Karachi Metropolitan Corporation
The Islamic Republic of Pakistan

THE STUDY FOR KARACHI TRANSPORTATION IMPROVEMENT PROJECT IN THE ISLAMIC REPUBLIC OF PAKISTAN

FINAL REPORT
VOLUME-2
(FEASIBILITY STUDY)

DECEMBER 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
YACHIYO ENGINEERING CO., LTD.
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Exchange Rate

1 Pakistan Rupee (Rs.)	= 0.871 Japanese Yen (Yen)
1 Yen	= 1.148 Rs.
1 US dollar (US$)	= 77.82 Yen
1 US$	= 89.34 Rs.

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Abbreviation

ADA	Americans with Disabilities Acts
ADB	Asian Development Bank
ATM	Active Traffic Management
BOD	Biochemical Oxygen Demand
BRT	Bus Rapid Transit
CBD	Central District Business
CBU	Complete Build-up
CDGK	City District Government of Karachi
CKD	Complete Knock-down
CNG	Compressed Natural Gas
DPF	Diesel Particulate Filter
DSCR	Debt Service Coverage Ratio
DTRA	District Regional Transport Authority
EDA	European Disability Acts
EIIR	Economic Internal Rate of Return
F/S	Feasibility Study

FC	Foreign Currency
FIIR	Financial Internal Rate of Return
GCP	Ground Control Point
GOS	Government of Sindh
GPS	Global Positioning System
GST	General Sales Tax
GVM	Gross Vehicle Mass
HIS	Household Interview Survey
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
IEE	Initial Environmental Examination
ITS	Intelligent Transportation System
JICA	Japan International Cooperation Agency
JST	JICA Study Team
KBRTC	Karachi Bus Rapid Transit Corporation
KCR	Karachi Circular Railway
KDA	Karachi Development Authority
KMC	Karachi Metropolitan Corporation
KMC	Karachi Municipal Cooperation
KMTC	Karachi Mass Transit Cell
KTIP	Karachi Transportation Improvement Project
KTIP-EMS	Karachi Transportation Improvement Project’s Environmental Management System
KUTC	Karachi Urban Transport Corporation
KUTMP	Karachi Urban Transportation Master Plan
LC	Local Currency
LRT	Light Rail Transit
LTC	Lahore Transport Company
M/P	Master Plan
MCI	Maintenance Cost for Insurance
MPGO	Master plan Group of offices
MRT	Mass Rapid Transit
NCS	National Conservation Strategy
NEQS	National Environmental Quality Standards
NOC	No-Objection Certificate
NPV	Net Present Value
O& M	Operation and Maintenance
O&D	Origin & Destination
OAC	Other Administrative Cost
PCUs	Passenger Car Units
	PEPA Pakistan Environmental Protection Agency, or Pakistan Environmental Protection Act
PEPO	Pakistan Environment Protection Ordinance
PHPDT	Passenger per hour per direction
PM	Particulate Matter
QCL	Quality Control Laboratory
ROW	Right of way
RTA	Road Traffic Accidents
SCOOT	Split Cycle Offset Optimization Technique
SOSE	Study on Social Environment
TCD	Transport & Communications Department
TFL	Transport for London
TSS	Total Solved Solid and Sulphide
UC	Union Council
ULSD	Ultra Low-Sulfur Diesel
V/C	Volume Capacity Ratio

VAT	Value Added Tax
VIC	Vehicle Insurance Cost
VMC	Vehicle Maintenance Cost
VOC	Vehicle Operating Cost
W& SD	Work & Services Department
WPI	Wholesale Price Index

The abbreviations, CDGK and KMC, used in this report are the name of the local governments of Karachi.
These two names were used in the reports because during the study period, the CDGK renamed to KMC, as per GOS Notification in this regard.

Chapter 1 Introduction

1.1 Karachi Transportation Improvement Project

1.1.1 Background

This report (Final Report, hereinafter referred as FR) describes the concept plan of Bus Rapid Transit System (BRTS) along Green Line and Red Line proposed in the master plan stage of the Study on Karachi Transportation Improvement Project (hereinafter referred as "the KTIP Study").

The KTIP Study aims to formulate the Karachi Urban Transportation Master Plan (KUTMP) 2030 and conduct a feasibility study for the priority project. The JICA Study Team organized by the Joint Venture of Nippon Koei Co., Ltd, Yachiyo Engineering Co., Ltd, and Oriental Consultants Co., Ltd commenced the Study in the middle of April 2010. Karachi Mass Transit Cell (KMTC) is the counterpart of the KTIP Study. The JICA Study Team conducted a Person Trip Survey including a Household Interview Survey whose sample size was as large as 40,000 households but the survey was delayed to a large extent due to worsening law and order situation. To avoid the critical influence on the entire schedule, the JICA Study Team started the demand analysis using 36,000 samples that was collected by the beginning of March, and submitted the Interim Report-1 (1) that include the results of the master plan study on 30th June, 2011.

City District Government of Karachi (CDGK) has been promoting the implementation of Light Rail Transit (LRT) for the Priority Corridor-I among the Karachi Mass Transit Corridors that was notified by the Government of Pakistan (GOP) in 1995. KMTC has been the main authority for the activity. The JICA Study Team organized the study members and work plan assuming that a railway system would be selected as the project for the feasibility study. The JICA Study Team proposed Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT). The cost-benefit performance of BRT is higher than that of LRT, while the capacity of MRT is higher than that of LRT. At the same time, it was concluded that MRT should be developed after the implementation of Karachi Circular Railway (KCR) which had shown the progress recently, taking into account of the amount of JICA loan and the budgetary condition of the local government of Pakistan.

As far as BRT concerns, Asian Development Bank (ADB) proposed three routes based on "Private-Public partnership based Environment Friendly Public Transport System for Karachi, 2006" and KMTC regards the implementation of the proposed BRT as one of the important projects. On the other hand, promotion of the BRT project became an issue of KMTC since ADB discontinued the BRT project.

The JICA Study Team consulted with KMTC about the plan to select BRT for the project of the feasibility study based on the result of the master plan and the intension of JICA at the time of the submission of Interim Report-1 (1). After that, JICA and KMTC had a talk on 5th July, 2011 about the feasibility study project and agreed that the JICA Study Team would conduct the feasibility study for the Green Line and Red Line that are proposed in the master plan.

On the other hand, KMTC raised a plan to extend the Green Line and Red Line in the Technical Committee on 23th July, 2011. Although a careful consideration is necessary for the proposal because the master plan did not evaluate the route, it would be better to consider the extension of these lines because it would be possible according to the type of BRT.

The JICA Study Team reviewed the work plan and reorganized the team members for efficient conduct of the feasibility study of BRT. Interim Report-1 (2), in which the updated work plan and staffing schedule are described, was submitted to KMTC in the end of August, 2011.

Interim Report -2 was submitted in the end of January, 2012.

1.1.2 Work Items

The followings are revised work items in the feasibility study stage.

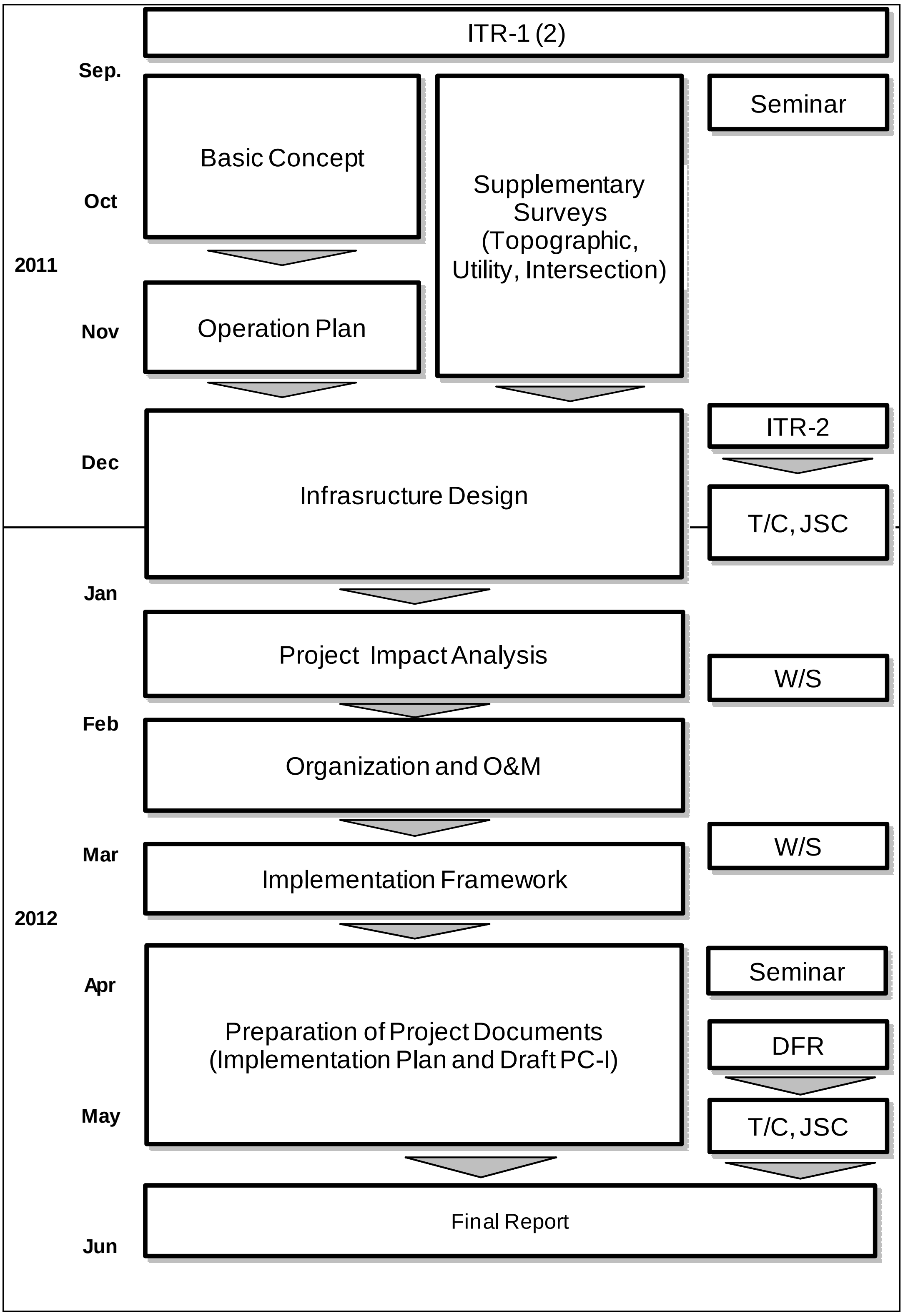
Table 1-1-1 Work Items in Feasibility Study Stage

Code-1	Work Item	Code-2	Sub Work Item
A	Master Plan Follow Up	A-1	HIS Analysis
		A-2	Demand Forecast Model Update
		A-3	Master Plan Update
B	Supplementary Surveys	B-1	Topographic Survey
		B-2	Utility Survey
		B-3	Turning Movement Traffic Count Survey
C	Conceptual Design	C-1	Bus Network and Route
		C-2	Station Locations
		C-3	Cross Section
		C-4	Vehicle Type
		C-5	Demand Forecast
		C-6	Selection of Depot
D	Operation Plan	D-1	Traffic Management
		D-2	Operation Plan
		D-3	Traffic Signal
		D-4	Fare Structure
E	Vehicle Plan	E-1	Vehicle Design
		E-2	Manufacturer Survey
		E-3	Procurement Cost Estimate
F	Infrastructure Design	F-1	Alignment Plan and Cross Section Plan
		F-2	Station
		F-3	Intersection
		F-4	Depot and Terminal
		F-5	Intermodal Facilities
		F-6	Cost Estimate
G	Environmental Consideration	G-1	Scoping
		G-2	Impact Forecast
		G-3	Impact Evaluation and Comparison of Alternatives
		G-4	Study of Mitigation Measures
		G-5	Monitoring Plan
		G-6	Stakeholder Meeting
H	Project Impact	H-1	Operation and Effect Indicator
		H-2	Environmental Improvement
		H-3	Qualitative and Quantitative Check
		H-4	Economic & Financial Analysis
J	Operation & Maintenance Plan	J-1	O& M Cost Estimate
		J-2	Cash Flow Analysis
K	Implementation Framework	K-1	Institutional Arrangement
		K-2	Project Cost Estimates
		K-3	Financing Plan
		K-4	Implementation Schedule
		K-5	Procurement
		K-6	Capacity Development Programme
L	Preparation of Project Documents	L-1	Implementation Plan
		L-2	PC-I
M	Technology Transfer	M-1	Workshop
		M-2	Seminar

Source: JICA Study Team

1.1.3 Work Schedule

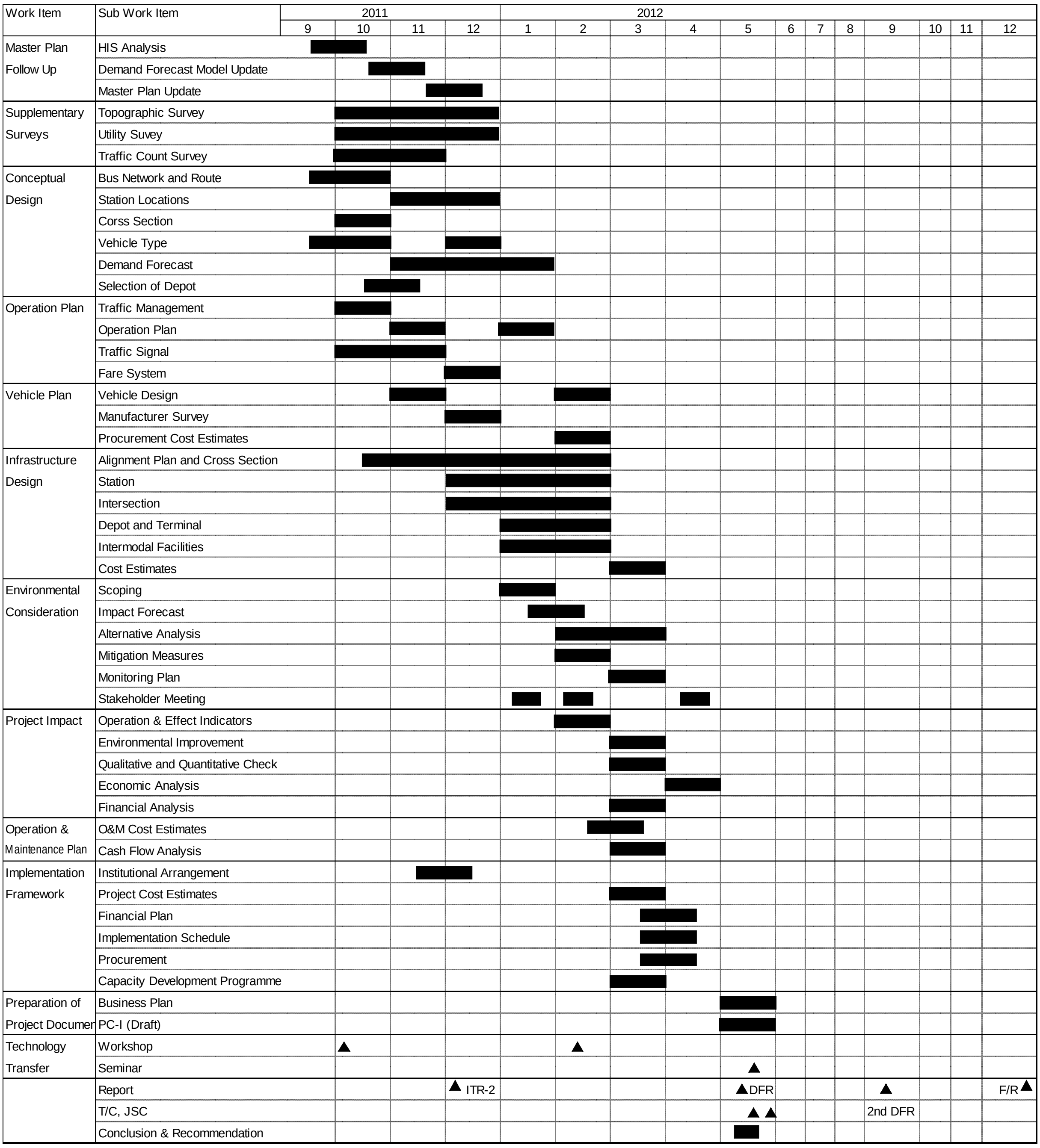
The figure below shows the original work schedule of the feasibility study.



Source: Prepared by the JICA Study Team

Figure 1-1-1 Work Flow

The schedule was changed according to the progress of the study. For example, the Technical Committee and the Joint Steering Committee after the Interim Report-2 were not held. Although the work in Karachi finished in the end of May as the original schedule, the submission of the Final Report was delayed because there were JICA's comments on the Draft Final Report and the JICA Study Team revised the report and submitted it as 2nd Draft Final Report to KMTC. Figure below shows the actual schedule of the study.



Source: Prepared by the JICA Study Team

Figure 1-1-2 Actual Schedule of the Study

1.2 Progress of the Household Interview Survey (HIS)

There remained sample backlogs in Clifton Cantonment while the survey in other areas in Karachi was completed. Although the number of samples collected in the HIS has already reached 41,225 in total against the target sample of 40,000, the collected number of samples in Clifton Cantonment was still low.

The reason of the poor response in Clifton Cantonment was that residents hesitate to give detail information of their family in fear of security risk. From this, the JICA Study Team simplified the questionnaire and removed detail information, while question about trip information remained in the survey form. In addition, the survey method was changed from direct interview method to drop-off & pick-up method.

1.3 Seminar & Workshop

The 1st seminar for the master plan study was held on September 29th, 2011 at Avari Tower Hotel. There were 75 participants from various stakeholders. The chief guest was Minister for Local Government. The contents of the presentation were:

- Study Presentation by Director General, KMTC
- Introduction of KTIP Study by JICA Study Team
- Household Interview Survey by Exponent
- Analysis of Household Interview Survey by JICA Study Team
- Master Plan Summary by JICA Study Team
- Detail Analysis of Master Plan by JICA Study Team

A workshop was held on March 2nd, 2012, at Avari Tower Hotel, to discuss BRT system as a part of the capacity development. The key topics were 1) Infrastructure, 2) Alignment, and 3) Station. The basic concept of BRT system proposed for Karachi was presented by the JICA Study Team, and the content was discussed by participants.

The 2nd seminar was held on May 24th, 2012 at Avari Tower Hotel. There were 65 participants from various stakeholders. The contents of the presentation were:

- The Presentation on the Study Report and Master Plan
- The presentation of the Feasibility Study on BRT Corridors

Photo: JICA Study Team (Left: 1st seminar. Right: 2nd Seminar)

1.4 Supplementary Survey

1.4.1 Topographic and Utility Survey

(1) Field Works for the Topographic and Utility Survey

Field works for the topographic and utility survey has been implemented under a contract with a local subcontract.

(2) Outline of survey

The outline of digitization and survey for Satellite Image Processing is as follows.

- Field reconnaissance & identification of GCPs
- GPS survey for establishing – GCP
- Adjustment of Satellite Image
- Image digitization after image processing and adjustment
- Adjustment of Satellite Image using GCPs
- Vertical & horizontal control points for field survey
- Topographic & Cross-section survey
- Depot area and its approach survey
- Utility survey
- Preparation of survey drawings

(3) GCP Control Points

Reconnaissance survey was carried out to identify the Ground Control Points – GCP. Initially 15 GCP points were selected for short-listing. Out of these 15 GCP points, 6 points were finalized for GCP observation.

Location of six control points is shown in Figure 1-4-1 and observed GCP coordinates are shown in Table 1-4-1.

Source: JICA Study Team

Figure 1-4-1 Location of Six Ground Control Points

Table 1-4-1 GCP Coordinate Value

STATIONS	EASTING	NORTHING	ELEVATION
GCP1	301710.517	2752303.742	16.284
GCP2	301274.505	2758151.343	27.964
GCP3	304643.030	2762131.735	41.895
GCP4	304849.165	2766814.327	56.808
GCP5	309756.354	2758497.752	52.198
GCP6	305284.291	2755314.136	27.791

Source: JICA Study Team

1.4.2 Water Quality Survey

The water quality survey to obtain the data of the present status around the project area was conducted during two seasons. Description of water quality survey is shown in Table 1-4-2. Total 38 parameters of chemical and biological were measured and analyzed.

As a result, average character of stream during dry and wet season is not showing a viable difference with respect of its criteria parameters. Some figures are exceeding than National Environmental Quality Standard (NEQS) for Municipal and Liquid Industrial Effluent including Biochemical Oxygen Demand (BOD), Total Solved Solid (TSS) and Sulphide.

Table 1-4-2 Description of Water quality survey

Site No.	Sampling Site	Water body	Survey Period
St. 1	Shaharah-e-Pakistan road bridge (End of Lyari Express)	Lyari River	1st : July 07, 2011 (Wet Season) 2nd :October 10, 2011 (Dry season)
St. 2	Jahangir Sethna road bridge	Lyari River	
St. 3	Mauripur road bridge	Lyari River	

Source: The Study for Karachi Transportation Improvement Project

1.4.3 Turning Movement Traffic Count Survey

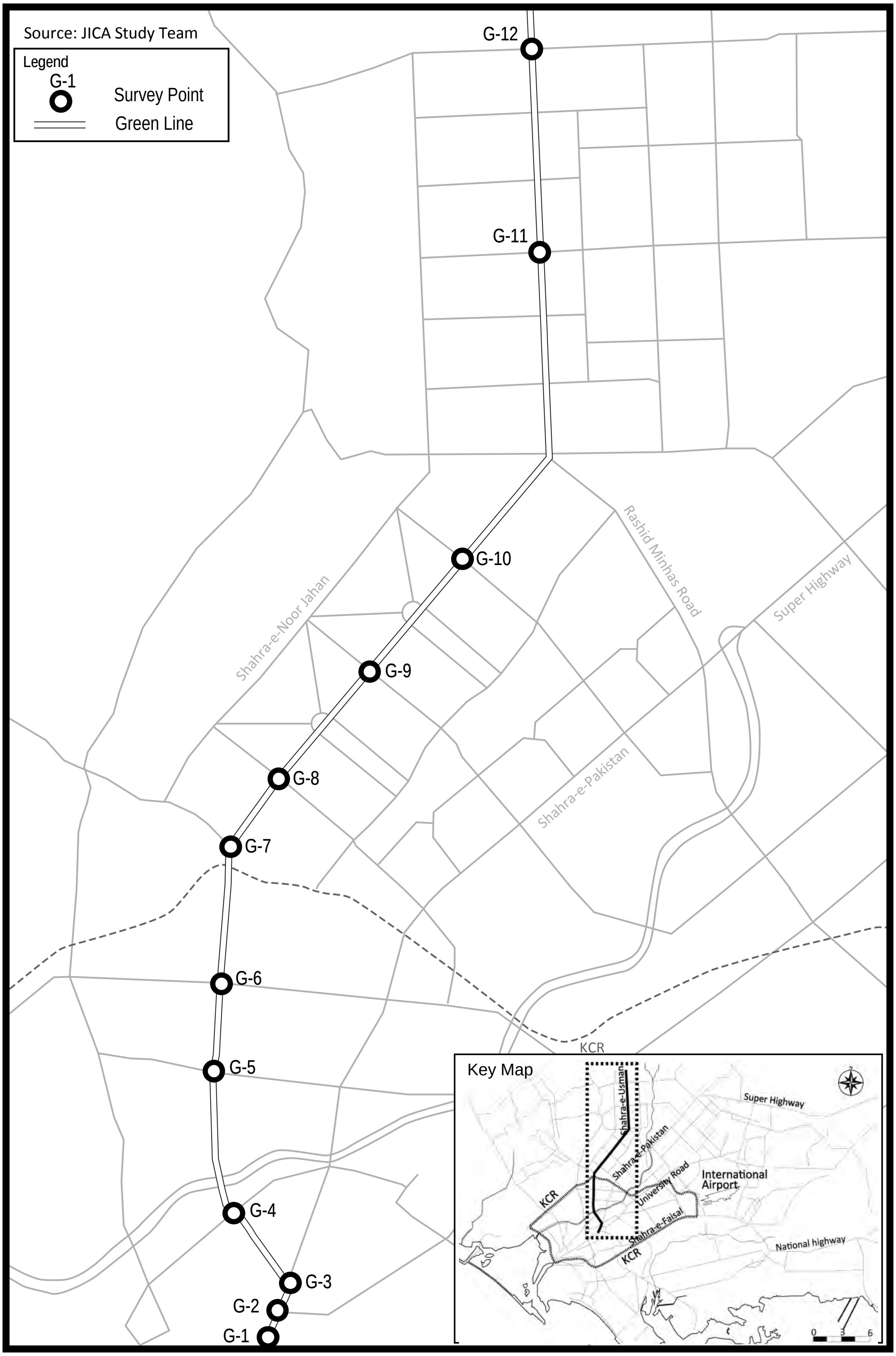
Introduction of BRT system requires signalization of BRT corridors. To analysis existing intersections, Turning Movement Traffic Count Survey was conducted at 20 major intersections along Green Line and Red Line. The contents of the survey are as follows.

- Traffic volume count by turning direction
- Surveys from 7:00 to 23:00 (16 hours)
- A weekday for each survey location
- 20 intersections including roundabouts (Figure 1-4-2, Figure 1-4-3)
- Vehicle classification is shown in Table 1-4-3.

Table 1-4-3 Vehicle Classification

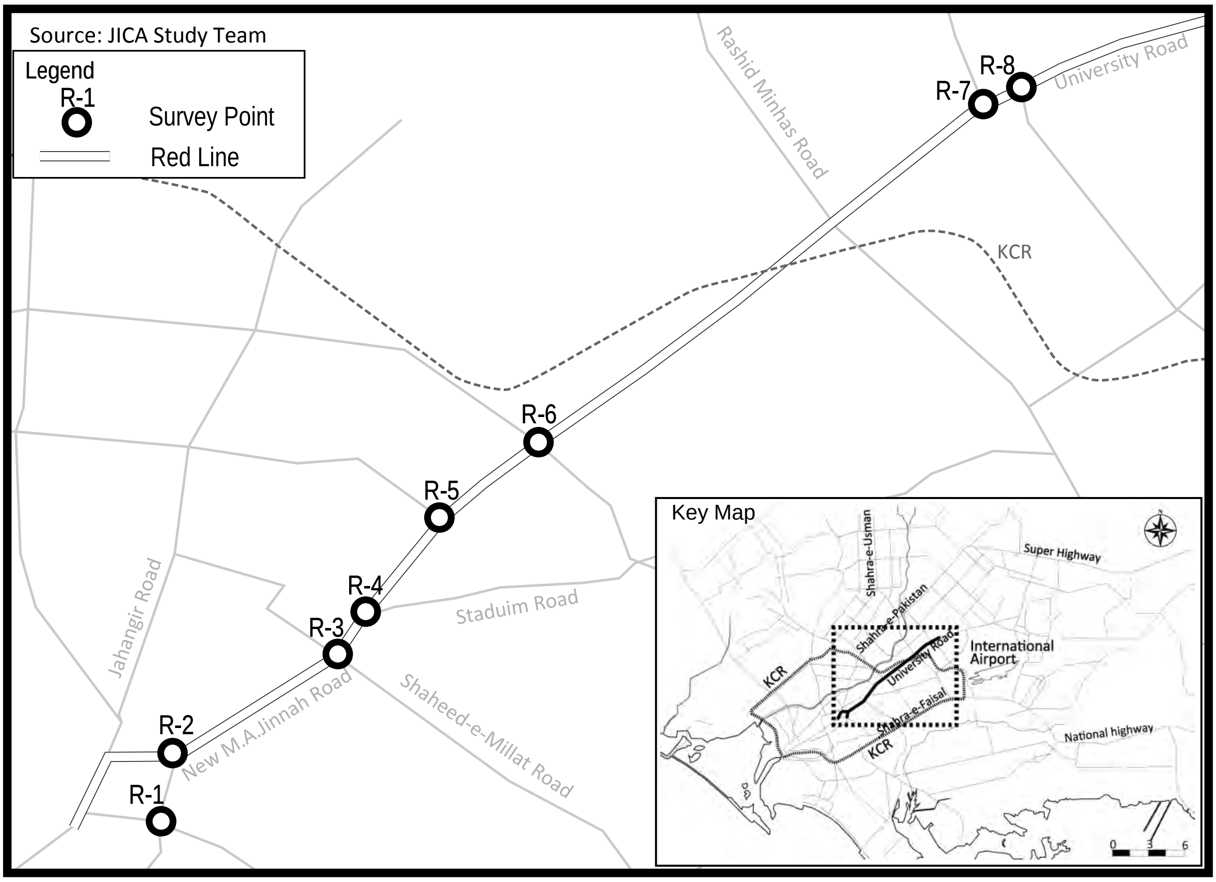
No.	Type	Description
1	Motorcycle	Motorcycles & Scooters
2	Auto Rickshaw	Old Style & CNG 4-Stroke
3	Car / Jeep / Taxi / Van	Cars, Jeeps & Station Wagons, Vans, Taxis
4	Pickup	Suzuki Pickups
5	Mini Bus	Mini Buses, Coaches
6	Large Bus	Intercity buses, UTS, KPTS
7	Truck / Trailer	Trucks, Trailers

Source: The Study for Karachi Transportation Improvement Project



Source: JICA Study Team

Figure 1-4-2 Location of Turning Movement Count Survey (Green Line) , 2011



Source: JICA Study Team

Figure 1-4-3 Location of Turning Movement Count Survey (Red Line), 2011

The results of Turning Movement Traffic Count Survey were recorded by survey location. Figure 1-4-4 and 1-4-5 show daily and peak traffic volume by direction (up and down) along Green Line, and 1-4-6 and 1-4-7 show one of Red Line.

UP ↑ SURJANI ↓ DOWN

Station	UP: Car+Pickup	UP: Rickshaw+ Motorcycles	UP: Bus+Minibus	UP: Truck/Trailer	DOWN: Car+Pickup	DOWN: Rickshaw+ Motorcycles	DOWN: Bus+Minibus	DOWN: Truck/Trailer
G-12	12,642	41,386	3,114	1,454	9,466	45,620	2,740	524
G-11	9,214	23,679	1,540	421	10,439	26,605	1,978	476
G-10	59,286	91,714	4,956	1,764	38,252	112,098	4,358	2,016
G-09	35,242	56,404	2,548	1,223	32,690	73,021	2,225	534
G-08	55,468	103,038	5,392	1,416	60,322	86,216	4,592	560
G-07	28,497	67,645	1,817	1,216	27,842	78,440	3,298	381
G-06	24,516	45,428	1,472	431	27,895	70,644	2,063	1,079
G-05	23,428	44,204	1,521	160	26,609	70,327	1,494	358
G-04	15,343	34,668	1,042	191	15,430	31,972	1,438	141
G-03	12,583	34,329	2,566	195	12,886	42,088	1,057	254
G-02	16,678	36,122	3,380	151	15,807	47,553	2,794	125
G-01	29,686	42,682	4,296	226	24,633	61,860	3,089	158

TOWER

Legend:

Car+Pickup	Rickshaw+ Motorcycles	Bus+Minibus	Truck/Trailer

Source: Turning Movement Count Survey 2011, the JICA Study Team

Source: JICA Study Team

Figure 1-4-4 Daily Traffic along Green Line

UP ↑ SURJANI ↓ DOWN

Station	UP Peak Hour	Car+Pickup	Rickshaw+ Motorcycles	Bus+Minibus	Truck/Trailer	DOWN Peak Hour	Car+Pickup	Rickshaw+ Motorcycles	Bus+Minibus	Truck/Trailer
G-12	20:00 – 21:00	864	4,620	238	32	08:00 – 09:00	564	5,726	286	34
G-11	20:00 – 21:00	657	2,657	154	15	10:00 – 11:00	981	3,288	101	43
G-10	17:00 – 18:00	5,072	8,268	340	142	20:00 – 21:00	1,916	8,504	264	78
G-09	18:00 – 19:00	3,223	5,606	147	75	09:00 – 10:00	2,262	7,092	183	51
G-08	18:00 – 19:00	4,586	9,168	346	94	08:00 – 09:00	4,698	10,144	442	8
G-07	18:00 – 19:00	2,452	7,556	131	151	08:00 – 09:00	2,974	6,641	225	9
G-06	20:00 – 21:00	3,041	4,329	68	14	08:00 – 09:00	2,795	6,755	201	55
G-05	18:00 – 19:00	1,719	5,364	105	13	10:00 – 11:00	1,782	6,214	109	31
G-04	19:00 – 20:00	1,801	3,873	68	16	09:00 – 10:00	1,416	3,396	135	27
G-03	19:00 – 20:00	809	4,427	148	9	13:00 – 14:00	895	3,834	98	12
G-02	19:00 – 20:00	1,637	4,533	201	6	09:00 – 10:00	2,716	4,405	236	14
G-01	19:00 – 20:00	2,999	4,881	340	10	12:00 – 13:00	2,614	6,184	236	11

TOWER

Legend: Car+Pickup | Rickshaw+ Motorcycles | Bus+Minibus | Truck/Trailer

Source: Turning Movement Count Survey 2011, the JICA Study Team

Source: JICA Study Team

Figure 1-4-5 Peak Traffic along Green Line

SAMAMA CHOWK

Station	UP Car+Pickup	UP Rickshaw+Motorcycles	UP Bus+Minibus	UP Truck/Trailer	DOWN Car+Pickup	DOWN Rickshaw+Motorcycles	DOWN Bus+Minibus	DOWN Truck/Trailer
R-08	26,981	23,212	1,269	291	14,970	13,138	1,136	63
R-07	26,731	24,091	1,252	387	1,259	1,946	1	4
R-06	41,772	48,568	4,077	848	32,826	34,233	3,431	645
R-05	18,622	53,488	2,513	264	27,908	39,556	2,071	361
R-04	17,267	19,160	1,753	174	51,493	53,029	4,480	125
R03	17,962	22,243	679	96	31,797	48,274	2,213	340
R-02	23,206	48,876	364	120	42,558	47,548	1,284	210
R-01	9,585	25,797	121	43	13,377	23,742	139	31

SHAH AHMED NOORANI CHOWK

Legend:

Car+Pickup	Rickshaw+ Motorcycles	Bus+Minibus	Truck/Trailer

Source: Turning Movement Count Survey 2011, the JICA Study Team

Source: JICA Study Team

Figure 1-4-6 Daily Traffic along Red Line

UP — SAMAMA CHOWK — DOWN

Station	UP Time	UP Car+Pickup	UP Rickshaw+Motorcycles	UP Bus+Minibus	UP Truck/Trailer	DOWN Time	DOWN Car+Pickup	DOWN Rickshaw+Motorcycles	DOWN Bus+Minibus	DOWN Truck/Trailer
R-08	14:00 – 15:00	2,811	1,583	110	26	08:00 – 09:00	1,801	1,869	66	3
R-07	19:00 – 20:00	3,308	2,425	79	27	14:00 – 15:00	116	152	0	0
R-06	19:00 – 20:00	4,323	5,018	253	46	08:00 – 09:00	4,103	2,191	247	13
R-05	19:00 – 20:00	1,743	6,401	215	17	09:00 – 10:00	3,445	3,354	218	35
R-04	09:00 – 10:00	1,771	1,695	241	15	09:00 – 10:00	3,717	5,002	361	6
R03	19:00 – 20:00	1,843	2,233	41	7	09:00 – 10:00	3,796	4,558	182	16
R-02	19:00 – 20:00	3,016	5,410	4	0	09:00 – 10:00	6,198	5,036	134	6
R-01	19:00 – 20:00	1,039	3,019	3	0	09:00 – 10:00	2,150	3,242	5	1

SHAH AHMED NOORANI CHOWK

Legend:

Car+Pickup	Rickshaw+ Motorcycles	Bus+Minibus	Truck/Trailer

Source: Turning Movement Count Survey 2011, the JICA Study Team

Source: JICA Study Team

Figure 1-4-7 Peak Traffic along Red Line

Chapter 2 Bus Rapid Transit (BRT) for Karachi

2.1 Feature of Bus Rapid Transit (BRT)

2.1.1 World Trend

Bus Rapid Transit (BRT) is a high quality bus system providing high speed, reliable, and comfortable services compared to traditional bus services. The concept of BRT is based on railway system, i.e. running along exclusive way, high speed, accurate travel time, and high capacity.

Curitiba (Brazil) introduced a high quality bus service system in 1974, which is now recognized as the first successful case of BRT in the world although some advanced bus transit services such as busway and bus exclusive lanes had been introduced in some cities. In 2000, Bogota (Columbia) opened innovative BRT system (TransMillenio) which made great impact on transit planners and decision makers in the world, showing that the BRT can achieve high capacity transport service similar to railway system.

Curitiba
Photo: Toshiyuki Okamura

Bogota
Photo: Toshiyuki Okamura

In the 2000s, a number of capital cities in the world introduced BRT such as Taipei (2001), Seoul (2004), Jakarta (2004), Beijing (2005), New Delhi (2008), Istanbul (2008), Lima (2010), and Bangkok (2010).

BRT has been recognized as a cost-efficient mass transit system which can solve urban transport problem in not only developing country but also developed country.

2.1.2 BRT Type

There are a number of variations for BRT, and the boundary between BRT and conventional bus services is not clear as far as the physical appearance concerned. A typical BRT is the bus transit service on exclusive lanes in road spaces.

As defined in "Private /Public Partnership based Environmentally- friendly Public Transport System For Karachi, 2006", there are three levels of BRT system commonly used for the classification of BRT.

- Level 1 Bus Lane
- Level 2 Busway
- Level 3 BRT

Level-1 system usually provides a bus lane along kerb side. The bus lane is sometimes a priority lane which gives priority of using the lanes to buses but other vehicles can use the lanes when the bus traffic is not heavy, and other times an exclusive lane. In case that this system is introduced in the urban street system where access demand along the road side exist and there are intersections with crossing streets, the bus lanes are easily interrupted by other vehicles.

To avoid interweave of buses and other traffic, bus lanes are located in the center of roads in Level-2 systems. The Busway system is usually a part of the network of general bus services. The improvement of bus services by introduction of this system would be insufficient in case that there are a number of operators (like Karachi) and it is allowed to use the busway by many operators. The BRT systems in Seoul and Taipei are the examples of this system.

Level-3 system is similar to railway system. In most cases, buses are only operated on the dedicated lanes controlled by a single operator along the lanes. Since the BRT buses need not run in general traffic roads, advanced vehicle technologies can be used to increase the capacity and speed. In addition, pre-board fare collection reduces dwell time at bus stations.

Seoul (Level 2)
Photo: Thoshiyuki Okamura

Lima (Level 2)
Photo: Nippon Koei Co., Ltd.

Metrobus (Istanbul) is the example of BRT of Level-3. Note that Level-3 does not necessarily mean high capacity system. For example, TransJakarta (Jakarta) is categorized to Level-3 system but the capacity is very small.

TransMillenio (Bogota) is quite different from other BRTs in terms of the capacity, speed, and quality. It is classified as “Full BRT”.

Jakarta (Level 3)
Photo: Nippon Koei Co., Ltd.

Istanbul (Level 3)
Photo: http://www.iett.gov.tr

2.1.3 BRT Capacity

The Bogota BRT (TransMillenio) shows that BRT system can provide transport capacity as high as railway system, by achieving the capacity of 43,000 passengers per hour per direction. From this, BRT has been proposed in many cities as an alternative of rail-base mass transit system.

However, TransMillenio is very special case and no other BRT has achieved such a high traffic throughput. The success of TransMillenio brought about misunderstanding of BRT capacity as if BRT can be an alternative of railway system in terms of capacity.

The maximum capacity of a standard BRT is approximately 13,000 passengers per hour per direction.

BRT capacity depends on the service frequency and vehicle capacity as same as railway system. The service frequency depends on dwell time and clearance time. In case that dwell time and clearance time is 20 and 20 seconds, respectively, the frequency is calculated at 1.5 buses per minutes (60/(20+20)), meaning 90 buses per hour (1.5*60). If articulated buses having the capacity of 150 passengers are used, the capacity is calculated at 13,500. This is the case when the stopping bay is fully used by vehicles all the times. The percentage of time that a stopping bay is used by vehicles (saturation level) affects the vehicle speed. It is recommend that saturation level is less than 0.4 to ensure the proper operating speed[1]. If the saturation level of 40% is applied, the above calculated capacity becomes 5,400 passengers per hour per direction.

Additional stopping bays can increase the capacity. The following is the formula to calculate the system capacity of BRT.

$$\mathrm{Ca[pax/hour]} = \sum_{\mathrm{i=1}}^{\mathrm{Nsp}} \mathrm{X_i} \times \frac{\mathrm{3600[sec/hour]}}{\mathrm{Tsb[sec/bus]} \times (1 - \mathrm{Dir_i}) + \mathrm{To[sec/bus]}} \times \mathrm{Cp[Pax/bus]}$$

Where,

Ca [pax/hour]	System capacity (Passengers per hour per direction)
Nsp	Number of stopping bays
Tsb [sec/bus]	Passenger boarding and alighting time per bus (Dwell time)
To [sec/bus]	Minimum interval between buses (Clearance time)
$\mathrm{Dir_i}$	Ratio of passing buses
Cp [pax/bus]	Bus capacity (passengers capacity per bus)
$\mathrm{X_i}$	Saturation level

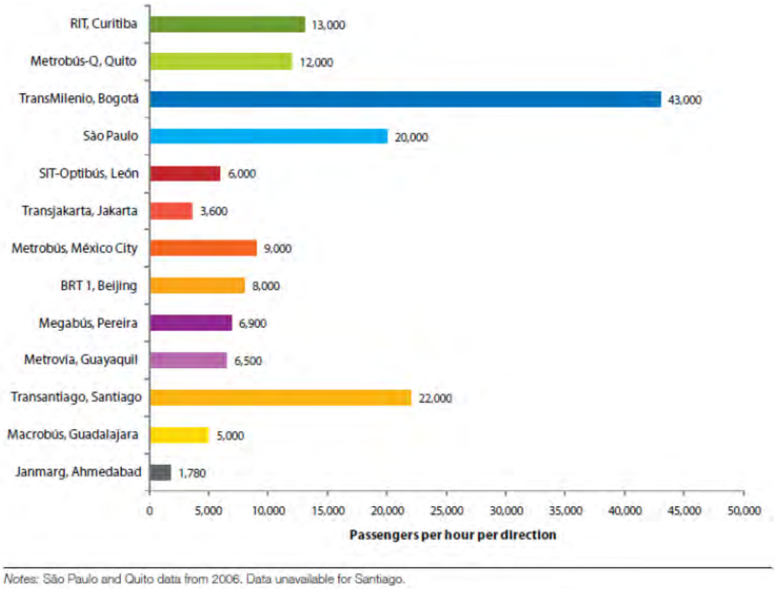
Source: EMBARQ (translated from the original in Spanish)

If a station has three stopping bays, the above calculated capacity (5,400) increases to 16,200. The ratio of passing buses (express operation) is also an important factor to increase the transport capacity.

Note that the addition of stopping bays requires passing lane at station.

Figure below shows examples of passenger volume per hour per direction in the world. Only Bogota's BRT achieves the capacity of 43,000, followed by Sao Paulo and Santiago at the capacity of approximately 20,000. The throughput of Curitiba and Quito is approximately 12,000 – 13,000. Other cities show the passenger volume of 3,600 – 9,000.

[1] Bus Rapid Transit Planning Guide, June 2007



Source: EMBARQ

Figure 2-1-1 Comparison of Hourly Passenger Volume per Direction

The capacity of BRT is similar to Light Rail Transit (LRT) of at-grade type.

As far as the capacity concerned, the present bus operation in mixed traffic lanes shows relatively high passenger volume. For example, M.A. Jinnha Road carries 21,000 bus passengers per hour per direction in a peak hour and Shahra-e-Faisal carries 14,000 bus passengers. Bus passenger volume reaches 22,000 per hour per direction along University Road near Jail Chowrangi.

2.1.4 Speed

The world experiences show that BRT is not necessarily high speed system. The average commercial speed of a standard BRT is approximately 20km/h ranging from 15 to 25km/h, while Transmillenio achieves approximately 30km/h. It is expected that a standard BRT can achieve a commercial speed of 25-30km/h. The commercial speed depends on the distance between stations, the density of intersections to be crossed, and necessary time at stations. Due to the delay at intersections, the maximum speed of a BRT without stopping at stations would be approximately 30-40km/h depending on the signal pashing given to BRT lanes. With the stopping at stations, the speed would reduce to 20-30km/h.

Since the average speed of existing minibuses in Karachi is approximately 17km/h, the speed of 20km/h will produce very small benefit from travel time saving. Therefore, it is necessary to achieve higher commercial speed.

2.1.5 Elevated BRT

Since low cost urban transport system is the basic concept of BRT, it is not popular to use elevated structure although elevated structure can segregate bus lanes completely from mixed traffic. The examples of elevated BRT are:

- Nagoya (Japan) introduced “guideway” bus in 2001, having 6.5km elevated section. Nagoya City subsidized 85 % of the cost of the infrastructure.
- Expresso Tiradentes is the elevated BRT system in Sao Paulo (Brazil), which was put into service in 2007 with length of 8.5km.
- Xiamen (China) BRT is an elevated BRT system with 3 lines in the total length of 67.4km. The system was put into service in 2008.

Stations of these systems are similar to that of elevated railway systems. The higher operational speed can be achieved compared to at-grade BRT systems because intersection delay does not exist along the elevated section. However, capacity of these systems is not necessarily high because passing lanes are not provided.

2.1.6 Cost Performance

The construction and equipment costs of BRT are very low compared to other mass transit system. Capital costs of BRT system varies from US$ 1.4 million per kilometer (Transjakarta) to US$ 5.7 million per kilometer (Megabus, Pereira) while the capital costs of Transmillenio was US$12.5 million per kilometer[2]. Since Transmillenio is exceptional case, the capital costs of BRT is less than US$6 million per kilometer.

The cost of BRT system in Karachi was estimated as Rs. 270 million (US$ 3.2 million) per kilometer in Interim Report-1 (I/R-1), which is lower group of BRT costs in the world. On the other hand, railway network of the master plan in I/R-1 was estimated as Rs. 5.0 billion per kilometer, which is 20 times higher than that of BRT system.

Most BRT systems use existing right-of-way (ROW) of roads for bus exclusive lanes, which consume median space or carriageways. The cost of losing the road space should be considered in the BRT planning.

The disadvantage of BRT over the cost performance is operation and maintenance (O&M) costs, especially fuel costs. Presently, O&M cost of a modern large bus is approximately Rs.40 per kilometer in Karachi (excluding drivers' salary and other administrative costs). Assuming an average occupancy rate of 40 passengers per bus, the O&M cost per passenger-kilometer is calculated as Rs. 1. Since buses need to run between depot and main routes without passengers, the average number of passengers must be lower than the assumption, which means that the O&M cost must be higher than Rs. 1. On the other hand, the O&M cost of railway systems proposed in the master plan was calculated as Rs. 0.5 per passenger-kilometer including staff salary and administrative costs.

2.1.7 Institutional Structure

(1) Typical Structure

There are various institutional structures for BRT operation in the world depending on the local conditions. However, the following is the typical principal for the successful operation of BRT.

- Competition of private sectors for the concession of BRT operation by proper bidding to reduce the cost
- Independent concession of fare collection for transparent distribution of fare revenue
- Payment to the operator based on the service output such as vehicle-kilometers
- Infrastructure (bus lanes, stations, and terminal) is developed by public sector
- Vehicles are purchased by private sector
- Fare system is integrated with feeder buses

(2) Best Practice: URBS-Curitiba Urbanization

This is a public organization developed for management of BRT system.

- Created by Municipal Law in 1963
- Based on the Master Plan of1966
- Planning and development –Institute of Urban Research and Planning (IPPUC)
- Implementation and Management –URBS
- Similar to TransMilenio - report to the Mayor

[2] EMBARQ (Lessons learned from major bus improvements in Latin America and Asia, Modernizing Public Transportation)

(3) Best Practice: TransMilenio, Bogotá

This is a Public Company developed for the BRT system

- Created in 1974 as a public company
- Report to the Mayor through a Board of Directors
- Manage vehicle operations, fare collection system through private sector operators
- Plan the System
- Program the Operation
- Oversees Quality Control
- Contract Management

(4) Best Practice: Transport for London (TfL)

This is a PPP Company with wide range of coordinating activities across entire London metropolitan area Contracts private firms for infrastructure development and operations of London Bus System, London Underground System, Light Rail Lines, Traffic Management and Taxi Regulation.

- Created In March 1998 as a PPP company with the goals and objectives to provide a sustained high-level of funding together with engineering skills required to rehabilitate and regenerate the London Underground (Tube).
- The PPP structure divides London Underground into four parts or the next 30 years-three private sector infrastructure companies. Public sector operating company, London Underground, is a part of TfL.
- In this PPP structure, three private sector infrastructure companies take control of London Underground assets - trains, tracks, tunnels, signals and stations – that are effectively privatized for 30 years. London Underground will manage the PPP contracts and provide train operation and station staff.
- It is the responsibility of private infrastructure companies to raise the money to invest in London Tube network and carry out maintenance and engineering work that should lead to its regeneration and improvement.

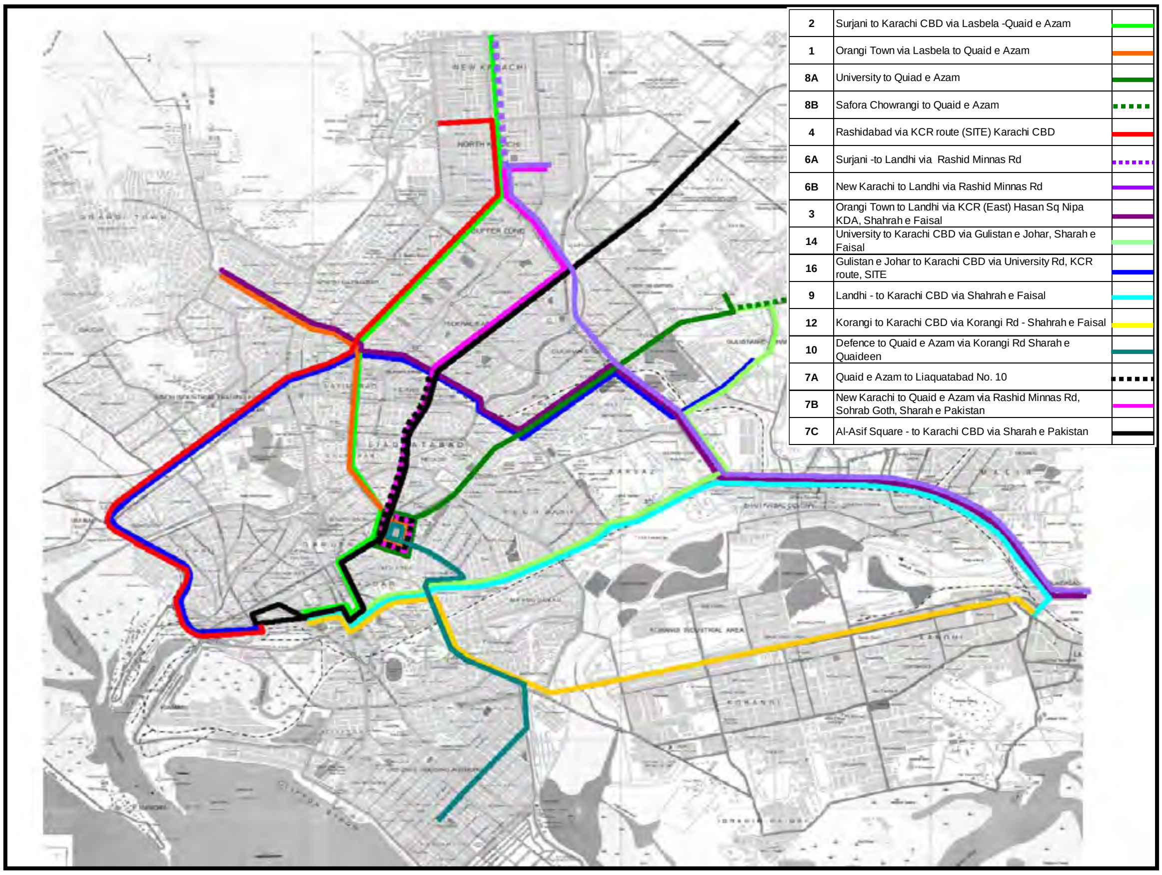
2.2 Review of BRT Studies in Karachi

2.2.1 PPP Environmental Friendly Public Transport System (2006)

BRT as mass transit system for Karachi was proposed in "Detailed Study on a Private /Public Partnership based Environmentally-friendly Public Transport System for Karachi". According to KMTC, this is one of the most important studies about mass transit system in Karachi.

(1) BRT Route

This study proposed 16 bus routes as shown in Figure 2-2-1. Out of 16 proposed BRT routes, 3 lines were proposed to use the KCR line Karachi Central Station and NIPA. From this figure, it is clear that the KCR route plays an important role to formulate BRT corridors in the study. The study emphasized the advantage of converting KCR to BRT. In this case CDGK must purchase the right-of-way of KCR from Pakistan Railways.



Source: Detailed Study on a Private /Public Partnership based Environmentally-friendly Public Transport System for Karachi

Figure 2-2-1 Proposed BRT Network

The BRT routes were grouped into 4 phases. Table 2-2-1 shows the route number of the proposed bus routes by phase and the corresponding routes in the KTIP Study. Most BRT routes in the study were incorporated in the KTIP master plan to some extent except for No. 9 and 14 along Shahrah-e-Faisal Road. Instead of No. 9 and 14, KCR was proposed in the KTIP.

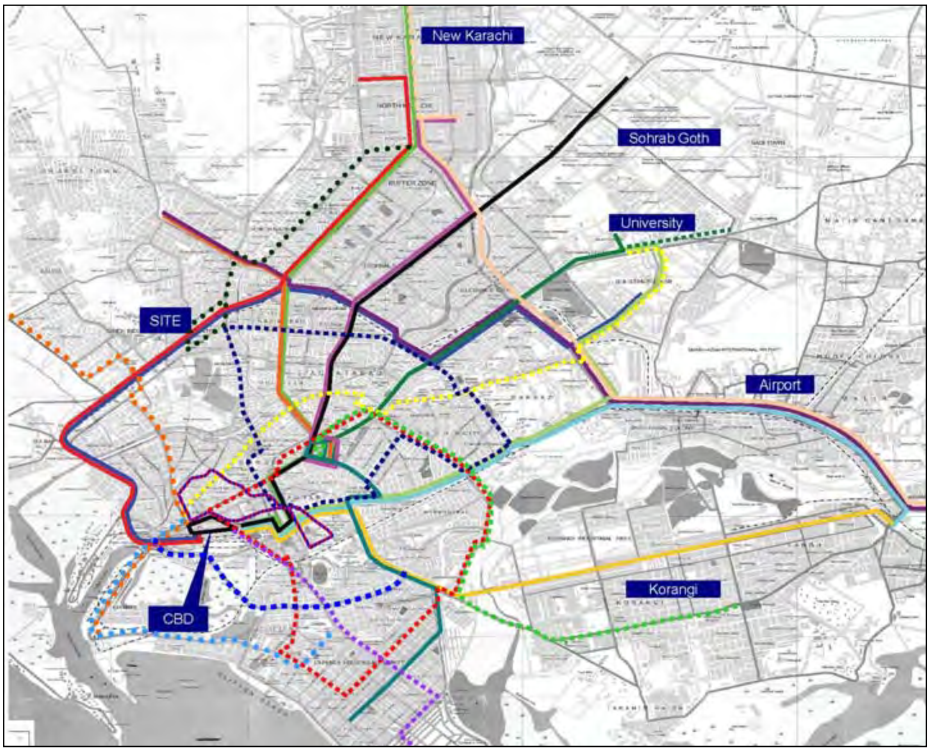
Table 2-2-1 Proposed BRT Routes

Phase	No.	Corresponding Routes in KTIP
1	2	Green Line
	1	Orange Line
	8A	Red Line
	8B	Red Line
2	4	**KCR** + Green Line
	6A	Brown Line
	6B	Brown Line
	3	Orange Line + **KCR** + Red Line
3	14	--
	16	**KCR** + Red Line + Brown Line
	9	--
	12	Yellow Line
	10	Red Line
4	7A	Blue Line
	7B	Blue Line + Brown Line
	7C	Blue Line

Source: Detailed Study on a Private /Public Partnership based Environmentally-friendly Public Transport System for Karachi

(2) Secondary Bus Network

Secondary routes (369km by 21 routes) were designed in this study to complement and support the BRT network as shown in the figure below. It was recommended that the gross cost contract model would be applied to the secondary routes as same as BRT routes.



Source: Detailed Study on a Private /Public Partnership based Environmentally-friendly Public Transport System for Karachi

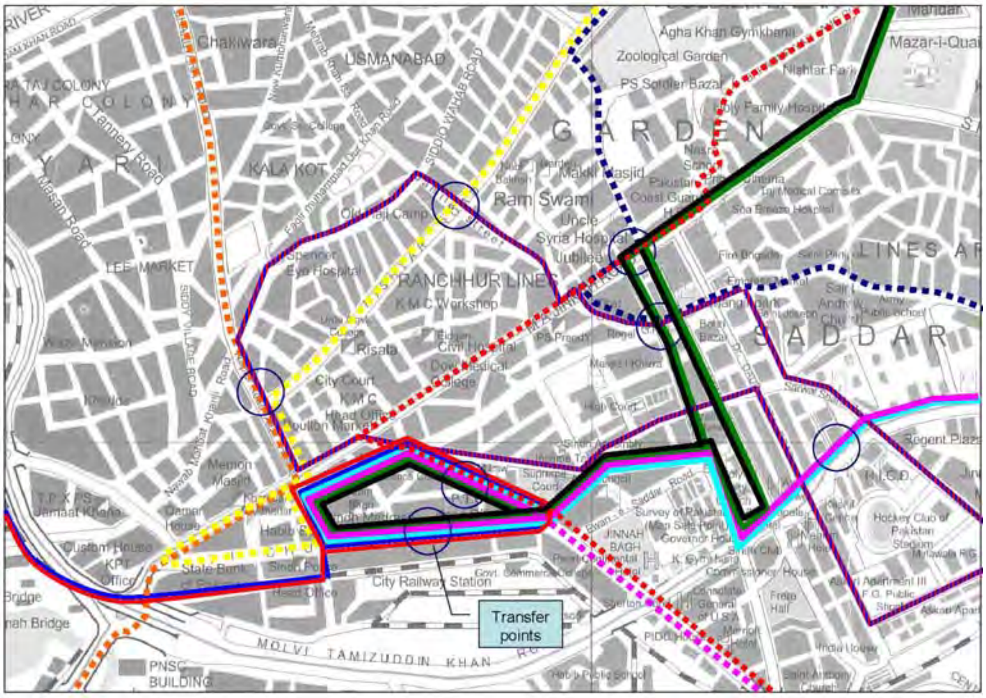
Figure 2-2-2 Proposed Secondary Routes

(3) Bus Routes in Saddar Area

BRT route between Tower and Garden Square was not proposed in the study. For the access to CBD, a one-way route was proposed from M.A. Jinnah Road turning left to Zaibunissa Street to Galaxy Chowk, and returning through Metropole Roundabout and Abdullah Haroon Road to M.A. Jinnah Road.

