Municipal Council of Maputo
Republic of Mozambique

Comprehensive Urban Transport Master Plan for the Greater Maputo

Final Report

Volume 2

Pre-Feasibility Study Report

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JAPAN INTERNATIONAL COOPERATION AGENCY

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1 USD = 30.25 MT
1 USD =100 JPY
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Abbreviations

AfDB	African Development Bank
ANE	*Administração Nacional de Estradas* (National Roads Administration)
ATROMAP	*Associação dos Transportadores de Maputo* (Maputo Association of Transport Operators)
BADEA	*La Banque Arabe pour le Développment Economique en Afrique* (Arab Bank for Economic Development in Africa)
BCR	Benefit Cost Ratio
BMS	Bridge Management System
BOQ	Bill of Quantity
BOT	Build, Operate and Transfer
BRT	Bus Rapid Transit
CBD	Central Business District
CCO	Control Centre for Operations
CFM	*Caminhos de Ferro de Moçambique* (Mozambique Ports and Railways Company)
CMM	*Conselho Municipal de Maputo* (Maputo Municipal Council)
CTA	*Confederação das Associações Económicas* (Confederation of Economic Associations of Mozambique)
DCF	Discounted Cash Flow Analysis
DCU	*Departamento de Urbanização e Construção* (Department of Construction and Urbanization)
DFID	UK Department for International Development
DfT	UK Department for Transport
DM	Distrito Municipal
DMTT	*Direcção Municipal de Transportes e Transito* (Directorate of Transport and Traffic)
EA	Executing Agency
EC	European Commission
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return

EMTPM	*Empresa Municipal de Transportes Públicos de Maputo*
EU	European Union
FCA	*Fundo de Compensação* (Compensation Fund)
FDD	District Development Fund
FIA	*Fundo de Iniciativa Autárquica* (Municiapal Initiatives Fund)
FEMATRO	*Federação Moçambicana das Associações dos Transportadores Rodoviários* (Federation of Road Transport Associations)
F/S	Feasibility Study
GDP	Gross Domestic Product
GIS	Geographic Information System
GMMTA	Greater Maputo Metropolitan Transport Agency (*Agencia Metropolitana de Transporte*)
HDM	Highway Design and Management
HIS	Household Interview Survey
IA	Implementing Agency
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IEE	Initial Environmental Examination
IMF	International Monetary Fund
INATTER	*Instituto Nacional dos Transportes Terrestres* (National Institute of Land Transport)
INAV	*Instituto Nacional de Viação* (National Traffic Institute)
INE	*Instituto Nacional de Estatística* (National Institute of Statistics)
INNOQ	*Instituto Nacional de Normalização e Qualidade* (National Institute of Standards and Quality)
IRI	International Roughness Index
IRMS	Integrated Road Management System
JICA	Japan International Cooperation Agency
kph	Kilometers per hour
LRT	Light Rail Transit

M/P, MP	Master Plan
MCC	Millennium Challenge Cooperation
MICOA	*Ministério para a Coordenação da Acção Ambiental* (Ministry of Coordination of Environmental Affairs)
MT	Metical
MTC	*Ministério dos Transportes e Comunicações* (Ministry of Transport and Communications)
MTFF	Medium-Term Fiscal Framework
NPV	Net Present Value
OD	Origin and Destination
ODA	Official Development Assistance
pax	Passengers
PCU	Passenger Car Unit
PEUCM	*Plano de Estrutura Urbana da Cidade da Matola* (Urban Structure Planning of City of Matola)
PEUMM	*Plano de Estrutura Urbana do Municipio de Maputo* (Urban Structure Planning of City of Maputo)
PMU	Project Management Unit
pphd	Passengers at peak hour per day
PPP	Public Private Partnership
PRISE	*Programa Integrado do Sector de Estradas* (Integrated Road Sector Program)
ProMaputo	*Programa de Desenvolvimento Municipal de Maputo* (Maputo Municipality Development Programme)
PRSP	Poverty Reduction Strategy Paper
RMM	*Região Metropolitana de Maputo*
SADC	Southern African Development Community
SC	Steering Committee
SEA	Strategic Environmental Assessment
SP	Stated Preference
TDM	Traffic Demand Management
TOD	Transit-Oriented Development

TOR	Terms of Reference
TPM	*Transportes Públicos de Maputo* (Maputo Bus Company)
TRAC	Trans African Concessions
UEM	*Universidade Eduardo Mondlane* (Edurado Mondlane University)
UNICOTRAM	*União das Cooperativas de Transportes da Matola, Matola Urbano* (Union of Transports Associations of Matola)
USAID	United States Agency for International Development
VCR	Volume-Capacity Ratio
VOC	Vehicle Operating Costs
VOT	Value of Time
WB	World Bank

Chapter 1 Introduction

1.1 Background

Urban and economic development and population growth has increased the movement of passengers and goods, and consequently, there has been an influx of both bus and automobile traffic on the roads between Maputo and Matola as well as Maputo and Marracuene, resulting in great congestion. The need to strengthen the public transport services on the N1 (North-South) and N4 (East-West) corridors is now obvious, especially as the road network becomes increasingly congested with private cars and chapas. Plans exist for BRT and metro tram networks, but to this point there has not been sufficient demand forecasting or financial planning for these plans to progress forward.

The Government of Mozambique had adopted ProMaputo, the development program for Maputo. They have also adopted a land use plan and infrastructure development policy. There are proposals for a Bus Rapid Transit (BRT) system for Maputo, and a Light Railway Transit (LRT) system that connects Maputo and Matola. However, there has not been any progress to deliver these plans due to a lack of financial support and a concrete, long-term vision for urban transport, thereby making it difficult to make investment decisions.

Under these circumstances, the Government of Mozambique requested the Government of Japan for assistance in formulating a “Project for the Comprehensive Urban Transport Master Plan for the Greater Maputo”. This project has produced a new comprehensive urban transport master plan for Greater Maputo with the target year of 2035, as well as developed an implementation plan for high-priority projects. After discussion at the Steering Committee meeting, BRT N1 corridor has been selected as a prefeasibility study (pre-F/S) project among these high-priority projects.

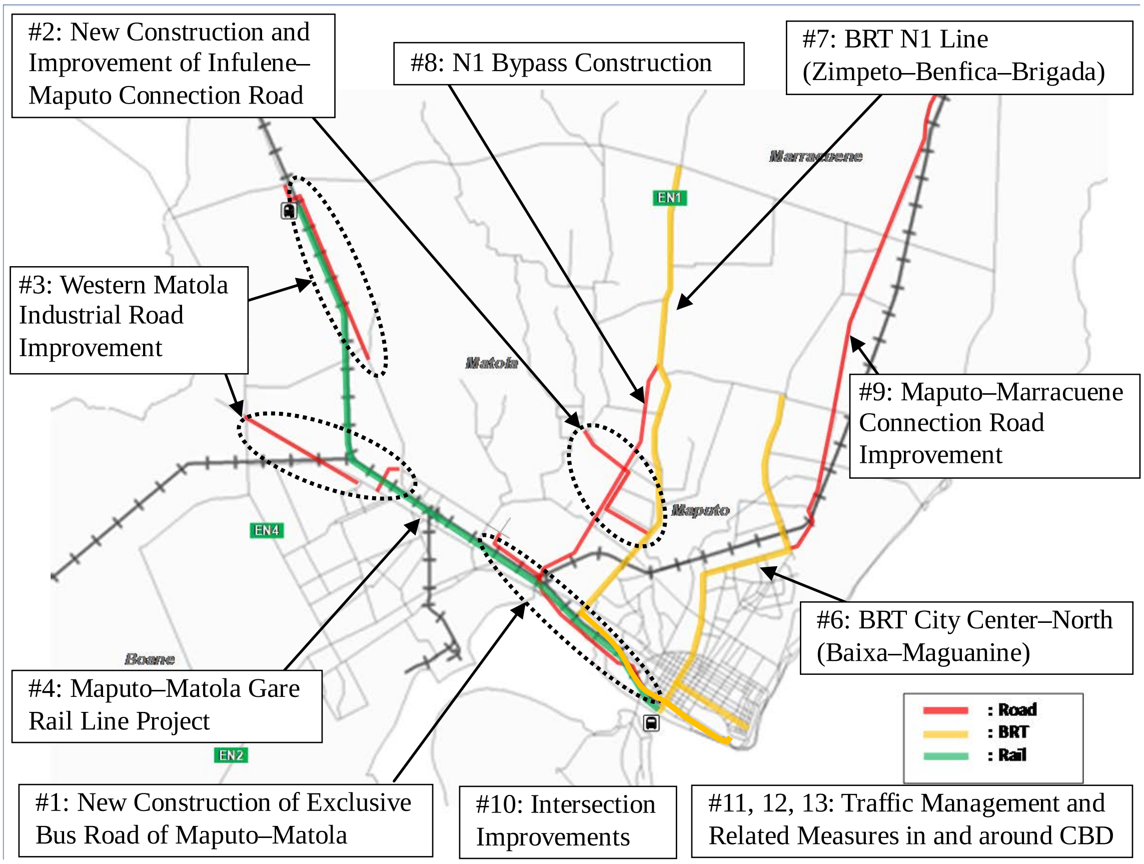
1.2 Study Scope and Project Components

1.2.1 Priority Projects

After careful analysis of existing traffic conditions in Greater Maputo and projections of traffic demand up to 2035, a Master Plan with short-, medium-, and long-term projects was presented. Proposals for higher-capacity public transport systems such as BRT and commuter railways have been considered and recommended in the plan for trunk public transport systems with exclusive rights-of-way to ensure high-speed, high-capacity, and safe transport.

Among the projects proposed in the Master Plan, priority projects were selected based on common criteria including “Urgency”, “(Potential) Effect”, and “Implementability”. The selection process identified several projects that should be urgently implemented in a short-term period to fulfill short-term transport needs and contribute to overall public transport-oriented planning and development.

High-priority projects were identified as shown in Figure 1.1.

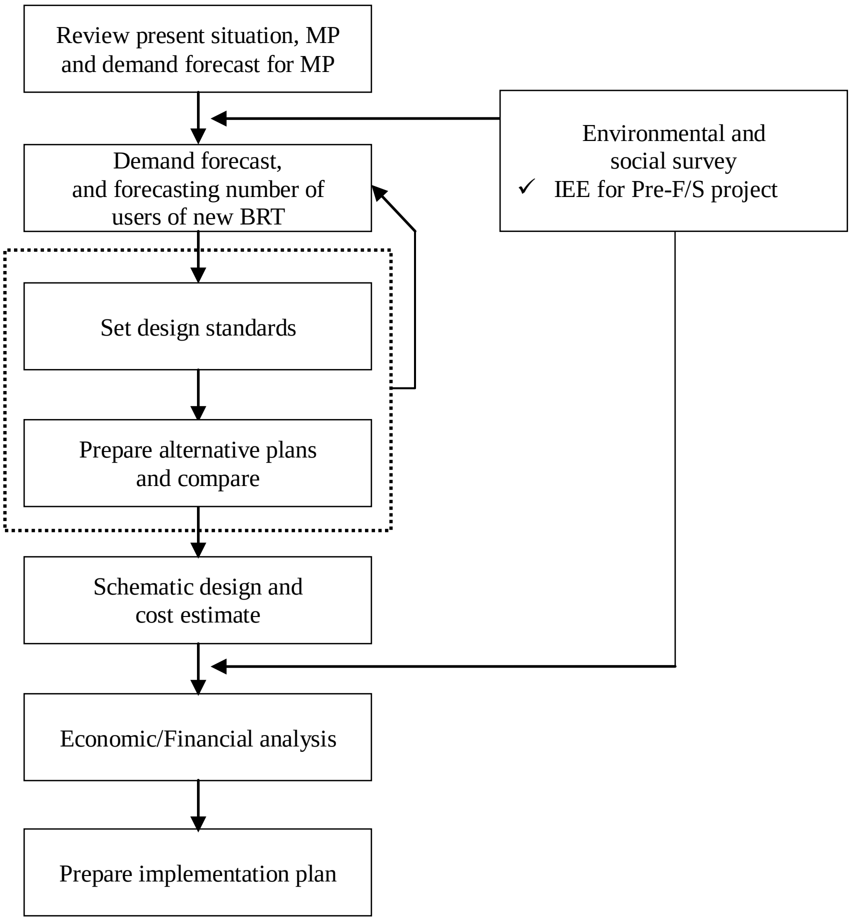


Note: The map shows the proposed priority projects #1–#13 except for #5 Reconstruction of Boane Bridge which is located outside of the above map, toward southwest along N2.
Source: JICA Project Team

Figure 1.1: Priority Projects

1.2.2 BRT N1 Line

BRT N1 Line was selected for a pre-F/S project amongst the priority projects. The pre-F/S consists of the improvement / widening of the existing N1, development of BRT facilities on N1, and the improvement / development of transport nodes. Figure 1.2 presents the overall work flow, and Table 1.1 and Figure 1.3 show the schematic development of the proposed BRT.



Source: JICA Project Team

Figure 1.2: Pre-F/S Survey Work Flow

Table 1.1: Proposed Development of BRT N1 Line

Section	Overview of Development
North Section	• Develop the north part of BRT N1 (between Benfica–Zimpeto, approx. 6.6 km). • Develop the terminal on north side. • Procurement of appropriate size and number of BRT buses based on demand forecasting and operation plans (assuming a center BRT lane, with doors opening onto a platform on the right side) • Develop a depot. • Consider private car use on N1.
South Section	• Develop the south side of N1 (between Malanga–Benfica, approx. 8.7 km) as a BRT line (bus lane, bus stop, terminal development—includes preparations such as widening of bridges and roads, improvement of intersections, etc.). • Facilities for connecting to trunk bus routes. • Consider development of an exclusive road (for connecting to bus/rail) using the railway ROW between Malanga and Maputo Central Station (approx. 3.8 km) • Develop a depot. • Consider private car use on N1.

Source: JICA Project Team

Source: JICA Project Team

Figure 1.3: Proposed BRT Route along N1

In addition, the following will also be examined:

N1 Bypass Development: to examine the need for N1 bypass development (#8 in Figure 1.1 shown earlier). In the pre-F/S, the main focus will be on the BRT development along N1, but N1 bypass development will also be briefly described.

Coordination with BRT plans supported by Brazil: connecting nodes with the BRT supported by Brazil and assess the consistency of operation and implementation schedules between the two plans.

Implementation / Operation and Maintenance Structures and Finance Plans: Prepare plans for implementation, operation and maintenance structures, and finance plans for the BRT development along N1 through discussions with local stakeholders.

Chapter 2 Existing Conditions of the Project Area[1]

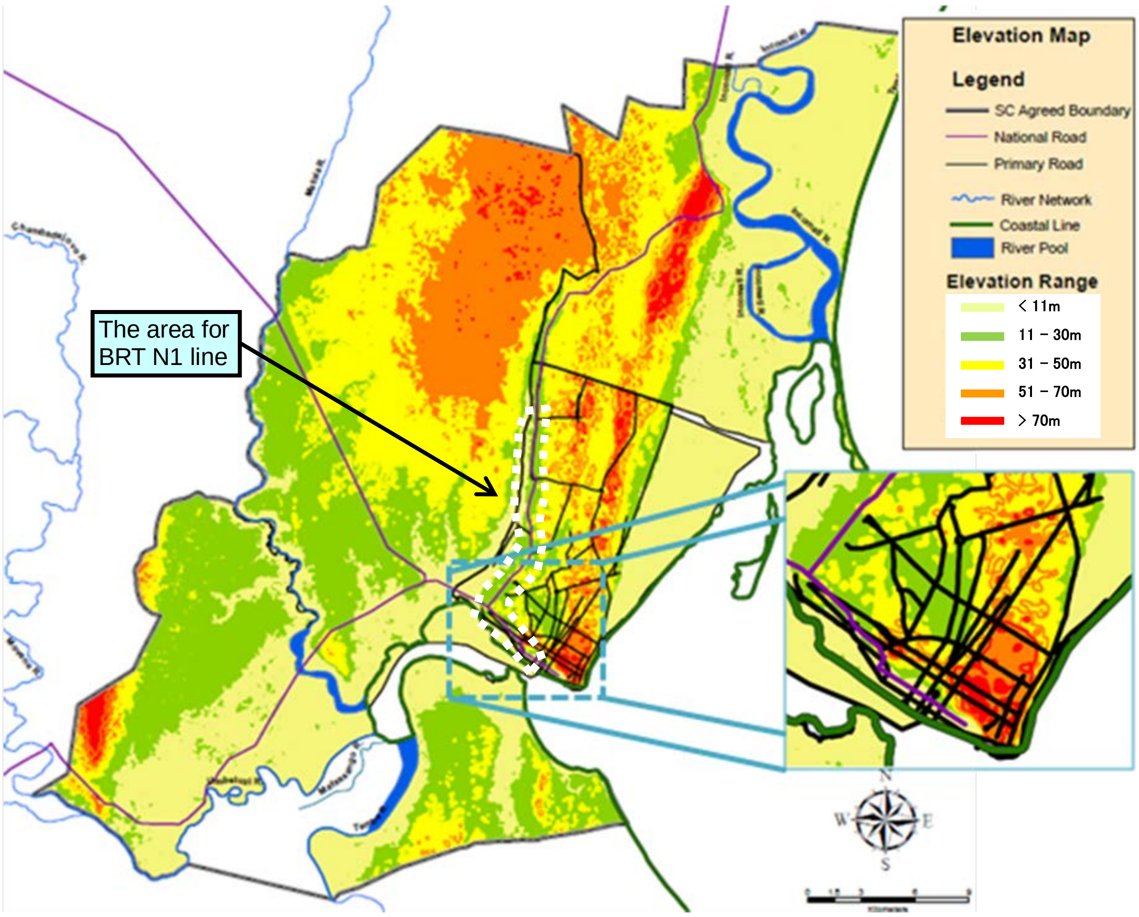
2.1 Natural and Socio-Economic Conditions

2.1.1 Natural Conditions

(1) Topography

Greater Maputo, consisting of Maputo City, Matola City, the southern part of Marracuene District, and the eastern part of Boane City, is located in the southern part of Mozambique with a coastline of approximately 45 km and a total area of 1,147 km^2. About 5 km inland from the coastal area of Greater Maputo consists of lowlands, including Maputo Bay in the south.

The area where the target project of BRT N1 line is sited runs between low terrace and high terrace areas (Figure 2.1). Low terrace area (elevation between 11–30 m above sea level) in Greater Maputo tends to lie in inner land areas, mostly in Maputo City and part of Boane City. Medium terrace area (elevation between 31–50 m) is concentrated in the northern part of Greater Maputo, covering the northwest part of Maputo City, the west part of Marracuene District and the central part of Maputo City. There is only a small amount of concentrated high terrace area (elevation between 51–70 m) in the Greater Maputo area, in Maputo City.



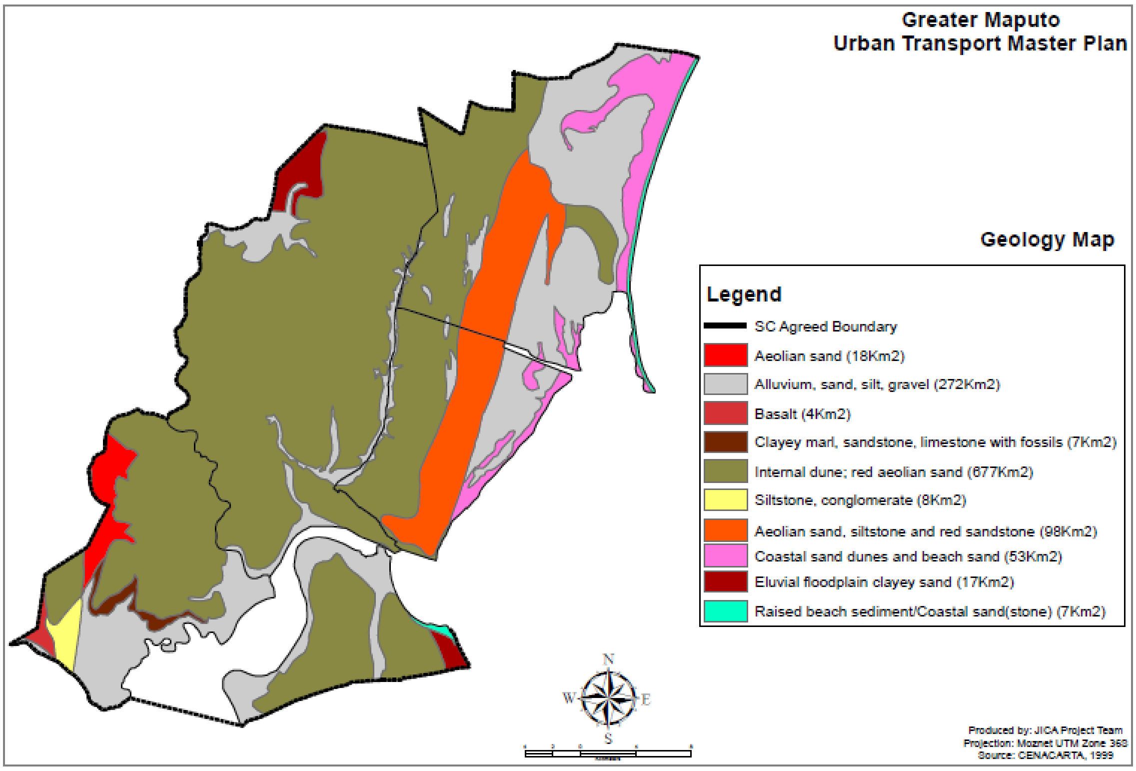
Source: Prepared by JICA Project Team (Based on ASTER DEM 90m)

Figure 2.1: Topographical Map

[1] Indicate the area where the project is located; same as the Study Area defined in the Master Plan.

(2) Geology

Having a relatively firm basement consisting of aeolian sand, siltstone and red sandstone, which runs through middle of Maputo City and Marracuene from the south to the north, the rest of Greater Maputo is covered mostly with internal dune, red aeolian sand, followed by a mixture of alluvium, sand, silt and gravel covered-area in the coastal side where the elevation is below 10 m sea level (which covers 23% of the project area) as shown in Figure 2.2.



Source: CENACARTA, prepared by JICA Project Team

Figure 2.2: Geological Map

(3) Development Constraints

From a natural environmental perspective, development constraints that may need to be considered within the Greater Maputo area including the Project Area would be flooding measures during the rainy season in the lowlands. When any development is required in these areas, a water flow management plan or system would be required. As for soil composition, detailed boring studies may be required for a specific project site if construction of a new bridge or new road is being planned for it.

2.1.2 Socio-Economic Conditions

(1) Population Trends

The population in Maputo is gradually shifting to the suburban areas in Matola City, Marracuene District, and Boane City, partly due to the rising costs of housing and other expenses in Maputo City. The population in the city center of Maputo has been gradually declining, and has been replaced with commercial and retail uses. Since the population density in the suburban areas is still relatively low, population growth is expected to continue there.

(2) Economic Growth

The economy in Mozambique has been robust during the past decade. The economic growth is expected to accelerate in the medium term. In particular, industrial and commercial activities have been growing along the Maputo Corridor, the major national roads in the suburban areas, industrial parks, and the area closest to Maputo Port. Maputo Municipality is the largest regional economy in Mozambique, comprising 19% of the national GDP, followed by Maputo Province. Both Maputo City and Maputo Province have demonstrated a steady growth of Gross Regional Domestic Product (GRDP) over the last decade.

(3) Land Use

The existing land use in Greater Maputo shows that most of Maputo City and about half of Matola City is being used for human settlements while most of Boane City and Marracuene District is being used for agricultural purposes. Considering the rapid expansion of urbanization in the Greater Maputo area in recent years, more development along the N1 and N4 road will be anticipated in the future, bringing even more traffic demand for both public and private transport modes.

(4) Development Trends

The capital and economic center of Mozambique, "Greater Maputo," has experienced rapid growth in the past decade. Significant population growth can be seen particularly in northern areas of Maputo and Matola. Boane City and Marracuene District have more than doubled their populations since the 1997 census and continue to grow at a speedy pace alongside the new industrial and commercial development in these areas. While Boane City and Marracuene District show a steady population growth, much of Greater Maputo's economic activities still remain concentrated in Maputo and Matola Sede.

2.2 Transport and Traffic

2.2.1 N1 Road

The N1 is a national road which the National Roads Administration (ANE) manages, and is a main artery of the north-south axis in Greater Maputo, with a traffic volume exceeding 30,000 vehicles per day. The south section (8.8 km) from Brigada to Missão Roque is located in an urban area, and has four lanes with a median and a sidewalk. The existing road width is about 23 m, and has a margin width such as building setbacks on both sides. The north section (6.6 km) from Missão Roque to Zimpeto is located in a suburban area, and has two lanes without a median or a sidewalk. It has sufficient margin width on both sides.

There are road bridges in two places; one of the bridges, which J. Chissano intersects, has sufficient width (and includes a median and a sidewalk). The other bridge, located over a railway, is narrow, having a width of about 18 m, and has a sudden horizontal alignment shift in the approach sections. Bus stops with bus bays are placed about 500 m apart, however many chapas (or minibuses) stop at different locations along the road.

Although four lanes were already improved, the N1 section in the urban area is still experiencing chronic traffic congestion, the existence of bottlenecks (caused by numerous continuous intersections), and the absence of alternative routes. The vehicular traffic is a mix of truck traffic, which connects the large districts, and regional transport such as commuting and shopping, resulting in N1's function as a national road being not fully utilized.

2.2.2 Public Transport

The majority of people living and working in Greater Maputo depend on public transport for their mobility. Bus and chapa provide the core public transport service with other modes such as rail and ferry services having a small share.

There are about 400 full-sized buses operating in Maputo, 50 of which are owned by private individuals and are operated similarly to chapas, while others are operated by the publicly-owned Transportes Publicos de Maputo (TPM) on about 60 routes. Typically, TPM operates only about 140 buses daily in Greater Maputo. Along the N1 route, few passenger shelters were observed, although there are some roadside stopping points for both buses and chapas. Currently, there are no traffic lanes reserved for buses on the N1, but there is ample space for bus-only lanes to be created.

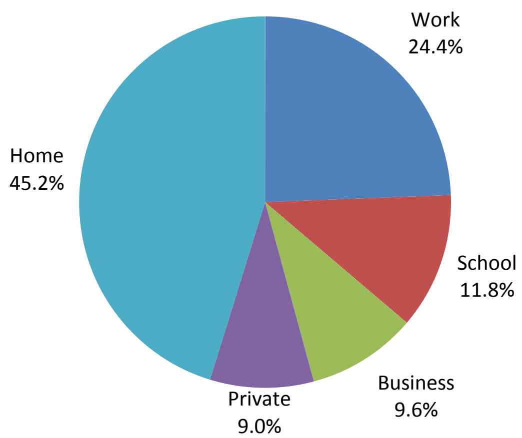
The road-based public transport system in Greater Maputo is based primarily on a network of routes operated by chapas (minibuses or midibuses[2] generally with either 15 or 25 seats), of which there are estimated to be between 4,000 and 4,500, operating on about 130 routes. There are three chapa terminals along the N1 route, located at Zimpeto, Benfica, and Drive-in. Currently, a new chapa terminal with a capacity of 120 vehicles is under construction at Zimpeto. The new Zimpeto terminal has five island-type bus bays with benches for passengers, a police station, an administrative office, and convenience shops.

2.2.3 Current Users of Public Transport

As per the Household Interview Survey (HIS) conducted, the following characteristics of public transport users were observed:

(1) Trip Purpose

As shown in Figure 2.3, the breakdown of trip purpose for trips made by public transport are: to go home (45.2%), to go to work (24.4%), to go to school (11.8%), for business (9.6%), and for private errands (9.0%). Compared to the breakdown of trip purpose for all modes, among users of public transport the proportion of trips to work and for business are higher, and trips to go to school and private errands are lower.



Source: JICA Project Team

Figure 2.3: Breakdown of Trip Purpose for Public Transport User

[2] Midibus is a classification of single-decker minibuses that is generally larger than a traditional minibus but smaller than a full-size single decker.

(2) Car Ownership and Use of Chapas/TPM

With 42.1% of all trips made by public transport, public transport is the second most used mode of transportation after "walk/bicycle." Of the total 1.304 million trips made by public transport, 1.126 million (86.3%) are made by households that do not own a car (Table 2.1).

Table 2.1: Car Ownership and Trip Mode

Unit: 1,000 passengers /day

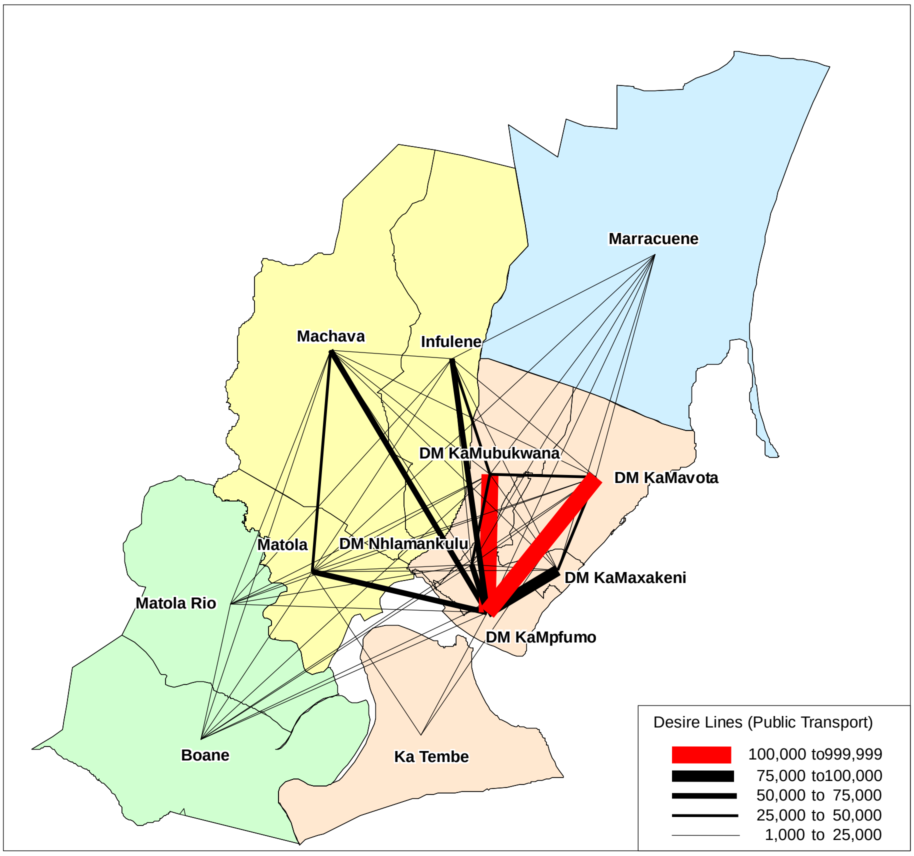
Transportation Mode		Car Not Owned	Car Owned	Total
Private Transport	Walk, Bicycle	1,284	138	1,422
	Car, Motorbike, Truck	121	222	343
Public Transport	Chapa, TPM	1,126	178	1,304
	Railway	17	1	18
	Ferry	12	1	13
Total		2,560	540	3,100

Source: JICA Project Team

(3) Trip Distribution of Public Transport Users

The Distrito Municipal (DM) Origin-Destination (OD) pairs which generate a great deal of public transport trips are:

- DM KaMavota to DM KaMpfumo – 100,000 trips
- DM KaMubukwana to DM KaMpfumo– 100,000 trips
- DM KaMaxakeni to DM KaMpfumo – over 75,000 trips



Source: JICA Project Team

Figure 2.4: Desire Lines (Public Transport)

Figure 2.4 shows that much of public transport traffic consists of trips ending in Maputo City or running between Maputo-Matola. Moreover, these trips are concentrated in DM KaMpfumo, which is in central Matola.

2.3 Development Issues

There are a number of inherent challenges and constraints with the current system that will not function efficiently as the city grows and the demand for travel increases. These are caused by poor and inefficient network design and capacity, inadequate service levels and quality (particularly poor reliability), inadequate public transport infrastructure provision, fare level and structure issues, and inherent constraints with the institutional, regulatory, and organizational aspects of the public transport sector.

In addition to conventional public transport systems comprised of various bus services, there are more effective and efficient modes of transport (Table 2.2). In the Master Plan, the BRT option is proposed as a short-term measure to expand transport capacity along the north-south axis of Greater Maputo (including the N1).

Table 2.2: Comparison of Mass Transit System Types

Item	Heavy Rail	LRT[1]	BRT
Maximum Speed (km/h)	90–100	60	60[3]
Capacity (passengers/unit)	1920 [2]	160	160
Line Capacity (pphpd)	28,800 (frequency: every 4 minutes)	1,800 (frequency: every 5 minutes)	10,000 (frequency: every 1 minute) for a single lane 7 m busway
Typical Construction Cost	High	Medium (In some cases, similar to Heavy Rail)	Low
Application to Greater Maputo	Possible to construct existing rail right of way.	Requires new right of way or structure and can be expensive.	Possible to construct with available road space.

Note 1: Type of LRT in Hiroshima, Japan was considered; Note 2: 10 cars per train
Source: JICA Project Team

2.3.1 BRT Development Plan

The overall BRT development plan was outlined in the Master Plan volume and the plans related to this pre-F/S are summarized as follows (Figure 2.5):

Phase I – Praça da Juvententude (Magoanine) to Baixa, via the municipal corridor of Julius Nyerere, the present bus terminal of Xiquelene and the Guerra Popular corridor; plus a link via Av. Eduardo Mondlane to a Center Terminal at Museu.

Phase II – Zimpeto to Estação CFM, via the National Highway N1, a new terminal at Missão Roque, Brigada and a busway next to the railway. This will include a station integrating with the proposed LRT[4].

Phase III – Matola area to the CFM Terminal using the infrastructure from N1 to the City center built in Phase II. No practical route is planned at this moment although one recommended route is shown in Figure 2.5.

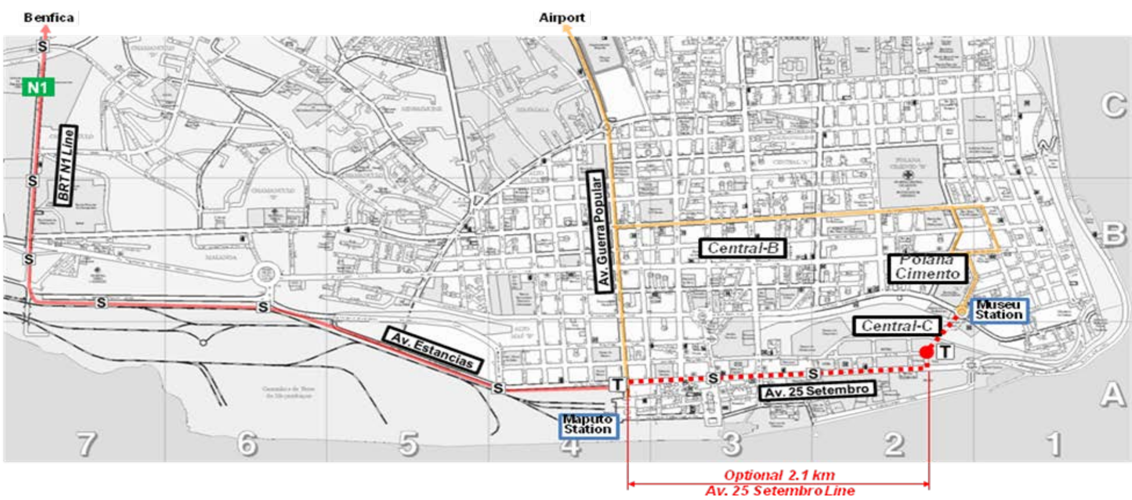
[3] Examples of BRT operation in Denver, Pittsburgh and San Jose, USA. Bus Rapid Transit Planning Guide, Federal Ministry for Economic cooperation and Development, 2004.
[4] Proposed by Chinese Contractor.

(Note that the above Phases I, II, and III will be used in this pre-F/S volume, representing the implementation phases of BRT development related to the BRT N1 line, the subject of this pre-F/S volume. These phases are different from the phases of BRT development for entire Greater Maputo in the short, medium, and long terms, which are proposed in the Master Plan volume.)

Source: JICA Project Team

Figure 2.5: BRT Development Phase

An extension of the busway will be added on the Av. 25 de Setembro roadway, linking the CFM with the New Downtown Terminal in front of Park Antonio Repinga, with one intermediate station (Figure 2.6). This simple busway, an important link in the Master Plan but not part of the Phase II Pre-Feasibility Project, will be 7 m in width with standard BRT lanes separators and no overtaking. Parking will be restricted in constrained areas and at the station.



Source: JICA Project Team

Figure 2.6: Location of Maputo and Museu Stations in Relation to BRT II (red) and BRT I (yellow)

With two major terminals (Museu and New Downtown) in close proximity, but separated by a 50 m tall cliff face, an elevator link will be needed as part of the system to replace the existing stairway, which is in poor repair. The model shown below in Salvador, Brazil, for example, carries some 40,000 passengers/day and dates from the 19th century (Figure 2.7 and Figure 2.8).

Source: Salvador Tourist Office

Figure 2.7: Elevator System in Salvador, Brazil

Source: JICA Project Team

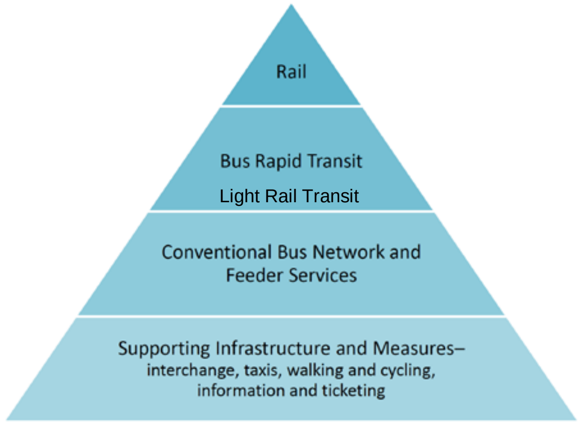
Figure 2.8: Site of the Proposed 50 m Elevator Link – Current Stairway

2.3.2 Railway Development Plan

A well designed passenger railway network can transport passengers in a congested urban area from one point to another in the largest number and in the shortest time in comparison with other modes of transport such as private vehicles, *chapas*, and buses, and even BRT. This is particularly true during peak periods when a large number of workers commute between their home and workplace.

