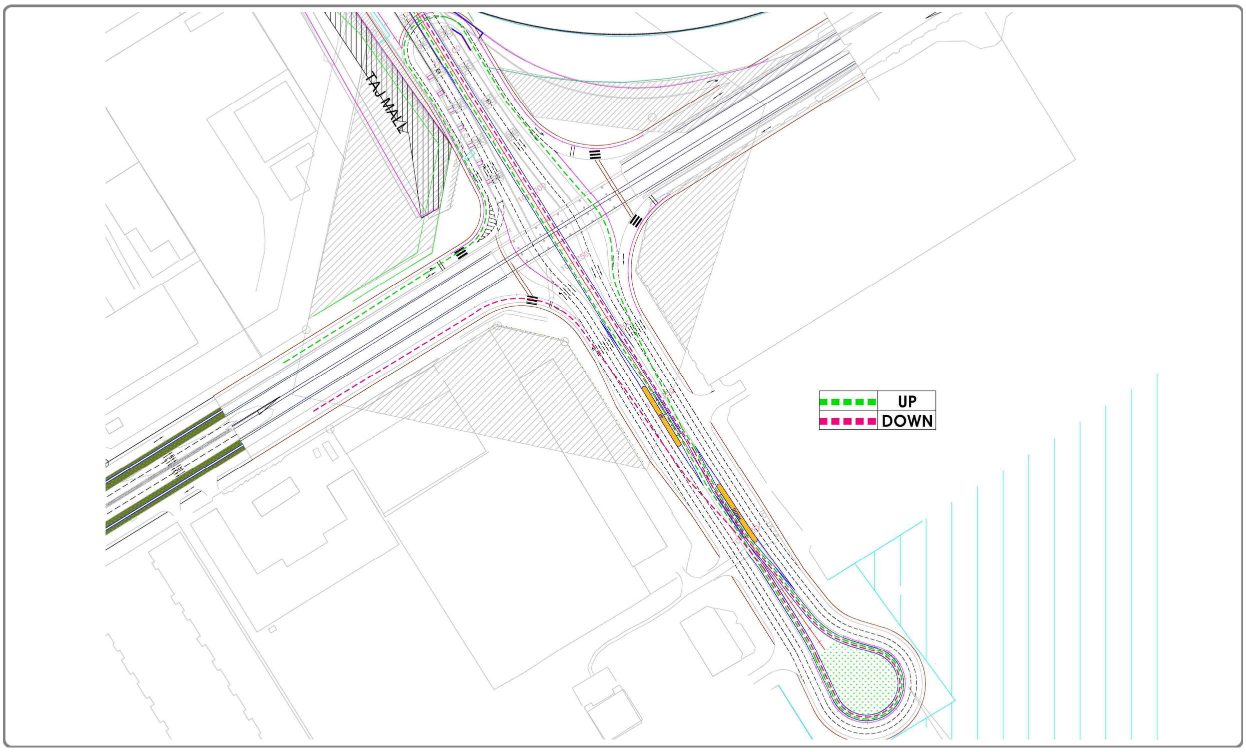
<Figure 5-55> Traffic Improvement Plan for the Ending point of ORR route

- The traffic flow of BRT system can be diversified depending on the BRT route
- The following illustration shows the traffic flow of circular line of ORR



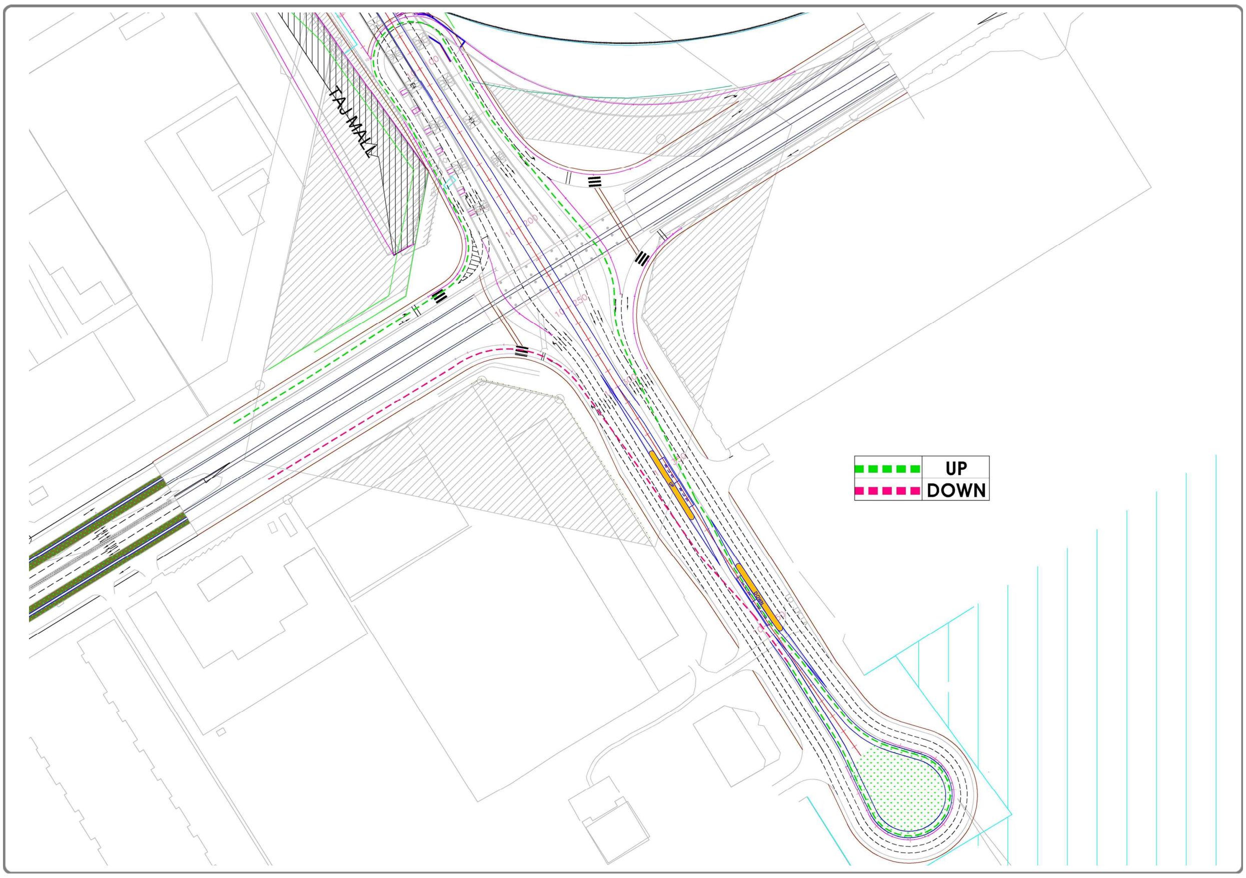
<Figure 5-56> Traffic Flow Pattern on the Ending Point of ORR route (Circular Line of ORR)

- The following illustration shows the traffic flow of both lines which use ORR route and CBD in Nairobi.