Although Fatima Jinnah Road (approximately 20m) can fiscally accommodate a single BRT lane between Garden Square and Metopole Roundabout, it would require difficult traffic management on stopping or parking traffic for roadside commercial buildings.

This route is congested so heavy that it would be difficult to accommodate dedicated BRT lanes. In peak hours, Metrople Roundabout is heavily congested due to private car traffic for all directions.



Source: Detailed Study on a Private /Public Partnership based Environmentally-friendly Public Transport System for Karachi

Figure 2-2-3 BRT in CBD

(4) Business Model

The study proposed a performance based contract for the BRT operation. In this case, the operator will receive the contact payment from the government based on vehicle kilometers of bus operation. Operators must pay operation and maintenance cost. The government will receive the fare revenue from passengers. The government needs to take revenue risk. Even if fare revenue is small due to low passenger demand, the government must pay the contract price to the operator based on the vehicle kilometers.

(5) Vehicle Type

The study proposed following types:

- Articulated bus
- More than 160 passengers capacity
- Doors on right side for boarding and alighting
- 0.9m floor height

(6) Infrastructure Design

After the study, infrastructure design for BRT was studied by Karachi Mass Transit Cell in 2007 employing Engineering Associates as the consultant. The characteristics of the drawings are:

- BRT lanes are proposed along KCR lines.
- BRT stations are proposed near intersections with pedestrian bridges which can be accessed from all corners of the intersections.
- BRT lanes are located along curb side along the narrow roads.
- Right door BRT is assumed but left door BRT is proposed at some sections.
- Solution of traffic conflict between U-turn and BRT lanes is not shown.

2.2.2 Karachi BRT Pre Feasibility Planning Study

(1) Status of the Study

Based on the above mentioned study, Asian Development Bank (ADB) identified 11 BRT Lines and selected Lines 1 and 3 as the initial pilot project. After that, ADB conducted a pre-feasibility study for the two BRT routes – Lines 1 and 3. Lines 1 and 3 correspond to Green Line and Orange Line in KTIP, respectively. On the other hand, Line 2 corresponds to Red Line. This study had not been completed because of the withdrawal of ABD from the BRT project as a part of Megacity Project in 2007. The results of the study are described in the draft final report.

Note that the plan of BRT Line-1, 2, and 3 is one of the official master plans in Karachi, according to KMTC.

(2) Vehicle Type

The proposed BRT system was center BRT lanes with median stations in the center for right door buses. This is as same as the proposal in "Private/ Public Partnership based Environmentally - friendly Public Transport Systems for Karachi.

(3) Traffic Management

The study pointed out the issues about traffic management at roundabouts and median breaks. For the median break, it is described as follows.

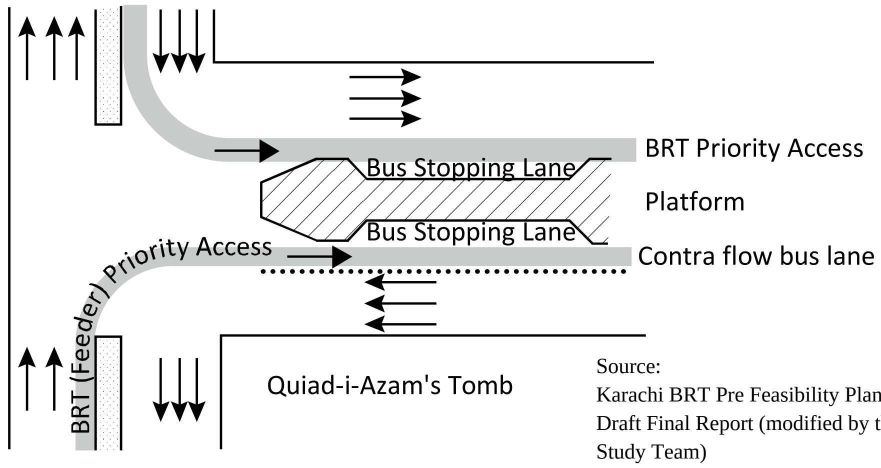
> *The general recommended treatment for the median breaks is to close them to maintain the integrity of the BRT alignment. Traffic will either be diverted to the next signalised intersection or roundabout along the alignment. Where feasible, the local service roads in the alignment should be refurbished and/or upgraded to enable this local traffic to circulate relatively easily. These measures will minimize the impact of the closure of the breaks and in the process, reduce the requirement for them. – Page 27*

> *The median break between Station 7 and 8 at the SSGC Gas Customer Centre will require closure to maintain the integrity of the BRT alignment. – Page 36*

(4) BRT in Saddar Area

This study concluded that it would not be feasible to provide BRT services in Saddar Area and proposed feeder system between Saddar Area and Mazar Terminal. The proposed route is similar to that in "Detailed Study on a Private/Public Partnership based Environmentally-friendly Public Transport System for Karachi".

Mazar Terminal was proposed along the part of M.A. Jinnah Road located in the north of Quaid-e-Azam Mausoleum. The conceptual layout plan in the BRT Pre Feasibility Study is shown in the figure below. A terminal station is proposed for the transfer between BRT (right door) and feeder buses (left door). It is not described how BRT buses return to the BRT lane in the north and how feeder buses return to CBD.



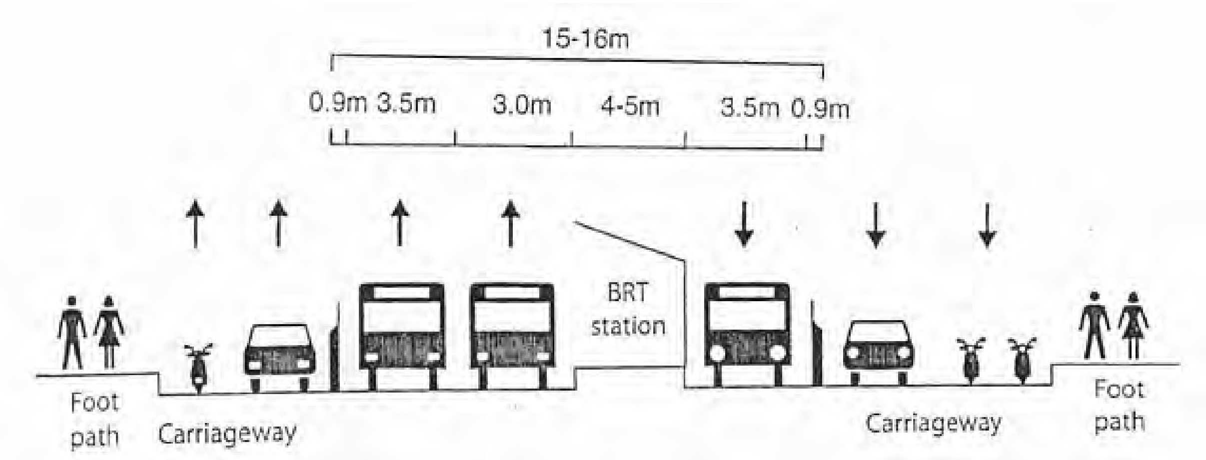
Source:
Karachi BRT Pre Feasibility Planning Study, Draft Final Report (modified by the JICA Study Team)

Figure 2-2-4 Concept Sketch of Mazar Terminal

(5) Cross Section

Typical cross section proposed in the study is illustrated as shown below. The width of BRT section at the station is 15-16m consisting of two passing lanes (3.5m×2), a bus stopping lane (3.0m), platform (4-5m), and two spaces for barrier structure (0.9×2). The total width excluding sidewalks becomes 30m in case of two-lane carriageway for both sides.

The ticket sale booth and the ticket gate are proposed to locate on the pedestrian bridge which connects sidewalks and the station platform.



Source: Karachi BRT Pre Feasibility Planning Study Draft Final Report

Figure 2-2-5 Typical Cross Section at BRT Station

(6) Elevated Section

The section between Nazimabad No.1 Chowrangi and Lyari River is heavily congested due to road side parking for market activity. Since the parking vehicles usually occupy two or three lanes, only a single lane is available for both directions in most time. The study evaluated that at-grade BRT along this section would not be feasible and elevated sections are proposed between Nazimabad No.1 Chowrangi and Gurumandir.

(7) Station Location

The study identified 18 BRT stations for Line-1 between Quaid-e-Azam and Surjani. The study report mentions that the locations were selected with KMTC staff.

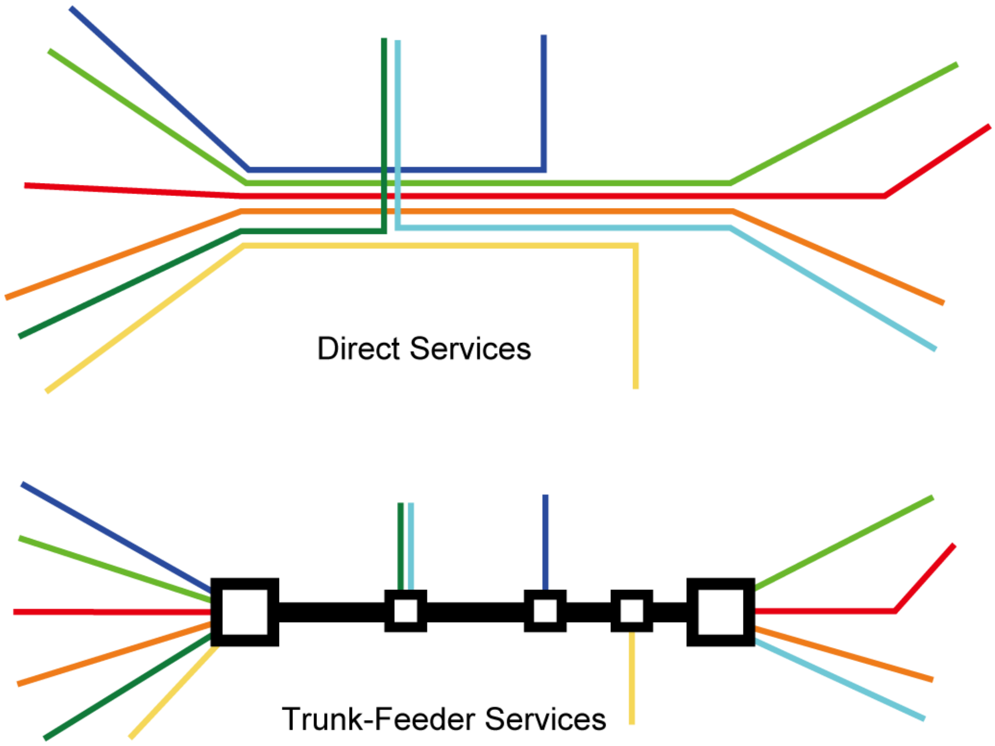
2.3 BRT Scenario in Karachi

2.3.1 Trunk–Feeder Services and Direct Services

(1) Characteristics of Trunk-Feeder Services and Direct Services

Development of a high capacity BRT system requires specialized types of vehicle which are usually different from normal buses presently running on mixed traffic lanes. For example, articulated (generally 18m) or bi-articulated (generally 24m) buses are used to increase passenger capacity. To decrease boarding and alighting time, floor height is adjusted for platform height and on-board fare collection is not considered in most systems. Due to these differences, BRT buses run along the BRT corridors only, and feeder routes provide services outside the service area of the corridors. This means that high capacity BRT system requires truck-feeder services in nature.

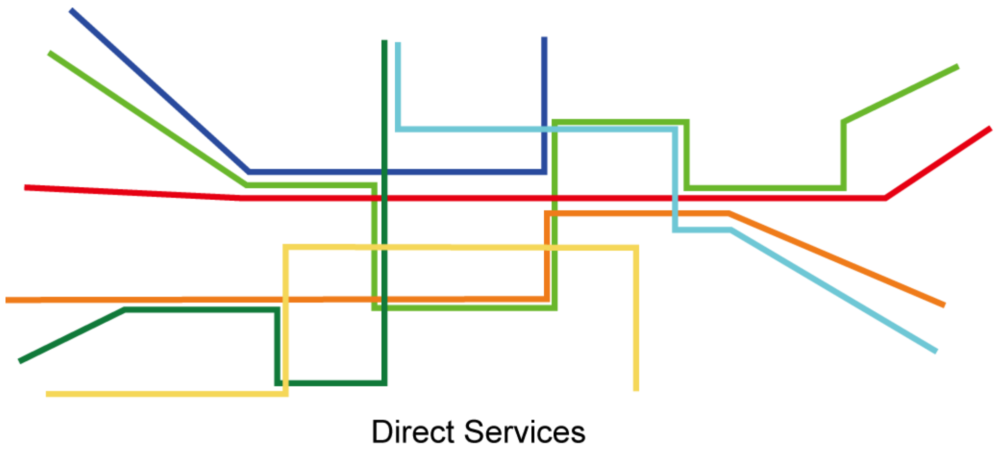
The figure below illustrates the concept of direct services and trunk-feeder services.



Source: illustrated by JICA Study Team

Figure 2-3-1 Conceptual Diagram of Trunk-Feeder Services

Restructuring of bus network from direct services to trunk-feeder services will improve operational efficiency if high demand corridors are properly transformed to trunk routes and the outside of the service area of trunk routes are covered by feeder services. The degree of the improvement by introducing trunk-feeder services depends on the present urban structure. If the passenger demand is almost the same along the major arterial roads all over the area, identification of trunk routes is difficult. If traffic demand concentrates on several corridors, trunk routes can be identified easily. There is a chance that restructuring bus network connecting various areas by direct service as shown in the figure will not improve operational efficiency.



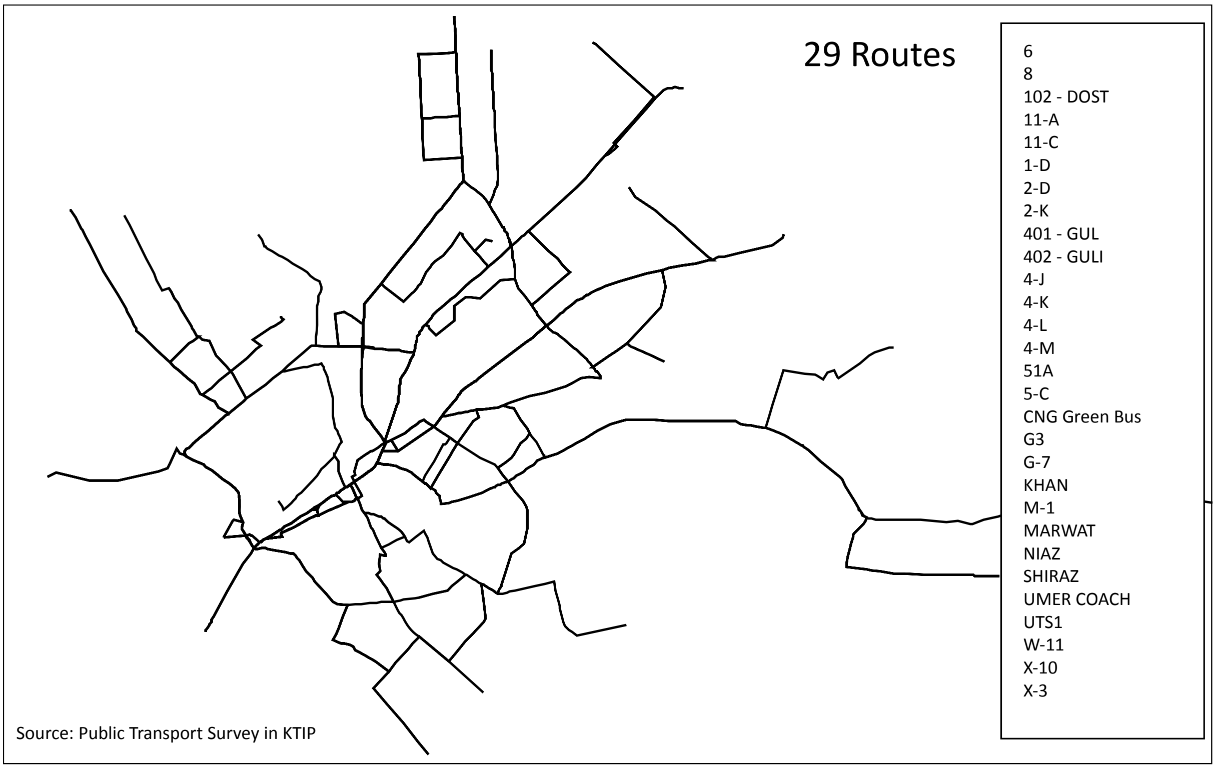
Source: illustrated by JICA Study Team

Figure 2-3-2 Conceptual Diagram of Direct Services of Various Routes

(2) Present Bus Network

Reorganization of the present bus network from direct services to trunk-feeder services requires a large scale change in bus network in Karachi.

There are 29 bus routes for various destinations that go through M.A. Jinnah Road as shown in Figure 2-3-3. Introduction of trunk system along M.A. Jinnah Road requires a large scale of terminal for various directions. Otherwise trunk routes should be developed for all the major corridors at once to provide BRT services for various areas in Karachi. Since available corridors that can accommodate BRT lane are limited, this will be a difficult task.



Source: Public Transport Survey in KTIP

Figure 2-3-3 Bus Routes through M.A. Jinnah Road (Quaid-e-Azam – Dr Daud Pota Road)

Figure 2-3-4 and 2-3-5 show the present bus routes that go through a part of Green Line and Red Line, respectively. If a trunk route is developed for Green and Red Lines each, these bus routes will be affected. In case that a trip consists of one trunk route and two feeder routes (origin and destination), passengers for the trip need two transfers. The complex bus network in Karachi means that some passengers need transfer between trunk lines.

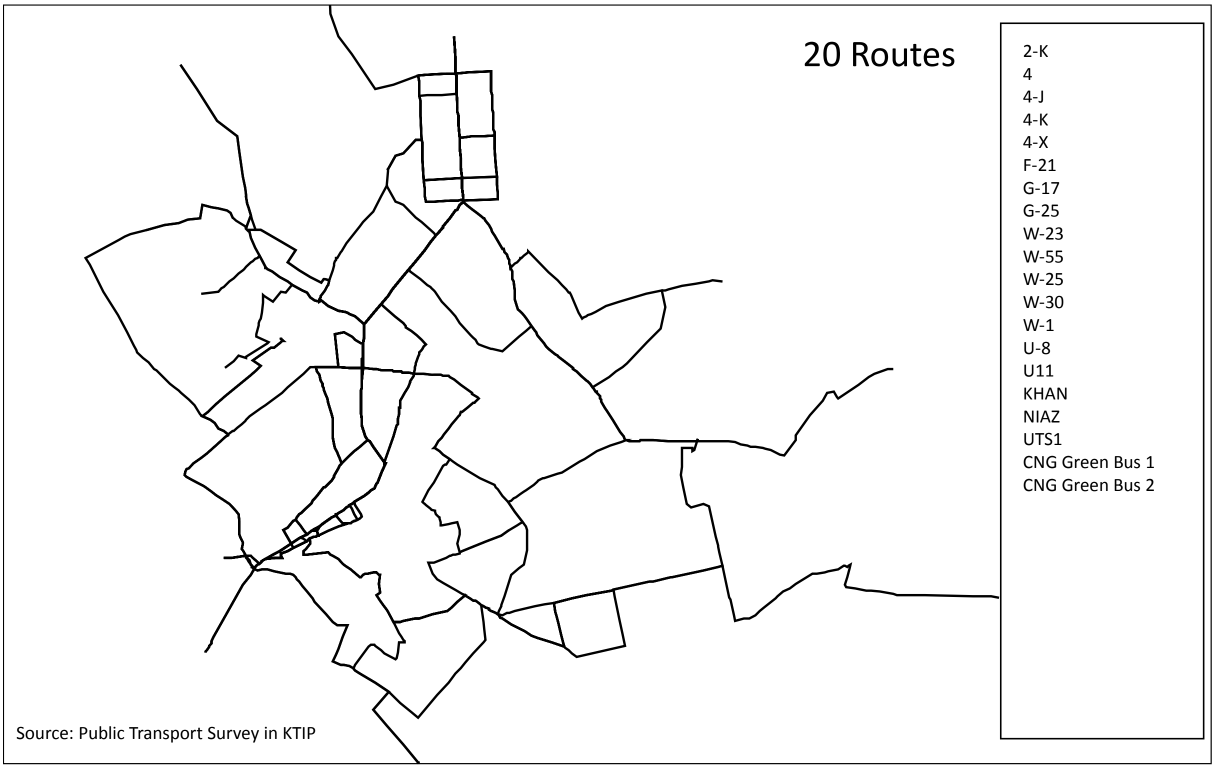


Figure 2-3-4 Bus Routes through Khayaban-e-Sher Shah Suri (Front of Hydri Market)

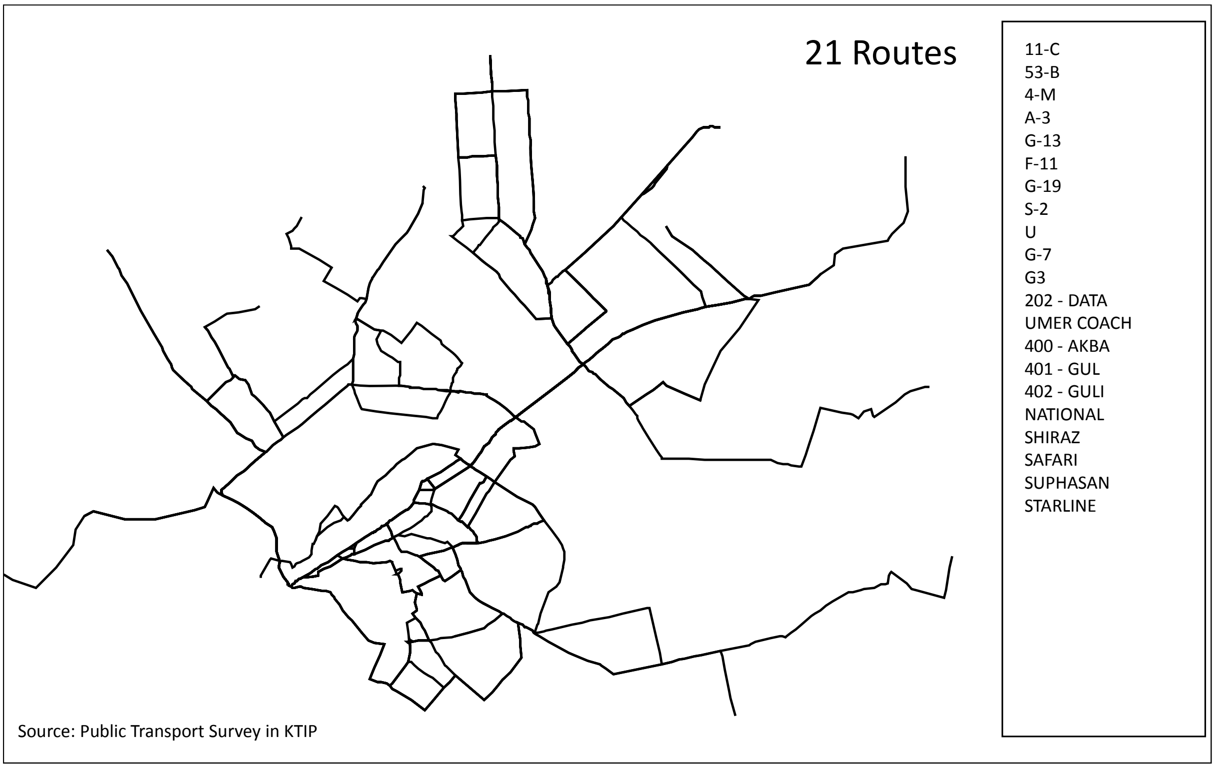


Figure 2-3-5 Bus Routes through University Road (Front of Urdu University)

(3) Issues of Trunk-Feeder System

To evaluate both systems (trunk-feeder vs. direct services), issues of them are studied from existing conditions. Issues of the trunk-feeder system in Karachi are:

- Need trunk routes for various corridors
- Need feeder services
- Need transfer terminals in CBD
- Need fare integration between trunk routes and feeder routes

Need trunk routes for various corridors

As shown in the present bus network, introduction of a trunk route along Green Line or Red Line will affect various bus routes in Karachi. To maintain the bus services for various directions, it is necessary to provide a number of transfer terminals along the corridor. Otherwise most present bus routes except for the same route as the new BRT lines should remain in mixed traffic lanes, which will bring about heavy congestion of roads where two lanes are given to BRT. To avoid this situation, trunk lines should be developed along major corridors at once. In addition to Green and Red Lines, other corridors such as Blue Line, Brown Line, Shahra-e-Faisal, Yellow Line, and inner ring road should be developed as BRT corridors.

Need feeder services

Since road space is not enough in Saddar Area for BRT lanes, any trunk routes cannot go through Saddar Area. It is necessary to provide feeder services to reach the center of the city for all trunk routes.

Need transfer terminals in CBD

For the transfer between feeder routes and trunk routes, large scale of transfer terminals should be provided. The empty land in Mazar Area can be a transfer terminal that covers trunk routes for north and east part of Karachi. Mazar Terminal proposed in the ADB study might be only possible for Green Line because the access from other routes such as Red Line to the proposed terminal is difficult.

Need fare integration between trunk routes and feeder routes

The trunk-feeder system increases the number of transfers. If the feeder services are as same as the present bus system, passengers who use two feeders and one trunk need to pay approximately three times the present fare. Although some passengers afford to pay this amount, most people need alternatives to avoid the extra payment. This means that the present bus network should remain even if BRT system is introduced and BRT services will suffer from competition with the present bus network. If BRT can go to Tower or other important points in Saddar Area directly, independent fare system would be possible. However, since feeder system to reach Saddar Area is inevitable in case of trunk-feeder system, the fare integration is one of the important requirements of the introduction of BRT system.

Need clearance of roadside encroachment

There are three major bottleneck roads along the corridors: Business Recorder Road (roadsides are occupied by rickshaw market.), Nawab Sadiq Ali Khan Road (roadsides are occupied by parking cars for sanitary market.), and New M.A. Jinnah Road near Jail Road (roadsides are occupied by car dealers.). For trunk-feeder system, the roadside encroachment of these roads should be cleared before the construction of BRT lanes. However, construction of bus exclusive lanes along these roads would cause political and social problems.

Parking by Car Dealers
Photo: The JICA Study Team

Rickshaw Market along Business Recorder Road
Photo: The JICA Study Team

(4) Issues of Direct Services

Issues of direct services for BRT system in Karachi are:

- Need discontinuance of existing bus routes that are related to BRT routes.
- Need more bus stations to disperse passenger boarding and alighting
- Need feeder services
- Need on-board fare collection

Need discontinuance of existing bus routes that are related to BRT routes

The present bus routes along the proposed BRT corridors will be converted to BRT routes. In addition, some routes that run a part of the BRT corridors should be terminated, and the route permission should be given to the BRT operator to reduce the number of existing bus routes in mixed traffic lanes. This is due to the existence of various routes along the proposed corridors. For example, two-thirds of buses running along Khayaban-eSher Sha Suri, which is the main part of Green Line, have different destinations from the proposed Green Line. This means that if BRT is provided only for the same route as Green Line, two-thirds of buses will remain in the mixed traffic lanes where the number of lanes is reduced due to bus lanes. The percentage is 60% in case of Red Line.

Need more bus stations to disperse passenger boarding and alighting

The problem of direct services is less capacity than trunk-feeder system because of constrained vehicle design for capacity increase. For example, articulated buses cannot run outside BRT lanes in most cases. Introduction of high floor vehicles is difficult because buses need to stop at bus stops in mixed traffic lanes where low step is necessary for boarding and alighting. This will increase boarding and alighting time compared to high floor vehicles that can provide flat access from station platform to buses.

In order to decrease boarding and alighting time, concentration of passenger demand at one station should be avoided, especially in the center of the city where providing passing lanes is difficult.

Need feeder services

Even if the system of direct services is employed as the BRT system, feeder services should be provided because some routes need be merged so that route numbers become simple enough for passengers to understand easily. In addition, routes should be reorganized in view of efficient operation. Some direct services currently provided by minibuses might not be proper routes for high capacity buses of BRT system.

Need on-board fare collection

Equipment of fare collection is necessary in vehicles because buses will use the present bus stops outside BRT routes in case of direct services. This will cause some problems in case of performance based contract because it is necessary to ensure the transparency of fare collection. The mixture of on-board fare collection in mixed traffic lanes and pre-board fare collection in BRT lane require careful arrangement of fare collection mechanism.

If ticket sale stands are provided at all bus stops, pre-board fare collection would be possible but the concern over transparency of fare collection still remain as the major issue.

(5) Selection of Service Type

In general, trunk-feeder system is the popular and advantageous public transport system using BRT system. However, local conditions should be carefully considered.

Initial Proposal – Direct Services

In the beginning of the F/S of KTIP, it was recommended by the JICA Study Team that direct services should be adapted to BRT system in Karachi. The major reason was that the difficulty to construct a trunk line that goes through CBD area. If truck routes are introduced, transfer to feeder routes will be inevitable for passengers. Since providing better services to bus passengers is one of the important objectives of BRT, transfer to feeder lines near CBD is not a good plan. The possibility of mixed traffic operation on bottleneck roads was another important reason to avoid the trunk-feeder system. On the other hand, the BRT system of direct services can absorb present bus routes into the BRT lanes while many routes will remain in mixed traffic in case of the truck-feeder system.

Second Proposal: Trunk-feeder System

Meanwhile, after the analysis of institutional and operational aspects of bus transport in Karachi, it was recommended that fare should be collected by different organization than the bus operators to ensure the transparency and financial stability. This means that fares should be collected outside buses at the stations where paid and unpaid areas are separated. Such operation will not be possible along mixed traffic roads. Therefore, direct services are not applicable for this case.

For the bottleneck sections, Karachi Mass Transit Cell (KMTC) ensured that the illegal parking and usage of road space would be cleared by the time of BRT project.

KMTC also insisted that BRT should be introduced along M.A. Jinnah Road up to Tower. Although the introduction of BRT to Tower is not realistic, it was assured from the strong opinion of KMTC for the BRT along M.A. Jinnah Road that the road space would be able to be used for BRT project as much as possible.

The table below shows the expected issues in case of trunk-feeder system in Karachi and its counter measures for the solution.

Table 2-3-1 Issues and Solutions of Trunk-Feeder System in Karachi

Issues of Trunk-Feeder in Karachi	Solution
Need trunk routes for various corridors	Maintain direct services along Green Line and Red Line that connect various corridors instead of construction of new corridors and transfer points
Need feeder services	Introduce BRT system to the center of the city as near the Tower as possible
Need transfer terminal in CBD	Construct transfer terminal near Quaid-e-Azam Mazar
Need fare integration between trunk routes and feeder routes	Maintain direct services along Green Line and Red Line for alternatives Enable direct access to CBD
Need clearance of roadside encroachment	Clear the encroachment by the initiative of KMTC

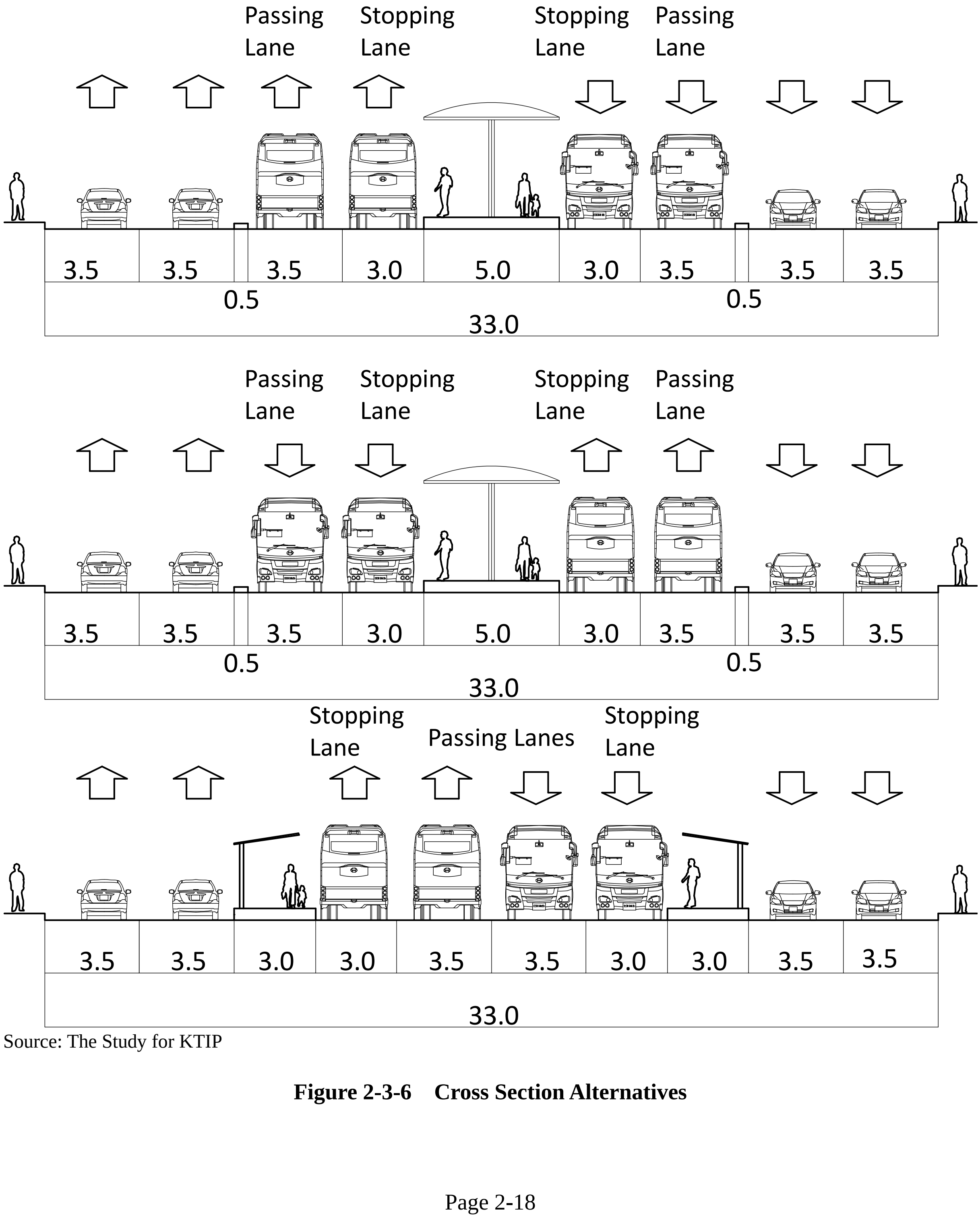
Source: JICA Study Team

2.3.2 Configuration of Lanes, Station, and Vehicle

(1) Alternatives

A typical BRT has stations between the exclusive lanes for both directions in the median of the road and buses run for the same directions of other lanes. In this case, doors of boarding and alighting should be equipped in the right side of vehicle and due to this existing buses cannot use BRT lanes. As an alternative, stations are provided at the both sides of bus exclusive lanes in the median but this requires wider width of road. Providing lanes for the opposite directions is also an alternative. Installing bus exclusive lanes along curb sides is also another alternative.

Figure 2-3-6 shows alternatives of cross section at a station in case of 33m width road (excluding sidewalk).



Source: The Study for KTIP

Figure 2-3-6 Cross Section Alternatives

(2) Road Space

M.A. Jinnah Road is very busy road but road width is so narrow that it is difficult to introduce BRT lanes. Figure 2-3-7 shows the road width along M.A. Jinnah Road between Tower and Gurumandir. The width of most parts of the road is less than 33m which is desirable for BRT. In the section between Tower and Cloth Market, the width of road is less than 22m, which is the minimum for BRT without bus stations.

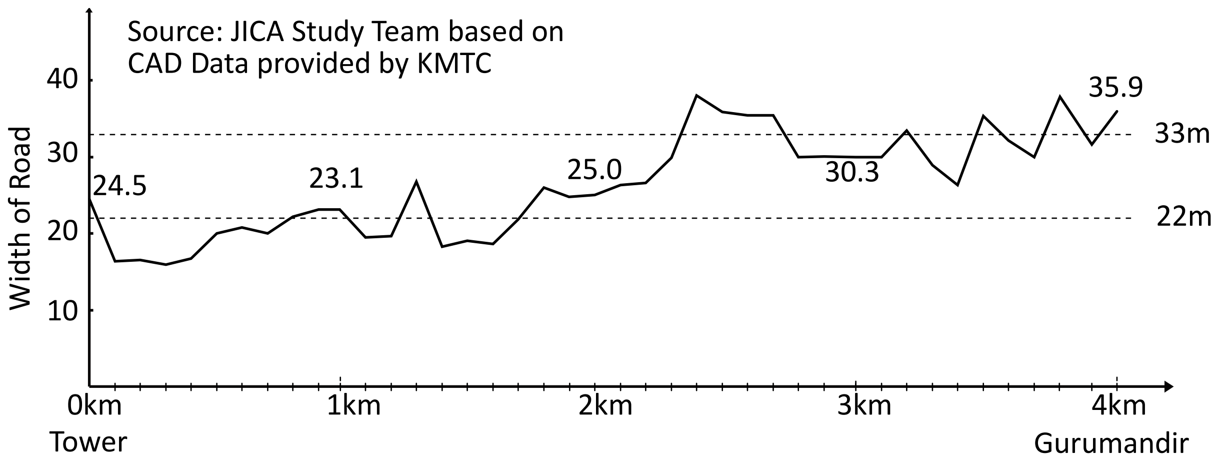


Figure 2-3-7 Road Width of M.A. Jinnah Road

2.3.3 Traffic Control

(1) Signal Free Corridor and BRT

The Signal Free Corridor project is implemented by CDGK. A signal free corridor is a highway corridor where traffic is not interrupted by traffic signal with flyovers, underpasses, U-turns, and pedestrian bridges. Signals are removed from Signal Free Corridors. In October 2009, CDGK approved 29 Corridors (Notification NO.DCO/CDGK/PS/373/09). So far, Signal Free Corridors 1, 2, and 3 have been completed. Corridor-3 corresponds to Red Line.

There is a collision between Signal Free Corridors and BRT corridors.

Median breaks for U-turn traffic is essential part of a signal free corridor to provide a way for right turn traffic without signals. Since BRT lanes will be provided in the center of roads, U-turn traffic will conflict with BRT traffic. To avoid the conflict, intersections along BRT corridors should be signalized, which is incompatible with the policy of Signal Free Corridor.

Transjakart – Bus lane is blocked by U-turn traffic
Photo: Nippon Koei Co., Ltd.

(2) U-Turn Traffic (Red Line)

Figure 2-3-8 shows the locations of U-turns along University Road. There are four median breaks for U-turn traffic between Shaheed-e-Millat Road and Rashid Minhas Road. And Table 2-3-2 shows traffic volume at U-turns along Red Line by vehicle types.

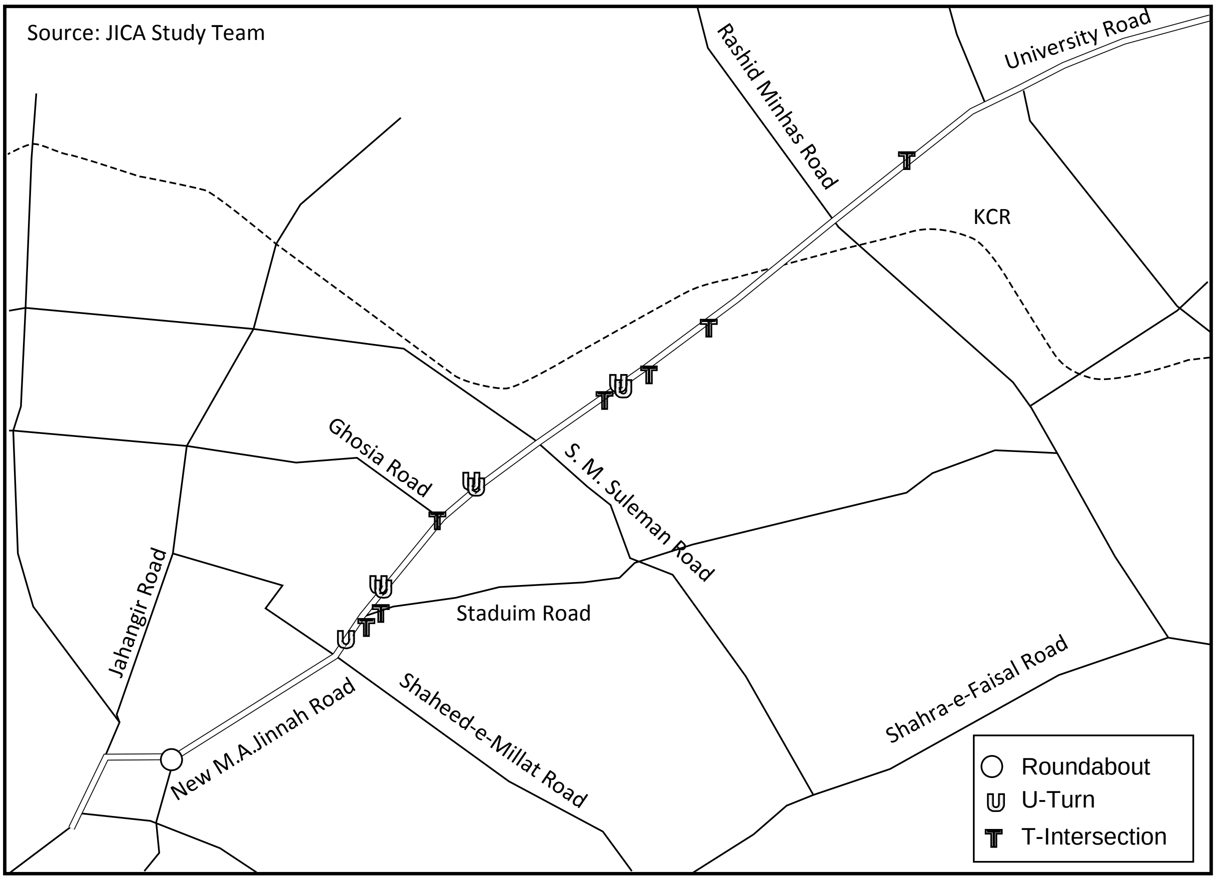
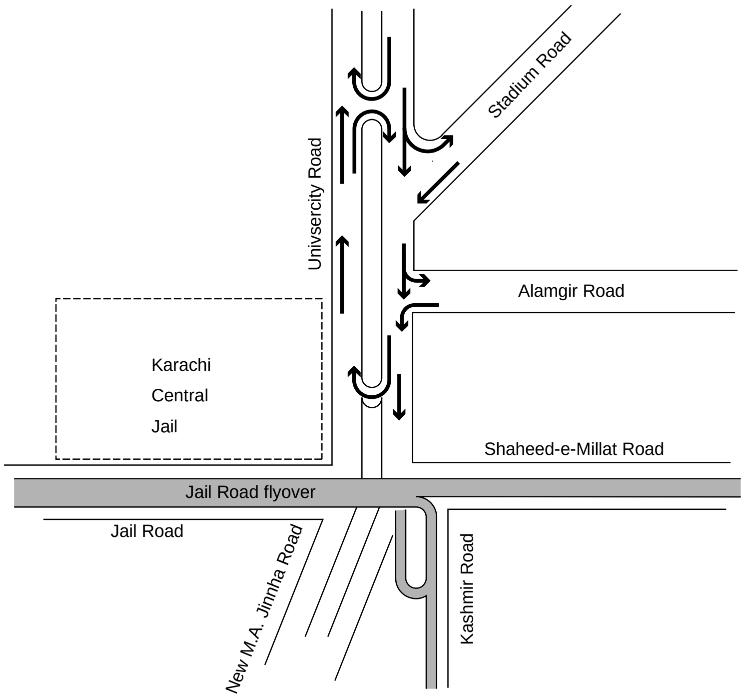


Figure 2-3-8 U-Turn Locations along Red Line

Signalization of intersections between University Road and Stadium Road will be an issue because two T-intersections are located very near as shown in Figure 2-3-3.



Source: JICA Study Team

Figure 2-3-9 Traffic Movement along University Road near Karachi Center Jail

Table 2-3-2 Traffic Volume at U-turns along Red Line

Location ID	Direction (from/to -)	14 hours (7:00 - 21:00) / 1 hour of peak hour	Cars & Jeeps & Taxis & Vans	Rick shaws	Motor cycles & Scooters	Pickups	Mini Buses & Coaches	Large Buses	Trucks & Trailers	Total
RU-1	Civic Center	7:00 - 21:00	5480	2380	5638	316	1517	8	15	15,354
		18:00 - 19:00	804	267	753	21	132	1	1	1,979
RU-2	Jail Chowrangi	7:00 - 21:00	6357	2614	7169	436	179	176	34	16,965
		19:00 - 20:00	471	221	878	61	11	14	2	1,658
RU-3	Civic Center	7:00 - 21:00	2416	1664	4451	738	27	5	104	9,405
		14:00 - 15:00	236	175	512	67	8	0	5	1,003
RU-4	Jail Chowrangi	7:00 - 21:00	3440	1698	5146	1354	94	25	89	11,846
		19:00 - 20:00	520	142	521	228	17	10	12	1,450
RU-5	NIPA Chowrangi	7:00 - 21:00	5714	2228	5432	556	632	41	175	14,778
		16:00 - 17:00	510	145	634	43	31	6	23	1,392
RU-6	Bait-ul-Mukkar am Masjid	7:00 - 21:00	11,491	1,799	6,502	448	40	0	54	20,334
		14:00 - 15:00	1,191	173	525	65	18	0	9	1,981
RU-7	PIA Garden	7:00 - 21:00	5,504	2,018	8,471	457	14	3	28	16,495
		13:00 - 14:00	486	170	739	38	0	0	4	1,437

Source: JICA Study Team

(3) U-Turn Traffic (Green Line)

Figure 2-3-10 shows U-turn locations along Green Line and Table 2-3-3 shows traffic volume at U-turns by vehicle types in North Nazimabad. There are six median breaks for U-turn traffic in North Nazimabad and seven U-turns in New Karachi. If intersections are signalized, U-turns can be closed in New Karachi because the U-turns are provided for right-turn traffic at intersections in New Karachi.

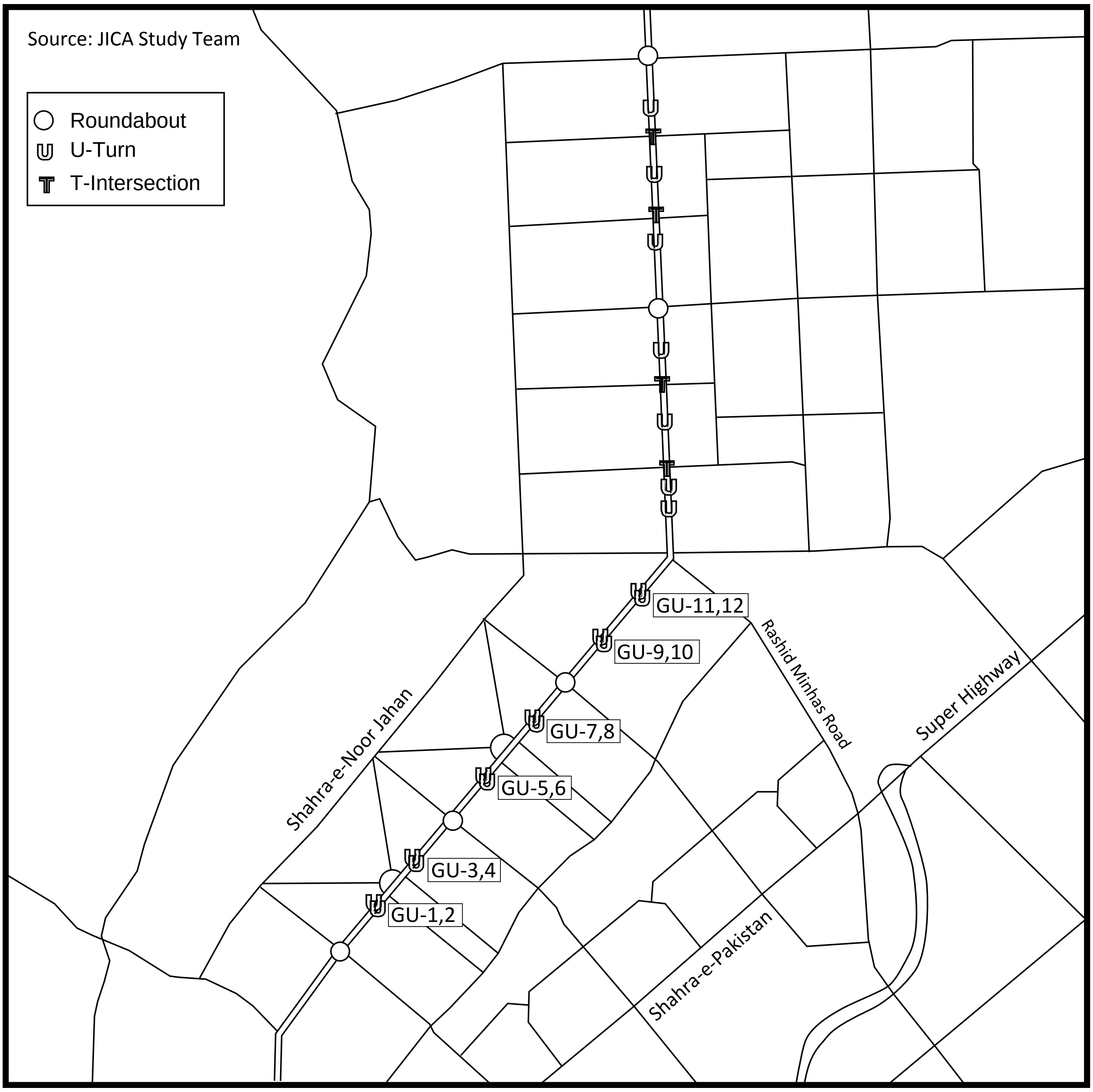
On the other hand, it will be difficult to close U-turns in North Nazimabad because signalization of intersection is not proper along the corridor in North Nazimabad. Figure 2-3-11 illustrate the location of U-turns and connecting roads between KDA Chowrangi and Five Star Chowrangi. Since the distance between the two interchanges is as long as 1.6km, it is desirable to provide additional intersections to access the opposite side. There are two T-intersections but they are close each other in the distance of 220m, which is too short to convert them to two signalized intersections.

Traffic along North Nazimabad
(U-turn traffic in red circles)
Photo: JICA Study Team

(4) U-turn Traffic (Blue Line)

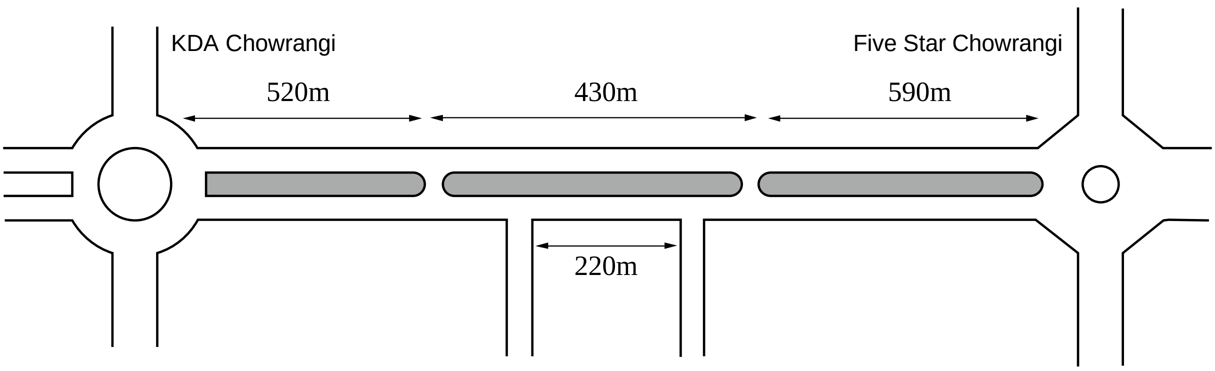
There are three U-turn locations along Blue Line between Gurumandir to Sohrab Goth at present. The U-turn under flyover of Sohrab Goth Intersection is important for traffic using Super Highway to access the opposite side of the road. The U-turn at the city side of Sohrab Goth is also important for traffic from the north side of the road to the south side. The U-turn at the north of Shah Abdul Aleem Melthi provides access to the west side of Shara-e-Pakistan Flyover.

There are no U-turn points between other major intersections: Karimabad Intersection, Aysha Manzil Intersection, and Water Pump Chowrangi. On the other hand, turning demand at these intersections is very high and making median breaks between them would be one of the solutions to cease the congestion.



Source: JICA Study Team

Figure 2-3-10 U-Turn Locations along Green Line



Source: JICA Study Team

Figure 2-3-11 U-turn Location between KDA Chowrangi and Five Star Chowrangi

Table 2-3-3 Traffic Volume at U-turns along Green Line

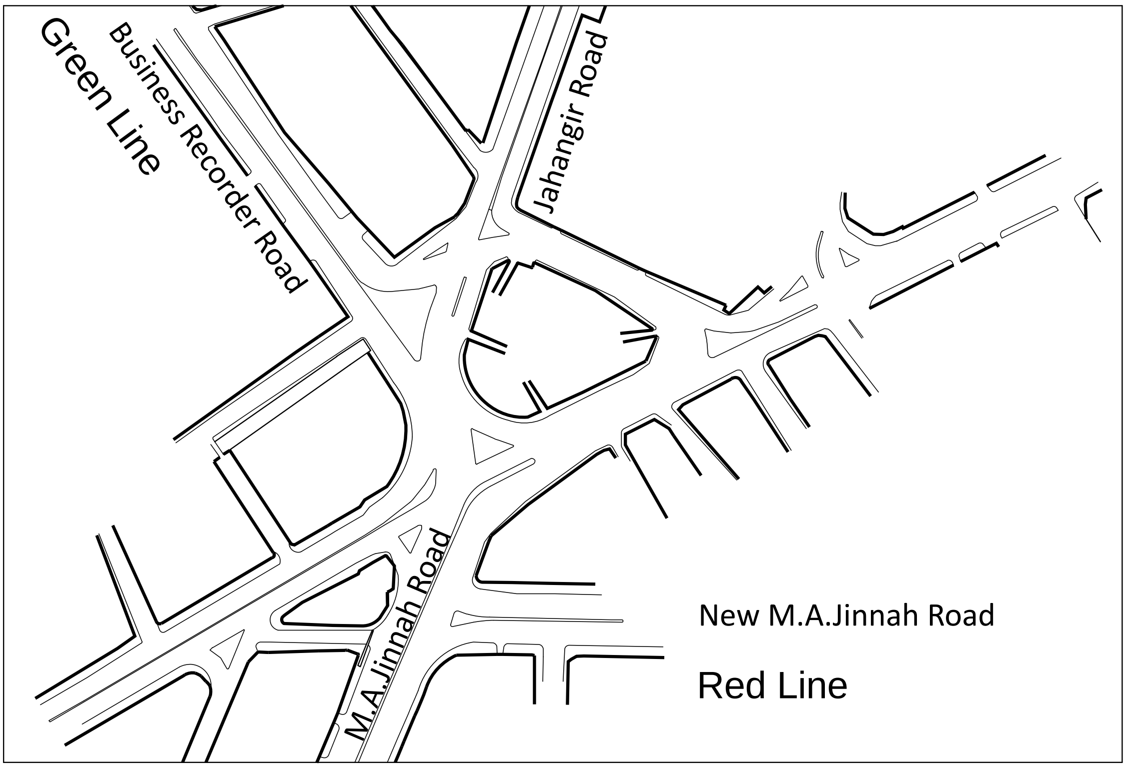
Location ID	Direction (from/to -)	14 hours (7:00 – 21:00) / 1 hour of peak hour	Cars & Jeeps & Taxis & Vans	Rick shaws	Motor cycles & Scooters	Pickups	Mini Buses & Coaches	Large Buses	Trucks & Trailers	Total
GU-1	KDA Chowrangi	7:00 – 21:00	122	61	494	9	10	1	0	697
		7:00 - 8:00	26	5	27	2	1	0	0	61
GU-2	Hyderi Market	7:00 – 21:00	3,918	1,483	3,824	300	31	9	32	9,597
		14:00 - 15:00	442	158	303	34	13	0	4	954
GU-3	Hyderi Market	7:00 – 21:00	4,320	1,646	3,888	174	45	1	54	10,128
		18:00 - 19:00	518	158	268	14	0	0	4	962
GU-4	Five Star Chowrangi	7:00 – 21:00	195	41	253	13	2	2	1	507
		12:00 - 13:00	18	5	19	5	0	1	0	48
GU-5	Five Star Chowrangi	7:00 – 21:00	50	22	231	3	0	0	0	306
		12:00 - 13:00	6	3	24	0	0	0	0	33
GU-6	New Hyderi Market	7:00 – 21:00	1,295	349	1,458	117	15	7	11	3,252
		13:00 - 14:00	146	40	130	15	3	1	2	337
GU-7	New Hyderi Market	7:00 – 21:00	1,537	497	1,672	128	26	38	15	3,913
		13:00 - 14:00	158	50	141	7	1	5	0	362
GU-8	Sakhi Hasan Chowrangi	7:00 – 21:00	41	26	135	7	0	0	0	209
		18:00 - 19:00	6	4	14	1	0	0	0	25
GU-9	SakhiHasan Chowrangi	7:00 – 21:00	170	25	234	8	2	0	1	440
		19:00 - 20:00	29	4	14	0	0	0	0	47
GU-10	Nagan Chowrangi	7:00 – 21:00	1,006	586	1,781	88	16	4	16	3,497
		17:00 - 18:00	116	87	175	5	1	0	1	385
GU-11	HaroonShoping Ceter	7:00 – 21:00	1,280	608	2,078	156	28	15	15	4,180
		19:00 - 20:00	157	53	163	9	2	2	0	386
GU-12	Nagan Chowrangi	7:00 – 21:00	1,086	766	2,322	223	129	2	19	4,547
		13:00 - 14:00	110	69	200	24	17	0	2	422

Source: JICA Study Team

(5) Roundabout Traffic

A roundabout is one of the difficult road elements for a BRT operation. There are roundabouts without traffic signals along Green Line. There are some examples of BRT systems in the world that are operated along roads having roundabouts. For example, there are roundabouts along the major route of TransJakarta (Jakarta). BRT systems in Quito (Ecuador) and Cali (Colombia) also have roundabout intersections. In case that a roundabout is heavily congested, it is better to signalize the roundabout so that BRT buses are not delayed by the congestion. So far, roundabouts in North Nazimabad and New Karachi are not so saturated that the delay of BRT buses at roundabouts would not be a problem.

Gurmandir is the bottleneck roundabout for Green Line. The roundabout has five legs and traffic congestion is very heavy. In peak hours, traffic of three major corridors (Business Recorder Road to Surjnai, Jahangir Road to Sohrab Goth, and New M.A. Jinnah Road to University Road) concentrates on the roundabout.