Since the railway system attracts a large number of trip makers along a fixed corridor, land use along the corridor often becomes denser (particularly at nodes). The Transit Oriented Development (TOD) is in line with the public transport policies already outlined and therefore is a key component in making rail a successful component of the integrated public transport system.

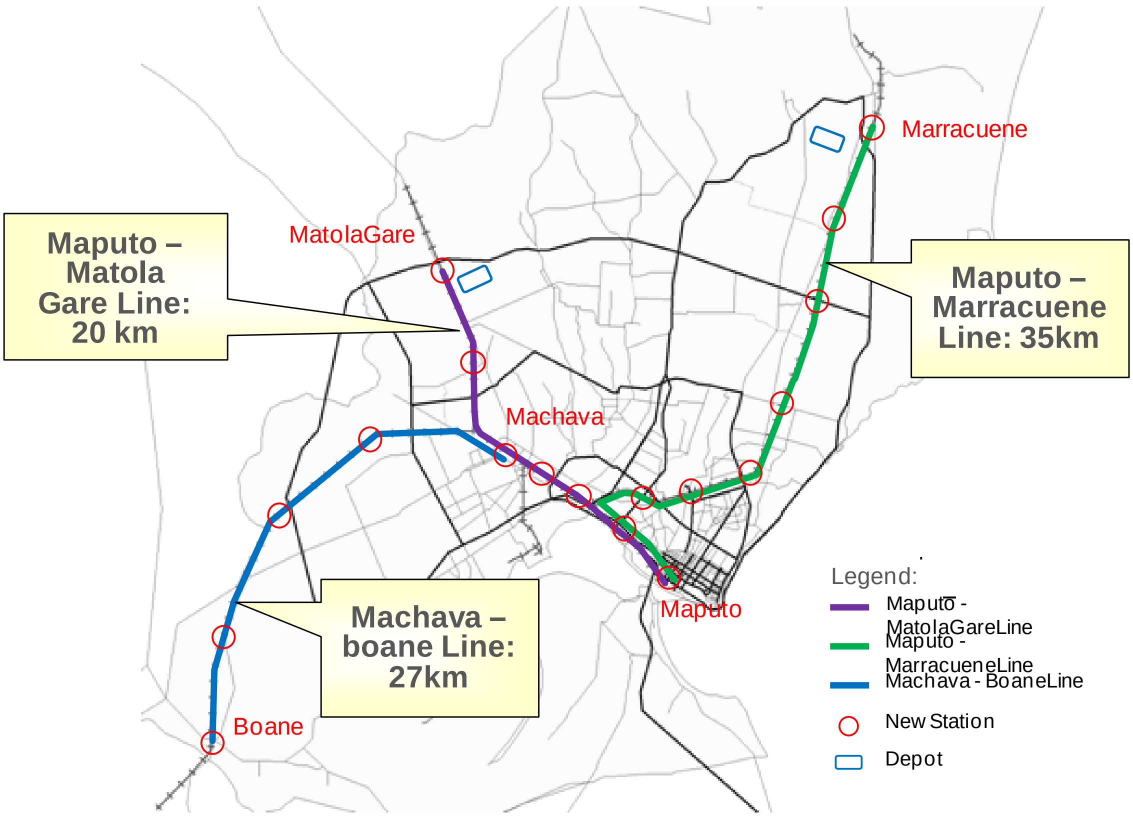
The railway system is able to carry a large number of passengers; however, due to less coverage of network in Greater Maputo, the combination of other modes of transport such as trunk BRT, TPM, and feeder bus systems makes a overall public transport system more effective, efficient and attractive to existing public transport users as well as potential users moving from passenger car use to public transport (Figure 2.10).



Source: JICA Project Team

Figure 2.9: Hierarchy of Public Transport Systems

Current railways operated by CFM are mainly for freight transport with less frequent passenger services, which have not played a major role for passenger transport service in Greater Maputo. In consideration of passenger transport needs along the major corridors especially between Maputo and Matola more frequent and modernized passenger service will significantly contribute to urban transport system in Greater Maputo (as shown in Figure 2.10 proposed in the master plan).



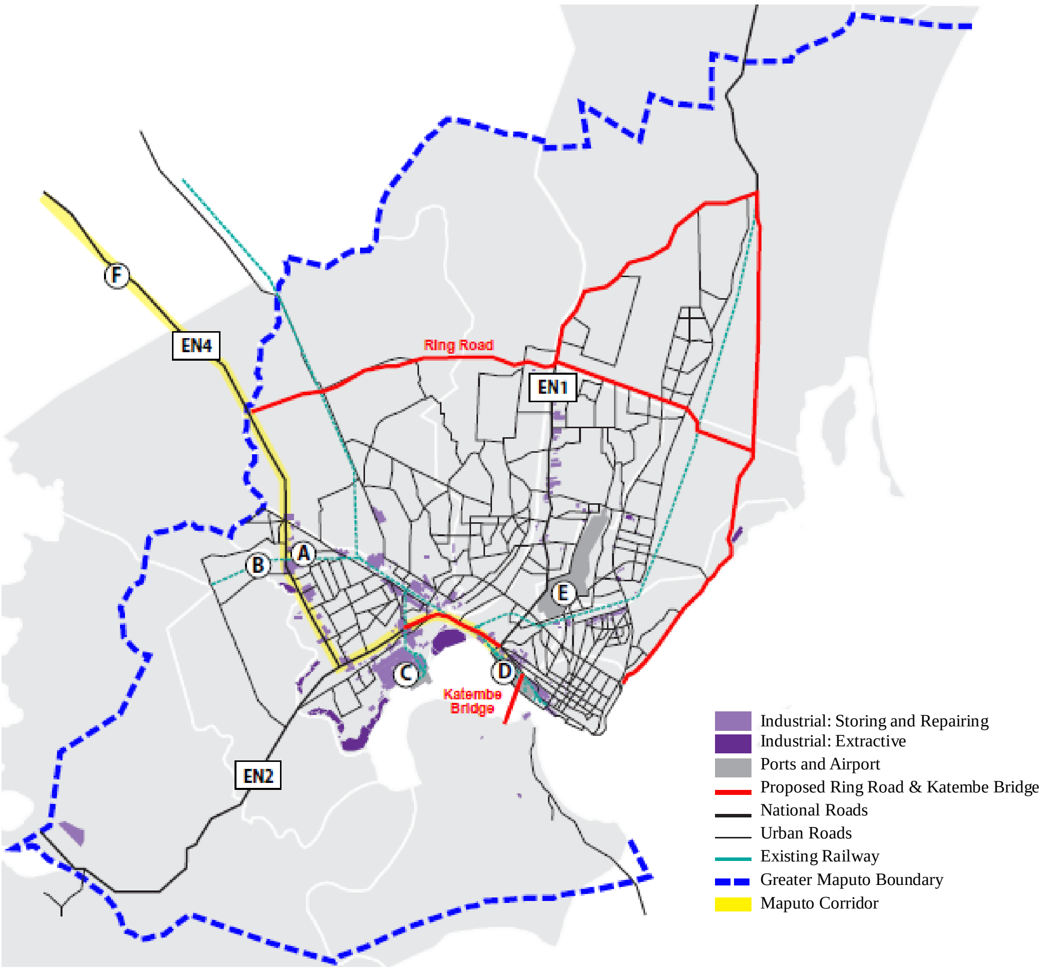
Source: JICA Project Team

Figure 2.10: Proposed Passenger Rail System

2.3.3 Other Transport and Related Developments

(1) Industrial and Commercial Developments

There are several industrial and commercial developments which will influence transport needs in the future. Figure 2.11 shows the location of past developments in the Greater Maputo area.



Source: JICA Project Team based on information from PEUMM 2008, PEUCM 2010, and CENACARTA Land Cover 1997

Figure 2.11: Industrial and Commercial Development in Greater Maputo

Belaluene Industrial Park and Matola Industrial Zone

Belaluene Industrial Park (BIP) (A in Figure 2.11), which is the country's largest industrial park, was established in 2007 with financing from the World Bank's Private Sector Development Project (PODE). The park is located in the Matola Industrial Zone in Boane District. It is approximately 15 km from Matola Port, immediately west of the Matola River, and a few hundred meters north east of the Mozal Aluminium Plant.

Mozal Aluminium Smelter

The Mozal Aluminium Smelter in Matola (B in Figure 2.11) is the area's first megaproject in the region. The 2.8 billion USD project involves a joint venture of companies from Australia, Japan, South Africa, and a minority stake by the Government of Mozambique. The alumina originates in Australia, and after the smelting process, the output of about 506,000 tons of aluminium ingots per year is mainly exported to the European Union.

Other Export and Manufacturing

Other large manufacturing and processing companies (beer, soft drink, cement, and cereal milling industries), such as Cimentos de Mozambique, Cervejas de Mozambique, and Coca-Cola are located in Greater Maputo. Much of these export and manufacturing industries are located along the N4 route with convenient access to the Matola Port (C in Figure 2.11)[5]. Furthermore, proximity to Maputo International Airport and its cargo terminal (E in Figure 2.11) is beneficial for products that require speedy transport.

Agri-Business

There are also large agri-businesses, such as the Maragara sugar mill and Bananalandia, which supply products to both domestic and South African markets. Such products are most likely exported via the land route on the Maputo Corridor (F in Figure 2.11) or via the ocean route through Maputo Port (E in Figure 2.11).

(2) Ring Road Project

The Ring Road Project, a major arterial road, is being developed in the northern suburban areas about 20 km from the centers of Maputo and Matola municipalities. The four-lane arterial road has a design speed of 60–80 km/h, and will serve as a bypass allowing motorists to avoid the urban area by connecting the existing N1 and N4. The route is divided into six sections and has a total length of 74 km (Figure 2.12). When completed, the ring road will be a toll road.

Source: Presentation video and Drawing of China Road and Bridge Corporation

Figure 2.12: Ring Road Route

(3) Catembe Bridge Project

The proposed Catembe Bridge Project, which crosses Maputo Bay, will connect Maputo and Catembe municipalities. The project implementing agency is Maputo-Sul. The project is to consist of a long span bridge, connection road, and development of the KaTembe residential area by the BETAR Group (Figure 2.13)[6].

5 World Bank, Prospects for Growth Poles in Mozambique, 2010.
6 Beta Consultants/Betar Consultants Group

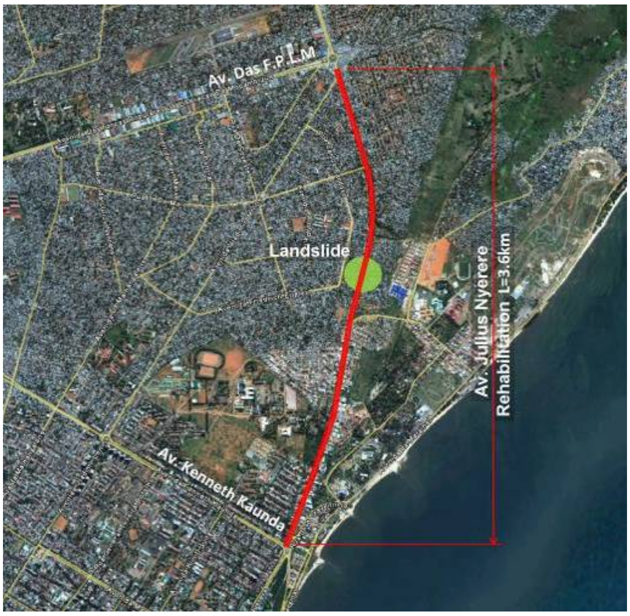
The cable-stayed bridge will be 700 m long, with a central span of 350 m, and a main tower height of 130 m. The bottom girder clearance is planned to be 57 m in consideration of large container ships. The approach road connection runs through the already heavily-congested Maputo urban area, and is expected to worsen traffic conditions in the area.

Source: Maputo-Sul, E.P.

Figure 2.13: Location of Catembe Bridge

(4) Rehabilitation of Av. Julius Nyerere

Av. Julius Nyerere is a north-south, primary road in Maputo. In 1998, a landslide heavily damaged the road, making it difficult for traffic to traverse. To rehabilitate the damaged road, ProMaputo planned to construct two-lane roads of about 3.6 km. The rehabilitation project consisted of road ditches and a pedestrian overpass, which would also function as a crossing channel between the divided areas. The rehabilitation works started in March 2012 and were scheduled to be completed in early 2013. Figure 2.14 illustrates the landslide location and planned rehabilitation of Av. Julius Nyerere.



Source: JICA Project Team

Figure 2.14: Location and Rehabilitation of Av. Julius Nyerere

Chapter 3 Traffic Demand Forecast

3.1 Methodology

The traffic allocation for this pre-F/S study is different from that of the Master Plan study. That is because this traffic demand forecast requires individual calculations of the number of passengers for the regular bus route, for the BRT Lane, and for the LRT route. Therefore, the transit assignment modeling was adopted in which the future demand for public transport will be allocated on the new public transport routes.

The maximum number of buses needed for each route is calculated as follows: first, public transport demand is allocated on the bus routes on regular roads. This number of buses is then incorporated as the initial traffic amount, and the traffic allocation of vehicles is calculated. This also factors in the traffic congestions caused or alleviated by the introduction of these buses.

3.2 Assumptions

3.2.1 Future OD Chart

As selected in the Master Plan study, the land use for Greater Maputo in 2035 will be the "compact corridor type development" (Scenario C). The OD chart which corresponds with the land use pattern based on this scenario is adopted. The traffic amount for each mode in this case is presented below.

Table 3.1: Comparison of Present and Future Person Trip OD

	2012		2035 Scenario C (Compact Corridor type)			2035 Scenario A (Trend type)	
Mode	**Person Trip (1 million trips)**	**%**	**Person trip (1 million trips)**	**%**	**Factor Increase**	**Person Trip (1 million trips)**	**%**
Private Transport	0.34	20.4	1.13	29.8	3.32	1.39	39.1
Public Transport	1.33	79.6	2.66	70.2	2.00	2.16	60.9
Sub Total	1.67	100.0	3.79	100.0	2.27	3.55	100.0
Walk	1.42		2.71		1.91	2.95	
Total	3.09		6.50		2.10	6.50	

Source: JICA Project Team

The number of public transport trips in 2035 will increase by a factor of 2.10 times the current amount if walking is included, and by a factor of 2.27 if walking is excluded. Alongside this increase, private transport increases by a factor of 3.32, and public transport doubles. At present, when excluding the trips made by foot, the proportion of trips made by public transport is 80%. In the future, as LRT and BRT will be developed, this proportion of public transport trips will drop to 70%.

If LRT and BRT development did not take place and the current land use trends were to continue, then the proportion of public transport trips would decrease dramatically from 79.6% to 60.9%, and thus the proportion of private transport trips would increase from 20.4% to 39.1%, which would result in even heavier traffic congestion on the roads.

On the other hand, if LRT and BRT development occurred and the land use was changed to the "compact corridor" type, the growth of private transport trips would shift to public transport. The increase would be from 20.4% to 29.4%, an increase of only around 9% as opposed to 20%.

3.2.2 Setting of Future Road Network

The future road network assumes that the following road projects, currently under construction, will be completed:

- Ring Road
- Catembe Bridge Road
- Julius Nyerere Road
- Costa del Sol Road

3.2.3 Setting of Future Bus Routes

The future bus routes are set by combining the current main chapa/TPM routes with the new bus routes that will run once the roads currently under construction (as listed in Section 3.2.2) are completed.

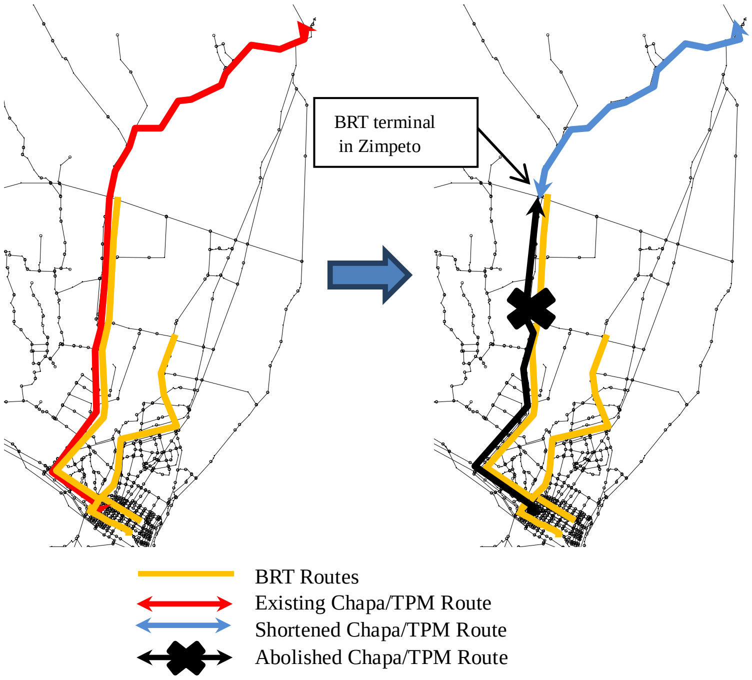
Ring Road	Catembe Bridge and Access Road	Julius Nyerere Road	Costa del Sol Road

Source: JICA Project Team

Figure 3.1: Future Bus Routes Running Along Planned Roads (Roads Under Construction)

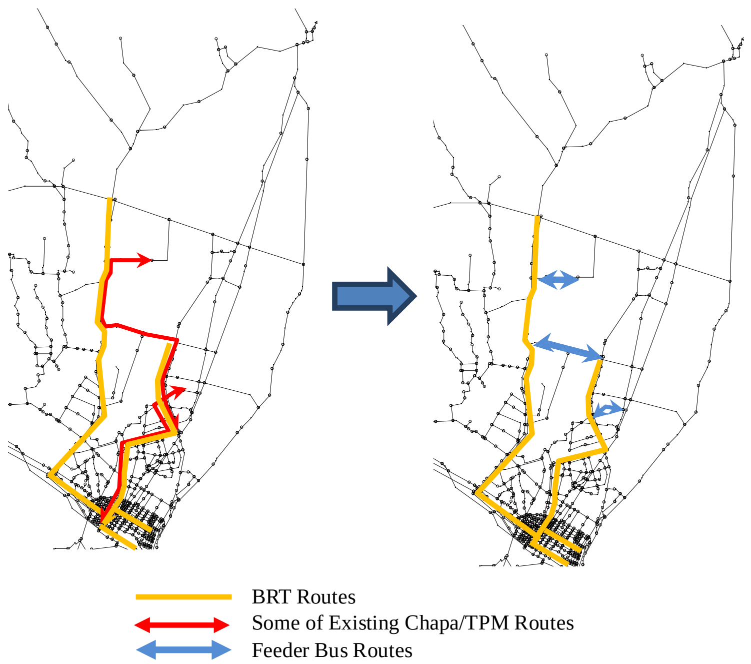
The following procedures were applied to eliminate or shorten the existing chapa/TPM routes that will compete with the new BRT routes:

- Chapa/TPM routes which start/end along the BRT route, and the route runs along the BRT route → These are to be eliminated
- Chapa/TPM routes which start/end along the BRT route or along the extension of that road, and run along the BRT route → Their terminals will be changed, and any sections which overlap with the BRT route will be eliminated (see Figure 3.2).
- After applying the above modifications, in case there are chapa/TPM routes which have become extremely short → These are to be developed as feeder bus routes. Feeder bus fares will be free, but passengers will be forced to get on the BRT afterwards (see Figure 3.3).



Source: JICA Project Team

Figure 3.2: Sample Modification of Chapa/TPM Routes



Source: JICA Project Team

Figure 3.3: Feeder Bus Example

3.2.4 Fares

The fares for chapas/TPM running within Greater Maputo will be kept as the current amount of MT 7.0–32.5 (see Table 3.2).

Table 3.2: Fare Table for Chapas (Unit: MT)

Maputo	7.0			
Matola	9.0	7.0		
Marracuene	15.0	17.5	7.0	
Boane	17.5	12.0	32.5	7.0
	Maputo	Matola	Marracuene	Boane

Source: JICA Project Team

For BRT, the local government is currently considering setting the fare at MT 15, so this amount will be used for the traffic forecast. For LRT, the same fare as BRT will be used.

3.2.5 Traffic Allocation Cases

The following cases are considered for traffic allocations:

- Case-0 (Base Case): Only the Maputo-Matola LRT and the Phase I BRT have started operating, and no N1 BRT operations.
- Case-1: Base Case, plus full operation of both the North and South sections of N1 BRT.
- Case-2: Base Case, plus only the North section of N1 BRT.

Case-2 is tested in order to examine the level of traffic to be expected on the North section if this portion of the project, which can be developed with greater ease than the South section, is implemented first.

3.3 Traffic Assignment Results

3.3.1 Ridership of N1 BRT

When both the North and South sections are fully operational (Case-1), there will be approximately 106,000 people/day in 2020, and 135,000 people/day in 2035. However, when only the North section is operating (Case-2), there are only approximately 1,400 people/day in 2020, and even in 2035, only 2,200 people/day.

In Case-1, the fare revenue is estimated to be approximately USD 48,000/day in 2020, and USD 64,000/day in 2035. From these results it is safe to say that to increase fare revenues it is necessary to make the entire line fully operational as quickly as possible. Ridership and revenue by case and by year is shown in Table 3.3.

Table 3.3: Estimated Ridership of N1 BRT

Case	Year	Route Length (km)	No. of passengers (pax/day)	Average Trip Length (km)	Estimated Revenue (USD/day)
Case-1	2020	19.1	106,300	12.4	48,200
	2035		134,800	13.2	63,700
Case-2	2020	7.3	1,400	5.0	700
	2035		2,200	5.2	1,100

Source: JICA Project Team

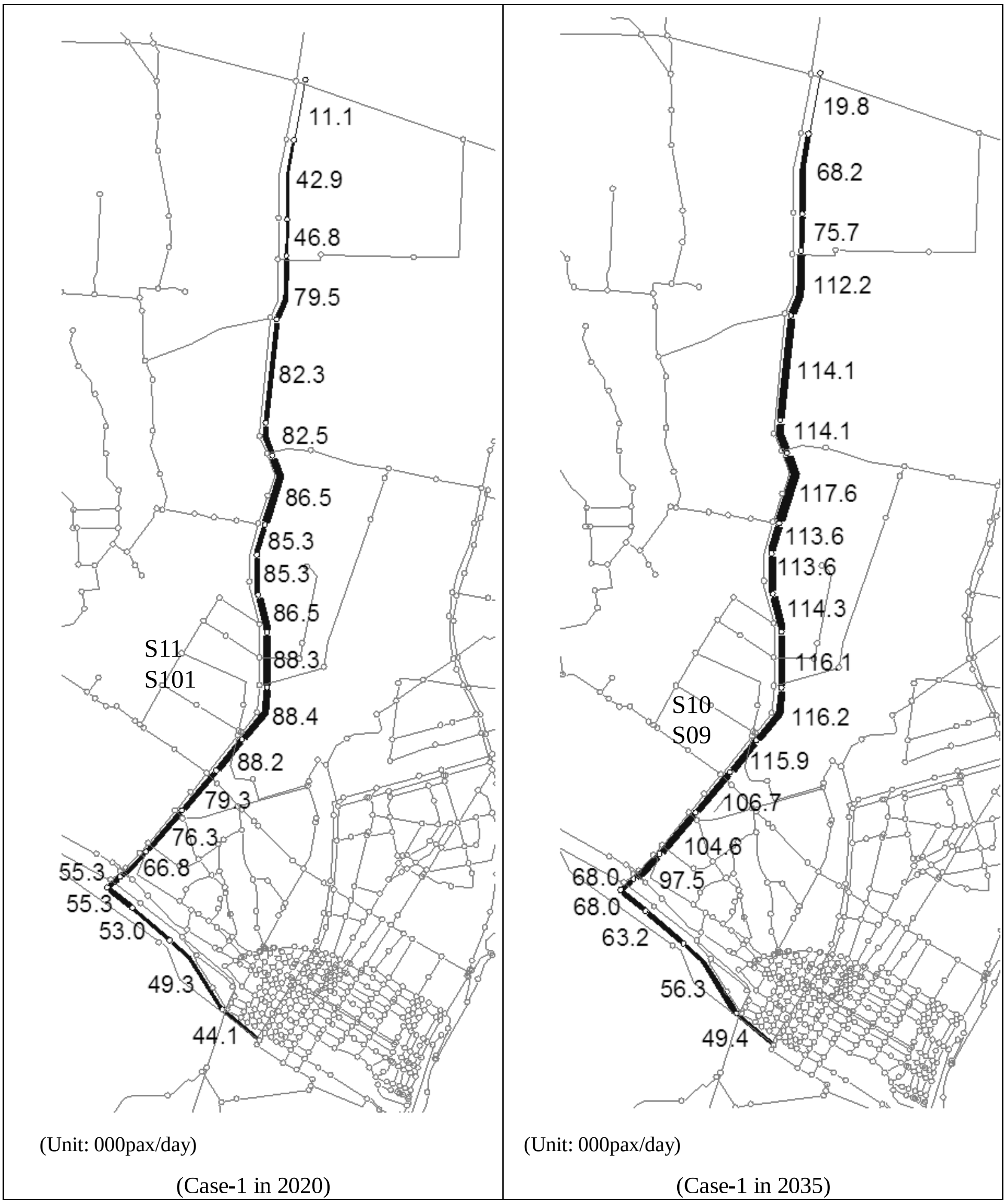
3.3.2 Ridership between Stations

The numbers of passengers riding between stations for Case-1 and Case-2 are shown in Figure 3.4 and Figure 3.5.

For Case-1, in which the whole line is operational (North and South), the section with the highest expected ridership is between S8 and S9, which will have 88,400 passengers/day in 2020, and in 2035, it will shift to the section between S12 and T2, with 117,600 passengers/day. On the other hand, in Case-2, the section with the highest ridership is between T2 (Missão Roque) and S15, with 1,300 passengers/day in 2020 and 1,800 passengers/day in 2035.

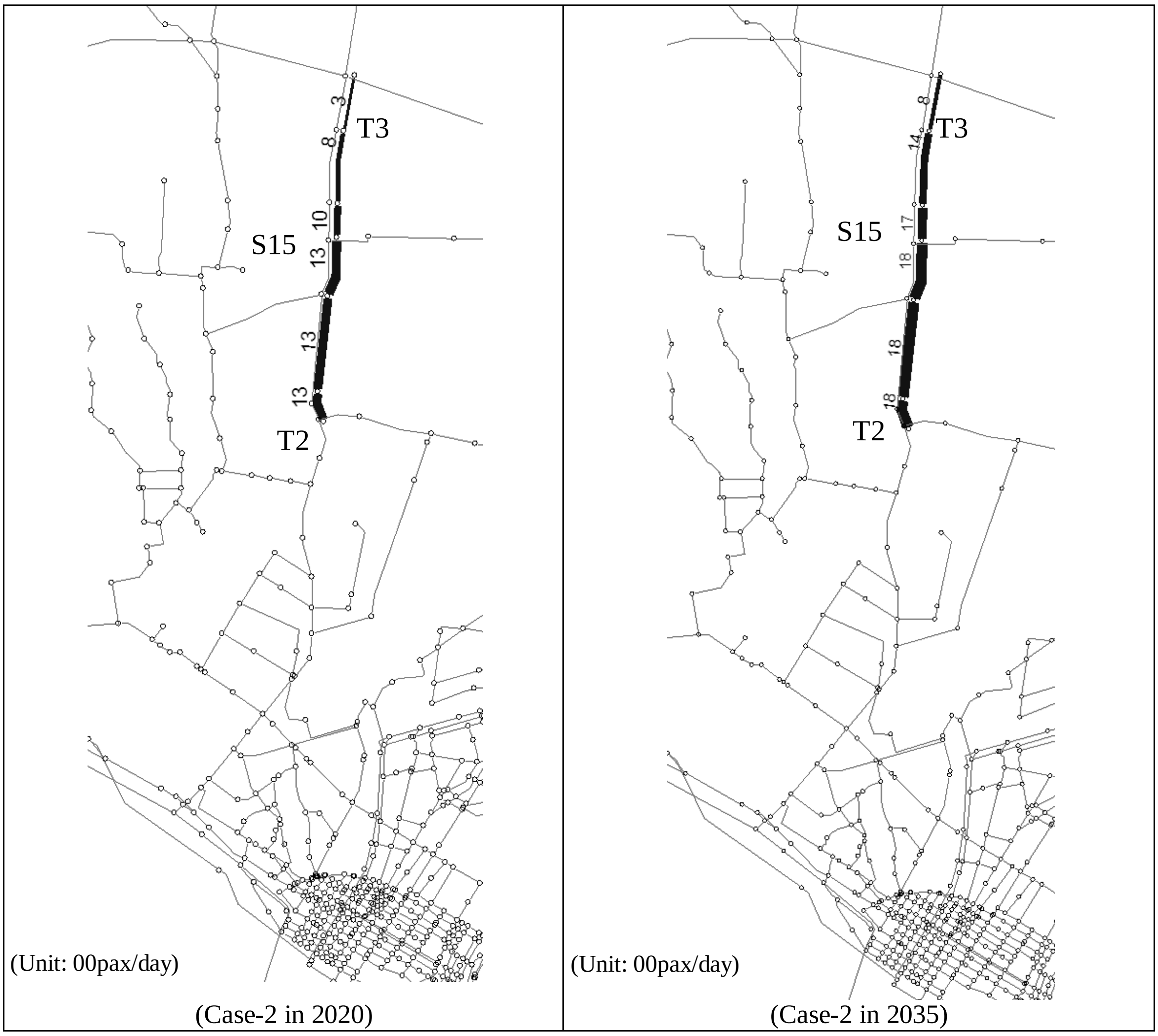
The maximum traffic volume from T3 (Zimpeto) to T1 (Maputo Central) in the morning peak hour will be 6,000 passengers/hour in 2020, and 8,000 passengers/hour in 2035, using the peak hour factor (10%) and the heavier directional flow rate (68%), which were obtained from the results of the traffic survey for Maputo central area.

The number of BRT buses to be required will be 35 vehicles/hour (1.7 minute interval) in 2020, and 46 vehicles/hour (1.3 minute interval) in 2035. It is assumed that each BRT bus will have a capacity of 160 passengers, and the congestion rate at peak hours is 110%.



Source: JICA Project Team

Figure 3.4: Number of Passengers on BRT by Section (Case-1)

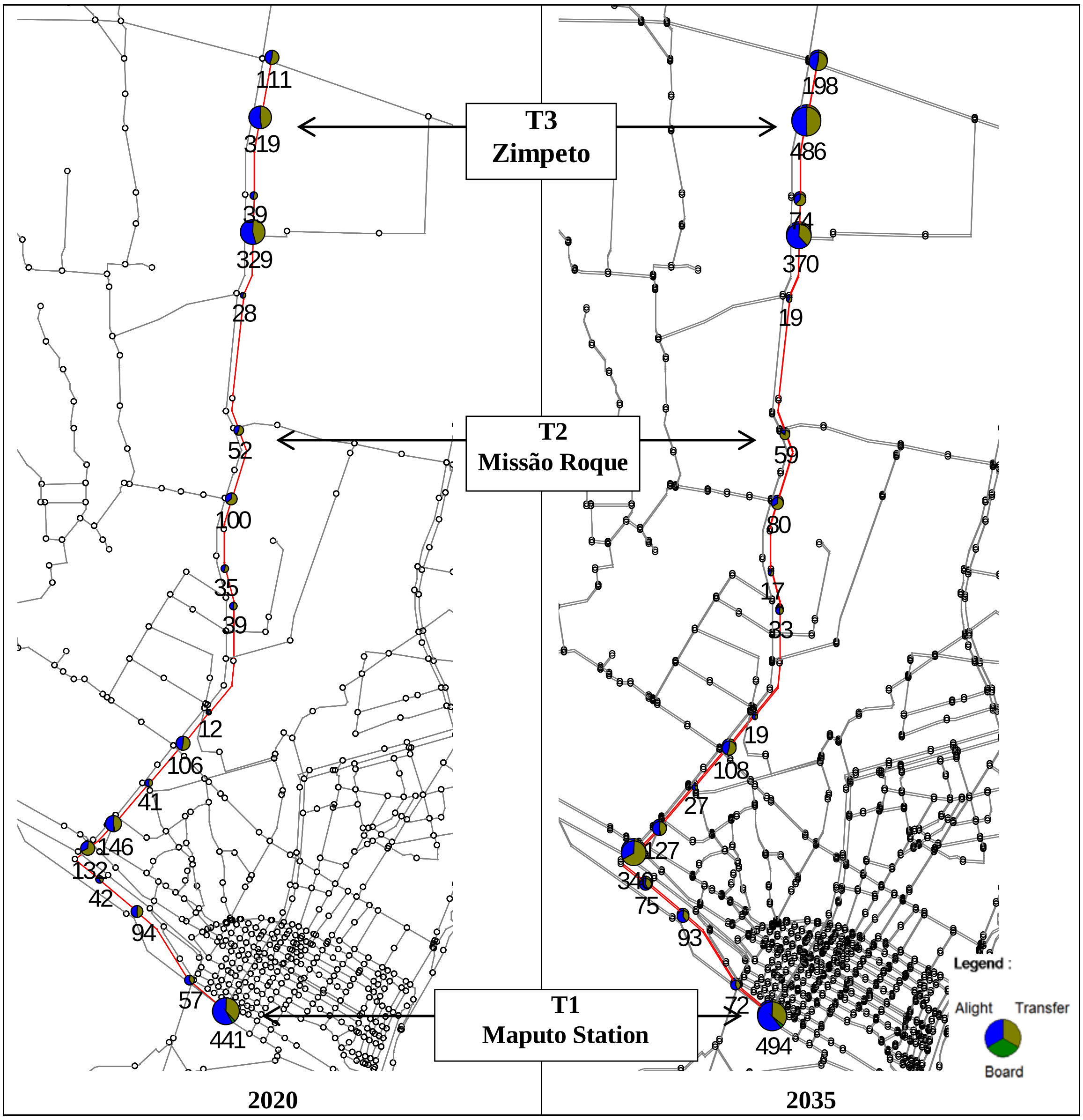


Source: JICA Project Team

Figure 3.5: Number of Passengers on BRT by Section (Case-2)

3.3.3 Number of Users at Major Terminals

In 2035, when the whole line is operating (Case-1), the greatest number of users (not passengers) will be at T1 (Maputo Station), followed by T3 (Zimpeto). Even before that, in 2020, the T1 station will have already reached 44,000 users/day, including 17,000 transit passengers/day. T3 station will have reached 32,000 users/day, including 17,000 transit passengers/day. Therefore, it is recommended that these stations be developed as main terminals from the beginning.



Source: JICA Project Team

Figure 3.6: Number of Users at Terminal and Intermediate Stations

Table 3.4: Number of Users at Terminal Stations

Terminal Name	Year	Alight	Board	Transfer	Total
T3 (Zimpeto)	2020	16,500	0	15,400	31,900
	2035	24,800	0	23,800	48,600
T2 (Missão Roque)	2020	2,000	100	3,100	5,200
	2035	800	100	5,000	5,900
T1 (Maputo)	2020	25,700	1,700	16,700	44,100
	2035	30,200	1,300	17,900	49,400

Source: JICA Project Team

3.3.4 Impact on Regular Roads

When N1 BRT is fully operational in 2020, 197,000 people/day of chapa/TPM users will transfer over to using BRT or LRT. This will decrease the number of chapa/TPM users by 9,200 pcu[1]/day. For public transport users, this will decrease their average trip time by 2.1 minutes and shorten their trip length by 0.5 km.

Furthermore, by the year 2035, it is expected that 298,000 people/day of chapa/TPM users will transfer to other public transport modes, which will further decrease the chapa/TPM traffic by 17,400 pcu/day. For public transport users, their average trip time will decrease by 1.5 minutes and average trip length will decrease by 0.4 km.

However, examining the road congestion levels within Greater Maputo, the development of the N1 BRT will lower the congestion level by only 0.1%, and its impact on regular roads is similarly limited.

Table 3.5: Ridership, Average Trip Time/Length, Average Congestion

		Ridership of Public Transport (000 pax/day)					For Public Transport Users		For Private Transport Users
		Chapa/TPM	**BRT**	**LRT**	**Others**	**Total**	**Avg. Trip Time (min)**	**Avg. Trip Length (km)**	**Avg. Congestion**
2020	Case-0	3,226	47	40	564	3,877	31.5	9.7	0.43
	Case-1	3,029	168	47	788	4,032	29.4	9.2	0.43
	Change	−197 (−9,200 pcu/day)	121	7	224	155	−2.1	−0.5	0.00
2035	Case-0	5,184	45	58	563	5,850	36.3	11.2	0.62
	Case-1	4,886	191	65	917	6,059	34.8	10.8	0.61
	Change	−298 (−17,400 pcu/day)	146	7	354	209	−1.5	−0.4	−0.10

Source: JICA Project Team

[1] Passenger Car Unit (PCU) is a unit used for calculating road capacity. One car is considered to be a single unit (1 PCU). A motorcycle is 0.5 PCU, and a bus is 3 to 4 PCU.

Chapter 4 Alternative Plans

4.1 Route and Phasing Options

4.1.1 Proposed Route for BRT N1 Line

The proposed BRT N1 route starts from the Brigada intersection with N4, then runs northward along N1, goes through Missão Roque, and ends at Zimpeto. Missão Roque is an important node on the road network connecting Benfica, Magoanine, and Infurene. Zimpeto has a stadium and a market, and there are also many road users from the residential area in northern Matola. Furthermore, it is predicted that it will have many additional users as a road network node after the construction of the ring road. Although the road right-of-way is 50 m based on law, in actuality, residential and commercial establishments have already been encroached upon this right of way. In particular, a high-density urban area has been developed in the section from Brigada to Benfica, and there is no alternative space which can be used as a detour. Therefore, a BRT route is proposed to be set aside on the inside lane of the existing N1. The proposed BRT N1 route is shown in Figure 4.1.