<Figure 5-57> Traffic Flow Pattern on the Ending Point of ORR route (ORR+CBD Route)

- The following illustration shows the traffic flow of feeder line for JKIA airport.



<Figure 5-58> Traffic Flow Pattern on the Ending Point of ORR route (Feeder line for JKIA airport)

5.9. Strategies of BRT Implementation

5.9.1. BRT Executing Agency

- Even though several BRT projects are undergoing in Nairobi according to the MRTS plan, there is no entity to manage the overall BRT system. Each project is assigned to the authority which is in charge of the roads being constructed, for example, BRT line 1 and 2 is carried out by KeNHA and line 3 to 5 by KURA.
- It is better to have only one authority manage the planning and design task to ensure consistency, integration and efficiency of the BRT implementation processes. Processes such as construction and O&M should be handled by a responsible authority.
- Since the coordination between the related agencies would not be easy in the short-term period, NaMATA should serve as a coordinator between KURA and KeNHA until a proper execution agency is sett up.
- In the long-term period, it is recommended that the proper execution agencies for each processes such as the BRT's plan and design by NaMATA, construction by KURA, and management & operation by MOTI should be assigned.

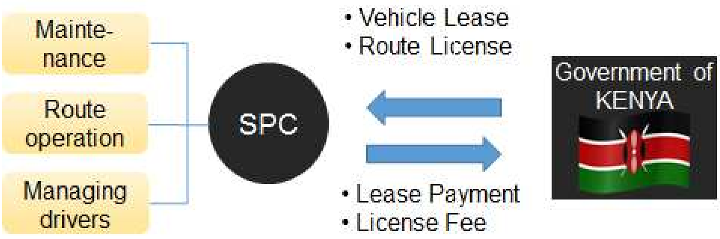
<Table 5-45> Proper executing agency on each BRT process

Alternative	Short-term	Long-term
Executing Agency	KeNHA — Planning & Design BRT 1 & 2 KURA — Planning & Design BRT 3~5 NaMATA — Coordination	NaMATA — Planning & Design KURA — Construction MOTIH&UD — Operation & Management

5.9.2. BRT operation unit

- Since every PSVs in Nairobi are owned and operated by the private sector, almost all PSV routes are concentrated in the CBD. The inefficiency and duplication of PSV routes should be improved to increase their level of service.
- It is very important to build an integrated public transport system to succeed BRT system in Nairobi. In order to create such an integrated system, the current PSV routes should be adjusted such that they will not compete with BRT routes. Changing Matatus routes to feeder lines may cause a lot of resistance because there are no benefits such as subsidies on the PSV. Some incentives may be required to reduce the objection for the bus route reform.

- An SPC (Special Purpose Company) which consists of the related SACCOs may be a solution to acquire the consent of Matatus owners and employees.
- GoK should construct all BRT infrastructures, acquire BRT fleet, create routes & operation plans, reform PSV routes and build ITS system. Then SPC will lease the BRT vehicles, hire BRT drivers, operate BRT routes, receive the fare, maintain BRT fleet and infrastructure and train drivers and staff.



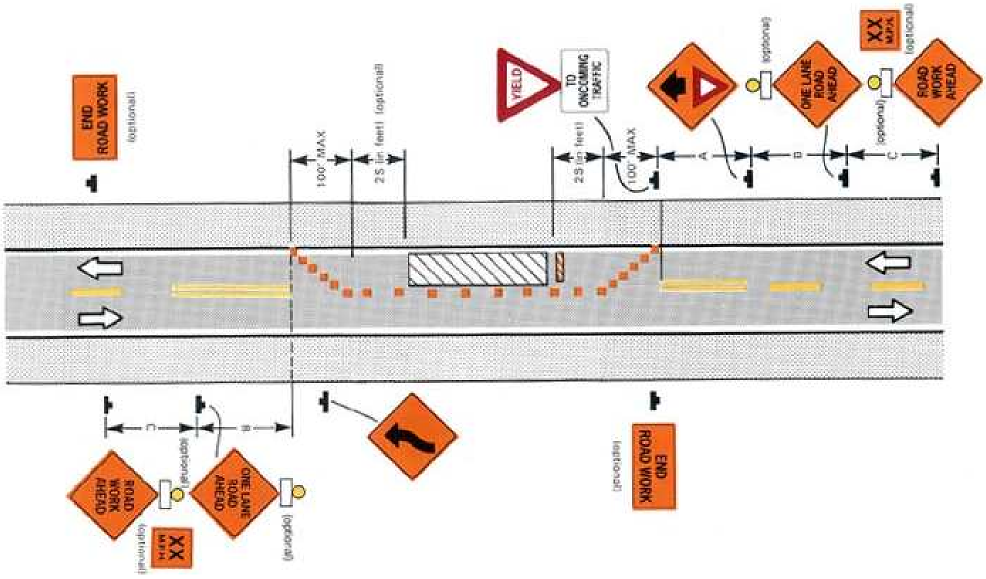
<Figure 5-59> Recommended business model for BRT system

5.9.3. Work Zone Traffic Control during BRT Construction

- The ORR (Outer Ring Road) expansion project is almost finished even though some aspects such as foot-bridges have not yet been completed. Several years would be needed to construct all the BRT infrastructure. The ORR would also be completed by the time the BRT infrastructure is complete. A TMP (Traffic Management Plan) should be prepared during the construction of the BRT infrastructure in the median space of the ORR.
- A few pictures from a construction site on the ORR have been gathered from several field investigations but it is not clear as to whether or not there is any manual of a work zone traffic control body such as MUTCD of United States of America in Kenya. But for a few traffic cones placed around the work zone, there are no warning signs, arrow boards and temporary barriers according to the results from field investigations.

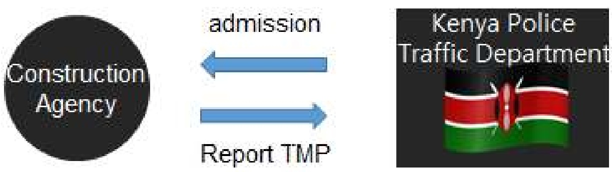
<Figure 5-60> Traffic management of the work zone on ORR

- A prototype traffic control in a work zone based on MUTCD is as follows in the diagram below. Most temporary traffic control work zones can be divided into four parts such as 1)advanced warning zone, 2)transition area, 3)activity area and 4)termination area.



<Figure 5-61> Traffic control diagram of a work zone

- If there is no specific procedure in Kenya, it is desirable that the work zone traffic control during BRT construction should follow MUTCD's requirements.
- After preparing a TMP which is composed of the procedure proposed by MUTCD, the executing agency that is in charge of construction should submit the project details and plan to KPTD (Kenya Police Traffic Department) and the TMP should be accepted before commencement of construction.