Source: JICA Study Team

Figure 2-3-12 Gurmandir Intersection

2.3.4 Business Model, Institution and Organization

(1) Experiences of Public Transport in Karachi

Currently, public transport services in Karachi are provided by small private operators. They provide public transport services based on the route permission given by District Regional Transport Authority (DRTA). Bus fare is regulated by the Government of Sindh. Only routes and fares are regulated and the level of services is not controlled by public sector. Transforming the existing system to a good system for BRT would be a very challenging issue.

In Pakistan, Punjab Province introduced franchise bus scheme in the early 2000s. Exclusive right to use a certain routes is given to those operators that satisfy the requirement of the level of services. The outline of the scheme is:

- The franchise for a route is awarded through a “transparent and competitive bidding process”.
- Franchise period is for 10 years.
- Franchise affords exclusivity of operations on the franchised route, provided the franchisee is able to cater to the entire load of passengers.
- Fares are flexible (more on this later).
- A subsidy of 4 percent for non-air-conditioned buses and 8 percent for air-conditioned buses is awarded to operators for the purchase of vehicles.
- Bids are advertised in the press. A bids evaluation committee, made up of senior officials from the province, evaluates all bids, with special attention given to the financial stability of the bidding operator. The recommended bids are sent to the provincial chief minister for approval, who issues the franchise for an initial 10-year period.

On the other hand, CDGK also introduced the similar scheme as Urban Transport Scheme (UTS) in 2000 for 18 bus routes. However, the scheme was failed because the exclusive rights for routes were not sufficient and the contract companies faced competition with mini buses.

The good practice of successful BRT systems is that bus routes of BRT are operated by a private company and the public authority pays the contract fee to the private company based on the performance such as vehicle-kilometer. The public authority receives the fare revenue through a fare collection company and the contract fee of fare collection is given to the company. CDGK once introduced a well-designed business model, which is popular solution for the successful operation of BRT, for the CNG Green Bus Pilot Project. CDGK received fare revenue and paid contract fee to private operators for the route of Green Bus Pilot Project. However, the fare revenue was smaller than the contract fee and it was difficult for CDGK to burden the deficit. From this, CDGK changed the contract with the private company. In the new business structure, the private companies receive the fare revenue directly instead of receiving the fee from CDGK. For the compensation of using bus depot and other infrastructure and rolling stock, the private companies pay contract fee to CDGK.

The failure of the initial scheme of the pilot project shows that the following issues.

- The present fare level which is determined by the government is too low to maintain the high quality of service.
- The financial situation of CDGK is so bad that it is difficult for CDGK to take a risk of fare revenue.
- The network size of the pilot project is so small that the project buses can get only a limited number of passengers along the corridor.
- Bus operators in Karachi are so small and not sophisticated as a public transport company that it is difficult to formulate a competitive operator to participate in the bidding.

(2) Institutional Issues

Institutional issues in transport sector are discussed in the Interim Report-1 and establishment of a new organization is proposed.

The major points of the institutional problem in Karachi for BRT are follows:

- The successful BRT depends on the mechanism of the fare regulation. Currently, bus fare in Karachi is regulated by the Department of Transport of the Government of Sindh (GOS) based on Motor Vehicle Ordinance (45). The maximum and minimum fares are fixed by GOS based on Vehicle Ordinance. The fare decision is often affected by political pressure.
- There are some overlaps between DRTA under CDGK and Regional Transport Authority (RTA) under GOS.
- There is a risk of battles over the public transport responsibility between CDGK and GOS.
- Generally, the cost of BRT is low and it is affordable for a local municipality. However, the financial status of CDGK is bad and the support from GOS or the central government would be necessary. Otherwise CDGK need to ask for private investors.
- BRT system can be developed under the present legal scheme in Pakistan. However, there remain a risk that giving dedicated lane to a private company using existing roads will cause legal challenge from road users because there is no sentence about such exclusive use of lanes in Pakistan’s laws and regulations.

2.3.5 Recommendation

Considering the available space for BRT in the road network in Karachi and the difficulty of institutional reform, the following BRT scheme is proposed.

- Busways should be developed in the center of road to ensure the speed.
- Fare collection should be ensured for the stable operation of BRT. Therefore, the BRT system should employ pre-board fare collection system.
- Buses should be reasonable and the repair and spare parts should be available in local market in Pakistan.
- Major intersections should be signalized to avoid the conflict of BRT traffic with right turn and U-turn traffic.
- The fare should be set at a sustainable level. Existing buses providing reasonable fare for low income people should remain for some years.
- A new law about mass transit development should be enacted so that the transit authority can take necessary actions without legal challenges.

Chapter 3 Conceptual Design

3.1 BRT Network and Route

3.1.1 Green Line

The route of Green Line was originally proposed as the same route as the BRT line-1 proposed by ADB in 2007. The original line terminates at the north side of Quaid-e-Azam Mausoleum and transfer to feeder lines are proposed for the access to Saddar Area.

There are two options for Green Line, which was proposed by KMTC during the master plan stage. Option-1 is connecting Green Line to Shaheed-e-Millat Road, which is wide enough to accommodate bus lanes. Option-2 is connecting Green Line to Shahrah-e-Quaideen which is busy but relatively wide road.

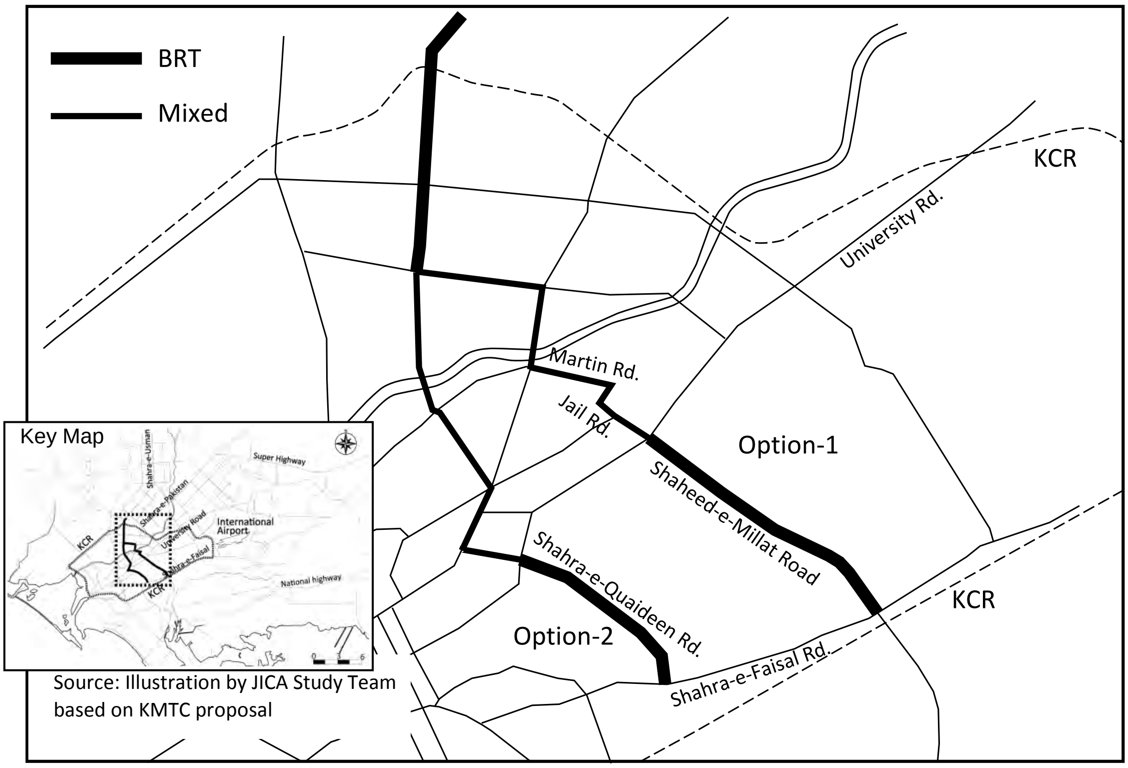


Figure 3-1-1 Option-1 and 2 for Green Line Proposed by KMTC

<u>Option-1</u>

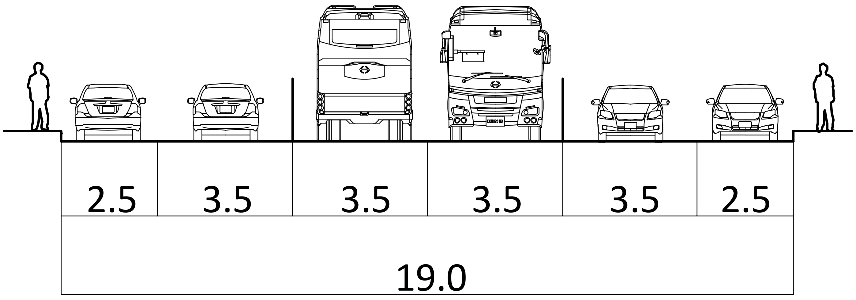
There is a bottleneck section in the route of Option-1. Martin Road is too narrow (15.5-19.5m) to accommodate BRT lanes and so is Jail Road. Mixed traffic operation of BRT along Martin Road and Jail Road will worsen the image of BRT because of congestion and slow speed in this section. U-turn operation at the terminal point of Shaheed-e-Millat Road will be also a problem because there is no U-turn place at present. There is an alternative to extend the route to Korangi. However, traffic demand of private cars along this road is very high, so it is difficult to provide bus lanes. From these points, Option-1 is not recommended.

<u>Option-2</u>

Shahrah-e-Quaideen Road can accommodate BRT lanes. However, BRT operation will be difficult at the trumpet interchange with Shahrah-e-Faisal Road. The road width is narrow for BRT lanes at the ramp of the flyover that crosses Shahrah-e-Faisal Road. U-turn under flyover will cause crossing of BRT and mixed traffic before the flyover. Instead of terminating the route at this point as the extension of Green Line, it is recommended that Yellow Line is extended to Shahrah-e-Faisal Road and go to Shahrah-e-Quaideen Road.

M.A. Jinnah Road

There is strong opinion that BRT should be provide up to Tower along M.A. Jinnah Road because it is high demand corridor. However, the section is narrow between Tower and Cloth Market. Since this is very busy commercial area, the road must have parking lanes or emergency shoulder for both sides. Considering the demand of commercial vehicle for loading and unloading, the width of parking lane should be 2.5m. This means that even if a bus stop is not provided along this section, a minimum of 19m plus sidewalk width is required for road width. The road width near Tower is approximately 15m for the length of 400m.



Source: JICA Study Team

Figure 3-1-2 BRT Cross Section in Urban Streets

The section of a bus station needs to have at least 22m plus side walk. The road width is 23.5 m in front of Karachi Municipal Cooperation (KMC) building but the width between Tower and KMC building is less than 22m. This means that bus stations cannot be provided between Tower and KMC building.

From this, the JICA Study Team does not recommend to extend Green Line to Tower. The previous studies about BRT in Karachi also did not recommend BRT along M.A. Jinnah Road.

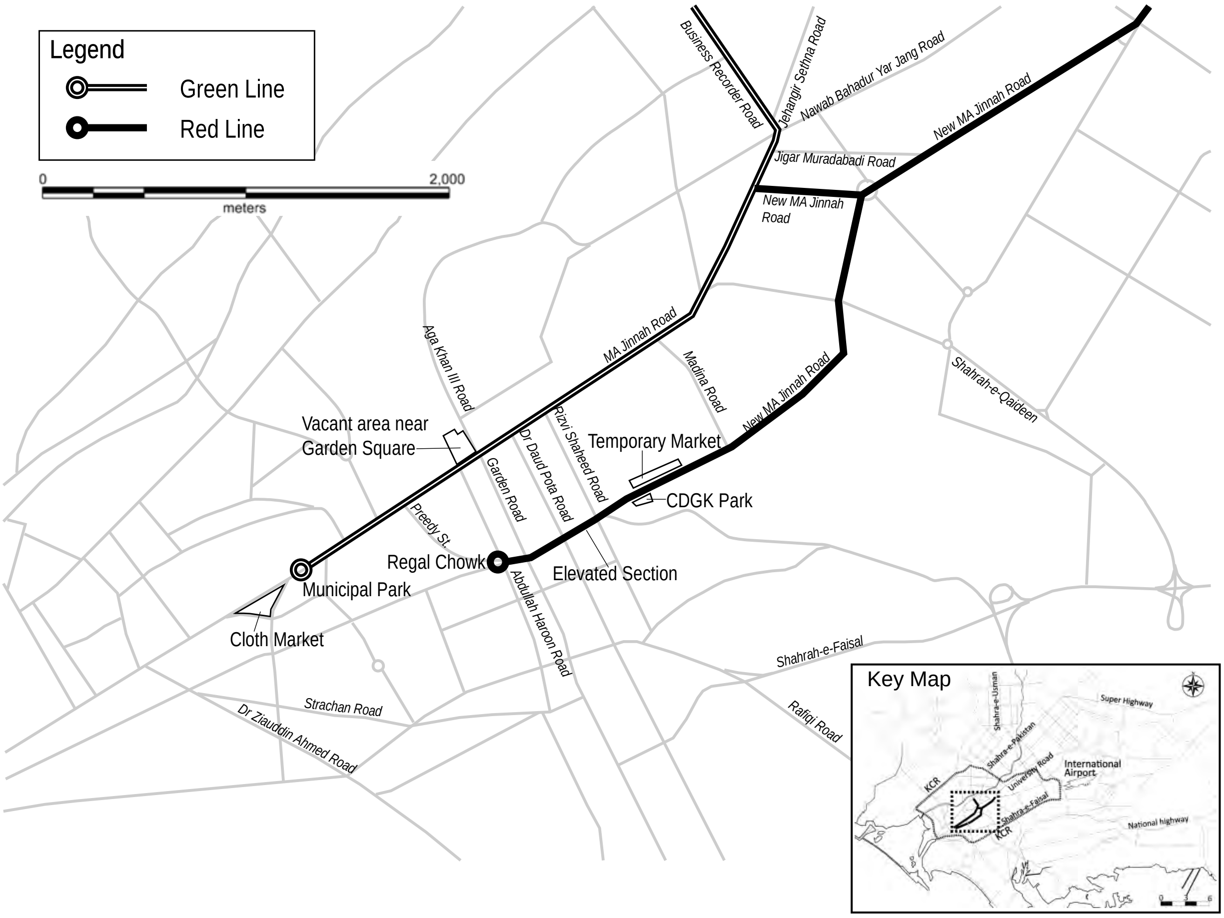
Instead of shuttle services proposed in the previous BRT studies, it is proposed to construct BRT lanes along M.A. Jinnah Road up to the point as close to Tower as possible. Since the one-way section of M.A. Jinnah Road is narrow and no U-turn point is available, Municipal Park near Cloth Market was selected as the end point (or start point) of BRT lanes along M.A. Jinnah Road. Figure 3-1-3 shows the location of Municipal Park.

3.1.2 Red Line

Red Line is proposed along University Road, and there is no alternative except for the terminal points of both sides. The terminal point is proposed to Model Colony of Malir Town. From Malir Town to the center of the city, Shahrah-e-Faisal Road is the best route while University Road becomes a detour. The advantage of the BRT route on University Road for Malir Town depends on the travel time along Shahrah-e-Faisal Road. The terminal point should be decided by the location of the depot.

The major issue of this route is that University Road was developed as a Signal Free Corridor in recent years despite the road was proposed as a BRT corridor by KMTC.

KMTC proposed the route along New M.A. Jinnah Road and Preedy Street up to Regal Chowk including elevated section between CDGK parking and Regal Chowk. Figure 3-1-3 shows the route along Preedy Street up to Regal Chowk. Since the road is narrow, elevated structure is proposed for this section.



Source: JICA Study Team

Figure 3-1-3 BRT Route along M.A. Jinnah Road

3.1.3 Blue Line

Blue Line is proposed as a railway system in the master plan, although the project is proposed after the completion of KCR. On the other hand, a rapid urban development along Super Highway is expected because of the rapid increase in population. To encourage the usage of public transport instead of private transport mode in new development area, public transport services along Blue Line should be developed.

There are three bottlenecks along Blue Line: M.A. Jinnah Road, Jahangir Road, and the bridge near Sohrab Goth. BRT along M.A. Jinnah Road is described in 2.1.1. Jahangir Road is as narrow as 17-18m in width and stations cannot be constructed along this road. There is no alternative route for Jahangir Road. It is recommended that the road should be widened to increase traffic capacity regardless of BRT project.

The bridge near Sohrab Goth is narrow especially the direction from the center of the city to Super Highway where the width of carriageway is only 10m. This is too narrow considering the heavy traffic along this road.

The analysis and the future plan of Blue Line are described in Appendix-1.

3.2 Station Location

3.2.1 Distance between Stations

Commercial speeds of BRT depend on the number of stations because buses need to spend a time at each station for boarding and alighting. The longer the distance between stations, the faster the commercial speed of BRT. On the other hand, walking distance becomes longer if the distance between stations is longer. For passengers, total travel time is the sum of walking time, waiting time for a bus, and on-board time. There will be an optimum distance that minimizes the total passenger-hours. In general, the optimum distance between stations is approximately 500m considering the standard BRT systems in the world.

Although a better transport system usually increases the acceptable walking distance, there will be a maximum limit. Considering the law and order situation in Karachi, walking distance should be as short as possible. Assuming the proper walking time along the major road is less than 5 minutes, and the walking speed is 4km/h, the maximum distance between stations is calculated as 667m.

3.2.2 Proposed Station Locations

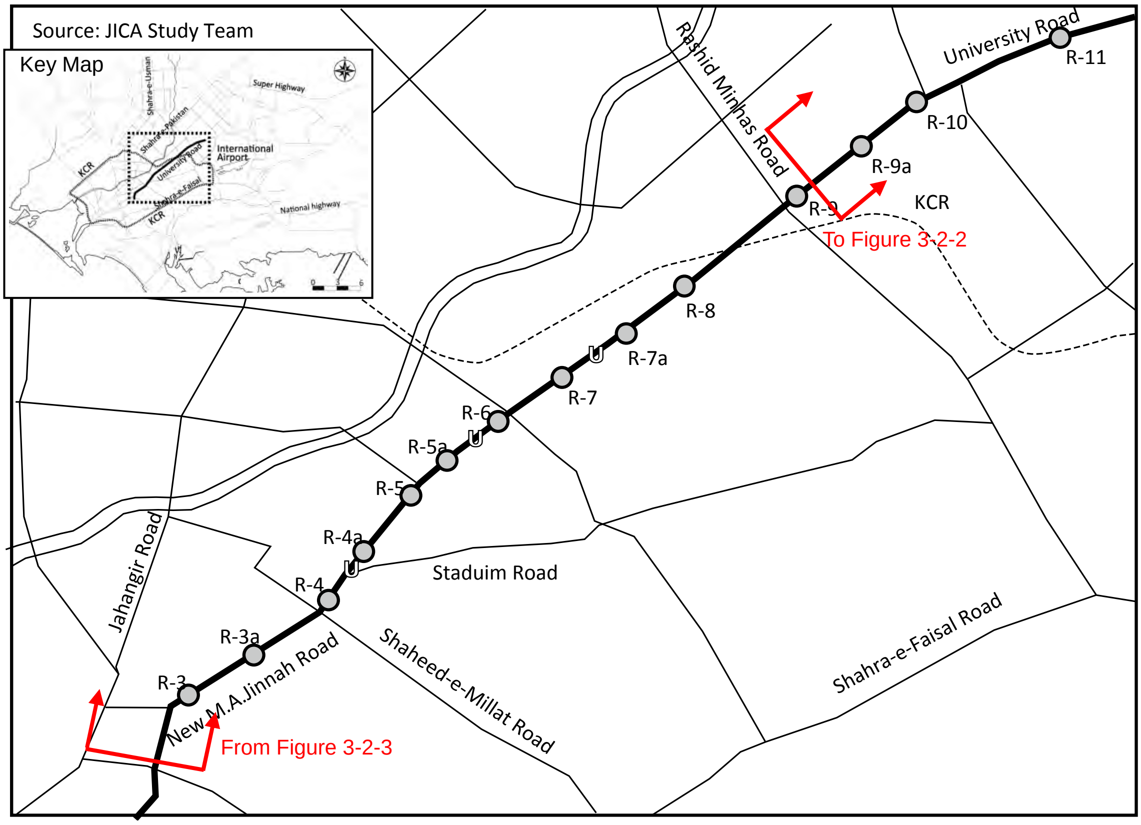
(1) Red Line Stations

Figures 3-2-1 - 3-2-3 show the locations of proposed BRT stations of Red Line. There are 21 stations proposed for Red Line in which one station (R01) is as same as the Green Line station at the same place. The station locations should be finalized considering the relation with intersection and traffic management along University Road because the corridor is currently developed as Signal Free Corridor.

Table 3-2-1 List of BRT Station (Red Line)

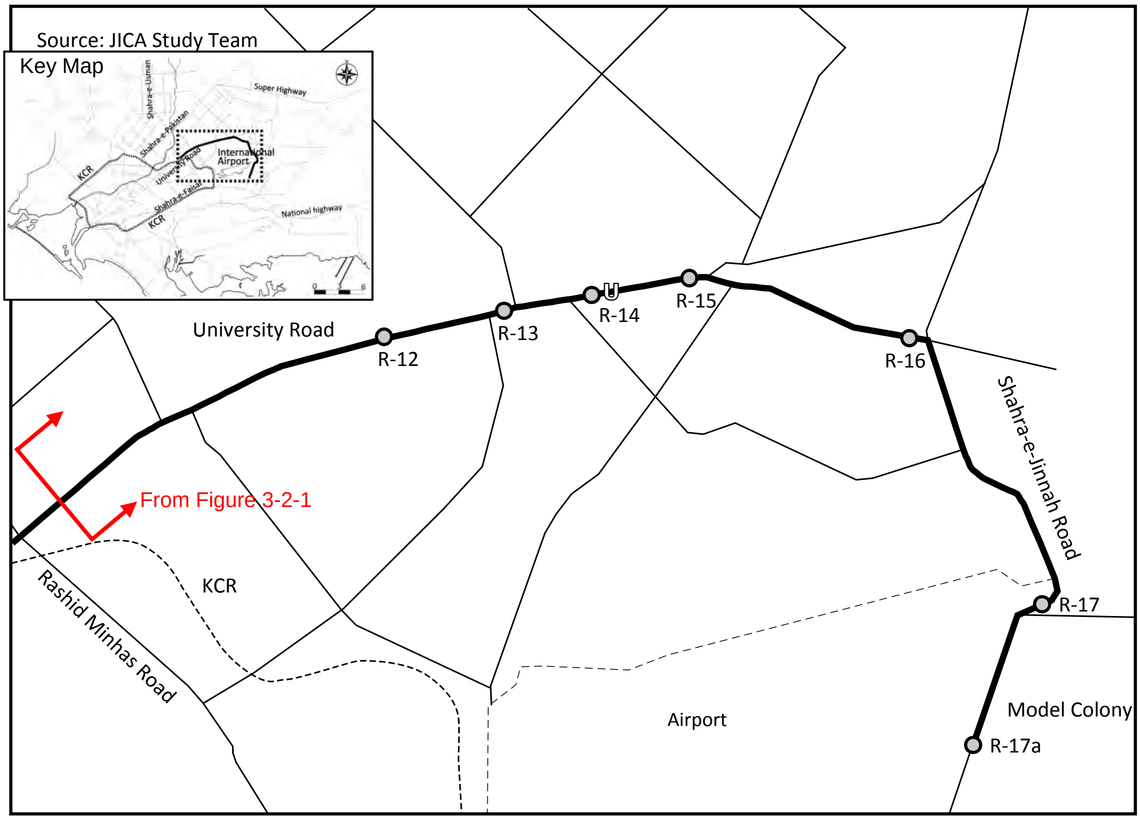
No.	Location	Distance between Stations (m)	Remark
P1	Regal Chowk		Elevated Station (U-turn point)
P1a	Empress Market	490	Elevated
P2	CDGK Parking Plaza	472	Transfer terminal proposed
P3	Shah Ahmad Noorani Chowrangi	718	Reservation for future development
P3a	Near Numaish Underpass	480	
R01	West of Quaid-e-Azam	860	Same station as Green Line
R02	North of Quaid-e-Azam	-	Middle of intersections
R03	People’s Roundabout	-	Between roundabout and Jail road
R03a	Car Dealer Shop	720	
R04	Center Jail	743	Near flyover
R04a	U-turn Stadium Road	489	
R05	Askari Park	613	Both sides of T-intersection
R05a	Near U-turn Gulsan Iqbal	537	
R06	Civic Center	580	Between Askari Park and Flyover
R07	PIA Planetarium	596	
R07a	Hakeem Sayeed Family Ground	667	Transfer to Jilani KCR Station
R08	Urdu University	729	Before flyover
R09	National Institute Management	1321	After flyover
R09a	Near Elevated U-turn	735	
R10	Safari Park	645	Near interchange
R11	NED	993	After flyover
R12	University of Karachi	1429	Near Shaikh-Zaid Islamic Center
R13	City Towers	869	Before T-intersection at Rabia Villas
R14	Near Blue mt CNG Station	896	Near Ranger Office (proposed depot)
R15	Safura Circle	712	Before Safura Circle
R16	Malir Cant Check Post	2193	Near PSO Petrol Pump
R17	Gulshan-e-Roomi	2953	Reservation for future development
R17a	Model Colony	1260	Near End Point

Source: JICA Study Team



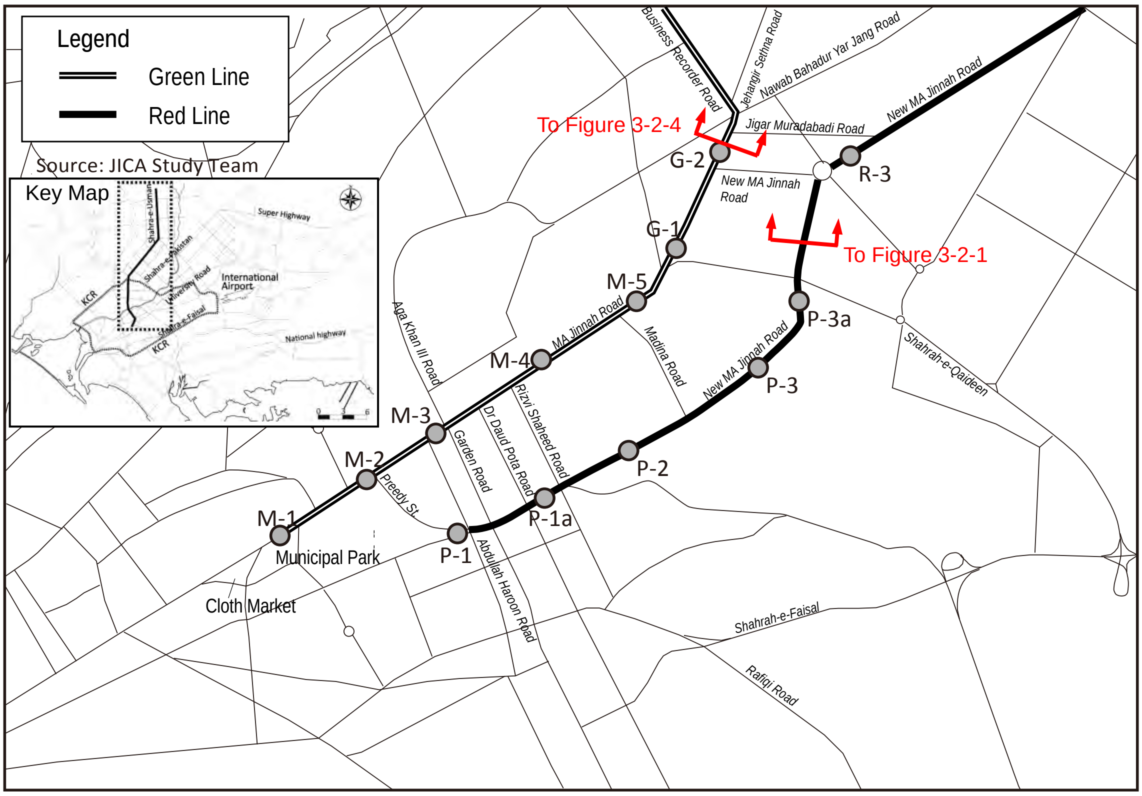
Source: JICA Study Team

Figure 3-2-1 Station Locations along Red Line (1)



Source: JICA Study Team

Figure 3-2-2 Station Locations along Red Line (2)

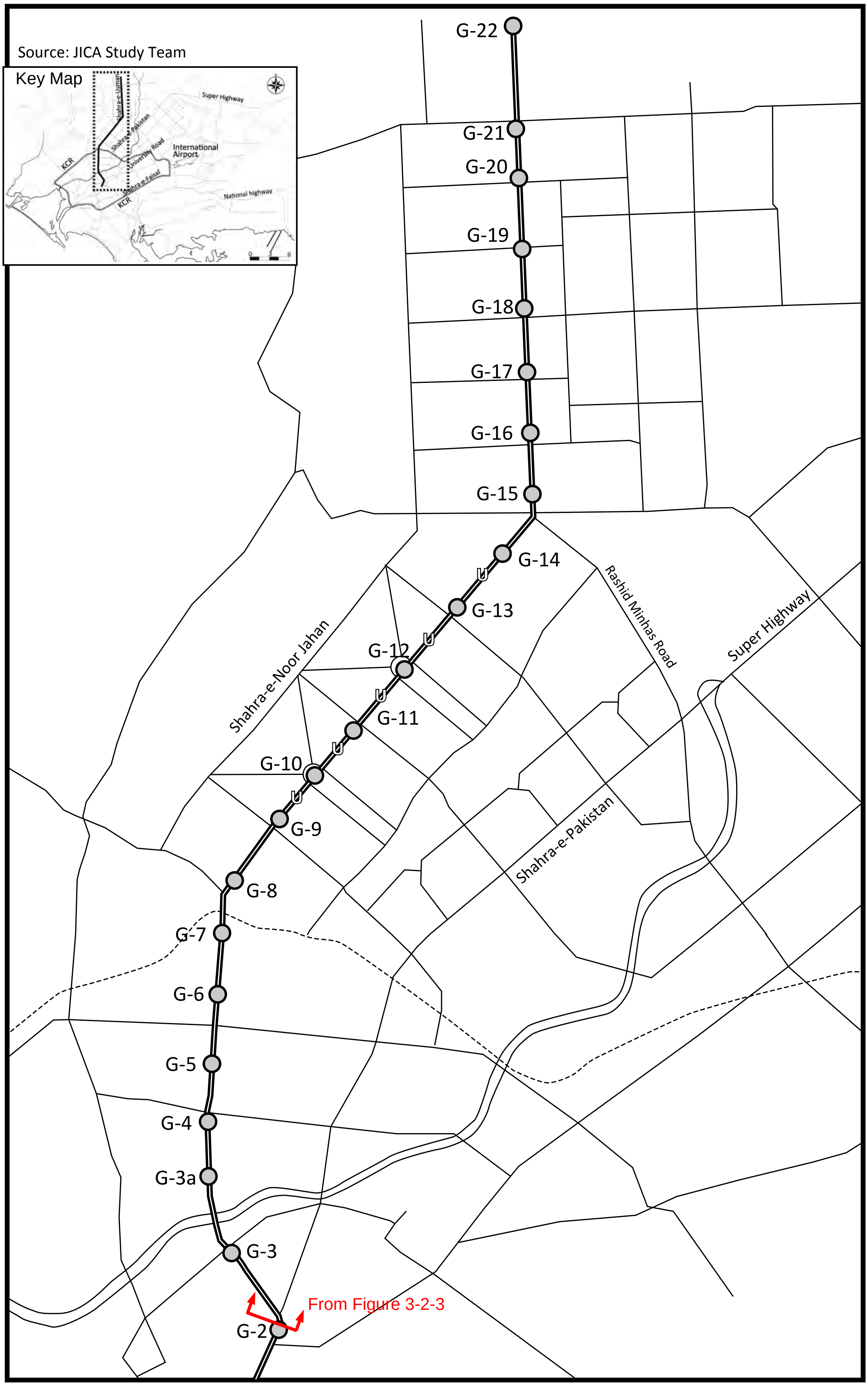


Source: JICA Study Team

Figure 3-2-3 Station Locations along Red Line and Green Line in CBD

(2) Green Line Station

The station locations of Green Line were proposed based on "Karachi BRT Pre Feasibility Planning Study, ADB". In addition to the proposed 18 stations in the study, additional four stations are proposed. Figure 3-2-3 and 3-2-4 shows the proposed location of Green Line. The list of the stations is shown in Table 3-2-2.



Source: JICA Study Team

Figure 3-2-4 Station Locations along Green Line

Table 3-2-2 List of BRT Station (Green Line)

No.	Location	Distance between Stations (m)	Remark
M1	Municipal Park	564	Start point (or end point) of Green Line/ Without passing lanes/ Access by pedestrian crossing
M2	Radio Pakistan	422	A transfer terminal is proposed in the vacant area near Garden Square/ Without passing lanes/ Access by pedestrian crossing
M3	Garden Square	724	Without passing lanes/ Access by pedestrian crossing
M4	Taj Medical Complex	481	Without passing lanes/ Access by pedestrian bridge
M5	KGA ground	441	
G01	West of Quaid-e-Azam	510	The same station as Red Line/ Access by Pedestrian Bridge
G02	Gurumandir	1117	Between Gurumandir and G01
G03	Lasbela Chowk	1007	North side of Lasbela Chowk
G03a	Sanitary Market	621	
G04	No. 1 Chowrangi	569	South side of No.1 Chowrangi
G05	Model Park	1027	Additional proposal in KTIP
G06	Baqai Hospital	514	Access by a pedestrian bridge
G07	Public Park near Bridge	793	At Nazimabad No. 7 intersection
G08	Board Office	880	Access by a pedestrian bridge
G09	KAD Chowrangi	674	Additional proposal in KTIP
G10	Hydri Market	554	Access by a pedestrian bridge
G11	Five Star Chowrangi	1019	Both sides of the intersection
G12	Jummah Bazaar	968	Access by a pedestrian bridge
G13	Sakhi Hassan Chowrangi	865	Both sides of the roundabout
G14	Erum Shopping Emporium	724	Between Nagan Chowrangi and Sakhi Hassan Chowrangi
G15	Nagan Chowrangi	736	Between the first and second pylon in front of Haji Qadir Pakwan
G16	U.P. Mohr intersection	732	South of roundabout
G17	Rd 2400	775	Signalizing T-intersection
G18	Power House Chowrangi	679	South of the roundabout
G19	Rd 4200	740	Signalizing T-intersection
G20	2 minutes Chowrangi	604	North of the pylon outside Sultan Plaza Complex
G21	Surujani Chowrangi	1532	The north of the roundabout
G22	KDA Chowrangi Surjani Town	1858	Outside CDGK site office on the southern side of 5000 Road
G23	KESC Power House		Terminal station

Source: JICA Study Team

3.3 Cross Section

3.3.1 Station Place in Road Space

As discussed in Chapter 2, there are two types of cross section proposed for BRT in Karachi. One is the center station for right-door buses, and the other is curb-side stations for left-door buses.

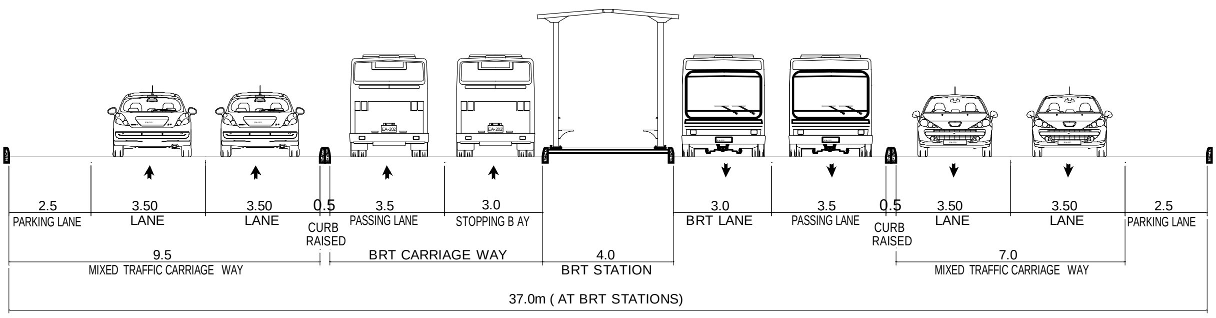
In the beginning of the F/S, cross section with curb side stations in both sides of bus lanes for left door buses was proposed so that the BRT buses can go use mixed traffic lanes. The proposal to introduce direct services for BRT was rational since the trunk-feeder system seemed to be a difficult option considering various challenges in Karachi. On the other hand, after the further analysis and discussion with KMTC, it was decided that BRT buses need not run in mixed traffic lanes. BRT buses only run on the dedicated lanes except for intersections. From this, the door configuration of BRT buses and station place in road space were selected difference criteria.

The JICA Study Team proposed the cross section of center station for the right door buses, and KMTC agreed the plan. The major reasons for the selection are:

- Approach to stations should be provided by a pedestrian bridge instead of pedestrian crossing because of heavy traffic of the corridor. Separation of stairs for both side stations will increase the cost.
- Passing lanes should be provided at major stations. Center side stations are better than curb side stations in view of design.
- Protecting paid area from unpaid passenger is an important issue in Karachi BRT. Center side stations are easier to manage paid and unpaid passengers than curb-side stations.

3.3.2 Cross Section at Station

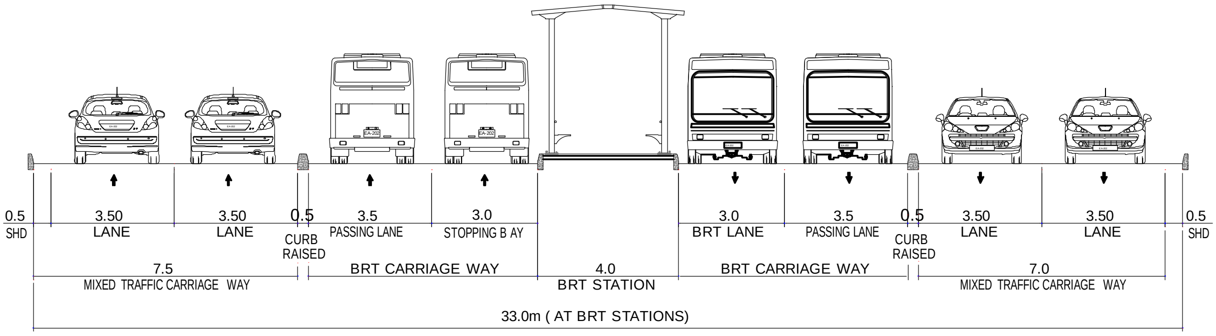
Figure 3-3-1 shows the cross section at station with passing lanes for both sides. The station is wide enough for both boarding and alighting with 4m width. Parking lanes are provided for both sides of carriageways. The road with one-lane for mixed traffic is not recommended as a BRT corridor. Therefore, at least two lanes for one direction are necessary. The road width excluding pedestrian walks is 37m. Only North Nazimabad, New Karachi and a part of University Road have enough space to satisfy this width. However, after the analysis of the corridors, it was decided that passing lanes would not be provided at the BRT stations because of limited spaces of roads.



Source: JICA Study Team

Figure 3-3-1 Cross Section at Station (37m)

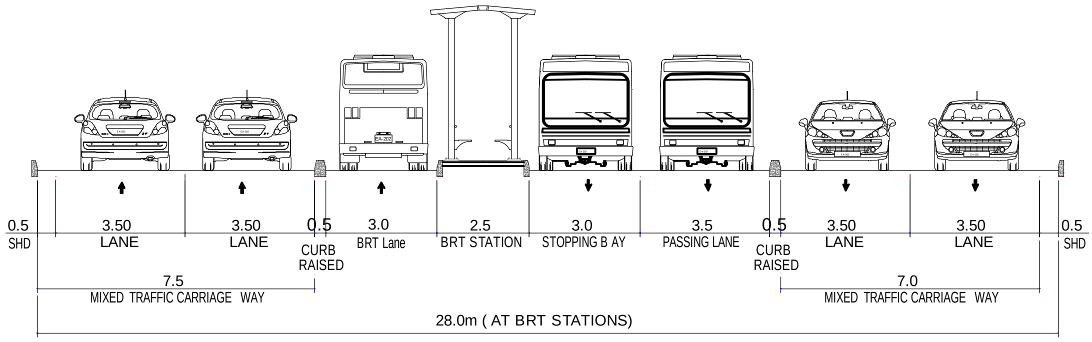
Alternative cross sections were studied to evaluate the possibility to provide passing lanes. If the parking lanes are not provided at station section, the width can be reduced to 33m as shown in Figure 3-3-2. The width of 33m was not acceptable considering the available space of roads.



Source: JICA Study Team

Figure 3-3-2 Cross Section at Station (33m)

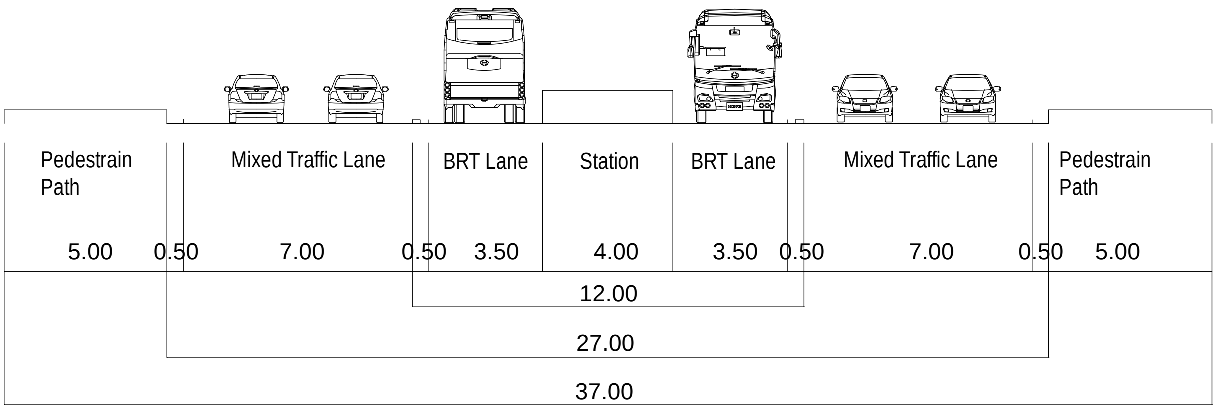
If platforms are provided at different locations by direction, the necessary width can be reduced to 28m as shown in Figure 3-3-3. However, the length of a station becomes longer. This plan was not applied because the length of a station would become long and it would not be cost efficient.



Source: JICA Study Team

Figure 3-3-3 Cross Section at Station (28m)

In case that passing lanes are not provided, the width of cross section at BRT station is 27m as shown in Figure 3-3-4. The capacity of BRT system becomes small if passing lanes are not provided. In addition, express bus services would not be possible. The station with passing lane would bring about a large scale of negative impact on road traffic because of narrow sections along the corridors. The advantages and disadvantages were studied, and it was finally decided that the BRT stations would be planned without passing lanes.

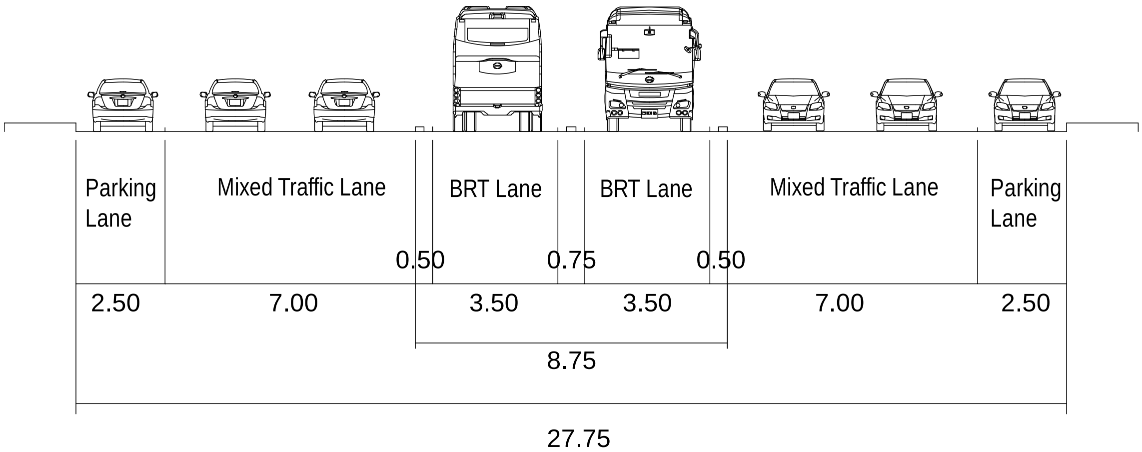


Source: JICA Study Team

Figure 3-3-4 Cross Section at Station (Without Passing Lane)

3.3.3 Cross Section between Stations

Figure 3-3-5 shows the cross section between stations where parking demand along the road exists. The necessary width is 27m. If parking lanes are not provided, the width can be reduced to 23m.



Source: JICA Study Team

Figure 3-3-5 Cross Section between Stations (With Parking Lanes)

3.4 Vehicle Type

3.4.1 Candidate of the vehicle

Basically, vehicle type of bus for BRT is determined according to passenger demand and conditions of the route. Moreover, a vehicle plan, an operation plan and an infrastructure design such as station and BRT lane are related and are taken into account to each planning, mutually. Consideration of purchase cost is also key factor to select the vehicle. Additionally, the local situations such as fuel supply condition and level of vehicle maintenance skill are also matters to be considered in vehicle selection.

There are various kinds of BRT vehicle according to differences of body types of standard bus and articulated bus, high-floor type and low-floor type, doorway arrangement, and fuel type. The factors for vehicle selection and candidates of vehicles are shown in the following table.

Table 3-4-1 Factors to be examined and candidates of vehicle

Item	Factors	Examination item	Candidates
Basic specification	- Passenger demand - Operation service - Road conditions - Purchase cost and maintenance skill - Social system, practice	- Vehicle size - Seating capacity - Vehicle capacity - Layout	- Standard bus - Articulated bus - Bi-articulated bus
BRT lane and station	- Layout of BRT lane (centre side or curb side) - Station design - Fare collection system	- Numbers and arrangement of doorways - Floor height - Care for passenger with disabilities	- High-floor bus - Low-floor bus - Doorways: Right side/ Left side/Both side
Operation	- Fare collection system - Operation service - Drivers' employment	- Numbers and arrangement of doorways - Easy driving	- Arrangement of plural doorways - Wide doorway - Standard/articulated bus
Engine	- Emission standard - Supply condition of fuel	- Fuel type - Engine type	- Standard diesel - Clean Diesel - CNG drive - Hybrid

Source: JICA Study Team

(1) Vehicle size

The type of bus being used for BRT in the world is classified into three types shown in the following table. Standard bus is the vehicle currently widely used in urban transport. Standard bus is being provided by numerous manufactures and purchase cost is lower than that of articulated bus.

Articulated bus and bi-articulated bus are selected in the routes which require the large corridor capacity and are operating after upgrading and improving of infrastructures such as the BRT lane, station and intersection. Bi-articulated bus has the vehicle capacity of 240 and more.

Table 3-4-2 Bus body type

Type	Standard bus	Articulated bus	Bi-articulated bus
Appearance			
Vehicle length	10.5m~12.0m	18.0~18.5m	24.0~25.0m
Number of doorways/side	2~3	2~4	3~5
Vehicle capacity	60~75	140~170	240~270

Source: JICA Study Team

(2) High-floor bus and Low-floor bus

Generally, floor height of high-floor bus is 800mm~1,100mm. High-floor bus can be categorized into two types of a curb-level boarding and a platform-level boarding. The former has the stairs at the doorways, and is the type to which passengers board from and alight to the bus stop of the same height as the curb. The latter is the type to which passengers board from and alight to the platform of the same height as the vehicle floor. In this type, there are examples which have mitigated the gap between vehicles and platform by installing of the bridge plate at each doorway. In conjunction with this platform-level boarding actually offer faster dwell times and greater access for the physically disabled than low-floor bus without platform-level boarding.

Moreover, the principal advantages of high-floor bus relate to the procurement and maintenance costs of the vehicles. The procurement cost of high-floor bus using the rudder frame is cheaper than that of the low-floor bus which is using the exclusive parts such as hub reduction. Also, impact on seating arrangement from the wheel wells is small.

As for the low floor bus, the height of the floor is as low as about 300–380mm from the road surface, and since the level difference between the vehicle floor and the bus stop height on the curb is small, the passengers including the person with disabilities can easily board and alight. The kneeling system, which can lower the floor of doorway further by inclining or dropping by operating of the air spring at the time of boarding and alighting, has been also developed.

Low-floor bus can also be preferred for aesthetic and urban design reasons. The 70 cm difference in floor height means that the station height is reduced 70cm. This height reduction can help to mitigate concerns over roadway severance. The low height will also marginally reduce the construction cost of the stations since the concrete base of the station will be reduced by 70cm.

Table 3-4-3 High-floor bus and low-floor bus

Type	High-floor bus		Low-Floor bus	
Appearance	 Curb-level boarding type	 Platform-level boarding type	 Ramp for wheelchair	 The same height as the curb
Floor height	800mm～1,100mm		300mm～380mm	
Features	・The vehicle floor is mostly flat, and the flexibility of the seat layout is high. ・The interference to interior by wheel wells is small, vehicle capacity is larger than low-floor bus. ・The common parts of the track are used, vehicle price is cheaper and parts supply is easier than low-floor bus ・When high level platform is applied, it is easy to secure the passenger from the collision of the road vehicle. ・When high level platform is applied, it is easy to prevent the illegal ride which does not pass the ticket gate.		・Boarding and alighting by passenger including the person with disabilities from/to the curb height is easy. ・Boarding time is shorter than that of curb-level type of high-floor bus. ・High level platform is not required so the station construction cost is cheaper than that of platform-level boarding type of high floor bus. ・By using the exclusive parts such as hub reduction, the vehicle price is more expensive than high-floor bus.	
For Wheelchair user	Curb-level boarding: Lift or exclusive platform Platform-level boarding: Bridge plate		Ramp	

Source: JICA Study Team

(3) Doorway arrangement

By performing pre-board fare collection at the ticket gate in the station and arranging two or more doorways with the suitable width on the vehicle, the station dwell time can be shortened.

Arrangement of the doorway of a vehicle is determined based on the arrangement of BRT lane and station. In the typical examples of BRT which has BRT lane in the median strip side, the station is constructed between the BRT lanes of both directions, and in the case of left-hand traffic, the doorways are installed in the right-hand side of vehicles. When the bus runs not only on the BRT lane set at the median strip side but also at the curb side, the doorways shall be quipped in both side.

Although dwell time can be shortened by increasing the number of doorways, vehicle capacity is reduced.

(4) Emission Standards

In order to reduce the amount of emissions of air pollution substances generated from road traffic, the emission standards of the commercial vehicles including buses are changing to the stricter regulation value on the worldwide scale. EURO-I to EURO-V are the major indices of the emission standards for road vehicles as of 2011.

Table 3-4-4 EU Emission Standards for Heavy-Duty Diesel Track and Bus Engines

Tier	Implementation dates	CO (g/KWh)	HC (g/KWh)	NOx (g/KWh)	PM (g/KWh)	Smoke (m^{-1})
EURO-I	1992	4.5	1.1	8.0	0.36	
EURO-II	1996.10	4.0	1.1	7.0	0.25	
EURO-III	2000.10	2.1	0.66	5.0	0.10	0.8
EURO-IV	2005.10	1.5	0.46	3.5	0.02	0.5
EURO V	2008.10	1.5	0.46	2.0	0.02	0.5

Note) CO: Carbon monoxide, HC: Hydrocarbon, NOx: Nitrogen oxides, PM: Particulates matter
Source: http://ec.europa.eu/environment/air/transport/road.htm

To reduce the particulate matter (PM) and the nitrogen oxide (NOx), the countermeasures by using the engine applying the latest clean diesel technology and by attaching the exhaust post-processing equipment are being taken. Moreover, as the alternative system of the diesel engine, there are the low emission vehicles applying CNG (Compressed Natural Gas) drive and hybrid system.

Table 3-4-5 Emission measures and features of each drive system

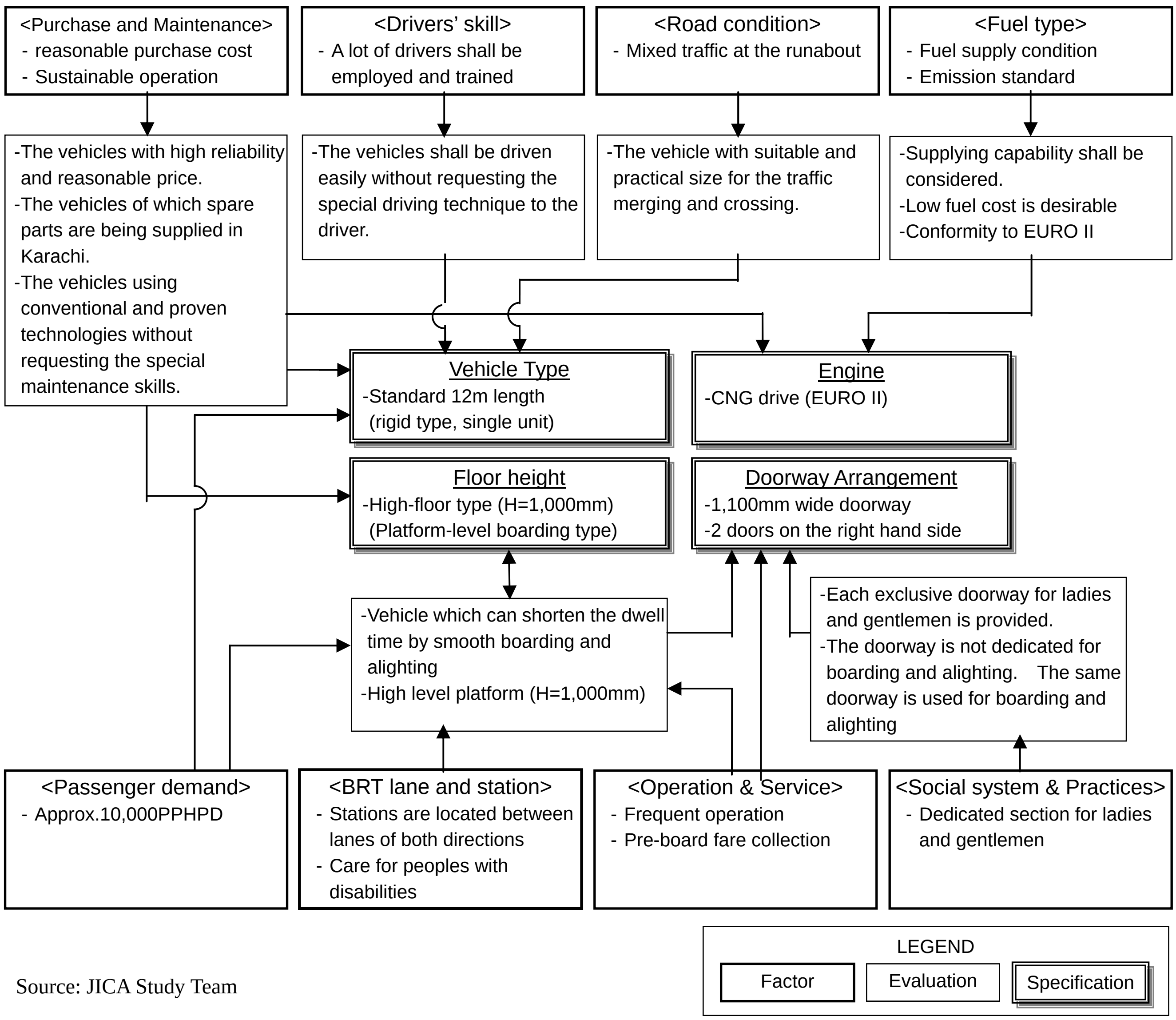
	Standard Diesel	Clean Diesel Engine	CNG drive	Hybrid System
Type of fuel	Diesel	ULSD (Ultra Low-Sulfur Diesel)	CNG	ULSD + Electric
Emission measures	・DPF (Diesel Particulate Filter)	・Improvement of combustor efficiency by common-rail type fuel injection. ・Reduction of burning temperature by Exhaust Gas Recirculation ・DPF	・PM is not discharged. ・The amount of discharge of NOx is half or less than that of Diesel	・In the situation of which big power is required, such as start, acceleration and going up the slope, the motor operates to assist the engine. ・In the situation of the deceleration, the motor operates as the dynamo, and the battery is charged (regeneration).
Features Subject	・Fuel supply is relatively easy.	・Low-sulfur diesel (LSD, s500) or ULSD(s15) is required.	・Inferior in the aspect of storage and hauling compared with diesel oil ・CNG station which has fast fill capability is required.	・LSD, ULSD is used. ・Since the batteries can be equipped on the roof, the low-floor bus can also adopt this system. ・Vehicle price is higher than that of clean diesel bus.

Source: JICA Study Team

3.4.2 Basic Specification of Vehicles of Karachi BRT

Figure 3-4-1 shows the summary of evaluation for vehicle selection. Selected type of the vehicle for the BRT is:

- The standard bus of 12m length
- Platform-level boarding type of high-floor bus
- Two doorways on the right hand side
- Propulsion system: CNG drive



Source: JICA Study Team

Figure 3-4-1 Evaluation of Basic Specification of vehicle

3.4.3 Vehicle Size

The standard bus of 12m length is selected. The matter taken into consideration in selection is described below.

1) The following matters should be considered; (i) The vehicle should be able to be purchased with reasonable and suitable price compared with the profit and benefit of the project, (ii) It should have the high reliability so that failure hardly occur, (iii) It should be able to be maintained by the technical level of Karachi, and (iv) the parts supply should be stable. From the above mentioned point of view, the vehicles produced by CKD (complete knock-down) which imports the parts with the form completely decomposed per parts and mainly performs the welding, fabrication and painting in Karachi are recommended. The standard bus is selected as vehicles applicable to this.

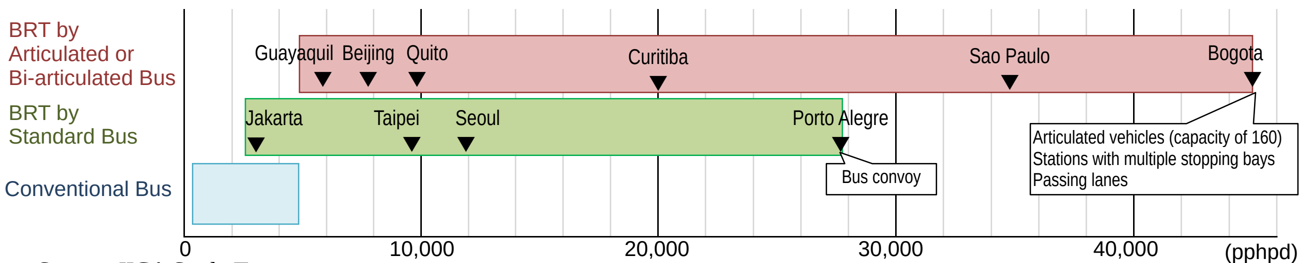
2) Among the candidates of bus vehicle supplier mentioned later, no supplier is manufacturing the articulated bus by CKD as of 2011. If the articulated bus is needed, the bus will be imported as CBU (Complete build-up).