Source: JICA Project Team

Figure 4.1: BRT N1 Route

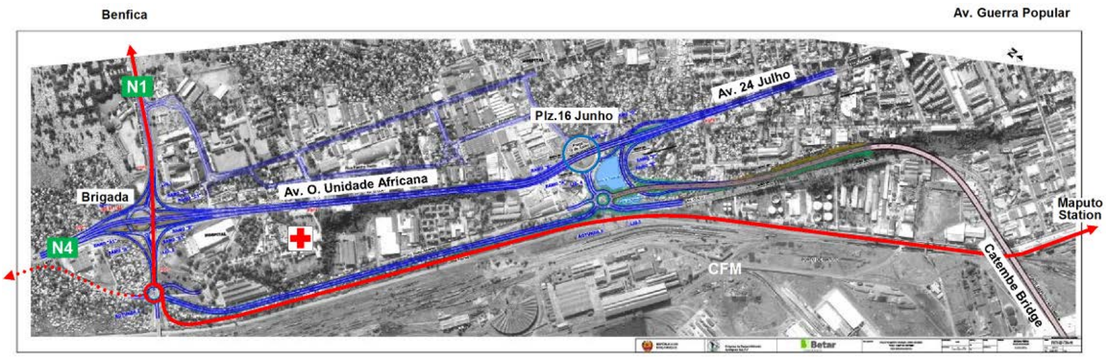
4.1.2 Additional Maputo Station Access Route in Railway Side

The BRT travel to the central urban area should be smooth for the convenience of users. The unique express type of BRT is recommended for the N1 Line, covering a medium distance (about 19 km) and connecting central urban areas to suburban areas. The distance from the southern end of the N1 route at Brigada to the Maputo central urban area is about 4 km. For the cases where the BRT priority lane is within an existing road, such as Av. 24 Julho, there will be a serious problem of heavy traffic congestion during peak hours. However, if there were to be road widening, there will be a social/environmental impact for commercial establishments and factories located by the roadside. On the other hand, although there are a few residences along the railway side, it has space and an existing road (Av. 25 Setembro and Av. Estancias) suitable for BRT. Av. Estancias also has a suitable detour route.

Therefore, N1 Line is recommended to use the Maputo Station access route on the railway side for smooth and effective BRT. Furthermore, this alignment is in harmony with the access road plan related to the Catembe Bridge construction. Figure 4.2 presents the additional Maputo Station access line; Figure 4.3 presents the relationship with the Catembe Bridge Access Road Plan.

Source: JICA Project Team

Figure 4.2: Maputo Station Access Line



Source: JICA Project Team based on Maputo Sul, E.P. Project Maputo/Katembe/Ponta do Ouro

Figure 4.3: Relationship with Catembe Bridge Access Road Plan

4.1.3 Related BRT North-South Line in Eastern Maputo

The BRT north-south line of eastern Maputo is to be developed with assistance from Brazil. The proposed route is connected to Maguaine through Av. A. Lusaka, Av. FPLM, and Av. J. Nyerere from Baixa, and is already slated for construction. The basic design will start in October 2013 and a detailed design will be finished in the middle of 2014. Figure 4.4 shows the BRT north-south line route in eastern Maputo.

Source: JICA Project Team

Figure 4.4: BRT North-South Line in Eastern Maputo

4.1.4 Assessment of the Alternative Route

(1) Alternatives Route as Maputo Station Access Line

The distance from the southern end of the N1 route at Brigada to the Maputo central urban area is about 4 km. In the Maputo urban area, automobile traffic is increasing, and the arterial road has severe traffic congestion. The N1 Line should be connected to the Maputo central urban area via a smooth transportation network for an effective BRT. Alternatives were proposed, including the abovementioned route option, considering the safety, convenience, and efficiency of operation. The proposed alternative routes for Maputo Station access are shown in Table 4.1.

Table 4.1: Proposed Alternative Routes as Maputo Station Access

Alternative 1 Railway Side Route	**Alternative 2** 24 Julho Route	**Alternative 3**[2)] Airport South Route
		
The route which utilizes the railway side space and an existing road from Brigada to Maputo Station.	The route connected to Av. G. Popular through 24 Julho from Brigada.	The route which connects with Plz. Herois through airport south side from N1, and utilizes the eastern BRT route.
Length[1)]: 19.1 km	Length: 18.9 km (19.9 km)	Length: 14.5 km (19.1 km)

Note 1): "Length" indicates the distance from Zimpeto to Maputo Central Station (Alternative 1) and to Brazil-assisted BRT line (Alternative 2 and 3), being equivalent to the distance of red lines. Distance in parentheses expresses the total BRT distance from Zimpeto to Maputo Central Station via each route.
Note 2): Alternative 3 is a low cost option considered in Technical Report F: Public Transport Improvement.
Source: JICA Project Team

(2) Assessment of Alternatives

As a result of multiple analyses, Alternative 1 (Railway Side Route) was estimated to be more dominant than the other two alternatives. The comparative analysis of the three alternative routes is shown in Table 4.2.

Table 4.2: Analysis of Alternative Routes

Item		**Alternative 1** Railway Side Route	**Alternative 2** 24 Julho Route	**Alternative 3** Airport South Route
Length/Infrastructure Cost		18.5 km	18.3 km (19.3 km)	14.5 km (19.1 km)
		USD 53 million	USD 57 million	USD 44 million
Consistency with M/P		4: Good Consistent with M/P	5:Very good Consistent with M/P	2: Bad Different from M/P
Engineering Factors	Alignment/ Intersection	4: Good Good alignment and few intersections	3: Fair Good alignment and many intersections	2: Bad Many curves and many intersections
	Travel Speed	4: Good Very smooth	2: Bad Heavy traffic congestion	2: Bad Central urban congestion
Economic Factors	Construction Cost	3: Fair	2: Bad Somewhat high	4; Good Low cost
	Local Access	4: Fair Wide utilization area	5: Fair Convenient in commercial area	2: Fair Narrow utilization area
Environmental Factors	Resettlement	3: Fair Little relocation	3: Fair Little relocation	3: Fair Little relocation
Evaluation		✓(22)	(20)	(13)

Source: JICA Project Team

<u>Alternative 1</u>

The Railway Side Route allows for a safer and more efficient operation of BRT, because it has a better alignment and fewer intersections compared to the other alternatives. Development will be realized at an early stage as the impacts of the route will result in comparatively little resettlement. Also, it harmonizes with the access road plan related to the construction of the Catembe Bridge. It is the most effective route for the express-type BRT that connects the northern suburban and central urban areas in Maputo and Matola.

<u>Alternative 2</u>

The Av. 24 Julho Route is more convenient for roadside access because it passes through a commercial area. However, the route passes through many intersections and experiences traffic volumes of over 20,000 per day due to serious traffic congestion. Although a flyover is planned at the Plz. 16 Junho intersection, it is thought that traffic congestion will remain the same at the intersection. Since the width of Av. O. U. Africana is 25 m, there will be higher costs and longer construction period needed for road widening.

<u>Alternative 3</u>

The Airport South Route is more dominant with respect to the cost and construction due to its shorter distance. However, user access is restricted because this BRT route will not pass through the southwest district of Maputo. Furthermore, new traffic congestion will be generated by the confluence with the east route.

4.1.5 Phasing of BRT Development

The BRT system should be continuously connected from origin to destination for a greater development effect. The demand forecast conducted in Chapter 3 indicated that the entire line should be fully operational in order to generate greater benefits and revenues from the project. The overall BRT development plan was outlined in the Master Plan volume and the plans related to the Pre-F/S are summarized as follows:

Phase I – Praça da Juvententude (Magoanine) to Baixa, via the municipal corridor of Julius Nyerere, the present bus terminal of Xiquelene and the Guerra Popular corridor; plus a link via Av. Eduardo Mondlane to a Center Terminal at Museo (assisted by the Brazilian government).

Phase II – Zimpeto to Estação CFM, via the National Highway N1, a new terminal at Missão Roque, Brigada Montada and a busway next to the railway. This will include a station integrating with the proposed LRT (the subject of this Pre-F/S).

- North Section 6.6 km
- South Section 12.5 km

Phase III – Matola to the CFM Terminal using the infrastructure from N1 to the City center built in Phase II.

Phase I and II are related to the traffic along north-south corridor, whereas the Phase III BRT will handle traffic along east-west corridor, which is the largest traffic demand among three. Currently a railway along the same corridor as Phase III BRT is being planned as a priority transport mode.

For completing the entire line as early as possible, project implementation should take into account the conditions along the N1 corridor that differ by section; the portion that will require a longer implementation period should be started earlier. Along the BRT N1 route, the South Section is more difficult to construct, resulting in a longer period of implementation than the North Section. The southern portion has a traffic volume of over 30,000 per day and has many intersections. The BRT development will need bridge widening and lighting facilities relocation. Numerous residential and commercial establishments are already developed along the road, especially in the high-density urban area in Benfica.

It is expected that the implementation of the BRT north-south line in eastern Maputo (Baixa–Magoanine) will be started first, and thus it is referred to as Phase I, and that the BRT N1 line, the subject of this pre-F/S, is to follow as Phase II. This phased development is summarized below with main features of Phase II shown in Table 4.3 and Figure 4.5.

Table 4.3: BRT N1 Line by Section (Phase II)

Section	Outline
North Section	Section: North area of BRT N1 Line (Missão Roque–Zimpeto) Length: 6.6 km Outline: Construction will start at the north area of N1, from Missão Roque intersection to Zimpeto. - BRT Runway: 5.4 km - Stations: 4 - Terminal and Depots: 1 (Zimpeto) - Road Improvements: 6.6 km
South Section	Section: South area of BRT N1 Line (Brigada–Missão Roque) and Maputo Station access road Length: 12.5 km Outline: The south area of N1 from Brigada to Missão Roque intersection and Maputo Station access route will be constructed as the BRT N1 Line connecting the suburbs with downtown Maputo. - BRT Runway: 12.5 km - Stations: 12 - Terminal: 2 (Maputo Station, Missão Roque) - Road Improvements: 8.8 km

Source: JICA Project Team

Source: JICA Project Team

Figure 4.5: BRT N1 Line by Section (Phase II)

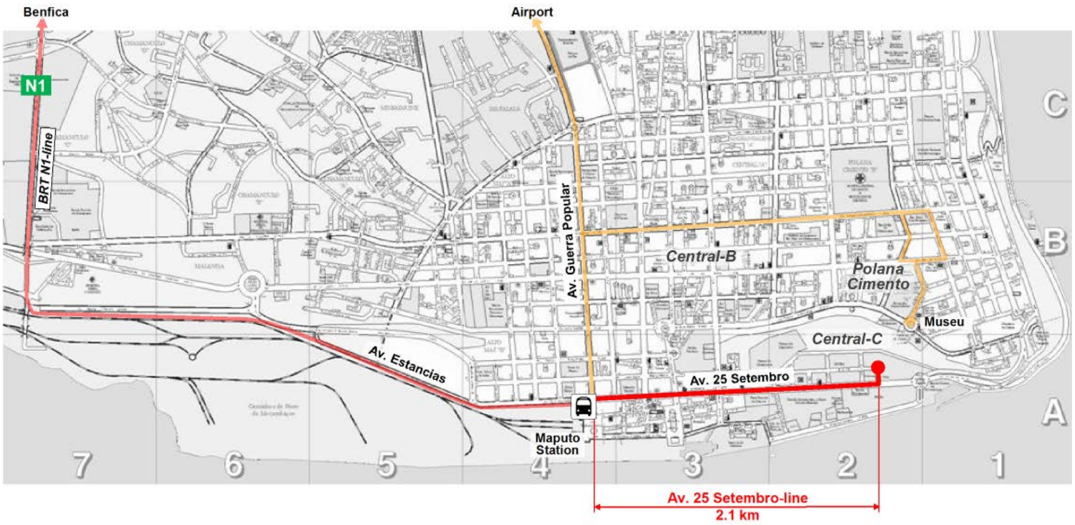
4.2 Optional Av. 25 Setembro East Route

As shown in Figure 4.6, the BRT route plan in the Maputo central urban area is developed in the direction of east-west to Polana Cimento (with Museu being a terminal) via Av. Eduardo Mondlane from Av. Guerra Popular, branched from the north-south BRT line supported by Brazil. This route (specifically the Museu Terminal), however, may not serve the traffic to and from the Central-C East District well.

The Central-C East District is a newly developed urbanized district with many commercial establishments including hotels, offices, and high-rise buildings. And nearby are public facilities such as the ferry port and park. As for population, at night there are 7,900 people occupying the area, but this increases to 59,000 during the day due to the influx of workers. There is, however, a problem with the access from the Museu Terminal to this district due to a 50m tall cliff that lies between Museu and the district.

Another choice to access the district is by conventional buses or cars via Av. 25 Setembro, which is currently very congested. In order to provide smooth transport services for a large number of passengers given the limited parking spaces along the avenue, the BRT from Maputo Station to this area is recommended for further implementation.

Figure 4.6 presents the plan of the Av. 25 Setembro route option.



Source: JICA Project Team

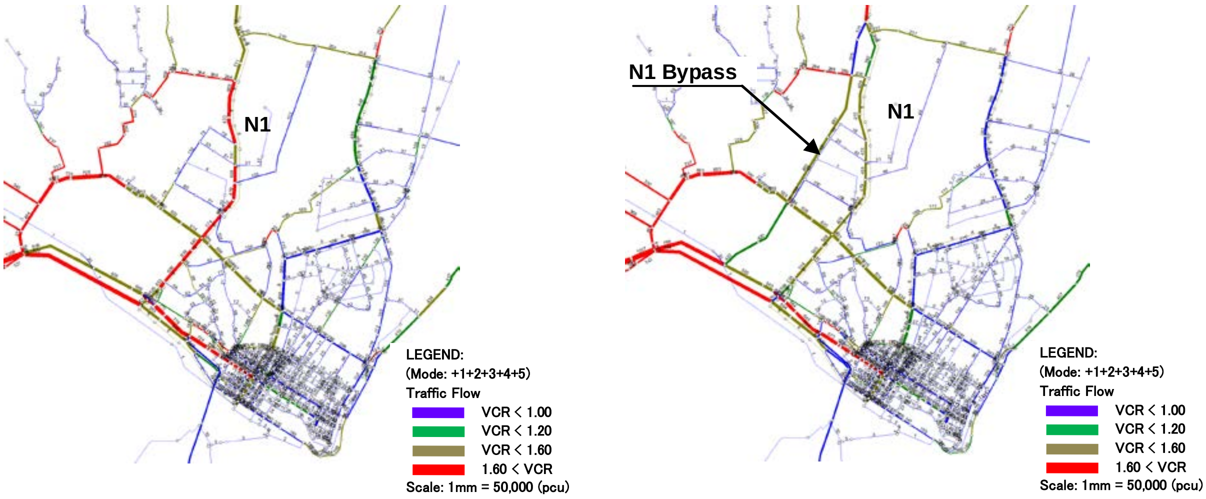
Figure 4.6: Av. 25 Setembro Route

4.3 Proposal of N1 Bypass

(1) Necessity for N1 Bypass

N1 is one of the main national roads in Mozambique and is also a heavily traveled route along the north-south axis of Greater Maputo where travel demand will continue to grow rapidly. It serves various kinds of traffic including local, urban and regional traffic (e.g., commuting, business, and shopping), interregional/long-distance traffic, and a mixture of freight and passenger traffic. The development of N1 BRT will expand the transport capacity substantially, but because of the high travel demand especially on the urban sections of N1 that serve various kinds of traffic, it is expected that BRT development will not be sufficient to meet the future transport demand. In order for N1 to provide high quality urban transport in the medium to long term, further capacity expansion will be necessary along the urban sections of N1 by constructing a bypass route as recommended in the master plan.

Figure 4.7 shows the extent of congestion with and without the development of N1 Bypass estimated for 2035. Without N1 Bypass, the urban sections of N1 are expected to face a high level of congestion by 2035 while the extent of congestion on N1 with the bypass would be substantially lower due to a diversion of much traffic from N1 to the bypass. Note that the N1 Bypass construction is one of the priority projects proposed in the master plan as shown in Chapter 1 of this Pre-FS report.



Without N1 Bypass in 2035 **With N1 Bypass in 2035**

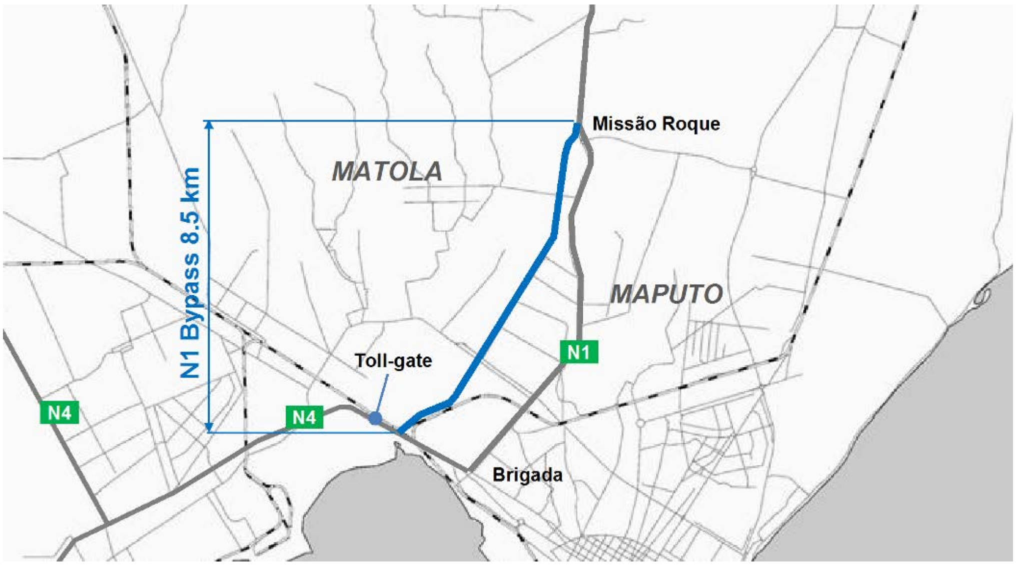
Source: JICA Project Team

Figure 4.7: Congestion Degree With/Without N1 Bypass in 2035

(2) N1 Bypass Route

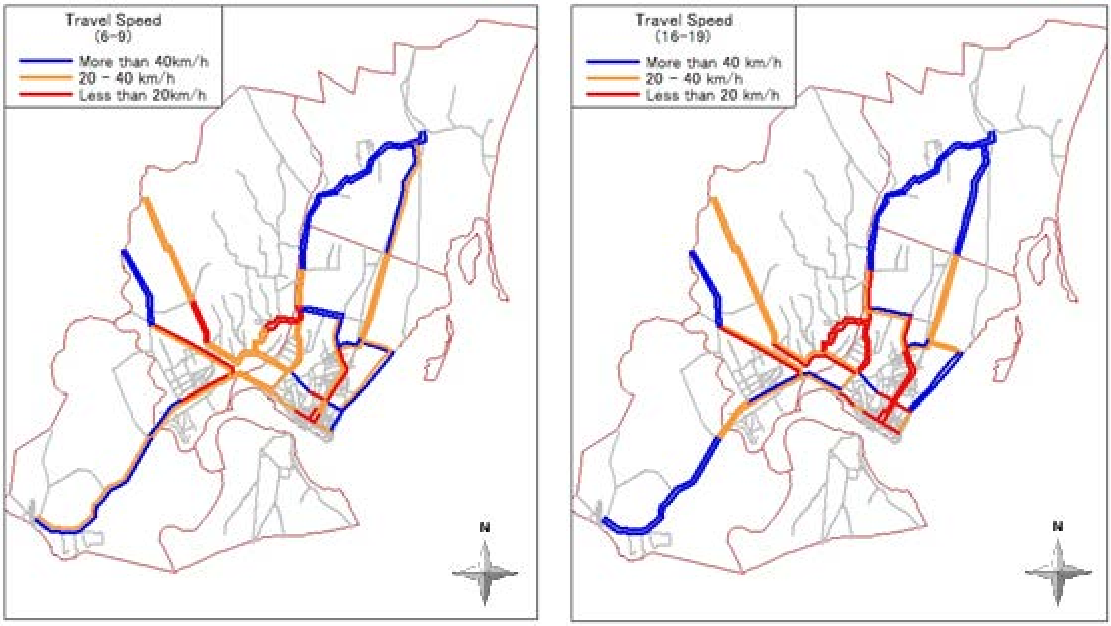
Since commercial establishments and dense residential housing areas can be found on both sides of N1, a detour far from this area is needed for the N1 Bypass route. Between Maputo and Matola, a 500-m wide farmland continuing to an estuary runs parallel to N1. On the other hand, the urban areas from Brigada to Missão Roque have nine intersections. In the suburban section, average travel speed is smooth as mentioned (above 40 km/h), whereas in the urban section it is only 20 km/h during the daytime. Therefore, the development of the N1 Bypass utilizing the available space between Maputo and Matola is recommended for a smooth physical distribution and urban traffic congestion solution. The target section is about 8.5 km from the N4 tollgate to Missão Roque. Figure 4.8 presents the proposed N1 Bypass route, Figure 4.9 presents the results of the road network travel speed survey (both the morning and evening commuting hours), and Figure 4.10 presents the travel speed along N1.

According to the travel speed survey of the study area (Figure 4.9) the speed along major roadways close to Maputo CBD area is very low especially along north-south corridors. This can be seen especially during evening peak periods including N1 road. The figure for the N1 travel speed conditions show very clear tendencies of bottle neck points between Zimpeto and Brigada, where N1 merges to N4. The speed is low near Zimpeto where there is a market and connecting roads. The speed near Benfica is low because of a roundabout of N1 and intersecting road. The figure also clearly indicates that the traffic bottlenecks of south part from Benfica to Brigada are very frequent because of intersections and commercial activities compared with north part of N1. Even diverting road toward Matola direction is crowded (Figure 4.9), which implies the necessity of high grade and high capacity roadway from Benfica area toward Matola direction.



Source: JICA Project Team

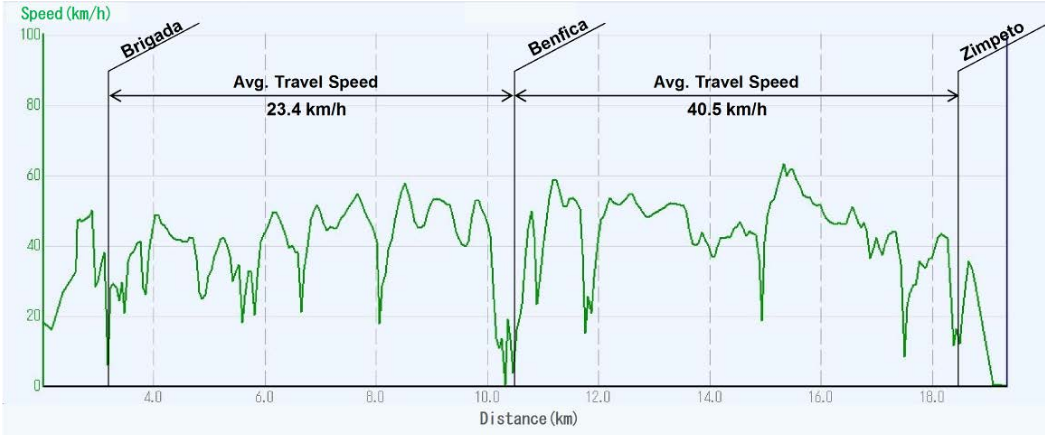
Figure 4.8: N1 Bypass Route Plan



Morning (6 a.m. to 9 a.m.) **Evening (4 p.m. to 7 p.m.)**

Source: JICA Project Team

Figure 4.9: Result of Travel Speed Survey



Source: JICA Project Team

Figure 4.10: N1 Travel Speed

4.4 Summary of Assessment Results

With the addition of BRT on the N1 route, two additional lanes are required, and the road will have four lanes to utilize the space in both directions to maintain the current traffic capacity. The unique express-type BRT recommended for the N1 Line covers a medium distance connecting the central urban areas to suburban areas. The recommended connection route to the central urban area is a railway-side route in consideration of the impacts of a related bridge-access project and in order to minimize the amount of resettlements required for short-term construction. Overall, these decisions lead to an overall effective BRT system. Furthermore, because there is little fixed infrastructure, BRT is a flexible public transportation system. For example, extension routes such as the Av. 25 Setembro East Line and the Maputo Airport Access Line can be examined in consideration of future needs. Figure 4.11 presents the BRT N1 Line as proposed by this study.

Source: JICA Project Team

Figure 4.11: Proposed BRT N1 Line

Chapter 5 Preliminary Design

5.1 Design Objectives and Standards

5.1.1 BRT System Design Objectives

BRT systems have been applied in cities all over the world which are rapidly developing their public transport networks. Accordingly, the BRT design objectives for this project should include will offer solutions to improve the efficiency, cost effectiveness, accessibility, and so on of the current urban transport system in Maputo. By approximate order of importance the basic design objectives are:

- Safety
  - When at grade, pedestrian and passenger access to stations/platforms/terminals should have raised crossings for low flows at low speeds.
  - At signals, pedestrian should have non-conflicting phases that are enforced by the presence of other vehicle movements.
  - At the last resort, speed bumps and raised pedestrian crossings can be used.
  - All non-signaled turning or crossing movements should be avoided for all infrastructure users, with the exception of bus x bus movements.

- BRT Efficiency (Operating Speed)
  - Stations should permit trunk route overtaking (where possible) to allow for express-type services to be used in peak periods.
  - Multiple stages/signal phases should be reduced to minimize delay and allow the implementation of signal bus priority – thus conflicting turns (right) at junctions should be eliminated.

- BRT Accessibility and Special Needs
  - Stairs are to be avoided by the use of ramps to reach stations and terminals.
  - Lowered curbs at crossings and raised pedestrian crossing ‘platforms’ are to be used.
  - Station distancing should be optimized for BRT – between 500 m and 800 m.
  - Pedestrian walkway accessibility to all infrastructure will be part of the overall system design (sidewalks, signals, lighting, pedestrian passages, etc.). This includes the maintenance of these features.

- Impact on Other Modes (Congestion)
  - Simplify junctions with one-way systems where possible.
  - Avoid right turns and remove turning lanes and signal stages.
  - Maintain current levels (minimum) of saturation and accessibility – compensate for banned movements with new access points or junctions.
  - Calibrate BRT signal priority to avoid saturation on side roads.
  - No parallel cycle paths (as cyclists tend to use the busway).
  - Fence off BRT overtaking zones to avoid wandering pedestrians.

- Environmental and Social Impacts (Resettlement)
  - Minimize intrusion on human settlements.
  - Minimize intrusion of green or public spaces.
  - Optimize existing transport infrastructure (road space/ highway RoW/ Rail RoW).
  - Minimize visual intrusion of grade-separated works in built-up zones.

- Cost Effectiveness
  - Maximize use of at-grade solutions and simple, two-stage signal control.
  - Minimize land acquisition.
  - Best use of local pavement/base/sub-base.
  - Minimize pavement maintenance using reinforced concrete at intersections and station approximations.

5.1.2 BRT Route Design Objectives

(1) Design Speed and Geometric Design Standard

The geometric design standard should be properly established in consideration of the characteristics of the district, traffic, and road network, in order to secure a safe and smooth traffic flow. Lane layout is a very important subject for BRT introduction. BRT bus traffic, ordinary vehicle traffic, and pedestrian traffic should be properly allocated given the limited right of way. Although the national road which ANE manages already has a design standard, there is no design standard for BRT.

The proposed lane layout/design standard, including BRT, is based on both the "ANE's Design Standard" and the Institute for Transportation & Development Policy's 2007 "BRT Planning Guide." In consideration of the existing traffic volumes of 40,000–50,000 vehicles/day, a four lane road has been selected. The design speed is set at 60 km/h in consideration of the express-type BRT passing through an urban area with numerous intersections. The design standards used for BRT and N1 are shown in Table 5.1.

Table 5.1: Design Standard for BRT and N1

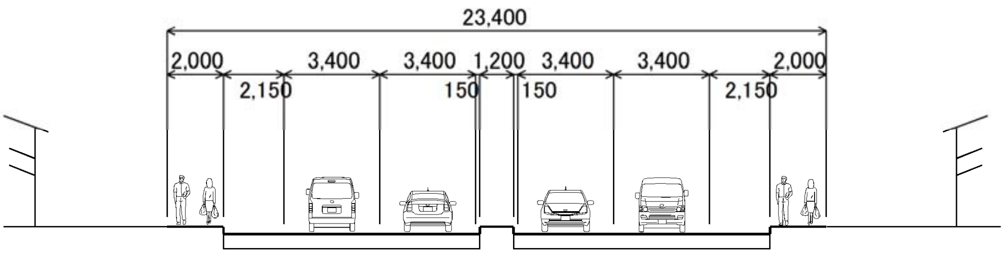
Item	BRT	N1
Name	BRT N1 Line	N1 (ordinary national road)
Road Classification	BRT exclusive right-of-way	ANE primary
Design Speed	60 km/h	60 km/h
Number of Lanes	2	4
Lane Width	3.5 m (3.0 m)	3.5 m (3.25 m)

Source: JICA Project Team

(2) Standard Cross-Section

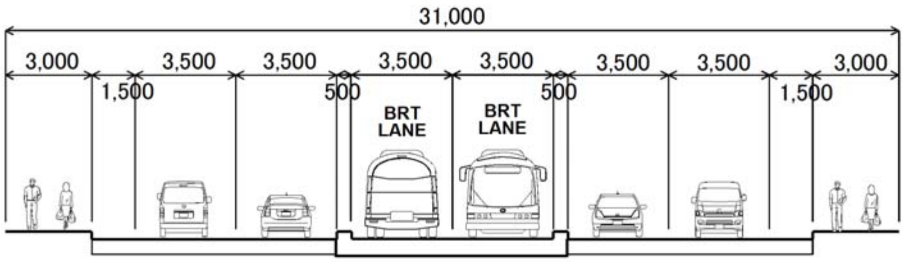
The cross-section should take into consideration the combination of all the necessary factors and component characteristics of a road network and traffic. Roadside utilization, bus stops, and environmental space should also be taken into consideration. N1 has some existing margin on both sides, and that space will be utilized to accommodate the BRT corridor and four lane N1 road.

The lane width of a BRT runway is 3.5 m in consideration of the margin of trafficability and safety for 2.5-m wide BRT vehicles. The curb is placed on both sides of the BRT to clearly separate the BRT lanes as exclusive. Therefore, it is recommended that a separator stud be placed in the center to serve as guide for bus operators. The ordinary lane width should be 3.5 m in consideration of its traffic function as a national road with a large-sized vehicle mix-rate (10%–20%). The shoulder is recommended to be 1.5 m wide for parking and surface drainage considerations. The sidewalk is desired to be more than 3 m; but in unavoidable cases, it should have be at a minimum 2 m. The standard total width including the BRT N1 Line is 31 m, and it should be adjusted as necessary to fit the right of way. Figure 5.2 presents the standard cross-section of the BRT N1 Line.



Source: JICA Project Team

Figure 5.1: Existing Standard Cross-Section on N1



Source: JICA Project Team

Figure 5.2: Proposed Standard Cross-Section of BRT N1 Line

(3) BRT Road Layout

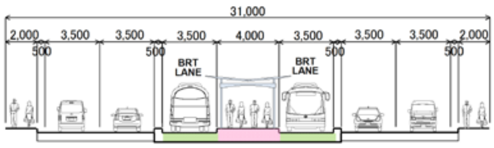
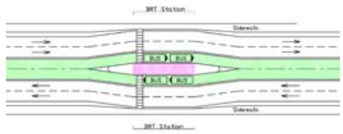
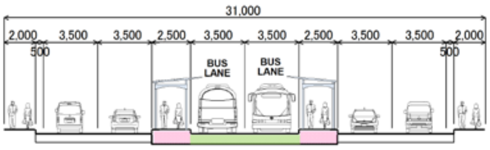
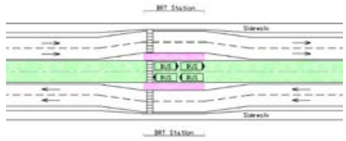
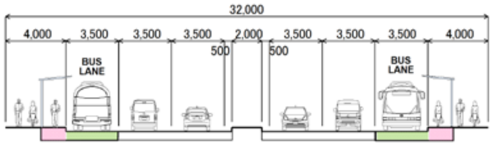
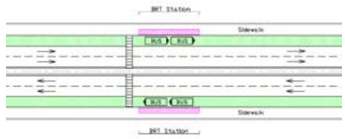
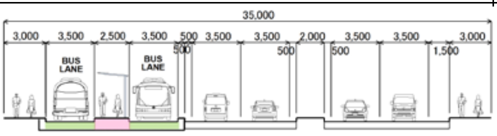
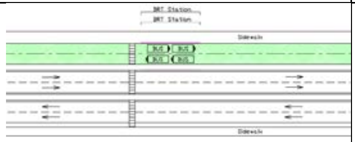
The BRT lane layout, the user's safety, operation efficiency, and roadside land use are taken into consideration when selecting the overall cross-section for a specific section on the route. Since there are commercial establishments located continuously on both sides of N1, roadside access should not be blocked by the exclusive BRT road. According to current worldwide trends, the main BRT lane should be located in the median area. The north-south route in eastern Maputo, which will be developed in advance, is also planned with the BRT lanes in the median. Therefore, the layout should adopt a median-type BRT with a middle station (right-side door) in consideration of user and ordinary traffic safety and roadside convenience. BRT lane, station layout, and vehicle type are shown in Table 5.2, while alternative layouts for the BRT lane are shown in Table 5.3.

Table 5.2: BRT Lane, Station Layout, and Vehicle Type

Item	BRT
BRT Lane Layout in Road	Center BRT Lanes
Station Layout in BRT	Median Station
Vehicle Type	Right-side Doorway

Source: JICA Project Team

Table 5.3: Alternative Layouts for BRT Lane

Alternative	Cross-section	Plan	
Alternative 1 Center BRT Lane Median Station Right-side Door			✓
Alternative 2 Center BRT Lane Each-side Station Left-side Door			
Alternative 3 Each-side BRT Lane Each-side Station Left-side Door			
Alternative 4 Separate BRT Lane Median Station Right-side Door			

Source: JICA Project Team

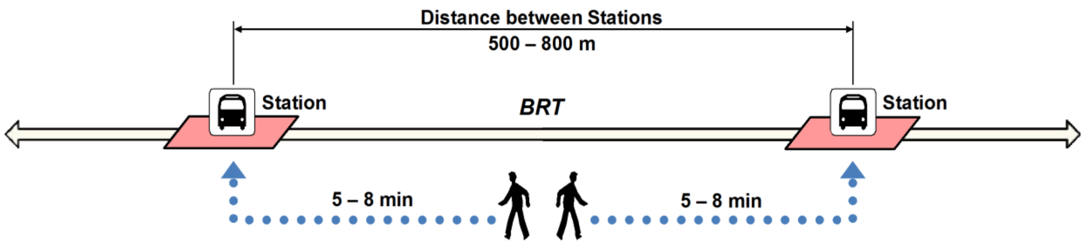
5.1.3 BRT Station Placement

(1) Distance between Stations

The distance between BRT stations affects both the users' convenience and the efficiency of operations. An appropriate distance between stations is about 500 m, which is the standard distance for other BRT systems in the world. Assuming the average walking time along a major road is less than 5 min and the walking speed is 4 km/h, the maximum distance between stations was calculated at 667 m through the following equation:

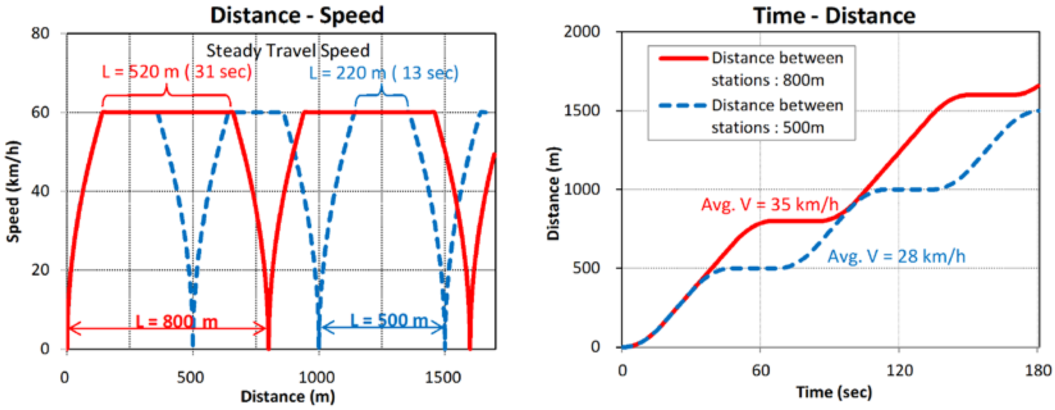
4000 m / 60 min * 5 min * 2 = 667 m

For distances between 500 m, the average travel speed was calculated at 28 km/h and steady travel distance at 220 m. The precondition was postulated such as that the travel speed is 60 km/h, acceleration/deceleration force is 1G, and the station stoppage time is 20 sec. In the case of 800 m intervals, the average travel speed was calculated as 35 km/h with steady travel distance at 520 m. Therefore, the station distance is recommended at 500-800 m for pedestrian convenience and BRT operational efficiency. Figure 5.3 presents station distance and pedestrian access time, while Figure 5.4 shows the relationship between station distance, travel speed, and travel distance.



Source: JICA Project Team

Figure 5.3: Station Distance and Access Time of Pedestrians



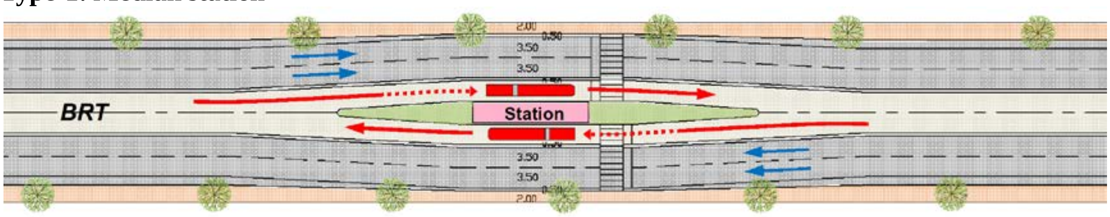
Source: JICA Project Team

Figure 5.4: Relationship between Station Distance, Travel Speed, and Travel Distance

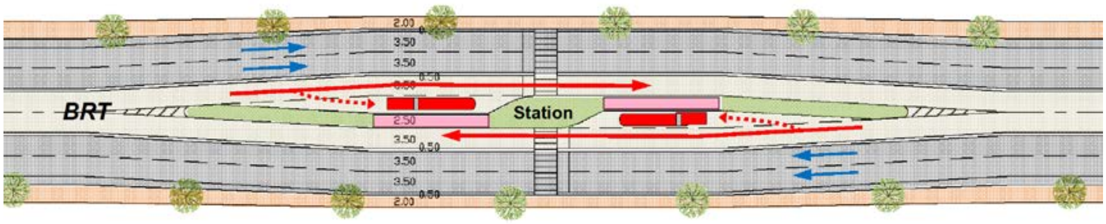
(2) Station and Passing Lane

The median-type station should have a minimum width of 4 m and should be as wide as possible for smooth movement of pedestrians. In the case of the alternate-type station for narrow right of ways, the minimum width is 2.5 m. At any given BRT station, the passing lane is recommended for express-type service and operational efficiency. Dimensions for the recommended station are: a stopping lane at 3 m wide and a passing lane at 3.5 m wide. Figure 5.5 shows the two types of BRT stations.

