No.

JAPAN INTERNATIONAL
COOPERATION AGENCY (JICA)

MUNICIPAL COUNCIL OF MAPUTO
THE CITY OF MAPUTO
THE REPUBLIC OF MOZAMBIQUE

THE STUDY ON THE MASTER PLAN AND FEASIBILITY STUDY FOR THE ROAD DEVELOPMENT OF THE CITY OF MAPUTO IN THE REPUBLIC OF MOZAMBIQUE

FINAL REPORT

MAIN TEXT II

October 2001

Oriental Consultants Company Limited

Japan Engineering Consultants Company Limited

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TABLE OF CONTENTS

VOLUME 2 of 5 : MAIN TEXT I

LIST OF TABLES

CHAPTER 2 Present Situation

CHAPTER 3 Present Environmental Condition

CHAPTER 4 Present Road Network System

CHAPTER 5 Pilot Project Road

CHAPTER 6 Traffic Surveys

CHAPTER 7 Traffic Survey Results

CHAPTER 9 Future Traffic Demand

CHAPTER 10 Initial Environment Examination and Recommendation of Mitigation Measures

CHAPTER 11 Formulation of Road Development Master Plan

CHAPTER 12 Middle Term Plan for Road Development and Maintenance

CHAPTER 13 Identification of the Feasibility Study

CHAPTER 14 Introduction

CHAPTER 15 Engineering Survey and Analysis

CHAPTER 16 Environmental Survey

CHAPTER 17 Basic Design Standard

CHAPTER 18 Preliminary Engineering Design

CHAPTER 19 Construction Plan and Cost Estimate

CHAPTER 20 Environmental Impact Assessment

CHAPTER 21 Implementation Plan

CHAPTER 22 Project Evaluation

CHAPTER 23 Management System and Operations

CHAPTER 24 Conclusion and Recommendations

LIST OF FIGURES

CHAPTER 5 Pilot Project Road

CHAPTER 6 Traffic Surveys

CHAPTER 7 Traffic Survey Results

CHAPTER 8 Establishment of Socio-economic Framework

CHAPTER 9 Future Traffic Demand

CHAPTER 11 Formulation of Road Development Master Plan

CHAPTER 12 Middle Term Plan for Road Development and Maintenance

CHAPTER 15 Engineering Survey and Analysis

CHAPTER 16 Environmental Survey

CHAPTER 17 Basic Design Standard

CHAPTER 18 Preliminary Engineering Design

ABBREVIATIONS

(In alphabetical order)

AASHTO	:	American Association of State Highway and Transportation Officials
ANE	:	Administração Nacional de Estradas (National Road Administration of Mozambique)
B/C	:	Benefit / Cost Ratio
BHN	:	Basic Human Needs
CBD	:	Central Business District
CBR	:	California Bearing Ratio
CO	:	Carbon Monoxide
dB	:	Decibel
DBST	:	Double Bitumen Surface Treatment
DSM	:	Directorate of Municipal Service
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
FIRR	:	Financial Internal Rate of Return
GDP	:	Gross Domestic Products
HDI	:	Human Development Index
HDM	:	Highway Development Management
HNMS	:	Highway Network Management System
IEE	:	Initial Environmental Examination
IRI	:	International Roughness Index
IRR	:	Internal Rate of Return
JICA	:	Japan International Cooperation Agency
MCM	:	Municipal Council of (the city of) Maputo
Mt	:	Meticals
NO_2	:	Nitrogen Dioxide
NOx	:	Nitrogen Oxides
NPV	:	Net Present Value
OD	:	Origin-Destination (matrix)
pcu	:	Passenger Car Unit
ppm	:	Parts per Million
PRSP	:	Poverty Reduction Strategy Paper
PSI	:	Present Serviceability Index
ROCS	:	Road and Coastal Shipping Projects
ROW	:	Right-of-Way
SATCC	:	Southern African Transport & Communications Commission
STRADA	:	System for Traffic Demand Analysis
TPM	:	Transportes Públicos de Maputo (Municipal Public Transportation Operator)
UNDP	:	United Nations Development Programme
VAT	:	Value Added Tax
VOC	:	Vehicle Operation Cost
WHO	:	World Health Organization

The following foreign exchange rate is applied in the study :