<Figure 5-62> Procedure of Construction Traffic Management Plan

6. Feasibility Analysis of the BRT Implementation

6.1. CBA (Cost Benefit Analysis) Method

6.1.1. Overview of Economic Analysis

- Economic analysis estimates the feasibility of public work in terms of social profit based on cost and benefit analysis of public works using a holistic approach. In general, benefit derived from investment in the transport industry is defined as a direct benefit from the transport system itself and indirect social benefits from transport improvement.
- Direct benefit is social profit for the people that utilize the transport system established by Bus Rapid Transit (BRT) project. Examples of direct benefit include reduced vehicle operating cost, curtailment of trip time, decreased vehicle accident, improvement of traffic, increased punctuality and better safety.
- Indirect benefits are derived positive effects from the implementation of transport-related project for non-users of the transportation system, including regional development, market expansion, and restructuring of industry. Nonetheless, indirect benefits require additional investment in corresponding fields to quantify.
- This project involves construction of BRT system in Nairobi and may generate both direct and indirect benefits. However, direct benefits (reduced vehicle operating cost, reduced travel time) are considered by the economic analysis as existing direct benefit computation methodology is available and can take account of project conditions, data collection and usability of method.
- Determination of the social discount rate and evaluation period are the most important two factors when economic analysis is conducted. As for the discount factor, unfortunately, there is no recommended value in Kenya so we used the value from previous literature.
- The most important factor in economic analysis is to set the social discount rate. In Kenya, there is no government recommendation, so we applied a discount rate of 12% considering the market interest rate.
- The preconditions for economic analysis are as follows.

<Table 6-1> BRT Costs and Benefits considered in economic analysis

BRT Costs	BRT Benefits
• Planning and design • Construction cost - Civil, Structure, ITS, BRT depot • Bus operations and maintenance • Infrastructure operations and maintenance • Vehicle purchase cost • Construction supervision and other costs	• The Valuation of Travel Time Savings - Travel Time Saving of BRT users - Travel Time Saving of travelers except BRT users • The Valuation of Vehicle Operating Costs Savings • The Valuation of Accident Costs Savings • Green house gas Costs Saving

6.1.2. Method of Economic Analysis

- Benefit-Cost analysis and Cost-Effectiveness analysis are primarily used as the methods of analysis for public sector investment project, where the results of Benefit-Cost analysis are most widely used as absolute standards.
- The Benefit-Cost analysis method consists of benefit/cost Ratio (herein after referred to as “B/C Ratio”), net present value (herein after referred to as “NPV”) and internal rate of return (herein after referred to as “IRR”) methods

<Table 6-2> Economic Feasibility Analysis Method

Category	Description
Benefit-Cost Ratio (B/C)	• Ratio of B/C by dividing the present value conversion of the total benefit and cost • $B/C = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} / \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$ • If B/C value is larger than "1", it is evaluated as economically feasible, but the ratio may differ dependent on the categories of items for cost and benefit
Net Present Value (NPV)	• Net present value defined as the difference between the discounted amount of cost and benefit arising from alternative projects and evaluated as a prevalent proposal with a larger size • $NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$
Internal Rate of Return (IRR)	• As a discount rate resulting in the sum of the present value of cost and benefits to be equal, it is a discount rate which makes the value of the net present value to be "0" • $IRR = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$ • If the discount rate, which results in the equal sum of the present value of benefit and cost, is higher than the social opportunity cost, it is evaluated as having profitability • It is defined as the rate at which revenue can be generated while recovering costs such as construction costs and operation costs during the project period

- The investment standard of economic feasibility analysis is a boundary standard for evaluating the feasibility of the alternative and the standard is the point of agreement between cost and benefit. In other words, the point is NPV=0, B/C=1 or IRR= the opportunity cost of the capital.

<Table 6-3> Economic Feasibility Evaluation Standard

Category	B/C	NPV	IRR
Evaluation Standard	Over 1.0	Over 0	Over Real Discount Rate 8%

6.2. Cost estimation for BRT

6.2.1. Project Cost

- The objective of this project is to establish the BRT system on ORR according to the MRTS Plan. The project costs are mainly composed of 6 items such as 1) construction, 2) ITS, 3) BRT bus, 4) indirect, 5) land acquisition and 6) contingency cost.
- Total project cost is estimated at about \$ 79.8 million. Among those, 55.0% is for the BRT infrastructure cost, 16.4% is for the indirect cost and 12.5% is for purchasing cost of the BRT fleets.
- The proportion of the structure construction cost among the BRT infrastructure cost is estimated at 66% (\$ 29 million) because there are many structures (5 bridges and 10 footbridges) to install for constructing the BRT runningway.
- The number of BRT bus will be needed about 40 fleets in 2020 and the purchasing cost is estimated at about \$ 10.0 million. In 2030, the needed fleets are 56 and the purchasing cost is estimated at about \$ 14.0 million.
- The contingency cost is generally estimated about 10% of the total cost and will be \$ 7.3 million.

<Table 6-4> Project Cost of CRIPP

(Unit: million USD)

Item	Cost	(%)	Remark
1. BRT Infrastructure Cost	**43.9**	**55.0**	-
- Earthwork	9.7	12.2	BRT Runningway, Station
- Structure	29.0	36.3	Bridge 24.5, Footbridge 4.5
- Depot	5.0	6.3	-
- Etc.	0.2	0.2	-
2. ITS	**0.5**	**0.8**	AFC, BIMS, etc.
3. BRT Bus	**10.0**	**12.5**	Purchase Costs (2020)
	(14.0)	**-**	Purchase Costs (2030)
	(15.0)	**-**	Purchase Costs (2040)
4. Indirect Cost	**13.1**	**16.4**	Management Fee, etc.
5. Land Aquisition Cost	**5.0**	**6.2**	Depot
6. Contingency Cost	**7.3**	**9.1**	10% of direct+indirect cost
Total	**79.8**	**100**	-

note : Some of above values may be changed after adopting the local unit price.

6.2.2. Operation and Management Cost

- The operation and maintenance cost for BRT vehicles is divided into three parts such as replacement, operation and maintenance cost. Considering the average life expectancy of the BRT's vehicle, replacement period of the BRT fleets is applied as every 10 years.
- The number of BRT fleets and manpower are roughly estimated as followings.

<Table 6-5> The number of fleet and manpower

Fleet and Manpower	2020	2030	2040
Fleets	40	56	60
Drivers	73	96	111
Security and Customer service staffs	50	50	50
Maintenance staffs	20	28	30

- The maintenance cost of the BRT infrastructure is also included into the O&M cost and will be applied at 5% of the construction cost annually and 15% for every 15 years based on the lump-sum cost.
- The O&M cost will be about \$ 5.3~7.7 million every year and the additional cost should be included the fleets cost every 10 years and additional maintenance cost every 15 years. The total estimated cost of O&M for 30 years will be \$ 259.0 million.