Type-1: Median station



Type-2: Alternate-type station with passing lane



Source: JICA Project Team

Figure 5.5: Types of BRT Stations

5.1.4 Building & Facility Works

All the buildings and facilities should be planned and designed to ensure the effective operation of BRT as well as the improvement of the overall environment along the route. Resettlement is a major issue, in particular on the section from Brigada to Missão Roque. The impact on environment and resettlement should be minimized while the benefits to local communities should be maximized. The following design principles are observed for each project stage (Plan - Design - Construction - Operation) in approximate order of importance:

- Plan
  - Long term future developments should be considered for planning of stations and terminal buildings/facilities, especially for the Zimpeto area.

- Design
  - Stations and terminal buildings will fit in with the existing environment, minimizing resettlement as much as possible.
  - The design process will involve local consultation on design, materials, construction methods, etc.

- Construction
  - Locally-available construction methods and building materials will be utilized as much as possible in order to make repair/maintenance works easy and timely.

- Operation
  - The operation (not only of the terminal but for the BRT system as a whole) should be environmentally-friendly. Waste of materials should be reduced as far as possible to minimize environmental pollution.

- Overall
  - The work process itself will aid in local capacity development, by empowering local people with new skills, knowledge, techniques, etc.
  - Energy use, particularly of fossil fuels, should be minimized in the selection of materials, the process of construction, and the operation of BRT.

5.1.5 Terminal Design

(1) Design Objectives

Similar design priorities exist for the terminal facilities as the stations:

- Safety for all users
- Ensuring BRT efficiency
- Good physical integration between trunk and feeder routes
- Ease of control of access points – pedestrian and bus
- Comfort and special needs accessibility
- Minimizing impact on traffic circulation
- Reinforcing the BRT “image”

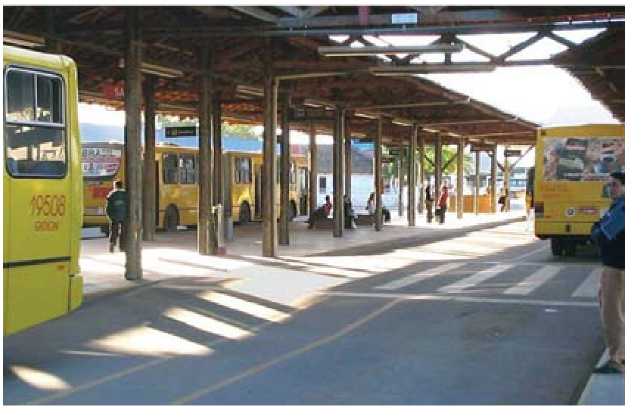
In particular, BRT efficiency is best served by adopting the following criteria:

- Minimize BRT turning movements and keeping BRT through-routes on the axis of the corridor.
- Using signals with two vehicle stages whenever possible to allow for prioritization and thus minimizing delays.
- Adopting a turning radius of 12 m at all trunk turn-arounds.
- Including overtaking lanes of 3.5 m minimum in each direction (note: for a two-direction platform this means a minimum road width of 13 m, ideally 14 m).

Good physical integration between trunk and feeder routes is best obtained by:

- A close proximity between trunk and feeder platforms.
- The placement of feeders routes with the highest demand on the platform nearest to the BRT and close to the crossings.

- Covered walkways and crossings. (shown as Figure 5.6)



Source: JICA Project Team

Figure 5.6: Covered Walkways and Raised Crossings in Joinville, Brazil

Controlled access to the terminals can be aided by:

- Minimizing bus entry zones (preferably two).
- Avoiding pedestrian “invasion” of bus zones with barriers/fences.
- Having all pedestrian crossings lead directly to terminal entry/exit areas.

Traffic congestion can be minimized by:

- Simplifying junction movements so that they can operate with a minimum number of signal phases.
- Maintaining overall traffic capacity (lanes) and accessibility as far as possible.
- Avoiding conflicts of all traffic with buses by physical measures and signaling.

Passenger comfort and special needs are catered for by:

- The use of BRT platforms with a minimum width of 8m.
- Feeder platforms with a minimum width of 6m ideal.
- Avoiding sharp turns with passengers.
- CCTV supervision.
- Ramps, lowered curbs, and pavement texture to indicate pathways and passenger limits.

Finally, system image is largely defined by the terminals – where passengers have the closest contact with infrastructure. Poorly-designed or cheaply-built terminals reflect directly on the system. As a rule there should be:

- Standardized design elements for all terminals with specific color scheme, logo and system identification.
- “Conventional bus terminal” specifications should be avoided in favor of ”metro” style designs.
- All internal roadways should have a concrete road pavement.
- Landscaping of exterior elements should be made in order to try and keep the terminal area “trash-free.”

The layouts of the terminals reflect these standards as shown in the figures in 5.2.9.

(2) Design Standards and Construction Permissions

Design standards should be conforming to international standards. In Mozambique, the standards promoted by the Instituto Nacional de Normalização e Qualidade (INNOQ), which was established on March 24, 1993 by Law Decree 02/93 of the Council of Ministers under the Ministry of Industry and Energy, should be applied.

To proceed with a building construction project, several permissions and/or authorizations must be obtained. A typical procedure to complete building construction work in Maputo is as follows:

- Request and obtain topographic plan from the Municipal Council of Maputo City, Departamento de Urbanização e Construção (Department of Construction and Urbanization: DCU).
- Request and obtain building permit from DCU.
- Receive inspections from the municipality during construction.
- Request water and sewage connections from the Water Department of Municipality.
- Receive inspection and obtain approval of plumbing plan from the Water Department of Municipality.
- Request and obtain phone connection from Telecommunications Mozambique.
- Receive final inspection from Municipality and other departments (fire, health, and water, etc.) and obtain occupancy permit from DCU.
- Register the new building at the property registry (Conservatória do Registo Predial).

5.2 Design Principles

5.2.1 Alignment Plan

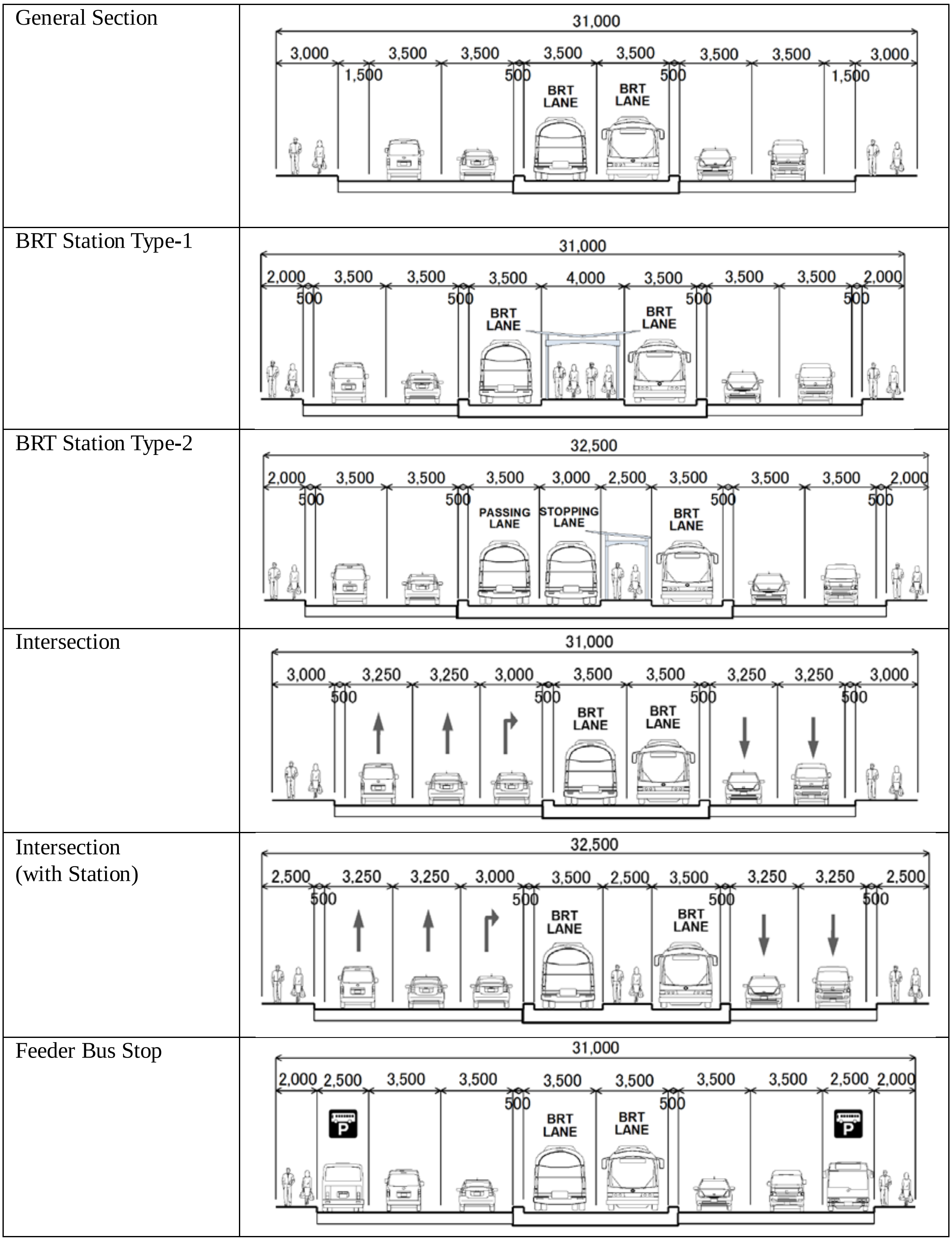
A preliminary design was carried out for the proposed BRT N1 Line (15.3 km, Brigada-Zimpeto) and the Maputo Station Access Line (3.8 km, Maputo Station-Brigada). The alignment plan was adjusted in consideration of the station layout and the impact of a roadside house based on the existing N1 centerline. The railway bridge widening was designed in consideration of the two-way crank alignment. In the section which has an intersection and topographical restrictions, an appropriate design speed and standard should be applied for a rational design. Figure 5.7 presents the alignment plan of the BRT N1 Line.

Source: JICA Project Team

Figure 5.7: Alignment Plan of BRT N1 Line

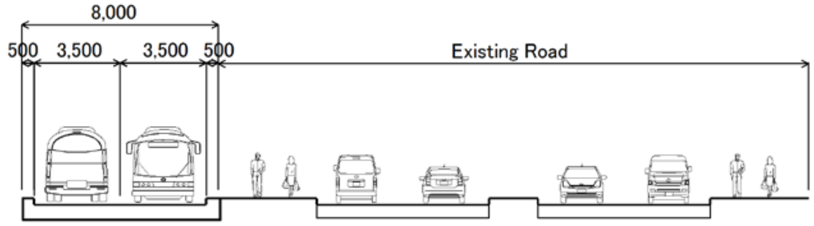
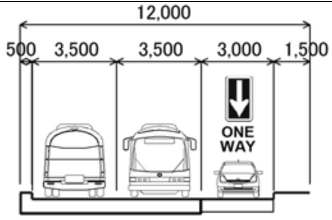
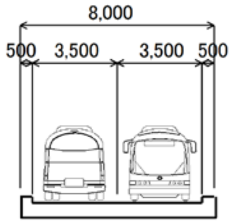
5.2.2 Typical Cross-Section

As stated in Chapter 4, the BRT N1 Line is formed from the combination of two routes. One is the BRT N1 Line and another is the Maputo Station Access Line. The basic style of BRT should be consistent such as having a median-type station and vehicles with right-side loading doors in each route. The cross-section with compact width is proposed in consideration of the right-of-way about a station, an intersection, and a feeder bus stop. A station can either be a median-type or an alternate-type with a passing lane. An intersection includes a type with a right-turn lane, and a station combination-type. Typical cross-sections of the BRT N1 Line are shown in Figure 5.8 while that of Maputo Station Access Line are shown in Figure 5.9.



Source: JICA Project Team

Figure 5.8: Cross-Section of N1 Line

Existing Road Side (Av. 25 de Setembro)	Station 
Existing Road (Av. das Estancias)	 Railway Factory
Railway-side	 Railway Houses

Source: JICA Project Team

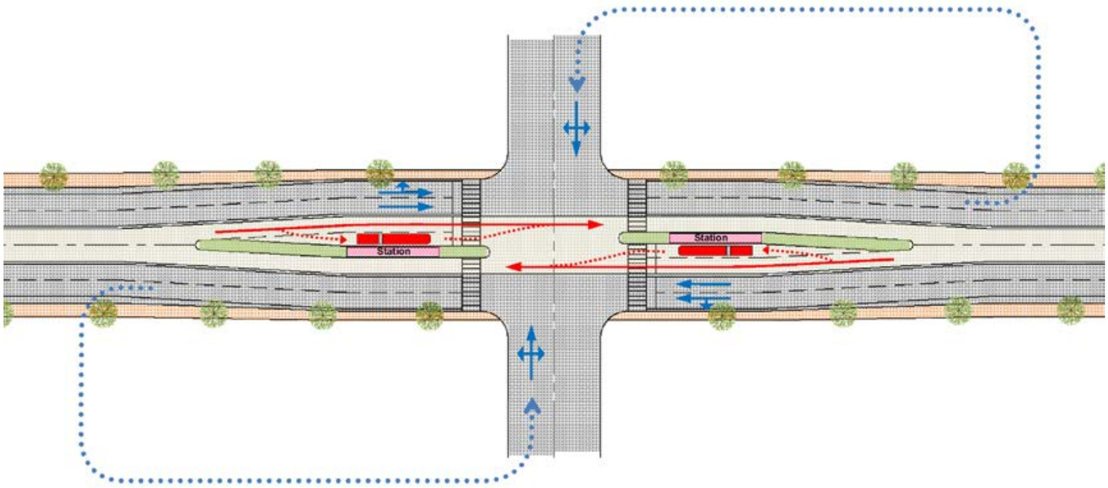
Figure 5.9: Cross-Section of Maputo Station Access Line

5.2.3 Intersections

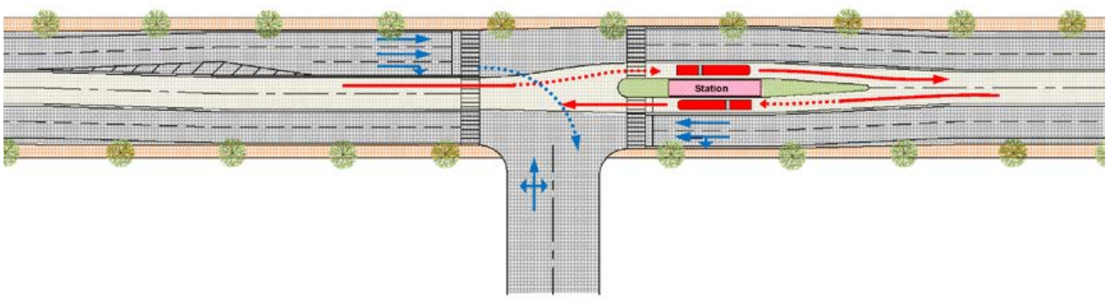
(1) Cross Intersection

In a traffic network, the role of an intersection is very important. The safety and operational efficiency in all the traffic modes should be considered especially when BRT and ordinary vehicles cross paths. At intersections where BRT lanes cross, right-turning lanes should be excluded or not allowed as much as possible for safety and operational efficiency. Right-turning vehicles can reach their destination by going through neighborhood streets as a substitute. Traffic flow mode is simplified by the exclusion of right-turn lanes, and traffic congestion will be improved because the effective green time increases. The road width is compact and the user's convenience improves because stations are closer to the crosswalks. Furthermore, an appropriate signal cycle length and split will be adjusted based on the traffic survey and intersection analysis. Figure 5.10 presents the two types of standard intersections including BRT. Figure 5.11 presents the signal indication improvement.

Cross Intersection

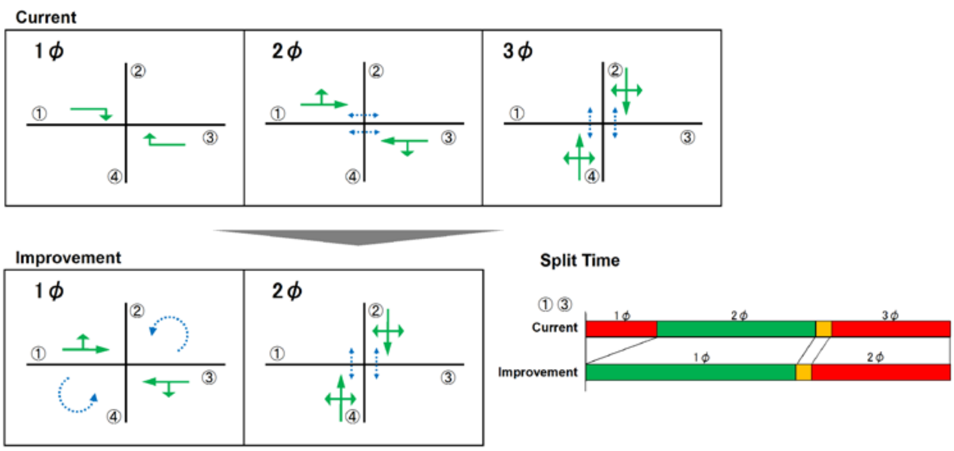


T-shaped Intersection



Source: JICA Project Team

Figure 5.10: Standard Cross Intersection Including BRT

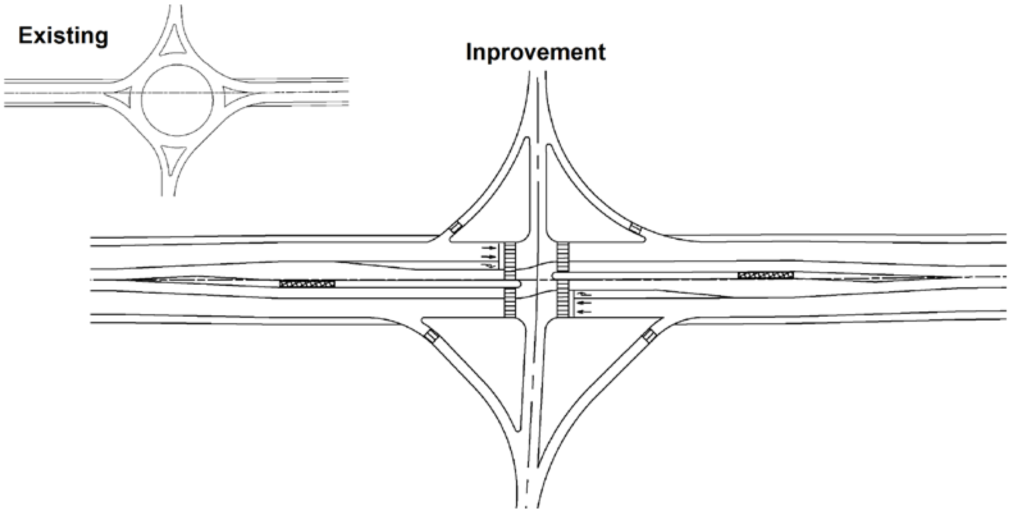


Source: JICA Project Team

Figure 5.11: Signal Indication Improvement

(2) Roundabout

In a roundabout, BRT and ordinary vehicular traffic intersects in a very complicated way, which affects safety and BRT efficiency. When a roundabout has a BRT station, road user safety (vehicle and pedestrian alike) becomes an issue. The BRT N1 Line has two roundabouts, and stations are recommended to be built there since they act as feeder nodes. Therefore, converting these roundabouts into signalized intersections is considered top priority because of the safety considerations. Figure 5.12 presents this improvement.

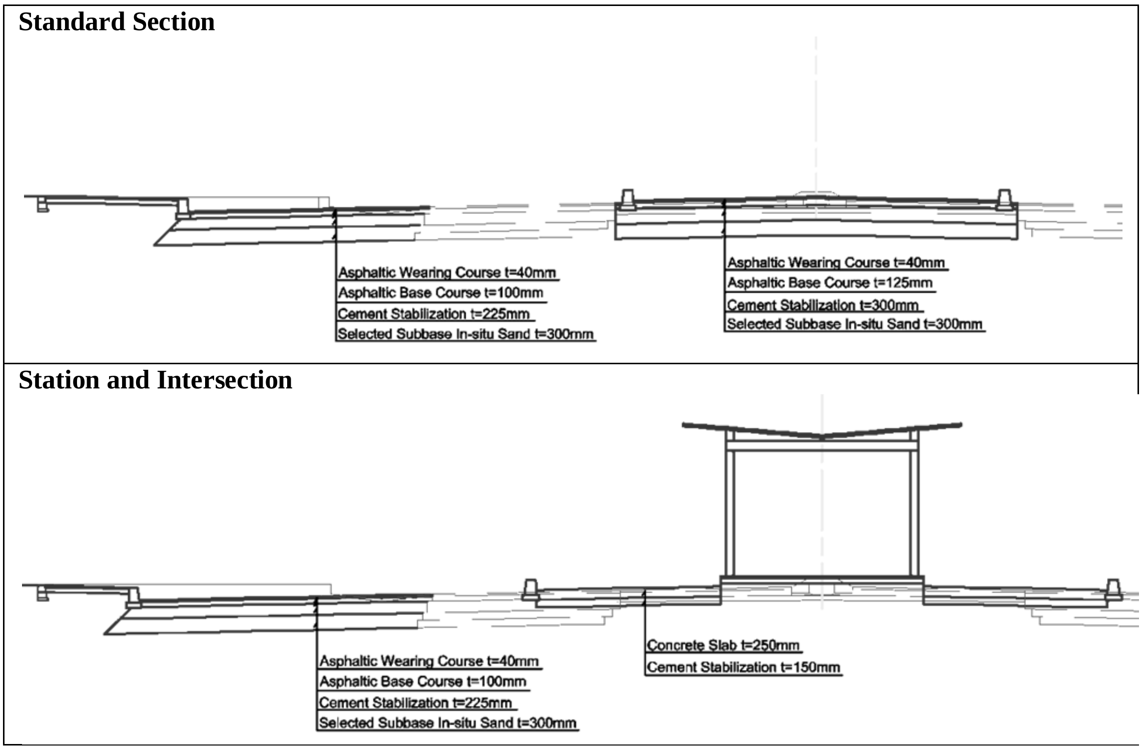


Source: JICA Project Team

Figure 5.12: Improvement of Roundabout

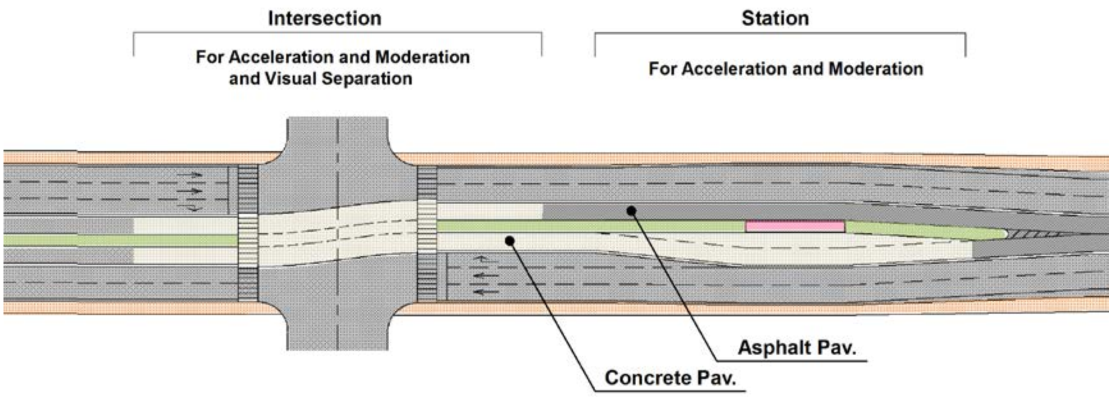
5.2.4 Pavement Design

Concrete pavement and asphalt pavement are mainly used in other parts of the world. Although concrete pavement is desired for durability, it has higher costs and requires longer construction times. Although asphalt pavement is preferable with respect to cost and ease of construction, there is a possibility of road subsidence because of the repetitive acceleration and deceleration of heavy vehicles. As an example, in Trans Jakarta, only asphalt pavement was adopted initially and eventually there were instances of subsidence. Since then, some road portions have been changed to concrete pavement. The geology of Maputo is comparatively stable as the ground surface is covered with red aeolian sand. Asphalt pavement can be kept in good condition through appropriate subgrade preparation, construction and maintenance. Therefore, for the standard section, asphalt pavement, which is more preferable with respect to cost, construction, and maintenance, is recommended. At stations and intersections where the loading from acceleration, deceleration, and torsion is more of an aggregate concern to road wear-and-tear, concrete pavement is recommended due to its durability. At intersections, it is recommended that visual separation, achieved by use of different materials, is implemented as a safety feature. Furthermore, pavement components should be properly designed by analyzing the loading and traffic conditions based on a geological survey. Figure 5.13 presents the pavement components of different sections. Figure 5.14 shows a plan of a concrete pavement area.



Source: JICA Project Team

Figure 5.13: Pavement Component

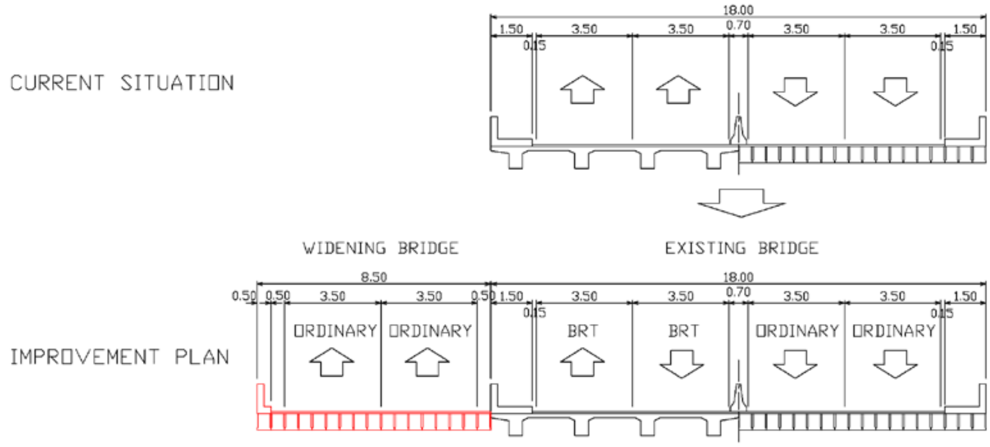


Source: JICA Project Team

Figure 5.14: Concrete Pavement Area

5.2.5 Bridge Widening Design

The south section of the BRT N1 Line has an overpass which crosses the railway line going to Marracuene. The existing bridge has a record indicating that it was previously widened from two lanes to four lanes. However, as it does not have any additional margin available, bridge widening is necessary for BRT development. Although widening was considered for both sides, the bridge has unsuitable horizontal alignment, because of bends in both directions. Therefore, a single-sided widening plan, on the bridge's west side, is proposed in consideration of the alignment issues and ease of construction. Figure 5.15 presents the cross-section for bridge widening.



Source: JICA Project Team

Figure 5.15: Cross-Section for Bridge Widening

5.2.6 Station and Terminal Placement

The location of stations should be determined in consideration of user safety, operational efficiency, accessibility, user needs, and convenience. The terminals should be placed at the main nodes where feeders gather and with a wide space. The policies of determining the location of stations and terminals are as follows:

- Station distance or interval is recommended to be about 500 to 800 m;
- Stations should be placed at signalized intersections with a crosswalk for the safety of all the users and other systems;
- The feeder network should be considered as a node function; and
- The overall user needs and station accessibility should be taken into consideration.

There are 16 stations and three terminals proposed for the 19-km BRT N1 Line from Maputo Station to Zimpeto. The location outline of stations and terminals is shown in Table 5.4 while the list of stations and terminals is shown in Table 5.5.

Table 5.4: Location Outline of Stations and Terminals of the BRT N1 Line

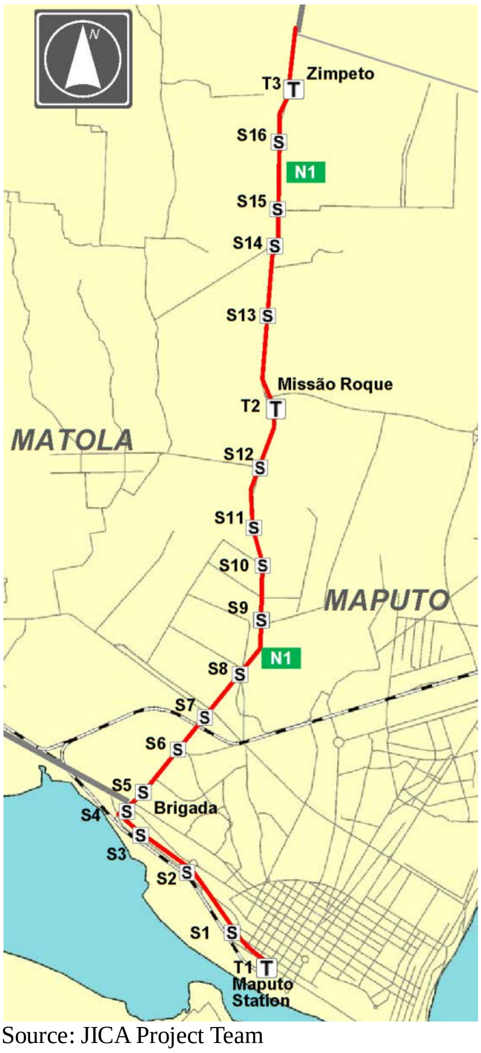
Section	Length	Terminal/Number of Stations	Station Distance
Maputo Station–Brigada	3.8 km	3 stations, 1 terminal	Avg. 950 m, Max. 1,500 m
Burigada–Missão Roque	8.7 km	9 stations, 1 terminal	Avg. 850 m, Max. 1,150 m
Missão Roque–Zimpeto	6.6 km	4 stations, 1 terminal	Avg. 1,100 m, Max. 1,200 m
Total	19.1 km	16 stations, 3 terminals	

Source: JICA Project Team

Table 5.5: List of Stations and Terminals of the BRT N1 Line

Line	No.	Location	Remark
Maputo Station Access Line	T1	Alto Mae B	CFM Maputo Station
	S1	Alto Mae B	Rua Paulino Santos Gil
	S2	Mai Anga	Praca 16 de Junho (Toyota)
	S3	Mai Anga	(Hospital Geral J. Macamo)
N1 Line (South)	S4	Mai Anga	N4 (Brigada)
	S5	Chamanculo C	Av. do Trabalho
	S6	Chamanculo C	Rua Gago Coutinho
	S7	Aepo Porto B	Av. Joaquim Chissano
	S8	InhagoiaB	Rua 2.551
	S9	25 de Junho	Rua de Sao Paulo
	S10	25 de Junho	Rua 5.500
	S11	25 de Junho	Rua 5.514
	S12	Georoge Dimitrov	Av. 4 de Outubro (Benfica)
	T2	Georoge Dimitrov	Av. M. Lurdes Mutola
N1 Line (North)	S13	Zimpeto	
	S14	Zimpeto	Rua. De Macute
	S15	Zimpeto	Av. Nelson Mandela
	S16	Zimpeto	
	T3	Zimpeto	(Stadium/Chapa Terminal)

Source: JICA Project Team



Source: JICA Project Team

Figure 5.16: Location of Stations and Terminals of N1 Line

5.2.7 Stations and Other BRT Facilities

In many cases, architectural design simply follows functional requirements as determined by the operational plan, although the aesthetics of station and terminal should be considered carefully as it affects the users' willingness to "accept" the system, and thus, impacts ridership.

The stations will be designed to attract passengers. In this case, modernized appearance will be applied for the stations to make an impression of new class public transport in Maputo City.

(1) Stations

The design components of the stations (shape, colors, materials, etc.) will be varied. In this case, the basic materials are steel and glass, which gives a modern and light design due to their high reflectivity and transparency.

The station image is shown in Figure 5.17. The glass has good transparency, but as a downside it requires daily cleaning.

Source: JICA Project Team

Figure 5.17: Bus Station

Main frame (column & beam) are steel with anti-corrosion paint. Roofing will be in heat reflective sheeting. No ventilation equipment is installed for the stations. Basically, louver is used for natural ventilation considering transparency.
Station structures are planned for all the 16 stations (plus 3 terminals) arranged on the BRT route as shown in Table 5.6.

Table 5.6: Station Structure List (N1)

No.	Name	Location (km)	Length (m)	Width (m)	Area (m^2)	Remarks
1	T1 (Maputo Station)	0.000	-	-	-	Terminal; refer to 5.2.9
2	S1	0.600	20.0	3.5	70.0	
3	S2	2.050	20.0	3.5	70.0	
4	S3	3.225	20.0	3.5	70.0	
5	S4 (Brigada)	4.000	20.0	3.5	70.0	Near intersection
6	S5	4.475	20.0	2.0	40.0	
7	S6 (Junta)	5.475	20.0	2.0	40.0	
8	S7	6.225	20.0	3.5	70.0	At intersection
9	S8	7.275	20.0	2.0	40.0	
10	S9	8.425	20.0	2.0	40.0	
11	S10	9.375	20.0	3.5	70.0	At intersection
12	S11	10.150	20.0	2.0	40.0	
13	S12 (Benfica)	11.200	20.0	3.5	70.0	Near Chapa Terminal
14	T2 (Missão Roque)	12.350	-	-	-	Terminal; refer to 5.2.9
15	S13	13.550	20.0	2.0	40.0	
16	S14	14.925	20.0	2.0	40.0	
17	S15	15.950	20.0	2.0	40.0	
18	S16	16.725	20.0	2.0	40.0	
19	T3 (Zimpeto)	17.900	-	-	-	Terminal; refer to 5.2.9
20	(S17)	18.600	20.0	2.0	40.0	Future
21	(S18)	19.100	20.0	2.0	40.0	Future (at the ring road)

Source: JICA Project Team

In Table 5.6, the distance from T1 is shown as “Location” (rounded up). It is recommended that the station names be chosen based on local public reference points.

All the dimensions of width and length are shown on a “center-to-center” basis. The length of the station structure is 20 m, which is sufficient for the assumed 20 m long articulated buses. The station width is 2.0 m or 3.5 m – this depends on the location of the station and is governed by other constraining factors on road width/cross-section.

The station platform size will have an impact on the passenger flow and comfort. Minimum area required for waiting passengers is estimated by the following equations[1]:

$Aw = Qp / Dw_{max}$

Where: Aw = Minimum area required for waiting passengers

Qp = Maximum number of passengers projected to queue

= Σ Pbbi (Average number of passengers boarding per 1 BRT bus on i line)

Dw_{max} = Capacity of a square metre to hold waiting passengers

It is assumed that each BRT bus will have a capacity of 160 passengers (as shown in Chapter 3 of Pre-FS report). Normally, 3 passengers per square meter is assumed as a capacity for waiting passengers.
Accordingly, the area Aw is calculated as 160 / 3 = 54 m^2 for the station with one-sided platform (single line), and 320 / 3 = 107 m^2 for the station with two-sided platform (double line).
The platform area is designed for the capacity of two BRT buses (108m^2 for single line, 214 m^2 for double line) at a minimum to secure the passengers’ safety.

[1] Bus Rapid Transit Planning Guide June 2007, published by Institute for Transportation & Development Policy (ITDP), USA

(2) BRT Facilities

The following facilities are required to operate the BRT system. All of them are arranged at the two end terminals (Zimpeto and Maputo Station).

- Repair & maintenance
- Car wash
- Petrol station
- Parking spaces
- Office (including ticket office)
- Waiting room/space
- Other facilities as necessary

5.2.8 Feeder Services and Intermodal Transfer

Transfer stations and/or facilities are crucial to facilitate easy and effective passenger movement. Feeder services and intermodal transfer facilities should be planned carefully to facilitate passenger movement between different services.

Feeder bus services will be arranged at the three terminals, T1 (Maputo Station), T2 (Missão Roque), and T3 (Zimpeto) on the BRT route.

Bus bays for BRT and feeder buses are arranged parallel to each other to increase the ease of transfer. The transfer will be free, so fare evasion is not a concern.

5.2.9 Terminal and Depot – Basic Design Specifications

Three terminals are planned on this BRT route, at Zimpeto, Missão Roque, and Maputo Station.

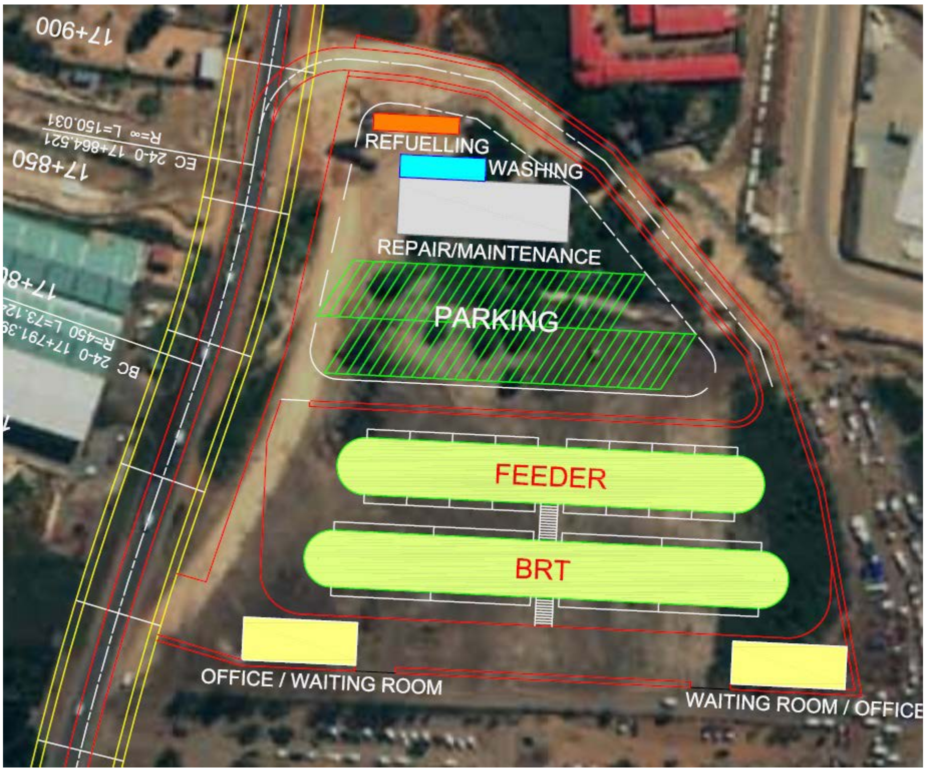
Zimpeto Terminal (T3) has the largest area among three terminals because of the main depot. Missão Roque Terminal (T2) is a transfer terminal, and thus no buildings and facilities are arranged. Maputo Station Terminal (T1) will be arranged carefully as it is located in the central area of Maputo City. All terminal and depot areas will be paved with concrete.