1 US dollar = 22,000 Meticals = 125.00 Japanese Yen (July 2001), or

1 Meticals = 0.00568 Japanese Yen

PART B

FEASIBILITY STUDY

CHAPTER 14

INTRODUCTION

CHAPTER 14 : INTRODUCTION

14.1 GENERAL

As stated in the Master Plan Study (Part A of this Study), High Priority Projects were selected among the road development plans proposed for the sort-term plan. The selection of these high priority projects was made taking into consideration the following factors:

- Classified Road Development to improve Basic Human Needs and Community Environment
- To contribute settlement of existing Road Problems such as pavement deterioration, traffic congestion and poor drainage system
- To enhance Future Traffic efficiency
- To promote the Metropolitan Development
- Economic Efficiency of the investment
- Vitalization of local economy
- Minimizing resettlement on the viewpoint of environmental impact
- Availability of development fund
- Sustainability of maintenance fund
- Improvement of accessibility to public transport services
- Improvement of environment along the Proposed Project Roads
- Urgency of the project from the viewpoint of necessity and safety
- Consistency with national and regional policy.

The high priority projects consist of three categories; namely, road development plan, traffic management plan and public transport plan as outlined below:

(1) Road Development Plan

Trunk Road Development Plan:

1. Construction of Missing Link on Av. Julius Nyerere
2. Improvement of Av. Vladimir Lenine
3. Rehabilitation and Improvement of Av. Acordos Lusaka, Av. Guerra Popular
4. Rehabilitation and Improvement of Av. Angola
5. Rehabilitation and Improvement of Av. Marien Ngouabi

Collector Road Development Plan:

1. Rehabilitation of Industrial and Commercial Area Roads
2. Rehabilitation of Port Area Roads

Residential Area Roads:

1. Rehabilitation of District 1 Area Roads
2. Rehabilitation of District 2 Area Roads
3. Rehabilitation of District 3 Area Roads

(2) Traffic Management Plan:

Rehabilitation and Improvement of Intersections in the CBD

(3) Public Transport Plan:

Rehabilitation and Improvement of Bus Stops and Terminals

A Feasibility Study for the development of the projects was conducted during May – October 2001 in accordance with the Scope of Works mutually agreed by the Mozambique Government and the Japanese Government on July 19, 2000. All findings and issues of it have been compiled in Chapter 14 through Chapter 24 herein and are presented as Part B: Feasibility Study for High Priority Projects.

14.2 SUBJECT PROJECTS FOR THE FEASIBILITY STUDY

As described in Section 13.1, Chapter 13, Part A: Master Plan Study, the Feasibility Study was to be conducted for the following three categories and twelve high priority projects.

- Road Development Plan
  1) Construction of Missing Link on Av. Julius Nyerere:
     Early linking of the Missing Link on Av. Julius Nyerere through construction of two-lane trunk road (total length of about 5.6 km).

  2) Improvement of Av. Vladimir Lenine:
     Construction of bus bays and improvement of intersections on Av. Vladimir Lenine.

  3) Rehabilitation and Improvement of Av. Acordos Lusaka:
     Rehabilitation of pavement and drainage of Av. Acordos Lusaka (L=2.8 Km) and Widening of Av. Guerra Popular (L=0.7 km) from 2 to 4 lane road.

  4) Rehabilitation and Improvement of Av. Angola:
     Reconstruction of pavement and drainage of Av. Angola (L=3.1 km) and Rua S. Cabral/Largo de Deta (L=0.6 km).

5) Rehabilitation and Improvement of Av. Marien Ngouabi:
Widening to dual-carriageway on a section from Av. Mau Tse Tung to Av. Acordos Lusaka on Av. Marien Ngouabi (L=0.9 km) and reconstruction of pavement and drainage on a section from Av.Acordos Lusaka to Rue Joao Arbasini on Av. Marien Ngouabi (L=1.0 km).

6) Rehabilitation of Industrial and Commercial Area Roads (total length= 6.03 km):
Rehabilitation of pavement and drainage on Av. Josina Michel (1070, L=0.9km), Av. Fernao de Magalhaes (1038, L=1.3 km), Av. Zedequias Manganhela (1034, L=1.3 km), Av. Mohamed Siad Barre (1203, L=0.85 km), Av. Romao Fernandes (1199, L=0.85 km), Rue 1229 (L=0.25 km) and Av. As Estancias (1030, L=0.58 km).
Reconstruction of Rua Paulino Santos Gil (L=0.2km) and Av. ONU (L=1.5km) have been excluded from the priority project because the reconstruction work has been commenced by a financial support of Dutch Government.