<Table 6-6> Operation and management cost

(Unit: million USD)

Year	Costs	Year	Costs	Year	Costs
2020	15.3	2030	20.7	2040	22.7
2021	5.3	2031	6.7	2041	7.7
2022	5.3	2032	6.7	2042	7.7
2023	5.3	2033	6.7	2043	9.9
2024	7.5	2034	13.8	2044	7.7
2025	5.3	2035	6.7	2045	7.7
2026	5.3	2036	6.7	2046	7.7
2027	5.3	2037	6.7	2047	7.7
2028	5.3	2038	6.7	2048	7.7
2029	7.5	2039	8.9	2049	14.7
Total O&M Cost for 30 years: 259.0 million USD					

6.2.3. Total CBA Cost

- The total cost for 30 years is estimated about \$ 338.8 million. The total cost which are used for CBA will be about \$ 331.5 million after removing the contingency cost from the total project cost.

<Table 6-7> Total Cost

(Unit: million USD)

Item	Value	CBA Cost	Remark
Project Cost	79.8	72.5	exclude the contingency cost
O&M Cost	259.0	259.0	
Total	338.8	331.5	

6.3. Benefit Estimation of BRT

6.3.1. The Valuation of Travel Time Cost Savings

- Value of Time (VOT) is the monetary value of psychological feeling of sacrifice that one experiences per unit time while using transport service. Total value of time is estimated by multiplying traffic per vehicle type by value of time for a link based on trip assignment.
- In the calculation of the benefit from reduction of time, total time per transport type is estimated for the two cases: 1) the condition with the project, 2) the condition without the project. Different value of time is applied to the total time to estimate total time cost for each case.
- The benefit from reduction of time is equivalent to total time cost difference of the two cases. The following equation expresses VOTS per year of analysis.

$$VOTS = VOT_{condition\,without\ project} - VOT_{condition\,with\ project}$$

Where, $VOT = \left\{ \sum_{l} \sum_{k=1}^{3} (T_{kl} \times P_k \times Q_{kl}) \right\} \times 365$

T_{kl} = Time per vehicle type for link ℓ $\quad$ P_k = Value of time per vehicle type

Q_{kl} = Trip quantity per vehicle type for link ℓ $\quad$ k = Vehicle type

<Table 6-8> The Valuation of Travel Time Savings

(Unit: 1,000 USD)

Valuation of Travel Time	2020	2030	2040
Do Not (A)	1,420,088	2,465,020	3,182,320
Do (B)	1,410,101	2,455,543	3,172,547
B-A	9,987	9,477	9,773

6.3.2. The Valuation of Vehicle Operating Cost Savings

- Vehicle Operating Cost (VOC) includes fixed costs (tax, insurance, etc.) and variable costs (fuel cost, tyre, maintenance cost, depreciation cost, etc.), which are the direct costs for the user. It is also inclusive of external costs such as time costs, accident costs, environmental costs, etc.
- The calculation of vehicle operating cost requires speed of travel for a link based on trip assignment and traffic quantity, which are then used to estimate unit cost of vehicle operating cost per rate of travel.
- That is, traffic volume per vehicle type of individual link in network of roads selected for analysis is multiplied by distance of individual link. This value is then multiplied by unit cost of vehicle operating cost per vehicle type at average speed of link travel. The final outcome is the vehicle operating cost of the individual link.

- This calculation method is applied to all links in network of roads for analysis and the vehicle operating cost difference between the condition with the project and the condition without the project is the benefit of vehicle operating cost.

$$VOCS = VOC_{condition\ without\ project} - VOC_{condition\ with\ project}$$

Where, $VOC = \sum_{l} \sum_{k=1}^{3} (D_{kl} \times VT_k \times 365)$

$D_{kl} =$ vehicle-km by Vehicle type of Link ℓ $\quad k =$ vehicle type

$VT_k =$ vehicle operating cost per vehicle type at corresponding speed of travel

<Table 6-9> The Valuation of Vehicle Operating Costs Savings

(Unit: 1,000 USD)

Valuation of Vehicle Operating	2020	2030	2040
Do Not (A)	1,048,085	1,365,714	1,598,484
Do (B)	1,047,625	1,365,215	1,598,058
B-A	460	498	426

6.3.3. Travel Time Cost Savings of BRT

- Travel Time Savings of BRT is calculated based on bus commercial speed of 12.0 km/h in case the project is not implemented and 27.0 km/h in case the project is implemented.
- VOT is estimated at 1.0 USD. Considering the number of user and travel distance, Travel Time Savings for years are as follows.

<Table 6-10> Travel Time Saving of BRT

(Unit: 1,000 USD)

Item	2020	2030	2040
Travel Time Saving of BRT	9,890	11,737	13,758

6.3.4. GHG Cost Savings of BRT

- The implementation of the BRT will result in users switching to buses, leading to a decrease in existing vehicles, resulting in a decrease in C02.
- The decrease in CO2 is estimated to be 199Thousand USD in 2020, 252Thousand USD in 2030, and 299Thousand USD in 2040.

<Table 6-11> CO2 Saving of BRT

(Unit: 1,000 USD)

Item	2020	2030	2040
CO_2 Saving of BRT	199	252	299

6.4. Economic Analysis Results

6.4.1. Economic Analysis

- The economic analysis for this project is divided into two parts: cost (construction and maintenance) and benefit (reduced vehicle operating cost, curtailment of trip time)
- As result of the economic analysis, The value of B/C, NPV and IRR are respectively 1.41, 41,138 Thousand USD and 22.91%.

<Table 6-12> Economic Analysis Result

Economic Analysis	Total Discounted Costs (1,000 USD)	Total Discounted Benefit (1,000 USD)	B/C (Benefit/Cost)	NPV (1,000 USD)	IRR (%)
Vehicle Operation Costs Savings	99,160	3,027	0.03	-96,133	-
Vehicle Operation Costs Savings+Travel Time Savings	99,160	66,907	0.67	-32,252	-1.99
Vehicle Operation Costs Savings+Travel Time Savings+Travel Time Savings of BRT	99,160	138,790	1.40	39,631	22.54
Vehicle Operation Costs Savings+Travel Time Savings+Travel Time Savings of BRT+CO_2 Savings of BRT	99,160	140,297	1.41	41,138	22.91

Note: applied social discount rate is 12%

6.4.2. Sensitivity Analysis

- Sensitivity analysis was performed considering the changes in cost and benefits.
- As a result of the economic analysis of the changes in costs and benefits, the B/C ratio is over 1.0 within ±20% of the cost and benefits, which is considered to be economically feasible.

<Table 6-13> Sensitivity Analysis Results

Item		Total Discounted Costs (million USD)	Total Discounted Benefit (million USD)	B/C	NPV (mil. USD)	IRR (%)
Cost	-20%	91,833	140,297	1.53	48,464	26.86%
	-10%	95,496	140,297	1.47	44,801	24.74%
	0%	99,160	140,297	1.41	41,138	22.91%
	+10%	102,823	140,297	1.36	37,474	21.31%
	+20%	106,486	140,297	1.32	33,811	19.91%
Benefit	-20%	99,160	112,238	1.13	13,078	15.59%
	-10%	99,160	126,267	1.27	27,108	19.28%
	0%	99,160	140,297	1.41	41,138	22.91%
	+10%	99,160	154,327	1.56	55,167	26.51%
	+20%	99,160	168,357	1.70	69,197	30.11%

6.5. Financial Analysis of BRT

6.5.1. Overview

1) Purpose

- The purpose of a financial analysis is to determine whether a given investment project will generate returns on the investor's investment. It involves reviewing the feasibility of the given project by comparing the investor's financing capability and the likely return rate of the project, thereby evaluating how the project will affect the investor's financial status.