The parking space allocated for each bus type is as follows:

- BRT bus (articulated bus of 20 m length): 35 m length, 3.5 m width
- Feeder bus (standard bus of 10 m length) : 20 m length, 3.5 m width

(1) Zimpeto Terminal (T3)

Zimpeto Terminal is located near the national stadium "Estádio do Zimpeto", which has a capacity of 42,000 spectators and an assumed area of about 37,000 m^2, and is a multi-use stadium which opened on April 23, 2011. The general layout is shown below.



Source: JICA Project Team

Figure 5.18: General Layout of Zimpeto Terminal & Depot

Zimpeto Terminal is arranged to face the "Zimpeto Market," which is one of the biggest local markets in Maputo. There are two office buildings in the terminal, including offices and a staff waiting room, arranged to the southeast and southwest near the market.

The bus bays are covered with roofs for passengers. The amount of bus bays planned at the terminal are sufficient to handle the projected 32,000 passengers/day in 2020.

Table 5.7: Bus Bays (Zimpeto Terminal)

Name	Number	Length (m)	Width (m)	Remarks
BRT bus	8	35	3.5	20 m articulated bus
Feeder bus	16	15	3.5	10 m bus

Source: JICA Project Team

The depot of this terminal will be a main base for the BRT fleets. Facility buildings and/or areas to be required for Zimpeto Terminal are summarized in Table 5.8. These buildings/areas are surrounded by the in-plant road for easy access to the 58 parking spaces.

Table 5.8: Facility Buildings (Zimpeto Terminal)

Name	Length (m)	Width (m)	Area (m^2)	Remarks
Repair & Maintenance	60	20	1,200	
Car Wash	30	8	240	
Petrol Station	30	6	180	
Office	40	15	600	including waiting space
Waiting Room	40	15	600	including ticket office

Source: JICA Project Team

(2) Missão Roque Terminal (T2)

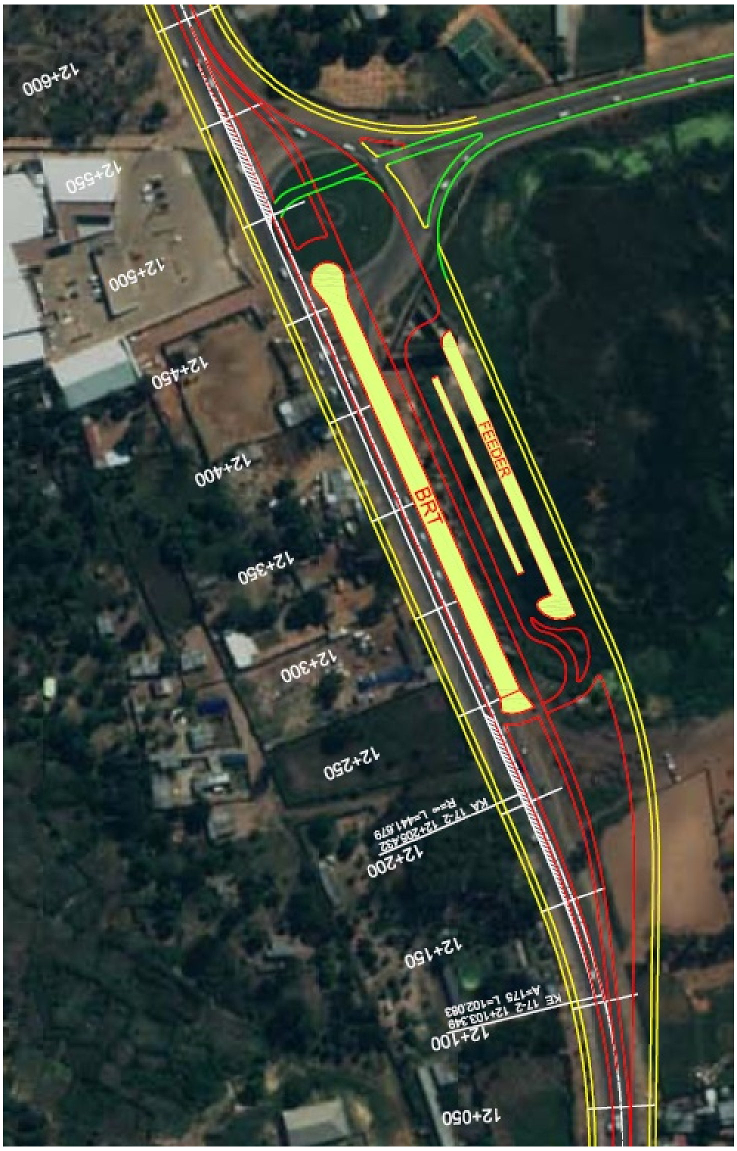
Missão Roque Terminal is planned at the intersection of N1 and Maria Lurdes Mutola Avenue. The area for this installation is approximately 5,000 m^2. The general layout is shown in Figure 5.19.

Missão Roque Terminal does not have buildings or facilities, and only bus bay structures for BRT and feeder buses are planned. This terminal is arranged to avoid the wetlands (used as a flood retention reservoir) on the east side of the N1.

Table 5.9: Bus Bays (Missão Roque Terminal)

Name	Number	Length (m)	Width (m)	Roof Area (m^2)	Remarks
BRT bus bay	12	200	10.0	2,000	20 m articulated bus
Feeder bus bay 1	6	120	2.5	300	10 m standard bus
Feeder bus bay 2	6	140	6.0	840	10 m standard bus

Source: JICA Project Team



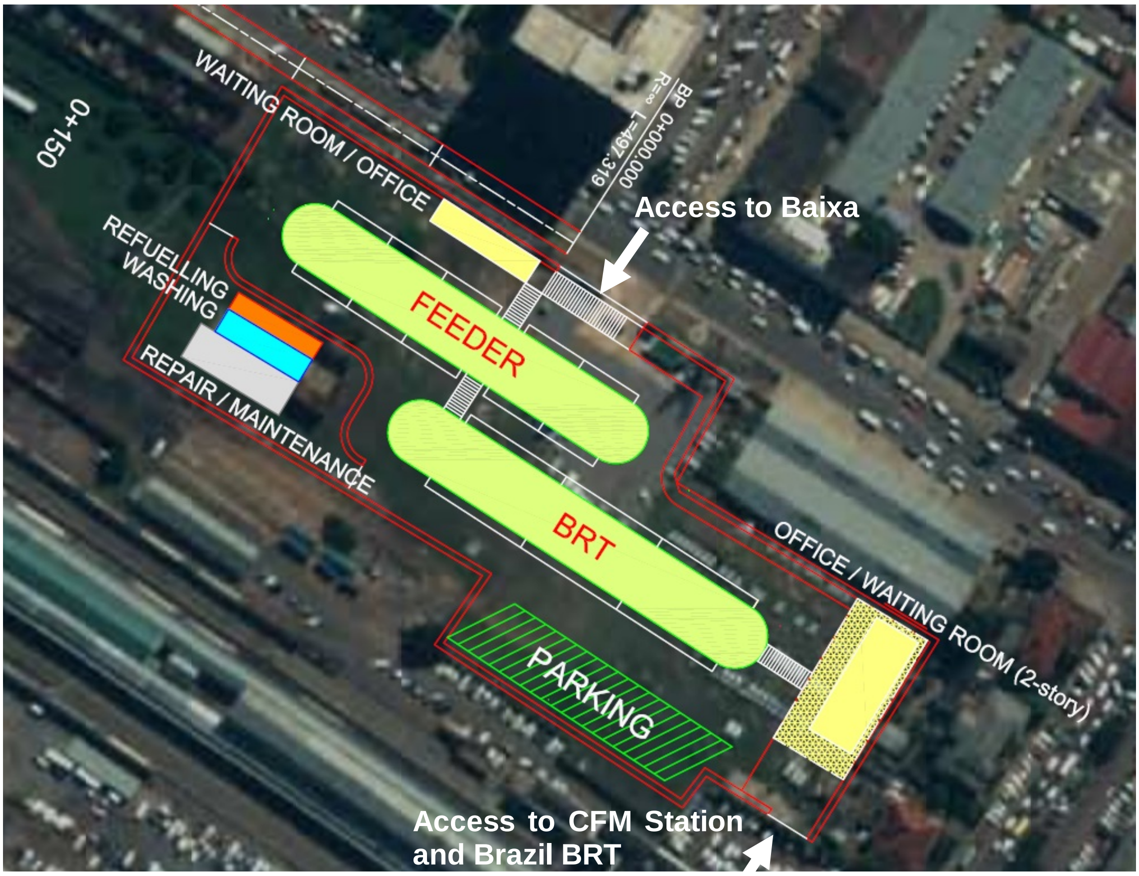
Source: JICA Project Team

Figure 5.19: General Layout of Missão Roque Terminal

(3) Maputo Station (T1)

Maputo Station Terminal is planned at the end of the route and next to the Maputo Central Station of CFM. Its area is assumed to be approximately 24,000 m^2.

Two accesses are arranged to achieve smooth transfer among terminals and commercial area. One is open to Baixa district, which is the biggest commercial center of Maputo city. Another access is at the south-east end of the premise to face the CFM station and the terminal of Brazil BRT, which is located at the south end of Av. Guerra Popular.



Source: JICA Project Team

Figure 5.20: General Layout of Maputo Station Terminal & Depot

The terminal locations around the CFM Station are shown in Figure 5.21.

Source: JICA Project Team

Figure 5.21: Terminal Locations around CFM Station

These BRT terminal developments together with the railway terminal developments will be a trigger of commercial and business development for the Maputo city center, which will be enhanced as a core of the public transportation network. These terminals will be in approximately 200 m × 300 m rectangular area and developed/operated as a part of the "terminal complex". Direct operation and inter-connected through service or mutual entry service will be considered in the BRT operation stage.

The number of bays is less than that of the end terminal at Zimpeto. When Phase III is completed and the entire BRT system is rolled out, the space allocated for feeders/extension to the New Downtown units can be easily transformed into trunk unit bays.

Table 5.10: Bus Bays (Maputo Station Terminal)

Name	Number	Length (m)	Width (m)	Roof Area (m^2)	Remarks
BRT bus bay	6	115	20	2,300	20 m articulated bus
Feeder bus bay	10	110	20	2,200	10 m standard bus

Source: JICA Project Team

Similarly, the facilities can also be adapted for a more efficient use of space.

Table 5.11: Facility Buildings (Maputo Station Terminal)

Name	Length (m)	Width (m)	Area (m^2)	Remarks
Repair & Maintenance	35	12	420	
Car Wash	30	8	240	
Petrol Station	30	6	180	
Office	40	15	1,200	2-story building including waiting space
Waiting Room	35	8	280	including ticket office

Source: JICA Project Team

The perspective view of the image of Maputo Station Terminal is shown in Figure 5.22.

Source: JICA Project Team

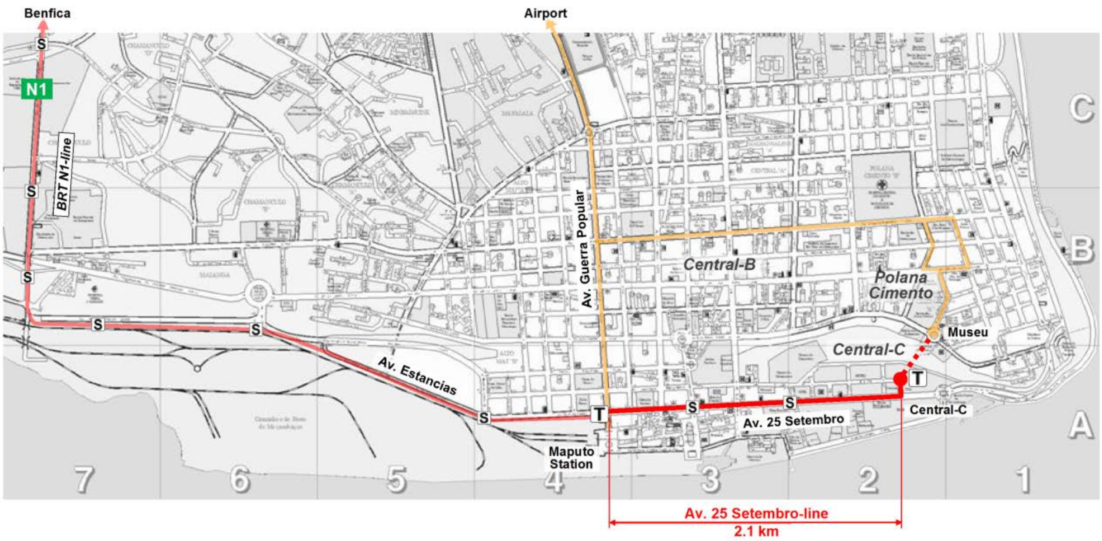
Figure 5.22: Perspective View of Maputo Terminal Station

5.3 Schematic Design of Optional Route

5.3.1 BRT 25 Setembro East Line Route

(1) Alignment Plan

As recommended in Chapter 4, a preliminary design should be carried out for the BRT 25 Setembro East Line. The design section is about 2.1 km from Maputo Station to R.1.231, which is located before a roundabout. The BRT alignment is placed in the median in consideration of the two-way roadside access to the N1 Line. Figure 5.23 presents the plan of the BRT 25 Setembro East Line.



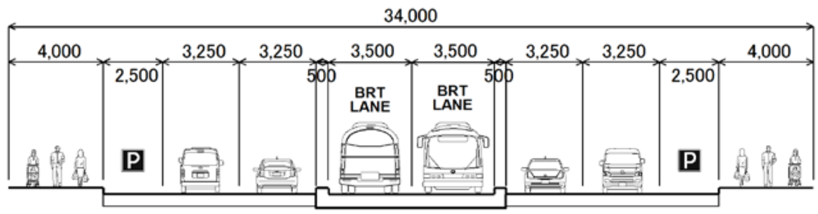
Source: JICA Project Team

Figure 5.23: Plan of BRT 25 Setembro East Line

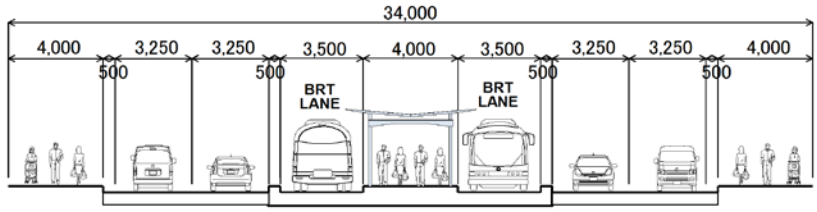
(2) Typical Cross-Section

The 25 Setembro East Line is a four-lane road which has a wide sidewalk and parking space on both sides. A proposed cross-section aims to secure the existing functions of traffic and space within the right of way as much as possible. The proposed typical cross-sections for the 25 Setembro East Line is shown in Figure 5.24.

General



BRT Station



Source: JICA Project Team

Figure 5.24: Typical Cross-Section of 25 Setembro East Line

(3) Station and Terminal Placement

Two stations are proposed in consideration of user needs at main intersections, and one terminal is located in the R. 1.231 block. The list of stations and terminals in 25 Setembro East Line is shown in Table 5.12.

Table 5.12: List of Stations and Terminals of the Maputo Station Access Line

No.	Location	Remarks
S1-b	Central C	Av. Samora Machel (Baixa)
S2-b	Central C	Rua Belmiro Obadias Muianga
T1-b	Central C	R. 1.231 (Edificio JAT)

Source: JICA Project Team

Station structures and terminals are as follows.

Table 5.13: List of Station Structures of the 25 Setembro East Line

No.	Location (km)	Length (m)	Width (m)	Area (m^2)	Remarks
T1 (Maputo Station)	0.000	--	--	--	Terminal – see 5.2.9(3)
S1-b	0.725	20.0	2.0	40.0	
S2-b	1.450	20.0	2.0	40.0	
T1-b	2.100	--	--	--	Terminal – see 5.2.9(3)

Source: JICA Project Team

The assumed area for T1-b is around 12,000 m^2, half of that of Maputo Station (T1). One office with a waiting room (600 m^2) will be included, while other facilities (repair & maintenance, car wash, and petrol station) will not be included at this location.

(4) Preliminary Project Cost Estimates

Preliminary project costs in this section are a reference for future implementation of the BRT, which is out of scope of the pre-F/S study project. Table 5.14 outlines the cost of the additional terminal, while Table 5.15 shows the total project costs of the terminal as well as the roadworks, intermediate stations, etc. required for the extension line. The total project cost is approximately USD 7.8 million.

Table 5.14: T1-b Terminal Project Costs (Preliminary)

Item	Area (m^2)	USD/m^2	Total Cost	Remarks
Bus bay structure	2,300	250	0.575	
Office	600	660	0.396	One-story building, including waiting space
Civil works	12,000		2.600	Concrete pavement
Total (USD million)			3.571	

Source: "Doing Business" Website and JICA Project Team

Table 5.15: BRT 25 Setembro East Line Project Costs (Preliminary)

Item	Cost	Remarks
Civil works		
Pavement	2.2	
Drainage	1.3	
Other	0.7	
BRT facilities and terminal cost	3.6	Not including management system
Total (USD million)	7.8	

Source: JICA Project Team

Note: Does not include engineering services costs.

5.3.2 N1 Bypass

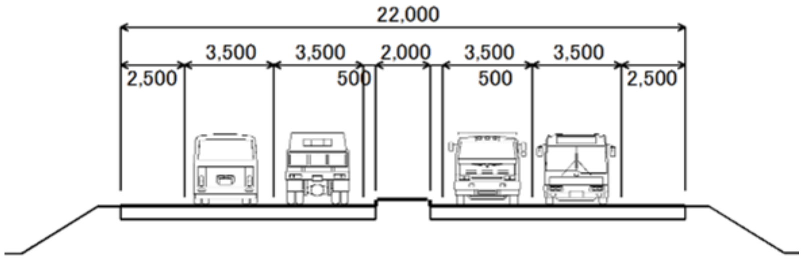
(1) Design Standard and Cross-section

As recommended in Chapter 4, a preliminary design is to be carried out for the N1 Bypass as a reference for future development. The section is about 8.5 km from the N4 tollgate to Missão Roque. The purpose of a bypass is to secure a smooth physical distribution of traffic and a comfortable urban condition. Truck traffic, a major source of congestion on N1, will detour to this bypass. In consideration of traffic volumes of about 35,000 vehicles/day by 2035, a four-lane road is proposed with a design speed of 80 km/h. Table 5.16 presents the design standards of the N1 Bypass, while Figure 5.25 presents the standard cross-section of N1 Bypass.

Table 5.16: Design Standard of N1 Bypass

Name	N1 Bypass
Length (Origin / Destination)	8.5 km (N4-tollgate / N1-Missão Roque)
Number of Lanes	4 lanes
Road Width	22 m
Road Classification	ANE's Primary
Design Speed	80 km/h
Road Specification	- Motorway access control - Low embankment structure, including flyover

Source: JICA Project Team



Source: JICA Project Team

Figure 5.25: Standard Cross-section of N1 Bypass

(2) Alignment Plan

The N1 Bypass is a route about 8.5 km long that passes through the farmland between Maputo and Matola; connected from N4 tollgate to Missão Roque. There are sparse residences in parts of the farmland. The topography is flat up to an estuary and has a small river in the middle of a farmland. Geologically, it mainly has a dune of red aeolian deposits. Near the river, it has alluvial deposits including sand, silt, and gravel. The design principles of the N1 Bypass are as follows:

- Traffic function should be considered a top priority, and the expressway access control should be planned;
- Flyovers should be designed above main intersections and at an existing road connection;
- A low embankment-type road structure should be designed in consideration of the existing box culvert being used by pedestrians (farmers); and
- Residential and farm resettlement should be considered.

Figure 5.26 presents the alignment plan of the N1 Bypass.

Source: JICA Project Team

Figure 5.26: Alignment Plan of N1 Bypass

(3) Preliminary Project Costs and Implementation Schedule

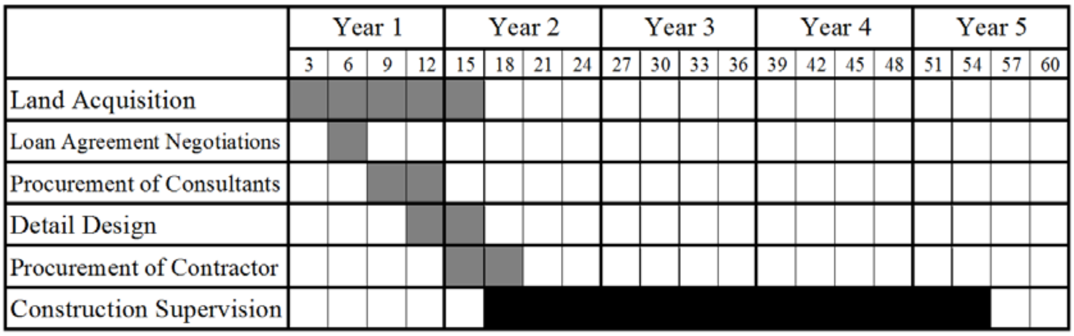
Preliminary project costs of N1 Bypass that are out of scope of the pre-F/S project are provided as a reference for further development as follows:

Table 5.17: BRT N1 Bypass Project Costs (Preliminary)

Item	Quantity	Cost
Civil works		
Road	8.5 km	23.1
Flyover	2	26.2
Bridge	5	11.3
Box culvert	16	1.9
Retaining wall	Many	3.0
Engineering services		9.8
Total (USD million)		**75.3**

Note: Does not include resettlement and land acquisition costs.
Source: JICA Project Team

The implementation of the N1 Bypass would require project duration of 4.5 years (54 months) and a construction time of 3.3 years (39 months). It is shown in more detail in Figure 5.27.



Source: JICA Project Team

Figure 5.27: BRT N1 Bypass Preliminary Project Schedule

Chapter 6 Operation Plan

6.1 Bus Operation Plan

Much of bus operation will depend on the design guide, practices of other countries and coordination with the designer and contractor of Phase I, which is supported by Brazil. As a result, some of the same elements were used in Phase II, the subject of this pre-feasibility study.

The electronic ticketing and revenue system will have to be the same if integration between systems is to be encouraged together with a 'Chamber of Compensation' to guarantee equitable revenue distribution between all the companies of the consortia (including owner/driver shareholders, the new feeder routes operators and possibly TPM).

The station elements will also have to be the same in terms of bus door access as will the doors and internal platform height of the bus fleet as well as the operational characteristics of the terminals.

It will also be important to maintain a common system image in signaling and the color coding of visual elements, logos, etc.

6.1.1 Fleet Characteristics

For the purposes of this study the bus units considered for trunk routes are all 20 m articulated units, which are now fairly standard for BRT use worldwide. These have the following basic specifications:

- Motor – Position: central, front or rear; Minimum power 310 HP (1550 Nm) Euro 4; Turbo-powered
- Transmission – Automatic
- Tires – Radial, Dimension: 29580 22.5" Street (tubeless Radial)
- Suspension – Pneumatic
- Dimensions – Length 20.3 meters, width 2.5 meters.
- Doors – 3, installed on the right side of the vehicle, electro-pneumatic, with a unobstructed width of 1,100 mm (minimum).
- Height from the ground – Loading and unloading height from the ground of 0.95 m (plus or minus 10 mm).
- Internal air conditioning.
- Emergency exits – At least 2 (two) doors and 2 (two) emergency windows on the opposite side of the main doors.

Source: Marco Polo Ltd., Brazil

Figure 6.1: Articulated 20 m Unit for BRT

Feeder buses will be conventional units with age limits, and higher than existing standards of maintenance, cleanliness, driver training and livery.

These will be fitted with card readers (or manual card readers if conductors are retained to minimize fare “leakage”) which allow passengers to access the BRT trunk route platforms (or other integrated services).

6.1.2 Fare Collection System

The electronic ticketing system is a set of software and hardware that manages travel credits to be used by users in public transportation. This has proven to be a powerful instrument for combating illegal transportation, gratuities and fleet monitoring.

Contactless smartcard technology has consolidated its position in the market due to reductions in price, increased transaction security, and simplicity of operation. The major benefits offered with the deployment of the system are:

- Revenue control
- Reduction of costs
- Reduction of revenue evasion
- Control of gratuities
- Control of beneficiaries
- Control of off peak discounts
- Elimination of the parallel market
- Ease of access to users with shorter boarding
- Generation of operating statistics
- Better working conditions for system operators
- Reduction in the use of cash on-board and the associated risks of robbery
- Future possibility of integration of the lines of the mass transit systems as the use of card allows the user to transfer between lines over a given time period (Temporal Integration)
- Allows recharging of credit at various points
- Allows the audit of cards, credits and operators
- Allows user loyalty programs to be considered as a marketing tool
- Allows the refund of credits in the case of loss or theft of the card for registered users

The automatic electronic ticketing system is composed of:

- **Card Readers:** on-board, electronic smart card readers.
- **Contactless cards:** Smartcards with large storage capacity and processing of information, without the need for contact with the read and write drives. These cards can accumulate various types of credits in a same card.
- **Communication System:** This is installed on BRT Buses and at the Depots and is a system based on a wireless local area network for the communication and transfer of information between the bus and the depot computers. This system enables the bus to enter the local network coverage area, to transfer the information contained in the card readers, and receive information from the depot system, without the need for any special positioning, thus streamlining the entire process.
- **Depot Accountancy:** This is a set of equipment, software and applications for sending and receiving information between the bus and the central control system, in addition to the control and management of accounts of the collectors in the treasuries of enterprises.

- **Central Control System:** This is a set of equipment, software and applications, for the storage and centralized processing of all the information received, as well as the distribution of the processed data. In addition this handles the management of user registration, issuance and control of gratuities, issuance, control and sale of student cards, and issue and control of any "technical staff" cards. This system is also responsible for the control and management of sales and registration.
- **Registration stations:** These are the equipment and software for passenger service – the registration, sale, issuance of the cards, and recharging at sales points.
- **Sales Points:** Equipment and software where passengers can buy reload or check their card balance for use in public transportation.

6.2 Trunk Route Characteristics

6.2.1 Operational Data

The basic operational plan is based on the model data obtained for the BRT systems (Phases I and II) in the base year of 2020. This allows for a lead construction time of four years for Phase I and a follow-on time of two years to build up Phase II.

Cordon line counts were used to establish the peak load factor as well as the directional loadings.

The node with highest daily flow was Missão Roque (N813) with 45,839 trips/day in the morning peak. This corresponds to the Benfica region, towards the City Center. In the opposite direction the highest daily flow was at node N814 (Junta)– also in the Benfica zone – with 42,553 trips.

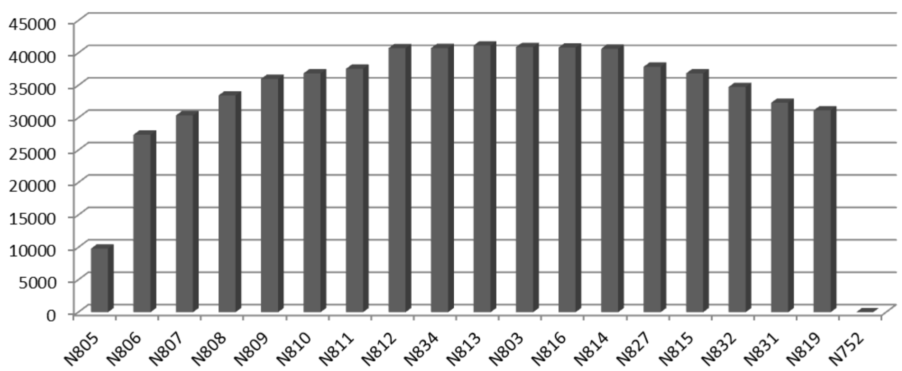
The model predicts the following data:

Table 6.1: Model Operational Data (2020)

Max daily load on directional link	45,839
Peak hour factor	10%
AM peak hour directional flow	4,584
Total daily passenger boardings	106,314

Source: JICA Project Team

The model also clearly shows that the corridor has two main levels of demand: from the Center (N819) to Missão Roque and a reduced level from Missão Roque to Zimpeto (N805), as shown in Figure 6.2.



Source: JICA Project Team

Figure 6.2: Passengers Transported per Hour (Direction: Zimpeto–Center)

The main trunk routes for Phase II are thus considered to be:

- Zimpeto–CFM (stopping at all stations)
- Missão Roque–CFM (stopping at all stations)

The demand levels to the south of Missão Roque (Benfica) and to the north (Zimpeto) require different service levels and, as such, there is a turnaround at Missão Roque for the trunk route ending at this point and separate platforms for the Zimpeto and Missão Roque Routes.

During peak hours it is expected that the demand for through services will be significant enough for additional through routes:

- Zimpeto–CFM (stopping at Missão Roque – direct)
- Missão Roque–CFM (direct)

Thus the Missão Roque and CFM Terminals will need four distinct platforms in each direction for the trunk routes of Phase II BRT.

The CFM terminal will also need a provision for similar number of platforms for the Phase III operations.

In addition, a peak extension of the Missão Roque route could be made to the New Downtown zone. During the off-peak it is expected that a separate 'shuttle' route will run between the CFM and the New Downtown Terminal (and also the elevator link to Museo).

Table 6.2: Trunk Routes for Phase II

Route	Service Type
Zimpeto–CFM	stopping at all stations
	direct, one stop at Missão Roque
Missão Roque–CFM	stopping at all stations
	direct (no stops)

Source: JICA Project Team

6.2.2 Trunk Fleet Dimensioning

The amount of trunk fleet needed is determined by the number of units needed to carry the peak hour load on the highest loaded stretch (Volume/Capacity of 1, or 100% loaded).

A BRT speed of 25 kmh has been used – a value slightly higher than in some Brazilian cities but significantly lower than some more modern systems (the more direct route of the Transoeste in Rio, for example, operates at 48 kmh).

This has assumed that the traffic problems encountered due to encroachment and at signals would be offset by the use of direct or semi-direct services and the faster travel times in the segment next to the railway corridor.

6.2.3 Feeder Bus Fleet Dimensioning

Feeder fleet tends to be more complex as, in principle, the fare is a flat fare and there is always the political temptation to increase not only the number of feeder routes but also their extension and frequency. This can quickly increase overall system costs.

At this design stage a basic network of four feeder routes at each terminal has been established, with a distance compatible with the geographical occupation. This extension is shown as the round trip.

Table 6.3: Feeder Routes

Feeders Zimpeto		**Ext. km**
Feeder 1	Ring Road West	15.0
Feeder 2	Ring Road East	15.0
Feeder 3	N1	10.0
Feeder 4	Local	8.0
Feeders Missão Roque		**Ext. km**
Feeder 1	West	8.0
Feeder 2	East	8.0
Feeder 3	North N1	8.0
Feeder 4	Local	8.0

Source: JICA Project Team

Table 6.4: Operational Data, Fleet and Mileage

Route			Demand by		Ext.	Trips /	Trips /	Headway	Joruney time		Operation Distance (km)	
Name	Via	Type	up	down	(km)	day	hour	(min)	(min)	Fleet	Work day	Month
Zimpeto − CFM	Jardim	Trunk	2,400	1,000	36.4	120	12	5	87	17	4,368	122,304
Missão Roque − CFM	Benefica	Trunk	2,184	2,025	25.2	110	11	5	60	13	2,772	77,616
									Subtotal	**30**	**7,174**	**199,920**
Feeders Zimpeto												
Feeder 1	Ring Road West				15.0	40	4	15	45	3	600	16,800
Feeder 2	Ring Road East				15.0	40	4	15	45	3	600	16,800
Feeder 3	N1				10.0	40	4	15	30	2	400	11,200
Feeder 4	Local				8.0	40	4	15	24	2	320	8,960
Feeders Missão Roque												
Feeder 1	West				8.0	40	4	15	24	2	320	8,960
Feeder 2	East				8.0	40	4	15	24	2	320	8,960
Feeder 3	North N1				8.0	40	4	15	24	2	320	8,960
Feeder 4	Local				8.0	40	4	15	24	2	320	8,960
									Subtotal (Feeders)	**18**	**3,200**	**89,600**
									Total	**48**	**10,340**	**289,520**

Source: JICA Project Team

6.3 Operating Costs

The two vehicle types indicated for trunk and feeder operation – a 20 m articulated unit and a 10 m conventional unit – have well-known and transparent operating costs per kilometer in usage in world-wide BRT systems.

Based on Brazilian experience, these operating costs can be broken down, as shown in Table 6.5, by:

a. dependent costs (fuel, tires, spares and maintenance);
b. staff (including social and other benefits and administration);
c. depreciation of vehicles and buildings;
d. remuneration of investments; and
e. taxes.

Table 6.5: Operational Cost per km per Unit Type

	10m Unit	Articulated 20m
Dependent Costs	**0.2860**	**1.0804**
Fuel	0.1837	0.7345
Lubrification	0.0074	0.0294
Tires	0.0236	0.0626
Spares and maintenance	0.0713	0.2539
Operational Staff	**0.8731**	**1.3113**
Operational Staff (plus Social Welfare Costs)	0.7319	1.0805
Benefits	**0.0743**	**0.1321**
Lunch vouchers	0.0610	0.1085
Health Insurance	0.0120	0.0213
Life insurance	0.0013	0.0022
Assistance Fund	0.0106	0.0155
Administrative Staff (plus Social Welfare)	0.0563	0.0832
Administration	**0.1209**	**0.1423**
General Administration	0.0449	0.0663
Operational Administration (Central Control)	0.0760	0.0760
Depreciation	**0.1745**	**0.3648**
Vehicles	0.1656	0.3448
Buildings and Installations	0.0089	0.0200
Remuneration	**0.2547**	**0.4717**
Vehicles	0.1268	0.2478
Sales Tax	0.0680	0.1130
Instalations	0.0390	0.0761
Tax and Rates	0.0209	0.0347
Taxes on Invoices	**0.1826**	**0.3600**
TAX BASE	**1.7093**	**3.3705**
Federal Taxes	**0.0691**	**0.1362**
Social Tax on Overall Earnings 1	0.0123	0.0242
Social Tax on Overall Earnings 2	0.0568	0.1119
Municipal Taxes	**0.1135**	**0.2238**
Service Tax on Invoices 1	0.0378	0.0746
Service Tax on Invoices 2	0.0757	0.1492
Total Cost/km	**1.8919**	**3.7305**

Source: JICA Project Team

Essentially, this cost is directly dependent on rolling stock and staff: the number of buses on the road during the peak hour.

Smaller units have higher staff costs as they tend to operate less in the off-peaks – drivers have to be paid for the full shift even if the unit is at the depot.

This model does present one major flaw: it is a cost per km (and often per road type – hilly, paving type, etc.), but does not consider speed. Obviously, a unit operating at a higher and smoother speed, with fewer stops/stations, fewer stops at signals (priority signaling) and no congestion stopping and starting, will have a lower cost per km.

Nevertheless, 20 m articulated buses are now the industry standard for BRT and these costs now reflect the normal operating conditions of wider spacing between stops and a running speed of over 20 kmh.

6.4 Fleet Costs

These are the standard specifications for most BRT fleet worldwide. The unit cost of a BRT bus is USD 280,000. It is possible that in consideration of the positive social impacts of the introduction of the BRT system that import duties could be waived for the BRT fleet, but for this analysis a 5% import duty and 1% import cost were nevertheless included, for a final unit cost of USD 296,800.

The fleet requirement to meet demand in Phase II in 2020 is estimated at 30 units (see Table 6.4). Standard practice requires at least a 10% reserve capacity and reserve fleet (for maintenance, accident repair, etc.). For this project, a spare fleet of four units will be used, two each for the North and South BRT segments. Therefore, the total fleet requirement will be 34 units.

This would require a capital investment of USD 10,091,000.

Feeder buses will either be operated as part of the BRT or be subcontracted. In the latter case, the 10 m units would be formed from the more modern and serviceable units of the existing fleet. Depreciation costs of both fleets are included in the operational costs.

6.5 Fares

Based on the operating costs per unit type per kilometer in Table 6.5, an estimate of daily fleet operation costs is shown in Table 6.6 below:

Table 6.6: Fleet Operating Costs

	Feeder bus	BRT bus
Total Cost/km (USD)	1.8919	3.7305
km/day	200	6,188
daily cost (USD)	6,054	23,084

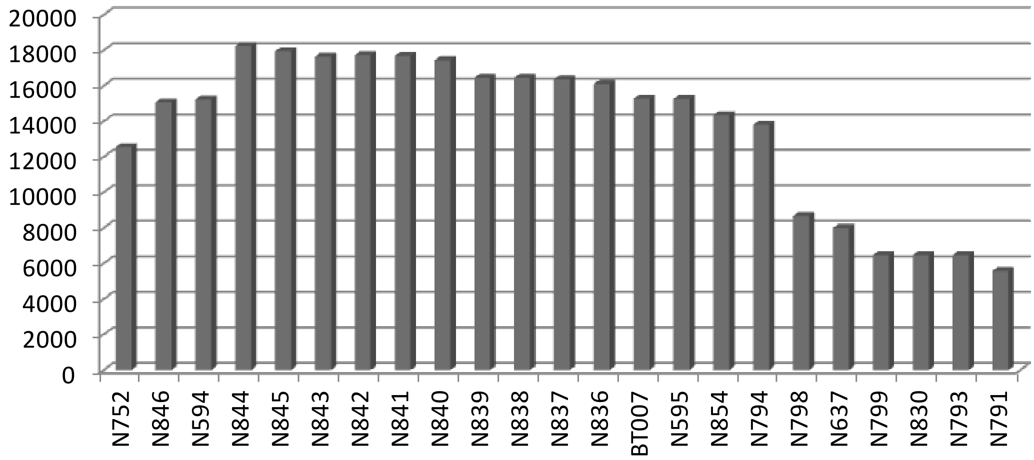
Source: JICA Project Team

Given a total daily passenger demand of 91,500 integrated trips, the break-even fare is thus about USD 0.32.