3) Although an articulated bus has the vehicle capacity of approximately twice that of a standard bus, its price is expensive. The vehicle price of the standard and high-floor CNG bus purchased by CDGK CNG bus pilot project (2009) is Rs.4.2 million. On the other hand, as for the vehicle price of the articulated and high-floor CNG bus, according to Jakarta BRT (Indonesia) example, even a vehicle of the domestic manufacture which attained the cost down is approximately USD 425,000.

4) Although the bus vehicles run the segregated BRT lane, in the roundabout and the intersection, the bus will merge into the general traffic and/or cross to the general traffic. Moreover, at the terminus of the route, the bus will turn in the road space. It is also assumed that the bus will enter the existing CNG station in the city. In such road condition, the long vehicle like the articulated bus of which turning circle is large will be inferior to vehicle manoeuvrability compared with the standard bus. There is also a possibility of interference with general traffic.

5) In this project, for the Red line and the Green line, hundreds of bus vehicles will be purchased, and hundreds of drivers will be employed and trained. To arrange the drivers and secure the safe operation, the vehicles that do not require the special driving technique as much as possible are desirable. So, the standard bus is recommended than the articulated bus.

6) As for the relationship between the amount of passenger demand of proposed route and the corridor capacity by the standard bus, the adaptability of the standard bus is evaluated as follows. The amount of demand of the Red line and the Green line are forecasted to approximately 10,000 pphpd each, and the standard bus is applied by Taipei BRT and Seoul BRT which demonstrate comparable corridor capacity.



Source: JICA Study Team

Figure 3-4-2 Example of vehicle type and corridor capacity of BRT

Furthermore, according to Bus rapid Transit Planning Guide (ITDP, 2007), corridor capacity of

BRT is calculated by following formula.

$$Co = \frac{Nsp * X * 3600}{\left[\frac{Td * (1-Dir)}{Cb} + Ren * T1 \right]}$$

Where;

Co: Corridor Capacity (pphpd)
Nsp: Number of stopping bays
X: Saturation level of the slots)
= Td * F + [{Pb * Tb} + (Pa * Ta)]
(F: vehicles/hour, Td: dwell time,
Pb: total number of passengers boarding,
Tb: average boarding time per passenger (seconds)
Pa: total number of passengers alighting,
Ta: average alighting time per passenger (seconds)
3600: 1hour=3600 seconds
Td: = 10 + (L / 6)
10: average time for pulling in and out of bay (seconds)
L: vehicle length,
L/6: additional second for each additional meter of vehicle length)
Dir: Percentage of vehicles that are limited stop or express service
Cb: Vehicle capacity
Ren: Renovation rate
T1: Average boarding and alighting time per passenger

Source: Bus rapid Transit Planning guide (ITDP, 2007)

Corridor capacities by standard bus and articulated bus according to the number of stopping bays are shown in Table 3-4-6. The amount of demands of approximately 10,000 pphpd forecasted in Karachi BRT can correspond by the standard bus and the station which has three stopping bays and passing lane.

Table 3-4-6 Corridor capacity according to number of stopping bays

Number of stopping bays (Nsp)	Corridor capacity (pphpd)	
	Standard bus (12m, 2 doorways)	Articulated bus (16m, 4 doorways)
1	4,600	9,400
2	9,300	18,800
3	13,900	28,300

Source: JICA Study Team

Where;

X=0.4 (saturation level to secure the average velocity of 25km/h, according to Bus Rapid Transit Planning Guide)
Td = 10 + L/6, Td=12 seconds (Standard bus), 13 seconds (Articulated bus)
Dir = 0 %
Cb = 75 passengers (Standard bus), 140 passengers (Articulated bus)
Ren=20% (based on hypothesis)
T1 = Refer to the examples of Columbia and Mexico which are applying the pre-board fare collection and at-level boarding and alighting, 0.75 seconds (Standard bus), 0.30 seconds (Articulated bus)

Source: JICA Study Team

Similarly, the operation frequency of each stopping bay is calculated as follows.

When the standard bus that has the vehicle capacity of 75 conveys the passengers of 10,000 pphpd, the frequency of departures in three stopping bays at the station becomes 53 buses per hour, respectively.

$$Cb = \frac{Co}{[Lf * F * Nsp]}$$

Where;
Cb: Vehicle capacity (passengers/vehicle)
Co: Corridor capacity (pphpd)
Lf: Load factor (refer to example, Lf=0.85)
F: Service frequency (Vehicles/ hour)
Nsp: Number of stopping bays

Source: Bus rapid Transit Planning guide (ITDP, 2007)

Table 3-4-7 Service frequency per stopping bay

	Standard bus	Articulated bus
Corridor capacity(Co) (pphpd)	10,000	10,000
Vehicle Capacity(Cb) (passengers/vehicle)	75	140
Number of stopping bays(Nsp)	3	2
Frequency per stopping bay(F)	53	42

Source: JICA Study Team

3.4.4 Doorway Arrangement

Based on the following consideration, two doorways with a width of 1,100mm are installed on the right-hand side of the vehicle. In addition, since the fare collection is performed at the ticket gate in the station, the equipment for fare collection is not installed in the vehicle.

1) The doorways equip on the right hand side according to the layout of BRT lane and station.

2) Since the driver's seat is located on the right hand side, two doorways are allocated in the wheelbase.

3) Car interior is divided to the ladies section of the front side and the gentlemen section of the rear side by a transparent partition. Each doorway is dedicated to and allocated for the ladies section and the gentlemen section.

4) Two doorways are dedicated for ladies and gentlemen, respectively. However, each doorway is used for both of the boarding and the alighting. In order to shorten the time of boarding and alighting, the doorway ensures the width of 1,100mm which two passengers can pass through simultaneously.

3.4.5 Floor Height

Based on the following consideration, high-floor vehicles, which apply the platform to facilitate easy boarding and alighting, were selected.

1) Car interior of buses is divided to the sections of ladies and gentlemen, and the seats, a doorway and the wheelchair position are allocated in each section. High-floor buses of which interference by the wheel ware is small, and the flexibility of the layout of car interior is high, are desirable.

2) Vehicle price of the high-floor type, which is using the ladder frame, is cheaper than that of low-floor type buses. As for high-floor buses that use common parts with a track, the parts supply is relatively easy. Since it is necessary to supply a lot of bus vehicles and to maintain at a long period, selection of high-floor bus is proposed.

3) In the station, the platform of which height is the same level of the vehicle floor is installed to facilitate easy boarding and alighting. The construction cost of the station increases with raising the vehicle floor. The minimum floor height is assumed to be 1,000mm. In addition, as the effects of using high level platform, the illegal ride which enters into the station without

passing the ticket gate will be prevented, and it is easy to secure the passenger in the station even if the collision of the car to the station occurs.

4) In order to mitigate the gap between platform and vehicle, installation of a bridge plate at each doorway of the vehicle is proposed. The bridge plate deploys and retracts automatically when the door is open and closing.

3.4.6 Engine

Based on the following consideration, CNG buses, which can be adapted to the emission standard of EURO II, were selected. However, if CNG supply is not stable in the future and supply of the diesel oil which can adapt to EURO II is started in Karachi, the standard diesel bus adapted to EURO II is considered as the alternative.

1) According to Environment Protection Agency (EPA), the particulate matter below 2.5 micron (PM2.5) in the atmosphere of Karachi is 41.49 microns/m^3 in the annual average from June 2010 to May 2011. It is exceeding a yearly average of 25 microns /m^3 of the national environmental quality standards.

2) When diesel oil burns in engine, sulphur contained in diesel oil is changed to the particulate matter, and PM is discharged as black smoke. Amount of sulphur contained in diesel oil supplied in Pakistan in 2000 was 10,000 ppm (1.0%) – 5,000 ppm (0.5%). Although the quality of diesel oil has been improved so far, contained amount of sulphur is still in high level of 6,000 ppm (0.6%) - 2,000 ppm (0.2%) as of 2011. In addition, in order to adapt to EURO-II and III, low-sulphur diesel of which contained sulphur were reduced to 500 ppm and 350 ppm is needed, respectively.

3) In Pakistan, the measure to adapt to EURO-II as emission standards is being undertaken. The Ministry of Environment has determined to adapt all diesel cars which will be imported or manufactured on and after July 2012 to EURO-II. Also, it was planned that the Ministry of Petroleum and Natural Resources supplies the low sulphur diesel oil (500 ppm) which can be adapted to EURO-II on and after January 2012. However, upgrade of the oil refinery facilities not seem to be proceeding, and the prospect of supply of low-sulphur diesel oil is not clear.

4) Clean diesel engine and Hybrid system, which can adapt to EURO-V, use ultra-low sulphur diesel oil (15ppm). From the view point of the fuel supply situation in Karachi, Clean diesel engine and Hybrid system are removed from the candidate of BRT vehicle in Karachi.

5) According to Pakistan Clean Air programme (PCAP) established by the Ministry of environment, gradual exclusion of the diesel car from the centre of the city is being described. In Pakistan, CNG has been spread as an alternative fuel of oil to reduce the amount of oil import and to control air pollution. CNG engine does not discharge PM and can adapt to EURO-II by equipping the oxidation catalyst.

6) Comparison of the fuel cost of CNG bus and diesel bus is shown in Table 3-4-8. Each cost was calculated by using the fuel unit price in Karachi as of December 2011, the fuel consumption of the CNG bus currently operating by CDGK, and the fuel consumption of the diesel bus of the city bus in Japan.

Table 3-4-8 Fuel cost of buses

Fuel	Unit price	Fuel consumption	Fuel cost
CNG	Rs.69.62/kg	2.5km/kg	Rs.27.8/km
Diesel	Rs.98.81/litter	2.7km/litter	Rs.36.6/km

Source: JICA Study Team

7) As for the CNG buses, refuelling of CNG takes a long time if the number of CNG stations that have the fast fill capability is small. According to CDGK, as of June 2010, there are 31 CNG

stations with the pressure of 200bars which can refuel to bus within 10 minutes. Among this, 13 stations have high pressure nozzle.

Table 3-4-9 Existing CNG stations with 200bar

No	CNG Pump Name	Location	No. of Dispensers/ Nozzles	Storage Capacity	Compressor Type & make	Pressure (Psl)	High Pressure Nozzle
1	Monolite CNG Int (Pvt) Limited	Near PF Base Shahrah-e-Faisal	10/20	9,960 Litter	630 cu/m/hr 570 cu/m/hr	200	-
2	Combine CNG Filling Station	Block-12, Gulistan-e-Johar	6/12	6,270 Litter	700 cu/m/hr 520 cu/m/hr	210	-
3	Arshi CNG Filling Station	Abu Al-Hassan Isphani Road Near Mubina Police Station	4/8	3,000 Litter	520 cu/m/hr 520 cu/m/hr	220	-
4	Ahsan CND Filling Station	Abu Al-Hassan Isphani Road Near Munbina Police Station	6/12	6,270 Litter	1,000 cu/m/hr 1,000 cu/m/hr	210	
5	Al Gaso CNG Station	Al Hilal Cop. Housing Society, University Road	4/8	2,400 Litter	700 cu/m/hr 700 cu/m/hr	200	-
6	Farzam Fuel Station	PP1, Sec.Z-IV, Gulshan-e-Maymar	1/2	420 kg	Safe 520	200	Yes
7	Friend Packages CNG Filling Station	Mehmood Opp. City Chapter School	3/2	-	Jordan Safe Compere	200	Yes
8	Fuel Star Services Station & CMG Station	Block-A, Nazimabad, B-169	2/4	5,600 Litter	IMW x 2	200	Yes
9	Venus CNG Filling Station	Plot No. FL-2, Madina Housing Society main Korangi Road	2/4	28 cylinders /100kg	Safe	220	Yes
10	Al-Mustafa CNG Filling Station	Block-N, North Nazimabad	2/4	30 cylinders /90kg	Safe Italy	220	Yes
11	CNG Station of Pakistan State Oil	7th Floor PSA House Khayaban-e-iqbal, Clifton	2/4	32 cylinders /3600Psi	Compere	220	Yes
12	Rayon Gas CNG Filling Station		3/6	4,400 Litter	Bring Field	200-40	Possible
13	EPLA	D/12-B, Estate Avenue SITE	2/4	n/a	-	-	-
14	Sartaj Fuel Station	Near Ghani Chowrangi	2/4	3,000 Litter	520 cu/m/hr	200	-
15	Millennium CNG Station	Near Surjani Town	2/4	3,840 Litter	270 cu/m/hr 270 cu/m/hr	220	-
16	Caltex Amman S/S	Plot No. SA.2 North Karachi	1/2	40 Cylinders	Compare	210-220	-
17	Classic CNG Filling Station	Plot No.B-1.B-2 & B.N39 Mehran Town main Korangi Road	2/4	3,408 Litter	Compare	200	Yes
18	TS International	PSO outlet, Southern Gasoline. Plot-ST-2 Sector S.A/4, North Karachi Township	2/4	24 Cylinders	L-Type	190-200	-
19	Asif Autos F/S	Shell Outlet Plot No. 11/25 Patel Para	1/2	28 cylinders /60kg	Jodier Germany	200	Possible
20	QFS Intt (Pvt) Ltd	Chevron outlet Yasin Bros F/S KTC Depot Shahrah–e-Faisal Halt, national Highway	2/4	48 cylinders/ 50kg	Apollo	200	Possible
21	Al-Yasin F/S	PSO outlet Plot No.ST.1/2 Block.1.15.Al.North	2/4	40 cylinders /80kg	Compere	210-220	Yes
22	Army Welfare Trust	PSO Outlet. MS.I I Phase.II near Defence Police Station main Korangi Road	2/4	32 cylinders	Compere x2	200-10	Yes
23	Al-Madina Enterprises	PSO Outlet ST-2 Sector 5/C North Karachi	2/4	40 cylinders /75kg	Compere	200-210	Yes
24	Gateway CNG	Shell Outlet, S-245, Main National Highway, opposite prince Karim Agha Khan Girls School,	1/2	40 cylinders /129 kg	Compere	200	Yes
25	A.G.CNG Services	Pso Retail Outlet A.G.Services Station ST-1, Sector 11-H, North Karachi	2/4	36 cylinders /25kg	Compere	210-220	-
26	Paradise CNG Filling Station	Plot No2, Sector-15&16 Gulshan Mazdoor, Baldia Township	2/4	32 cylinders /79kg	Compere x2	230	-
27	Shell Pakistan Ltd	Shell Outlet, Jinnah Terminal Filling station, Deh Safoorah, Dice Malir, Shahrah- e-Faisal	2/4	30 cylinders/ 79kg	-	200	Yes
28	Royal CNG	Griyan No.2406, Deh Thano, Thappo Malir, Shahr-e-Faisal Malir city	3/2	30 cylinders /81kg	IMW	200-10	-
29	Al-Rafay CNG Services	Chevron retail Outlet, ST-16, Sector 5D, Surjani	2/4	30 cylinders /80kg	-	220-30	-
30	Friend Services Station		1/2	Not disclosed	-	200	-
31	Jinnah CNG	Catholic co-op housing Society M.A.Jinnah Road	4/8	18 Water Liter Cylinders/60kg	IMW	200-210	Yes

Source: JICA Study Team

3.5 Demand Forecast

3.5.1 Present Traffic

The number of passengers along major corridors was estimated in detail in "Confirmatory Green Routes Study for Karachi, March 2010". Table 3-5-1 shows the passenger volume per direction per hour along Green Line, Red Line, and M.A. Jinnah Road taken from the result of the estimation in the study.

Table 3-5-1 Present Passenger Volume in a Peak Hour

Corridor	Code	Motorcycle	Bus	Total	Period
Green Line	MB-C39	3,743	4,337	12,913	19:00-20:00
	MB-C70	5,343	9,076	20,156	19:00-20:00
	MB-28	6,720	7,616	24,194	18:00-19:00
	MB-C27	8,174	10,277	23,827	09:00-10:00
	MB-56	4,319	7,011	19,865	08:00-09:00
Red Line	MB-77	429	1,976	2,823	12:00-13:00
	MB-79	2,231	5,021	13,524	18:00-19:00
	MB-80	3,479	15,042	32,262	08:00-09:00
	MB-C78	2,780	14,573	23,376	21:00-22:00
M.A. Jinnah Road	MB-10	7,542	21,340	34,171	19:00-20:00
	MB-C8	4,040	8,445	17,802	18:00-19:00
	MB-C2	1,563	3,599	6,686	18:00-19:00
	MB-C7	1,985	10,982	17,287	09:00-10:00

Source: Confirmatory Green Routes Study for Karachi, March 2010

Bus passenger volume in the peak hour is approximately 10,000 passengers per hour per direction (PHPDT) along Green Line, while the volume is as low as 4,337 in New Karachi (MB-C39). Total passenger volume (the sum of all mode traffic) is approximately 24,000 PHPDT along Green Line. This means that a standard BRT is enough along Green Line at present.

Bus passenger volume along University Road is as large as 15,000 PHPDT between Rashid Minhas Road and Shaheed-e-Millat Road. However, the volume decreases to 5,000 PHPDT near NED and drops to 2,000 PHPDT after universities. Bus passenger demand slightly exceeds the capacity of a standard BRT. If motorcycle demand is added to public transport, the passenger volume becomes 18,000, which is nearly the capacity of a saturated BRT. Total passenger volume is approximately 32,000 PHPDT at peak section along Red Line. If public transport needs to satisfy traffic demand of all modes along Red Line, a standard BRT is not enough although this case needs not to be considered.

Bus passenger volume is as large as 21,000 PHPDT along M.A.Jinnah Road in front of Quaid-e-Azam Mausoleum, which exceed the capacity of most BRT systems except for TransMillenio in Bogota. However, boarding and alighting demand is not so high at this point and the passenger volume is the sum of traffics toward Surjani, Super Highway, and University Road. In other words, passing demand is the majority of these passengers and a standard BRT will be capable of this demand.

On the other hand, bus passenger demand drops to 8,500 PHPDT near Garden Square and 3,600 near Cloth Market. This is not the result of the demand. Rather, this is the result of constraints from the heavy congestion along M.A. Jinnah Road. Bus passenger volume is 11,000 in the one-way section of M.A. Jinnah Road between Tower and City Park.

Not all bus passengers will shift to BRT. Some passengers will remain in mixed traffic using feeder services. From this, a standard type of BRT is enough for public transport under the present traffic demand.

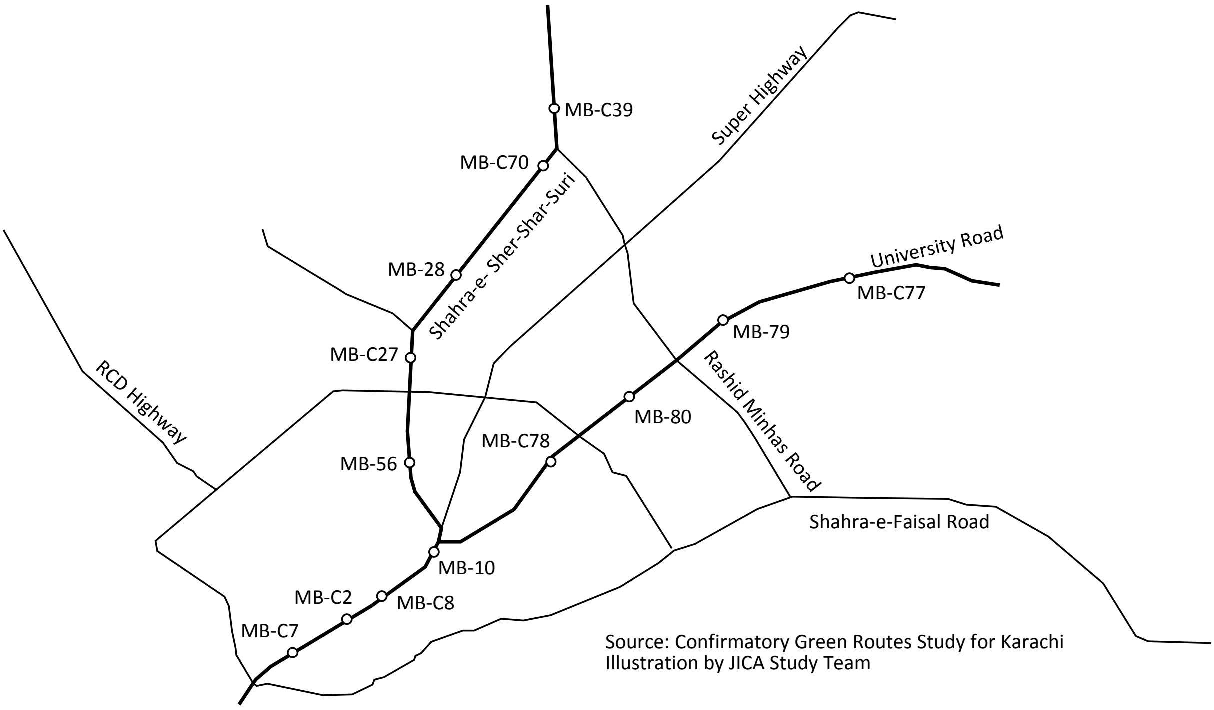


Figure 3-5-1 Survey Locations in Confirmatory Green Routes Study for Karachi

3.5.2 Future Traffic Methodology

(1) OD Matrices

Passenger demand of BRT was estimated by the traffic assignment using the network model developed in Master Plan Stage. The JICA-STRADA format was used for the traffic assignment. There are five OD matrices prepared in Master Plan Stage as shown in the table below. For the demand forecast, OD matrices of (B) and (C) were used.

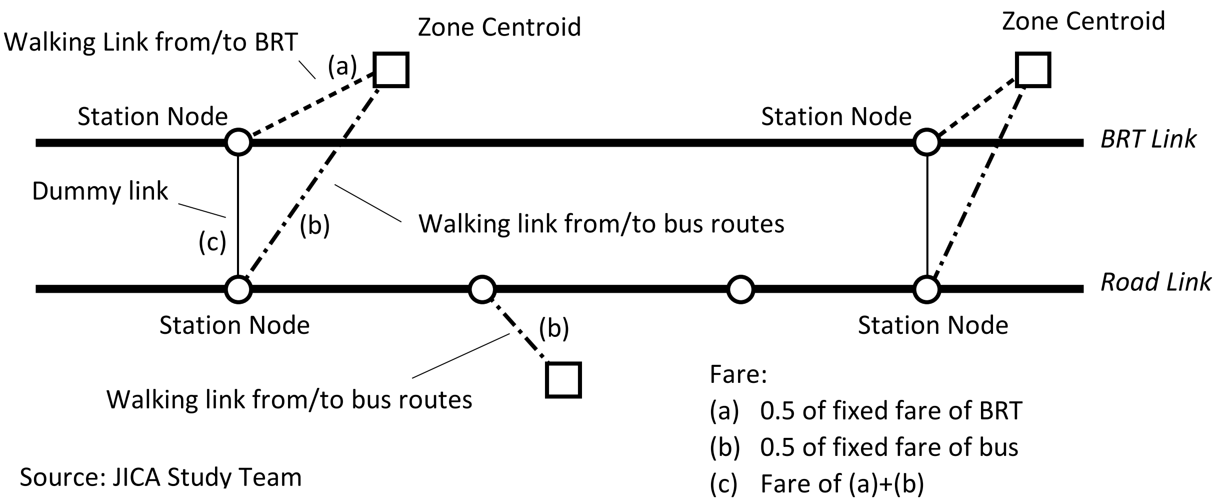
Table 3-5-2 OD Matrices

Scenario	2010	2020	2030
Without public transport development	(A)	(B)	(C)
With public transport development	--	(D)	(E)

Source: JICA Study Team

(2) Assignment Type

There are two types of traffic assignment: highway type assignment and transit type assignment. Modeling of public transport routes by highway type assignment is too simple for transit services that have fixed routes and complex fare system to estimate the passenger volume. Therefore, it is better to apply a transit type assignment for the estimation of the passenger volume of BRT. However, modeling of transit network in the traffic assignment mode requires the future plan of transit network which has not been proposed yet. At this beginning stage of BRT planning, the highway type assignment was used. The technique of modeling is illustrated in the figure below. In the demand forecast, it was assumed that passengers need to pay additional fare every time of transfers. There is a restraint in the model about the locations of stations because a zone centroid represents a traffic zone which is as same as UC.



Source: JICA Study Team

Figure 3-5-2 Network Modeling of BRT Lines in Highway Type Assignment

(3) Volume and Speed Relationship (QV)

The volume and speed relationship (QV) of road links are as same as the network model developed in Master Plan Stage (Chapter 5 of Interim Report-1). However, the maximum speed of buses was set as 17km/h based on Confirmatory Green Routes Study for Karachi (2010). In Interim Report-2, the QV function of the passenger capacity of 20,000 PHPDT was applied assuming that the standard BRT would be introduced. However, after the finalization of BRT system, the QV formula was reviewed and the flat-type QV formula of a capacity of 12,000 PHPDT at a speed of 25km/h was applied. In this QV formula, the speed is fixed at 25km/h but the like is blocked when the passenger volume exceeds 12,000 PHPDT. The proposed BRT system can carry more than 12,000 passengers per hour but the speed of 25km/h will not be possible. In order to maintain the level of services, the BRT lanes should not be overloaded by buses. The traffic demand forecast considered this capacity constraint. Since the OD matrix in this study is a daily base, the capacity of the QV was set at the equivalent of 320,000 (12,000/0.075).

(4) Value of Time

To convert the fare to time in the assignment, a logit model for bus and BRT selection was developed based on the result of the passenger interview survey. The parameter for the time valuable (in minutes) was -0.03826 (a) while that of the fare parameter (in Rs.) was -0.05745 (b). From this, the time value factor (time/cost) was estimated as (b)/(a) = 1.5 minutes per rupee.

If BRT is more comfortable than existing minibuses, more passengers will shift to BRT even if it takes more time and higher fare. The logit model gives a constant value for mode choice although this is based on the comparison between a minibus and a railway system. The constant value was calculated as Rs. 15 equivalent. Passengers' preference to use BRT compared to minibus is smaller than that of railway systems. Therefore, actual demand is found between the constant values of 0 and Rs. 15. For the demand forecast, Rs.10 was charged for buses.

(5) Fare Setting

In Interim Report-2, the BRT fare was set as Rs. 15 and no additional fare was charged for the transfer between BRT and other buses because it assumed direct services. After the finalization of BRT system, the BRT fare was set at a flat fare of Rs. 20 but the fare was not integrated with other buses. It was assumed that the fare of railway network is a flat fare of Rs. 30. The fare of railway systems and buses were separated and additional fare would be charged for the transfer between railway network and bus network.

(6) Network Scenario

The traffic assignment network was prepared for five network scenarios.

(A) Green & Red Lines on the present road network (2010)
(B) Master Plan (M/P) network (2020).
(C) M/P network (2020) without KCR
(D) M/P network (2030)
(E) Green & Red Lines + KCR on the 2030 road network

Road network is assumed to be developed as proposed in the M/P as shown in Table 3-5-3. Road capacity was reduced from the M/P along BRT routes assuming that two lanes (one lane each) are removed.

Table 3-5-3 Arterial Road Length in Master Plan

Year	Expressway	Highway	Principal Highway	Minor Arterial	Total
2010	25.6	173.2	157.2	527.9	884
2020	35.8	173.2	199.8	547.7	956.5
2030	76.9	257.2	229.1	609.2	1,172.4

Source: The Study for KTIP

In the M/P network, KCR is included in 2020 network while Blue Line and Brown Line are included in 2030 network as railway system. For the network in 2020, “Without KCR” scenario was prepared (C). This is the case when only Green & Red Line are developed as mass transit system by 2020. The scenario (E) is the case when no mass transit system is implemented after Green & Red Lines and KCR by 2030.

In addition to above scenarios, the following scenarios were prepared for the “Without Project” analysis.

- M/P network (2020) without Green & Red Lines
- M/P network (2030) without Green & Red Lines

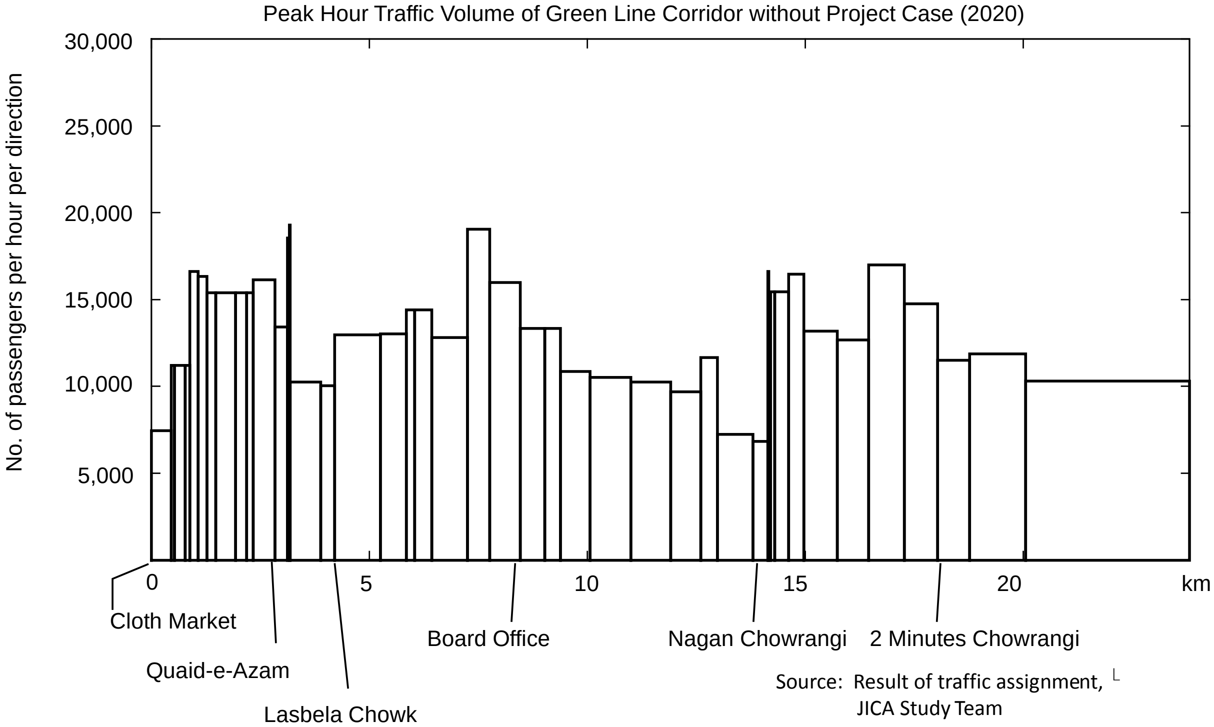
3.5.3 Without Project Case

(1) Without Green Line and Red Line

Figure 3-5-3 shows the projected number of bus passengers of the corridor of Green Line in 2020 without the BRT project, while Figure 3-5-4 shows that of the corridor of Red Line in the same conditions. Each bar represents the traffic of a link in JICA STRADA data.

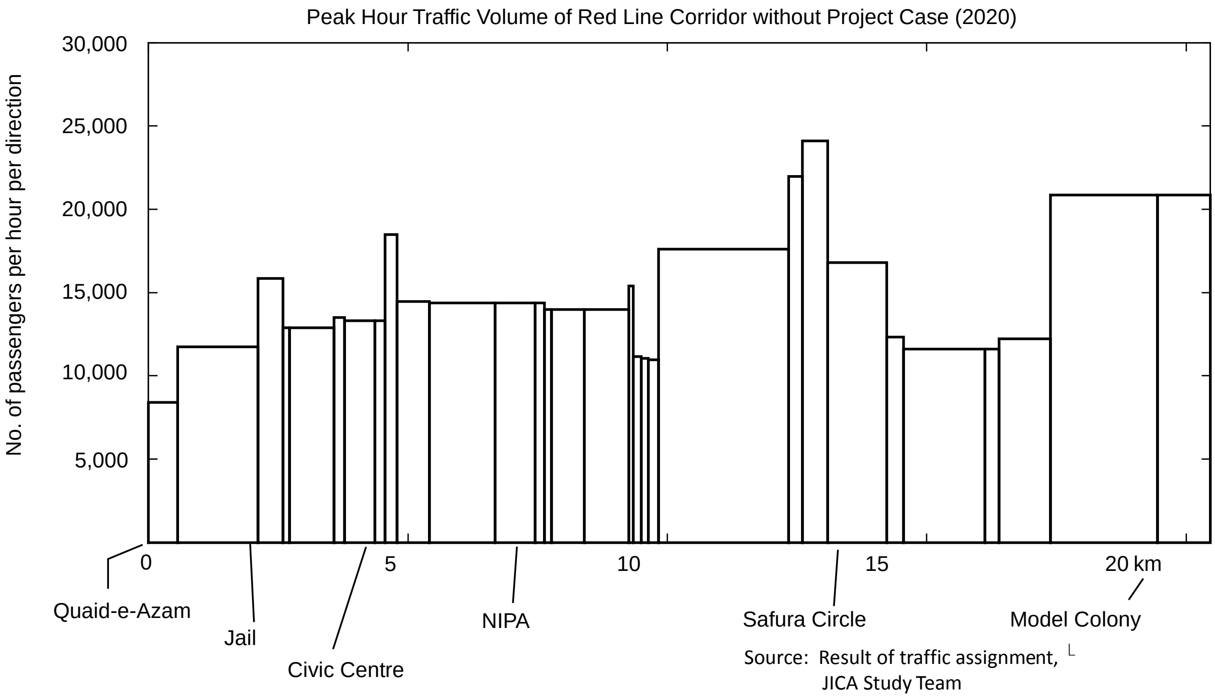
The figure illustrates the number of bus passengers per hour per direction in the peak hour. The demand exceeds the capacity of standard BRT systems (10,000 PHPDT) at some links along Green Line.

Bus passenger demand exceeds 15,000 PHPDT in most sections along University Road. The demand characteristics along Red Line are quite different from the present situation in which traffic demand rapidly becomes low in the east of universities. In 2020, the demand becomes high in the east of the corridor near Model Colony.



Source: JICA Study Team

Figure 3-5-3 Bus Passenger Demand along Green Line (2020), without Project Case



Source: JICA Study Team

Figure 3-5-4 Bus Passenger Demand along Red Line (2020), without Project Case

3.5.4 Results of Demand Forecast of Green & Red Lines

(1) Green & Red Lines on the present road network (2010)

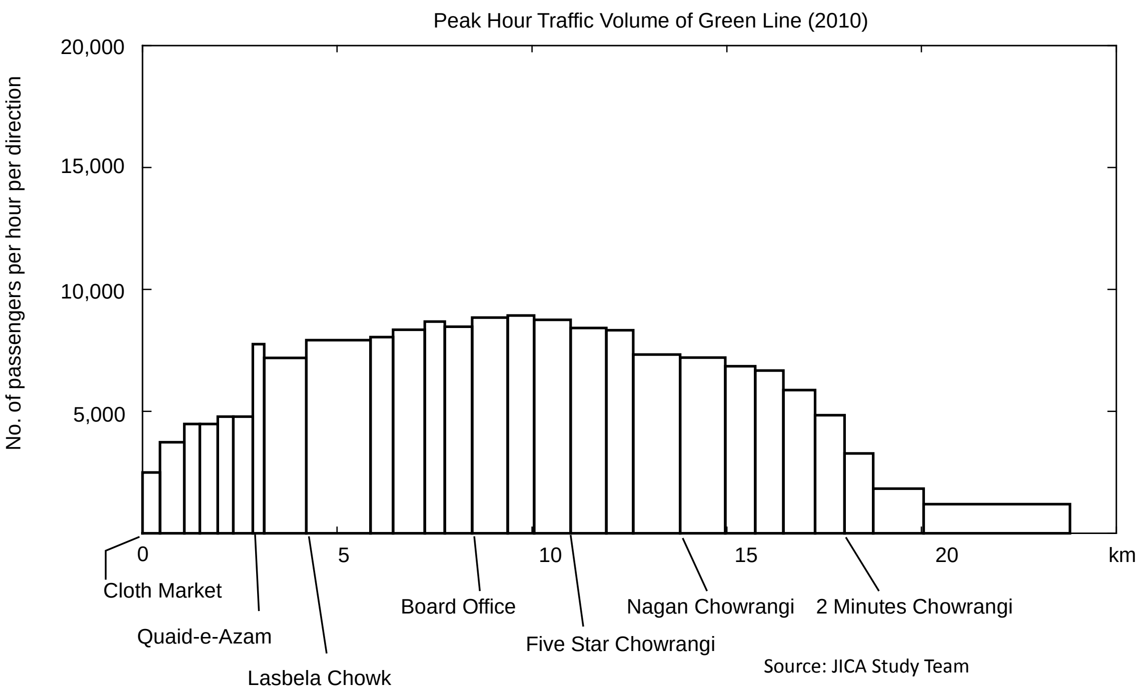
This is the result of the demand forecast of Green & Red Lines in 2010 if these BRT lines existed at present.

Passenger volume per hour per direction of Green Line would be 2,000-5,000 PHPDT (peak hour peak direction traffic) between Quaid-e-Azam Mausoleum and 2-minutes Chowrangi as shown in Figure 3-5-5. The volume would be smaller in the north section of North Nazimabad and New Karachi at 2,000-4,000 PHPDT. From Surjani to the north area, the volume would be as small as approximately 1,000 PHPDT. The volume along M.A. Jinnah Road up to Quaid-e-Azam Mausoleum would be approximately 3,000 PHPDT. This is smaller than the peak section because not all passengers along Green Line go through M.A. Jinnah Road.

The passenger volume of Red Line would be 3,000-3,500 PHPDT between Jail Road and NIPA. The volume between NIPA and NED would be approximately 3,500 PHPDT. From NED to the east along University Road, the volume would be smaller than other sections as approximately 2,500 PHPDT. The volume along New M.A. Jinnah Road and Preedy Street would be approximately 1,500 PHPDT.

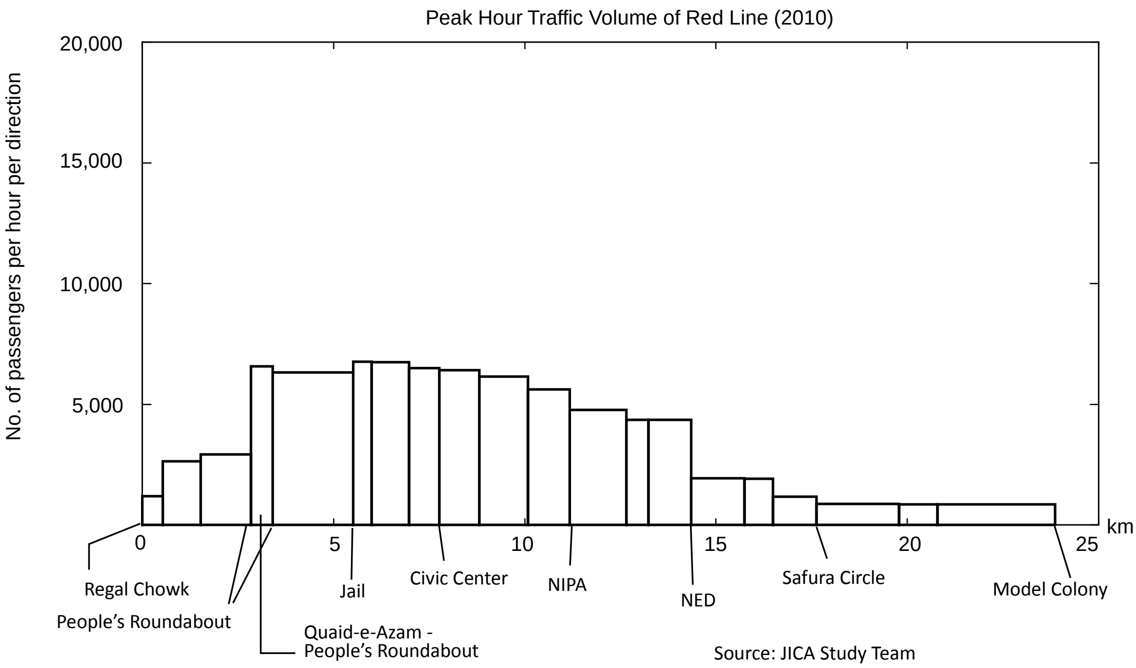
The demand forecast shows that passenger volume in Saddar Area is smaller than other peak sections. Since the length of BRT lines in Saddar Area is short, it cannot attract those passengers whose origin and destination are not along Green or Red Line outside Saddar Area. Note that fare integration between BRT lines and other lines is not considered in the demand forecast. Therefore, passengers transferring existing system and BRT lines need to pay extra fare while transfer between Green and Red Lines is free in the demand forecast model.

Since the capacity is determined in the QV formula for each link of the BRT lines, the result of the forecast of traffic volume does not exceed the capacity.



Source: JICA Study Team

Figure 3-5-5 Peak Hour Traffic Volume of Green Line (2010)



Source: JICA Study Team

Figure 3-5-6 Peak Hour Traffic Volume of Red Line (2010)

(2) Master Plan network (2020)

This is the case of the M/P network. Green & Red Lines and Karachi Circular Railway (KCR) are developed as mass transit system and road projects in the M/P in 2020 are completed in this case. Figure 3-5-7 and 3-5-8 shows the result of traffic demand forecast in 2020 for Green Line BRT and Red Line BRT, respectively.

Passenger volume of Green Line would be 8,000-13,000 PHPDT between Quaid-e-Azam Mausoleum and Surjani. Passenger volume from Surjani to the north area would increase to 5,000 - 6,000 PHPDT because of population increase in Gadap.

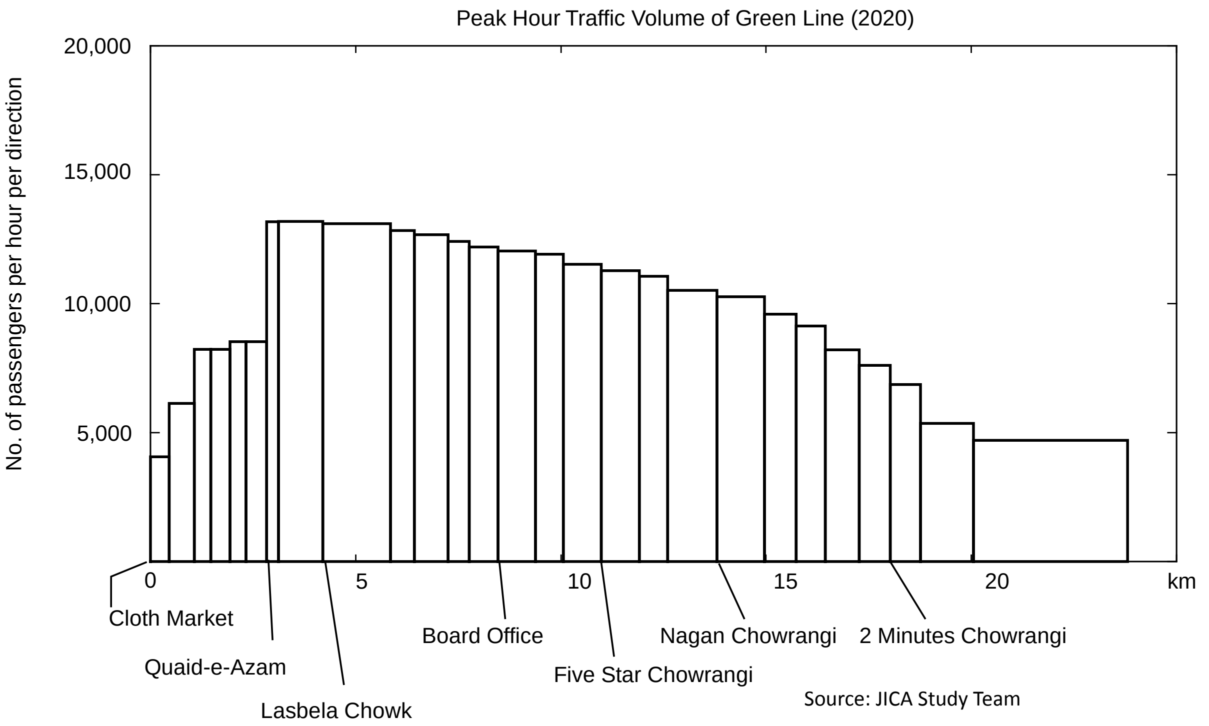
Passenger volume of Red Line would be 10,000 – 13,000 PHPDT along University Road up to Malir Gate, while it is approximately 8,300 PHPDT between Malir Gate and Model Colony. Compared to the demand in 2010, the passenger volume by section would become flat. This is because of the estimated population and industrial growth in Bin Qasim which will increase traffic demand for the east west corridor along Shahrah-e-Faisal and National Highway.

(3) M/P network (2020) without KCR (2020)

This is the case when Green & Red Lines are developed but KCR does not exist in 2020. Road projects by 2020 in the M/P are included. The difference from M/P network (2020) is the absence of KCR. Figure 3-5-9 and 3-5-10 show the results.

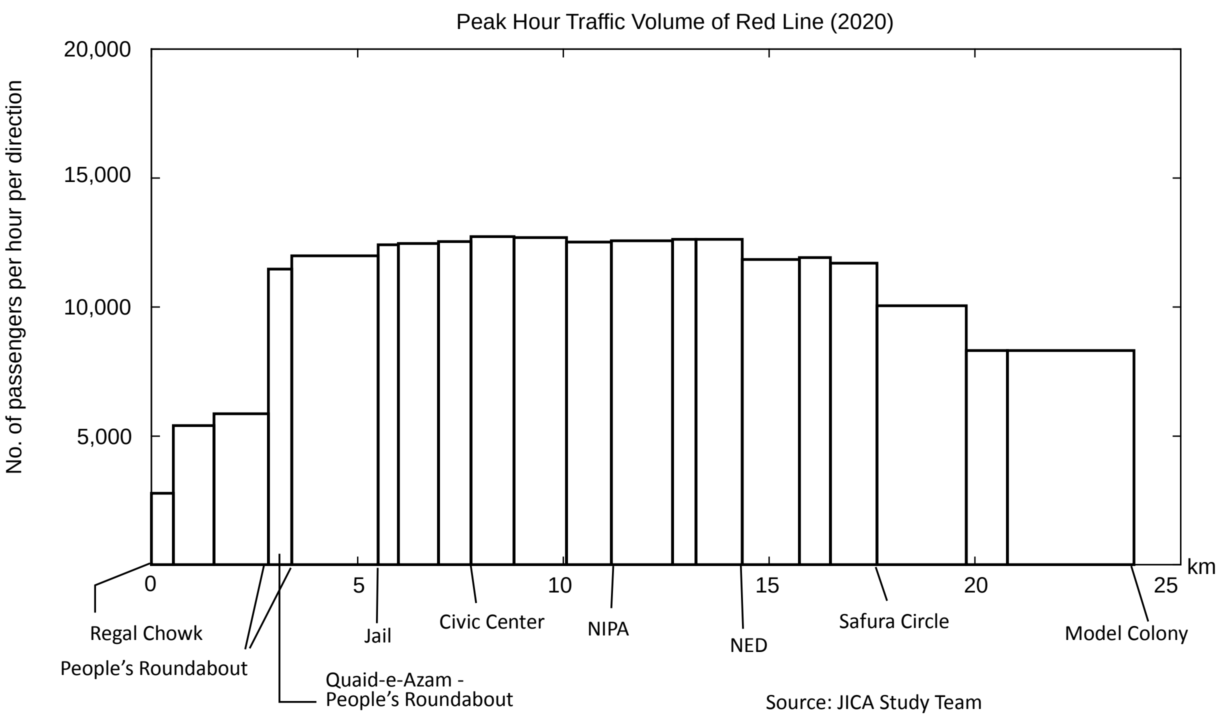
Passenger volume of Green Line in North Nazimabad, New Karachi, and the north area would be almost the same as the M/P network (2020) case. However, passenger volume of Green Line from Board Office to Surjani would be 15% smaller than the M/P network (2020) case.

Passenger volume of Red Line will increase by approximately 10% along University Road if KCR does not exist. This is because of KCR has a parallel section with University Road. KCR passengers between North Nazimabad Station and NIPA Station would shift Green and Red Line in case of the absence of KCR. In this case, passengers need to transfer between the two lines.



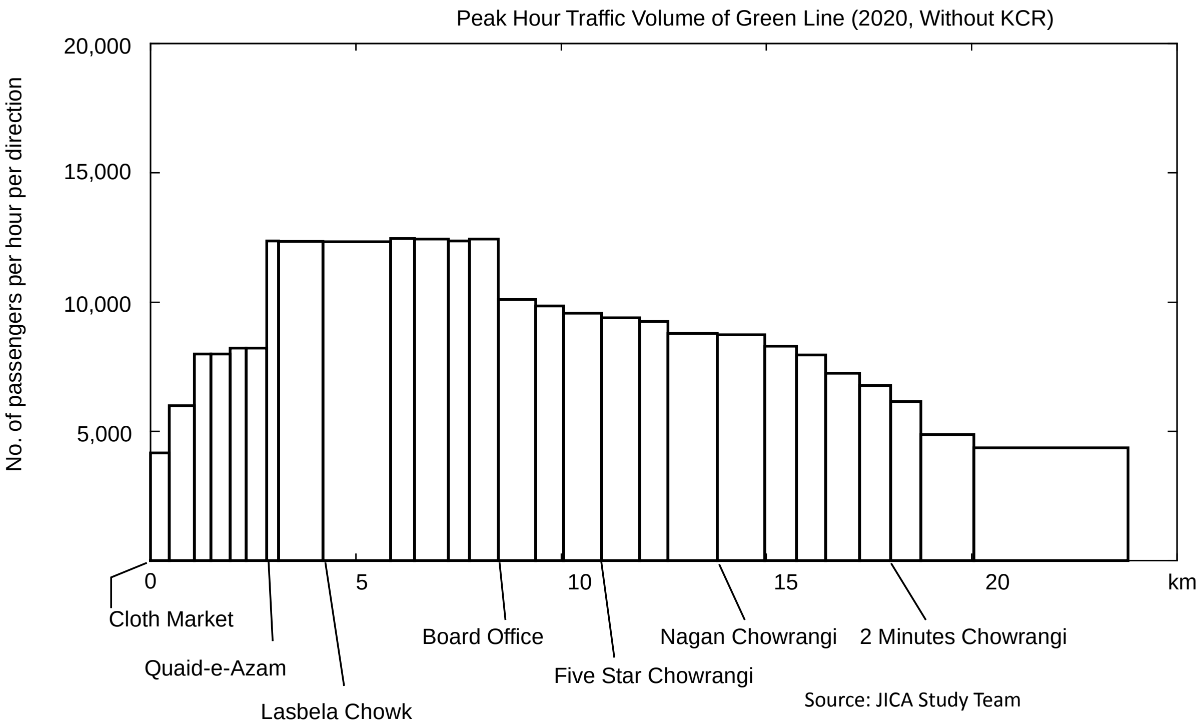
Source: JICA Study Team

Figure 3-5-7 Peak Hour Traffic Volume of Green Line (2020)



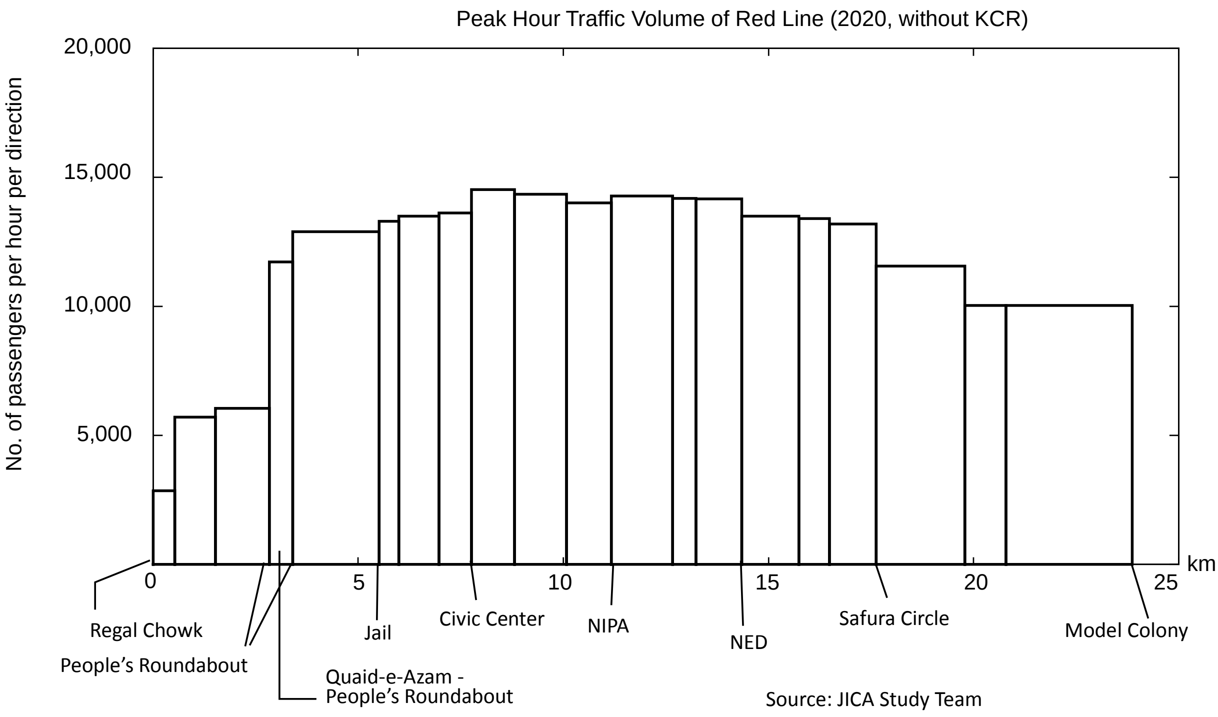
Source: JICA Study Team

Figure 3-5-8 Peak Hour Traffic Volume of Red Line (2020)



Source: JICA Study Team

Figure 3-5-9 Peak Hour Traffic Volume of Green Line (2020)



Source: JICA Study Team

Figure 3-5-10 Peak Hour Traffic Volume of Red Line (2020)

(4) M/P network (2030)

Blue Line and Brown Line are developed as railway system in addition to KCR by 2030 in M/P network (2030) scenario. The length of arterial roads is 1,172km.

Figure 3-5-11 shows the passenger volume of Green Line in 2030. The passenger volume between Nagan Chowrangi and Surjani would become larger than that of 2020 (M/P). However, there would be a drop in passenger volume between Board Office and Nagan Chowrangi. The volume becomes 9,000-10,000 PHPDT in this section. Since Blue Line, which run through Super Highway, Shahrah-e-Pakistan, and M. A. Jinnah Road provides quick access to the center of the city, traffic from New Karachi and its northern area will shift to Blue Line via Brown Line. In the traffic assignment, many bus passengers will remain in mixed traffic because of the increase in travel speed along the corridor by Blue Line. Passenger volume between Quaid-e-Azam Mausoleum and Board Office is 11,000-12,000 PHPDT.

Figure 3-5-12 shows the passenger volume of Red Line in 2030. Passenger volume between Quaid-e-Azam Mausoleum and NED is smaller than that of 2020 projection by approximately 18%. The volume is approximately 9,000-10,000 in this section. The volume between NED and Safura Circle is approximately 9,000 PHPDT, which is also smaller than that in 2020 projection. The volume near Model Colony is 35% smaller than the 2020 projection. This is because of development of Blue Line and Brown Line. KCR extension and other BRT lines also contribute to the reduction of the passenger volume of Red Line.

Note that the capacity of BRT links is set as 12,000 PHPDT and the volume-speed relationship is as given in Figure 3-5-3, considering that a standard BRT would be suitable in Karachi. If a full scale BRT like Bogota is introduced, the passenger demand would be higher than this forecast.

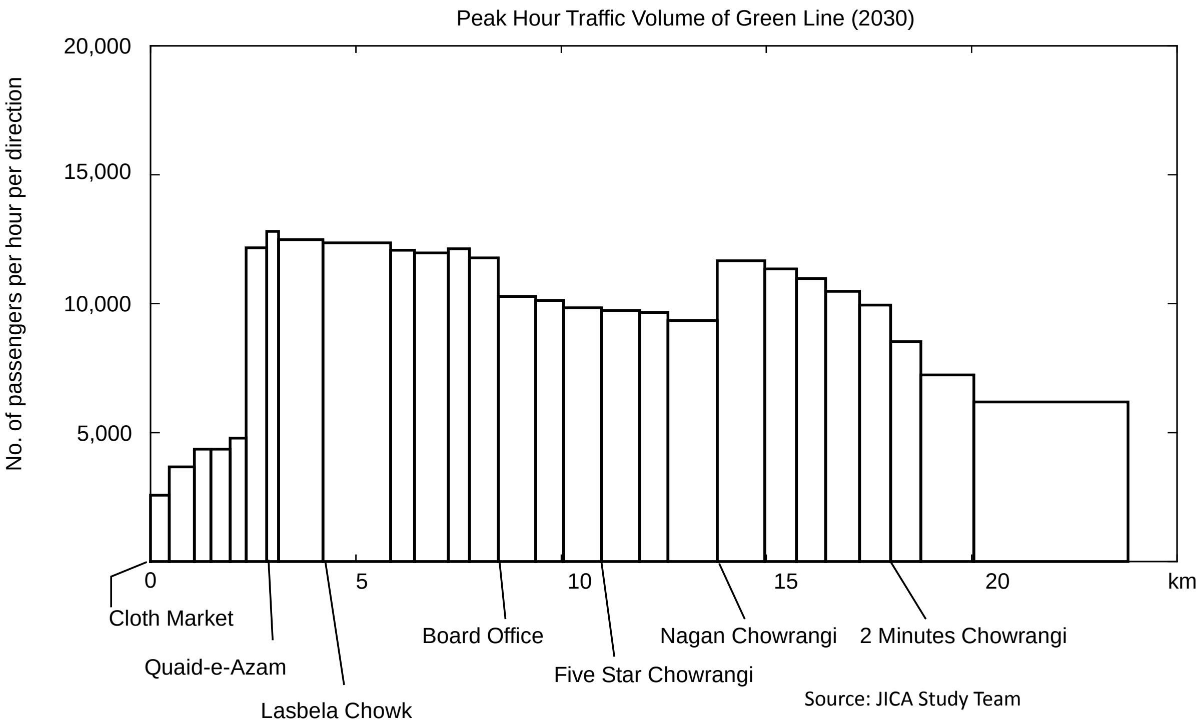
(5) Green & Red Lines + KCR on the 2030 road network (2030)

In this case, Green Line, Red Line and KCR exist in 2030 but no other mass transit system is implemented by 2030 while road projects are implemented as the M/P.

Figure 3-5-13 shows the passenger volume of Green Line in this case. Passenger volume is larger than that of 2020 projection for all sections. It is 10,000-12,000 for most sections.