2) Difference from an economic analysis

- An economic analysis involves estimating and comparing the economic costs and benefits of a given project on the national level so as to determine whether the project offers net benefits greater than those offered by alternative investment opportunities. On the other hand, a financial analysis involves analyzing the profitability of a given project for the individual/corporate investor, demonstrating whether returns can be realized, and estimating how the project will affect the investor's financial status, given the investor's financing capacity and the financial aspects of the project.

<Table 6-14> Economic Analysis vs. Financial Analysis

Type	Economic analysis	Financial analysis
Benefit vs. profit	• The Valuation of Travel Time Savings • The Valuation of Vehicle Operating Costs Savings • Travel Time Saving of BRT • CO_2 Saving of BRT	• Non-operating income • Operating income
Cost	• Economic cost (taxes not included)	• Accounting cost (taxes included)
Discount rate	• Social discount rate	• Financial discount rate (WACC)

3) Analysis method

- The most common technique for evaluating financial feasibility is the cash flow discount method, which involves forecasting the future cash flow and discounting its present value by the opportunity cost of capital, i.e., the weighted average cost of capital.
- There are, in fact, several cash flow discount methods, including the NPV method, IRR method, and profitability index method.
- The profit index (PI) refers to the amount of cash inflow for each year, after the beginning of operation, divided by the cash outflow (operating, maintenance, and administration costs). The cash inflows and outflows are discounted using a fixed rate. When the PI is equal to or greater than 1, it indicates the profitability of the given project.

$$PI = \sum_{t=1}^{n} \frac{CI_t}{(1+r)^t} / \sum_{t=1}^{n} \frac{CO_t}{(1+r)^t}$$

Where, CI_t = cash inflow of year t

CO_t = cash outflow of year t

r = discount rate (i.e., WACC)

n = construction and operation period (analysis period)

- The Financial Net Present Value Method (FNPV) method involves discounting all the cash inflows and outflows attendant upon the given project down to their present values and subtracting the present value of cash outflows from that of cash inflows. An FNPV equal to or greater than zero, points to profitability.

$$FNPV = \sum_{t=1}^{n} \frac{CI_t}{(1+r)^t} - \sum_{t=1}^{b} \frac{CO_t}{(1+r)^t}$$

Where, CI_t = cash inflow of year t

CO_t = cash outflow of year t

r = discount rate (i.e., WACC)

n = construction and operation period (analysis period)

- The Financial Internal Rate of Return (FIRR) method involves looking for the discount rate, r, where the present values of cash inflows and outflows become equal to each other. In general, an FIRR greater than the market interest rate indicates profitability.

$$FIRR : \sum_{t=1}^{n} \frac{CI_t}{(1+r)^t} = \sum_{t=1}^{n} n \frac{CO_t}{(1+r)^t}$$

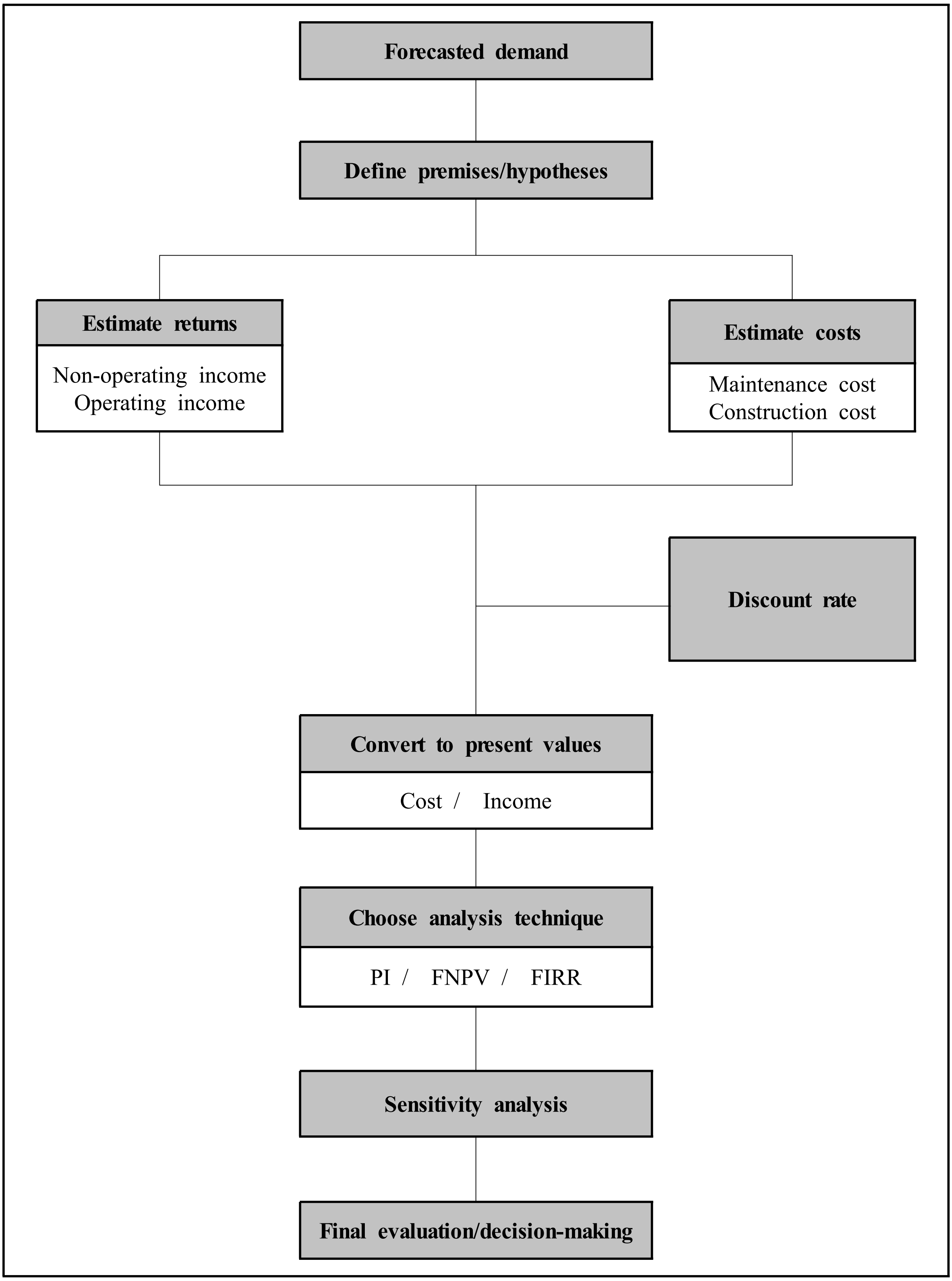
Where, CI_t = cash inflow of year t

CO_t = cash outflow of year t

r = discount rate (i.e., WACC)

n = construction and operation period (analysis period)

4) Analysis process



<Figure 6-1> Financial Analysis Process

6.5.2. Basic conditions for Financial Analysis

- Basic conditions for the financial analysis are shown in the table below.