However, this does not include the probable extension of new feeders, the costs of the Phase I and II links along the Ring Road and from Maria Lourdes Mutola, nor the extension to the New Downtown (or eventual discount for the elevator link).

6.6 Integration with Phase I

Similar simulations show that the expected 2020 daily passenger flows on Phase I to be of the order of 61,853/day. This estimate is probably on the low side due to the difficulty in modeling the feeder routes. However, the peak link loading/direction during both the morning and evening peaks is close to 2,000 pax./hour/direction for most of the trip as can be seen in Figure 6.3



Source: JICA Project Team

Figure 6.3: Passengers Transported per Day – Phase I (2020); Direction: Praça da Juventude

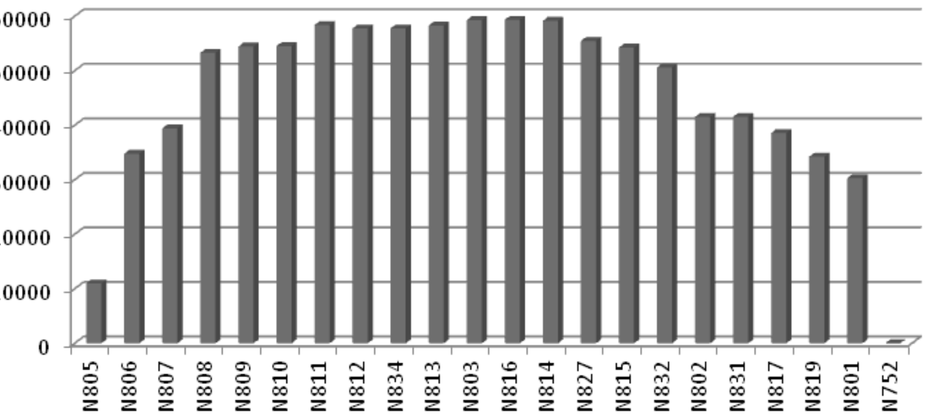
Thus the expected trunk routes would be a semi-direct service and a service that stops at all stations. A similar exercise indicates that a break-even fare would be around USD 0.25. When the additional cost of including the Museo link is considered, this fare level would be similar to Phase II.

Thus, if import duties on the units, tires and spares are kept to a minimum, then an integrated fare level of about USD 0.50 should be financially feasible for both Phases I and II.

6.7 BRT in 2035

A check has been made on the expected demand levels for both Phases I and II for the horizon year 2035.

For the JICA Project - Phase II, the predicted demand levels are shown below in Figure 6.4.



Source: JICA Project Team

Figure 6.4: Passengers Transported per Day – Phase II (2035); Direction: Zimpeto–Center

Peak hour loadings can be seen to be around 6,000 pax./hour/day (using the peak load factor of 10%). This is well within the capacity of the BRT and is equivalent to a headway of about two minutes.

Chapter 7 Preliminary Cost Estimates

Considering that there is no precedent in Maputo City for the construction of such a large system, certain costs are difficult to estimate. However, given the price estimates on documents provided by Maputo City, it was found that construction costs in Maputo are actually similar to those in Japan. Therefore, Japanese costs have been applied in those cases where no local cost information is available – such as the BRT stations.

7.1 Cost Estimate by Component

7.1.1 Civil Works

(1) Unit Cost of Major Civil Works Items

The unit costs of major civil works items estimated by the JICA Project Team were based on the Maputo City Roads Contract for Rehabilitation of Streets (Package 1). The price inflation in Mozambique is increasing every year, and the International Monetary Fund (IMF) forecasted that price inflation in 2013 will be at 5.44% as indicated in Table 7.1. As per Table 7.1, the total price inflation from 2006 to 2013 is 64.95%.

The JICA Project Team estimated the unit cost of civil works by referring to the forecasted inflation rate of the IMF. However, the bridge and asphaltic base course costs were not obtained during this work period. Therefore, these costs were assumed. The unit costs of major civil works items are shown in Table 7.2, including taxes.

Table 7.1: Annual Average Inflation in Mozambique for the Past Eight Years

Year	2006	2007	2008	2009	2010	2011	2012	2013
Annual Average Inflation (%)	13.245	8.161	10.326	3.255	12.699	10.351	2.091	5.44

Note: Inflation in 2012 and 2013 are indicated IMF staff estimates.
Source: IMF, World Economic Outlook Database, April 2013

Table 7.2: Unit Cost of Major Civil Works Items

Work Category	Description	Unit	Unit Cost (USD): Rehabilitation of Streets 2006	Unit Cost (USD): 2013 Estimation
Earth Work	Clearing and Grubbing	m^2	0.44	0.73
	Cutting	m^3	10.40	17.15
	Filling	m^3	8.47	13.97
Sub-base and Base	Asphaltic Base Course (t=12.5 cm)	m^2		20.00
	Cement Stabilization	m^3	24.59	40.56
Surfacing	Asphaltic Wearing Course (t=4 cm)	m^2	11.06	18.24
	Tack Coat	m^2	0.38	0.63
	Concrete Slab	m^3		134.67
Removal Work	Breaking of Existing Road Pavement	m^3	33.92	55.95
Drainage	Pipe Culvert (D=600 mm)	m	158.17	260.90
Structure	Bridge	m^2		4,400.00
	Curb Block	m	20.05	33.07

Note: Asphalt base course and bridge cost are assumed costs.
Source: JICA Project Team

(2) Total Estimated Civil Works Cost

The total estimated civil works cost is shown in Table 7.3. It is estimated to be USD 32.4 million.

Table 7.3: Estimated Civil Works Cost

Work Category	Cost (USD)
Earth Works	5,790,000
Sub-base and Base	11,040,000
Surfacing	8,210,000
Removal Works	2,240,000
Drainage	410,000
Structure	2,480,000
Relocation	2,030,000
Others	170,000
Total Civil Works Cost	32,370,000

Source: JICA Project Team

7.1.2 BRT Facilities

Regrettably, as built, the existing stations and terminals observed in Maputo City were designed to meet only the basic functional requirements. Furthermore, their construction costs were not available, and could not be used as a baseline for estimates for BRT facilities.

Therefore, the unit cost in Japan has been applied after some research of construction costs and commodity prices in Maputo City.

(1) Stations

The design components of the stations (shape, colors, materials, etc.) will be varied, and accordingly, the costs will have a wide range. Based off data from the website of the Japan Ministry of the Environment[1], the range as follows (JPY 100 = 1 USD):

- Basic Design Station Structure: USD 17,000–23,000 per station
- Enhanced Design Station Structure: USD 29,000–41,000 per station

The suggested Enhanced Design Station (as explained in detail in Section 5.2.7) will presumably have the maximum cost of the range mentioned above (USD 41,000 per station), and this cost has been applied to the estimation in Table 7.4.

Table 7.4: Total Cost of Station Structure

Type	Number	Unit Cost (USD/station)	Total Cost (USD)	Remarks
Single bay type (Width: 2.0 m, Length: 20.0 m)	9	41,000	369,000	
Double bay type (Width: 3.5 m, Length: 20.0 m)	7	71,800	503,000	The area is 1.75 times larger than the single bay type
Total	16		872,000	

Source: Website of the Japan Ministry of the Environment and JICA Project Team

[1] https://www.env.go.jp

(2) Terminals & Depots

The building costs depends on the local cost of materials, labor, construction methods, etc. According to the "Doing Business" Website[2], a product of the World Bank and the International Finance Corporation (IFC), the unit construction cost for an industrial warehouse in Maputo City is roughly estimated as 330 USD/m^2. No inflation adjustment is required as the data was collected in 2013.

Based on this unit cost, a rough estimation can be done for construction costs of the buildings (bus bay structure, repair & maintenance building, office, and waiting Room) for terminals and depots. The rough trend of unit cost is as follows:

- Bus bay structure: 75% of an industrial warehouse → 250 USD/m^2
- Repair and Maintenance: Almost the same as an industrial warehouse → 330 USD/m^2
- Office: Twice the cost of an industrial warehouse → 660 USD/m^2
- Waiting Room: Almost same as an industrial warehouse → 330 USD/m^2

For the special facilities, the car wash and petrol station, this area-based cost estimation method cannot be applied because of the special equipment required. The rough cost estimation for these facilities is as follows:

- Car Wash: USD 200,000
  Washing machine: USD 100,000
  Utilities (piping works, drainage): USD 100,000

- Petrol Station: USD 1,000,000
  Underground tank: USD 800,000
  Metering equipment: USD 60,000
  Utilities (piping works, fire-fighting facilities, drainages): USD 140,000

The cost estimation for the three terminals, including the depots, is summarized in Table 7.5, Table 7.6 and Table 7.7.

Table 7.5: Cost for Zimpeto Terminal & Depot

Name	Item	Area (m^2)	Unit Cost (USD/m^2)	Total Cost (USD)	Remarks
Bus bay structure	BRT	3,000	250	750,000	150 m × 20 m
	Feeder	2,600	250	650,000	130 m × 20 m
	Total	5,600		1,400,000	
Building	Repair & Maintenance	1,200	330	396,000	
	Office	600	660	396,000	including waiting space
	Waiting Room	600	330	198,000	including ticket office
	Total	2,400		990,000	
Special Facilities	Car Wash	240		200,000	30 m × 8 m
	Petrol Station	180		1,000,000	30 m × 6 m
	Total	420		1,200,000	
Total				3,590,000	
Civil Works		37,000		7,150,000	Concrete pavement
Total				**10,740,000**	

Source: "Doing Business" Website and JICA Project Team

[2] http://www.doingbusiness.org/

Table 7.6: Cost for Missão Roque Terminal

Name		Area (m^2)	Unit Cost (USD/m^2)	Total Cost (USD)	Remarks
Bus bay structure	BRT	2,000	250	500,000	200 m × 10.0 m
	Feeder 1	300	250	75,000	120 m × 2.5 m
	Feeder 2	840	250	210,000	140 m × 6.0 m
	Total	3,140		785,000	
Civil Works		5,000		1,050,000	Concrete pavement
Total				**1,835,000**	

Source: "Doing Business" Website and JICA Project Team

Table 7.7: Cost for Maputo Station Terminal

Name		Area (m^2)	Unit Cost (USD/m^2)	Total Cost (USD)	Remarks
Bus bay structure	BRT	2,300	250	575,000	115 m × 20 m
	Feeder	2,200	250	550,000	110 m × 20 m
	Total	4,500		1,125,000	
Building	Repair & Maintenance	420	330	138,600	
	Office	1,200	660	792,000	2-story building including waiting space
	Waiting Room	280	330	92,400	including ticket office
	Total	1,900		1,023,000	
Special Facilities	Car Wash	240		200,000	30 m × 8 m
	Petrol Station	180		1,000,000	30 m × 6 m
	Total	420		1,200,000	
Total				3,348,000	
Civil Works		24,000		5,970,000	Concrete pavement
Total				**9,318,000**	

Source: "Doing Business" Website and JICA Project Team

(3) Permissions and Authorizations

To obtain permissions and authorizations for building construction, application fees are required for each procedure. According to the "Doing Business" Website, around 450,000 MT (USD 15,000) will be required in total.

(4) Summary

Total cost of construction and permitting of the three terminals and depots is summarized in Table 7.8.

Table 7.8: Summary of BRT Facilities Costs

Name	Type	Area (m^2)	Total Cost (USD)	Remarks
Station structure			872,000	Table 7.4
Terminal & Depot	Bus bay structure	13,240	3,310,000	
	Building	4,300	2,013,000	
	Special facilities	840	2,400,000	
	Total		7,723,000	
Total (Station structure/Terminal & Depot)			8,595,000	
Civil Works		66,000	14,170,000	Concrete pavement
Total (Station structures/Terminal & Depot/Civil Works)			22,765,000	
Permissions and Authorizations			15,000	MT 450,000
Total			**22,780,000**	

Source: "Doing Business" Website and JICA Project Team

7.1.3 Bus Fleet

(1) BRT Fleet

As outlined in Section 6.1.2, BRT requires a specialized set of fleet, and cannot reuse or recommission existing standard buses for its operations. This is mostly a consideration of function, in that these specialized buses greatly improve capacity and operational efficiency (by reducing loading/unloading times), but is also a factor of heightening the overall image or attractiveness of the BRT system. (Fare revenues are crucial to the financial success of the system, and attracting users to BRT is a key consideration of the infrastructure design choices.)

In general, the key fleet characteristics of BRT as compared to non-BRT are as follows:

Table 7.9: BRT vs. Non-BRT Fleet

BRT Fleet	Non-BRT Fleet
20.3 m long	10 m long
3 doors (front, middle, back)	2 doors (front, back)
Articulated units	Single unit
160 pax. (as per demand model)	60–80 pax.
Off-board fare collection	On-board fare collection

Source: JICA Project Team

These are the standard specifications for most BRT fleet worldwide. The unit cost of a BRT bus is USD 280,000. It is possible that in consideration of the positive social impacts of the introduction of the BRT system that import duties could be waived for the BRT fleet, but for this analysis a 5% import duty was nevertheless included.

Fleet size is dictated by the highest required capacity – that is, the fleet required to carry passengers during peak hours. Fleet requirements with respect to demand are detailed in Table 6.4 of Chapter 6.

A fleet of 30 units is required to meet the demand for this project. However, at a minimum, a 10% reserve fleet must be kept on hand to fill in for running fleet in cases of maintenance, accident repair, etc. For this project, a spare fleet of four units will be kept on reserve, two each for the North and South BRT segments. Fleet requirements and costs are summarized below in Table 7.10.

Table 7.10: Summary of BRT Fleet Requirements and Costs

	Units	Unit Cost (USD)	Cost (USD)
Base Fleet	30	280,000	8,400,000
Spares	4	280,000	1,120,000
Subtotal	34		9,520,000
Import Duty		5%	476,000
Import Cost		1%	95,200
Total			**10,091,000**

Source: JICA Project Team

(2) Feeder Route Fleet

As outlined in Chapter 6, a network of feeder routes running standard 10 m buses are required to bring users from areas outside the BRT network to the BRT terminals. Four feeder routes each are proposed for Zimpeto and Missão Roque Terminals (a total of eight routes).

However, no new fleet procurements will be required to service these routes; instead, existing 10 m buses will be rerouted/recommissioned to meet this demand. Therefore, while these routes contribute to operating costs in our financial modeling, there is no fleet procurement cost for these feeder routes.

7.1.4 Engineering Services and Other Costs

In this project, the engineering service cost is set at 15% of the total cost. The following are the studies assumed to be carried out under the engineering services:

- Topographic survey;
- Route survey (setting of center line, profile leveling and cross-sectioning);
- Boring survey;
- Consulting services in basic design and detailed design; and
- Consulting services in construction supervision.

In addition, some 20% of the cost of civil works and BRT facilities has been budgeted as "miscellaneous expenses" in construction based on the bill of quantity (BOQ) of other projects in Maputo. The following are the assumed items under miscellaneous expenses:

- Daywork such as labor, materials and contractor's equipment;
- Contractor's establishment on site and general obligations;
- Housing, offices, and laboratory for the engineer's site personnel; and
- Traffic management.

7.2 Total Project Cost

The total project cost is USD 88,965,000 (excluding Capacity Building), and the construction cost (which is the total of civil works and miscellaneous expenses) is approximately USD 400,000/lane-km. Compared with the general cost of road construction in Mozambique (approximately USD 350,000–400,000 /lane-km), this cost is considered reasonable. The estimated total project cost is summarized in Table 7.11. The breakdown of quantities and costs is attached in Appendix A.

Table 7.11: Estimated Total Project Cost

Work Category	Cost (USD)
Civil Works (Roads, Bridges, Culverts, Utilities, etc.) Cost	32,370,000
BRT Facilities (Station Structures, Terminal Buildings, Depots, etc.) Cost	22,780,000
Miscellaneous Expenses	12,120,000
Bus Fleet Cost[3]	10,091,000
Project Cost	77,361,000
Engineering Services (15% of Project Cost)	11,604,000
Total Project Cost (incl. Engineering Services)	88,965,000
Capacity Building[4]	4,000,000
Total Project Cost (incl. Capacity Building)	92,965,000

Note: The land acquisition and relocation cost is not included due to significant uncertainty involved in its estimate at this prefeasibility study stage.
Source: JICA Project Team

[3] Includes 5% import duty + 1% import costs
[4] See Chapter 9. Represents programs to facilitate the establishment of a metropolitan transportation authority and training for government personnel involved with transportation service delivery and planning

7.3 Operation and Maintenance Cost

(1) Operation Cost

A previously mentioned, two types of fleet operations will exist: a fleet of 10 m buses running on feeder routes, and a larger fleet of 20 m BRT buses on the main trunk routes (North and South Sections).

Both fleet types have well-documented per-km operation costs from worldwide usage in other BRT systems. Per-km costs were outlined in detail in Table 6.5 of Section 6.3, but the main elements are summarized below, based on Brazilian BRT experience:

Table 7.12: Summary of per-km Operation Costs

Item	Feeder bus	BRT bus
Dependent Costs (fuel, maintenance, etc.)	0.2860	1.0804
Operational Staff	0.8731	1.3113
Worker Benefits	0.0743	0.1321
Administration Costs	0.1209	0.1423
Depreciation on Capital Costs	0.1745	0.3648
Remuneration Costs	0.2547	0.4717
Taxes on Invoices	0.1826	0.3600
Total Cost/km (USD)	**1.8919**	**3.7305**

Source: JICA Project Team

The major cost components of the final per-km cost come down to fleet costs and staff costs. While in theory the per-km costs can be reduced if the system runs with higher efficiency (staff, fuel, fleet size requirement, etc. can all be reduced), the costs listed above in Table 7.12 reflect the normal operating conditions of 20 m BRT buses running with appropriate stop spacing and operating speeds of over 20 km/h.

To move from these per-km operation costs to a daily cost, the missing factor is demand. Given a total daily passenger demand of 91,500 integrated trips between the feeder and BRT buses, a daily cost of USD 29,138 is obtained, as per Table 7.13 below:

Table 7.13: Daily Fleet Operating Costs

	Feeder bus	BRT bus
Total Cost/km (USD)	1.8919	3.7305
km/day	3,200	6,188
daily cost (USD)	6,054	23,084

Source: JICA Project Team

(2) Maintenance Cost for Civil Works

The principal maintenance cost after construction will be for pavement repair. The annual maintenance cost is approximately USD 55,000 after completion of the Phase II project.

Computation of cost for pavement repair after 2020 is shown below.

- Lifetime period: 15 years
- Reliability of pavement: 90%
- Cost of surfacing: USD 8,210,000

USD 8,210,000 × 0.1 failure rate / 15 years = USD 54,733 per year

Thus, the annual maintenance cost after 2020 is approximately USD 55,000.

(3) Maintenance Costs for Buildings & Facilities

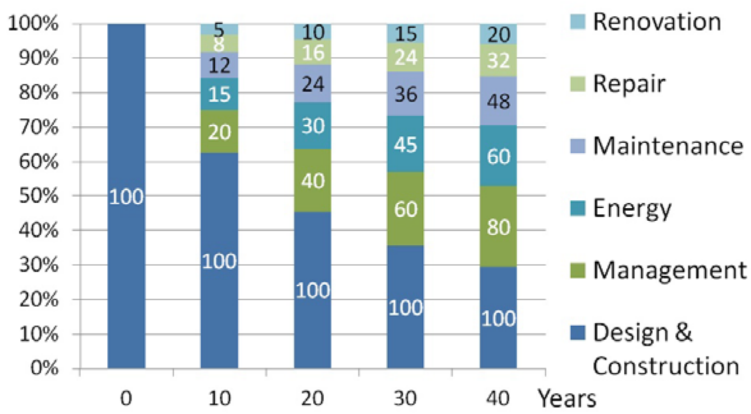
"Maintenance" cost for buildings & facilities are crucial considering the life cycle cost (LCC), especially for the long term. In general, the LCC of buildings & facilities includes the following components:

- Renovation
- Repair
- Maintenance (such as cleaning, daily checking, replacement, etc.)
- Energy (electricity, gas, etc.)
- Management (to organize maintenance, repair, and renovation works)
- Design & construction

In this case, maintenance is defined as "LCC except Design & Construction".

Naturally, just after completion of construction, maintenance cost consists of 0% of Life Cycle Cost (LCC). However, it will become more than 50% of LCC after 20 years, and become 70% of LCC after 40 years of the completion of construction.

In the *example* case below in Figure 7.1 for an office building in Japan, "Design & Construction" costs, the only cost in the first year, are 100. The figure shows how this shifts from 100% of LCC to below 30% after 40 years because of increasing maintenance and repair costs, suggesting that the maintenance work will be a big issue to consider for long-term financial planning.



Source: JICA Project Team

Figure 7.1: Example Case: Increasing Share of Maintenance and Repair Costs over Time

For BRT buildings and facilities, at least 50% of construction cost should be considered for maintenance during the 20 year period after project completion. The construction cost for buildings and facilities are estimated at USD 8,595,000 (Table 7.8). 50% of this is USD 4,298,000, and thus over the 20 year period maintenance costs are estimated to be USD 214,900 per year.

Chapter 8 Construction Implementation Plan

For the economic and financial evaluation of this project, the JICA Project Team conducted a study of the construction implementation plan. The construction implementation plan of this project is described below.

8.1 Construction Plan

The procedures for the construction of major works are as follows:

(1) Road Works
1) Preparatory works;
2) Relocation works for obstacles such as streets lighting, road traffic signs, and underground services;
3) Pavement works for road widening (drainage and pavement);
4) Road-switching and setting up median;
5) Pavement works for BRT (curb block, foundation for BRT station, concrete pavement, and asphalt pavement); and
6) Sidewalk works.

(2) Facilities Works
1) Architectural works for stations, terminals, and facilities; and
2) Appurtenant works for electricity, mechanical equipment, guard rails, traffic signs, etc.

(3) Bridge Works
1) Temporary earth retaining works,
2) Foundation and substructure works,
3) Girder fabrication works,
4) Erection works, and
5) Bridgedeck works, such as guard rails and pavement.[1]

8.2 Phased Implementation

As described in Chapter 4, it is expected that the implementation of the BRT north-south line in eastern Maputo (Baixa–Magoanine) will be started first, and thus it is referred to as Phase I, and that the BRT N1 line, the subject of this pre-F/S, is to follow as Phase II. Table 8.1 and Figure 8.1 outline the Phase II development by section.

- Phase I: North-South Line in Eastern Maputo (Baixa–Magoanine) (assisted by the Brazilian government)

- Phase II: BRT N1 Line (the subject of this pre-F/S)
  - North Section 6.6 km
  - South Section 12.5 km

[1] Note: In order to have road-switching, bridge works must be completed first. During bridge works, sufficient temporary facilities and safety management are required, because the bridge is adjacent to a busy road, houses, and in-service railway.

Table 8.1: Development of BRT N1 Line by Section (Phase II)

Section	Overview of Development
North Section	• Develop the north part of BRT N1 (Between Benfica–Zimpeto, approx. 6.6 km). • Develop the terminal on north side. • Procurement of appropriate size and number of BRT buses for the entire N1 line based on demand forecasting and operation plans (assuming a center BRT lane, with doors opening onto a platform on the right side) • Develop a depot. • Consider private car use on N1.
South Section	• Develop the south side of N1 (between Malanga–Benfica, approx. 8.6 km） as a BRT line (bus lane, bus stop, terminal development – includes preparations such as widening of bridges and roads, improvement of intersections, etc.). • Facilities for connecting to trunk bus routes. • Consider development of an exclusive road (for connecting to bus/rail) using the railway ROW between Malanga and Maputo Central Station (approx. 3 km) • Develop a depot. • Consider private car use on N1.

Source: JICA Project Team

Source: JICA Project Team

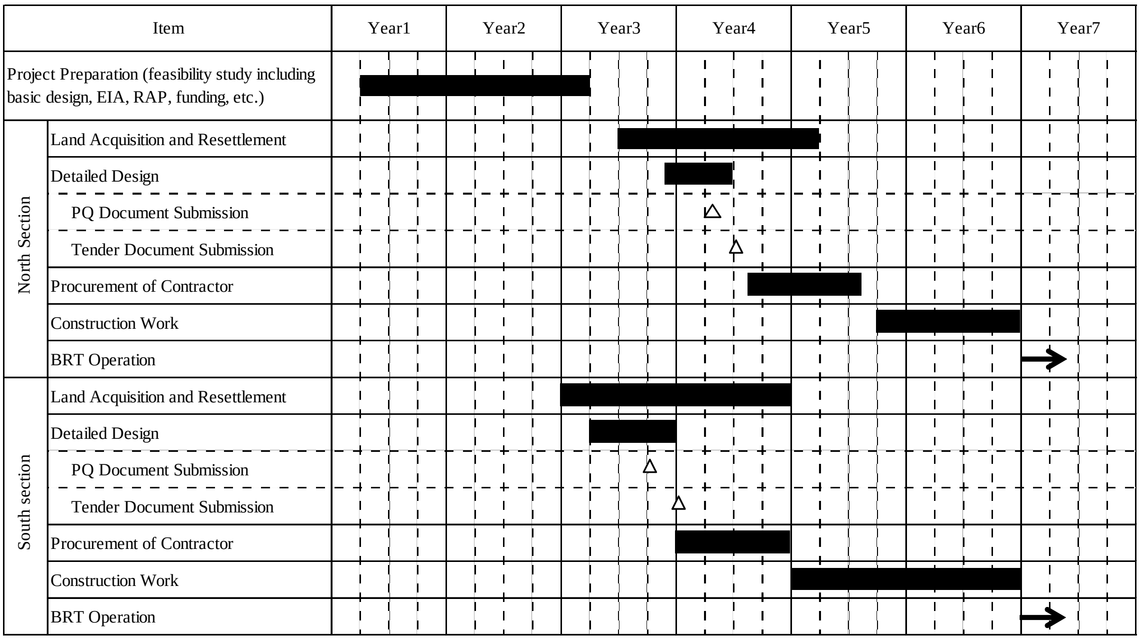
Figure 8.1: Development of BRT N1 Line by Section (Phase II)

8.3 Expected Implementation Schedule

Table 8.2 shows the project implementation schedule. This schedule is formulated with the following conditions:

- After completion of this JICA study, project preparation for the N1 BRT will be undertaken, including the following:
  - To implement a feasibility study on the N1 BRT (i.e., a more detailed study than this Pre-F/S) including, but not limited to, the preparation of a basic design and determination of the right-of-way (ROW)
  - To implement an environmental impact assessment (EIA) and prepare a resettlement action plan (RAP), both to be approved according to the relevant procedures designated in Mozambique
  - Funding arrangement for project implementation, which may include seeking external financing source(s)
- Once the project is approved and funding is secured, land acquisition and resettlement will be started.
- For the procurement of a contractor, pre-qualification (PQ) and tender documents will be finalized and submitted during the detailed design period.
- The duration of procurement of a contractor is estimated to take 12 months.
- The construction period for the North and South Sections is estimated at 15 months and 24 months, respectively.
- The operation of the N1 BRT is expected to start after six years of project preparation and implementation.

Table 8.2: Expected Project Implementation Schedule

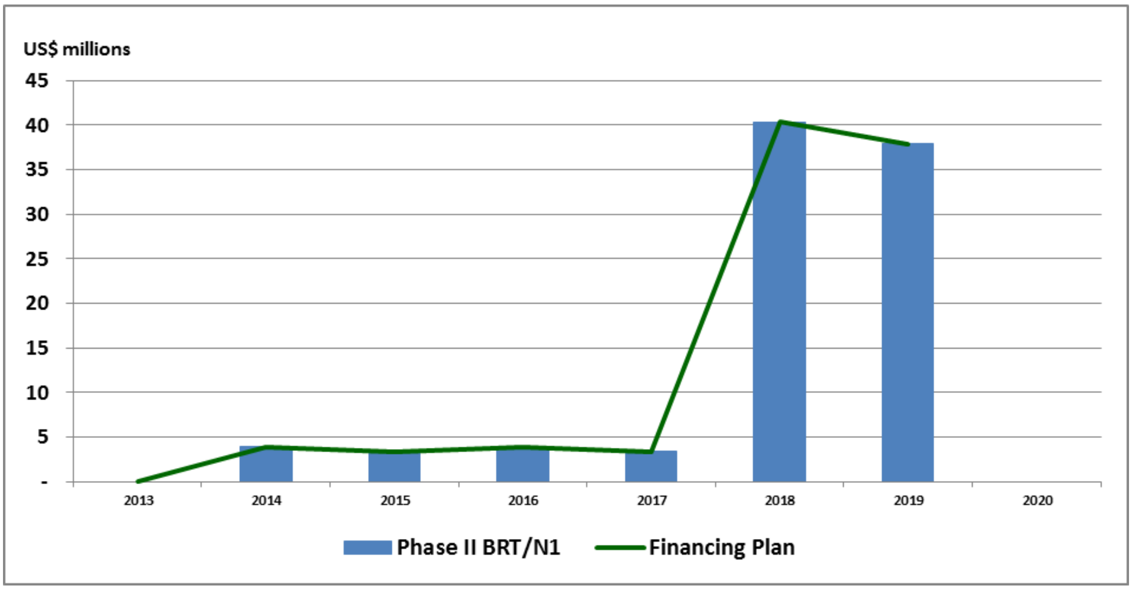


Source: JICA Project Team

8.4 Annual Fund Requirement

Expenditures between 2014 and 2019 for investment in Phase II of the BRT are estimated at USD 93.0 million (MT 2,812 million).[2] Funding for these expenditures is projected to be provided from existing sources including local capital funding sources, the Road Fund and MTFF, potentially with financial assistance from development partners.

The figure below displays annual project implementation expenditures and annual funding estimates.



Source: JICA Project Team

Figure 8.2: Phase II BRT Annual Project Expenditures and Funding

The following table identifies the suggested funding sources for implementation of Phase II of the BRT.

Table 8.3: Phase II BRT Annual Funding Requirement Detail

Unit: USD million

Fund Source	2013	2014	2015	2016	2017	2018	2019	2020
MTFF	--	--	--	--	--	0.9	7.8	--
Road Fund	--	2.0	0.9	2.3	2.5	2.7	3.0	--
FIA	--	1.9	2.5	1.7	0.9	4.4	4.2	--
Other Local[3]	--	--	--	--	--	32.3	22.9	
Total Funding	**--**	**3.9**	**3.4**	**4.0**	**3.4**	**40.3**	**37.9**	

Abbreviations: MTFF = Medium Term Fiscal Framework, FIA = Fundo de Iniciativa Autárquic
Source: JICA Project Team

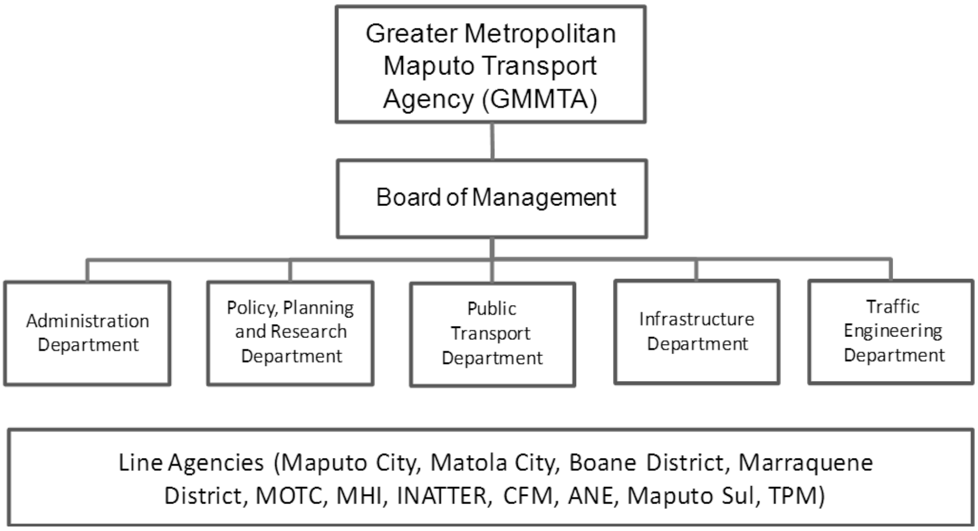
[2] All values are stated in constant 2013 prices.
[3] Includes central government transfers.

Chapter 9 Implementation, Operation, and Maintenance Scheme

9.1 Implementation Structure

9.1.1 Overall Structure

As recommended in the Master Plan Report for this study,[1] a Greater Metropolitan Transport Agency (GMMTA, or *Agencia Metropolitana de Transporte* in Portuguese) should be established as soon as possible because (among other reasons) it will allow for effective tendering, construction, and operation of the proposed BRT system, which crosses municipal boundaries. Indeed, the Phase II BRT (the subject project of this JICA prefeasibility study) will follow the Phase I BRT (to be developed by a Brazilian contractor with financing from EXIM Brasil, the Credit Agency for Exports from Brazil), the promoters of which have also assumed establishment of a GMMTA.[2] In any case, since it is now planned that the GMMTA will be established by April 2014, it is considered that it will be in place for the implementation of BRT. Figure 9.1 presents a tentative organizational structure of the GMMTA as recommended in the Master Plan Report for this study.[3]



Abbreviations: ANE = National Roads Administration (Administração Nacional de Estradas), CFM = Mozambique Ports and Railways (Portos e Caminhos de Ferro de Moçambique), MHI = Ministry of Housing and Infrastructure, MOTC = Ministry of Transport and Communications, TPM = Transportes Publicos de Maputo (the public bus company in Maputo)
Source: JICA Project Team

Figure 9.1: Tentative Organizational Structure of GMMTA and Its Relationship with Line Agencies

As recommended in the Master Plan Report, the GMMTA should serve as the executing agency (EA) for implementing the proposed BRT (and other master plan) projects in order to assure consistent overall leadership, policy formulation, and coordination of institutional roles. A single EA will be most effective in considering the broad scope of projects and managing scheduling, financing, and other tradeoffs that inevitably will occur.

[1] Chapter 12 (Institutional Improvement and Capacity Development Programs), Master Plan Report for the Comprehensive Urban Transport Master Plan for Greater Maputo.
[2] The Phase I BRT system will have feeder routes that cross municipal boundaries although the trunk route is entirely within Maputo Municipality.
[3] Additional details on the organization of the GMMTA are set out in Section I.3 of Technical Report I on Institutional and Capacity Development Issues in the Urban Transport Development Process.

In addition, a project management unit (designated PMU 2 in the Master Plan Report) should be established within the public transport department of the GMMTA for the proposed BRT (and conventional bus) projects, to monitor project activity and ensure completion of the project according to schedule and budget.[4] Alternatively, separate project management units may be established for each development partner (e.g., the World Bank, JICA, China, EXIM Brasil).

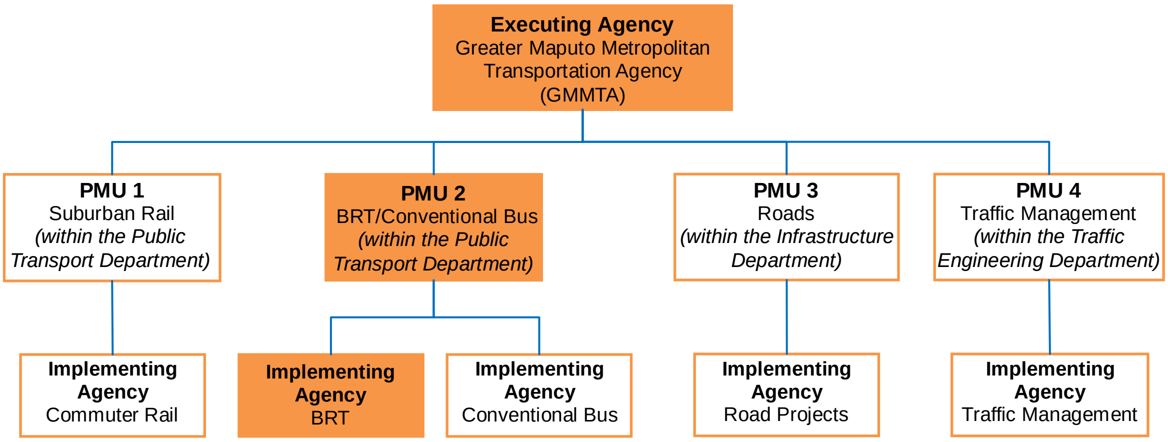
Also as recommended, under the GMMTA, an implementing agency (IA) for BRT should be established, with responsibility for putting the project in place, including scheduling, tendering for construction and operational fleet procurement, managing construction, developing financial and operating models, hiring staff, contracting with vendors, and developing policies and procedures to operate the business created by the project. The IA will draw on several resources including consultants (a construction management consultant will serve as the IA's project manager), other governmental entities,[5] and other development partners. As stated in the Master Plan Report, a newly established entity under the GMMTA will be most appropriate for BRT projects.[6] Such a new entity has the benefit of a clearly defined mission without the distractions of existing responsibilities. A separate entity may also facilitate other objectives such as structuring the new operation to be managed and operated along private sector lines.

Figure 9.2 summarizes this structure involving a GMMTA (as EA), PMUs, and IAs. The following subsections specifically address BRT infrastructure and maintenance (9.1.2) and BRT operations (9.1.3).

[4] The Master Plan Report recommends that the PMU for Conventional Bus and BRT Projects include: (i) Councilors for the Maputo City Transport and Traffic Municipal Directorate, (ii) Councilors for Matola City Transport and Traffic Municipal Directorate, (iii) Representatives of Boane City and Marracuene District, (iv) a Representative of Directorate of Municipal Transport and Traffic (*Direcção Municipal de Transportes e Transito* (Directorate of Transport and Traffic), DMTT Maputo, and DMT Matola), (v) a Representative of Directorate of Municipal Infrastructure (Maputo Municipal Directorate of Infrastructure [DMI, *Direcção Municipal de Infraestrutura]* Maputo, DMI Matola), (vi) a Representative of *Administração Nacional de Estradas* (ANE, the National Roads Administration), (vii) a Representative of *Expresso da Empresa Municipal de Transportes Públicos de Maputo* (EMTPM), (viii) a Representative of Federação Moçambicana das Associações dos Transportadores Rodoviários (FEMATRO), (ix) a Representative of the Maputo City Councilors Finance Municipal Directorate, (x) a Representative of the Road Fund, (xi) a Representative of the Development Fund of Transport and Communications (FTC), and (xii) a Representative of Maputo City Councilors Urban Planning and Environment Municipal Directorate.