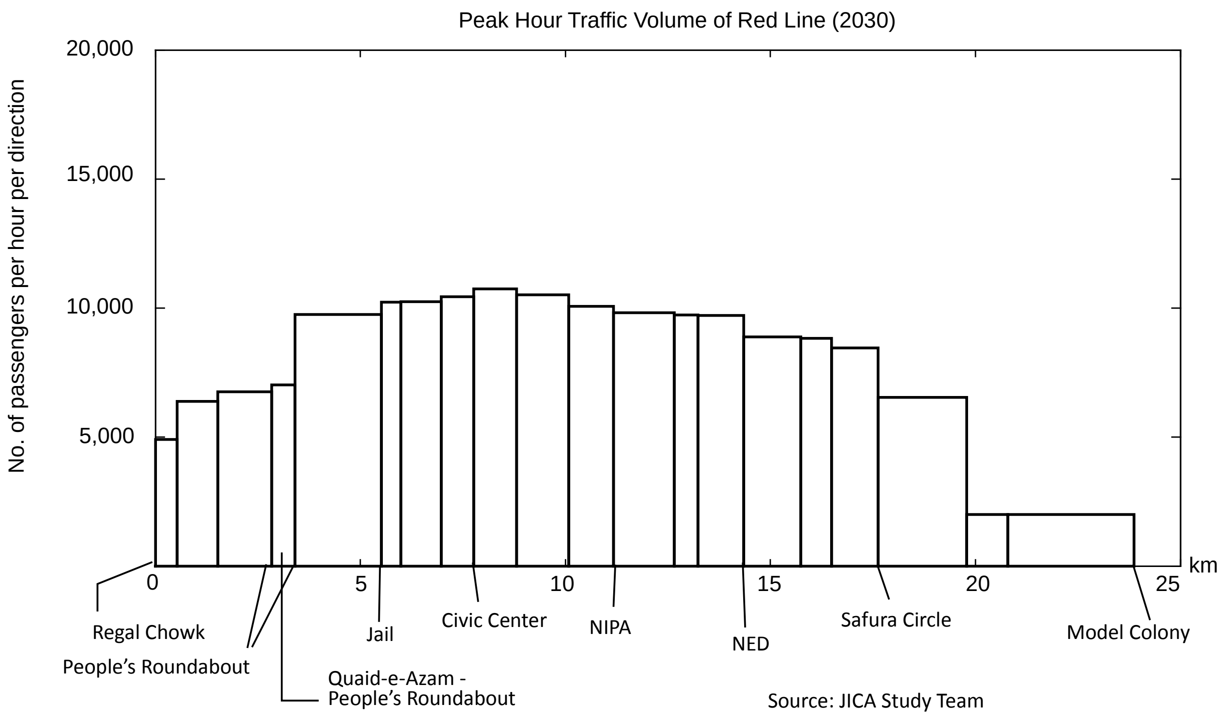
Figure 3-5-14 shows the passenger volume of Red Line in this case. Passenger volume is almost the same as that of 2020 projection for most sections. Passenger volume near Model Colony shows a reduction by 50%. This is because of road development such as Malir Expressway which will reduce traffic congestion for the east-west corridor.

Figure 3-5-15 and 3-5-16 show the passenger volume of mass transit system in 2020 and 2030, respectively.



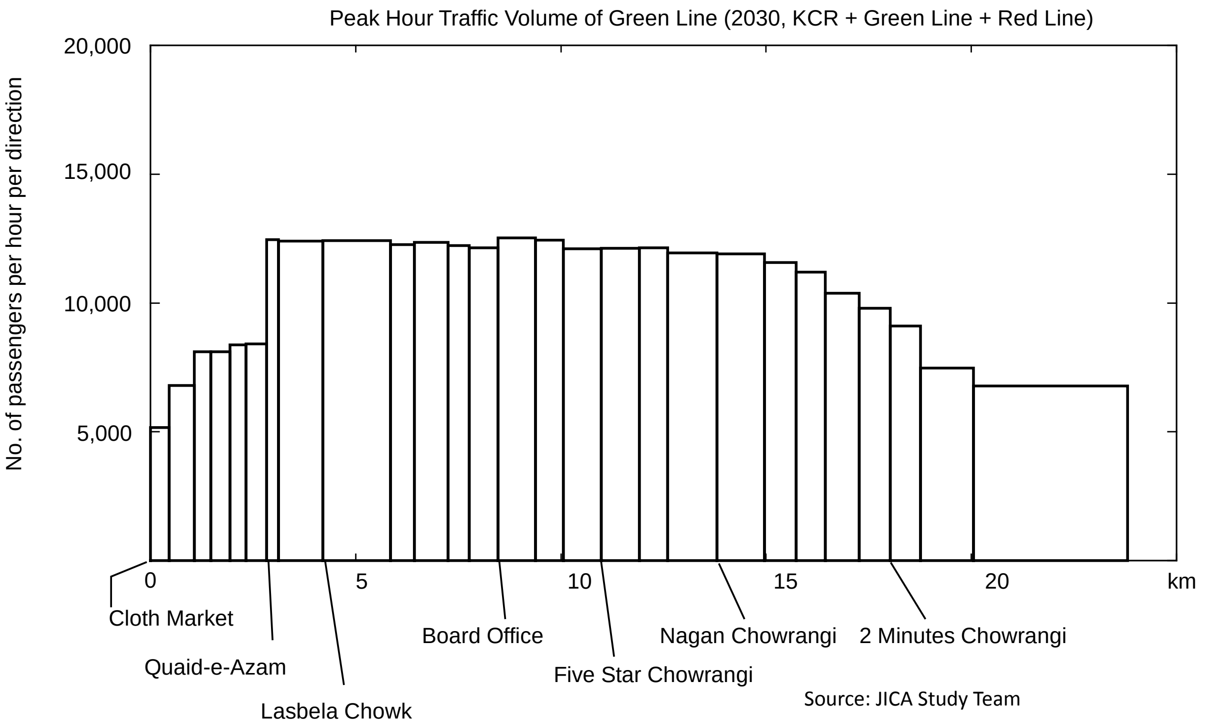
Source: JICA Study Team

Figure 3-5-11 Peak Hour Traffic Volume of Green Line (2030)



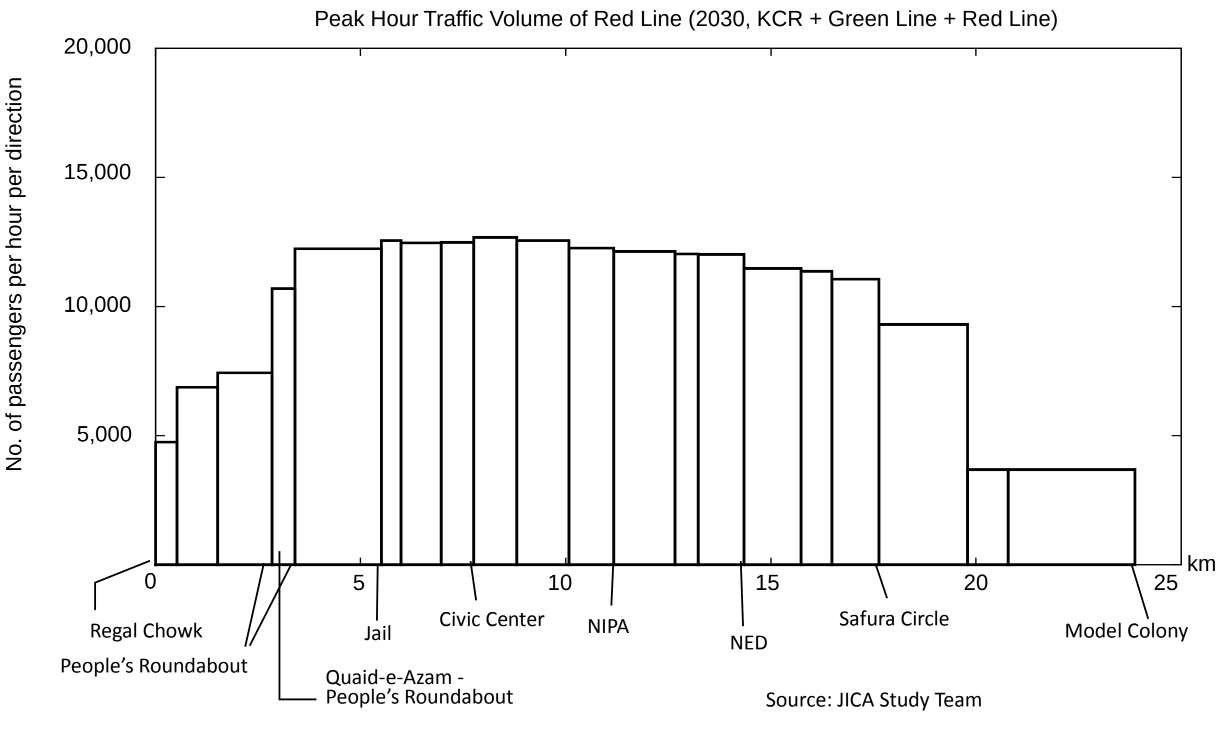
Source: JICA Study Team

Figure 3-5-12 Peak Hour Traffic Volume of Red Line (2030)



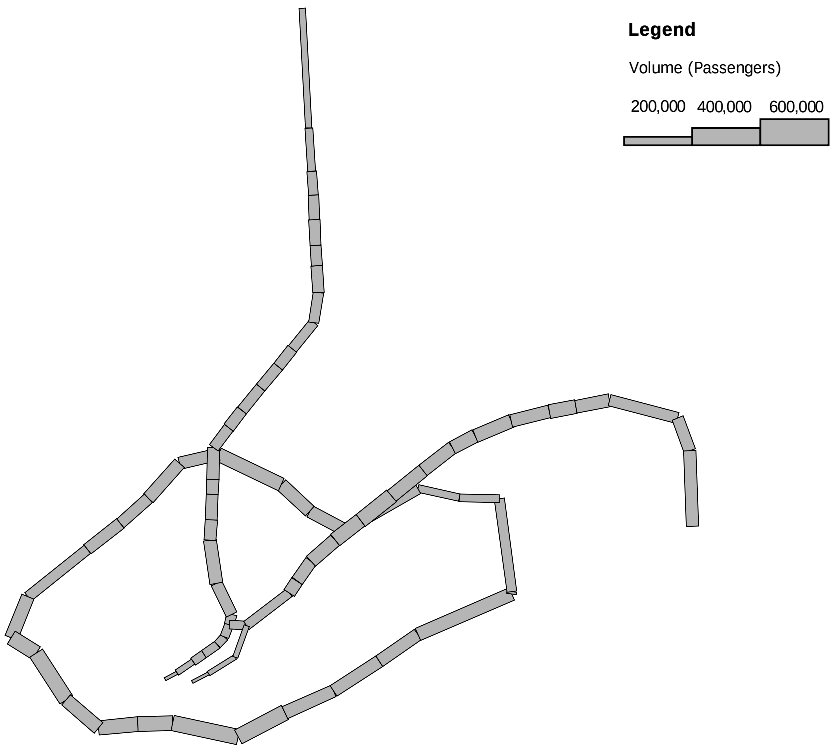
Source: JICA Study Team

Figure 3-5-13 Peak Hour Traffic Volume of Green Line (2030)



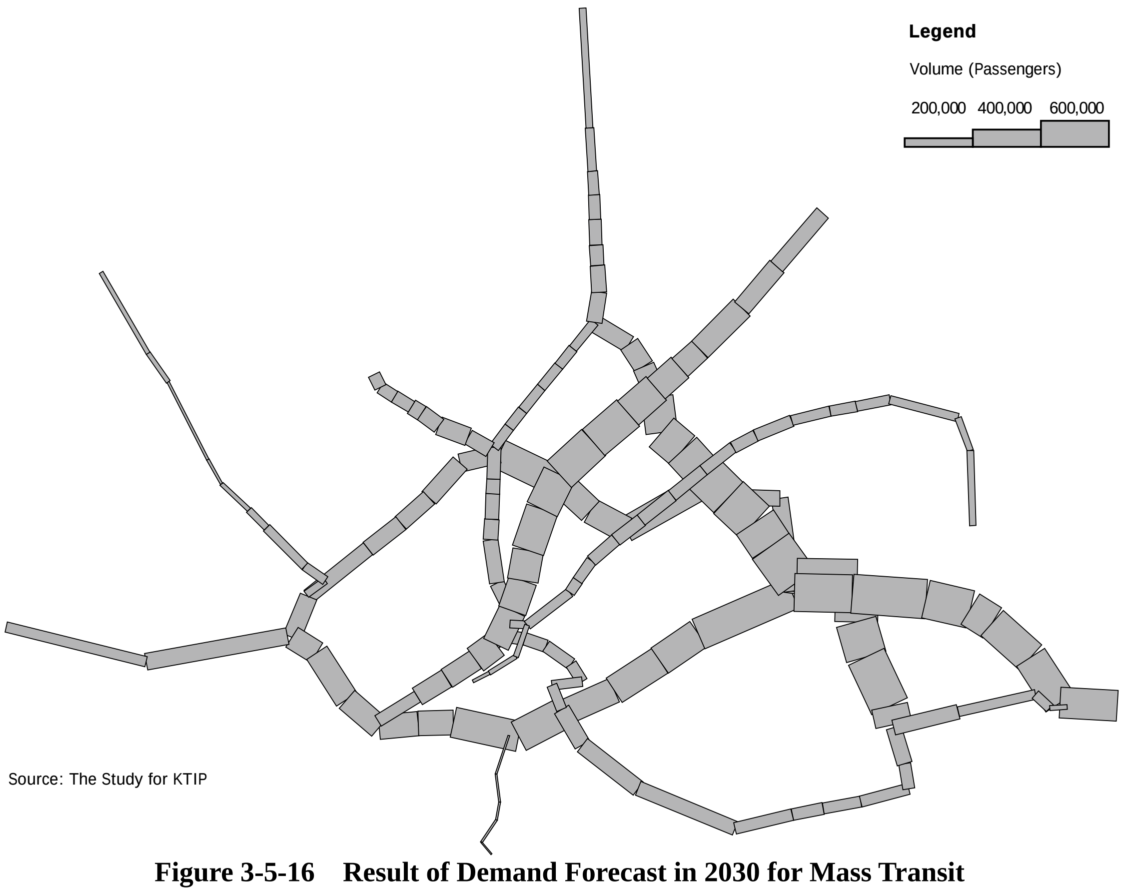
Source: JICA Study Team

Figure 3-5-14 Peak Hour Traffic Volume of Green Line (2030)



Source: The Study for KTIP

Figure 3-5-15 Result of Demand Forecast in 2020 for Mass Transit



Source: The Study for KTIP

Figure 3-5-16 Result of Demand Forecast in 2030 for Mass Transit

3.5.5 Traffic Volume Data of the Demand Forecast

Table 3-5-4 shows the result of the demand forecast of the daily passenger volume (both directions) of Green Line and Red Line for the five scenarios. This is computed by traffic assignment using daily OD matrices. The codes in the section column represent station codes.

Table 3-5-5 shows the peak hour passenger volume per direction. This was calculated from the daily traffic volume assuming the peak hour rate of 7.5% per direction.

Table 3-5-6 shows the result of the demand forecast of the number of passenger boarding at stations. The total number of passenger boarding is 370,000 in 2010, 733,000 in 2020, and 1.26 million in 2030. The number of daily passenger boarding was used for revenue calculation.

Table 3-5-7 shows the passenger boarding and alighting at stations in peak hour. The peak hour rate of 7.5% was used to calculate the volume.

3.5.6 Passenger Shift from Present Road

BRT will be constructed in existing roads and a part of passengers using a road section will shift to the BRT in the same section. Although BRT passengers will come from not only the same road but also other roads, the majority would be the passengers from the same section. To calculate how many passengers who are using a road section in without BRT case will shift to BRT in the same road section in with BRT case, OD data of each link was prepared by incremental traffic assignment method. The assigned volume to a BRT link was aggregated as the shift traffic if the same OD of the same mode was also assigned to the road link where the BRT link was introduced. The following is the formula to calculate the shift.

$$VS^k = \sum_{i=1}^{N} \sum_{m=1}^{M} \sum_{s=1}^{Z} \sum_{e=1}^{Z} V_{i,m}^k[s,e] \times \delta_{i,m}^k[s,e]$$

Where, VS^k = passenger volume of the shift from road to BRT link k, N= No. of iterations of incremental assignment, M = No. of travel modes, Z= No. of zones, $V_{i,m}^k[s,e]$= passenger volume from origin s to destination e by mode m assigned to link k in iteration of i, $\delta_{i,m}^k[s,e]$= 1 if passenger volume from origin s to destination e by mode m is assigned to the road link parallel to link k and 0 if not.

Table 3-5-8 and 3-5-9 shows the result of the calculation for 2010 and 2020, respectively. From this, approximately 40-70% of bus passengers will shift to BRT while 3-10% of motorcycle and car passengers will shift to BRT. Note that in the traffic assignment, it was assumed that motorcycle and car passengers would not use feeder bus system. Therefore, only OD pairs which are directly connected by BRT links were assigned in case of motorcycle and bus passengers.

The result shows that not all passengers will shift to BRT. Capacity limitation of BRT is one of the reasons. If more passengers use the BRT, it is necessary to increase the BRT capacity which will reduce the travel speed of BRT.

Table 3-5-4 Daily Passenger Volume (Both Directions)

Section			2010	2020		2030	
			Green&Red	Green&Red +KCR	Green&Red only	M/P Network	Green&Red +KCR
Green Line							
M1	-	M2	27,331	108,576	111,176	68,591	137,886
M2	-	M3	50,652	163,869	159,635	98,152	181,132
M3	-	M4	60,626	219,570	213,086	116,576	216,460
M4	-	M5	64,356	227,498	219,097	127,526	223,614
M5	-	G01	64,356	227,498	219,097	324,218	224,376
G01	-	G02	99,988	351,322	329,634	341,679	331,913
G02	-	G03	92,630	351,803	329,187	332,852	330,689
G03	-	G04	105,650	349,676	328,967	329,743	331,430
G04	-	G05	107,604	342,338	332,130	322,007	326,906
G05	-	G06	111,780	337,996	331,825	319,421	329,414
G06	-	G07	116,056	331,097	329,879	323,692	326,072
G07	-	G08	113,491	325,385	331,569	314,107	323,818
G08	-	G09	118,665	321,376	269,543	274,452	333,970
G09	-	G10	119,608	317,880	262,673	269,905	331,772
G10	-	G11	117,519	307,462	255,031	262,488	322,763
G11	-	G12	112,723	300,958	250,234	259,553	323,357
G12	-	G13	112,371	294,944	246,776	257,933	323,765
G13	-	G14	98,061	280,266	234,292	249,359	318,555
G14	-	G15	96,659	273,816	233,175	311,136	317,481
G15	-	G16	92,053	255,923	221,088	302,777	308,643
G16	-	G17	89,519	243,757	212,219	293,032	298,653
G17	-	G18	79,153	218,931	193,416	279,485	276,881
G18	-	G19	64,177	202,752	180,420	265,497	261,234
G19	-	G20	43,622	183,059	163,954	227,668	242,607
G20	-	G21	24,514	142,839	130,044	193,148	199,210
G21	-	G22	15,966	125,190	116,540	165,327	181,014
Red Line							
P1	-	P2	16,383	73,929	76,406	131,002	126,860
P2	-	P3	35,335	144,188	152,647	170,098	183,761
P3	-	R02	39,290	156,145	161,530	180,026	198,487
R01	-	R02	91,495	305,943	312,655	186,971	285,196
R02	-	R03	88,770	319,558	343,745	259,949	326,565
R03	-	R04	94,971	330,721	354,953	272,817	334,848
R04	-	R05	94,941	332,169	360,123	272,954	332,411
R05	-	R06	91,392	334,209	363,184	278,360	333,044
R06	-	R07	90,064	339,391	387,292	286,537	338,479
R07	-	R08	85,549	338,727	382,556	280,030	334,805
R08	-	R09	78,424	333,843	373,503	268,320	327,285
R09	-	R10	66,424	335,472	380,595	261,901	323,547
R10	-	R11	61,339	336,729	378,565	259,313	321,120
R11	-	R12	61,339	336,546	378,184	259,125	320,938
R12	-	R13	26,327	315,611	359,950	236,960	305,918
R13	-	R14	26,193	317,730	357,840	235,219	303,462
R14	-	R15	15,629	311,832	351,940	225,203	295,250
R15	-	R16	11,716	267,839	308,345	174,579	248,537
R16	-	R17	11,412	221,604	267,932	53,359	98,408
R17	-	R18	11,412	221,604	267,932	53,359	98,408

Source: The Study for KTIP

Table 3-5-5 Peak Hour Passenger Volume per Direction

Section	2010	2020		2030	
	Green&Red	Green&Red +KCR	Green&Red only	M/P Network	Green&Red +KCR
Green Line					
M1 - M2	1,025	4,072	4,169	2,572	5,171
M2 - M3	1,899	6,145	5,986	3,681	6,792
M3 - M4	2,273	8,234	7,991	4,372	8,117
M4 - M5	2,413	8,531	8,216	4,782	8,386
M5 - G01	2,413	8,531	8,216	12,158	8,414
G01 - G02	3,750	13,175	12,361	12,813	12,447
G02 - G03	3,474	13,193	12,345	12,482	12,401
G03 - G04	3,962	13,113	12,336	12,365	12,429
G04 - G05	4,035	12,838	12,455	12,075	12,259
G05 - G06	4,192	12,675	12,443	11,978	12,353
G06 - G07	4,352	12,416	12,370	12,138	12,228
G07 - G08	4,256	12,202	12,434	11,779	12,143
G08 - G09	4,450	12,052	10,108	10,292	12,524
G09 - G10	4,485	11,921	9,850	10,121	12,441
G10 - G11	4,407	11,530	9,564	9,843	12,104
G11 - G12	4,227	11,286	9,384	9,733	12,126
G12 - G13	4,214	11,060	9,254	9,672	12,141
G13 - G14	3,677	10,510	8,786	9,351	11,946
G14 - G15	3,625	10,268	8,744	11,668	11,906
G15 - G16	3,452	9,597	8,291	11,354	11,574
G16 - G17	3,357	9,141	7,958	10,989	11,199
G17 - G18	2,968	8,210	7,253	10,481	10,383
G18 - G19	2,407	7,603	6,766	9,956	9,796
G19 - G20	1,636	6,865	6,148	8,538	9,098
G20 - G21	919	5,356	4,877	7,243	7,470
G21 - G22	599	4,695	4,370	6,200	6,788
Red Line					
P1 - P2	614	2,772	2,865	4,913	4,757
P2 - P3	1,325	5,407	5,724	6,379	6,891
P3 - R02	1,473	5,855	6,057	6,751	7,443
R01 - R02	3,431	11,473	11,725	7,011	10,695
R02 - R03	3,329	11,983	12,890	9,748	12,246
R03 - R04	3,561	12,402	13,311	10,231	12,557
R04 - R05	3,560	12,456	13,505	10,236	12,465
R05 - R06	3,427	12,533	13,619	10,439	12,489
R06 - R07	3,377	12,727	14,523	10,745	12,693
R07 - R08	3,208	12,702	14,346	10,501	12,555
R08 - R09	2,941	12,519	14,006	10,062	12,273
R09 - R10	2,491	12,580	14,272	9,821	12,133
R10 - R11	2,300	12,627	14,196	9,724	12,042
R11 - R12	2,300	12,620	14,182	9,717	12,035
R12 - R13	987	11,835	13,498	8,886	11,472
R13 - R14	982	11,915	13,419	8,821	11,380
R14 - R15	586	11,694	13,198	8,445	11,072
R15 - R16	439	10,044	11,563	6,547	9,320
R16 - R17	428	8,310	10,047	2,001	3,690
R17 - R18	428	8,310	10,047	2,001	3,690

Source: The Study for KTIP

Table 3-5-6 Daily Passenger Volume of Boarding Only

Code	Station	2010	2020		2030	
		Green&Red	Green&Red +KCR	Green&Red only	M/P Network	Green&Red +KCR
	Green Line					
R0-01	M1	19,518	32,934	36,436	27,105	68,943
R0-02	M2	17,288	27,648	24,232	28,256	21,624
R0-03	M3	11,225	27,857	26,731	14,415	17,664
R0-05	M4	4,781	3,988	3,030	9,248	4,062
R1-01	G01	10,212	9,470	10,778	25,049	10,974
R1-02	G02	15,400	11,098	7,850	21,324	11,353
R1-03	G03	33,583	19,667	15,069	45,422	23,611
R1-04	G04	14,861	7,137	26,770	22,964	8,549
R1-05	G05	18,129	8,791	10,108	21,829	12,745
R1-06	G06	19,185	11,136	9,318	30,406	13,665
R1-07	G07	13,369	4,709	6,133	13,559	4,893
R1-08	G08	17,284	17,982	35,071	17,350	17,556
R1-09	G09	24,927	3,452	4,910	10,126	4,397
R1-10	G10	9,850	6,504	5,117	17,438	6,944
R1-11	G11	13,940	4,195	3,551	8,611	6,920
R1-12	G12	7,967	4,184	2,911	8,351	5,749
R1-13	G13	15,879	8,642	7,710	13,224	13,926
R1-14	G14	9,354	5,127	5,550	6,600	7,394
R1-15	G15	14,374	10,062	7,159	15,460	12,737
R1-16	G16	11,802	6,677	5,029	16,444	6,831
R1-17	G17	12,275	14,225	11,047	16,989	15,903
R1-18	G18	16,610	8,659	7,068	22,876	9,951
R1-19	G19	25,273	10,845	9,231	39,806	14,408
R1-20	G20	21,126	21,434	18,651	31,897	25,033
R1-21	G21	10,630	9,136	7,646	28,116	11,278
R1-22	G22	15,870	62,595	58,270	127,903	90,507
	Red Line					
RZ-00	P1	16,057	36,965	38,203	157,630	63,430
RZ-01	P2	22,301	35,289	29,498	31,978	28,670
RZ-02	P3	9,021	6,091	4,570	12,488	7,586
R3-02	R02	5,241	3,005	2,688	4	4,147
R3-03	R03	13,611	10,731	9,441	21,573	12,614
R3-04	R04	78	4,524	6,094	1,498	5,262
R3-05	R05	39,307	14,635	10,603	32,719	16,485
R3-06	R06	11,611	14,244	20,865	34,585	16,998
R3-07	R07	34,874	17,318	16,146	48,042	18,207
R3-08	R08	29,869	12,282	12,126	31,727	13,484
R3-09	R09	15,248	11,909	12,128	17,647	10,652
R3-10	R10	6,489	5,274	5,240	5,659	2,454
R3-11	R11	0	91	190	96	91
R3-12	R12	35,171	22,938	18,046	61,360	28,961
R3-13	R13	139	5,366	2,551	988	2,981
R3-14	R14	10,004	6,511	5,454	17,328	6,372
R3-15	R15	3,913	31,412	40,990	26,914	26,187
R3-16	R16	304	25,663	23,005	60,636	88,494
R3-17	R17	0	0	0	0	0
R3-18	R18	11,373	110,802	133,966	59,347	49,204

Source: The Study for KTIP

Table 3-5-6 Peak Hour Boarding and Alighting

Code	Station	2010	2020		2030	
		Green&Red	Green&Red +KCR	Green&Red only	M/P Network	Green&Red +KCR
	Green Line					
R0-01	M1	2,928	4,940	5,465	4,066	10,341
R0-02	M2	2,593	4,147	3,635	4,238	3,244
R0-03	M3	1,684	4,178	4,010	2,162	2,650
R0-05	M4	717	598	455	1,387	609
R1-01	G01	1,532	1,420	1,617	3,757	1,646
R1-02	G02	2,310	1,665	1,177	3,199	1,703
R1-03	G03	5,037	2,950	2,260	6,813	3,542
R1-04	G04	2,229	1,071	4,016	3,445	1,282
R1-05	G05	2,719	1,319	1,516	3,274	1,912
R1-06	G06	2,878	1,670	1,398	4,561	2,050
R1-07	G07	2,005	706	920	2,034	734
R1-08	G08	2,593	2,697	5,261	2,602	2,633
R1-09	G09	3,739	518	736	1,519	659
R1-10	G10	1,478	976	767	2,616	1,042
R1-11	G11	2,091	629	533	1,292	1,038
R1-12	G12	1,195	628	437	1,253	862
R1-13	G13	2,382	1,296	1,157	1,984	2,089
R1-14	G14	1,403	769	832	990	1,109
R1-15	G15	2,156	1,509	1,074	2,319	1,911
R1-16	G16	1,770	1,002	754	2,467	1,025
R1-17	G17	1,841	2,134	1,657	2,548	2,385
R1-18	G18	2,491	1,299	1,060	3,431	1,493
R1-19	G19	3,791	1,627	1,385	5,971	2,161
R1-20	G20	3,169	3,215	2,798	4,784	3,755
R1-21	G21	1,594	1,370	1,147	4,217	1,692
	Red Line					
RZ-00	P1	2,409	5,545	5,730	23,645	9,515
RZ-01	P2	3,345	5,293	4,425	4,797	4,301
RZ-02	P3	1,353	914	686	1,873	1,138
R3-02	R02	786	451	403	1	622
R3-03	R03	2,042	1,610	1,416	3,236	1,892
R3-04	R04	12	679	914	225	789
R3-05	R05	5,896	2,195	1,590	4,908	2,473
R3-06	R06	1,742	2,137	3,130	5,188	2,550
R3-07	R07	5,231	2,598	2,422	7,206	2,731
R3-08	R08	4,480	1,842	1,819	4,759	2,023
R3-09	R09	2,287	1,786	1,819	2,647	1,598
R3-10	R10	973	791	786	849	368
R3-11	R11	0	14	29	14	14
R3-13	R13	21	805	383	148	447
R3-14	R14	1,501	977	818	2,599	956
R3-15	R15	587	4,712	6,149	4,037	3,928
R3-16	R16	46	3,849	3,451	9,095	13,274
R3-17	R17	0	0	0	0	0
R3-18	R18	1,706	16,620	20,095	8,902	7,381

Source: The Study for KTIP

Table 3-5-7 Passenger Shift from Road to BRT in 2010

Green Line in case of 2010 demand

		Road Traffc without BRT			BRT Traffic from Parallel Road			% Shift to BRT		
Section		M/C	Car	Bus	M/C	Car	Bus	M/C	Car	Bus
Cloth Market	Garden Road	60,032	104,491	161,401	298	0	9,617	0.5	0.0	6.0
Garden Road	Shahra-e-Quaideen	89,754	170,969	235,549	859	0	12,662	1.0	0.0	5.4
Shahra-e-Quaideen	Gurmandir	99,203	196,907	235,549	830	0	12,649	0.8	0.0	5.4
Gurmandir	Lasbela	78,994	157,291	168,121	1,755	0	6,394	2.2	0.0	3.8
Lasbela	Nazimabad No.1 Chowrangi	94,161	149,642	182,107	2,459	0	7,685	2.6	0.0	4.2
Nazimabad No.1 Chowrangi	Board Office	118,458	170,842	257,518	2,123	0	8,177	1.8	0.0	3.2
Board Office	Nagan Chowrangi	90,642	142,388	120,528	1,356	0	3,286	1.5	0.0	2.7
Nagan Chowrangi	Surujani Chowrangi	82,665	105,240	118,266	656	0	3,388	0.8	0.0	2.9

Red Line in case of 2010 demand

		Road Traffc without BRT			BRT Traffic from Parallel Road			% Shift to BRT		
Section		M/C	Car	Bus	M/C	Car	Bus	M/C	Car	Bus
M.A. Jinnah Road	Jail Chowrangi	45,827	140,758	98,355	2,644	53	12,775	5.8	0.0	13.0
Jail Chowrangi	Hasan Square Roundabout	70,235	171,926	126,337	6,956	53	22,326	9.9	0.0	17.7
Hasan Square Roundabout	NIPA Chowrangi	78,855	189,403	110,850	4,292	22	10,172	5.4	0.0	9.2
NIPA Chowrangi	Safari Flyover	38,922	111,487	67,833	2,477	0	6,642	6.4	0.0	9.8
Safari Flyover	Safura Circle	13,794	51,925	83,912	0	0	1,056	0.0	0.0	1.3
Safura Circle	Malir Cant Check Post	6,760	34,291	18,861	0	0	133	0.0	0.0	0.7
Malir Cant Check Post	Model Colony	10,510	44,500	32,496	0	0	0	0.0	0.0	0.0

Note 1: Figures are the number of passengers per day for both directions
Note 2: Estimated by the Demand Forecast Model in KTIP
Note 3: M/C = Motorcycle

Source: The Study for KTIP

Table 3-5-8 Passenger Shift from Road to BRT in 2020

Green Line in case of 2020 demand

		Road Traffc without BRT			BRT Traffic from Parallel Road			% Shift to BRT		
Section		M/C	Car	Bus	M/C	Car	Bus	M/C	Car	Bus
Cloth Market	Garden Road	104,426	154,655	232,999	4,411	4,621	97,035	4.2	3.0	41.6
Garden Road	Shahra-e-Quaideen	142,416	250,349	323,770	7,716	8,761	141,474	5.4	3.5	43.7
Shahra-e-Quaideen	Gurmandir	154,805	282,393	323,770	7,756	8,792	141,495	5.0	3.1	43.7
Gurmandir	Lasbela	117,371	285,853	236,454	13,132	15,773	169,528	11.2	5.5	71.7
Lasbela	Nazimabad No.1 Chowrangi	154,300	299,279	315,854	13,135	15,322	188,024	8.5	5.1	59.5
Nazimabad No.1 Chowrangi	Board Office	208,046	333,971	417,258	13,611	14,048	189,958	6.5	4.2	45.5
Board Office	Nagan Chowrangi	133,347	240,218	326,980	19,740	18,177	223,927	14.8	7.6	68.5
Nagan Chowrangi	Surujani Chowrangi	143,663	259,337	349,300	16,326	14,994	185,646	11.4	5.8	53.1

Red Line in case of 2020 demand

		Road Traffc without BRT			BRT Traffic from Parallel Road			% Shift to BRT		
Section		M/C	Car	Bus	M/C	Car	Bus	M/C	Car	Bus
M.A. Jinnah Road	Jail Chowrangi	71,371	149,351	233,868	8,711	12,753	172,900	12.2	8.5	73.9
Jail Chowrangi	Hasan Square Roundabout	111,000	223,152	273,592	11,602	16,865	202,388	10.5	7.6	74.0
Hasan Square Roundabout	NIPA Chowrangi	143,791	301,714	280,965	10,155	14,978	214,449	7.1	5.0	76.3
NIPA Chowrangi	Safari Flyover	114,990	261,151	259,934	8,632	11,607	219,515	7.5	4.4	84.5
Safari Flyover	Safura Circle	121,321	295,414	435,430	3,986	5,762	238,779	3.3	2.0	54.8
Safura Circle	Malir Cant Check Post	84,743	278,333	238,516	4,190	5,977	136,191	4.9	2.1	57.1
Malir Cant Check Post	Model Colony	92,141	202,697	220,366	4,229	6,035	74,885	4.6	3.0	34.0

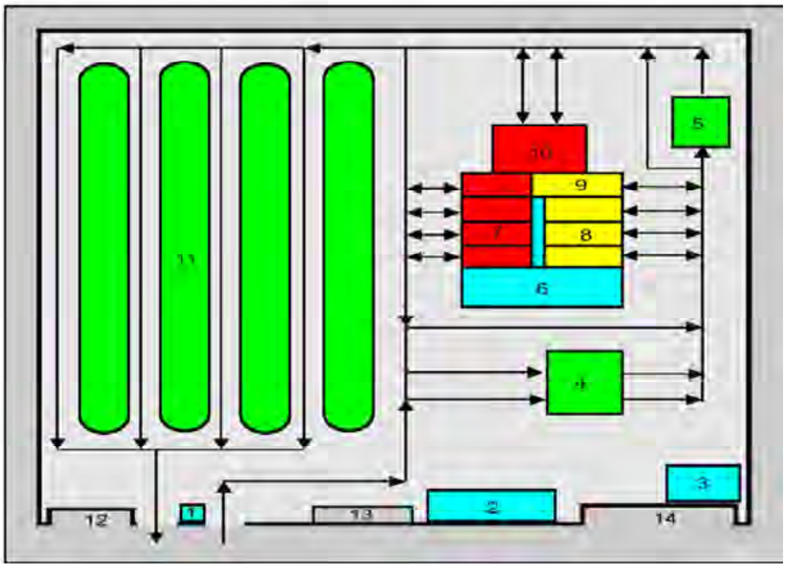
Note 1: Figures are the number of passengers per day for both directions
Note 2: Estimated by the Demand Forecast Model in KTIP
Note 3: M/C = Motorcycle

Source: The Study for KTIP

3.6 Selection of Depot

3.6.1 Total Area of Depot Facility

Depot areas have the role in bus parking areas, re-fuelling facilities, vehicle washing and cleaning, maintenance and repair areas, administrative space for operators and employee facilities. The standard layout for a depot area is described as bellow.



1. Gate and visual inspection area
2, 3 and 6. Administrative offices for the concessioned operators
4. Re-fuelling area
5. Vehicle washing and cleaning area
7 and 10. Major repairs
8 and 9 . Minor repairs and maintenance
11. BRT vehicle parking
12. Private vehicle parking

Green color ; Operational vehicles
Yellow color; Vehicles requiring minor or routine maintenance
Red color ; Vehicles requiring major repairs

Source: Bus Rapid Transit – Planning Guide 2007, Institute for Transportation and Development Policy (ITDP)

Figure 3-6-1 Standard Layout for a depot area

The size of the depots depends on the amount of operational vehicles. Since all vehicles stay in depot in night time, the depot should be large enough to accommodate all vehicles. The number of vehicles was estimated at approximately 200 per corridor.

The necessary area was estimated as 30,000m^2 or more on each line as shown in Table 3-6-1.

Table 3-6-1 Total Area of Depot

Facility	Area(㎡)	
Major Repair	585	Lot:W32.5m*D18m 4 Vehicles at the same time
Parking	23,940	Lot:119.7(㎡) Vehicle: 200
Re-fuelling	413.4	Lot:68.9(㎡) Nozzle: 6
Washing and Cleaning	388.36	Lot:97.09(㎡) 4 Vehicles at the same time
Other	175	Tire Storage, Driver's Rest Room, Security Office, Pray Room etc. # Refer to CNG Bus Project
Service Road	4,500	Sum of Parking Space *20%
Total	**Apx. 30,000 (㎡)**	Reference 7.4 (Acres)

Source: Calculated by JICA Study Team based on operation plan

Depots should be located at the places where vehicles need not travel a long distance between the depots and starting/ending points of BRT to save fuel consumption. If depots are located far from BRT routes and BRT vehicles need to run on mixed traffic lanes, there will be a risk that the BRT vehicles delay due to congestion of the mixed traffic lanes while travelling from the depot.

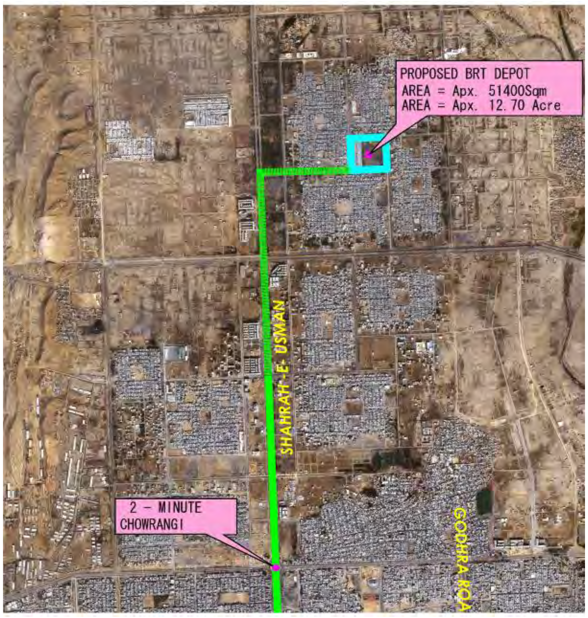
3.6.2 Depot Location

Locations of the depots of each line were selected as follows, based on discussions between the JICA Study Team, KMTC and MPGO.

(1) Green Line

The proposed location of the depot of Green Line is located to the north of New Karachi, approximately 1.3km from the terminal station of Green Line as shown in Figure 3-6-2.

Total Area	51,400m^2
Distance from BRT Route	Approximately 1.3km from the terminal station
Ownership	Government (KMC)
Location	



Source: JICA Study Team

Figure 3-6-2 Depot Location on Green Line

The proposed location is planned as an area of a sports complex in the city's land use plan, but it is currently used as one of the depots of the CNG Bus Project. Based on the discussion with MPGO and KMTC, this area can be reserved for the depot of Green Line by changing the land use plan.

The distance between the terminal station (G23) and the depot is approximately 1.3 km, which is acceptable in view of the fuel consumption before and after the daily service.

Existing Condition

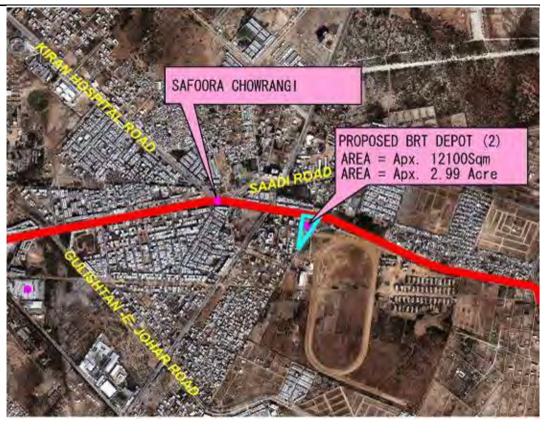
Frontal Road

Source: Photo by JICA Study Team

Figure 3-6-3 Present Condition of Depot area on Green Line

(2) Red Line

For Red Line, the depot is proposed to be constructed at two different locations because an area with large space to accommodate 200 vehicles was not found. One is located in Model Colony, next to Jinnah Airport, the other is the area near the Safoora Chowrangi.

Total Area	17,500m^2 (Red Line Depot 1)	12,100m^2 (Red Line Depot 2)
Distance from BRT Route	Approximately 0.9km from the terminal station of Red Line	Next to BRT Lane
Ownership	Government (GOS and KMC)	Government (GOS and KMC)
Function	Depot and Workshop	Pool Area, which is included of parking/stopping, re-fuelling and breaking area for driver
Picture		

Source: JICA Study Team

Figure 3-6-4 Depot Location on Red Line

Function of each depot is proposed as shown in Table 3-6-2. “Necessary” means that the depot must have the function from the beginning of the operation, while “Possible” means that it will be necessary in the future. “Not Necessary” means that there is no need to introduce the function.

Table 3-6-2 Function of Depot

	Red Line Depot(1)	Red Line Depot(2)
Gate and visual inspection area	Necessary	Necessary
Administrative Office for the concessioned operators	Time keeper Room Cashier Room Operator Room Office Admin & Reception office Kitchen Conference Driver's Resting Room Store	Time keeper Room Cashier Room Operator Room Driver's Resting Room Store
Re-fuelling area	Necessary	Possible
Vehicle washing and cleaning area	Necessary	Possible
Major repairs	Necessary	Not necessary
Minor repairs and Maintenance	Necessary	Not necessary
BRT vehicle parking	Necessary	Necessary
Private vehicle parking	Not necessary	Not necessary
Other		
Tire Storage	Space of 5m x 10m	Not necessary
Security office	Necessary	Necessary
Pray Room	Necessary	Necessary
Napping Room	Possible	Possible
Canteen	Possible	Possible

Source: JICA Study Team

Existing Condition of Red Line Depot(1)

Frontal Road of Red Line Depot(1)

Existing Condition of Red Line Depot(2)

Frontal Road of Red Line Depot(2)

Source: Photo by JICA Study Team

Figure 3-6-5 Present Condition of Depot area of Red Line

Chapter 4 Operation Plan

4.1 Traffic Management

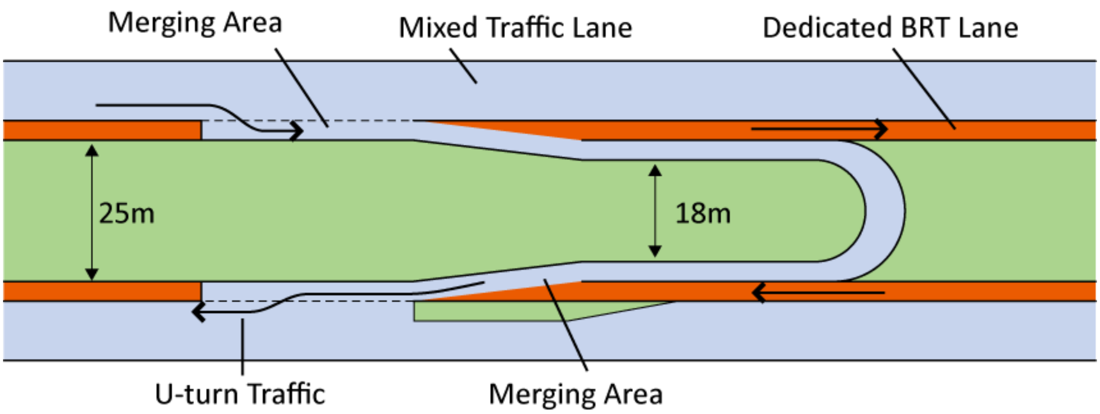
4.1.1 U-Turn Traffic

(1) Problem of U-Turn Traffic along BRT Corridor

Due to the unique street system, it is difficult to control right turn traffic by signal in North Nazimabad Area. There are two median breaks between major intersections, and the traffic volume using the U-turn is too high to be closed although the ADB Study of BRT proposed to close median breaks. Since BRT lanes are proposed in the center of roads, crossing of BRT traffic and U-turn traffic will occur.

To avoid the delay from the conflict between BRT and U-turn traffic, three alternatives are considered. One is a grade separation of BRT lanes and U-turn lanes. In this case, BRT lanes will be constructed as flyovers because it can make use of median area for new structures while U-turn flyovers use the present carriageway for the structure.

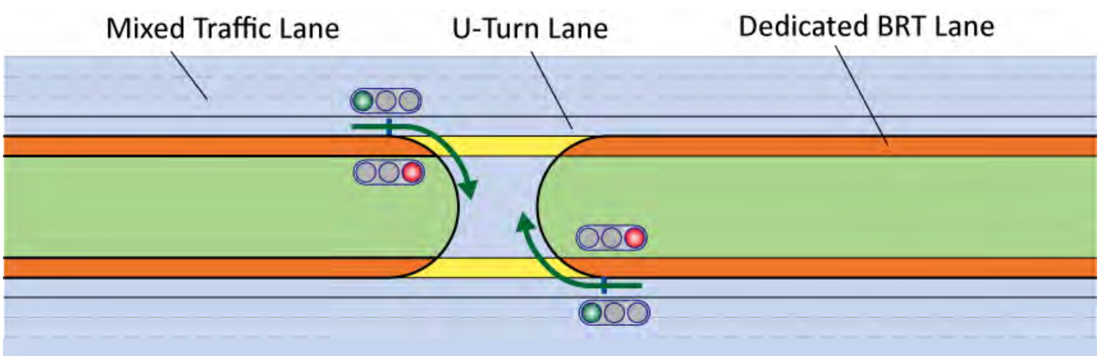
The second alternative is BRT lanes outside of U-turn lanes as shown in Figure 4-1-1. There are merging areas of BRT lanes and U-turn lanes. In this case, the risk of traffic accident becomes high if express bus services are introduced.



Source: JICA Study Team

Figure 4-1-1 U-turn traffic and BRT lanes (1)

The third alternative is installing traffic signals at U-turn location as shown in Figure 4-1-2. U-turn traffic and BRT traffic are separated by traffic signal. In mixed traffic lanes, U-turn lanes should be separated from straight traffic near U-turn section so that the U-turn traffic can smoothly exit U-turn area. Since the width of the median is approximately 25m at present, the radius becomes 18m and large buses cannot use the U-turn lanes.



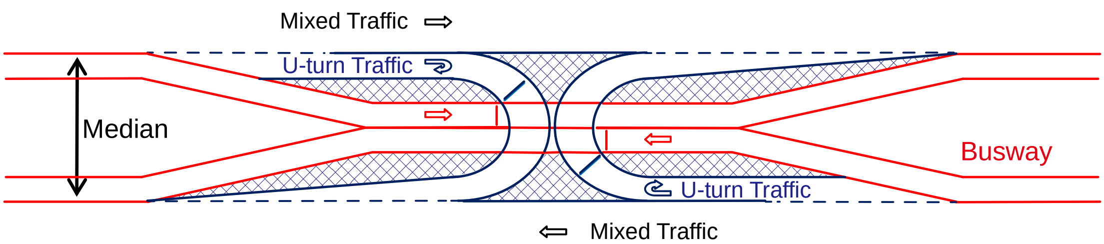
Source: JICA Study Team

Figure 4-1-2 U-turn traffic and BRT lanes (2)

U-turn signal of Bangkok BRT
Photo: Nippon Koei Co., Ltd.

(2) Proposed Solution of U-Turn along Green Line

Figure 4-4-3 shows the proposed plan of busway at U-turns along Green Line. Both upward and downward lanes are located in the center of median area at U-turn, while the two lanes are located outer of median along other sections.



Source: Illustrated by JICA Study Team

Figure 4-1-3 BRT lanes crossing U-Turn

4.1.2 Roundabouts

Roundabouts should be converted to standard 4-leg signalized intersections in principal. In case signalization is difficult due to the existence of monuments or fountain, traffic signals should be installed to the roundabout. Although it is better to convert Powerhouse Chowrangi into a signalized 4-legs intersection, this roundabout should remain with signal installation because there is an aircraft monument at Powerhouse Chowrangi. Table 4-1-1 shows the improvement policy of each roundabout along Green Line.

Table 4-1-1 Roundabouts along Green Line

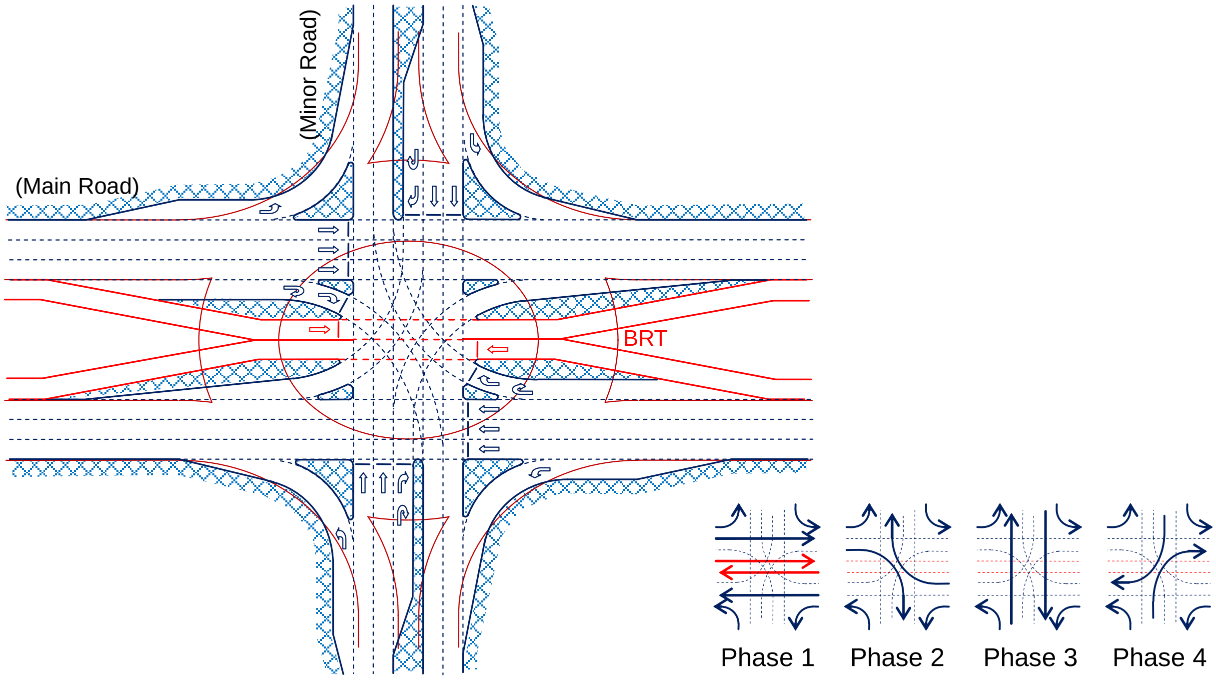
No	Location	Improvement Policy
1	Gurumandir	Signalized Intersection
2	KDA Chowrangi	Signalized + BRT lanes through the roundabout
3	Sakhi Hassan Chowrangi	Signalized + BRT lanes through the roundabout
4	Powerhouse Chowrangi	Signalized roundabout
5	Surjani Chowrangi	Signalized Intersection

Source: JICA Study Team

There are two roundabouts along Red Line. The roundabout near Quaid-e-Azam should be improved as the roundabout with signalized plus BRT lanes through the roundabout. Safura Circle should be signalized.

There is no roundabout along Blue Line.

Figure 4-1-4 shows the configuration of the basic type of a four-leg intersection based on signal control and fully channelized covering all traffic movements from all four legs. A dual direction busway is built into this intersection locating at the center of the main road next to the right-turn lane. A four-phase signal control as given in Figure 4-1-4 is required to allow all traffic movements. The BRT bus will be given green time concurrent with the through traffic on the main road.



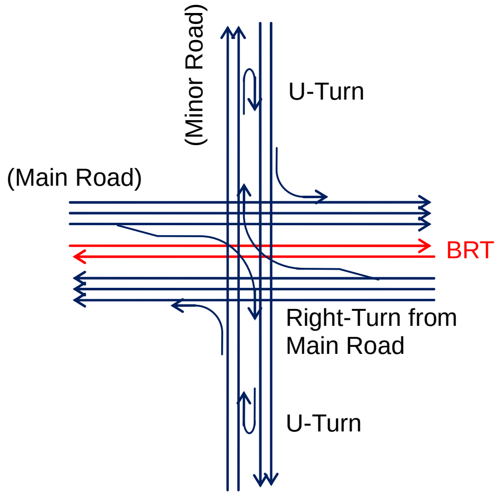
Source: Illustrated by JICA Study Team

Figure 4-1-4 Four-Leg Channelized Intersection

4.1.3 Control of right-turn traffic

Right-turning vehicles will cause substantial delay to through traffic and thus diminish effectiveness of intersection. Therefore, it is believed beneficial and so CDGK has currently practiced that right-turn movements should be prohibited to relieve traffic burden of the intersection and instead guide them to neighboring U-turns and intersections after passing through the intersection, to reach their destinations by alternative routes. However, this indirect right-turn maneuver has disadvantages as well, such as fuel consumption will increase with unnecessary travels and the additional U-turn and left-turn traffic will affect the operation of neighboring roads and intersections. It is generally desirable that right-turns should be allowed as near as practical to the point at which drivers desire to turn right.

It is proposed that U-turns should be removed from main roads and instead a large green time should be given to the right-turn traffic from the main roads at the intersections. In contrast, the right-turn traffic from minor road should be prohibited to give green time more to the main road, for where BRT buses run. By this right-turn control as shown in Figure 4-1-5, BRT buses need not stop between intersections except station stops, and the four signal phases of the intersection will be reduced to three phases by eliminating phase-4.

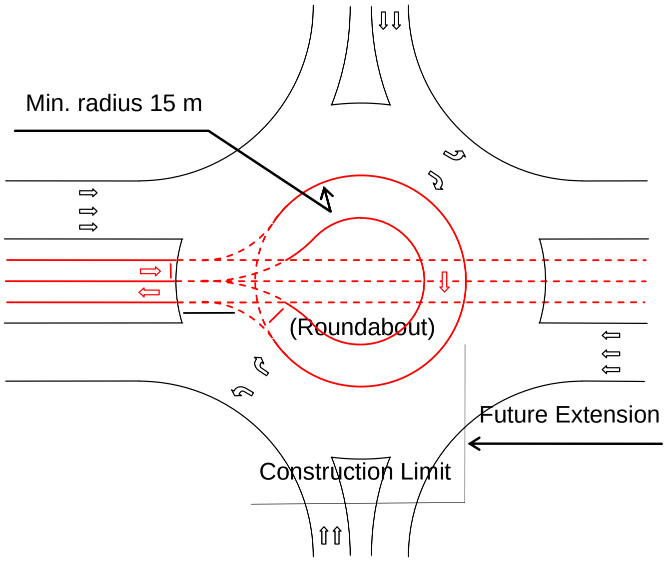


Source: Illustrated by JICA Study Team

Figure 4-1-5 Elimination of Right-Turn Traffic from Minor Road

4.1.4 Design of BRT Bus U-Turn Facility

The BRT bus U-turn facility is required at both ends of a BRT corridor and possibly at the middle point to turn travel direction of buses. The design of bus U-turn facilities proposed here are only for bus turning operation but do not consider station function. At the end of a corridor in suburb, buses can turn easily at an existing roundabout intersection as shown in Figure 4-1-6.



Source: Illustrated by JICA Study Team

Figure 4-1-6 At-Grade BRT Bus U-Turn

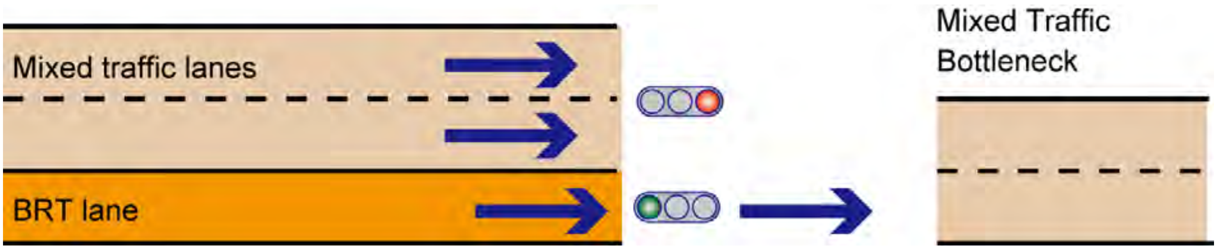
4.1.5 Bottleneck Sections

The proposed BRT routes have bottleneck sections such as the section of Nawab Siddiq Ali Khan Road between Nazimabad No.1 Chowrangi and Lasbela Chowk (Green Line), the section of Business Recorder Road between Lasbela Chowk and Gurmandir (Green Line), and New M.A. Jinnah Road between Roundabout and Jail Chowrangi (Red Line). Although the roads are wide enough to accommodate BRT lanes, parking and stopping demand along roads are so high due to the commercial activities that it is difficult to provide exclusive lanes for BRT.

There are three alternatives for these sections. One is construction of elevated structure for BRT lanes along the section as proposed in the BRT study by ADB. Elevated structure needs ramp section between at-grade and the elevated section. In case that an elevated structure is introduced along Business Recorder Road, the ramp should be constructed at both ends of the elevated section. Ramp sections cannot be constructed along the bottleneck sections because of roadside parking. If roadside parking is removed from the road, the construction of ramps is possible. However, at-grade busway should be constructed in case that roadside parking can be removed. From this, the ramp should be constructed in the south of Gurumandir and the North of Nazimabad Chowrangi, and the length of the elevated section will be approximately 2.7km. This will increase the initial investment cost of the BRT. As described in the financial analysis in Chapter 9, the financial return of the BRT project is very small, and the further increase in the cost will result in the failure of the project. Therefore, the elevated structure is not recommended in view of the financial viability of the project.