Classification	Description
Discount Rate	• 12.0%
Construction Period	• 2 years(2019 to 2020)
Analysis Period	• Base year : 2017 • Operation period : 30years(2020 to 2049)
Costs	• Planning and design • Construction cost • Bus operations and maintenance • Vehicle purchase cost • Construction supervision and other costs • Infrastructure operations and maintenance
Revenue	• Revenue(income) from fees of passengers
Analysis Indicators	• Financial Net Present Value(FNPV) • Financial Internal Rate of Return(FIRR) • Profit Index(PI)

6.5.3. Project Costs and Revenue

1) Project Costs

- The total estimated cost of BRT through the financial analysis is 116,779 thousand USD. The detail contents are as follows.

<Table 6-15> Project Costs

(Unit : 1,000 USD)

Description	Project Costs	VAT(16%) [Value added Tax]	Total Cost
Planning and design	10,198	1,632	11,829
Construction cost	48,560	7,770	56,330
Construction supervision and other costs	2,914	466	3,380
Vehicle purchase cost	39,000	6,240	45,240
Total costs	100,671	16,107	116,779

2) Revenue

- The general operating income of transport system includes operating income and non-operating income, but in this analysis non-operating income is not considered.
- Operating income is estimated by applying fare(30KES/5km + 10KES/2km) to expect annual travel demand based on projected travel demand. The income after 2040 is assumed to be the same.

<Table 6-16> Results of annual revenue

(Unit : 1,000 USD)

Year	BRT line - 5A (Original)	BRT line – 5B (Airport)	BRT line – 5C (CBD)	Total
2020	4,267	1,468	4,637	10,372
2021	4,343	1,563	4,709	10,615
2022	4,421	1,665	4,783	10,869
2023	4,501	1,773	4,858	11,132
2024	4,582	1,889	4,933	11,404
2025	4,664	2,011	5,010	11,685
2026	4,748	2,142	5,089	11,979
2027	4,833	2,281	5,168	12,282
2028	4,920	2,430	5,249	12,599
2029	5,009	2,588	5,331	12,928
2030	5,099	2,756	5,414	13,269
2031	5,187	2,813	5,483	13,483
2032	5,278	2,872	5,552	13,702
2033	5,370	2,931	5,622	13,923
2034	5,463	2,992	5,694	14,149
2035	5,558	3,054	5,766	14,378
2036	5,655	3,118	5,839	14,612
2037	5,753	3,183	5,913	14,849
2038	5,853	3,249	5,988	15,090
2039	5,955	3,316	6,063	15,334
2040	6,059	3,385	6,140	15,584
2041	6,059	3,385	6,140	15,584
2042	6,059	3,385	6,140	15,584
2043	6,059	3,385	6,140	15,584
2044	6,059	3,385	6,140	15,584
2045	6,059	3,385	6,140	15,584
2046	6,059	3,385	6,140	15,584
2047	6,059	3,385	6,140	15,584
2048	6,059	3,385	6,140	15,584
2049	6,059	3,385	6,140	15,584
Total	162,049	83,944	168,501	414,494

6.5.4. Financial analysis Results

- The financial analysis are carried out two scenarios. The first is that all project cost are supplied by Government of Kenya and the second is from EDCF loan. The land acquisition cost are removed from the project cost in scenario 1.
- Loan condition is equal as the Kexim Bank's EDCF loan which are 10 years grace period, 40 years redemption period and 0.1% redemption yield. The applied loan amount will be US$ 68,338 million except the land acquisition cost for BRT depot.
- The total discounted revenue is US$ 78,710 million and same for both of scenarios. But the total discounted cost will vary from US$ 73,917 million to US$ 115,025 million according to scenarios.
- As the results of this analysis, scenario 1 could not acquire the financial feasibility since the PI of it is 0.68, FNPV US$ -36,315 million and FIRR 2.95%. On the other hand, if GOK will receive the EDCF loan excluding BRT fleet purchasing cost and the land acquisition cost for a depot, scenario 2 could secure the financial feasibility of it, because PI of it is 1.06, FNPV US$ 4,783 million and FIRR 21.24%.

<Table 6-1> Financial analysis result

(Unit : 1,000 USD/30 years)

Description	Scenario 1	Scenario 2
Construction Cost	GOK	EDCF Loan
Idirect Cost	GOK	EDCF Loan
Contingecy Cost	GOK	EDCF Loan
BRT Purchasing Cost	O&M Entity	O&M Entity
O&M Cost	O&M Entity	O&M Entity
Total Discounted Revenue(A)	78,710	78,710
Total Discounted Costs(B)	115,025	73,917
FNPV(A-B)	-36,315	4,783
PI(A/B)	0.68	1.06
FIRR	2.95%	21.24%
Remark		Loan amount : US$ 68,338 mil Redemption yield : 0.1% Grace period : 10 year Redemption period : 40 year Except land acquisition cost

- Since above results was analyzed by using just the fare revenue from BRT project, if the indirect revenue may be added to the fare revenue, the index of the financial feasibility will more increase than the previous results.

6.5.5. Sensitivity Analysis in Financial Aspects

- Sensitivity analysis is conducted to analyze the changes of FIRR if the cost and/or revenue are increased or decreased.
- In all cases of scenario 1, FIRR will be below the discount rate 12%. On the other hand, FIRR of scenario 2 will higher than the applied discount rate 12% except 3 worst cases (cost 10% more or/and revenue 10% less).

<Table 6-2> Sensitivity analysis in financial aspects

Scenario	Description	-10% reduced costs	Current costs	+10% increased costs
S 1	+10% increased revenue	7.75%	5.27%	2.95%
	Current revenue	5.51%	2.95%	0.38%
	-10% reduced revenue	2.95%	0.08%	-3.16%
S 2	+10% increased revenue	45.98%	33.07%	21.79%
	Current revenue	33.97%	21.24%	7.48%
	-10% reduced revenue	20.52%	2.48%	-1.32%

6.6. Effect Analysis of BRT Implementation

- The transport-related factors among the United Nations' Sustainable Development Goals (SDGs) are: 1) responding to climate change; 2) Improvement of transportation accessibility, 3) increasing quality of life by strengthening health and 4) establishment of a sustainable transportation system.

<Table 6-17> Contribution for SDGs in by Transport Projects

Sector	Responding to climate change	increasing quality of life by strengthening health	Improvement of transportation accessibility	Establishment of a sustainable transportation system
Bus System	√√	√√	√√√	√√
Railway	√√√	√√	√√	√√
Road Network	-	-	√√√	-
NMT	√√√	√√	√	√√√

- The improvement effects of the BRT implementation are derived from various aspects, but the three items that are suggested as indicators for measuring the SDGs' targets are traffic accident reduction, transportation energy efficiency improvement and carbon dioxide emission reduction.
- On the contrary to the road network expansion project which likely cause the traffic accidents due to the increased traffic volume and vehicle speed, the implementation which is the most positive effects of all three items is railway network expansion, and the next is likely to be the establishment of a new BRT system.