[5] These may include: (i) the National Directorate of Transport and Logistics, Department of Road Transport, Division of Road Transport for Passengers; (ii) the Road Fund and FTC; (iii) the Ministry of Finance, (iv) the Ministry of Public Works and Housing; and (v) ANE.

[6] As the Master Plan Report recommends, the IA(s) for BRT should include an IA for BRT Road Development, including DMI Maputo, DMI Matola, ANE, and Maputo Sul, and an additional IA or IAs covering the BRT phases, which would be a new autonomous entity under the GMMTA.



Note: The departments in the figure correspond to those in the structure of the GMMTA shown in Figure 9.1. The shaded entities are those that would be involved in the proposed BRT project.
Source: JICA Project Team

Figure 9.2: Implementation Structure with the GMMTA as the Executing Agency, Project Management Units, and Implementing Agencies

If there are unexpected delays in the establishment of a GMMTA, an interim ("second best") solution may be pursued based on the current administrative structure. This approach would require a memorandum of understanding among Maputo Municipality, Matola Municipality, Boane City, Marracuene District, the Ministry of Finance, the Ministry of Transport and Communications, and other concerned organizations. The necessary PMU(s) could then be established on an interim basis (with legal authority to enter into procurement contracts) and later absorbed by the GMMTA when formally established. However, this "second best solution" is not recommended and not expected to be necessary.

9.1.2 BRT Infrastructure Development and Maintenance

As outlined in the previous subsection, the GMMTA, the PMU for BRT, and the IA for BRT will carry out their respective responsibilities with respect to BRT infrastructure and maintenance.

Most of the road infrastructure for the BRT project (i.e., from Brigada north to Zimpeto) will be along N1, a national highway, (currently) [7] the responsibility of the National Roads Administration (ANE, *Administração Nacional de Estradas*, under the Ministry of Public Works and Housing),[8] which would play a leadership role and provide valuable technical inputs on BRT construction and maintenance in its capacity as a member of the PMU for BRT. Some of the (trunk) road infrastructure for the project will be along roads under the control of the Maputo Municipality (as will feeder roads), which will also be represented on the PMU.[9] The construction and maintenance of related BRT infrastructure components (e.g., stations, terminals, depots) will also be the responsibility of the PMU for BRT. The IA for BRT will contract the services of a specialized, legally registered engineering firm or firms, with

[7] The law establishing the GMMTA may define the N1 road (known locally as *Avenida de Moçambique*), which will be used as a major metropolitan public transport corridor, as a (Maputo) municipal road within the boundaries of the metropolitan transport authority to be established. The Ministry of State Administration will play a role in this determination.
[8] ANE is a semiautonomous road authority that has jurisdiction over a large part of the national road and major arterial road network.
[9] The development and maintenance of various roads and streets in Maputo Municipality is the responsibility of DMI, Maputo. However, the current size of its engineering staff may constrain its capacity given the total road length under its jurisdiction.

experience in BRT construction, for the supervision of the construction works. To assure ensure a high-quality, durable product, it is recommended that long-term maintenance responsibilities be included in the construction contract.[10]

A similar model should be followed for both the Phase I BRT (expected to be developed by a Brazilian contractor with financing from EXIM Brasil) and the Phase II BRT (the subject project of this JICA prefeasibility study). In any case, implementation of the Phase II BRT will build upon the lessons learned during Phase I, which can be expected to work out "teething problems".

Considering evidence that BRT can influence development and thus be used as an effective development tool (e.g., as in Ahmedabad, Bogotá, Boston, Brisbane, Cleveland, Curitiba, Ottawa, and Pittsburgh), it will be important to maximize transit-oriented development (TOD) during the implementation of BRT in Maputo (see Box 9.1 for a brief discussion of BRT and TOD in Latin America). [11] The potential to realize significant TOD to support BRT implementation along the proposed route will depend on access to development sites (e.g., coordination with existing land use and development programs), investor interest (demonstrating potential returns), value capture (determining the best approach for each site, e.g., third party agreements, concessions, public private partnerships/PPPs, direct development), financing (developer financing, PPPs, special tax districts, general budget), and legal and regulatory requirements. The full feasibility/detailed design studies should first inventory all potential development sites along the proposed BRT corridor and evaluate them as potential TOD sites; based on the inventory, a formal feasibility study of one or two potential TOD sites may proceed.

Box 9.1: BRT and Transit-Oriented Development in a Latin America

Transit-oriented development (TOD) refers to development that is compact and has a mixture of land uses, often including residential, commercial, and office uses, as well as high-quality pedestrian environments that effectively connect with transit. In Curitiba, the Brazilian city with the first BRT system in the world, BRT has been used as a tool to spur development that in turn supports and reinforces the overall transit system.

A study of TOD and BRT in Latin America identified a wide range of possible built environments around BRT. For example, BRT-oriented satellite center type of stations, as found in Bogotá, contain significant commercial activities, public facilities, parks, and pedestrian amenities, while mixing in multifamily residential and single family attached housing, and form an ideal urban TOD. Similarly, the downtown city center type of BRT station, typified by the city center Quito stop, also has many attributes of urban TOD. Other BRT station/stop types in Latin America may be found along mixed use corridors, along institutional use corridors, at connections between/among BRT lines, in community or neighborhood centers, and in green areas.

Source: Daniel A. Rodriguez and Erik Vergel Tovar, *Bus Rapid Transit and Urban Development in Latin America*, Land Lines, published by the Lincoln Institute of Land Policy, January 2013

[10] In the TransMilenio case in Bogotá, the construction firms were not responsible for long-term maintenance; when severe road construction faults occurred after only three years of operation, the city had no legal recourse to hold the private companies the responsible. Lloyd Wright, *Sustainable Transport: A Sourcebook for Policymakers in Developing Cities, Module 3b, Bus Rapid Transit*, 2004, p. 304. Over time, the bus operators may be given more direct control of maintenance of the BRT-specific components (as for example in São Paulo), if the concession terms are long enough and the corridor profitable enough. However, this practice is rather rare since the metropolitan entity will lose leverage if a private company is given a long-term monopolistic concession contract. See, e.g.: (i) Institute for Transportation and Development Policy (ITDP), *Institutional and Reform Regulatory Options for Trans-Jakarta BRT System: Lessons from International Experience*, supported by the United States Agency for International Development, 1 May 2004, p. 30; and (ii) Lloyd Wright, *Sustainable Transport: A Sourcebook for Policymakers in Developing Cities, Module 3b, Bus Rapid Transit*, 2004, p. 168.

[11] Considering common or similar cultural roots, Latin American experience is particularly persuasive in Mozambique.

9.1.3 BRT Operations

Two broad options are envisaged for BRT operations:

(i) In one option, in the initial stage a strengthened *Expresso da Empresa Municipal de Transportes Públicos de Maputo* (EMTPM) would serve as the BRT system operator under the BRT implementing agency to be established (a new autonomous entity under the GMMTA),[12] analogous for example to systems in Delhi, Johannesburg, and various cities in China, Europe, and North America,[13] where public operators have run new BRT lines. It would have responsibility for bus operations, customer services, quality control and corrective actions, and marketing/promotion. However, over time, following best-practice models worldwide (e.g., following the TransMilenio model in Bogotá) EMTPM would compete with private operators, with the buses to be operated by contractors procured by the new autonomous entity competitively [14] on cost[15] per km or hour of operation (rather than based on number of passengers).[16]

(ii) In another option, the best-practice operator bidding process – which will encourage competition for the market but limit competition within the market – would begin from the initial stage, following a "big bang" approach.

Considering the financial and technical constraints of EMTPM, the second option may be preferable if it is politically viable and suitable public transport operators can be found. However, considering these constraints, more likely a hybrid solution will be formulated, with a strengthened EMTPM as a minority shareholder in the operating company during the initial stage.[17]

Best practice for operator contracts includes: (i) developing a fair and transparent process, (ii) ensuring sufficient competition for the market, (iii) quality-incentive contracting, and (iv) time-limited contracting. Minimum technical standards for the buses should be set in the competitive bidding procedures, with additional points given to private operators that exceed the standards. Assistance should be provided to individual operators in forming consortium groupings.[18] This process of consolidating a large number of small operators into a modern BRT system took several decades in Curitiba (which implemented the first BRT system in the world, in 1974), but was done in distinct "one-off" phases in Bogotá.[19] The service should include a system of feeder buses contracted by the regional metropolitan transport agency to be established and brought

[12]Technical Report F of this project (*Public Transport Improvement*), p. F-95 ["In the short term it is unlikely that suitable private sector operators will be found within Mozambique and unless implementation of the BRT is delayed for several years, it is likely that the only practical option will be for either or both of the TPM companies to take on the task. Subsequently, as the formal private sector expands, other operators may enter the market through the competitive bidding process."]
[13] As well as El Trole of Quito, which is operated by a public company.
[14] It is assumed that there will be multiple operators in the market.
[15] Gross cost contracts put the revenue risk on the public sector since the operator is paid only for delivery of the specified service offer, while net cost contracts require operators to collect and protect revenues. Thus, net cost contracting may be preferred. *Development of Bus Rapid Transit (BRT) in Africa: Experience from Lagos, Accra and Kampala*, Sub-Saharan Transport Program, 2012.
[16] A drawback of payment per km or hour is the separation of the service provider from the passenger; however, this may be overcome by the introduction of external auditing to measure passenger satisfaction
[17] About 25% of the shares may be held by the public company broadly consistent with Latin American experience.
[18] Competitive bidding rules should also encourage or require that employees have a minimum standard of security (e.g., health care, pensions), which would attract high-quality employees. See, e.g., Institute for Transportation and Development Policy (ITDP), *Institutional and Reform Regulatory Options for Trans-Jakarta BRT System: Lessons from International Experience*, supported by the United States Agency for International Development, 1 May 2004, p. 5.
[19] *Bus Rapid Transit – Planning Guide*, 2007, Chapter 15.

into service immediately but gradually to increase BRT ridership to its maximum operational capacity.[20]

An independent concession for fare collection is also required. Vehicle operators should not be involved in fare collection to avoid suspicions between and among stakeholders. Most of the highly successful Latin American BRT systems have independent electronic fare collection, revenue distribution, smartcard sales, and marketing. This system will need to be tendered in addition to the tenders for infrastructure and operating companies (both trunk and feeder). Lessons from an ongoing electronic ticketing pilot project undertaken by EMTPM should be taken into account.

As with the construction and maintenance of BRT facilities, it would be best if a similar model for BRT operations were followed in both the Phase I BRT (expected to be developed by a Brazilian contractor with EXIM Brasil) and the Phase II BRT (the subject project of this JICA prefeasibility study).

In short, the GMTTA will need to carry out three separate but complementary tendering processes, as shown in Figure 9.3.

Tendering of the Construction and Maintenance of the BRT Infrastructure

Tendering of the BRT Fleets — Trunk System and Feeders

Tendering of the Revenue Collection and Fare Distribution

Source: JICA Project Team

Figure 9.3: Tendering Processes to be Undertaken by the GMMTA

9.2 Regulatory System and Role of Proposed GMMTA

9.2.1 Establishment of the GMMTA (Metropolitan Transport Agency)

In addition to acting as the executing agency for master plan projects (including BRT), the GMMTA (or *Agencia Metropolitana de Transporte* in Portuguese) recommended in the Master Plan Report for this study will be in charge of planning, regulation, and management of the metropolitan Maputo transport sector. It is envisaged that the GMMTA will have several sectoral units including one for public transport, which would be responsible for all modes of public transport including BRT. Responsibilities would include (among others): (i) integrating and regulating the operation of buses and chapas operated within the metropolitan area, and (ii) integrating various public transport routes and addressing issues related to combined ticketing, feeder services, and the like. The process for establishing the GMMTA suggested in the Master Plan Report includes an initial phase, a trial phase, and a final phase. As noted, it is expected that the authority will be established by April 2014, although time may be required for it to be fully operational.[21] Lessons learned from the Lagos Metropolitan Area Transport Authority, one

[20] See, e.g., Institute for Transportation and Development Policy (ITDP), *Institutional and Reform Regulatory Options for Trans-Jakarta BRT System: Lessons from International Experience*, supported by the United States Agency for International Development, 1 May 2004, pp. 4, 21. An alternative by which feeder services are licensed by municipal authorities has been suggested in Maputo considering that feeder services are not in the metropolitan transport master plan.

[21] George A. Banjo (World Bank) and Dayo Mobereola (LAMTA), *Lagos Metropolitan Area Transport Authority – LAMATA, Its Genesis, Design, Performance and Future Prospects,* paper/PowerPoint for presentation at the

of the few multimodal metropolitan transport authorities in any developing city and which has delivered so-called BRT Lite, are presented in Box 9.2.

Box 9.2: Lessons Learned from the Lagos Metropolitan Area Transport Authority (LAMATA)

- Significantly addressing the problem takes time.
- The significant institutional reforms that led to creation of LAMATA required commitment from the highest office of government.
- Legislative, institutional, and management changes are essential before real impact (on transport issues) can be achieved.
- A clear vision and mission provides focus and direction to institutional activities.
- An experienced and capable staff, complemented by good management, is essential for success.
- The presentation of factual information from well-conducted research is key in persuading officials and politicians
- It is important to embark on a publicity campaign designed to sensitize transport users on the benefits of reform.
- The reorganization of urban transport service planning is a long-term process.
- Providing a dedicated financial source (a transport fund) is important.

Source: A. Banjo (World Bank) and Dayo Mobereola (LAMATA), *Lagos Metropolitan Area Transport Authority – LAMATA, Its Genesis, Design, Performance and Future Prospects*, PowerPoint for presentation at the CODATU XV Meeting in Addis Ababa, October 2012

Specifically regarding the GMMTA and the BRT, as for example in the case of Bogotá and Curitiba, the metropolitan transport agency will calculate and set fares, monitor operations, investigate passenger complaints, and be responsible for service quality.

9.2.2 Proposed Regulatory System

Regulation of the BRT would be the responsibility of the GMMTA, while management, control of services, and day-to-day planning would be the responsibility of the new autonomous entity under the GMMTA,[22] and the operation of services would be handled ultimately by private companies under a concession law.[23] Thus, following international best practice, it is recommended that a system with private sector competition under metropolitan (public) control would be implemented. A case that may serve as a model or at least as "inspiration" is TransMilenio SA, the public entity with overall responsibility for system management and quality control in Bogotá. The idea is to leverage private sector investment to defer financial risks while maintaining overall control of the system. The regulatory framework will include: (i) public ownership of the route network, (ii) controlled competition for operating rights of services specified by the metropolitan agency, (iii) operators willing and able to enter into contractual relationships for these services, and (iv) monitoring and enforcement capacity in the

CODATU XV Meeting in Addis Abba, October 2012 [eight years, from 1996 to 2004, required for implementation of the authority by the state government, fours after which it successfully delivered BRT Lite, in 2008].

[22] In the full feasibility and detailed design study it will be necessary to: (i) detail the organizational roles of the public management company in relation to other organizations, (ii) develop an organizational chart for the management company, (iii) formulate a position description and personnel requirements for each position within the proposed management company, (iv) provide an analysis of the legal steps required to implement the proposed institutional structure, and (v) detail the estimated timeline for the establishment of the entity to oversee system management.

[23] Contracts would be required for trunk line operator concessions, feeder concessions, and fare collection concessions. See Lloyd Wright, *Sustainable Transport: A Sourcebook for Policymakers in Developing Cities, Module 3b, Bus Rapid Transit*, 2004, p. 303.

public sector.[24] It is important that the legal framework includes adequate protection for bus operator concessionaires (e.g., against the risk that a new administration may change the rules). A BRT regulatory law should be enacted to define the necessary technical rules for the development of services, specify the rights and obligations of operators, and define mechanisms of intervention by the public authority. A lesson of BRT implementation elsewhere (e.g., Delhi) is that without such a regulation, coordination between and among agencies is difficult. Such a regulation will confer enforcement power to implementing agency operating the BRT corridor.[25]

9.2.3 Impacts on Existing Public Transport Modes (e.g., Chapas) and Proposed Measures to Address These Impacts

Experience with the implementation of BRT elsewhere has been that there has been strong opposition by informal public transport operators because of (legitimate) fears of impacts on their livelihoods.[26] One possible approach to providing a socially acceptable way of addressing the impacts of BRT on informal public transport operators has been that of Cape Town, which offers operators compensation for loss of profits and the opportunity to own shares in a newly established vehicle operating company, as summarized in Box 9.3. However, the Cape Town example (and other South African examples, such those as in Johannesburg [Rea Vaya] and Durban) may not be financially sustainable.

The Latin American model that has proved most successful is the incorporation of small owner-driver operators as minority shareholders on a first-come, first-served basis for the routes directly affected and effectively cancelled, together with the selection of operators as registered companies for the integrated feeder routes. Payment is on run-out mileage ("kilometerage") with buses conforming to tight controls on livery, roadworthiness, cleanliness, staff quality, and participation in training and passenger response. An alternative may be for operators to benefit from part ownership of the bus operating entity not as shareholders but as employees with dividend rights via warrants (i.e., securities that entitle the holder to buy the underlying stock of the issuing company at a fixed exercise price until the expiry date).[27]

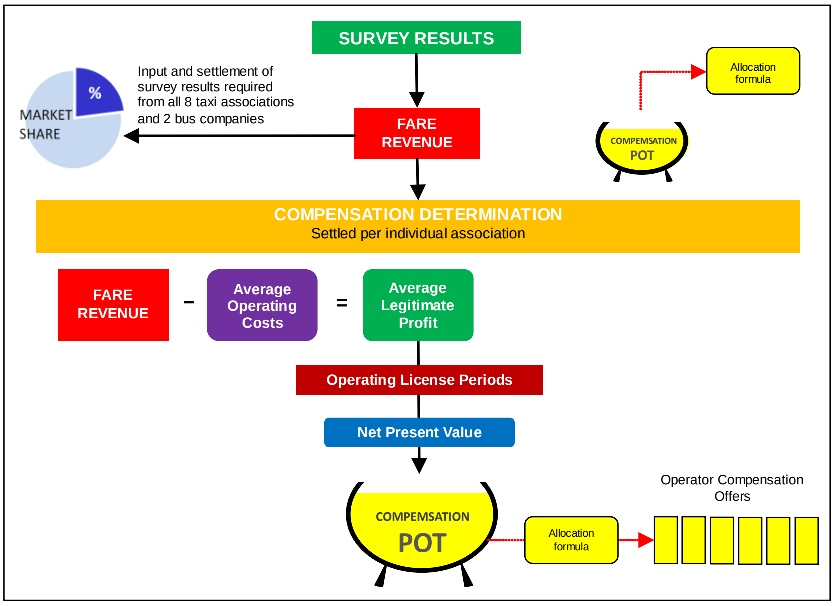
The TransMilenio case in Bogotá is particularly instructive in addressing impacts on informal public transport operators. In the concessioning of BRT routes, experience in operating public transport in the city was a prerequisite. An open dialogue was undertaken with transport companies in order to include them in the relocation of routes and negotiations of terms and conditions of contracts.[28]

Box 9.3: Approach of Cape Town in Addressing the Impacts of BRT on Informal Public Transport

Cape Town's MyCiti plan is driven by the need to integrate various modes of public transport into a single effective and seamless service. The city's approach for dealing with directly affected road-based public transport operators applies a complex process to determine the affected operator's existing market share (see the following figure). The operator is then given an option to be paid out this share in order to exit the industry, or to be given the determined value as a percentage share in the new vehicle operating company for the area in question. There are three possible rounds for

[24] See, e.g., *Development of Bus Rapid Transit (BRT) in Africa: Experience from Lagos, Accra and Kampala*, Sub-Saharan Transport Program, 2011.
[25] See *Delhi BRT System – Lessons Learnt*, p. 9, 2009,
[26] E.g., Sam Zimmerman, *The Soft Side of BRT: Lessons from Developing Countries*, 2012.
[27] HSBC, *How Banks Look at Bus Rapid Transit (BRT) Projects (and What Cities Can Learn from Them)*, 1 March 2010.
[28] Center for Clean Air Policy, *Case Study: Colombia Bus Rapid Transit (BRT) Development and Expansion, An Analysis of Barriers and Critical Enablers of Colombia's BRT Systems*, January 2012, p. 9.

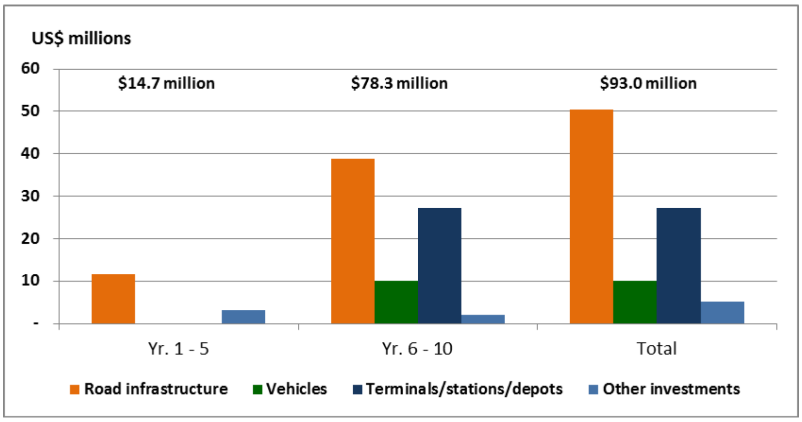
payment of compensation: early exit compensation, early compensation, and final stage compensation. Drivers and assistants who may lose their jobs when operators take up exit compensation are given preference for training to qualify for new positions in the MyCiTi system. One of the main aims of MyCiTi is to improve the work environment for those currently employed in the minibus taxi industry.



Sources: (i) *Highlights – 2012 MyCiti Business Plan*, September 2012; and (ii) *Summary of the City of Cape Town's Compensation Policy*, October 2011

9.3 Overall Financing Plan

The BRT N1 Project will cost an estimated USD 93.0 million (MT 2,812 million)[29] for construction and procurement. The investment schedule for the project is shown in Figure 9.4.



Source: JICA Project Team

Figure 9.4: BRT N1 Investment Schedule

Over the course of 18 years, the operation of BRT N1 (excluding the initial capital investment) is expected to generate a positive cash flow of approximately USD 47.1 million (MT 1,425 million) as shown in Table 9.1.[30] Based on expected passenger levels, government financial support is not expected to be necessary during the operation phase of BRT N1.

[29] MT 1 = USD 0.03306
[30] Estimates are in constant 2013 dollars.

Table 9.1: BRT N1 Operating Cash Flow

Unit: USD million

Item	2020	2021	2022	2023	2024	Year 6–10[31]	Year 11–16[32]
Passengers/day	106,314	108,009	109,731	111,480	113,258	118,791	129,604
Average fare (USD)	0.496	0.496	0.496	0.496	0.496	0.496	0.496
Average fare (MT)	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*	*15.0*
Passenger revenue	19.2	19.6	19.9	20.2	20.5	107.5	140.8
O&M expense	(19.2)	(18.9)	(18.7)	(18.4)	(18.1)	(88.5)	(118.7)
Operating profit before support	--	0.6	1.2	1.8	2.4	19.0	22.1
Government support	--	--	--	--	--	--	--
Capital spending	--	--	--	--	--	--	--
Net cash flow	**--**	**0.6**	**1.2**	**1.8**	**2.4**	**19.0**	**22.1**
Net cash flow (MT mils)	**--**	**18**	**37**	**55**	**73**	**575**	**667**

Source: JICA Project Team

This operating cash flow, however, produces a financial internal rate of return (FIRR) of negative 2.9% and a net present value of negative USD 43.7 million with the initial investment added to the cash flow as shown in Table 9.2.

Table 9.2: BRT N1 Financial Returns

Unit: USD million

Item	2013	2014	2015	2016	2017	2018	2019	2020	2021/ 2035
Project investments	--	(3.9)	(3.4)	(4.0)	(3.4)	(40.3)	(37.9)	--	--
Operating income	--	--	--	--	--	--	--	--	47.1
Capital expenditures	--	--	--	--	--	--	--	--	--
Terminal value[33]	--	--	--	--	--	--	--	--	16.7
Net cash flow	**--**	**(3.9)**	**(3.4)**	**(4.0)**	**(3.4)**	**(40.3)**	**(37.9)**	**--**	**63.8**
NPV at 7.5%[34]	**(43.7)**								
FIRR	**(2.9%)**								

Source: JICA Project Team

Given this negative financial return, two financing scenarios are evaluated. The first assumes that Greater Maputo and the Mozambique central government finance the project. The second assumes private sector investors participate.

Table 9.3: BRT N1 Financing Plan (Government Financing)

Unit: USD million

Component	2013	2014	2015	2016	2017	2018	2019	2020	2021/ 2035
BRT N1 Project Costs	--	(3.9)	(3.4)	(4.0)	(3.4)	(40.3)	(37.9)	--	--
BRT N1 cash flow before subsidy	--	--	--	--	--	--	--	--	47.1
Net BRT N1 cash flow	**--**	**(3.9)**	**(3.4)**	**(4.0)**	**(3.4)**	**(40.3)**	**(37.9)**	**--**	**47.1**
BRT N1 subsidy	--	--	--	--	--	--	--	--	
MTFF	--	--	--	--	--	0.9	7.8	--	
Road Fund	--	2.0	0.9	2.3	2.5	2.7	3.0	--	
FIA	--	1.9	2.5	1.7	0.9	4.4	4.2	--	
Other local	--	--	--	--	--	32.3	22.9		
Total Funding	**--**	**3.9**	**3.4**	**4.0**	**3.4**	**40.3**	**37.9**		
Net	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**47.1**

[31] Passengers per day is the average for the period.
[32] See previous footnote.
[33] 5X 2035 operating income to account for on-going value of the BRT
[34] 7.5% is the yield obtained in a recent auction of auction of 4-year Mozambique government bonds (IMF, Sixth Review Under Policy Support, July 9, 2013, page 16).

Source: JICA Project Team

As will be discussed in Chapter 10, the total financial requirement provisionally estimated for Maputo, including government funds, during construction of the Phase II of the BRT (BRT N1) and Phase I of the BRT and the LRT, is approximately USD 666.2 million.[35] The table above depicts a scenario for funding the BRT N1 solely from government resources. The particular funding resources are chosen based on the following:

- MTFF is used in this case as a source of funds when the estimated budgets for the other sources are not sufficient to meet the annual requirement.
- The Road Fund is assumed to fund most of the design and civil infrastructure costs associated with the BRT N1. It is understood that this will likely require negotiation with Ministry of Public Works and Housing.
- FIA is seen as a resource established to fund local infrastructure projects.
- "Other local" represents capital project funds transferred by the central government.

Considering the size of the investment required for BRT and LRT developments, it is highly recommended that external financing source(s) be sought in order to reduce the fiscal burden.

The financing plan proposed above is based on relatively conservative assumptions as detailed in Table 9.4:

Table 9.4: BRT N1 Forecast Assumptions

Item	Assumption	Source/comments
Project costs	Stated in year of expenditure values	Based on IMF inflation estimates
Ridership	Grows at 1.0% per year	Estimates from Transportation model
Fares	Constant at MT 15.00 per trip; no real price increases assumed	
O&M expense	Operating expense estimated at USD 3.13 per vehicle kilometer, based on experience of BRT's operating in Latin America; no real increase in costs assumed	Includes bus operations and maintenance
BRT equipment & infrastructure maintenance	Based on life cycle cost by major asset class with all assets replaced/refurbished according to their respective economic lives	Includes terminals, stations, depots & equipment, AFC systems
Road surface maintenance	Assumes surface life of 15 years and a 10% failure rate	0.7% of original cost included annually in maintenance expense (10%/15 years)
Capacity building	USD 4.0 million included in project costs for all areas of capacity building	
Capital maintenance:		
Buses	20% of original cost starting in the 5th year of operation	
Civil works	Based on life cycle cost with an increasing percentage of original cost estimated for each year of the projection period	42% of original cost expended over the projection period, does not include road surfacing

Source: JICA Project Team

A public private partnership structure is also considered for financing the BRT N1 project. As indicated by the negative FIRR estimated for the BRT N1, government sources will still be

[35] For the BRT N1 pre-F/S study it is assumed that Phase I of the BRT and the LRT are financed entirely by Maputo and Mozambique.

needed for about 78% of the initial investment in order to produce a return that may attract private investment. The key assumptions include the following:

- Private sector investors fund initial vehicle purchases and 10% of the infrastructure costs.
- Private sector investors fund all capital maintenance of assets (civil and vehicles).
- Improved cost management results in an average 1.3% reduction in O&M expense over the life of the project.
- Ridership is increased by an average of 2.4% under private sector management based on assumed improvements in service delivery.
- Fares remain the same as under public sector management.
- A concession fee of 0.6% of revenue is included for modeling.

Based on these assumptions, private sector investors could earn an approximate 13.3% return on an approximately USD 17 million investment. While this return is based on some fairly aggressive assumptions regarding ridership and expense management, the 13% return could be sufficient to interest potential investors.

9.4 Project Risks and Potential Mitigation Measures

Projects risks and potential mitigation measures include the following:

(i) One risk is that the GMMTA (the metropolitan transport agency) will not be established quickly enough, considering the time required for legal establishment of the authority and eventually for full implementation. The first BRT line (Phase I, to be financed by EXIM Brasil), is expected to start operation around 2016 (and the Phase II line, the subject of this study, in 2020). Full implementation of the Lagos Metropolitan Area Transport Authority, which delivered a BRT system elsewhere in Africa, required eight years. Technical assistance and capacity building (also see the following section) will be crafted to address this risk, but it will also require commitment from the highest levels of government, based on the presentation of facts from well-conducted research.

(ii) If EMTPM is selected to serve as part BRT system operator for a transitional period, it will lack sufficient capacity to serve as the BRT system manager and operator in the early stages. This risk may include a lack of experience with BRT, issues related to the workforce and organizational culture, and planning for the removal or distribution of old buses. Targeted capacity development of EMTPM (see the following section) would be necessary to address this risk. This company may also have problems obtaining financing for the new fleet of special trunk buses (left-side drive and doors on the left). International financing is available, but requires a letter of credit through a first-level bank and guarantees in terms of capital, debt levels, concession contract, and the like.

(iii) When the BRT operation is concessioned to the private sector, there is a risk that the operator(s) will lack BRT experience. Integrating personnel from disparate groups, establishing the required corporate culture, managing logistics, and maintaining discipline will be major challenges. To mitigate this risk, potential local operators may discuss partnerships with experienced international BRT operators.

(iv) Perhaps the greatest risk of BRT implementation is that informal chapa operators, fearing for their livelihoods, will oppose it.[36] Offering adequate compensation to operators, including the opportunity to own shares in newly established vehicle

[36] One specific risk is that chapa owners will operate competing services alongside the busways, thereby depriving the system of revenue. This risk may be mitigated by enforcing an exclusion zone on either side of the busway, and enforcing the removal of chapas and older buses from the system in instances in which the owners have joined the bus operation company.

operating companies, may be one way of addressing this risk, as attempted in Cape Town. Also (or alternatively), relevant lessons from the TransMilenio experience in Bogotá may be applied (see Section 9.2.3 for the TransMilenio experience). It will be important to bring local operators on board early on, engage with the mass media, and work with parties that are not susceptible to local pressure.

(v) There is a risk that new technology does not operate as planned. This risk can be mitigated in a variety of ways, e.g., by not opting for exotic powerplants, by choosing proven suppliers and technology for intelligent transport systems (ITS), by seeking a guarantee of bus support from bus suppliers, and by requiring suppliers to provide performance bonds.[37]

(vi) There is a risk that the payment of per-km costs (by vehicle type and according to the contracted services) will not be met by fares and/or the contracted subsidy. One mitigation measure is to have the ability to vary the passenger fare in line with inflation/costs to cover increased per km payments whenever a "trigger" value is reached in terms of inflation or a transport cost index. This sort of mechanism is also normally a part of the financial bank guarantees for fleet purchasing.[38]

(vii) The land use scenario adopted assumes development intensification along key transit corridors, combined with a prevention of uncontrolled sprawl elsewhere. A mitigation approach to this problem is to ensure that strong planning controls will be not only set but also actively enforced in this regard.

Economic and financial risks to the BRT Phase II project include:

(i) Implementation cost overruns: The total estimated project costs are USD 93.0 million. If actual costs exceed this amount by, for example, 10%, that would require an additional USD 9.3 million. This represents approximately 0.4% of the total estimated funding requirement of USD 2,107.3 million (see Chapter 10).

(ii) Failure to achieve projected passenger levels: The estimate of passengers utilizing the BRT Phase I was developed using a transportation model developed for this project by the JICA Project Team. The estimates range from 106,314 passengers per day in 2020 to 134,782 passengers per day in 2035. This represents a conservative 1.6% annual increase in passengers over the 15 year projection period. Still, there is a risk that the actual level of passengers will not be achieved or will take longer to reach the forecasted levels. If it is assumed that passenger demand is reduced to 75% of the estimated amount for 2020 (or approximately 80,000 passengers per day), and then a 1.6% average annual growth rate is applied until 2035 (approximately 101,422 passengers per day), then as a result over the projection period this would cause a revenue shortfall of approximately USD 86.0 million, or 25% of the original projection.

(iii) Failure to achieve projected O&M expense: O&M expenses are estimated at approximately USD 0.43 per passenger over the forecast horizon, beginning at approximately USD 0.50 per passenger and declining as passenger demand increases and operating efficiencies are achieved. But if it is assumed that initially O&M expenses per passenger are 10% higher than estimated (USD 0.55 per passenger), the increase in expenses over the forecast period is estimated as USD 32.2 million. This estimate assumes the original projections for passenger demand and expense efficiency.

Table 9.5 summarizes the project financial risks:

[37] HSBC, *How Banks Look at Bus Rapid Transit (BRT) Projects (and What Cities Can Learn from Them),* 1 March 2010.
[38] See previous footnote.

Table 9.5: Phase II BRT Project Financial Risks

Item	Risk	Potential Impact
Project costs	Project costs exceed estimated cost	A 10% increase in costs corresponds to USD 9.3 million, or 0.4% of total estimated funding requirement
Passenger demand	Passenger demand below expectations	A 25% shortfall in initial demand estimate results in a revenue shortfall of USD 86.0 million over life of project.
O&M expense[39]	O&M expenses higher than estimated	A 10% increase in O&M expenses per passenger results in an additional USD 32.2 million in expenses.

Source: JICA Project Team

Based on this analysis, passenger demand is the key driver of financial results, due to its potential to significantly affect revenue and O&M expenses. An additional risk emerges if there is an over-procurement of vehicles, since this is based on estimated demand. Procurement is based on requirements for the peak service hours, and the likely impact of a shortfall in demand is that already-procured vehicles would be out of service. This ties up investment capital in unproductive assets, and strains the budget for the Phase II BRT.

9.5 Capacity Development

In view of the risks set out in the preceding section, proposed capacity development measures include the following:

(i) technical assistance for the establishment of the GMMTA (the metropolitan transport agency), to strengthen its capacity to execute projects, with support in areas such as procurement, contract management, disbursement, planning and environmental and social mainstreaming;

(ii) if the option with EMTPM serving as BRT system operator in a transitional period is selected, measures for the greater professionalization of EMTPM, including new skills in BRT technology and planning, accounting, labor/management relations, and customer service;

(iii) capacity building for integrated public transit expansion, design, and operation; and

(iv) capacity building for developing catalytic transit neighborhoods.[40]

It is recommended to seek assistance from development financing organizations to facilitate capacity building. These organizations fund studies, workshops, and training programs focused on improving management and building organizational capacity that would support the efforts noted here.

[39] To simplify the analysis, O&M expense risk is analyzed on a per passenger basis, though the expense impact is not completely variable with passenger demand, as fixed costs are material.

[40] E.g., including (i) project development, high-quality design, market analysis, project preparation, and preconstruction planning; (ii) development of requests for proposals for public-private partnerships and evaluation, and collaboration agreements on TOD implementation; (iii) finance, including the development and packaging of funding proposals for domestic and international investors or development partners; and (iv) value capture mechanisms, including the design and structuring of advance land-based mechanisms for the investment, operation, and maintenance of TOD transit districts (e.g., tax increment financing, business improvement district fees); See, e.g., Center for Clean Air Policy, *Transit Oriented Development NAMA [Nationally Appropriate Mitigation Action] in Colombia*, 2013.

Chapter 10 Economic and Financial Analyses

10.1 Economic Analysis

This section outlines the approach and assumptions adopted and the results from the economic evaluation of the status quo transport development "Scenario A" set out in the Master Plan volume versus the proposed N1 BRT scheme "Scenario A+N1 BRT." Further details are available in Appendix B.

10.1.1 Land Use Scenario and Transport Network

The land use scenario selected as part of the Master Plan was scenario "C", which assumed that there would be development intensification along key transit corridors. The transport network being tested comprises Phase II of BRT construction, which is studied in this pre-F/S volume, consisting of the North and South Sections as seen in Figure 10.1. In this economic analysis, it is assumed that both the North and South Sections will be completed by the end of 2009.

Source: JICA Project Team

Figure 10.1: Bus Rapid Transit Network Being Tested

10.1.2 Economic Analysis Methodology

The economic analysis is predicated upon comparing a "Scenario A+N1 BRT" case against a "Scenario A" case. The difference between cases is the N1 BRT that is studied in this pre-F/S. The outline methodology can be described as follows:

1) Based upon transport model outputs (Section 10.1.5) and parameters for economic evaluation (Section 10.1.3), benefit streams are calculated by year.
2) Cost streams are also calculated by year (Section 10.1.4).
3) The resultant cost and benefit streams are then combined in order to perform a discounted cashflow analysis (DCF), as set out in Section 10.1.6, with a sensitivity analysis described in Section 10.1.7.

10.1.3 Parameters for Interpretation of Transport Model Outputs

(1) Value of Time

The value of time (VOT) was estimated based upon per capita GDP in the study area, price inflation to 2013 and estimated GDP per capita growth, and with reference to data from the Household Interview Survey (HIS) and other data supplied by INE. The resulting values are shown in Table 10.1.