For the bottleneck section along M.A. Jinnah Road, construction of a ramp is not possible due to U-turns along the road.

The second alternative is the BRT operation in mixed traffic lanes. In this case, BRT buses will face the same congestion as the present situation. It is necessary to employ traffic management measure to increase travel speed of the buses. Figure 4-1-7 shows "queue jump" solution to give priority to buses. This alternative was discussed in the early stage of the feasibility study, but it was concluded that the BRT vehicles should not be operated in mixed traffic lanes because it will worsen the level of service of the BRT.



Source: JICA Study Team

Figure 4-1-7 Queue Jump at Bottleneck

The third alternative is to clear all illegal parking from the road sides. The curb side lanes are occupied by rickshaws or cars for sales, trucks for loading and unloading, vehicles of customers, rickshaws and taxis waiting for passengers. Removal of these vehicles from the sections will involve a large number of stakeholders, and it will take time to reach the consensus for the removal of parking. However, construction of the busway along these sections at-grade, as same as other sections, is more feasible solution than the construction of elevated structure.

KMTC ensured that clearance of the bottleneck sections would be possible, and this alternative was applied for the BRT plan. On the other hand, it was necessary to consider the parking space for temporary stops, which would reduce the available space for the BRT system, and this became one of the reasons that passing lanes at stations were not provided in the plan.

4.2 Operation Plan

4.2.1 BRT Routes

(1) Cross Operation

It is proposed that both Green and Red Lines go to Cloth Market along M.A. Jinnah Road and Regal Chowk along New M. A. Jinnah Road to avoid transfer between two lines near the center of the city. The demand between Green and Red Lines cannot be ignored, but it is not proposed to connect Green and Red Lines directly because such demand will be covered with other transit lines such as KCR and Brown Line in the future.

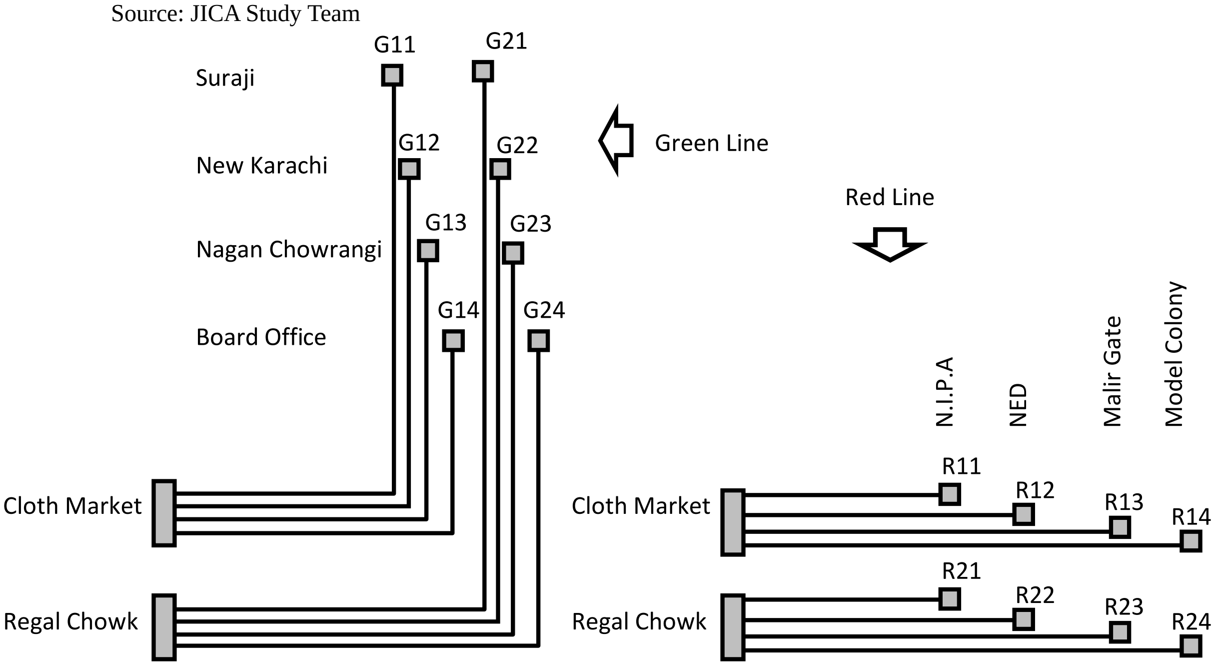
(2) Round Trip

The required number of buses is different by section. In the early stage of the operation, it is not necessary to provide the target capacity along the section which is far from the center. From the results of the demand forecast, it is proposed to provide eight routes for Green Line and four routes for Red Line as shown in Table 4-2-1 and Figure 4-2-1.

Table 4-2-1 Proposed Routes of Green and Red Line

Line	Round Route	Center	U-turn point
Green Line	G11	Cloth Market	Surjani
	G12	Cloth Market	New Karachi
	G13	Cloth Market	Nagan Chowrangi
	G14	Cloth Market	Board Office
	G21	Regal Chowk	Surjani
	G22	Regal Chowk	New Karachi
	G23	Regal Chowk	Nagan Chowrangi
	G24	Regal Chowk	Board Office
Red Line	R11	Cloth Market	N.I.P.A
	R12	Cloth Market	NED
	R13	Cloth Market	Malir Gate
	R14	Cloth Market	Model Colony
	R21	Regal Chowk	N.I.P.A
	R22	Regal Chowk	NED
	R23	Regal Chowk	Malir Gate
	R24	Regal Chowk	Model Colony

Source: JICA Study Team



Source: JICA Study Team

Figure 4-2-1 Diagram of BRT Routes of Green and Red Lines

4.2.2 Peak Hour Operation

The target capacity in peak hours is 12,000 passengers per hour per direction. Since the capacity of a BRT bus is planned as 80 passengers, the necessary frequency is calculated as 150 per hour (2.5 per minute). In this case, buses should arrive at station in 24 seconds interval. From this high frequency, the time table of bus arriving will not be necessary for passengers. However, BRT should be operated based on time tables for efficient operation.

(1) Time at Station

Short boarding and alighting time at stations will increase the capacity. However, it is proposed to fix the boarding and alighting time at stations at 20 seconds to enable the scheduled operation of buses. The time of 20 seconds at a station for boarding and alighting is the popular time of BRT operations in the world.

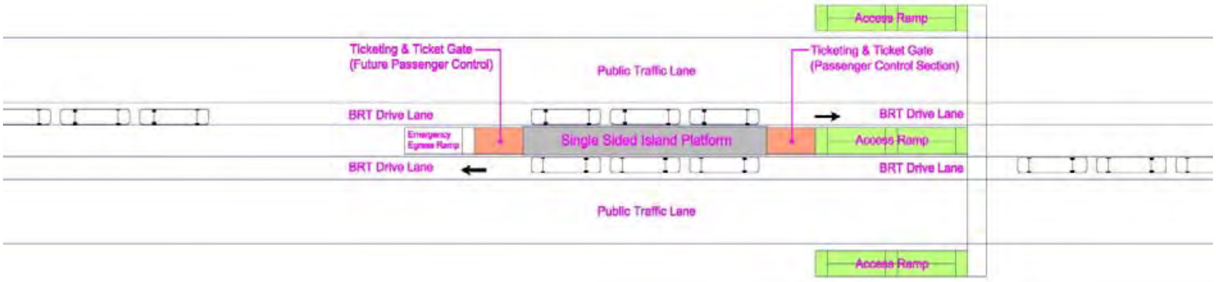
In addition to the boarding and alighting time, deceleration and acceleration time will be necessary at stations. For comfortable riding, rapid deceleration and acceleration should be avoided. The time is approximately 10-20 seconds. In total, 40 seconds will be necessary for a bus at a station.

(2) Speed

If speed is not a matter, the capacity can be increased. For example, if 12m buses with the capacity of 72 passengers per bus are moving continuously like a long train at a waking speed (4km/hour), it can carry 24,000 passengers per hour (= 72/12 * 4,000). However, it is necessary to keep the BRT speed even in peak hours otherwise the benefit of BRT will become small. The target speed is 25km/h.

(3) Convoy system operation

A boarding and alighting slot can deal with only 1.5 buses per minute (60/40). To achieve 2.5 buses per minute, two slots with a passing lane is necessary. However, due to the limitation of available road space, it was decided that passing lanes would not be provided to BRT stations. Instead, three slots for boarding and alighting were proposed to apply a convoy operation. In this case, two or more buses are operated in a group which arrive and departure at the same time. If two buses arrive at a 48 seconds interval, the capacity of 12,000 passengers per hour is possible.



Source: JICA Study Team

Figure 4-2-2 Convoy System Operation Image

(4) Peak Hours

Peak hours along Green and Red Lines differ by section. In morning, approximately two hours from 7:00- 9:00 is peak hour time, while evening peak continue approximately three hours from 18:00-21:00. In total, the peak hour operation should be applied for 5 hours in a day.

(5) Off-peak Hour Operation

The frequency should be reduced according to passenger demand. However, it is necessary to maintain the minimum frequency.

4.2.3 The number of buses

The number of buses needed for the operation (N) was calculated by the following formula.

N = T (minutes) / Peak hour interval (seconds) * 60

Where, T is the smaller one between the round trip time and the peak hour time. Since the round trip time is less than 2 hours both for Green and Red lines, while the peak hours continue more than 2 hours, round trip times were used for the calculation. In addition to the buses calculated above, spare buses will be necessary. The number of additional buses was assumed at 5% of the total number of buses needed for the peak operation. Table 4-2-2 shows the estimation of the number of buses. In total, 425 buses would be needed for the BRT system.

Table 4-2-2 Calculation of No. of Buses Needed for BRT System

Green Line

Section		Distance (km)	No. of buses per hour	No. of buses to be added	Interval sec	Speed km/h	Round time Hour	No. of buses
Cloth Market	Surjani	21.0	80	80	45	25	1.68	135
Mazar Area	Power House	14.8	100	20	180	25	1.18	24
Mazar Area	Nagan Chowrangi	11.0	138	38	95	25	0.88	34
Mazar Area	Board Office	7.2	150	12	300	25	0.58	7
Total								200

Red Line

Section		Distance (km)	No. of buses per hour	No. of buses to be added	Interval sec	Speed km/h	Round time Hour	No. of buses
CBD	Model Colony	23.3	70	70	51	25	1.86	131
Mazar Area	Malir Gate	17.0	100	30	120	25	1.36	41
Mazar Area	NED	11.5	120	20	180	25	0.92	19
Mazar Area	NIPA Station	8.3	140	20	180	25	0.66	14
Total								205

Source: JICA Study Team

Total	405
Spare	20
Grand Total	425

4.2.4 Vehicle-kilometers

The vehicle-kilometer, a unit which represents the total of the travel distance of buses, is one of the most important indicators of BRT systems. The vehicle-kilometers in peak hours can be calculated from the peak operation plan in the previous section. The off-peak operation was prepared based on the assumption of hourly distribution of passenger traffic.

(1) Hourly Distribution of Passenger Traffic

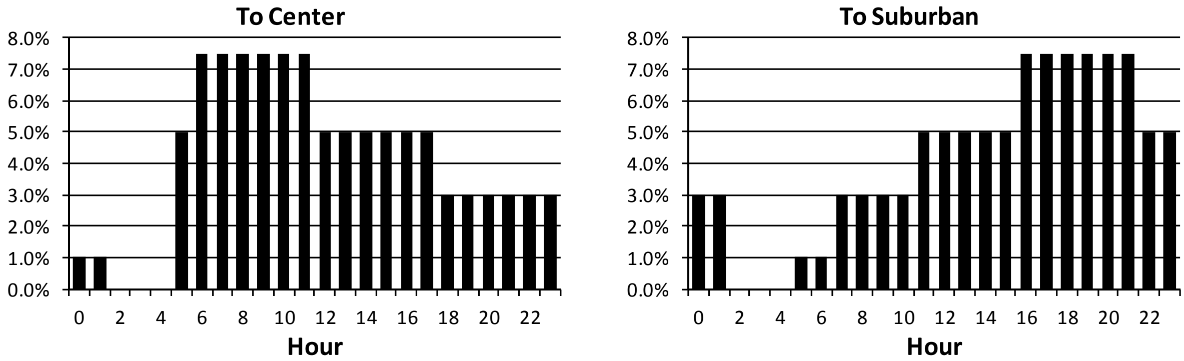
Off-peak operation plans were prepared for the following four traffic groups: 1) 7.5% of daily traffic, 2) 5%, 3) 3%, and 4) 1%. Table 4-2-3 shows the hourly frequency and the number of buses needed by the traffic group.

Table 4-2-3 Hourly Traffic Volume by Traffic Group

Line	Section		Traffic Group				No. of Required Buses			
			1	2	3	4	1	2	3	4
			7.5%	5.0%	3.0%	1.0%	0.5%	7.5%	5.0%	3.0%
Green Line	Cloth Market	Surjani	80	54	22	3	80	54	22	3
	Mazar Area	Power House	100	67	27	4	20	13	5	1
	Mazar Area	Nagan Chowrangi	138	92	37	5	38	25	10	1
	Mazar Area	Board Office	150	100	40	6	12	8	3	1
Red Line	CBD	Model Colony	70	47	19	3	70	47	19	3
	Mazar Area	Malir Gate	100	67	27	4	30	20	8	1
	Mazar Area	NED	120	80	32	5	20	13	5	1
	Mazar Area	NIPA Station	140	94	38	6	20	14	6	1

Source: JICA Study Team

Peak characteristics are quite different by directions. The morning peak is observed toward the center direction while the evening peak is observed from the center to suburb. Passenger traffic distribution was assumed as shown in Figure 4-2-3 for both directions.



Source: JICA Study Team

Figure 4-2-3 % Distribution by Hour by Direction

The number of hours by traffic group was prepared by combining the two charts (the average of the percentage of each hour). The result is 12 hours (7.5%), 7 hours (5.0%), and 2 hours (3.0%). This means that peak hour operation should be applied for 12 hours a day. The number of services was calculated by adding up the product of the number of hours and the number of required buses of each traffic group. Vehicle-kilometers of the BRT system were calculated at 173,000 per day by adding up the product of the number of services and the length of each section.

Table 4-2-4 Calculation of Vehicle-kilometers

Line	Section		No. of Services	Bus-km
Green Line	Cloth Market	Surjani	1,382	58,044
	Mazar Area	Power House	341	10,094
	Mazar Area	Nagan Chowrangi	651	14,322
	Mazar Area	Board Office	206	2,966
		subtotal	2,580	85,426
Red Line	CBD	Model Colony	1,207	56,246
	Mazar Area	Malir Gate	516	17,544
	Mazar Area	NED	341	7,843
	Mazar Area	NIPA Station	350	5,810
		subtotal	2,414	87,443
Total			4,994	172,869

Source: JICA Study Team

4.2.5 Reorganization of Present Bus Network

(1) Green Line

There are 49 routes that compete with Green Line, in which 18 routes should be discontinued because of these routes overlap Green Line for a long distance. Feeder routes should be provided for the 18 routes outside Green Line route. Table 4-2-5 is the list of bus routes that compete with Green Line. The route number with silver color is the proposed routes which should be discontinued for Green Line operation.

Table 4-2-5 List of Bus Routes Compete with Green Line

2-K	F-16	G-25	W-1	401-GUL
4	X-3	G-27	U-8	Khan
4-J	F-18	W-23	W-22	Niaz
1-D	W-11	C-17	X-10	National
4-L	C-25	P-3	U	Shiraz
2-D	F-21	W-55	G-11	Shama
4-X	G-17	W-25	G-3	UTS-1
5-C	W-18	W-19	U11	Masood
6	Z-A	W-21	Umer-Coach	
8	G-13	W-30	201-CITY	

Source: JICA Study Team based on Public Transport Survey in 2010

(2) Red Line

There are 44 routes that compete with Red Line in which 11 routes should be discontinued. Table 4-2-6 is the list of bus routes that compete with Red Line.

Table 4-2-6 List of Bus Routes Compete with Red Line

11-A	G-17	U-10	Umer-Coach	Starline
11-C	P-1	W-19	400-AKBA	9-B
51	G-13	U-8	101-BILA	Masood
53-B	G-27	W-22	401-GUL	51A
4-M	X-24	U	402-GUL	
52-A	C-17	G-11	National	
55	G-10	X-23	Shiraz	
A-3	F-11	G-7	Shama	
D-5	G-19	G-3	Safari	
F-21	S-2	202-DATA	Super Hasanzai	

Source: JICA Study Team based on Public Transport Survey in 2010

4.2.6 Operation Control Center

Control center for the BRT operation at the initial stage will not be considered. However, such facility may be necessary to monitor and control bus operation in order to keep quality service and to distribute convenient information for users when such sophisticated information system is installed for the system.

The center commonly consists of BRT operation and monitoring room (computerized main control center), fare collection administration, computer room, administrative office, training center, conference, canteen and others. It may be located in the depot land if space is available.

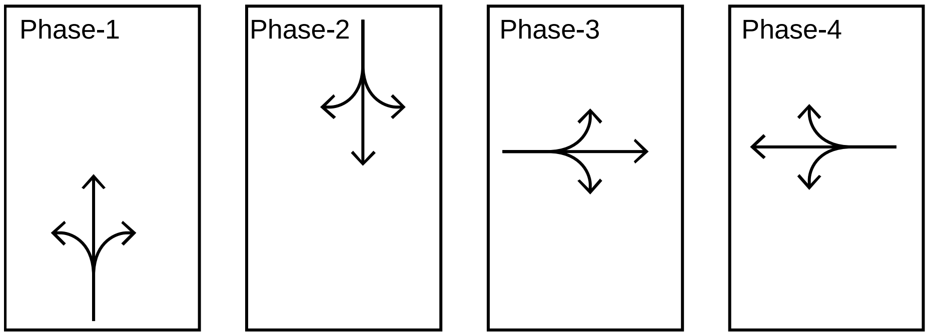
4.2.7 Traffic Signal

(1) Current Condition of Traffic Signal

CDGK had made efforts to introduce SCOOT system including traffic control centre under a World Bank project, which resulted in installation of fixed cycle time traffic signals in the first stage but traffic control center was not implemented. Many signalized intersections are often controlled by traffic polices because the existing traffic signals often stop due to frequent electricity off, and drivers tend to ignore traffic lights.

(2) Phase of Traffic Signals along Study Corridors

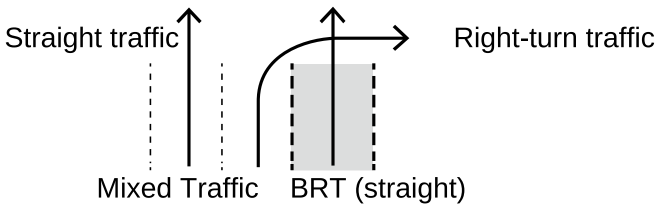
There is no signalized intersection along Red Line because it is Signal Free Corridor. There are 7 signalized intersections along Green Line. Lasbela and Nazimabad No. 1 apply four phases with a single directional approach on each phase as shown in below. Note that left-turn is always possible at these intersections.



Source: Field observation by the JICA Study team

Figure 4-2-4 Signal Phasing at Lasbela and Noazimabad No. 1 Chowrangi

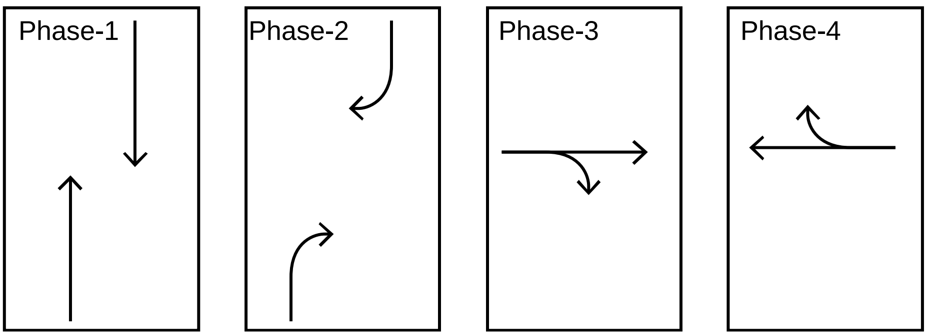
This configuration will cause conflict between buses on BRT lanes and right-turn traffic as shown in Figure 4-2-5.



Source: JICA Study Team

Figure 4-2-5 Conflict of Right-turn and BRT Traffic

To introduce BRT system, it is necessary to separate the straight traffic and right-turn traffic as applied at Five Star Chowrangi and Board Office intersection. Figure 4-2-6 shows the new configuration of the signal phase. Phase-1 is given to BRT traffic.



Source: JICA Study Team

Figure 4-2-6 Proposed Signal Phasing of BRT corridors

This signal phase type will bring about traffic congestion at these intersections. Figure 4-2-7 shows the traffic volume (PCU) at Nazimabd No.1 Chowrangi in an evening peak hour. The straight traffic is the major movement while right turn traffic from Nazimabad Flyover to SITE is also heavy for a right-turn phase. Assuming that the hourly capacity per lane is 2,000 PCUs, and one lane is given, the right-turn movement needs 42% (=831/2000) of a signal cycle for its green time.

Right turn traffic is also heavy at Lasbela Chowrangi as shown in Figure 4-2-8. The right-turn traffic needs 37% of signal cycle on the same assumption.

Presently, 4-lane carriageways are utilized as 5-lane or 6-lane according to the traffic situation. Photo below shows that one-lane is used for Rickshaws, which require narrower width, and the number of lane becomes five. After the introduction of BRT, this type of flexible use of road space will not possible, which will reduce the intersection capacity.

Nazimabad No.1 Chowrangi
Photo: JICA Study Team

On the other hand, the introduction of BRT will reduce the number of vehicles along the corridors. The number of passengers from Lasbela to Nazimabad Flyover at Nazimabad No. 1 Chowrangi is estimated as approximately 17,000 per hour in 17:00-18:00 while the capacity of BRT is expected to be 12,000 per hour per direction. If bus passengers and motorcycle users are shifted to BRT, traffic volume at the movement will become 1,477 PCU compared to 3,142. In addition, it is expected that the number of Rickshaw traffic will decease due to removal of the Rickshaw Market along Business Recorder Road.

Figure 4-2-9 shows the traffic volume at Five Star Chowrangi. The same signal phase will be applied to this intersection after BRT introduction. Although right-turn traffic from south (KDA Chowrangi) to north (Sakhi Hassan Chowrangi) is very heavy, the right-turn carriageway is wide enough, and it is necessary to keep the present width.

Figure 4-2-10 shows the traffic volume at Nazimabad No. 7 Chowrangi. The same signal phase will be applied to this intersection after BRT introduction.

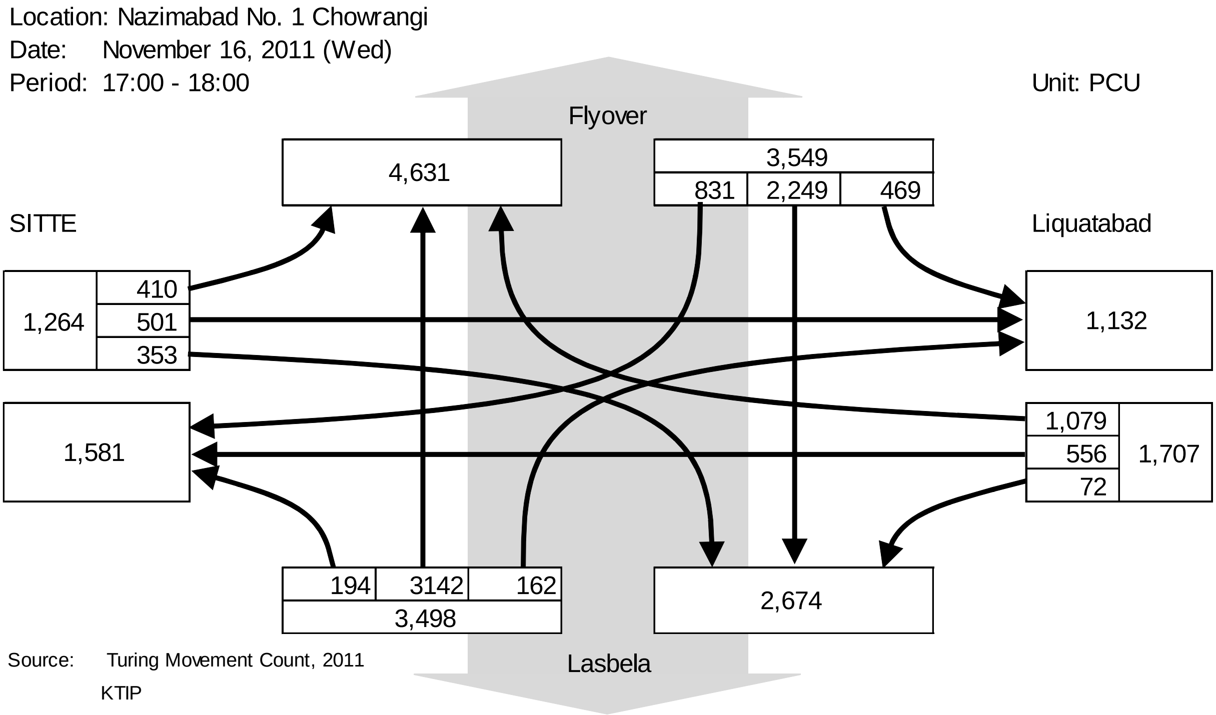


Figure 4-2-7 Traffic Volume by Direction at Nazimabad No.1 Chowrangi

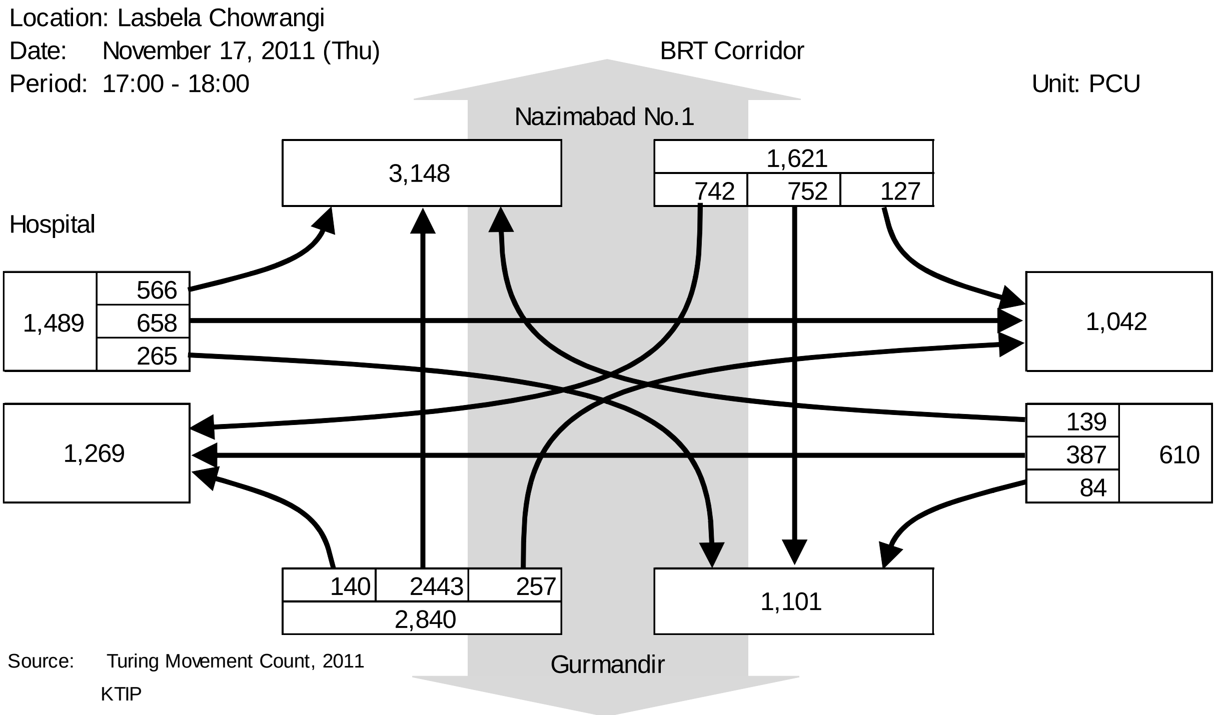


Figure 4-2-8 Traffic Volume by Direction at Lasbela Chowrangi

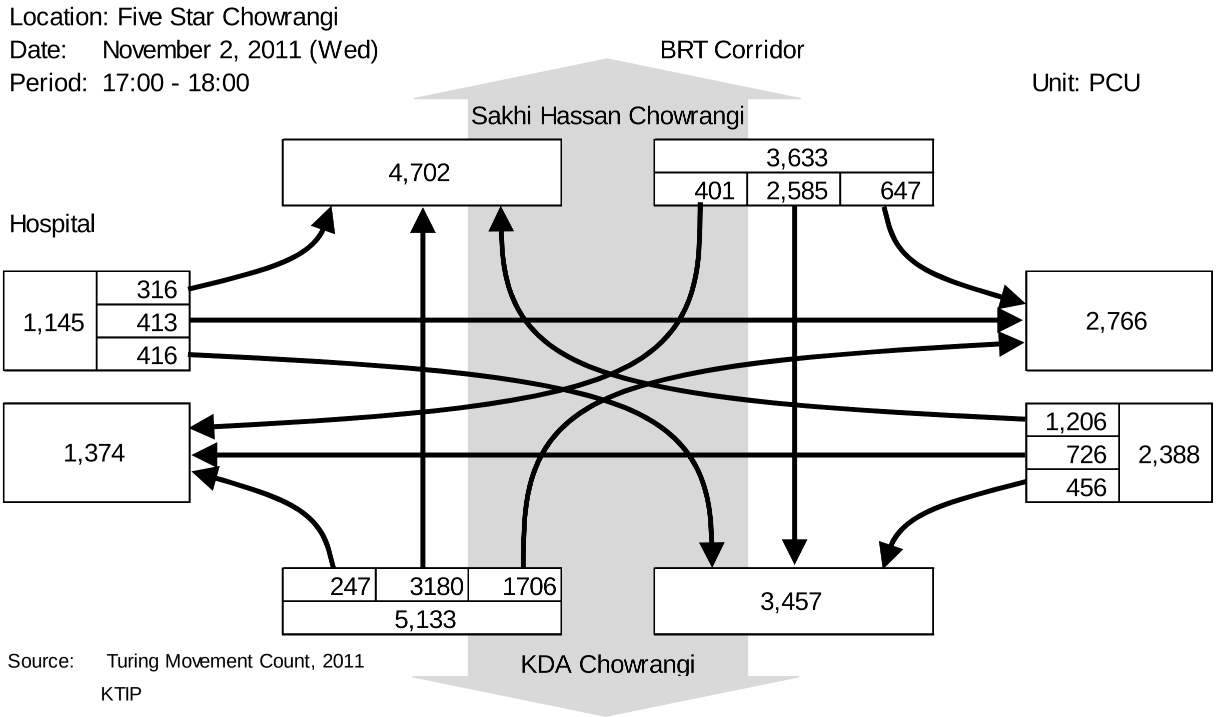


Figure 4-2-9 Traffic Volume by Direction at Lasbela Chowrangi

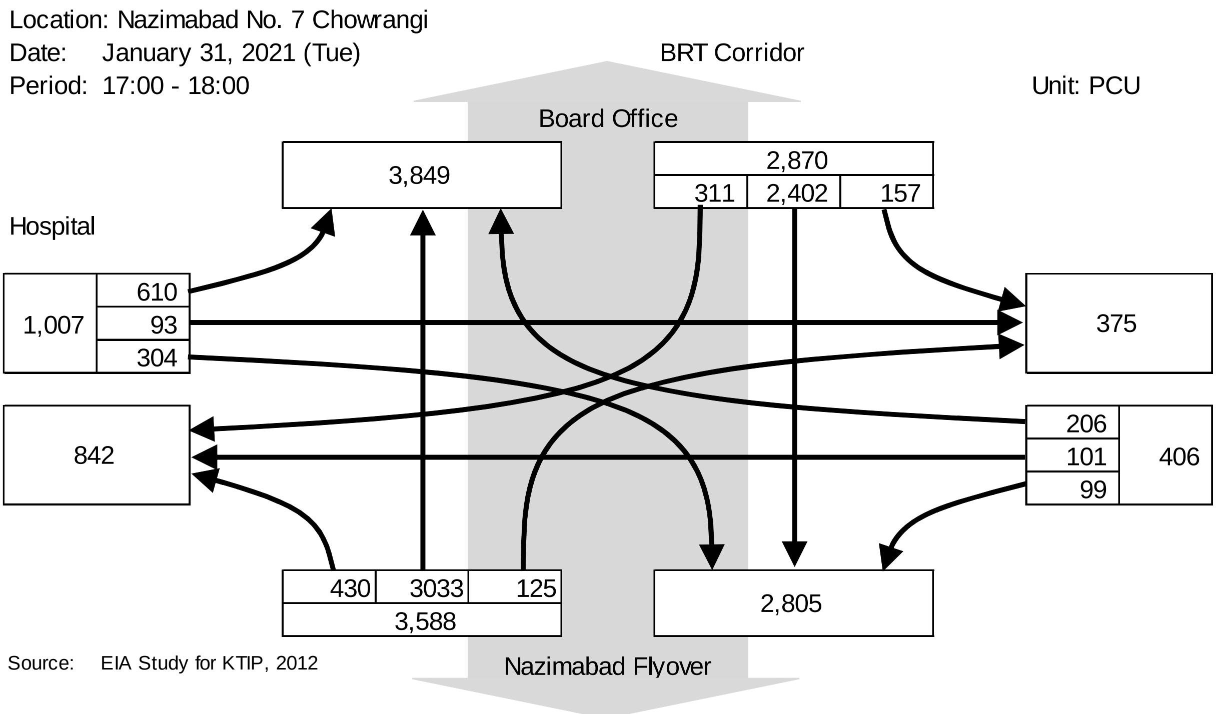
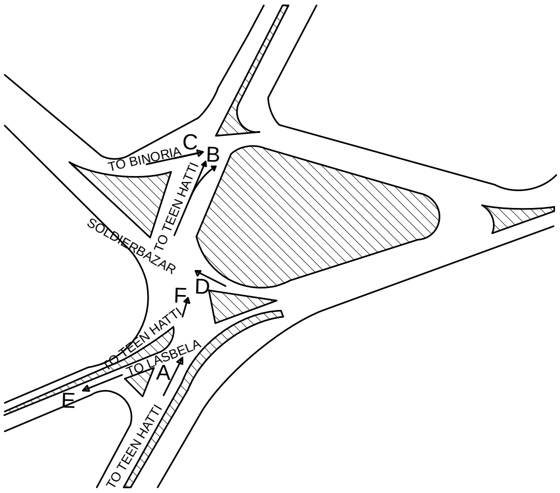


Figure 4-2-10 Traffic Volume by Direction at Nazimabad No.7 Chowrangi

Figures below show the phase of traffic signal along Green Line.

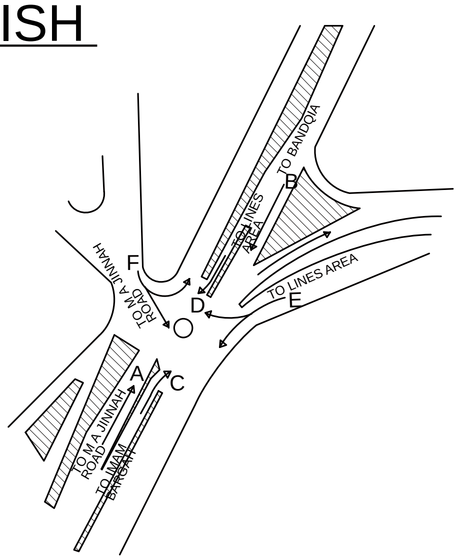
GURUMANDIR



STAGE DIAGRAM

TIMINGS	B A	C A	C	E	F
MORNING PEAK 8.00 AM - 1.00 PM	40	20	22	18	10
AFTERNOON PEAK 1.00 PM - 4.00 PM	50	30	18	20	10
EVENING PEAK 4.00 PM - 8.00 PM	55	30	25	18	10
LATE EVENING PEAK 8.00 PM - 11.59 PM	30	15	10	10	20
NIGHT TIME 0.00 AM - 8.00 AM	Flash	Flash	Flash	Flash	Flash

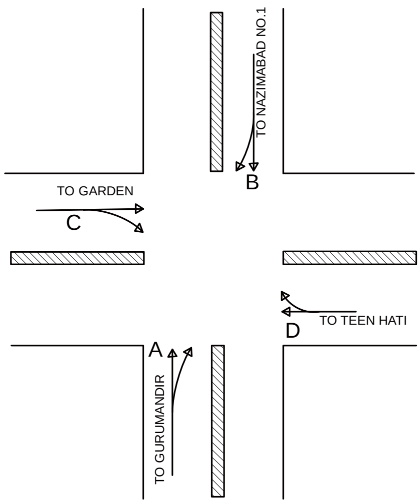
NUMAISH



STAGE DIAGRAM

TIMINGS	A B	A C	D C	E	F
MORNING PEAK 8.00 AM - 1.00 PM	40	60	30	20	15
AFTERNOON 1.00 PM - 4.00 PM	40	60	20	15	15
EVENING PEAK 4.00 PM - 11.59 PM	40	60	30	15	15
AFTER 0.00 AM	Flash	Flash	Flash	Flash	Flash

LASBELA



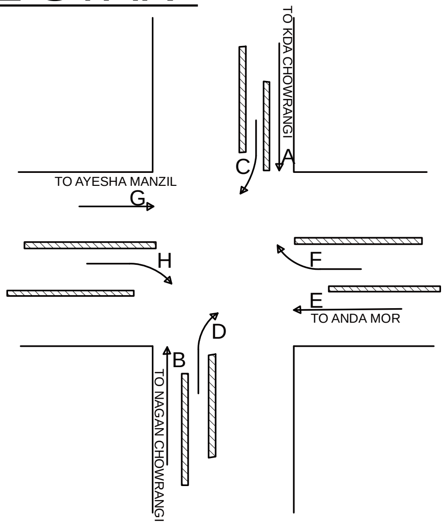
STAGE DIAGRAM

TIMINGS	A	B	C	D	
MORNING PEAK 8.00 AM - 1.00 PM	45	35	20	20	
AFTERNOON 1.00 PM - 4.00 PM	45	35	20	20	
EVENING PEAK 4.00 PM - 11.59 PM	45	35	20	20	
AFTER 0.00 AM	Flash	Flash	Flash	Flash	

Source: T&C Department, CDGK

Figure 4-2-11 The Phase of Traffic Signal (Gurmandir, Numaish, Lasbela)

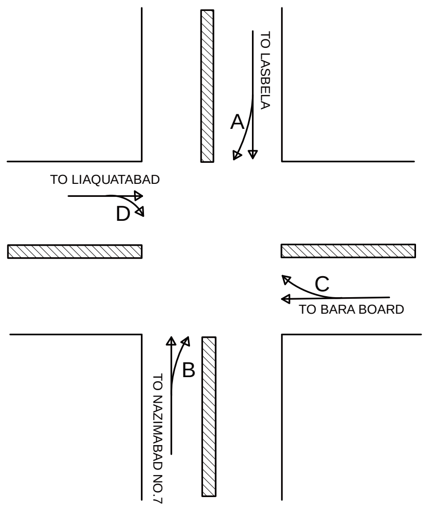
FIVE STAR



STAGE DIAGRAM

TIMINGS	B A	C D	G E	F H	
MORNING PEAK 8.00 AM - 1.00 PM	40	20	25	25	
AFTERNOON 1.00 PM - 4.00 PM	40	20	30	20	
EVENING PEAK 4.00 PM - 8.00 PM	50	20	40	20	
LATE EVENING 8.00 PM - 1.00 AM	50	30	30	20	
AFTER 1.00 AM	Flash	Flash	Flash	Flash	

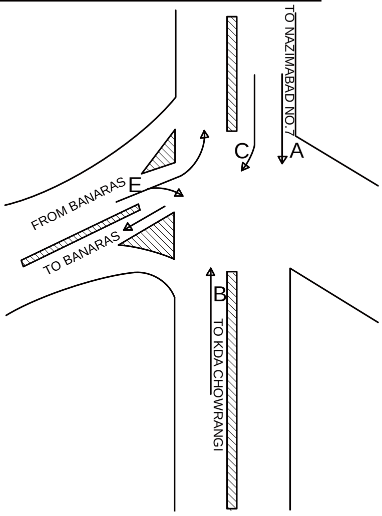
CHOWRANGI NO.1



STAGE DIAGRAM

TIMINGS	A	B	C	D	
MORNING PEAK 8.00 AM - 1.00 PM	50	40	20	25	
AFTERNOON 1.00 PM - 4.00 PM	50	40	20	25	
EVENING PEAK 4.00 PM - 11.59 PM	50	40	20	25	
AFTER 0.00 AM	Flash	Flash	Flash	Flash	

BOARD OFFICE

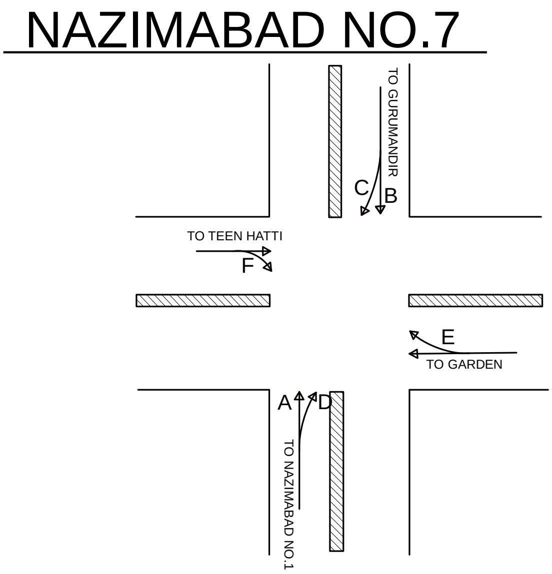


STAGE DIAGRAM

TIMINGS	B A	C A	E		
MORNING PEAK 8.00 AM - 1.00 PM	35	60	24		
AFTERNOON 1.00 PM - 4.00 PM	35	60	24		
EVENING PEAK 4.00 PM - 8.00 PM	35	60	24		
LATE EVENING 8.00 PM - 11.59 PM	35	60	24		
AFTER 0.00 AM	Flash	Flash	Flash		

Source: T&C Department, CDGK

Figure 4-2-12 The Phase of Traffic Signal (Five Star, Chowrangi No.1, Board Office)



STAGE DIAGRAM

TIMINGS	A B	C D	E	F	
MORNING PEAK 8.00 AM - 1.00 PM	60	25	25	25	
AFTERNOON 1.00 PM - 4.00 PM	54	20	25	25	
EVENING PEAK 4.00 PM - 8.00 PM	50	20	28	28	
LATE EVENING 8.00 AM - 11.59 PM	44	20	26	26	
NIGHT TIME 0.00 AM - 8.00 AM	36	20	20	20	

Source: T&C Department, CDGK

Figure 4-2-13 The Phase of Traffic Signal (Nazimabad No.7)

4.2.8 Fare System

Currently, flat fare system is proposed for BRT, because of easy management of fare collection and convenient transfer between Green Line and Red Line. It is necessary to ensure fare collection to avoid any fare evasion. Fare collection before boarding is commonly used method. In case of distance base fare system is employed, passengers need to keep their ticket during their journey and put it into the ticket machine when they leave the station. This will increase the project cost and will not be applied in the initial stage of the project.

The fare level of BRT is considered as Rs.20. Fare integration between BRT and existing minibuses is not proposed at present. This means that bus passengers who use feeder buses for both start and end need to pay approximately Rs.50 (Rs. 15 + 20 + 15) for one trip.

Recently, magnetic type ticket is more popular than coin type ticket for a ticket gate because the maintenance of magnetic ticketing system is easier than that of coin type, which requires complex mechanism to deal with coin in the ticket gate machine. Contactless smartcard is more reasonable than other types because it need not feed the ticket into the ticket gate machine. Magnetic ticket and smartcard enables discount usage such as commuter ticket, elderly ticket, visitor’s ticket, and so on. These tickets can be sold or charged at shops near stations which can reduce the congestion at ticket booths in stations.

Chapter 5 Vehicle Plan

5.1 Vehicle Design

Selected vehicle is the standard bus of 12m length, platform-level boarding type high-floor bus with floor height of 1,000-1,100mm. Two doorways which have 1,100mm width and bridge plate are placed on the right hand side. Propulsion system is CNG engine attaining the emission standard of EURO-II.

Car interior of the bus is divided to the ladies section of front side and the gentlemen section of the rear side by a transparent partition, and the seats, a doorway and the wheelchair position are allocated in each section.

Source: JICA Study Team

Figure 5-1-1 Vehicle Image

Table 5-1-1 Basic specification of vehicle

Item	Specification
1. Vehicle Dimensions Vehicle capacity	
1.1 Dimensions	Length: 11.0m – 12.2 m, Width: Maximum 2.5m (excluding side mirrors)
1.2 Vehicle Capacity	More than 80 passengers Number of standees shall be calculated on the basis of 6 passengers /m^2 (65kg/person)
1.3 Seating capacity	Approx. 10 seats in ladies section and approx.20 seats in gentlemen section
1.4 Inside free standing height	Minimum 2.2 m / maximum 2.4m
1.5 Floor height	1,000mm ~ 1,100mm 1,000mm is desirable for at-level boarding. If floor height exceeds 1,000mm, a gradient of a bridge plate shall be 10 or less degrees for wheelchair users
2. Gross Vehicle Mass (GVM)	
2.1 GVM	Minimum 13,000kg
2.2 Axle weight	Minimum 5,000kg (Front), 8,000kg(Rear)
3. Engine and Fuel Propulsion	
3.1 Engine placement	The vehicle shall have a rear/front mounted engine
3.2 Fuel Type	The engine shall be powered by compressed natural gas
3.3 Emission standard	EURO-II
3.4 Engine power	The engine shall have a minimum power of 170 hp
3.5 Fuel storage	The CNG gas shall be stored in high pressure cylinders stored under floor at maximum 200 bar
3.6 Fuel capacity and Service Period between fuelling events	The on-bus fuel storage shall have sufficient capacity to perform 300km of daily use without refueling.
4. Transmission	Both manual or automatic transmission options are permissible
5. Gradeability	The vehicle should have a minimum gradeability of 20%
6. Body Structure	
6.1 Rust proofing	It is used to prevent rust of the body frame suitable for 15 year life
6.2 Inspection	The body shall be fitted with heat and noise insulation so that interior noise level shall not exceed 90 Db during any part of the duty cycle
7. Internal Trim	
7.1 Floor material	Floor must be lined with a durable material with anti slip properties. Proper and safe trimming must be used at the edge of steps.
8. Windows and ventilation	
8.1 Front wind screen	Front wind screen shall consist of one piece or two piece wind shields /laminated glass. No tinting is permitted on the wind screen.
8.2 Drivers window	Driver shall have a sliding opening window.
8.3 Side window	Side windows shall made of toughened glass and shall allow opening (slide or inward flap)
8.4 Roof ventilation	Roof ventilation hatches shall be fitted (minimum two hatches) manually operated
9. Passenger Doors	
9.1 Door arrangement and width	2 doorways on the right hand side with width of 1,100mm. Each doorway is dedicated for ladies section and gentlemen section.
9.2 Door control	Doors shall be pneumatically controlled
9.3 Bridge Plate	A bridge plate which automatically deploys and retracts synchronized with door operation is installed at each doorway. Although at-level boarding is desirable, a gradient of 10 or less degree will be allowed in a bridge plate when the vehicle floor height exceeds 1,000mm.
9.4 Door safety interlock	Buses shall have an interlock system among the vehicle brakes, doors and bridge plates to avoid moving the bus from stop position with passenger doors open.
10. Emergency Door	The bus must be fitted with a manually controlled outward opening emergency door on the right hand side in the rear with stair
11. Seat Material	Fiberglass/plastic molded seats with grab handles aisle side of seat back
12 Ladies Section Partition	Transparent partitions shall be installed between ladies section and gentlemen section. Two(2) partitions should be equipped in order to change the ladies section from 4 seats(min.) to 9 or 10 seats(max.) The partition shall equip a door so that the passenger can move between both sides.
13. Wheelchair Position	A wheel chair position is provided in each of ladies section and gentlemen section
14. Air Conditioner	Not equipped
15. Destination Display	LED type displays, which can display route information written in English and Urdu, are installed above the front wind screen and at the right hand side.

Source: JICA Study Team

In addition, KMTC should obtain permission from the Pakistan government for stable reservation of required CNG for bus operation. If the whole quantity of required CNG would not be secured, an alternative which mixes the diesel buses can be considered. In this case, the basic specification of the diesel bus would be the same as that of CNG bus shown in table 5.1-1, except engine and fuel propulsion.

5.2 Manufacture Survey

5.2.1 Overview of Manufacture Survey

The major bus suppliers who can provide 12m-long CNG buses manufactured by CKD basis in Karachi and has high production capability are the following 3 manufacturers. Among these, Daewoo Pak Motors (PVT.) Ltd. and Hinopak Motors Limited have supplied each 25 and 50 CNG buses to the CDGK CNG pilot project.

1) Daewoo Pak Motors (Pvt.) Ltd.
2) Hinopak Motors Limited
3) Ghandhara Industries Limited

Furthermore, Foton Pak Bus Company (Pvt.) Ltd. has signed a MoU with the Sindh Government in August 2011 for the provision of 2,000 CNG buses to Karachi. Although this project is not yet finalized and the buses will be imported by Compete Build-up (CBU) basis from Beiqi Foton Motor co., Ltd of China, Foton Pak Bus Motors (Pvt.) may be one of the candidates of the bus supplier according to the vehicle price and its reliability.

In this project, hundreds of buses, which will be procured, are being requested operating effectively in a long period. Obviously, reliability is one of the most important issues in vehicle selection in order that this BRT responds to expectations by citizens as safe, sustainable and reliable public transport system. Although a bus procurement cost isn't a large portion in the whole project cost, BRT would lose its whole function if faulty vehicle is selected. In the bidding stage, since it might be difficult to evaluate the reliability of vehicles which will be provided in the future, it is recommended to qualify the manufacturers based on the following qualification requirements.

<u>Qualification Requirements for bidding (Proposal)</u>

i. The bidder must have proven reliability of successfully supplying the same product at least 50 units or more in Pakistan to Public and Private Sector.

ii. The bidder must furnish proof of the soundness of body structural design of the buses.

iii. The bidder must furnish documentary evidence duly witnessed by the client for the availability of strong back up support for the satisfactory operation of the buses and after sale service of the entire fleet for the client.

iv. The bidder must furnish the certifications of ISO 9001, ISO 14001 and OHSAS 18001 Certified.

v. The bidder must have prior experience of maintenance and repair of CNG buses directly or through authorized dealership facility.

vi. The bidder must possess a clean record with no cases of litigation and shall not have been blacklisted by any government body.

vii. The bidder must be an exporter of buses to measure the level of quality standards and its acceptance internationally.

5.2.2 Analysis by Manufacture

(1) Daewoo Pak Motors (Pvt.) Ltd.

In October 2004, Afzal Motors Private Limited signed a Technical Assistance Agreement with Daewoo Bus Corporation of Korea for the assembly and marketing of its product in Pakistan. In October 2008, Daewoo Pak Motors (PVT) Ltd. has been incorporated as a joint venture company of Daewoo Bus Corporation of Korea and Afzal Motors (Pvt) Ltd. of Pakistan.

The newly built assembly plant of Daewoo commercial vehicles in Pakistan by Afzal Motors (Pvt.) Ltd. is located at main National Highway, Karachi. This plant, with the capacity to produce 6,000 commercial vehicles on a single shift annually, is the biggest truck/bus assembling facility in the country.

Daewoo Bus Corporation is established in 1955 and is global bus manufacturer in its capacity of around 20,000 units per annum, which has 2 manufacturing plants in Korea and 7 overseas manufacturing plants as of 2010. Afzal Motors has experiences over 25 years in distribution and marketing of commercial vehicle stepped forward with the assembly project of Daewoo trucks and Daewoo buses in Pakistan.

According to Daewoo Pak Motors (Pvt.) Ltd., the production capability of buses is 25-30 vehicles per month.

Table 5-2-1 Daewoo Pak Motors (Pvt.) Ltd. Bus Line-up

Model	Bus body dimension(mm)			GVW (kg)	Fuel	Seating capacity	Remarks
	Length	Width	Wheelbase				
Luxury Bus							
BH116	11,550	2,490	6,100	16,500	DIESEL EURO-I	45	1 door in front Rear Engine
Intercity Buses							
BF120L	12,080 (chassis)	2,460 (chassis)	6,100	16,500	DIESEL EURO-II	62 52	2 doors in front/centre Front Engine
Urban Buses							
BH115E	11,550	2,490	6,100	16,500	DIESEL EURO-I	45	1 door in front Rear Engine
EH115E CNG	11,445 (chassis)	2,460 (chassis)	6,100	16,500	CNG EURO-II	40	2 doors in front/centre Rear Engine

Source: http://www.daewoobus.com.pk/product.html, Daewoo Pak Motors (Pvt) Ltd.

(2) Hinopak Motors Limited

Hinopak Motors Limited has been formed by Hino Motors, Ltd. and Toyota Tsusho Corporation of Japan in collaboration with Al-Futtaim Group of UAE and PACO Pakistan in 1985. Hinopak Motors Limited assembles, manufactures, and markets Hino diesel trucks and buses in Pakistan.

Backed by Hino Motors, Ltd.'s expertise, Hinopak Motors Limited has gained 65% market share making it the largest manufacturer in medium and heavy-duty truck and bus industry in Pakistan and has held the top position in the domestic market for medium and heavy-duty vehicles for 17 consecutive years. Hinopak Motors Limited is the first automobile company to export its buses to Middle East and African countries and also has successfully developed Pakistan's first dedicated CNG engine bus.

Hino Motors, Ltd has been established in 1942 and is the largest manufacturer of heavy and medium duty tracks in Japan. Hino Motors, Ltd. has three manufacturing plants in Japan and 7 overseas manufacture plants including Pakistan.

As for production capability of buses, according to Hinopak Motors limited, they have experience of contract which produces 50 units per month.

Table 5-2-2 Hinopak Motors Limited Bus Line-up

Model	Chassis dimension (mm)			GVW (kg)	Fuel	Seating capacity	Remarks
	Length	Width	Wheelbase				
Luxury Buses							
Splendor	11,470	n.a	6,000	16,000	Diesel EURO-I	46	1 door in front Rear Engine
Roadliner Shangrila bus	11,080	2,410	5,800	14,000	Diesel EURO-I	43	1 door in front Front Engine
Senator coach	7,045	2,100	3,780	8,400	Diesel EURO-I	23	1 door in centre Front Engine
Urban buses							
City Bus	11,470	n.a	6,000	16,000	Diesel EURO-I	46	2 doors in front/centre Rear Engine
Metro Bus	11,080	2,410	5,800	14,000	Diesel EURO-I	46	2 doors in front/centre Front Engine
CNG bus	11,175	2,445	5,800	14,000	CNG EURO-II	46	2 doors in front/centre Front Engine
Exclusive bus (AK1JRKA) (AK1JMKA)	11,080 10,280	2,410 2,410	5,800 5,000	14,000 14,000	Diesel EURO-I	63 53	2 doors in front/rear Front Engine
General purpose							
Citiliner Classic bus (AK1JRKA) (AK1JMKA)	11,080 10,280	2,410 2,410	5,800 5,000	14,000 14,000	Diesel EURO-I	63 53	2 doors in centre/rear Front Engine
Rapidline coach	7,045	2,100	3,780	8,400	Diesel EURO-I	31	1 door in centre Front Engine

Source: http://www.hinopak.com/, Hinopak Motors Limited

(3) Ghandhara Industries Limited

Ghandhara Industries Ltd. is the exclusive distributor of ISUZU products in Pakistan, and is part of the Bibojee Group of Companies. Their principal is from Japan and is introducing the diesel and CNG buses in the market.

The founder of the company acquired the facilities which had been established by General Motors Overseas Distribution Corporation U.S.A. in 1963 and renamed it Ghandhara Industries Limited. The Government of Pakistan nationalized this company in 1972 and renamed it National Motors Limited. In 1992 M/s. Bibojee Services (Pvt) ltd. acquired it under Privatization Policy of the Government, and adopted its original name Ghandhara Industries Limited in 1999

The major business activities of the company comprise of progressive manufacture, assembly and marketing Isuzu truck and bus chassis and fabrication of Bus and Load bodies.

Table 5-2-3 Ghandhara Industries Limited Bus Line-up

Model	Bus body dimension(mm)			GVW (kg)	Fuel	Seating capacity	Remarks
	Length	Width	Wheelbase				
Urban Buses							
NPR	6,540	1,995	3,815	8,800	DIESEL	n/a	1 door in front
MT133 (Diesel) 4-Shaft 3-Shaft	11,300 10,030 (chassis)	2,400 2,400 (chassis)	6,050 5,050	14,500 14,000	DIESEL	45	1 door in front
MT133(CNG)	12,200	2,500	6,050	15,000	CNG	40	2 doors in front/centre

Source: http://www.gil.com.pk/indx.html

(4) Foton Motors Company

Foton Pak Bus Company (Pvt.) Ltd. is a local division in Pakistan of Beiqi Foton Motor Co., Ltd. of China, and has been established in 2008.

Foton AUV Bus which is a bus business division of Beiqi Foton Motor Co., Ltd. in Beijing, China, manufactures 5-18m city/intercity buses and coaches. The total annual production capacity is 100,000 buses per year.

Lahore Transport Company (LTC) has also entered an agreement for the supply of 111 CNG buses. On September 2011, the first 56 units departed from Beijing to Lahore via Shanghai.

5.3 Procurement Cost Estimate

5.3.1 Bus Vehicle

For the objective of protection and activation of the domestic industries, import of completed cars is subject to a high custom duty in Pakistan. As of January 2011, the custom duties differ according to the kind of vehicle and its cylinder capacity, and that of CNG (CBU) buses is exempt as shown in Table 5-3-1. Custom duty for CNG (CKD) buses would be exempted as well.

Table 5-3-1 Custom Duty for the transport more than ten more persons

Pakistan Custom Tariff Code	Description	Custom Duty (%)
87.02	Motor vehicles for the transport of ten more persons, including the driver	
	- With compression-ignition internal combustion piston engine (diesel or semi-diesel)	
8702.1010	--- Components for assembly / manufacture of vehicles, in any kit form	20
	--- Other	20
	- Other	
8702 9010	--- Components for assembly / manufacture of vehicles, in any kit form	20
8702 9020	--- Fully dedicated CNG buses (CBU)	0
8702 9030	--- Fully dedicated LPG buses (CBU)	0
8702 9090	--- Other	0

Source: www.pakcustoms.org/pakistan_customs_tariff/

Procurement cost of a bus is estimated based on the catalogue price as of Dec. 2011 and by adding the expenses for special equipment for BRT. Content ratios are 60% of F/C (Parts) and 40% of L/C (Parts, assembly, fabrication, paint). A service life of vehicles would be 1,000,000km.