<Table 6-18> Influence on the SDGs indicators by public transport project

Indicator / Item	Decrease Accidents	Increase Fuel Efficiency	Diminish CO_2
BRT	★★	★★	★★
Railway	★★★★	★★★★	★★★★

- BRT systems can impact the quality of life, productivity, health, and safety of people living in cities. These impacts have been explored in varying depth in the existing research as travel time benefits, environmental impacts, and public health and safety benefits.

<Table 6-19> **Summary of Typical Impacts of BRT Systems**

Impact	How does BRT achieve the benefit?	Empirical Evidence
Travel time savings	• Segregated busways separate BRT buses from mixed traffic; • Pre-paid level boarding and high-capacity buses speed passenger boarding; • Traffic signal management and high-frequency bus service minimize waiting times	• Johannesburg BRT users save on average 13 minutes each way (Venter and Vaz 2011) • The typical Metrobüs passenger in Istanbul saves 52 minutes per day (Alpkokin and Ergun 2012)
GHG and local air pollutant emissions reductions	• Reduce VKT by shifting passengers to high capacity BRT buses • Replace/scrap older, more polluting traditional vehicles • Introduce newer technology BRT buses • Better driver training leads to improved driving cycles which have lower fuel consumption and emissions	• In Bogota, the implementation of TransMilenio combined with new regulations on fuel quality is estimated to save nearly 1 million tCO2 per year (Turner et. al. 2012) • Mexico City's Metrobús Line 1 achieved significant reductions in carbon monoxide, benzene and particulate matter (PM2.5) inside BRT buses, traditional buses and mini-buses (Wöhrnschimmel et. al. 2008)
Road safety improvements–reductions in fatalities and crashes	• Improve pedestrian crossings • Reduce VKT by shifting passengers to highcapacity BRT buses • Reduces interaction with other vehicles by segregating buses from mixed traffic • BRT can change drivers' behaviors by reducing on-the-road competition and improving training	• Bogota's TransMilenio has contributed to reductions in crashes and injuries on two of the system's main corridors (Bocarejo et. al. 2012) • On average, BRTs in the Latin American context have contributed to a reduction in fatalities and injuries of over 40% on the streets where they were implemented
Reduced exposure to air pollutants	• Cleaner vehicle technologies and fuels lower concentration of ambient air pollution citywide or inside the BRT vehicles; • Reduce time passengers are exposed to air pollution at stations or inside the bus by reducing travel times	• After the implementation of TransMilenio, Bogota reported a 43% decline in SO2 emissions, 18% decline in NOx, and a 12% decline in particulate matter (Turner et. al. 2012) • By reducing emissions of local air pollutants, especially of particulate matter, Metrobús Line 1 in Mexico City would eliminate more than 6,000 days of lost work, 12 new cases of chronic bronchitis, and three deaths per year saving an estimated USD $3 million per year (INE 2006)
Increased physical activity	• Spacing of BRT stations tend to require longer walking distances than all other motorized modes with the exception of Metro • Higher operation speeds increases passengers' willingness to walk to stations	• Mexico City's Metrobús passengers walk on average an additional 2.75 minutes per day than previously • Users of the Beijing BRT have added 8.5 minutes of daily walking as a result of the BRT system

source : Social, environmental and economic impacts of BRT systems, 2013, EMBARQ

- ICCT (the International Council on Clean Transportation) carried out CBA (cost and benefit analysis) in the three cities on Nairobi, Kampala and Addis Ababa in 2012. As a results of estimating the city-wide economic effects, which are composed of the pollutant emissions, fuel consumption, health impacts, and time saved, the BRT system in Nairobi will result in considerable overall benefits in the range of $42 to $51 million per year in 2035 compared to the costs for vehicles and infrastructure ranging $23 to 29 million per year.
- A recent research shows that BRT can save the travel time of commuters by millions of hours worldwide. For instance, BRT users in Istanbul, Turkey, can save 28 days per year and in Johannesburg, South Africa, meanwhile, can save 73 million hours between 2007 and 2026 which is equivalent to more than 9 million work-days. BRT Line 3 in Mexico City can save US$141 million by reducing travel time per year.
- BRT systems are now carrying more than 32 million passengers everyday in 165 cities around the world as of December 2017. An additional 176 cities are currently being under construction or planned the BRT systems.

7. Conclusions and Recommendations

7.1. Conclusion

- Government of Kenya is in the process of establishing and implementing an MRTS plan to raise public transport competitiveness in Nairobi to solve the severe traffic problems. This project, BRT Line 5, is also one of the MRTS plans, and it is expected that the project's effect will be improved if it is integrated with BRT Line 1 to 4 already underway.
- The infrastructure of BRT Line 5 will be only installed on the ORR, but it is necessary to find various service routes that can maximize passenger demand in order to overcome the weakness of routes connecting only the outskirts areas. To this end, a short-term route plan that connects the CBD and the airport line is presented, and in the long term, the inter-corridor route directly connected to BRT Line 3 and 4 is proposed.
- Most major cities in Africa have mini-buses as major public transport. Since BRT operates on a separate exclusive lane, it is excellent in mobility, but it has a disadvantage in that accessibility is poor compared to mini-bus. If transfers fare discounts are not achieved between PSV and BRT, it may be difficult to secure sufficient number of BRT passengers. To prevent these problems before introducing the BRT system, it is necessary to reform the PSV routes to convert as feeder routes rather than a competitive route. PSVs in Nairobi should also be reformed into a trunk & feeder system in order to be a competitive public transportation system in the future. Fortunately, BRT line 5 will not meet with such a problem because there are 3~4 PSV routes with less than 50% overlap. However, since most of the BRTs 1 to 4 are in competition with existing PSV routes, it is necessary to reform the PSV route.
- The passenger demand will be 32 thousand/day in 2020 and 38 thousand/day in 2030 for the scenario 1. The ridership of the scenario 2 will increase to 66~84 thousand/day which are more than 2.1 times compared to scenario 1. The reason why is that 3 BRT routes will operate not only on ORR but to CBD and JKIA.
- According to route scenario 1, only route 5A will operate on ORR. The number of buses required by scenario 1 will be 18 fleet in 2020 and 24 fleet in 2030. The dispatch interval should be 4 minute in 2020 and 3 minutes in 2030.
- Based on route scenario 2, three routes (5A, 5B and 5C) will operate on ORR, between Balozi and CBD and between S510 or S511 and JKIA. The number of

buses required by scenario 2 will be 40 fleet in 2020 and 56 fleet in 2030. The dispatch interval should be 4~10 minute (5A=4, 5B=10 and 5C=5) in 2020 and 3~5 minutes (5A=3, 5B=5 and 5C=4) in 2030.