Table 10.1: Value of Time in 2013 Prices for the Study Area as a Whole

	Year			
	2012	**2018**	**2020**	**2035**
VOT (MT/hour)	23.50	32.27	35.52	61.92
VOT (USD/hour)	0.78	1.07	1.17	2.05

Source: JICA Project Team

(2) Vehicle Operating Costs and Emissions

Vehicle operating costs (VOC) were estimated based upon the UK Department for Transport's WebTAG advisory guidance, which covers the build-up of VOC for urban transport models and also upon the World Bank's HDM model, by vehicle type. Data on individual cost elements were, however, collected locally by the JICA Project Team.

Emissions of CO_2 and NO_x were estimated on a per-vehicle km basis according to speed, using an equation form similar to that used for VOC.

For the economic analysis, carbon emission costs were monetized at USD 5.20 per metric ton of CO_2 in 2012 (equivalent to recent prices on European exchanges), increasing to USD 23.00 per metric ton of CO_2 in 2035 (equal to the all-time high on the European exchanges for emissions trading).

(3) PCU Factors and Vehicle Occupancies

The transport model assumed passenger car unit (PCU) equivalent factors of 1.0 for cars, 2.0 for bus (incorporating large buses and various sizes of minibus and chapas) and 2.5 for trucks. Based on surveyed vehicle occupancies, occupancy rates of 12 per chapa and 63 per bus were assumed. For BRT vehicles, 120 was assumed. 110% of these figures were assumed for peak hour occupancies (where crush loading is commonplace) and 75% in off-peak periods.

(4) Vehicle Speeds and Public Transport Passenger Waiting Times

The JICA STRADA transport model assumes the same speed for all vehicle types on a link. Therefore, as part of the processing of model outputs, trucks were assumed to be 10% slower than cars, chapas 20% slower than cars, and TPM buses 25% slower than cars (to take into account of the need to weave in and out of traffic to set-down and pick-up passengers). As BRT will be on a segregated right-of-way, BRT speeds are unchanged from the JICA STRADA outputs.

Public transport routes were coded into the JICA STRADA model as envisaged services per day. However, STRADA interprets these frequencies on a per-hour basis. As such, the model does not directly output meaningful waiting times. Therefore, as part of the post-STRADA processing of model data, waiting times were estimated.

(5) Annualization Factors

In order to convert modeled day metrics into annual metrics, a factor of 330 was used, based on local characteristics in Maputo (see Section B.4.7 of Appendix B for details of this assumption).

10.1.4 Project Cost Data

Not all costs shown in the financial analysis were included in the economic analysis directly. Vehicle fleet purchase and operating costs for road-running vehicles were modeled as part of VOC including those costs of the BRT fleet to be procured in the project. However, infrastructure design and construction, capability development, and maintenance costs have been included. These costs were obtained from the financial analysis, and were converted to economic costs. A shadow price conversion factor of 0.85 was applied to infrastructure-related costs (i.e. infrastructure design & construction; and, maintenance). This factor was obtained following review of a number of other development agency studies undertaken in Mozambique in recent years. The economic costs included in the analysis are shown in Table 10.2. This includes residual values for infrastructure design and construction.

Table 10.2: Economic Costs of the Project by Year (USD thousands)

Year	Infrastructure Design & Construction	Capacity Building	Maintenance	Total
2014	3,063	500		3,563
2015	2,466	500		2,966
2016	2,959	500		3,459
2017	2,466	500		2,966
2018	28,393	1,000		29,393
2019	27,860	1,000		28,860
2020to 2035			47	47
2036 (residuals)	(39,670)			(39,670)

Source: JICA Project Team

10.1.5 Transport Model Outputs

Table 10.3 shows daily passenger hours, vehicle-km and boardings obtained from post-processing of transport model outputs. Table 10.4 shows daily vehicle operating costs (VOC) and emissions as calculated based upon transport model outputs.

Table 10.3: Daily Passenger Hours, Vehicle-km, Speeds and Boardings

	2020			2035		
	Scenario A	**Scenario A + N1 BRT**	**Diff.**	**Scenario A**	**Scenario A + N1 BRT**	**Diff.**
Passenger Hours by Mode (per Day)						
Car & Truck	558,569	563,119	4,550	1,232,243	1,243,188	10,945
Chapa, Bus, Ferry	1,248,784	1,150,364	(98,300)	3,264,888	3,047,538	(217,350)
LRT	22,467	25,857	3,389	33,671	37,105	3,434
BRT & BRT Feeder	35,164	150,809	115,645	36,914	188,850	151,936
Walk	13,522	23,514	9,992	19,490	29,759	10,270
Total	**1,878,386**	**1,913,646**	**35,260**	**4,587,204**	**4,546,439**	**(40,765)**
Vehicle-km by Mode (per Day)						
Car & Truck	7,439,574	7,451,410	11,836	12,093,346	12,140,006	46,661
Chapa, Bus, Ferry	4,238,959	4,062,643	(176,317)	7,045,850	6,934,233	(266,443)
LRT	977	1,010	33	1,075	1,271	195
BRT & BRT Feeder	4,017	22,355	18,338	4,172	26,677	22,504
Walk	--	--	--	--	--	--
Total	**11,683,528**	**11,537,417**	**(146,111)**	**19,299,269**	**19,102,186**	**(197,083)**
Public Transport Boardings per Day						
Chapa, Bus, Ferry	3,383,106	3,153,393	(229,713)	5,386,653	5,088,661	(297,992)
LRT	40,360	47,376	7,016	58,451	64,980	6,529
BRT & BRT Feeder	82,446	257,727	175,281	74,106	270,509	196,403
Total	**3,505,912**	**3,458,496**	**(47,416)**	**5,519,210**	**5,424,150**	**(95,060)**

Source: JICA Project Team

Table 10.4: Daily Vehicle Operating Costs and Emissions

	2020			2035		
	Scenario A	**Scenario A + N1 BRT**	**Diff.**	**Scenario A**	**Scenario A + N1 BRT**	**Diff.**
Vehicle Operating Costs (Thousand MT per Day)						
Car & Truck	50,013	50,080	67	85,754	86,128	375
Chapa, Bus, Ferry	64,736	61,452	(3,284)	142,273	133,809	(5,465)
BRT & BRT Feeder	191	1,063	872	198	1,270	1,072
Total	**114,939**	**112,595**	**(2,345)**	**228,225**	**224,207**	**(4,018)**
CO_2 Emissions (kilograms of Carbon per Day)						
Car & Truck	4,520	4,532	13	8,175	8,218	43
Chapa, Bus, Ferry	6,652	6,363	(289)	12,849	12,378	(471)
BRT & BRT Feeder	7	42	34	8	50	42
Total	**11,179**	**10,937**	**(242)**	**21,032**	**20,646**	**(386)**
NOx Emissions (kilograms of NOx per Day)						
Car & Truck	33	33	0	51	52	0
Chapa, Bus, Ferry	119	114	(5)	224	216	(8)
BRT & BRT Feeder	0	1	1	0	1	1
Total	**152**	**148**	**(4)**	**276**	**268**	**(7)**

Source: JICA Project Team

10.1.6 Economic Evaluation Results

(1) Benefits

Three types of benefits were quantified, including the following:

- Travel time savings, estimated based upon the value of time indicated in Section 10.1.3 and passenger hours by transport mode for the whole network in the study area obtained from the transport model outputs (Table 10.3)
- Savings of vehicle operating costs (VOC), estimated based upon the VOC by vehicle type (see Section B.4.2 of Appendix B for the VOC equation used and the estimated values of parameters in the equation) and vehicle-km by transport mode for the whole network in the study area obtained from the transport model outputs (Table 10.3)

- Reduction in CO_2 emissions, estimated based upon the emissions on a per-vehicle km basis using an equation similar to that for VOC (see Section B.4.3 of Appendix B for the CO_2 emission equation used and the estimated values of parameters in the equation) and vehicle-km by transport mode for the whole network in the study area (same as those used for VOC savings), and monetized using the carbon emission costs indicated in Section 10.1.3

Daily transport model outputs were annualized using a factor of 330, as aforementioned. Interpolation was used to obtain benefit streams between 2020 and 2035.

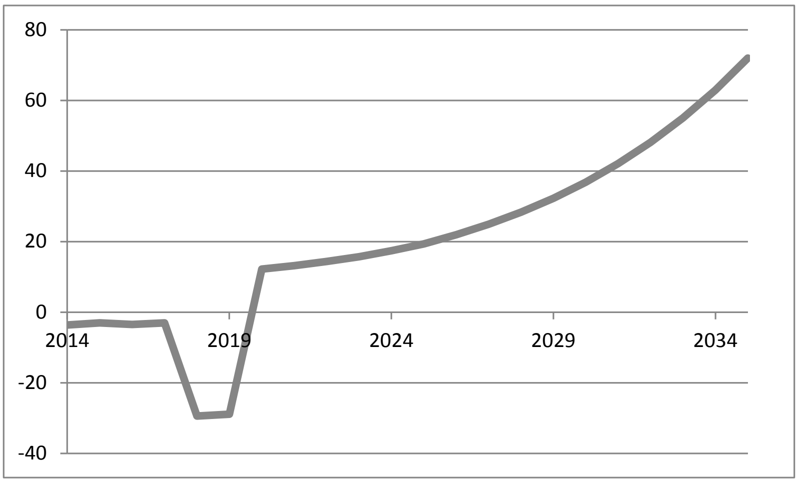
(2) Costs

The project costs considered in the economic analysis include capital investment costs and operation and maintenance costs, specifically as follows:

- Capital investment costs include the total project cost as described in Table 7.11 of Chapter 7, including the costs for civil works, BRT facilities, bus fleet purchase, miscellaneous expenses, engineering services, and capacity development. Note, however, that the BRT fleet purchase cost is modeled as part of the VOC and is not included in the cost stream, thereby avoiding double counting. As described in Section 10.1.4, a conversion factor of 0.85 was applied to infrastructure-related financial costs in order to obtain their economic costs. In addition, residual values for infrastructure design and construction were considered. The cost stream used for the economic analysis is shown in Table 10.2.
- Operation and maintenance costs include the costs for BRT operation and maintenance. As is the case for capital costs, the operation and maintenance costs for BRT fleet are modeled as part of the VOC and are not included in the cost stream in order to avoid double counting. The maintenance cost for infrastructure and facilities is included in the cost stream.

(3) Comparison of Costs and Benefits

Based on the economic benefits and costs estimated above, benefit and cost streams were obtained, and are shown in Figure 10.2.



Source: JICA Project Team

Figure 10.2: Net Benefit Stream (USD million per annum)

Based upon these data, the results of economic analysis are calculated to be:

- Economic Internal Rate of Return (EIRR) = 21.5%
- Net Present Value (NPV) at a 12% discount rate = USD 47.3 million
- Benefit/Cost Ratio (BCR) = 2.23

In conclusion, the robust EIRR, positive NPV and favorable BCR support implementation of the BRT scheme as planned.

10.1.7 Sensitivity Analysis

Sensitivity analysis was performed, comprising three tests:

- Increasing initial costs by 10%
- Decreasing benefits by 10%
- A combination of the above two tests

The results are shown in Table 10.5, showing that the scheme is still attractive even with a 10% increase in costs and 10% decrease in benefits.

Table 10.5: Results of Sensitivity Analysis

Case	EIRR	NPV (USD million)	BCR
Base Case	21.5%	47.3	2.23
(1) Costs + 10%	20.2%	43.5	2.03
(2) Benefits – 10%	20.1%	38.7	2.01
Combination of (1) & (2)	18.8%	34.9	1.82

Source: JICA Project Team

10.2 Financial Analysis

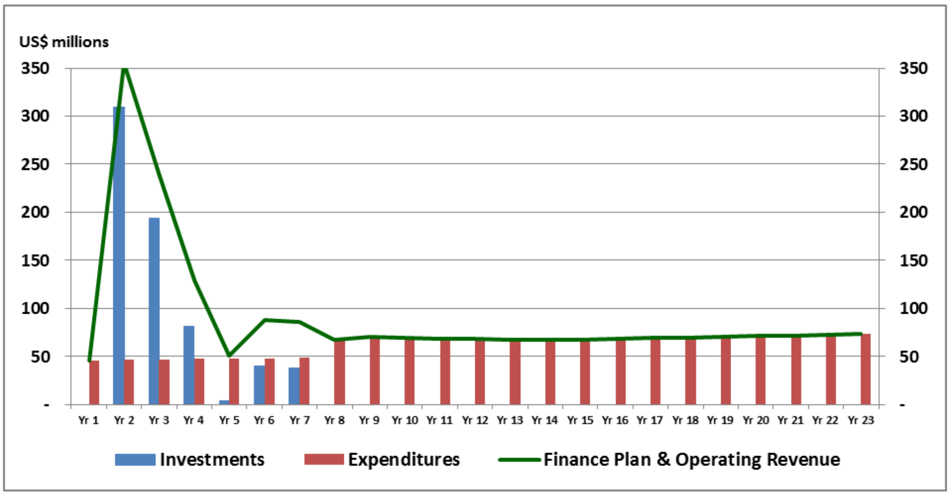
Section 9.3 of Chapter 9 estimated a cash flow of the N1 BRT project and analyzed its financial return, resulting in a positive operating income while a negative financial return expected with all of the initial investment added to the cash flow. Base on this result, alternative financing plans were evaluated including: (i) the initial investment to be financed entirely by the public sector, and (ii) a public-private partnership structure where investment will be partially made by the private sector (an operating entity).

In this section, a preliminary assessment is made of the financial capacity to implement the Phase I BRT and the LRT as well as the Phase II BRT (which is the N1 BRT project).

10.2.1 Analysis of Financial Capacity

Total expenditures between 2013 and 2035 for investment in Phase I and II of the BRT and the LRT, ongoing expenditures for road maintenance and local expenses, and subsidies to TPM and the LRT are estimated provisionally at USD 2.1 billion (MT 63.7 billion) over the 23 year period.[1] Approximately 47% of the total expenditure occurs in the first seven years during the implementation of the BRT and the LRT.

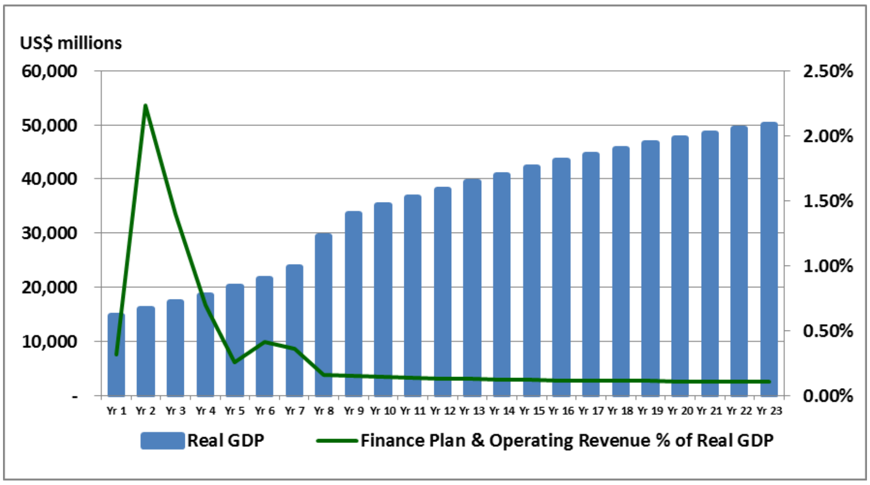
[1] MT 1 = USD 0.03306



Source: JICA Project Team

Figure 10.3: Estimated Expenditures and Financing Plan

Based on assumptions for real growth in Mozambique's gross domestic product (GDP)[2], funding available to greater Maputo through local budgets and central government transfers is estimated to support the funding requirement while maintaining historical trends. As illustrated by the figure below, the estimated funding required to support the projected expenditures averages to 0.33% of Mozambique's projected GDP. This compares favorably with the approximately 0.60% required from 2008 to 2012. The range of funding as a percent of GDP is 0.10% to 2.24% with the peak coming in 2014. This peak reflects the time of heaviest investment in the BRT Phase 1 and LRT. It then declines to 1.40% in 2015 and 0.70% in 2016.



Source: JICA Project Team

Figure 10.4: Funding as Percent of Real GDP

The estimates of funds available to Greater Maputo implicitly assume current funding programs and existing terms such as tax rates and items subject to tax. This approach, along with a relatively conservative estimate, suggests a manageable level of risk in the financing plan. The major risk is achieving the projected GDP growth. The estimate is based on the IMF analysis that real GDP growth will average 8.0% through 2018 and 8.9% from 2019–2033. While the

[2] Real GDP growth is estimated by the International Monetary Fund (Sixth Review Under Policy Support, July 9, 2013, Table 3, page 96).

estimates presented here assume only a fraction of that growth translates to increased receipts for the various funding programs (as illustrated by the figure above) there could still be a meaningful risk. This will be discussed further in the sensitivity analysis.

The table below presents the major assumptions and sources of information of the estimates.

Table 10.6: Assumptions Used for Financial Analysis

Item	Assumption/Source
Real GDP growth	Increase by an average 5.9% per year over the plan horizon, and 10.0% per year over the first 10 years. Sources: IMF 6th Review Under Policy Support, 9 July 2013, 2013–2022 (Yrs. 1–10); JICA Project Team 2023–2035
Inflation	Inflation (as measured by the GDP deflator) is estimated to average 1.8% through 2018 and 2.6% between 2019 and 2033. Note that the estimates for revenue and expenses are in constant prices and are not affected by inflation. Project costs and capital expenditures are included in year of expenditure values and are affected by inflation. Sources: IMF 6th Review Under Policy Support, 9 July 2013
Basis of funding program forecasts	Primarily percentage of real GDP using historical averages for individual programs as the basis of the projection. In addition, certain funding programs are used to balance funding with requirements represented by the BRT and LRT projects and budgetary expenses. The sources of historical figures for funding sources are various Maputo and Government of Mozambique agencies. The JICA Project Team is the source for projected funding levels.
TPM	TPM's projected operating income is based on historical results for passengers, revenue, and individual expense line items provided by TPM and the Ministry of Finance. The JICA Project Team is the source for projected revenue, operating expense and maintenance capital expenditures. Discussions with TPM management provided input to the team's analysis.
BRT	BRT projections for passengers are based on the JICA Project Team's transportation model developed for the pre-FS. Revenue, expenses and capital expenditures are based on JICA Project Team assumptions and the team's experience with BRT systems particularly in South America. The JICA Project Team's analysis undertaken to develop the BRT Projects included in the Master Plan aided the analysis. In addition, the JICA Project Team met with the consultants developing the Phase 1 BRT project.
LRT	LRT projections are based on the JICA Project Team's assumptions based on experience and discussion with Maputo government officials and the consultants preparing the LRT feasibility study.
Road Maintenance	Road maintenance expense and capital expenditure forecasts are based on historical information received from the Maputo Municipal Infrastructure Department, the Matola Municipal Infrastructure Department, the Marracuene Municipal Infrastructure Department, and ANE (for Boane). The JICA Project Team assumptions are based on analysis to develop the Road Project plans, a review of the road infrastructure, discussions with local officials, and previous experience.

Source: JICA Project Team

10.2.2 Section Financing Plan Detail

The following table provides an example of potential sources of funds to support the estimated project investments and local expenditures.

Table 10.7: Example of Potential Sources of Funding

Component	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021/ 2035**	**Total**
Project Costs	--	(309.2)	(194.1)	(81.2)	(3.4)	(40.3)	(37.9)	--	--	(666.2)
BRT Phase II net cash flow	--	--	--	--	--	--	--	--	47.1	47.1
BRT Phase I/LRT net cash flow	--	--	--	(1.1)	(1.1)	(1.2)	(1.2)	(0.5)	(40.5)	(45.6)
TPM net cash flow[3]	(2.9)	(2.7)	(2.4)	(2.0)	(1.7)	(1.5)	(1.2)	(0.4)	11.8	(3.1)
Local net cash flow[4]	(32.5)	(32.6)	(32.8)	(33.0)	(33.2)	(33.3)	(33.5)	(33.7)	(518.1)	(782.7)
Net cash flow before funding	**(35.4)**	**(344.5)**	**(229.3)**	**(117.4)**	**(39.4)**	**(76.3)**	**(73.8)**	**(34.6)**	**(499.7)**	**(1,450.5)**
MTFF	5.3	6.0	5.7	6.1	6.6	7.1	7.8	9.7	211.4	265.8
Road Fund	1.8	2.0	2.1	2.3	2.5	2.7	3.0	3.7	80.1	100.2
FCA	3.4	46.8	30.7	14.8	3.7	8.8	8.4	2.6	13.4	132.6
FIA	1.7	23.2	15.2	7.3	1.9	4.4	4.2	1.3	6.6	65.8
FDD	4.8	64.9	42.5	20.5	5.2	12.3	11.6	3.6	18.5	183.7
Parking/Vehicle Fees	0.8	0.9	1.0	0.8	0.9	0.9	1.0	1.3	27.5	35.1
Other Local Funds	14.6	198.0	129.7	62.4	15.8	37.4	35.5	10.9	56.6	560.9
TPM Subsidy	2.9	2.7	2.4	2.0	1.7	1.5	1.2	0.4	--	14.9
BRT Ph. I/LRT Subsidy	--	--	--	1.1	1.1	1.2	1.2	1.2	85.6	91.3
Total	**35.4**	**344.5**	**229.3**	**117.4**	**39.4**	**76.3**	**73.8**	**34.6**	**499.7**	**1,450.5**

Abbreviations: FCA = Fundo de Compensação Autárquica, FDD = District Development Fund, FIA = Fundo de Iniciativa Autárquica, MTFF = Medium-Term Fiscal Framework, TPM = Transporte de Moçambique (the Maputo public bus company)
Source: JICA Project Team

[3] Before subsidy
[4] Road maintenance and municipal expenses

As noted in Section 9.3, considering the size of the investment required for BRT and LRT developments, it is highly recommended that external financing source(s) be sought in order to reduce the fiscal burden during their implementation.

10.2.3 Sensitivity Analysis

As noted earlier, the major risk to achieving the estimates presented here is the forecast for Mozambique GDP growth. Other items that could have a significant impact on these results are variations in project implementation costs and below-targeted passenger levels on the BRT corridors and the LRT. The table below presents a sensitivity analysis of these items, considering the effect of a 10% above estimate performance and a 10% below estimate performance. The impact is stated in terms of the change in total funding that would result.

Table 10.8: Sensitivity Analysis

Item	Sensitivity	Impact on Required Funding
GDP Growth	± 10% versus estimate	± USD 132.0 million decrease
Project costs		
BRT Phase 2 (N1)	± 10% versus estimate	± USD 9.3 million increase
BRT Phase 1	± 10% versus estimate	± USD 9.5 million increase
LRT	± 10% versus estimate	± USD 43.7 million increase
Passenger levels		
BRT Phase 2 (N1)	± 10% versus estimate	± USD 34.8 million decrease
BRT Phase 1	± 10% versus estimate	± USD 16.0 million decrease
LRT	± 10% versus estimate	± USD 6.3 million decrease

Chapter 11 Natural and Social Environmental Analysis

11.1 Introduction

The social and environmental pre-feasibility study for the proposed BRT was conducted for two months, starting in October 2013. The purpose of the study was to collect baseline information on biophysical and social components that may be affected by the project through IEE level examination, and to identify potential environmental and social impacts of the project.[1] The survey was subcontracted to a local environmental consulting firm, Impacto - Projectos e Estudos de Impacto Ambiental, Lda. The following sections are based on the information collected by Impacto.

11.2 Impact Identification and Mitigation Measures

The list below is the brief summary of potential social/environmental Impacts of the BRT project that are identifiable at this stage. Potential mitigation measures were also identified.

Table 11.1: Potential Social / Environmental Impacts and Mitigation Measures for the Proposed BRT Project

Rating:
A: Serious impact is expected.
B: Some impact is expected.
C: Extent of impact is unknown.
D: No or negligible impact including positive impact is expected.

No.	Check Items	Rating	Notes	Mitigation
Social Environment				
1	Involuntary resettlement	B	The project will cause some involuntary resettlement. Although the exact number of affected people is not known, it is expected to be less than 200.	A more detailed survey is needed at the feasibility study stage. An Initial Resettlement Plan (IRP) or Abbreviated Resettlement Action Plan (A-RAP) needs to be made, including compensation and resettlement assistance programs.
2	Economic Activities	B	Currently, transport on the proposed BRT route is done mostly by private operators ("chapas"). One of the impacts will be the reduction of routes/trips for these transporters, which could lead to a reduction of income for these operators.	Implementation of job-creating program for chapa drivers. Also, chapa drivers should be involved in stakeholder meetings.
3	Traffic	B	Overall the project is expected to have a positive impact on traffic by promoting public mass transportation, However, some negative impact may be caused temporarily during construction.	The construction works should be planned to minimize impacts on local traffic. The possible mitigation measures are, for example, providing a bypass road or avoiding construction works during peak hours.
4	Public facilities	B	Some public facilities along N1 Road may be affected, such as footbridges, streetlights, bus stops and traffic signals.	The public facilities must be preserved or restored after construction of BRT.
5	Split of communities	D	The project will not cause a split of local communities.	

[1] This social and environmental study was conducted for the 19.1 km route of the proposed BRT between Zimpeto and Maputo Station, which does not include the Av. 25 Setembro East Extension Route and the N1 Bypass.

No.	Check Items	Rating	Notes	Mitigation
6	Cultural property	D	There are no cultural heritage sites located near the project site.	
7	Water rights and right of common	D	There will be no impact of the project on water rights.	
8	Health, sanitation and hazards.	D	The project will not have an effect on health and sanitation.	
9	Traffic accidents	B	During the operational phase, the BRT system may initially increase the risks to accidents when pedestrians and other vehicles are not yet used to the system. However the separation of public transport vehicles from mixed traffic is typically employed to make a new BRT operate efficiently, reducing the risks of accidents.	Public awareness campaigns on traffic safety, and training for the BRT operators on safe operation.
10	Indigenous people	D	There is no ethnic minority group or indigenous people in the project area.	
Natural environment				
11	Topography and geological features	D	The project will not have any impact on topography or geological features as it will be constructed on existing roads.	
12	Soil erosion	D	The project will not cause soil erosion.	
13	Hydrological situation	D	The project will not affect the aquatic environment.	
14	Flora, fauna and biodiversity	D	The project site is an urban area and there is no endangered species.	
15	Ecosystems	B	The project envisages having one terminal station located in a swampy area. This small patch of wetland habitat will be lost as well as its associated ecosystem services such as air purification.	Redesign/relocation of the BRT terminal to avoid the swamp.
16	Landscape	D	The project will not affect landscapes	
17	Global warming	D	The project is expected to have a positive impact on global warming, especially if the bus system uses clean energy.	
Pollution				
18	Air pollution	B	During the construction phase, emissions may increase temporarily due to the use of machinery and other construction equipment.	Emissions should be minimized by using low-emission machines and keeping good maintenance. The amount of emission should comply with Mozambican legal standards for air quality.
19	Water pollution	B	During the construction phase, liquid wastes that are not properly treated may pollute surface and underground water resources.	Waste oil, other lubricants, and industrial solvents should be recycled or disposed in an approved manner. Proper drainage system should be constructed.
20	Soil contaminations	B	During the construction phase, liquid wastes that are not properly treated may pollute soil.	Waste oil, other lubricants, and industrial solvents should be recycled or disposed in an approved manner. Proper drainage system should be constructed.

No.	Check Items	Rating	Notes	Mitigation
21	Waste	B	During the construction phase, a variety of solid waste may be generated.	The waste should be treated and disposed appropriately in compliance with Mozambican environmental regulations.
22	Noise and vibration	B	During the construction phase, noise and vibration levels may increase temporarily due to the use of machinery and other construction equipment.	The level of noise and vibration caused by construction works should be kept with the Mozambican legal limit.
23	Ground sinking	D	The project will not cause ground sinking.	

11.2.1 Involuntary Resettlement

According to ANE, EN1 is classified as a primary road, and therefore the ROW is 30 m wide as per the Land Law 19/97. Since the present BRT is designed to occupy 31 m width, available space is 1 m short of the requirement.

Especially, the roadside of the section between the N4 junction and the Malhazine Rotunda is densely occupied by different types of construction, infrastructure, and activities. In the section between Rotunda de Malhazine and Zimpeto terminal the ROW is almost free of occupation, posing a lower risk for resettlement.

In actuality, however, as observed in aerial photos and documented in the site visit, some structures are apparently even protruding into the ROW. These structures are mostly business enterprises, such as small shops, work yards and petrol stations. The exceptions are some residential structures, including one three-story building near the bridge over the railway (of which the ground floor is used as shops and upper floors seem to be an apartment complex), and a small community near the intersection of N1 and Avenida Ono.

Mitigation measures:

- Try to minimize property expropriation and resettlement to the practical extent by improving BRT design.
- Prepare an Initial Resettlement Plan to deal with compensation and resettlement issues.
- Follow Mozambican legislation and best practices, as well as World Bank Safeguard Policy, for compensation and resettlement.

11.2.2 Economic Activities

Currently, transport on the BRT proposed route is done mostly by private operators (“chapas”). One of the impacts will be the reduction of routes/trips for these transporters, which could lead to a reduction of income for these operators. As a positive impact, the project will generate employment during the construction phase. Construction jobs can be an important area of employment for unskilled labor groups.

Mitigation measures:

- Involve chapa drivers in stakeholder meetings.
- Implement job-creating program for chapa drivers.
- Special attention must be given to vulnerable groups such as women.

11.2.3 Traffic

Overall the project is expected to have a positive impact on traffic by promoting public mass transportation. However, the primary negative impacts are associated with the construction phase, such as temporary disruption to the local traffic on N1.

Mitigation measures:

- The construction works should be planned to minimize impacts on local traffic.
- Providing a bypass road or avoiding construction works during peak hours.

11.2.4 Public Facilities

There is public infrastructure along N1 such as street lights, traffic signals and signs, bus stops, garbage containers, and pedestrian bridges. These facilities may have to be displaced if they interfere with the BRT construction.

Mitigation measures:

- Consult and coordinate with relevant public organization about the relocation of facilities.
- Restore the public facilities if they are damaged during construction.

11.2.5 Traffic Accidents

Construction vehicles and heavy machinery will be using the N1 during the construction phase, traveling from the construction yard to the construction sites. This may increase probability of road accidents with other vehicles and pedestrians.

During the operational phase, the BRT system may initially increase the risks to accidents when pedestrians and other vehicles are not yet used to the system. However the separation of public transport vehicles from mixed traffic is typically employed to make a new BRT operate efficiently, reducing the risks of accidents.

Mitigation Measures

- Safe operation of construction vehicles.
- Improvements to pedestrian crossings and traffic signage.
- Training for the BRT operators on safe operation.
- Awareness campaigns.

11.2.6 Ecosystems

The project area is in an urban area, with little vegetation or natural habitats. However, there is a small patch of vegetation, a low land area, forming a swamp, close to the Rotunda de Malhazine. The project envisages having one terminal station located in this swampy area. This small patch of wetland habitat will be lost as well as its associated ecosystem services such as air purification. Also, on the margins of this swampy area there is some small-sale agriculture used by local people which may also be lost.

Mitigation measures:

- Relocation/redesign of the BRT terminal to avoid the swamp.
- If this is not possible, reduce the terminal footprint to minimize the impact.
- Compensate for crops loss.

11.2.7 Air Pollution

Vehicle emissions are the predominant source of pollutants in many urban centers and are directly linked to severe health and environmental problems. The existing older vehicles in Maputo produce high levels of contaminant emissions. The poor air quality in most developing cities limits economic growth and reduces the quality of life.

During the construction phase an increase in pollutant emissions from construction vehicles is expected, which will affect air quality in the project area. However, during the operation phase, this impact will reverse, and air quality may be improved by the BRT system, especially if clean technologies are used to run the buses. With a reduction in the number of obsolete transport vehicles and an increase in new vehicles with clean technologies, air quality can be improved, and public health can be improved though a reduction in respiratory illnesses caused by these emissions.

Mitigation measures:

- During construction, emission of air pollutants should be minimized by using low-emission machines and keeping good maintenance.
- The amount of emissions should comply with Mozambican legal standards for air quality.
- Ensure that the BRT system implemented in Maputo uses clean technologies.
- Encourage mode shifting from private vehicles to public transport.
- Monitor air quality.

11.2.8 Water Pollution

During the construction phase, liquid wastes that are not properly treated may pollute surface and underground water resources. Special attention must be paid to runoff water from construction sites, to prevent any contamination of the Infulene Valley region west of the BRT, which is located in a low lying area.

Mitigation measures:

- Waste oil, other lubricants, and industrial solvents should be recycled or disposed in an approved manner.
- Proper drainage systems should be constructed.

11.2.9 Soil Contamination

Similar to the impact above, during the construction phase, liquid wastes that are not properly treated may contaminate soil.

Mitigation measures:

- Waste oil, other lubricants, and industrial solvents should be recycled or disposed in an approved manner.
- Proper drainage systems should be constructed.

11.2.10 Waste

During the construction phase, various types of solid waste may be generated.

Mitigation measures:

- A waste management plan should be created before construction.

- Solid wastes should be recycled or disposed in an approved manner.
- Ensure the BRT stations and terminals are equipped with waste bins.

11.2.11 Noise and Vibration

During the construction phase, noise and vibration levels may increase temporarily due to the use of machinery and other construction equipment. However, during the operational phase, noise levels are expected to decrease. The existing older vehicles in Maputo generate considerable noise pollution (they generally lack of noise dampening devices, and have poor or no maintenance).

Mitigation measures:

- Respect noise levels as stated in Mozambican legislation.
- Do not conduct construction works during the night period.
- Minimize the construction time close to sensitive receptors like hospitals and schools.
- Employ noise dampening devices.
- Encourage shifting from private vehicles to public transport.
- Monitoring the noise levels along N1.

Chapter 12 Recommendations

12.1 Public Transport

The majority of people living and working in Greater Maputo depend on public transport for their mobility, and therefore public transport is a key element of the Urban Transport Master Plan. Although improvements have been made in recent years, the existing public transport services are inefficient, inadequate and unreliable, and offer poor value. Public transport is a key element in realizing the urban development vision of Greater Maputo as a "Socially and Environmentally Sustainable International Gateway Capital" and also its three strategy components i) multiple core structure; ii) sustainable economic development; and iii) international capital for culture. One of the priority projects that has been identified in the Master Plan is the Bus Rapid Transit (BRT) Development Project along the N1 Road. It is expected to provide high capacity, low-cost mass transportation system with preferential operation and road space.

12.1.1 Bus and Chapas

The public transport system in Greater Maputo at present is primarily road-based. There is an extensive network of routes operated by minibuses, known as *"chapas"*, and some full-sized buses, mostly owned by public sector companies (EMTPM) operating on certain routes. Even after the completion of the BRT network recommended by the Master Plan, the role of conventional bus system remains crucial for passenger transport service in the Greater Maputo area. The following are recommendations for bus and chapas in relation to the N1 BRT Line:

- The conventional bus system should serve as a trunk system to supplement the BRT system past its terminal points, in areas not densely populated enough to warrant BRT operations.
- The bus system should also play a role as a feeder service to both the BRT and the commuter railway system.
- The number of large-size buses should be increased to improve services and connectivity to BRT.
- Chapas should be gradually replaced by large-size buses.
- Mini-size buses can be used as feeders in densely-populated suburban areas.
- A reorganization of bus route network should occur alongside the BRT implementation.

12.1.2 BRT

Bus Rapid Transit (BRT) is a bus system with priority over other traffic in order to provide adequate capacity where passenger volumes are very high. BRT is a term generally used to refer to a high-capacity bus system in which buses operate on tracks which are segregated from other traffic for all or part of the route. For the N1 BRT project the following is recommended:

- Buses and stations should be kept clean all the times.
- The safety of bus use should be maintained.
- Full accessibility to the entire system with a single ticket should be guaranteed in the future.
- Electronic ticketing, such as currently used in Japan, should be introduced.
- Modern, high-efficiency, buses with high comfort levels should be used to attract demand from a significant portion of the middle class.

12.2 BRT Operation and Management

BRT operation and management is new in Mozambique. There will be management structures needs from experienced countries, such as Brazil or South Africa. The following are recommended practices of BRT operation and management.

12.2.1 BRT Operation and Management

- If EMTPM is selected to serve as BRT system (part) operator for a transitional period, targeted capacity development should be provided, including new skills in BRT technology and planning, accounting, labor/management relations, and customer service.
- Potential local BRT operators may benefit from discussing partnerships with experienced international BRT operators.
- Local chapa operators should be brought on board early on. It will be important to engage with the mass media, and work with parties that are not susceptible to local pressure.
- Measures should be taken to reduce the risk of using new technology, e.g., by not opting for exotic powerplants, and instead choosing proven suppliers and technologies for intelligent transport systems, by seeking a guarantee of bus support from bus suppliers, and by requiring suppliers to provide performance bonds.[1]
- Considering the risk that the payment of per km costs (by vehicle type and according to the contracted services) may not be met by fares and/or the contracted subsidy, it will be useful to have the ability to vary the passenger fare in line with inflation/costs to cover increased per km payments whenever a “trigger” value is reached in terms of inflation or a transport cost index.

12.2.2 Capacity Building

- Considering the risk that GMMTA (the metropolitan transport authority) will not be established quickly enough, technical assistance and capacity building should be provided, to strengthen the capacity to execute projects, with support in areas such as procurement, contract management, disbursement, planning and environmental and social mainstreaming. Commitment from the highest levels of government will be necessary, based on the presentation of facts from well-conducted research.
- Capacity building should be provided for integrated public transit expansion, design, and operation.
- Capacity building should be provided for developing catalytic transit neighborhoods, including value capture mechanisms (e.g., tax increment financing, business improvement district fees).[2]

12.3 Introduction of Solar Energy

Maputo is a relatively dry city and has a short rainy season lasting from November through March. Various sources indicate that the mean sunshine duration is around 2,800 hours per year, which is sufficient to introduce a photovoltaic (PV) power system effectively (as a comparison, the annual sunshine duration in Tokyo is around 1,800 hours on average).

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[1] HSBC, *How Banks Look at Bus Rapid Transit (BRT) Projects (and What Cities Can Learn from Them)*, 1 March 2010.

[2] See, e.g., Center for Clean Air Policy, *Transit Oriented Development NAMA [Nationally Appropriate Mitigation Action] in Colombia*, 2013.

Incorporating solar capture panels into BRT stations not only takes advantage of climatic conditions, but also gives the impression to users that the public transport system is "cutting edge." An example of PV panels incorporated into bus station infrastructure is shown in Figure 12.1.

Source: Website (http://www.kyocera.co.jp/news/2011/0702_erwp.html)

Figure 12.1: Bus Station with PV Panel