5.3.2 Vehicle Maintenance Equipment

In order to perform safe and reliable BRT operation, enforcement of the periodic inspection which prevents vehicle's failure is proposed. When a workshop is established in each one depot of Green and Red lines, each workshop shall have the maintenance capacity of approximately 200 buses. The major equipment which is needed to carry out the periodic inspection (e.g. monthly, every 3 month and every 6 month) and the unscheduled inspection for 200 buses in each workshop is estimated as shown in the following table. All equipment would be imported. A service life of the equipment would be 15 years according to Japanese taxation system.

Table 5-3-2 Major Equipment for Vehicle Maintenance

Item	Equipment	Remarks	Q'ty per workshop
Equipment for inspection	Movable frame lift	Capacity 10 tons	4
	Transmission gear jack	Capacity 800kg	1
	Wheel dolly		1
	Drum pump	Manually and rotatory type	1
	Mechanical tool set	General tool for large-sized vehicle	5 sets
	Pneumatic-hydraulic garage jack	Capacity 15 tons, 250~430mm	3
	Service creeper	420mm x 840mm	4
	Deferential gear jack	Capacity 300kg, 200~800mm	1
	Brake fluid bleeder	18 littler	1
	Engine compression gauge set		1
Wheel/Tire/Brake maintenance	Automatic tire inflator	Floor type, 10 -700 kPa	2
Engine/Transmission maintenance	Air valve lapper	0.58MPa	1
	Engine stand	Capacity 550kg	2
Car washing equipment	Heated water high pressure washer	Capacity 1,500 litter/hour	2
Electric tool	Air impact wrench and sockets	1/2 sq.in, 3/4 sq.in, 1 sq.in. drive	3 sets
	Torque amplifier	Capacity 1,500 Nm	1
	Port-power set	Capacity 10 tons	1
Hand tool	Socket wrench set	3/8 sq.in, 1/2 sq.in 1 sq.in.	3 sets
	Chain block	Capacity 1.5 tons	1
Measurement device	Torque wrench set	3/8 sq.in, 1/2 sq.in, 3/4 sq.in, 1 sq.in.	4 sets
	Digital multi tester	DC/AC, Power current and voltage	1
	Combination socket for impact wrench	1 sq.in. 41 x 21 mm	2
Battery maintenance	Quick battery charger	12-24V/100A	1
Air compressor	Air compressor	Capacity 15 kW, 0.93MPa, Receiver tank 340 litter	1
Welding	Semi-automatic CO2 welding machine	200A	1
	Plasma-arc welding machine	35 A (3-phase)	1
	Spot welding machine	8,500A	1
Electric component maintenance	Circuit tester	Analog	1
	Clamp tester	1,000A (DC/AC)	1
Hoisting device	Sling chain	Capacity 2 tons, single hook	2
	Sling chain	Capacity 2tons, double hook	8
	Movable floor crane	Capacity 1 ton	2

Source: JICA Study Team

5.3.3 Estimated cost of Bus and maintenance equipment

The estimated cost of Bus and Maintenance Equipment is as shown in Table 5-3-3. Here, the kind and quantity of maintenance equipment was assumed based on an example of the bus repair shop of similar size[1]. Maintenance equipment cost was estimated by evaluating total amount of the cost of the above example. It is not an estimate based on individual cost investigation of each apparatus.

Table 5-3-3 Estimated Cost of Bus and Maintenance Equipment

	Bus per vehicle (Rs. 000)	Maintenance equipment for 2 workshops (Rs. 000)
L/C	3,100	0
F/C (Note)	7,245 (Import duty is exempted)	130,200 (Import duty of 5% is included)
Sub total	10,345	130,200
GST	16%	16%
Total	12,000	151,032

Source: JICA Study Team

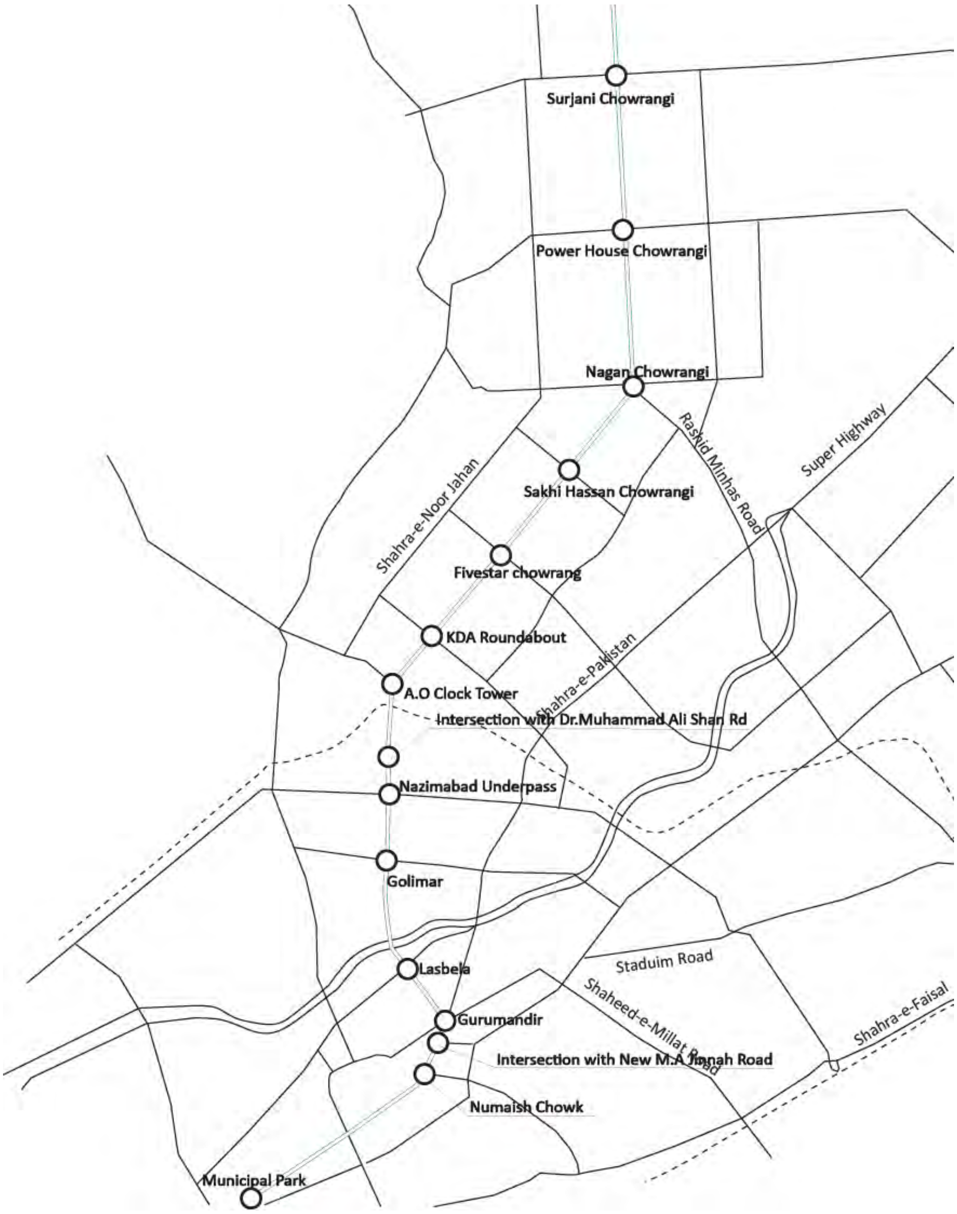
1 The result of the tender for "the Project for Improvement of Transportation Capacity of Public Bus in Vientiane"

Chapter 6 Infrastructure Design

6.1 Alignment Plan

6.1.1 Green Line

Green Line starts from Municipal Park (Aurangzeb Park), where a rotary is proposed for U-turn movements of BRT buses. The plane alignment extends along M.A Jinnah Road toward northeast up to Gurumandir, and after Gurumandir, the alignment runs northward along Business Recorder Road, Nawab Siddique Ali Khan Road, Sharah-e-Sher Shah Suri and Sharah-e-Usman, passing by some of major landmarks such as A.O Clock Tower and Nagan chowrangi. The outline of the alignment is shown in the figure below with major intersections where special considerations for BRT operation should be taken into account.

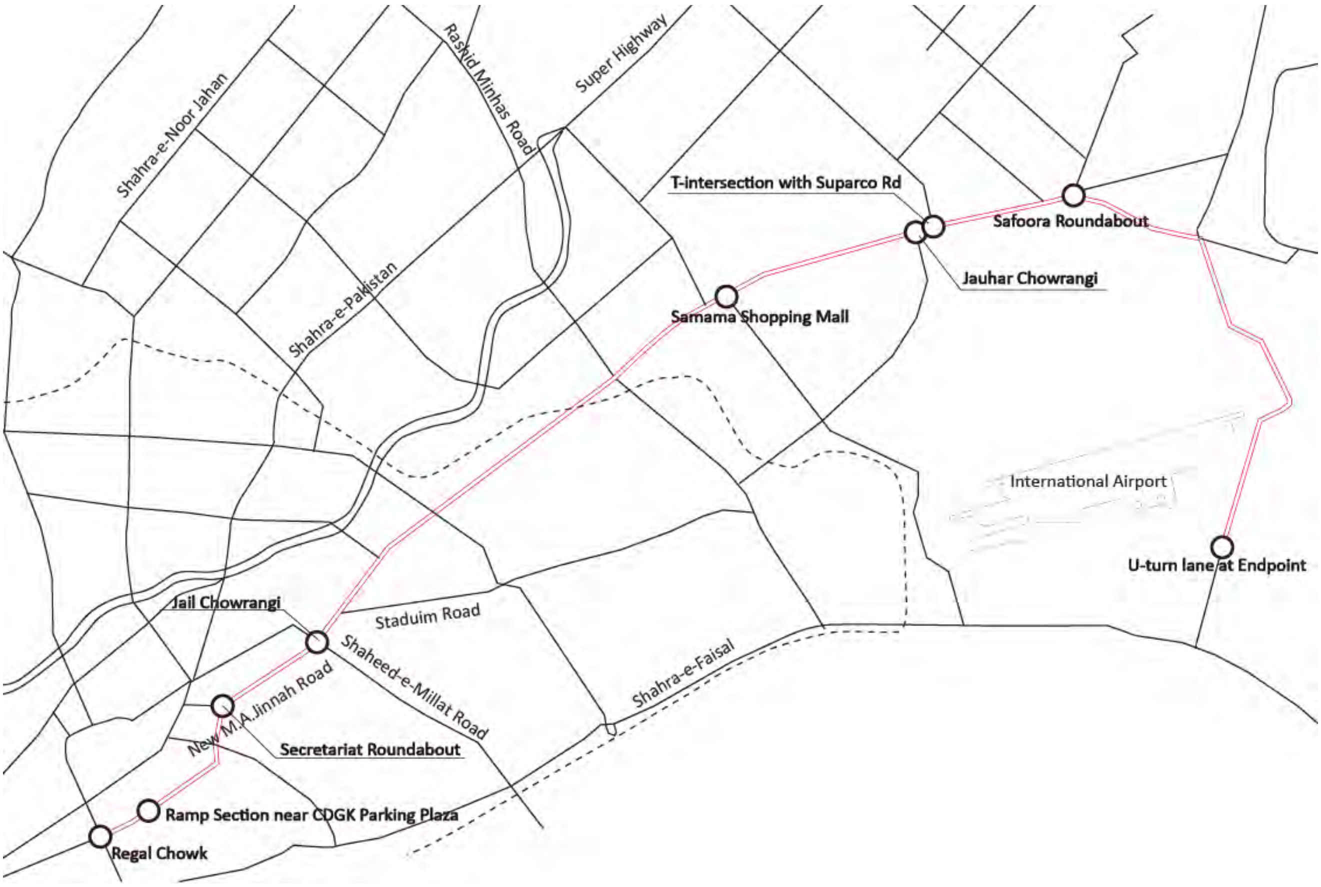


Source: Illustrated by JICA Study Team

Figure 6-1-1 Proposed alignment of Green Line

6.1.2 Red Line

Red Line links the city centre of Karachi, where the line starts from, with eastern section of Jinnah International airport, through New M.A. Jinnah Road, University Road etc. The major landmarks along Red Line are Empress Market, Jail chowrangi, Civic Center, Nipa chowrangi, NED, Safoora Chowk etc. As is the case of Green Line, there are several points where traffic management is necessary for BRT operation. Figure below shows the outline of Red Line together with major intersections along the line.



Source: Illustrated by JICA Study Team

Figure 6-1-2 Proposed Alignment of Red Line

6.2 Cross Section

6.2.1 Design Element of Typical Cross Section

(1) Design Widths of Cross-Sectional Elements

To reform urban roads, there are no specific geometric design criteria to adhere regarding widths. Re-allocation of roadway widths due to introduction of BRT busway itself is an important process of infrastructure design. Under the limit of right-of-way, the roadway should be shared among mixed traffic, pedestrian, and the BRT busway.

To determine the shares of roadway, the design widths of cross-sectional elements are suggested as given in Table 6-1-3, which were selected within the scope of normal road geometric design figures by taking into account the physical conditions of the BRT corridors and the size of bus. The design widths of traffic lanes recommended here are considered for urban roads assuming a travel speed of about 40 km/h.

Table 6-2-1 Recommended Widths of Cross-Section Elements

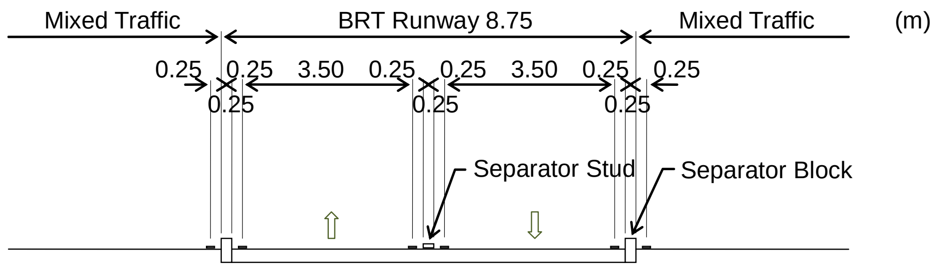
Roadway Elements	Desirable (m)	Minimum (m)
BRT Busway Lane	3.50	3.00
BRT Station Stop Lane	3.00	3.00
BRT Station Platform	4.00	2.50
Mixed Traffic Lane	3.50	3.00
Sidewalk	3.00	2.00
Pedestrian Bridge Deck and Ramp	3.00	2.00

Source: JICA Study Team

(2) Runway

A lane width of 3.5 m per direction is recommended with an offset clearance of 0.25 m on either side, considering the bus size of 2.5 m in width. Clear lane markings are necessary to guide the BRT buses properly. Low separator blocks and studs are recommended to allow buses leave the runway in an emergency.

As regards the surface pavement of runway, cement concrete pavement is preferable to asphalt concrete pavement because the cement concrete is more durable than the asphalt concrete. Although construction of cement concrete pavement is costlier than asphalt concrete pavement generally, the longer service life of cement concrete pavement will justify its higher initial cost, and that will be presumed considering heavy vehicle loading and frequent acceleration/deceleration operation of bus.

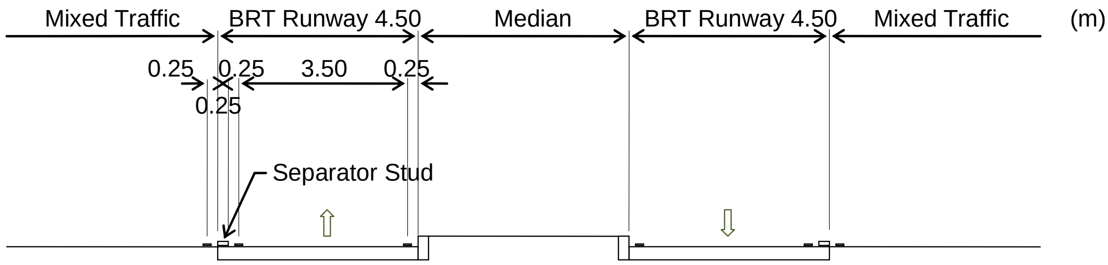


Source: Illustrated by JICA Study Team

Figure 6-2-1 Typical Runway

(3) Split Runway

Bus runway may be split by median for preservation of planted median. In such location, bus is difficult to flee to the median side in an emergency. Therefore, a stud type separator is suggested on the boundary with the mixed traffic lanes so as to allow bus flee to this side.

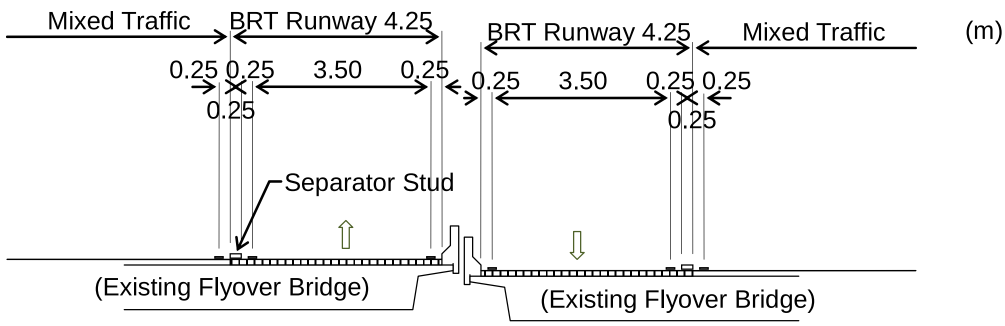


Source: Illustrated by JICA Study Team

Figure 6-2-2 Split Runway

(4) On Existing Flyover Bridge

There are several flyover bridges exist along the corridors. The bus runway will have no choice but to pass through on these flyover bridges by occupying their center sides. These flyover bridges are of separated structures by traffic direction, and each direction has three lanes. Since the bridges are marginally wide for three lanes with no extra space, a narrower bus runway will be required by sharing the same space with mixed traffic on the bridge. It is recommended to preserve two mixed traffic lanes beside bus runway. No station can be put on the bridges.



Source: Illustrated by JICA Study Team

Figure 6-2-3 Runway on Existing Flyover Bridge

6.2.2 Design of BRT Busway in Typical Road Configurations

As a conclusion of the above studies, the BRT busway was figured out in typical road configurations. Relative layout of the busway and other roadways and sidewalks were designed on typical plans and cross-sections of the BRT corridors, to show how to accommodate the busway in the corridors.

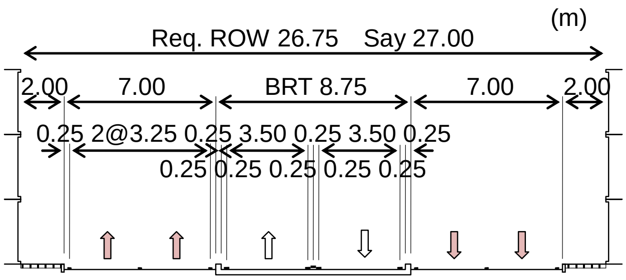
The following Figure 6-2-4 through 6-2-6 present various sample designs of road configuration with busway, covering a narrow road in downtown through wider road in suburban areas. The layout design is examined taking the station area, since the station area occupies the roadway the most widely.

(1) Busway in Narrow Corridor

For narrow corridors in central built-up area, the busway will be designed with a minimum width so as to fit inside the limited roadway.

1) Minimum right-of-way to accommodate bus runway

To accommodate a busway of non-station section and to preserve two mixed traffic lanes and a 2 m sidewalk on both sides, a right-of-way of 27 m is required as shown in Figure 6-2-6. It indicates that the corridor segments narrower than this right-of-way need grade separation to preserve two mixed traffic lanes both sides.

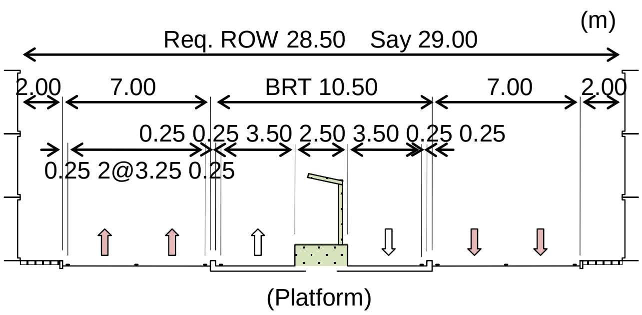


Source: Illustrated by JICA Study Team

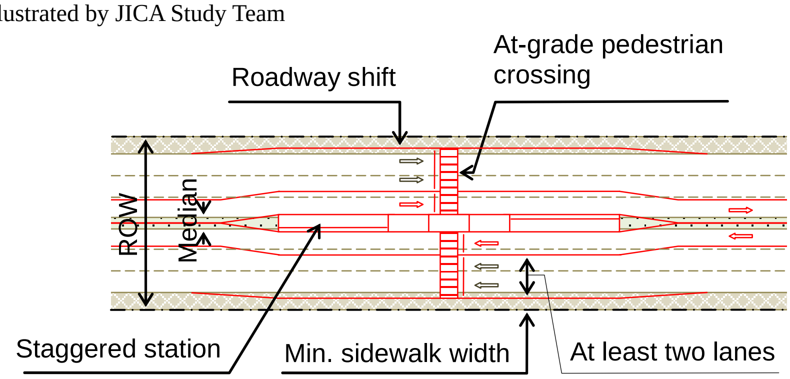
Figure 6-2-4 Minimum Right-of-Way to Accommodate BRT Runway

2) Station of minimum size in narrow corridors

A bus station of minimum size, which is staggered and 2.5 m in width but with no stop lane nor pedestrian bridge, is considered fit into narrow roads, if right-of-way is not less than 29 m as shown in the cross-section of Figure 6-2-5. This type of station may be designed in congested downtown, where traffic travels relatively low speed amid busy commercial activities and pedestrian movement. This being the case, it is an alternative option for the BRT operation in downtown to abandon express service and allow pedestrians at-grade crossing. This option will be incorporated by such a city redevelopment policy as to give priority to pedestrian movement and control vehicle traffic in downtown commercial area.



Source: Illustrated by JICA Study Team



Source: Illustrated by JICA Study Team

Figure 6-2-5 Station of Minimum Size in Narrow Corridor

(2) Elevated Busway for Narrow Corridor

Elevated busway is structurally proposed for narrow corridor. A design of elevated busway as shown in Figure 6-2-6 is proposed based on the following technical considerations:

1) Preservation of at-grade traffic space under viaduct

These corridor segments are currently operated with three traffic lanes or two traffic lanes plus a parking lane per direction with a small median separator. As shown in the cross sections of Figure 6-2-6, the existing roadway is required to be narrowed to create the space for viaduct columns.

There remains two mixed traffic lanes plus some parking and sidewalk space on either side within the existing road.

2) Viaduct structure

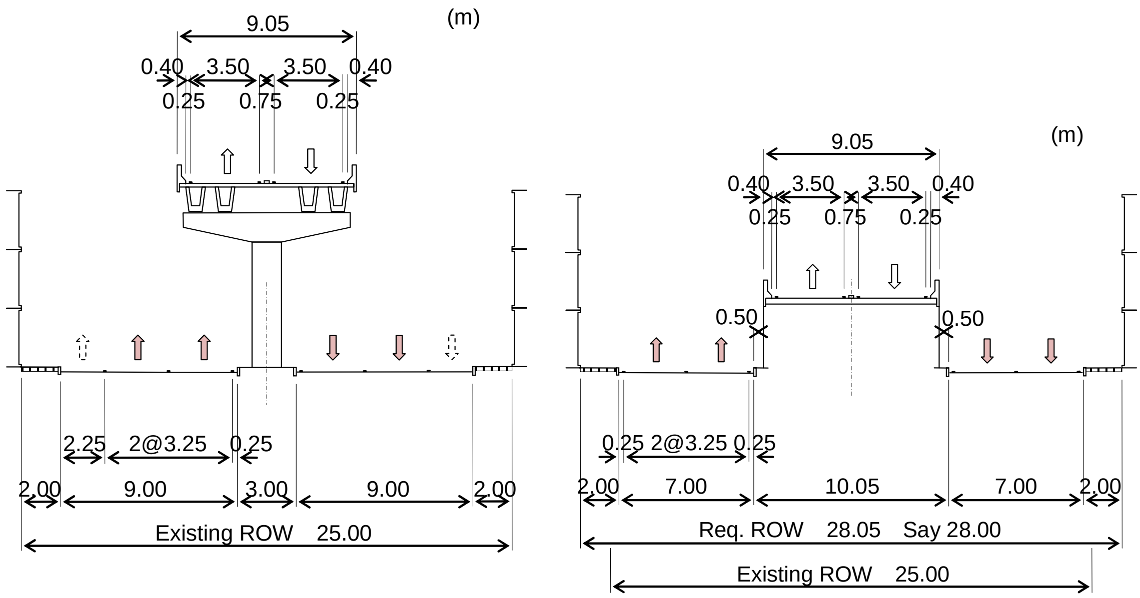
For construction economy, precast PC girders supported by single RC columns in 25 m intervals is recommended. A median of 3 m in width is required along the center of the road to locate viaduct columns.

3) Access to elevated station by a pedestrian bridge

Stairs or ramps are required for pedestrians to walk from sidewalk to elevated station. A pedestrian bridge is proposed to be constructed under the viaduct to connect sidewalks to the station platform. With this design of pedestrian access, the station platform will come to a height of about 10 m from street level. The design adopted turn-round ramps of 9 % gradient to secure maximum accessibility for wheelchairs.

4) Site acquisition for pedestrian bridge ramps

At station areas, site acquisition for the space of pedestrian bridge ramps along the sidewalk on either side of the road will be exceptionally required.



Cross-Section of Runway Cross-Section of Ramp

Source: Illustrated by JICA Study Team

Figure 6-2-6 Elevated Busway

6.3 Station

6.3.1 Introduction

(1) Overview of BRT Station and Other Facility Design

BRT system requires many facilities to complete basic operation program and needs with quality service for passengers. Core elements from an architectural point of view are bus stations, terminals and depot facility, which includes operator offices and maintenance service workshops for instance. A control center may be considered for sophisticated operation with passenger information system, although the project at the initial stage will not put this into the requirement due to simplified operation program and system facility.

Each facility is concerned with particular design criteria based on the operation design and policy decided by the local government. Typical station design shall be generated to suite common condition along the corridors to minimize complicated design task as well as to provide uniform identity of the BRT system with station appearance.

All facilities will be designed with consideration of environmental impact, appropriate construction cost, security and safety. Consideration toward climate of the region also will direct station design to make passenger space with the minimum required comfortable condition. Besides, stations and terminals are key elements to integrate existing transportation systems in order to improve metropolitan transit environment with comfort and convenience to the public users.

Stations are rather normally independent from other urban fabric, however, well integrated design code and guidelines should seek best appropriate design and aesthetic solutions toward the most possible service quality and amenity for the general public.

(2) Operational Design for Station Programming

Not only bus operation but also administrative program is fundamental for the station design of BRT project. Facilities in depots and terminals shall be also designed on the basis of the operation design. Bus frequency and fare collection method are major elements which largely affect and control station physical design. Bus operation program should impact on depot and maintenance facility design. There is another section of this report which describes in detail about the operation design and program to refer, and station design criteria and the same for depot and other facilities are set based on the operation program and design as discussed herein this section.

(3) Urban Setting and Condition which controls BRT Station Design

The city of Karachi is a growing metropolis with over 18 million residents. The project has selected two corridors for the first BRT implementation, and these are major urban spines which function as commercial and trade core, as well as most congested commuter drives. There are many public facilities, such as civic center, universities, shopping malls, libraries, parks and others along these corridors. Residential areas are spread all over the city so that high ridership demand will be expected also at entire stretch of the corridors.

The station layout study has to be made knowing above noted urban context to arrange most convenient and easy access for citizen. Thus, physical building layout shall seek the most effective positioning at each BRT station location to link well selected public facilities as well as to connect with other transport network.

According to the existing conditions of the project corridors, not only station locations but also the arrangement of station elements should vary, and some may require very specific layout, design or arrangement.

Both Green Line and Red Line have very congested traffic condition along stretches as well as narrow sections at several locations in the central district. Width of corridors and condition of intersections indicate a wide range of profiles, and these should be analyzed and categorized into typical sections and/or profiles to standardize the basic design process. After such analytical process, typical road sections and intersections with road structure, such as U-turn facility, have been set for further exercise of station design. Station facility must be designed to suite most possible conditions of the corridors in the city, and typical road width, road facilities and intersection profiles shall be well analyzed beforehand for station layout and arrangement.

6.3.2 Design Criteria for BRT Station

In order to generalize and standardize the station design, the project particular criteria should be set, and the design of BRT facilities needs to follow the same. Some design bases are set according to the policy decision made by Karachi Mass Transit Cell (KMTC) under the exercise of design development by JICA study team. Dimensions of structure as well as architectural details, spatial order and selection of building materials should meet the set criteria noted herein to achieve passenger friendly environment as well as safe station design for the project.

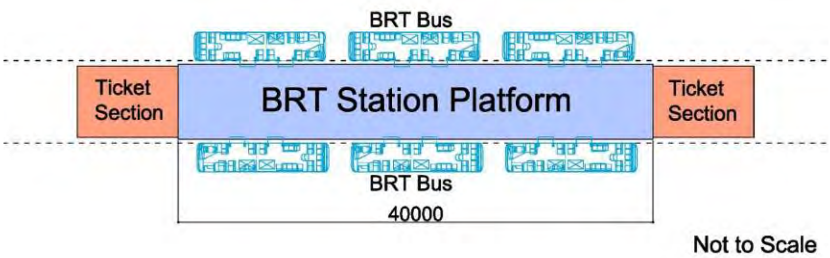
Major elements which control the design of stations are described hereafter.

(1) BRT bus operation and passenger management for boarding and alighting

According to the ridership demand analysis, there will be the operation with two to three buses per minute on each direction of corridors required, and there should be three stop bays per direction prepared at each station.

(2) Bus driving, approaching and departing

In order to minimize the length of platform, specific bus operation should be introduced, such as combined (or comboy) bus operation, separated boarding & alighting bay operation, and/or reduced parking capacity. With such operation program, the length of platform could be approximately 40m which is delivered under the basis of three 12m vehicle stop bays and 1m spaces between them. With this bus operation, express service may not be considered so that the passing lanes next to stop lanes are unnecessary. Buses will stop one by one and be departing by the same order.



Source: Illustrated by JICA Study Team

Figure 6-3-1 Design Criteria for BRT Station

(3) Vehicle passenger space and door arrangement

Based on the cultural needs, space for male and female as well as access doors shall be separated in vehicle design (Refer to the particular section of vehicle design). Station platform bus bay profile may follow such spatial order to match with the vehicle design.

(4) Passenger access program and universal access (barrier free design) concept

Due to heavy traffic movement at any location of streets in the city, passengers will be using pedestrian access bridges to cross over such road traffic that are provided with pedestrian ramps from sidewalk to stations. Design basis to the access path and any part of station public areas will be set under the design guidelines adopted in many countries such as Americans with Disabilities Act, 1990 (ADA), European Disability Act (EDA) and/or Japanese Barrier Free Design Code.

(5) Fare collection method and ticketing & paid/unpaid control system

Fare collection shall be made when passengers come into the station, and there is no fare collection activity in vehicles in order to maintain operation speed and time as well as uniform revenue management. Flat fare system is projected for the operation, and ticketing or fare collection will take place at the end of each platform. Passenger screening can be made by either automatic (Automatic Ticket Gate) or manual by man at each gate line. Ticket can also be sold automatic (Automatic Ticket Vending Machine) or manual (Ticket Issuing Window) before the gate line.

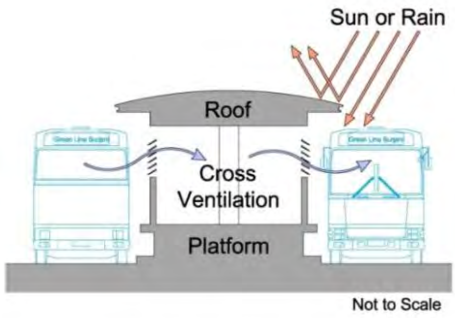
(6) Security and safety management & control

For security management purpose, each station will be overlooked by security personnel.

Any part of stations which exposes human body against bus runway or street, such as platforms, ramps and bridges, will be detailed with railing or similar means for protection purpose. Safety of users is the highest priority under the project implementation.

(7) Environmental control method and system

The city of Karachi has somewhat sever climate with heat and strong sun during summer seasons, and protection against such climate condition is the important matter when station facility is designed. Rain fall is another concern that may direct building design. However, because of budget limitation and platform edge treatment, the passive ventilation method is considered in stations. In addition, roof profile should be well designed to protect passenger and space against solar radiation and rain fall.

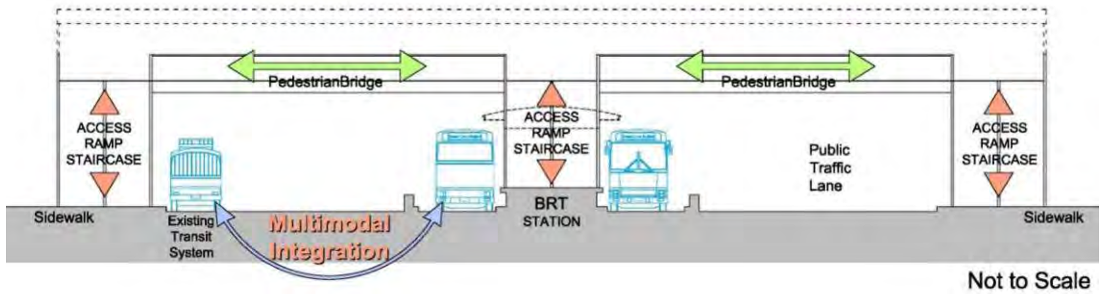


Source: Illustrated by JICA Study Team

Figure 6-3-2 Environmental Control Method and System

(8) Multimodal transit integration program

Where important connection or integration with other mode of transportation is required along the corridors in the city, physical connection shall be made via walkways and/or bridges for instance. Target systems may include KCR, existing bus services, feeder bus services, auto rickshaw pick-up/drop-off and park & ride facilities.



Source: Illustrated by JICA Study Team

Figure 6-3-3 Multimodal Transit Integration Program

(9) Connectivity to other public facilities

Where it is possible, public facilities, such as civic center, library and shopping mall, may be considered for the station locations. Physical connection may also be considered between stations and these facilities for user convenience and easy access.

(10) Additional services and facilities (toilet, venders and others)

At the initial operation of the project, public toilet and in-station vender activities are not considered due to management and maintenance issues. However, there should be enough space allocated within the station structure to accommodate small scale venders, ATMs and/or toilet facility in the future.

(11) Commercial activities in stations

There is an opportunity to consider commercial service and activities, including venders in stations or adjacent location. However, initial stage of the project does not include any commercial activity into consideration. Thus, stations will not be designed as a part of any other building complex.

(12) Aesthetic design basis and finish materials

Due to cost impact in concern, finish design for the project facility should seek commonly used methods and materials in local construction. However, minimum quality of protection, safety measures and environmental control must be achieved for user friendly station design. Appearance and aesthetical treatment may also be kept minimal to eliminate expensive details. Though, locally adopted architectural details and design concept should be considered while designing stations that correspond well to the urban context without undesirable visual impact to the public.

Not only these criteria but also statutory norms and requirement must be well studied so that the design of BRT facilities should be in compliance with all when they should be constructed. Some of these criteria are discussed in detail in the following sections.

6.3.3 Station Location

(1) List of Stations

Table 6-3-1 List of BRT Stations on Green Line

No.	Location	Chainage	Distance between station	Remark	Possible Station Type
M1	Municipal Park	00+050		Start point (or end point) of Green Line/ Without passing lanes/ Access by pedestrian crossing	Island, Both-sided
M2	Radio Pakistan	00+614	564	A transfer terminal is proposed in the vacant area near Garden Square/ Without passing lanes/	Island, Both-sided
M3	Garden Square	01+036	422	Without passing lanes/ Access by pedestrian crossing	Island, Both-sided
M4	Taj Medical Complex	01+760	724	Without passing lanes/ Access by pedestrian bridge	Island, Both-sided
M5	KGA ground	02+241	481		Island, Both-sided
G01	West of Quaid-e-Azam	02+682	441	The same station as Red Line/ Access by Pedestrian Bridge	Island, Both-sided
G02	Gurmandir	03+192	510	Between Gurmandir and G01	Island, Both-sided
G03	Lasbela Chowk	04+309	1117	North side of Lasbela Chowk	Island, Both-sided
G03a	sanitary market	05+316	1007		Island, Both-sided
G04	No. 1 Chowrangi	05+937	621	South side of No.1 Chowrangi	Island, Both-sided
G05	Model Park	06+506	569	Additional proposal in KTIP	Island, Both-sided
G06	Baqai Hosipital	07+533	1027	Access by a pedestrian bridge	Island, Both-sided
G07	Public Park near Bridge	08+047	514	At Nazimabad No. 7 intersection	Island, Both-sided
G08	Board Office	08+840	793	Access by a pedestrian bridge	split type
G09	KAD Chowrangi	09+720	880	Additional proposal in KTIP	split type
G10	Hydri Market	10+394	674	Access by a pedestrian bridge	split type
G11	Five Star Chowrangi	10+948	554	Both sides of the intersection	split type
G12	Jummah Bazaar	11+967	1019	Access by a pedestrian bridge	split type
G13	Sakhi Hassan Chowrangi	12+935	968	Both sides of the roundabout	Island, Both-sided
G14	Erum Shopping Emporium	13+800	865	Between Nagan Chowrangi and Sakhi Hassan Chowrangi	Island, Both-sided
G15	Nagan Chowrangi	14+524	724	Between the first and second pylon in front of Haji Qadir Pakwan Sheermal House	Landscape
G16	U.P. Mohr intersection	15+260	736	South of roundabout	Landscape
G17	Street Name	15+992	732	Signalizing T-intersection	Landscape
G18	Power House Chowrangi	16+767	775	South of the roundabout	Landscape
G19	Street Name	17+446	679	Signalizing T-intersection	Landscape
G20	2 minutes Chowrangi	18+186	740	North of the pylon outside Sultan Plaza Complex	Landscape
G21	Surujani Chowrangi	18+790	604	The north of the roundabout	Landscape
G22	KDA Chowrangi Surjani Town	20+322	1532	Outside CDGK site office on the southern side of 5000 Road	Landscape
G23	KESC Power House	22+180	1858	Terminal station (depot)	

Source: JICA Study Team

Table 6-3-2 List of BRT Stations on Red Line

No.	Location	Chainage	Distance between station	Remark	Possible Station Type
P1	Regal Chowk	00+120		Elevated Station (U-turn point)	Elevated, Single Sided (Long)
P1a	Empress Market	00+610	490	Elevated	Elevated, Both Sided
P2	CDGK Parking Plaza	01+082	472	Transfer terminal proposed	Island Both-sided
P3	Shah Ahmad Noorani Chowrangi	01+800	718	Reservation for future development	Island Both-sided
P3a	Near numaish underpass	02+280	480		Island Both-sided
R01	West of Quaid-e-Azam	-	860	Same station as Green Line	-
R02	North of Quaid-e-Azam	-	-	Middle of intersections	-
R03	People's Roundabount	00+790	-	Between roundabout and Jail road	Island Both-sided
R03a	Car dealer shop	01+510	720		Island Both-sided
R04	Center Jail	02+253	743	Near flyover	Island Both-sided
R04a	u-turn stadium road	02+742	489		Island Both-sided
R05	Askari Park	03+355	613	Both sides of T-intersection	Island Both-sided
R05a	Near u-turn Gulsan Iqbal	03+892	537		Island Both-sided
R06	Civic Center	04+462	570	Between Askari Park and Flyover	Island Both-sided
R07	PIA Planetarium	05+058	596	Transfer to Jilani KCR Station	Island Both-sided
R07a	Hakeem Sayeed Family Ground	05+725	667		Island Both-sided
R08	Urudu University	06+454	729	Before flyover	Island Both-sided
R09	National Institute Management (N.I.M)	07+775	1321	After flyover	Island Both-sided
R09a	near elevated u-turn	08+510	735		Island Both-sided
R10	Safari Park	09+155	645	Near interchange	Island Both-sided
R11	NED	10+148	993	After flyover	Island Both-sided
R12	University of Karachi	11+577	1429	Near Shaikh-Zaid Islamic Center	Island Both-sided
R13	City Towers	12+446	869	Before T-intersection at Rabia Villas	Island Both-sided
R14	Near blue mt CNG station	13+342	896	Near Ranger Office (proposed depot)	Island Both-sided
R15	Safura Circle	14+054	712	Before Safura Circle	Island Both-sided
R16	Malir Cant Check Post	16+247	2193	Near PSO Petrol Pump	Island Both-sided
R17	Model Colony	19+200	2953	Jinnah Ave. Intersection	Island Both-sided
R17a	Model Colony	20+460	1260	near end point	Island Both-sided

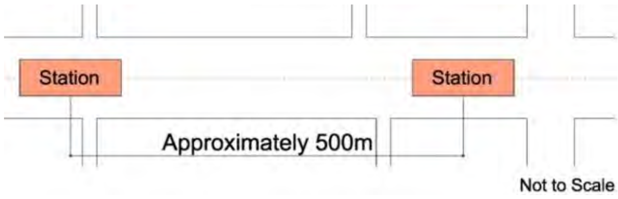
Source: JICA Study Team

Basic concept for the selection of BRT station location should be driven by the distance between stations in order to assure convenience and easy access for users. There are other elements in the city that the criteria should also include. Civic Center, University & College, Urban Park, Large Shopping Mall, Iconic or Memorial Monument and Cultural facilities are some of the important public functions to consider for possible station locations. Major street intersections, as well as existing public transit nodes along the corridors, shall also be taken into account for station location in order that such links should ease multimodal transit integration. The basic criteria for station locations are indicated in diagrams below.

The station locations have also been studied and fixed by KMTC in connection with JICA Study

Team design exercise. A set of studied station location layouts with architectural arrangement is included as appendix for reference.

Approximately 500m distance between stations

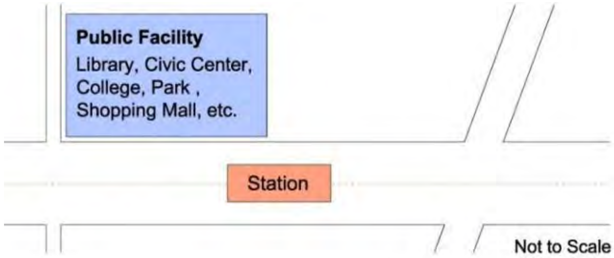


Source: Illustrated by JICA Study Team

Figure 6-3-4 Approximately 500m Distance between Stations

In order to provide the best service for users, 500m distance should be met for convenience. However, some station distances may be longer than 500m due to unavoidable condition in relation to the city street structure such as distance between intersections and existing U-turn facilities. In such cases station access may be specially arranged to reduce the distance.

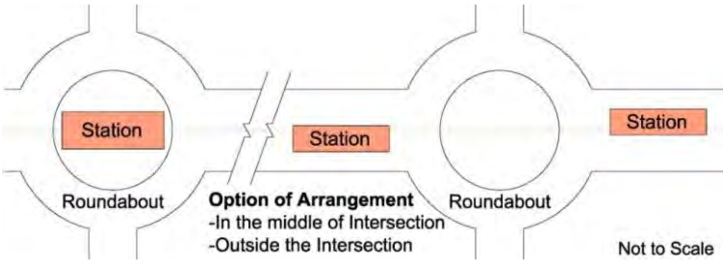
1) Locations of major public facilities and functions



Source: Illustrated by JICA Study Team

Figure 6-3-5 Locations of Major Public Facilities and Functions

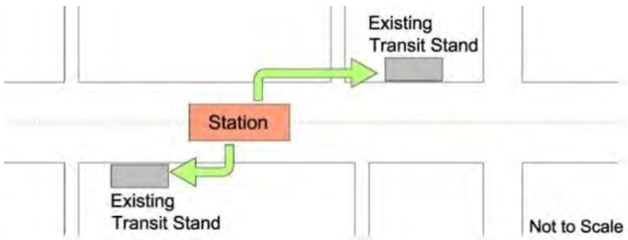
2) Major street intersections



Source: Illustrated by JICA Study Team

Figure 6-3-6 Major Street Intersections

3) Locations with other modes of transport for integration and connection expected



Source: Illustrated by JICA Study Team

Figure 6-3-7 Locations with other modes of transport for integration and connection expected

6.3.4 Basic Station Plan

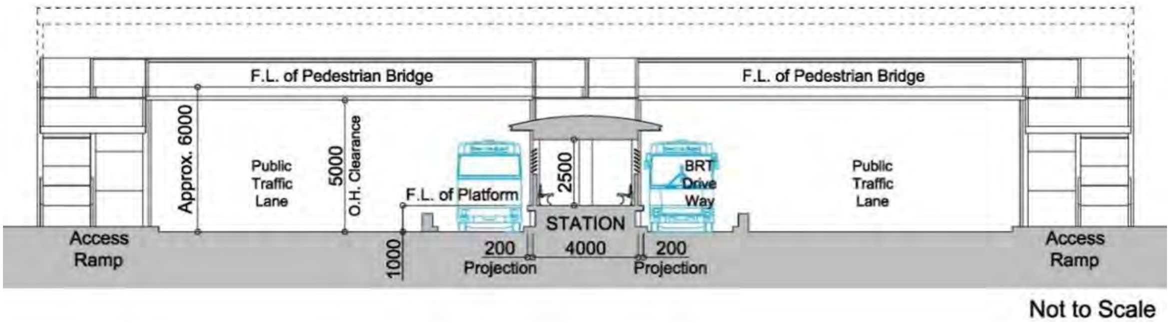
(1) Structural Arrangement

Projected BRT bus operation considers the bus runway (driveway) at the center of road with no exception. Thus, station facility and its structure should be arranged also at the center of road utilizing medians if exist.

The passenger access to the stations shall be made mainly via pedestrian bridges in order to avoid traffic accidents at the location. Either pedestrian ramp or staircase from each street sidewalk directs passengers up to the elevated level to cross over heavy traffic. Pedestrian bridge can be arranged at approximately 6m above the road surface to ensure the clearance of road traffic head space.

The width of each ramp must promise safe and comfortable cross passing between wheel chair users either going up or down, thus the minimum width of ramp shall be wider than 1.8m.

According to the most adopted international standard of ramp design, total length of ramp including flat landing section should become too long (over 80m if straight) so that arrangement of ramp shall be dogleg configuration in order to minimize the length of structure. Based on this design program, the structural width of the ramp as well as staircase should be minimum 4.2m considering structural steel column arrangement. Where steel structure is considered, fire resistant paint coating or fire proof covering is required under the regulation in Karachi.



Source: Illustrated by JICA Study Team

Figure 6-3-8 Structural Arrangement

Due to minimum structural arrangement of ramps, total station width can also be fixed at a minimum of 4.2m to accommodate architectural function, and reduction of width at any other station parts will not widen the bus runway. Thus, platform section and ticketing section of each station should be minimum 4m wide within the structural arrangement (excluding bus bay interface projection minimum 200mm each).

A sophisticated signaling system must be installed for pedestrian safety and operation time management if surface passenger access is considered through zebra crossing at the street level, although surface access is not highly recommended.

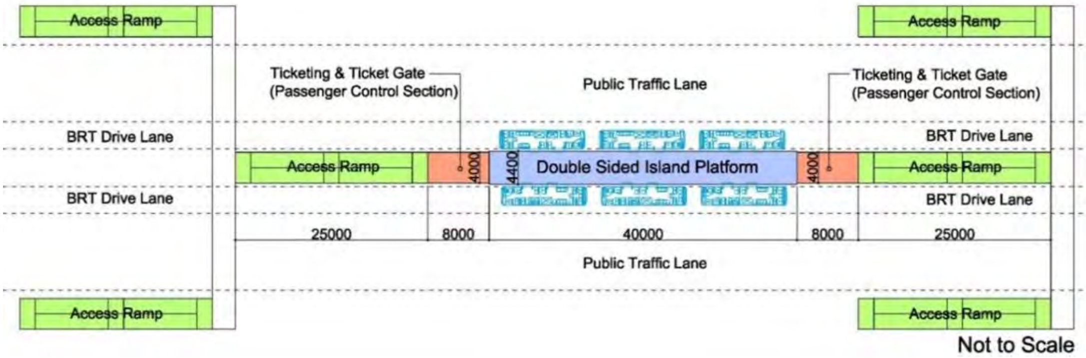
In order to protect passengers from strong sun exposure and rain fall in Karachi, the rigid roof structure should be arranged, and the projection of eaves shall comfortably cover the platform and ticketing section with clear soffit level above projected vehicle roof height.

(2) Spatial Order

Architectural programming shall follow the basic operational design, especially ticketing and fare collection method. The project operation design applies the fare collection at each station, not in each bus vehicle in order to minimize the duration of stop at stations. Thus, all passengers must purchase a ticket or make payment at the entry of each station, and this program drives fundamental spatial order of the station.

Because of nature in road profile and bus operation, station building tends to be liner, and normal access to the station is made at either end of station box. In order to meet the fare collection policy, all platforms should be considered as paid area, and the ticketing section should be located at the end section of the platform. Thus, typical passenger procession should be first through access ramp or stair moving into ticketing section then proceeding to the platform.

Bus arriving and departing operation then requires minimum three stop bays at each direction, and each bus bay must be arranged with minimum 1m spacing between them. This operation design controls the platform design with 40m long profile. Between bus stop bays, a space is provided as passenger waiting zone maybe with seating. Flow of passenger through the platform will be made along the center line of the structure as circulation spine.



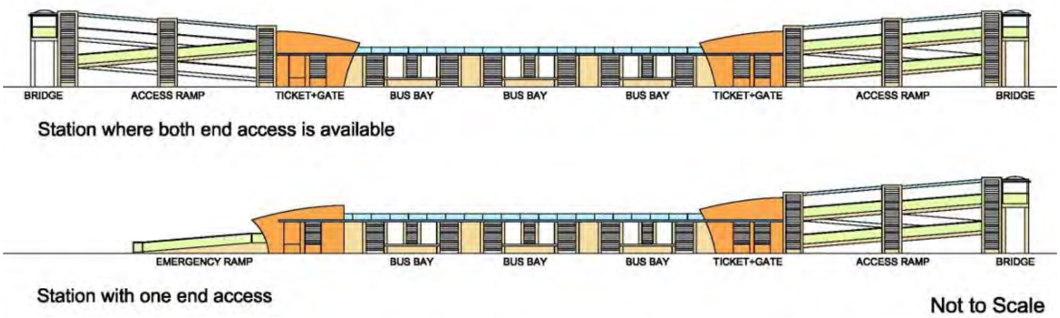
Source: Illustrated by JICA Study Team

Figure 6-3-9 Spatial Order

Both ends of station in typical can be the access point from the street sidewalk through pedestrian bridge and ramps or staircases. The stations vary in the access arrangement depending on the space availability – some station may only have one end access to the platform instead of two. In such case, other non-used platform end can be treated with the ticketing space for future provision, and an emergency egress ramp to the ground level will be provided with controlled door.

Means of access may also be chosen according to the space availability at each sidewalk entry point. Some sidewalk access points may not have large enough space to accommodate a set of ramp structure so that only a staircase may be applied. Thus, the selection of access mean and structure has to be carefully analyzed.

Where road width is significantly narrow to fit the typical profile station into, the alternative station design in particular must be made. For instance narrower ticketing and platform sections as a possible solution shall be studied. However, careful analysis of the space program for system arrangement and passenger flow as well as queuing pattern has to be made before physical station design is fixed. Ramps or staircases may also be arranged in straight profile instead of dogleg configuration. When such design change to the typical profile is considered, emergency operation analysis shall also be made for the narrower station for human safety.

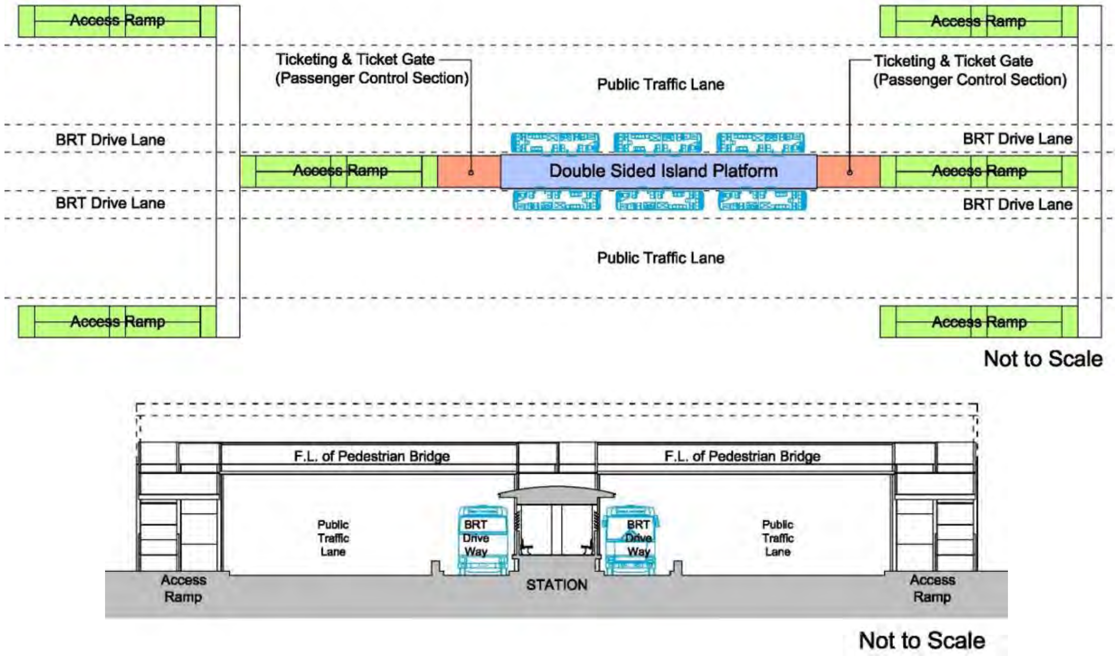


Source: Illustrated by JICA Study Team

Figure 6-3-10 Station Access

(3) Typical Station Configuration

There are several station arrangements based on the road condition and relationship to the traffic facilities, such as intersection and U-turn. The type of station will be selected based on the location specific physical condition and profile of road in order to limit land acquisition and to minimize impact to the public traffic. This will also be beneficial to meet the operational program and need, such as maintaining bus running time and speed.



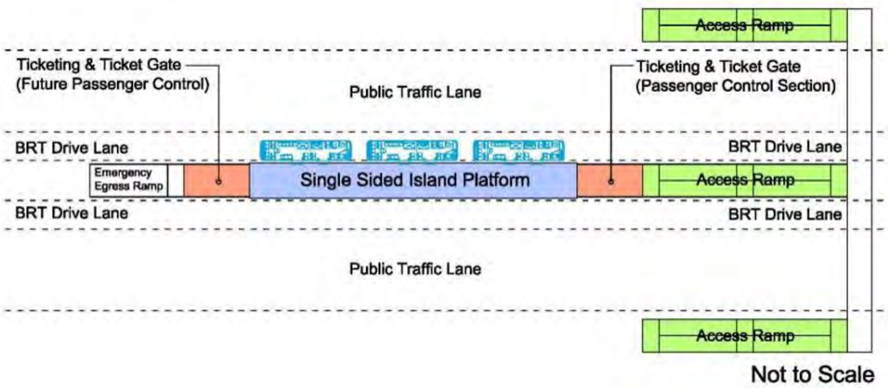
Source: Illustrated by JICA Study Team

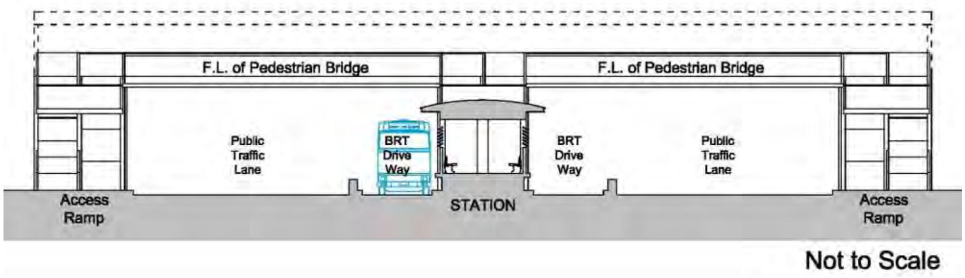
Figure 6-3-11 Single Platform with Both Side Bus Access

This configuration may be applicable to the typical road with more than 38m width on both corridors. However, the arrangement of access ramps shall be carefully studied location by location basis to suite best for public circulation pattern in the station area.

The set of pedestrian bridge and ramps (or staircases) may be only arranged at one end of station based on the land availability and demand forecast. Platform length may be stretched to meet increased ridership in the future where only one end is used for access.

Single (split) platform with one side bus access (possibly at street intersection)





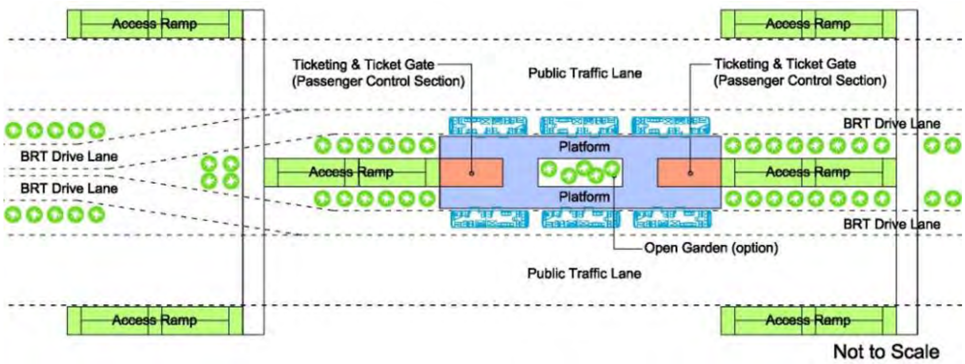
Source: Illustrated by JICA Study Team

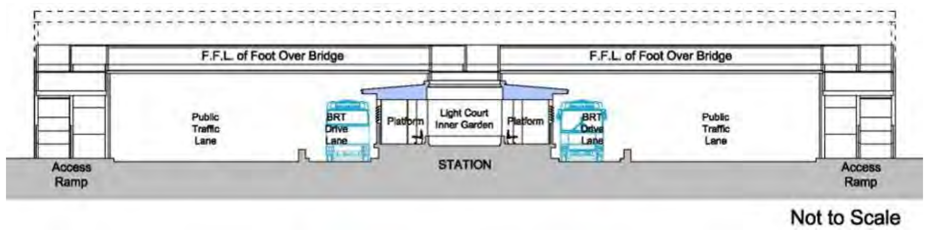
Figure 6-3-12 Single (split) Platform with One Side Bus Access

Where the station should be located at both ends of an intersection to avoid complicated traffic management, this option may be applied with/without traffic signal for both BRT bus and other traffic. Because of split configuration, public access program over the intersection should be carefully studied for most convenient approach by passengers.