- BRT's fare system is designed to provide a distance-based fare system that will pay an additional fee per 2km to the base fare within 5km, similar to the existing PSV fare. It is anticipated that it will be difficult to install AFC devices in the existing PSV in a short-term period. Therefore, it is planned to apply fare discount to the transfer between BRT Line5 and other BRT lines or an airport feeder line. In order to increase the AFC usage rate, it is necessary to provide incentives that could operate in the BRT exclusive lane if an PSV adopts AFC system.
- The ORR's expansion project, where the BRT Line 5 will be installed on, is already in its completion stage, and ROW of BRT is secured in the median space of the road. A total of five bridges are installed on the ORR, and the interval secured between ORR bridges in the road center is only 8 to 9.7 meters, making it impossible to install BRT stations on bridges.
- The at grade reserved space is also only 9.27m, so it is difficult to install the integrated single station for the both ways, the two separate stations as staggered type are inevitably planned. The total length of the BRT installed on the ORR is 10.37km, and it is planned that the stations will be installed in 10 places.
- Although most BRT stations are planned to have two bay stops, S510 and S520, which is the final station, is planned to secure four bays considering the transfer with the airport feeder line.
- In order to maximize the demand for BRT passengers, a convenient tranfer system with other PSVs is very important. The commuter railway is located adjacent to the ORR, it is necessary to install a transfer facility between railway stations and BRT stops, but it is not possible to plan such facilities because it is now operated as a halt stop without a station building. Since the commuter railway improvement project currently underway is considering the establishment of railway stations, it is desirable to plan transfer facilities after when the location and form of stations are determined.
- A total of 10 footbridges are planned for passengers to securely access the BRT stations. However, 10 pedestrian bridges will be installed in ORR regardless of BRT. As a result of the review about the locations, three sites were duplicated, but considering the uncertainties such as the civil complaints and the process of discussion between related agencies, the construction cost of 10 new footbridges is included in the project cost.
- Two sites for BRT depot has been selected as candidates. Considering vehicle

dispatching and accessibility, Alternative 1 located near thestarting point is preferable, but it has disadvantage that it is privately owned. Alternative 2 is located near A104, which takes a long time to dispatch and has poor accessibility. However, it has an advantage of being easily accommodated because of the public owned land.

- ITS system should take into account the present situation of Nairobi and construct a subsystem that is directly related to BRT implementation. It is necessary to focus on improving the implementation effect of BRT by establishing four subsystems such as AFC, BIMS, ATMS, and VES in the short term. It is desirable to have a BRT center operating on a minimum scale and integrate it into a mobility center for Nairobi ITS system operation in the future.
- It is expected that it will be difficult for quick turnover due to existing intersection geometry even though the intersection improvement should be considered at BRT starting and ending point for smooth turnaround. It will be necessary to develop more advanced improvements at the concept design or the detailed design stage in the future.
- For the consistency, uniformity, and efficiency of the BRT project, it is recommended that one entity should be responsible for each process, for example, planning and design on NaMATA, construction on KURA and operation and management on MOTIH&UD. But until the project executing organization ideally settles down, it is desirable that NaMATA will coordinate the contents and process between KURA and KeNHA in short-term period.
- Who is going to operate BRT routes in Nairobi is still discussing. Through experience in similar cities, since the existing PSV routes should be reformed inevitablely to accomplish BRT systems successfully, social conflicts between stake-holders are likely to arise. In order to solve this problem, it is recommended that the right to operate BRT route should be designated on the related SACCO or establish an SPC which is composed of stake-holders.
- The estimated project cost will be \$ 62 million in case of excluding the land acquisition cost, the BRT bus cost and the contingency cost. The largest of these is the construction costs, which account for 71.2% of the total, or \$ 43.9 million. The next is the project consulting and managing cost, which is 21.3% or \$ 13.1 million, the remain is the ITS cost.
- The project unit cost is reasonably estimated as 5.9 million \$/km which are intermediate between Concepcion of Mexico and Pachuca of Chile.

<Figure 7-1> BRT project unit cost (source : https://brtdata.org)

- The O&M (operation and management) cost will be needed $ 5.3~7.7 million per year and the total O&M cost for 30 years is estimated about $ 259.0 million.
- The project benefits or cost savings are composed of VOT(value of time), VOC (vehicle operating cost), VAC (traffic accident cost) and GHGC (green house gas cost). The VAC are removed from the items of cost savings because of not enough traffic accident data.
- The VOT by the scenarios will increase from $ 7.1~9.9 million in 2020 to $ 8.5~11.7 million in 2030. The GHGC by the scenarios will increase from $ 94~199 thousand in 2020 to $ 118~251 thousand in 2030.
- The total discounted social benefits from BRT implementation is estimated at $ 140.3 million and will be larger than compared to the total discounted social costs which is $ 99.2 million.
- The results of CBA (cost benefit analysis) that the value of B/C, NPV and IRR are estimated 1.41, $ 41.1 million and 22.91% respectively mean that this BRT project keeps the economic feasibility. If the VAC is included in the benefit items, the CBA results would be more high.
- In case of that the project cost might be 20% higher or the passenger demand be 20% lower, the B/C would decrease to 1.32 or 1.13 but the economic feasibility will be maintained.
- The fare revenue by the scenarios will increase from $ 4.4~10.4 million in 2020 to $ 5.3~13.3 million in 2030.
- The total discounted revenue is US$ 78,710 million and the total discounted cost will vary from US$ 73,917 million to US$ 115,025 million according to scenarios.
- Scenario 1 could not acquire the financial feasibility, but scenario 2 (EDCF loan scenario) could secure the financial feasibility as PI is 1.06, FNPV US$ 4,783 million and FIRR 21.24%.

7.2. Recommendation for the next step

- BRT can be an effective and efficient tool for achieving the goal of providing high-quality public transport for all people because BRT is cheaper to plan and implement and can be done in relatively short time-frames for infrastructure projects. By requiring less time and money for implementation, BRT empowers cities to become resilient and adaptable to urban growth and climate change. Coupling this implementation with on-the-ground community engagement in underserved areas, cities can ensure equitable access and mobility for those residents who need high-quality public transport the most. With proper planning and investment, high-quality BRT can help catalyze the movement towards a more livable and sustainable scale of development for all people and mitigate the effects of climate change.
- Implementation of BRT actually involves four separate activities, and the way for implementing these activities are as follows:
  1) Conceptual design (Service plan and basic design);
  2) Detailed engineering design;
  3) Construction;
  4) Operation and maintenance

<Table 7-1> Timetable for an BRT project

Activity	Minimum amount of time required
Conceptual design (Service plan and basic design)	5-8 months
Detailed engineering design	6-12 months
Construction	12-18 months
Total	23-38 months (without preparation and maintenance period)

- Currently, based on the analysis for Nairobi's present status of public transport, basic concept plan of the BRT on the Outer Ring Road was established.
- Ultimately the project concept must enter the governing mainstream in order to move toward official development. Governing will and commitment are probably the most critical and fundamental components in making the BRT a reality.