This option may also be applied at locations with median around 25m wide or wider, and each directional platform could be set at the edge of median so that the existing landscape, as well as space of median, should be maintained with minimum change.

Wide platform type with both side bus access (applicable to wide median)



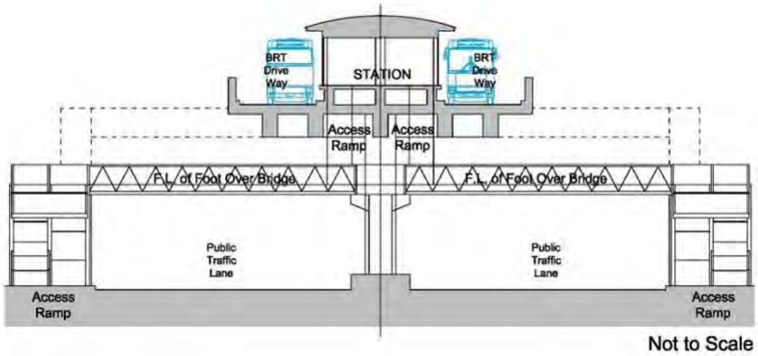


Source: Illustrated by JICA Study Team

Figure 6-3-13 Wide Platform Type with Both Side Bus

This configuration can be applied where the median is quite wide. Because of removing existing trees if any, the station plan will allow to set newly landscaped space within the station itself. Bus runway configuration may also have options to utilize the median space. Access arrangement should be independently designed to suite existing pedestrian circulation pattern.

Elevated station with both sided bus access (where runway is elevated)



Source: Illustrated by JICA Study Team

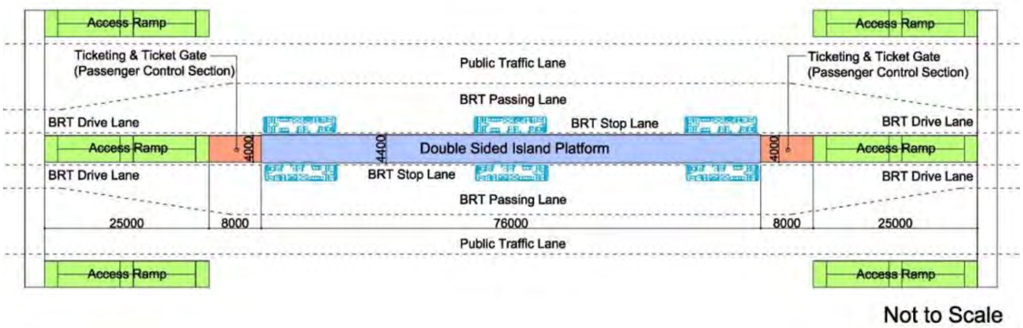
Figure 6-3-14 Elevated Station with Both Sided Bus Access

Where elevated bus runway is necessary, and station should be set within the same stretch, an elevated station should be arranged. Because of viaduct structure with large diameter piers at the center of the arrangement, the structural configuration for ramps should require wide space in minimum 6.5m. From this, the platform width is considered 7m.

Passanger procession should be made through mezzanine level link bridge between street level and platform level. Ticketing section, however, is considered at the platform level same as typical configuration.

Since this is the elevated station, egress from both end of the station platform is required for safety purpose. 2-way evacuation is necessary for emergency situations. One bridge for each end of the platform should be considered in order to assure safe and smooth evacuation from the platform, unless otherwise the width of one bridge is wide enough with calculation being separately made for this option.

Long platform option (if express service is expected at wider road)



Source: Illustrated by JICA Study Team

Figure 6-3-15 Long Platform Option

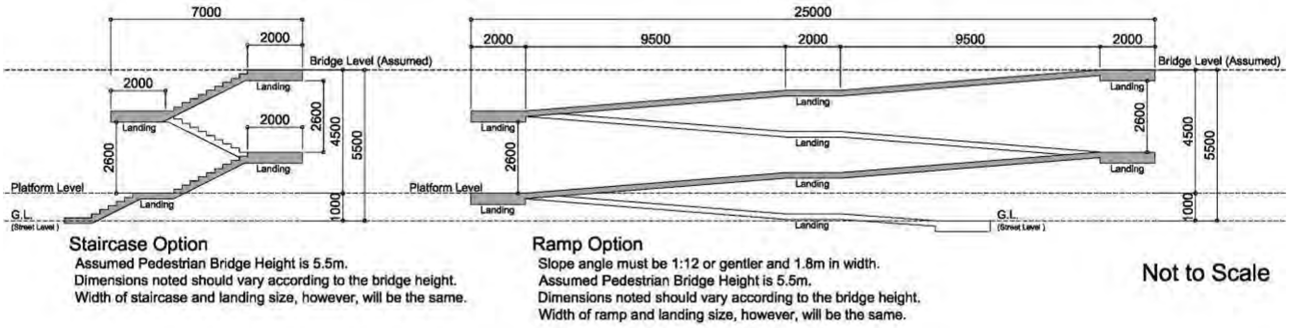
In case the BRT express service is considered, this long platform option may be used where it is necessary to fulfill the service requirement. If the implementation program is staged and express services are planned in the future, the 40m long platform station with one end access may be constructed at the initial stage. When the express service comes into reality, the platform will be extended to 76m to manage the bus operation and service. This option with the express service requires wider road profile for passing lanes for operation; thus it is only applicable at wider road sections of the corridors. The number of access points and bridges should be carefully studied based on the ridership demand.

6.3.5 Passenger Access

(1) Station Access and Accessibility

The policy made by the city government tends to have more pedestrian friendly facility which is generously concerned about disabled, elder and young children to access the BRT system. Although existing public road and its structure are not detailed with universal access consciousness, the project stations and terminals will be designed with universal access concept (barrier free concept) at all locations.

General access to the station should be made through gentle ramps with 1:12 slow angle to ease physically challenged person to walk or to drive wheel chair. A landing will be provided at every 75cm (+/-) rise along the slope with curb and handrail for safety purpose. In order to create easy side pass through of person and/or wheel chairs, minimum 1.8m width should be maintained for ramps.

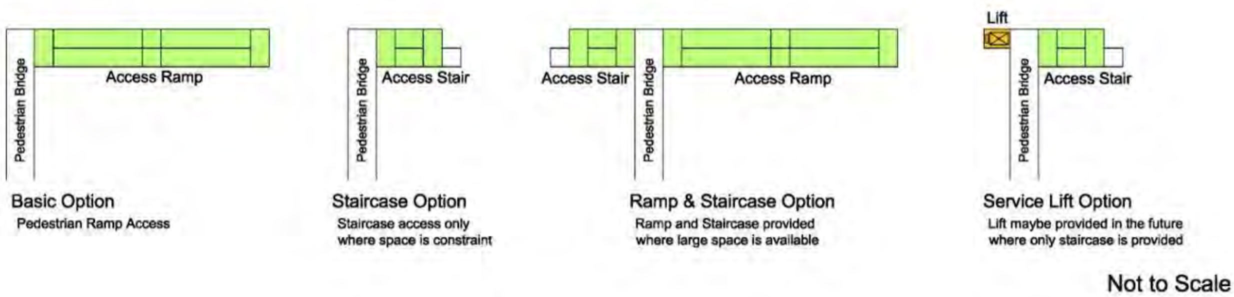


Source: Illustrated by JICA Study Team

Figure 6-3-16 Station Access and Accessibility

Wherever space is available, access ramp will connect pedestrian through the sky bridge to the BRT station. However, staircases will be provided where space is the major constraint. Further, both ramp and staircase will be provided at the same end of pedestrian bridge for better service, if space allows. Where only staircase is provided, lift service will be provided in the future stage so that the space provision for lift installation may be necessary for this option. If future lift installation is considered, circulation pattern at the crossing point of the staircase and lift queuing space should be carefully arranged to minimize pedestrian congestion, thus the initial arrangement of the staircase at each point must be well studied.

Staircase should have 15cm rise and 30cm tread for easy climb with landings. Railing to protect users from falling off shall be provided at all staircase and ramp paths including pedestrian bridges. Where the width of road becomes a major constraint, ramp or staircase may be arranged in the straight configuration although it should be a longer profile. Common width for pedestrian bridge for the project should be minimum 3m unless large pedestrian circulation is expected then it requires wider bridge otherwise.



Source: Illustrated by JICA Study Team

Figure 6-3-17 Access Ramp and Stair

International design standard shall be considered for the detailing of station facility. Surface of both ramp and staircase should be with non-slip treatment with possible roof covering. Minimum lighting fixture to light up the walk surface should be installed as well.

Not only access ramp, staircase and bridge but also any part of the station facility should be detailed with universal access concept and details commonly adopted in the world.

Land availability at some stretches of the corridors should be the major issue to layout the stations, particularly ramps or staircases at sidewalks. Due to narrow right of way profile or unavailability of open land at the projected station location, the profiles of these access means may differ with smaller dimension in order to fit them into the restricted spaces. In this regard, width of the ramp or staircase may be narrower than standard design described above.

(2) Fare Collection Methodology and Equipment

Basic station design is made with fare collection and gate space in approximately 35 to 40 square meter box which could be arranged at both or either end of the platform.

Ticket selling method could be both automatic and manual by persons at the ticketing section of each station, and the gate line could also be arranged at the same section. Where automatic fare collection (vending machine) system will be provided, automatic gates may also be installed in order to segregate boarding and alighting passengers at the same line. Permanent security personnel should be properly posted at each station, and cameras should be also installed to ensure the safety of money and tickets.

The station structure may be constrained with 4m width according to the road space and ramp configuration, and this shall also control possible arrangement of ticket gates at a line. Considering handicapped passenger use, particularly wheel chair users, there should be at least one wide gate installed with bi-directional control system. Besides, minimum one directional gate for each in and out path should be arranged. Accordingly, two wide gates or two narrow gates with one wide gate could be the possible options at each gate line of stations.

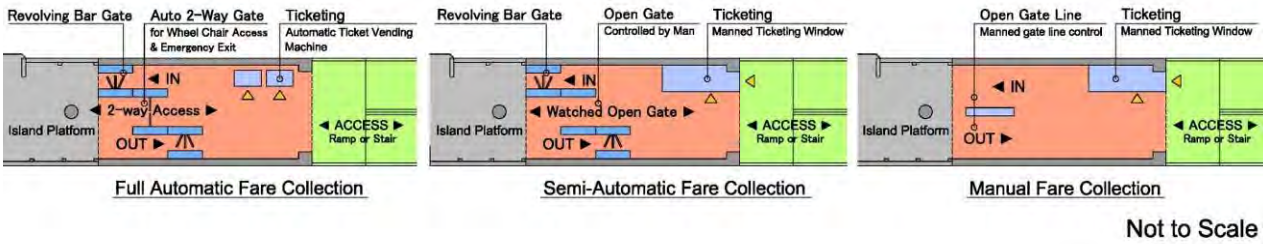


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Figure 6-3-18 Fare Collection

Ticket vending system and its number being installed should be based on the peak hour ridership at each station. However, the structural arrangement for the ticketing section should restrict the layout and quantity of vending machines. If there are stations with exceptionally large peak hour ridership demand, the ticketing section shall be separately calculated and detailed with a certain number of both ticket vending machine and ticket gate to suite such demand. Normally passenger queuing length for ticketing and gate line is considered approximately four to five meters.

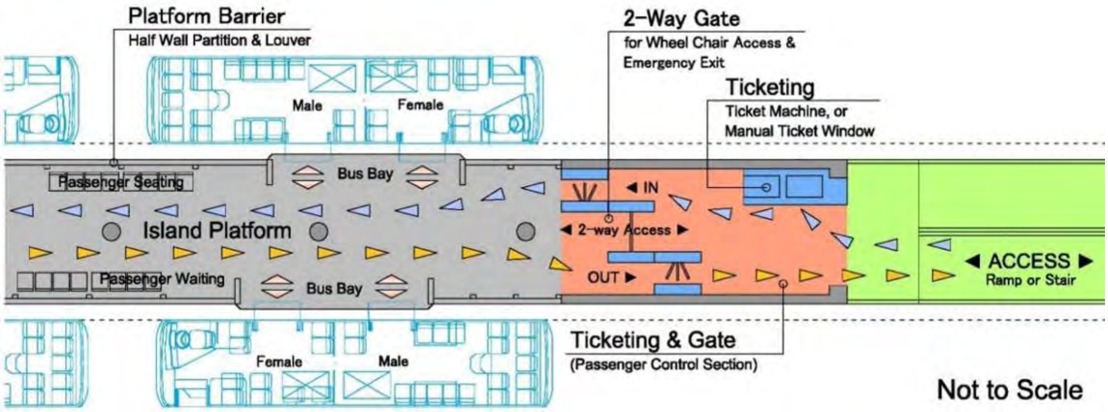
Typical manual ticket selling booth may be in rectangular profile with 3m by 1.2m to fit minimum required transaction equipment and space for ticket officer with safe for collected cash. Ticket vending machine if installed may be about 1m front face by 80cm side in plan.

The ticket gate if installed has to be arranged in most effective layout that considers passenger flow and emergency evacuation. The minimum width of gate alley for normal passenger flow is approximately 600mm, and the alley for wheel chair movement should have minimum 1.1m in clear passage width. The bi-directional access wide gate will be arranged at the center of both in & out gates. Gate box size may vary, and width of the box considered for the project is approximately 300mm, and length is about 1.8m.

(3) Circulation Pattern

Passengers and operation personnel are all able to access stations from the sidewalk through ramps, staircases and pedestrian bridges. Entry points at the ticketing section of each station are the lines that define realm of actual BRT station function. Outside of the ticketing section will be publicly open for all so that circulation will not be highly controlled in terms of moving direction or zones for particular purposes.

Once users or operators move through the ticketing section, circulation should be more controlled to manage effective flow of passenger and ticketing activities. When the ticketing machine and gates are installed at a station, passenger flow and direction should be maintained in particular, to simplify the movement of people and functional zones. Ticketing machine or even ticket sales person should be located at the side which also has an entry gate. The exit gate arrangement should be better set on the side of direct front to the access ramp or staircase so that the exiting passenger flow will not be disturbed by any unnecessary shifting or queuing. This passenger flow must be kept at all stations as a general principle so that users should not be confused of direction when they go in or out of platform realm at any station. This circulation concept is also very important during an emergency situation since people tend to go where they are used to do. Unusual gate arrangement shall be avoided at all.



Source: Illustrated by JICA Study Team

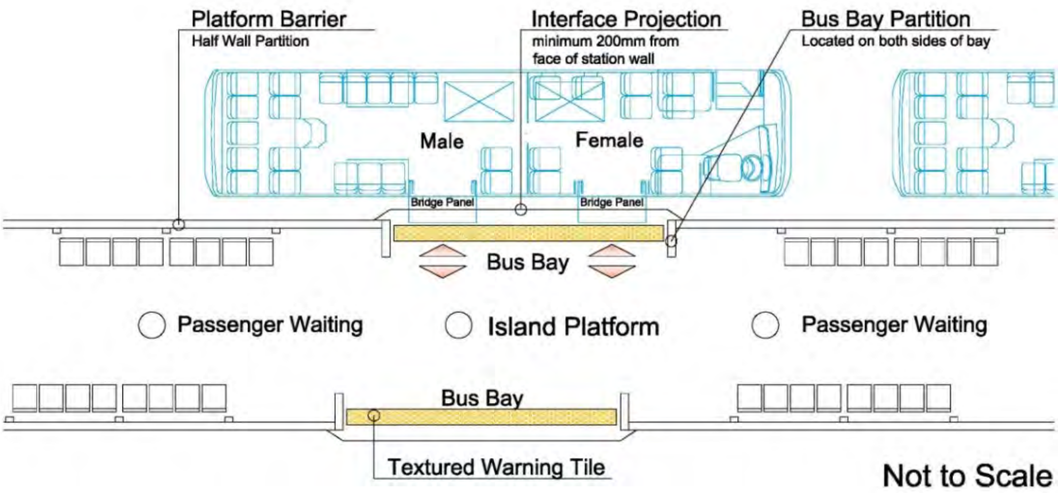
Figure 6-3-19 Circulation Pattern

The direction of passenger flow within the platform may be better if particular moving direction is set. However in reality, it should be difficult to control people without physical barrier, such as railing, and difficult to set order of walking position. Therefore, seating arrangement and signage layout will be well designed to draw attention of users to follow certain rules of circulation inside the gate lines (paid area).

(4) Bus Boarding/Alighting Interface & Platform Doorways

Ensuring passenger safety and proper fare collection through the operation are highly depending on the perimeter control with physical enclosure.

The city government policy toward bus interface at station platform with regard to the safety assurance is to provide simple railing separator or half solid wall along the platform edges with open interface bus bays (approximately 5.5m wide) to avoid high initial cost and maintenance problems. Detailing of safety partition at typical platform edges other than the open bus bay could easily achieve the level of safety for passenger. However, the open interface section may increase the risk of passenger accidents when buses are approaching.



Source: Illustrated by JICA Study Team

Figure 6-3-20 Bus Boarding/Alighting Interface

Particular signage design and floor detailing with color and texture should be the most viable solution to hazard control in such case. Architectural detailing with minimum openings for each bus interface bay shall be provided along with other architectural finish solution to minimize the possibility of passenger fall off from the platform or to prevent accidental contact with running vehicles. Other than such architectural solutions, manned control may be applicable to reduce hazard at open bus bays if it is allowed within operation cost and budget. It is still recommended the city government to upgrade the interface device in the future stage to further reduce hazard in both human safety and fare evasion.

6.3.6 Station Facilities

(1) Power Supply System and Facility

Highest level of power consumption may be considered to calculate the power supply capacity with most sophisticated operational system and equipment which will be installed in the future. In this regard, power supply should be made not only for lighting facility including emergency lighting but also ticketing and gate system equipment, automated bus interface and platform doors, security management system including CCTV system, digital bus operation information system, high level air conditioning system and possible firefighting system. If provided, these facilities should require not only higher capacity of power supply but also consistent power supply at all stations.

In order to meet this level of power supply and quality, diesel generator (or similar mean) and UPS system shall be considered when such high quality systems are installed because of the current condition of power supply in the city. Lighting fixture including emergency lighting system may be equipped with independent battery, but operational system including automatic door system and information system is depending on consistent power supply thus UPS facility.

Initial stage of the project may not consider such sophisticated operational system and sensitive equipment so that high power supply demand for station may not be necessary. However, the space allocation for future system upgrade is mandatory at the initial station design stage for transformer, generator and UPS facilities within each station premise.

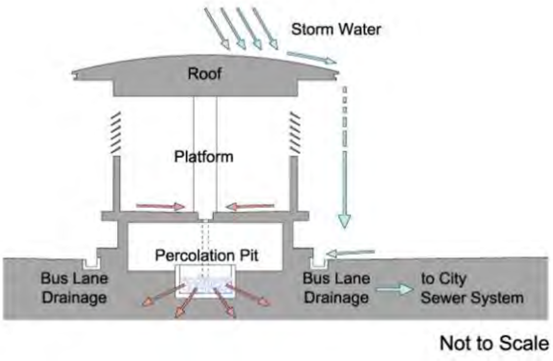
Locations for transformer, generator and UPS rooms or spaces may be arranged under the ramps or staircases at grade with maintenance access and security enclosure.

(2) Drainage and Storm Water Management

Station design does not provide any toilet and related facility at the initial stage so that water supply and waste water plumbing system will not be installed for this purpose. However, there may be a need of daily base facility cleaning at each station, and water supply for this activity will be provided. Waste water discharge for the cleaning purpose may require also minimum plumbing system, and water percolation pit connected to the soiled water pipe may be provided. In this case, selection of cleaning agent (chemical cleaner) should be carefully made. Otherwise, the waste water pipe must be connected to the city sewer system for water treatment.

Separately a storm water drain system will be provided along with the runway (driveway) drainage system so that rain water from the station roof or canopy will be released to runways adjacent to the station building.

Actual location of storm water collection drainage should be arranged in connection with the existing facility and road structure as well as composition of all bus runway elements. The drainage location might be at outer edges of the road instead of edges of stations.

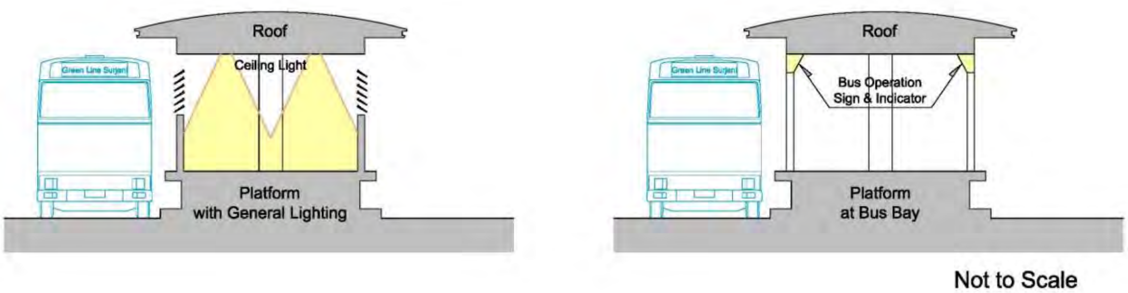


Source: Illustrated by JICA Study Team

Figure 6-3-21 Drainage and Storm Management

(3) Lighting Facility

Lighting facility and equipment are necessary for the night operation of BRT. Although the station in general is quite simple and small in a typical design, minimum lighting arrangement shall be made and designed from the initial operation.



Source: Illustrated by JICA Study Team

Figure 6-3-22 Lighting Facility

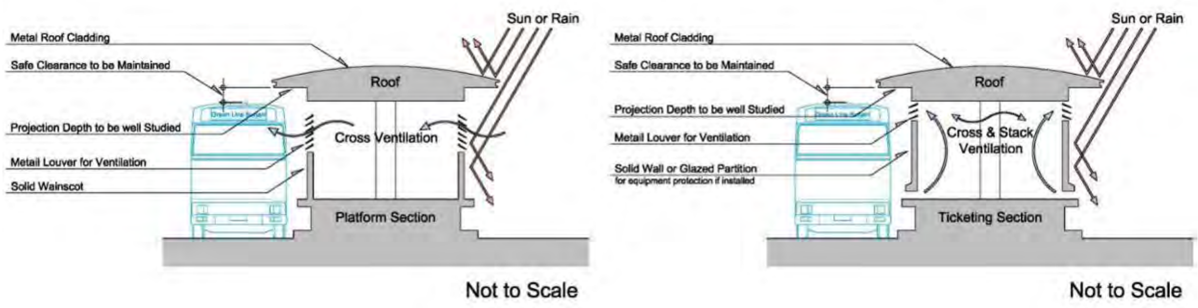
Platforms and ticketing sections, as well as ramps, staircases, and bridges should be equipped with lighting fixture minimum required for safety and security. In addition to this, signage should also be lit during the night operation so that users can identify the location and services easily.

(4) Climate & Environmental Control

Climate in Karachi indicates high temperature during summer seasons with rain fall in July. Solar radiation throughout the year is also strong, and heat gain from the sun light should be considered quite high in the city as well. To protect passengers and facility interior space from such climate condition, roof and/or canopy with deep projection is mandatory as a part of the fundamental station design.

Because of high temperature during summer seasons, ventilation for the station interior space is necessary, and this criterion should drive architectural detail with highly efficient passive ventilation effect. Due to higher cost for initial installation, operation and maintenance, mechanical ventilation and air conditioning system is not considered at the initial stage of the project. There may be ceiling fans to be installed at the initial stage.

Platform space in general will be protected for passenger safety. However, the separator or partition system should allow cross and stack ventilation to flow the air naturally in the station interior space. Thus, no complete and full height enclosure at each edge of the platform is designed. Rather, railing type separator or similar detail will be applied along the platform edges. Deeply projected roof then should cover the surface of the platform to protect the space against diagonal rain fall. The depth of eave projection shall be carefully studied with analysis of weather condition throughout the year. Horizontal louver system may also be considered to achieve both protection and ventilation together.



Source: Illustrated by JICA Study Team

Figure 6-3-23 Climate & Environment Control

On the other hand, ticketing section should be sufficiently protected against heat radiation as well as sun exposure in order to protect sensitive ticketing equipment if installed. In this regard, this area should be enclosed with more solid wall detail with insulation mass, though passive ventilation must be maintained at a minimum necessary level. Careful opening layout in wall surface as well as wall arrangement is required for the ticketing section design.

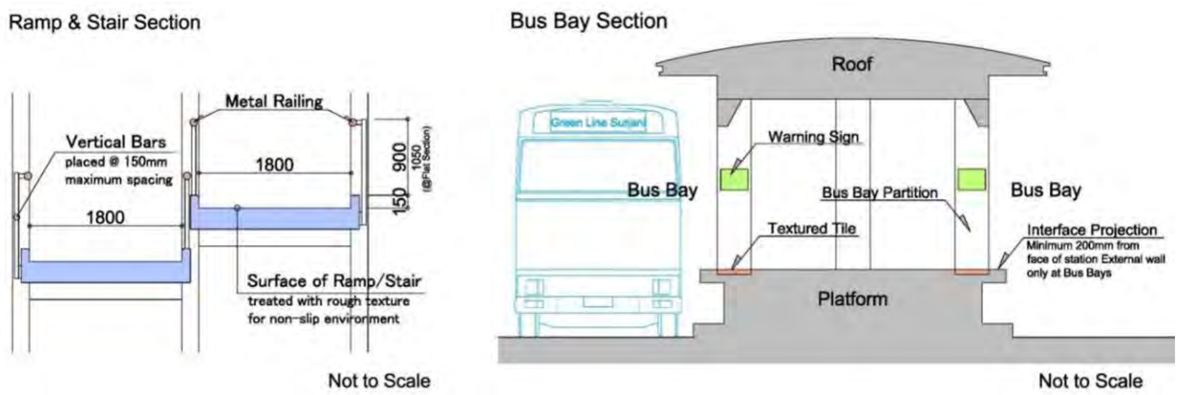
If ticketing and ticket gate equipment are installed, dust management becomes another issue, and higher level of air quality control measure must be taken into account.

(5) Safety Control and Security

Accident preventive details such as railings and curb stones should be provided at all stretches of passenger walkway, bridges, ramps and staircases as well as necessary material selection and surface treatment of building parts. Dimension of station facility for user and operator movement must be set in comfortable and effective manner.

Signages shall also be provided at certain locations for purposes to maintain safety of people and to manage emergency situation. Sizing and color selection in design shall follow international standard for common signs and emergency signs.

The bus bay interface should become the most difficult issue on both hazard & accident elimination and vulnerable to fare evasion against operation. Since the platform bus bays are considered as open interface based on the policy decision, passenger safety measure shall be made with some architectural solutions, such as floor color and texture arrangement as well as visual warning sign.



Source: Illustrated by JICA Study Team

Figure 6-3-24 Safety Control and Security

For blind passengers as part of universal access concept, textured (pebbled) tiles should be continuously installed to guide them in a certain direction avoiding any hazardous environment throughout the station. Such treatment should be designed under the simplest and safe circulation pattern within each space including bridges.

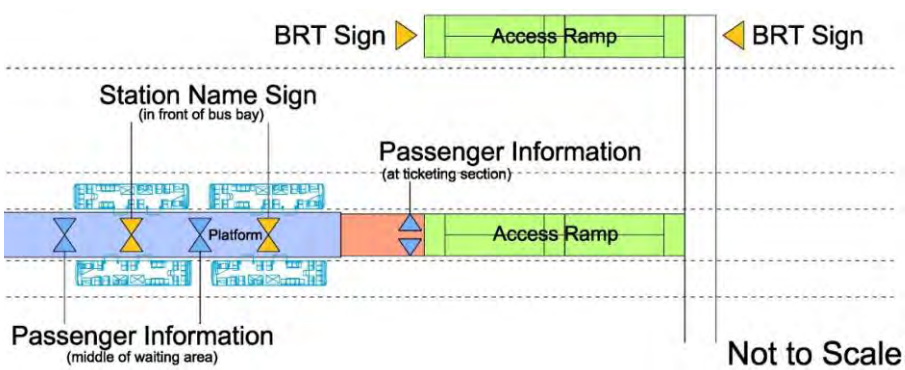
For emergency reason, all gates if installed must have emergency release system in order to maximize evacuation speed of passengers from station platforms to the point of safety, although most of the stations are located at grade. Evacuation to the runway from the open bus bay shall not be considered as alternative means of egress because any buses may be running at the time of emergency as well.

Security of stations is another concern to be well taken into consideration with solutions. The initial stage of operation may not go with very sophisticated operational system and facility so that simple manned security may be applied. Thus, small room for security officials should be provided at each station for the manned program.

When the upgrade of the system is applied in the future, tighter and more effective security system should be considered, such as CCTV system and/or automatic door and enclosure system at the perimeter of each station (both platform and station entry). However, this should be only studied as future provision under the city government policy.

(6) Signage Design Basis

There are a few fundamental signage elements should not be missed out to complete station design to assure quality passenger service. BRT station identity with station names, directional & emergency signs, BRT system map and information, caution & directive (such as do & don’t), and other service information are in the typical package for the project.



Source: Illustrated by JICA Study Team

Figure 6-3-25 Signage Design Basis

Not only for passengers inside stations but also passengers in buses are the subjects to consider for quality sign design and arrangement, since both of these depend on information such as locations and names of station. Color coding for corridors for identity and easy understanding of information by users is another basis of sign design. Location and layout of signs are also important design factor to complete effective and quality sign service for all users.

(7) Firefighting System for BRT Facilities

Regulations and codes under the firefighting purpose and procedure in Pakistan as well as Sindh and the city of Karachi must be met and required equipment and/or system shall be installed at all BRT facilities. The types of equipment and/or systems may depend on the size and function of each building.

(8) Other Facility and Services at Station

Not only BRT stations but also stations for other modes of transportation have a large opportunity to generate additional revenue through several options including small vender program and advertisement. Common public service facilities, such as public toilet, may be arranged within or adjacent location to the stations for convenience of users. Worldly accepted typical services in/at stations are

Commercial Space and Vender Activities, Cash Dispensing Facility (ATMs), Bicycle Parking and Rental Cycle Corner, and Toilet Facility

Under the city government policy over such services, however, the project will not consider those secondary services within stations at the initial stage of operation. The reason is that operation agency should or may be different in case of toilet facility, for instance, being provided considering water supply and cleaning matter, thus such circumstance may complicate the operation. For vender services, on the other hand, it may also create major problems over cleaning responsibility for BRT operation and further may cause worsening the station environment due to garbage trouble. Since the initial operation of the BRT system should be free of such problems including additional security measure for ATM management, it is decided not to provide services of these kinds in BRT stations.

As an exception, the stations may be equipped with advertisement panels to generate simple revenue based on the decision by the city government.

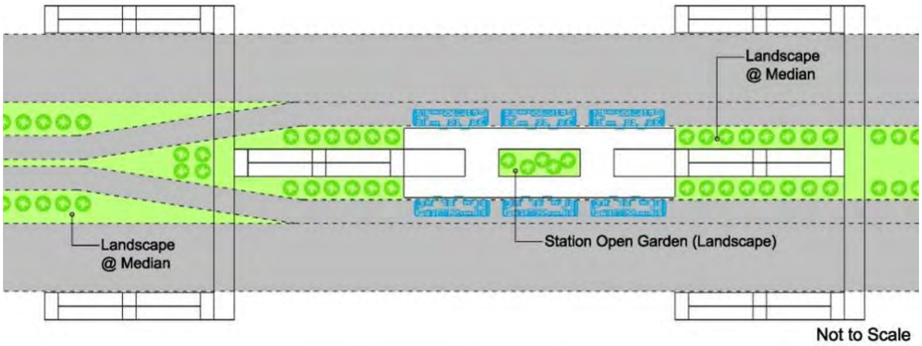
Other than the small vender services, stations shall have good connectivity to major public facilities as well as other modes of public transportation. Possible physical connection via pedestrian walkways or bridges from stations should be arranged for easy access for users, where it is necessary. This will also improve multimodal integration and commercial environment at the immediate locations of BRT station and terminal.

6.3.7 Environment

(1) Landscape Design

Environmental impact by the project development is one of the largest concerns to the city, and station design shall also be carefully made with awareness of this matter. The project from the beginning seeks best options to reduce traffic congestion in the city so that in return CO or CO_2 emission should also be reduced when current transport method is partly replaced with such mass transit systems like BRT.

The project and its design also have to take thoughtful attitude toward green and environmental protection, and protective action for existing plants along the project corridors should be strongly applied under the project. If clear cutting is necessary at some locations for facility construction purposes, relocation of the existing plants or planting new ones are suggested. If new plantation is necessary, landscape design with the station, terminal facility or depot should be carefully studied. Types & sizes of vegetation as well as layout & density of plants have to be carefully analyzed considering locally growing species and climate of the city.



Source: Illustrated by JICA Study Team

Figure 6-3-26 Landscape Design

Hardscape design is also important along with landscape design considering color coordination and selection of materials which well suites the existing city and street scape. Vernacular architecture and cultural elements in the region may also be studied for design improvement since these may well help to marge new structure into the existing urban fabric place by place.

(2) Aesthetic of Station Building

In order to minimize the cost impact to the project, detailing, color scheme and material selection for station design shall be studied and designed also minimum. Locally adopted construction methods and common materials may be applied to arrange building finishes.

Structural system for the stations, however, must consider higher grade compared to the local standard to build the station with much longer life span so that continuous rehabilitation to maintain the structure could be minimal thus less additional expense will be expected.

Time by time in the future, station facility may be upgraded with materials, technologies and methods available at the time of change, and structural integrity should promise such upgrade activities in the future.

Station Finish Schedule

Table Description:

Top Finish
Back Material or Structure
Secondary or Sub Course
Remarks

Interior Finishes

No.	Room or Space Name	Floor	Wall	Openings	Ceiling
1	**Ticketing and Gate Section**	**450x450 Stone Paving**	**Paint over Mortar Plastering t=20**	**Painted Metal Louver 150mm pitch**	**Painted Suspended Ceiling**
		120mm Concrete Slab with Wire Mesh	Concrete Block with Re-Bar (H=2000)		(Perforated Ceiling Panel)
		Soil Back fill	150mm Wall Base to be finished w/ Tile		Metal suspension rail system
			Bottom of walls to be open with horizontal slit (RC lintel required)	(@ top 500mm of wall)	
2	**Main Platform Area**	**450x450 Stone Paving**	**Paint over Mortar Plastering t=20**	**Painted Metal Louver 150mm pitch**	**Painted Suspended Ceiling**
		120mm Concrete Slab with Wire Mesh	Concrete Block with Re-Bar (H=1200)		(Perforated Ceiling Panel)
		Soil Back fill	150mm Wall Base to be finished w/ Tile		Metal suspension rail system
		150mm RC Slab to be set at Bus Bay Projection (full platform width)		H=1200	
3	**Security Room**	**Sealer Hardener**	**Concrete Block with Re-Bar**	**1mx1m Metal Framed Window**	**Direct Paint**
		120mm Concrete Slab with Wire Mesh	150mm Wall Base to be finished w/ Tile		RC Slab or metal roof system
		Soil Back fill			
			(H=2500)	Window: Single pane sliding window system	
4	**Generator & Transformer Space**	**Sealer Hardener**	**Mesh Fencing system H=2000**	**-**	**-**
		Conc. Pedestal H=600 w/foundation	RC Foundation included		
5	**Pedestrian Ramp / Stairs / Bridge**	**Brush Finish with Sealer Hardener**	**Painted Metal Railing System**	**-**	**Direct Paint**
		Concrete Decking			RC Slab or metal roof system
		Steel Structural System			
		Steel Decking System	H=1100, Railing Diam.=40 @ H=700 & 1100 Vertical Bar Placement @ 150mm O.C.		
6	**Electrical Circuit Board / MDF Room**	**Sealer Hardener**	**Concrete Block with Re-Bar**	**Painted Metal Louver 100mm pitch**	**Direct Paint**
		Concrete Decking	150mm Wall Base to be finished w/ Tile		RC Slab or metal roof system
			(H-2500)	(@ top 300mm of wall)	
7	**Ticketing Office**	**Sealer Hardener**	**Concrete Block with Re-Bar**	**1mx1m Metal Framed Window**	**Direct Paint**
		120mm Concrete Slab with Wire Mesh	150mm Wall Base to be finished w/ Tile	**Painted Metal Louver 100mm pitch**	RC Slab or metal roof system
		Soil Back fill			
	Approx. 1.5m x 2.5m in area Granite Finish Ticketing Desk 1m x 1.5m		Ventilation Slit to be provided @ bottom (H=2500)	Window: Single pane window system w/ transaction opening Louver: 1m of wall top	

Exterior Finish

Roof	Wall	Wall Base
Galvanized & Colored Metal Roofing	**t=9 Stone or Tile finish**	**Sealer Hardener**
Steel structural system	Mortar Plastering w/ stone bonding	Concrete w/ face skim coating
	Concrete Masonry Unit	
		(H=300)

Source: JICA Study Team

Figure 6-3-27 Station Finish Schedule

When BRT station is designed, culture, traditional aspects and climate in nature shall be also considered to select best details and appearance. Vernacular architecture may also be another guide to generate the basis of building design.

The design guideline of stations has to be set for the design development as well as terminal facility design. The appearance of stations becomes more standardized, and this will greatly help users to identify and locate the station in congested and busy city areas quickly and easily even without station sign. Station sign, however, is still very important as major eye catching element for all general public in both day and night.

(3) Station Amenity

Environmental control for station interior space is important. However, only natural ventilation effect will be considered for air exchange and space heat management. Controlling sun light exposure to the space should also be ensured by projected canopy. Louvers and similar materials should provide both protection and ventilation in this regard.

Other than the environmental control aspect, additional services may be considered in the future stage considering initial implementation cost. Some of these are drinking water fountain, city and local information display, bus running information, advertisement and others. This may also consider toilet and vender facilities as discussed earlier, though they may be only considered for future installation. When they come into a reality of installation, they may be arranged in the waiting sections of each station where they should not disturb main passenger flow at bus doorways.

Although discussed above, provided amenity in the station facility should be kept minimal in order to minimize operation and maintenance cost of them.

6.3.8 Multimodal Integration in Architecture

BRT system in Karachi is planned as trunk transit system which functions as spine or core of the transportation network in the city, and feeder transit systems should be connected to BRT stations to spread the integrated urban transportation network over the metropolitan area to fulfill public demand.

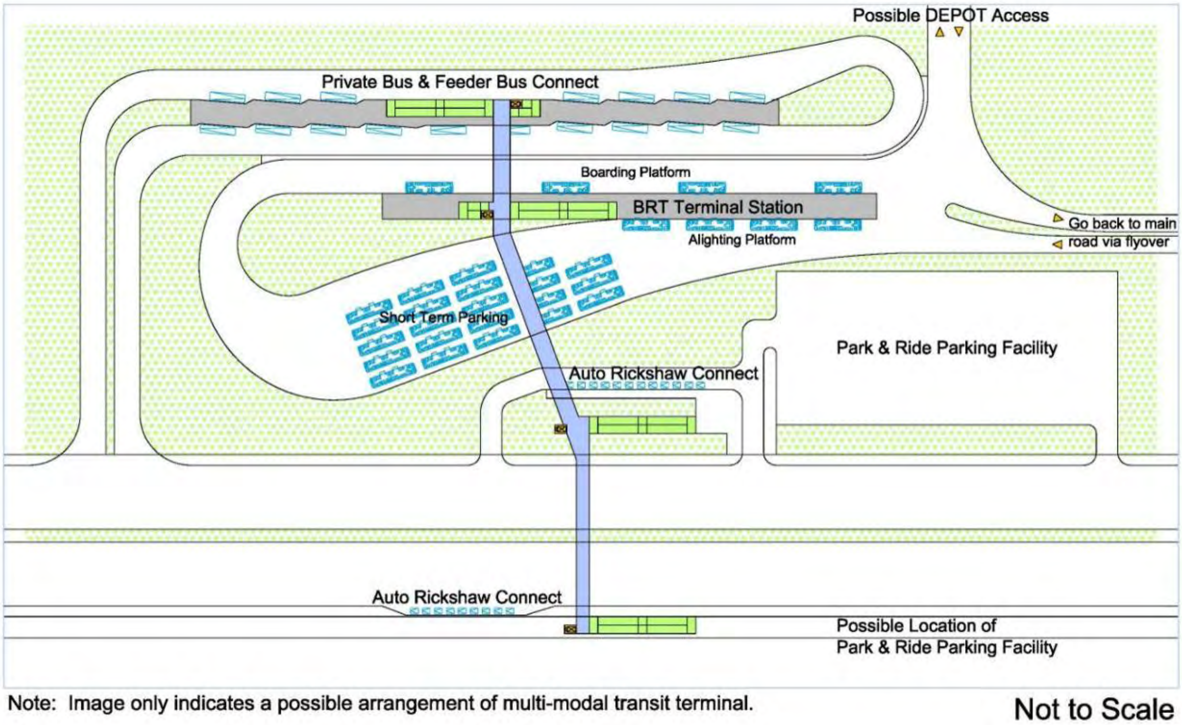
Wherever other modes of transport and their connectivity are expected along the corridors, BRT stations should be considered and designed as intermodal stations in order to provide convenient and easy accesses between different transit systems. Many of the existing bus or feeder bus systems have pick-up or drop-off points along major streets and intersections, and these will be connected with the BRT stations if they are proposed in close proximity. The station access ramps or staircases may be arranged at nearby locations to these existing transit systems, or these existing systems may be relocated with more convenient stop locations to BRT systems whichever feasible.

In order to achieve such connectivity, not only access location but also transit space should be carefully designed with easy and safe order of an integration program and facility. As categorized, there could be two typical types of multimodal integration facility for the project: Transfer/ Interchange stations and Terminal stations.

(1) Terminal Station

A terminal station is normally considered at the end points of each corridor and/or some important locations which also takes multiple transit systems as a network center. A terminal station may also be located nearby depot facility.

Where a larger number of transit systems concentrated at one location along a corridor but not at the ends of the corridor, a BRT station may be set as a transit hub with maybe larger number of bus bays and more service facilities for passenger use and convenience. According to the space availability, configuration of the station could be changed. However, effective interchange program with clear circulation system should be provided between systems. Sign system should also be well designed for users' convenience.



Source: Illustrated by JICA Study Team

Figure 6-3-28 Image of Multi-Modal Transit Terminal

Terminal station at the end of corridor may require a larger number of stop bays or parking space to accommodate a larger number of idling (engine should be stopped) buses instead of sending all back to depot bus yard during the operation hours. Terminal station at the end section in the suburban location may also require large parking space for motorbikes and cars in order to provide possible park & ride opportunity, if there is no convenient feeder system existing beyond this point. This park & ride concept and parking spaces shall not be provided in the central city area unless otherwise careful analysis should be made for exceptions.

As well as motor vehicles, bicycle parking facility at terminal station may also be prepared for user convenience.

(2) Transfer / Interchange Station

Where transit integration with one or a few other transport systems is expected at any typical stations, the BRT station will be designed with simple facilities connecting systems. Existing system may have stops or stands along the street and BRT access ramps or staircases may be arranged nearby to minimize transit time. With this program, auto rickshaw transfer may also be considered at adjacent sidewalk space.

Since KCR system is another major redevelopment project of the city, the KCR stations will also be connected within this type of integration unless otherwise terminal station is provided nearby.

In such transit hub locations, there might be possible bicycle parking spaces also prepared for passenger convenience. However, careful analysis of arrangement shall be made for the capacity of facility.

Where there is no public transit system connecting surrounding districts for networking, passengers may approach such stations by their own bicycles so that bicycle parking in such locations should be required for better transit service.

6.4 Intersection

This section describes the relation between intersections and busway. The plans are illustrated in the Appendix Drawings.

6.4.1 Green Line

(1) Municipal Park (Aurangzed Park)

The turning point of Green Line along M.A. Jinnah Road is proposed at Municipal Park (850 m^2) where the area is large enough to accommodate for the U-turn lane of BRT and the intersection of mixed traffic although the park needs to be removed.

The present mixed traffic lanes for the straight direction to Tower will be diverted to the outer of the busway to avoid the interruption between the busway and the mixed traffic lanes. A traffic signal will be installed before the turning point.

The terminal station is planned to be located at the U-turn point.

Source: JICA Study Team

Figure 6-4-1 U-turn Lane at Municipal Park

(2) Intersections along M.A. Jinnah Road

1) Preedy Street and Agha Khan III

BRT stations are proposed to be located near these intersections. Existing traffic signals should be upgraded to allow the BRT operation.

2) Dr. Daud Pota and Rizvi Shaheed

These signalized intersections are located between proposed stations. Since traffic demand of turning movement is high at these intersections, traffic signals should be upgraded.

3) Sharah-e-Quaideen (Numaish Chowk)

This signalized intersection is large, complex, and very busy. Existing right-turn lanes along M.A. Jinnah Road will be used by the busway. The layout of the intersection and signal phasing should be modified to allow efficient BRT operation and proper traffic movement in mixed traffic lanes.

4) New M.A. Jinnah Road

Green Line and Red Line will be merged at this intersection. To deal with traffic of two BRT lines and mixed traffic lanes properly, this intersection should be modified with signalization.

(3) Gurumandir

This is one of the busiest intersections along the study corridors. Presently, vehicles from Business Recorder Road to M.A. Jinnah Road circulate Gurmandir instead of making right-turn. The busway is proposed to be directly connected between the two roads north and south to avoid delay of BRT vehicles at the intersection. Traffic movements of existing mixed traffic lanes will remain as same as the present movements. Considering the heavy traffic at the intersection, underground or flyover is proper for the busway. However, this was not proposed because of the future plan of the railway system along M.A. Jinnah Road.

(4) Intersection along Nawab Siddique Ali Khan Road

There are three signalized intersections along this road, namely, Lasbela Chowrangi, Nazimabad Chowrangi, and Nazimabad No.7 Chowrangi. BRT stations are proposed to be located near Lasbela Chowrangi and Nazimabad Chowrangi. Signaling phase should be changed at these intersections for right-turn movements.

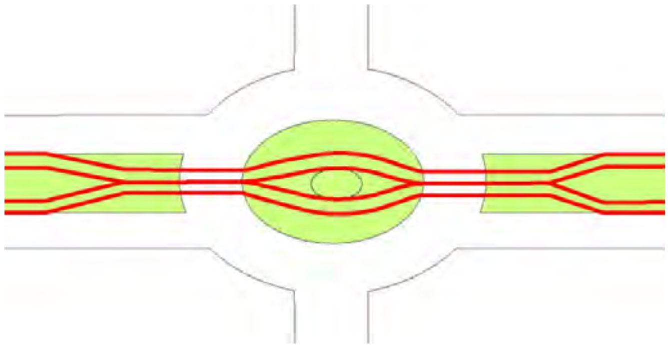
(5) Intersections along Sharah E Shershah Suri Road

1) A.O Clock Tower

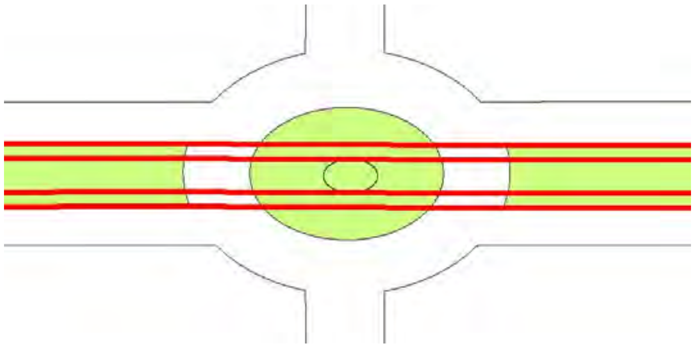
Upward and downward lanes are located in the median of the roads separated only by chatter bar and pavement marking between Municipal Park and A.O. Clock Tower. On the other hand, both lanes are separated by the wide median space from A.O. Clock Tower to the north. The intersection should be modified and A. O. Clock Tower should be removed for the busway. In the master plan, another BRT line is proposed from the intersection to Orangi Town along Dr. Adeeb Rizvi Road, namely Orange Line. Although the layout change in the intersection is not so large, it will be necessary to modify the intersection again when Orange Line is introduced.

2) KDA Roundabout

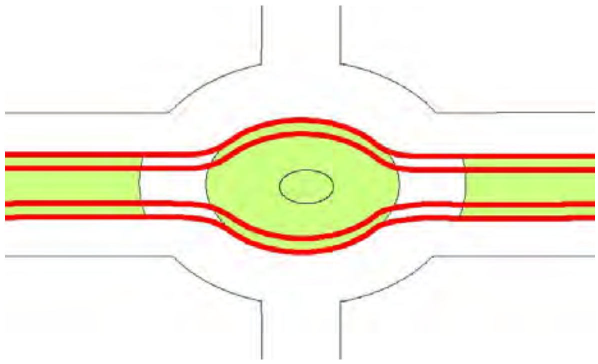
KDA Chowrangi is a non-signalized roundabout. Converting to a signalized intersection like Five Star Chowrangi is proposed. However, there is a concern to remove the monument in the roundabout. There are three alternatives to introduce the busway to the roundabout to keep the monument. First, the lanes of both sides of the median will merge before crossing at the roundabout, and then split at the middle of the roundabout to avoid some important monument, if necessary, and merge again before totally leaving the roundabout and after fully pass the roundabout area, the lane will be separated again. Secondly, the busway will pass straight through the roundabout keeping the same distance between the both lanes. The third alternative is that the busway will run along the fringe of the roundabout like the mixed traffic lanes, but utilizing the outer parts of the roundabout so that width of the existing carriageway should not be affected by the new busway. Signalization is necessary for all the alternatives. Since there are dead spaces in case of the alternative 2 and 3, the alternative 1 is recommended.



Alternative 1



Alternative 2



Alternative 3

Source: Illustrated by JICA Study Team

Figure 6-4-2 KDA Roundabout

3) Five Star Chowrangi

The separated lanes with the wide median will be merged in the intersection to enable signaling control. Existing island in a circle shape at the middle of the intersection should be removed.

4) Sakhi Hassan Chowrangi

This is a roundabout similar to KDA roundabout. It is proposed to convert this roundabout to a signalized intersection like Five Star Chowrangi.

(6) U-Turn along Sharah-e-Shersah Suri Road

As discussed in Chapter 4, U-turns along Sharah-e-Shershah Suri Road cannot be closed and should be remained. Traffic signals will be installed at all U-turns to separate BRT vehicles and U-turn vehicles. Since the busway will pass in the middle of the road, provision of storage lanes along u-turn section is necessary so that the vehicles taking u-turn have proper space to wait, particularly when BRT vehicles are passing in this area. The storage lanes should be properly painted with marking on a specified location so as to give warning to the other vehicles approaching to the storage lane and to the vehicles travelling on the same direction.

(7) Intersections along Sharah-e-Usman Road

There are power pylons along the median of Sharah-e-Usman Road, which makes it difficult to use the median space for the BRT system. Due to this, it is necessary to use existing lanes located outer of median for the busway. However, the width of the mixed traffic lanes will reduce to less than 10m at some sections. It is recommended to widening the carriageway along the road by utilizing some parts of the existing frontage road or even sidewalk in both sides if necessary.

1) Nagan Chowrangi

Flyovers provide right-turn movements from Sharah-e-Shersah Suri Road to Rashid Minhas Road and from Rashid Minhas Road to Sharah-e-Usman Road. There are two alternatives for the location of the busway in relation with the flyover ramp. The first alternative is that the busway is separated into both sides of the flyover in the south of Nagan Chowrangi. This will cause interruption between BRT vehicles going to Nagan Chowrangi at grade and mixed lane traffic going to the flyover. Signaling control will be necessary for the first alternative. Moreover, the frontage road should be used to provide space for the mixed traffic lane. The second alternative is that the busway will run east side of the flyover. In this case, the entire median space should be used for the busway. The second alternative was selected for the plan because the negative impact on traffic is smaller than that of the first one.

2) Powerhouse Roundabout

The busway is planned to pass straight through Powerhouse Roundabout as separated lanes due to existing electric tower in the middle of existing center island.

3) Surjani Chowrangi

This roundabout should be converted to a signalized intersection.

(8) U-turn along Sharah-e-Usman Road

All U-turns along this section are proposed to be closed due to narrow width of the road carriage way. Instead, intermediate T-intersections should be converted to 4-leg signalized intersection to provide access to both sides of the road except for the intersection of Sharah-e-Usman Road and 2200 Road (old U.P More roundabout) where a power pylon stands in the center of the intersection.

(9) Access to BRT depot

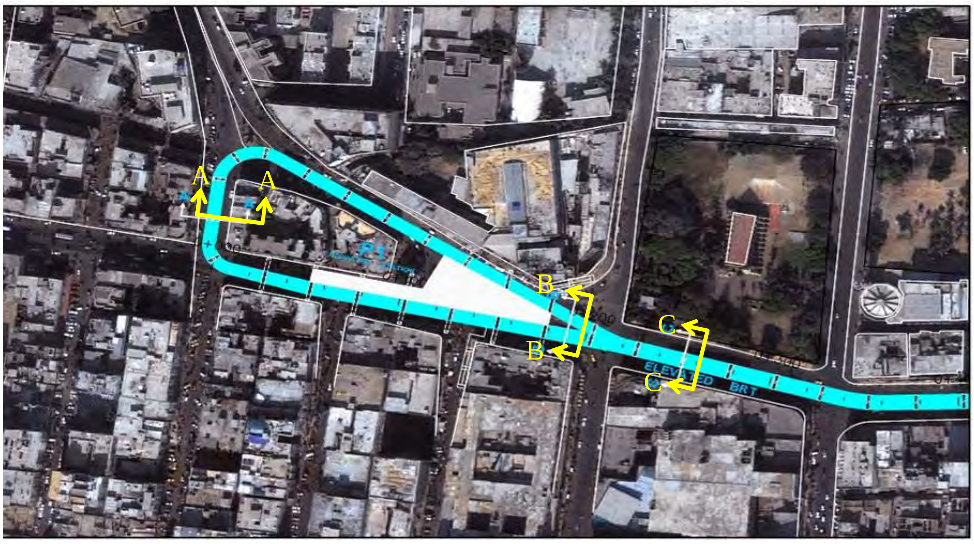
The busway for the depot access will be in combined lane as same as that of the beginning point. It will be separated only by chatter bar and pavement marking.

6.4.2 Red Line

(1) Elevated Structure near Empress Market

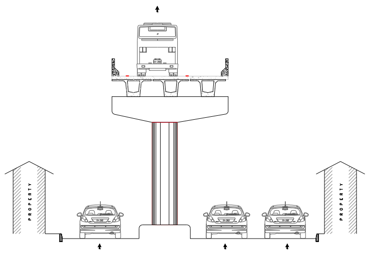
The terminal point of Red Line is planned at Regal Chowk where the busway make a loop to turn the direction. Since the road is narrow and busy in the area, the busway is planned to be constructed as an elevated structure.

Figure 6-4-3 shows the plan of the loop of Red Line at Regal Chowk. The minimum radius will be applied for the alignment. Demolition of the existing center island and monument is necessary to accommodate all the structures needed to be constructed. The BRT station will be located in the loop. The transition section between the elevated section and at-grade section will be located near CDGK Parking Plaza.

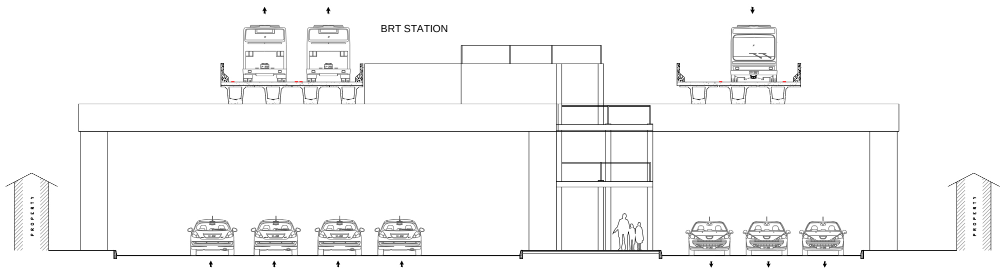


Source: Illustrated by JICA Study Team

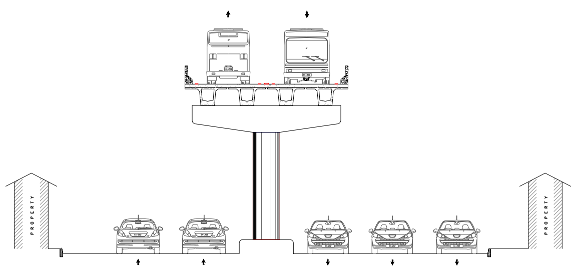
Figure 6-4-3 Elevated Structure near Empress Market



Section A-A



Section B-B



Section C-C

Source: Illustrated by JICA Study Team

Figure 6-4-4 Cross Section of Elevated Structure

(2) New M.A. Jinnah Road (Secretariat Roundabout)

The busway is planned to pass through the roundabout. It is necessary to provide various signages and pavement markings in all directions along the roundabout. Closure of median break along New M.A. Jinnah Road and Jigar Muradabadi Road is necessary to minimize the traffic interruption of BRT vehicles and other traffic. The traffic affected by the closure of the median break will be diverted to the nearby roundabout which is reasonable because it is near from the median break.

(3) Layout Plan near Central Jail and U-turn Section

The U-turn between Alamgir Road and Jail Road Flyover need to be blocked to enable the station construction at this place. To divert vehicles using the U-turn, intersections of University Road with Stadium Road and Alamgir Road will be converted to a signalized intersection. Accordingly, the two U-turns between Stadium Road and Ghosia Road will be closed.

(4) U-Turns near Gulshan-e-Iqbal Town Hall and Baitul Mukaram Mosque

These U-turns will remain with the same modification as the U-turn between Stadium Road and Ghosia Road mentioned above.

(5) Jauhar Chowrangi and Suparco Road (T-intersection)

Median breaks near these T-intersections should be closed to give the space for the busway. T-intersections should be signalized to provide alternative ways for the traffic affected by the closure of the median breaks. The BRT station will be located between the two T-intersections.

(6) Proposed U-turn Section at Km. 13+430

There are several median breaks between Suparco Road and Safoora Roundabout, all of which should be closed for the busway. For traffic using the existing median breaks, a set of U-turns will be provided approximately at Km 13+430 near Blue Mount CNG Station. The road should be widened to enable to accommodate the U-turns.

(7) Safoora Roundabout

Existing structure around the roundabout should be removed, and the entire part of the roundabout should be improved to provide proper space needed for traffic of every direction. The busway will be separated by the median after Safoora Roundabout to avoid existing power pylons located in the center of existing road. Widening of the road is necessary between Safoora Roundabount and the Military Camp.

(8) BRT U-turn at Endpoint (Model Colony)

The endpoint is planned as a loop using the space at the T-intersection of Airport Road and Jinnha Avenue. Widening of the intersection and road diversion will be necessary particular on the west side of the existing road to provide proper space for the loop. The BRT station at the entrance of Model Colony is planned with pedestrian crosswalk at grade..