7) Rehabilitation of Port Area Roads (total length =3.9 km):
Rehabilitation of pavement and drainage on Rue Consiglieri Pedroso (1022)/ Rue Joaquim Lapa (1020, L=0.8 km), Rue do Bagamoyo (1016)/ Rue de Timor Leste (1014, L=0.8 km), Av. Martires de Inhaminga (1006, L=0.8 km) and the other six port area roads (L=1.5 km).

8) Rehabilitation of District 1 Area Roads (total length = 8.7 km):
Rehabilitation of pavement and drainage on Av. Milagre Mabote (1369, L=1.0 km), Av. da malhangalene (1357, L=0.94 km), Av. Para O Palmar (1426, L=1.4 km), Av. Kaweme Nkrumah (1250, L=1.61 km), Av. Paulo Samuel Kankhomba (1152, L=0.55 km), Av. Emilia Dausse (1138, L=0.85 km), Av. de Maguiguana (1130, L=0.75 km), Av. Filipe Samuel Magaia (1183, L=0.4 km) and Av. Friendrich Engels (1009, L=1.2 km).

9) Rehabilitation of District 2 Area Roads (total length = 10.2 km):
Rehabilitation of pavement and drainage on Rua 2282/2265 (L=2.36 km), Rua 2275 (L=2.0 km), Rua de Xipamanine (2291, L=1.13 km), Rua dos Imaos Roby (2289, L=1.3 km), Rua 2315/2313 (L=0.7 km), Rua 2309/2324 (L=1.0 km), Rua 2522 (L=1.25 km) and Av. das Estancias (2000, L=0.49 km).

10) Rehabilitation of District 3 Area Roads (total length =9.5 km):
Rehabilitation of pavement and drainage on Rua da Goa (3027, L=0.8 km), Rua da

Lixera (3030, L=0.79 km), Av. Milagre Mbote (3001, L=1.98 km), Av. da Malhangalene (3259, L=1.83 km), Rua 1 de Maio (3374, 1.49 km), Rua 3306 (L=0.49 km), Rua 3523 (L=1.0 km) and Rua 3576 (L=1.1 km).

- Traffic Management Plan
  Construction of Right-turn lanes and signals (14 intersections) and control of on-street parking in intersection areas.

- Public Transport Plan:
  To provide suitable location and size of bus bays (22 bus bays) and one (1) terminal and to equip required function on to the bus terminal.

In addition to the above-mentioned projects, a study on Road Maintenance and Management system has been conducted on the viewpoint of structural strengthen.

14.3 OBJECTIVES AND BASIC CONDITIONS OF THE FEASIBILITY STUDY PROJECTS

1. Target Year

A target year for the priority projects has been established as a year 2010 in order to prepare suitable scale of the projects to meet a future traffic demand in the target year.

2. Objectives and Basic Components

The objectives of the priority projects has been established as shown in Table 14.3.1 and the basic project measures and components has also confirmed during the Master Plan Study as shown in Table 14.3.1 and a detailed study on the selection of each project components has been described in the following chapters.

In addition to the objectives, the General objectives and targets, which were established for the Master Plan, are the overall objectives to each of the priority projects.

In case of the project for Construction of Missing Link on Av. Julius Nyerere, followings are the project objectives and basic components:

- Early linking of the Missing Link on Av. Julius Nyerere through construction of two-lane trunk road (total length of about 4.8 km);
- To prevent Disaster through introduction of measures for Land-slide and Drainage and

- To function as a basic corridor for future extension through preparation of land for widening.

As for the project for Improvement of Av. Vladimir Lenine, followings are the project objectives and basic components:

- To decrease Traffic Congestion through construction of proper Bus-bays and improvement of the intersection with Av. Julius Nyerere
- To provide better Public Transport through construction of proper Bus-bays

As for the project for Rehabilitation and Improvement of Av. Acordos Lusaka, followings are the project objectives and basic components:

- For smooth vehicle running, rehabilitation of pavement and drainage of Av. Acordos Lusaka (L=2.8 Km) and
- To decrease Traffic Congestion through Widening of Av. Guerra Popular (L=0.7 km) from 2 to 4 lane road

As for the project for Rehabilitation and Improvement of Av. Angola, followings are the project objectives and basic components:

- For smooth vehicle running, reconstruction of pavement and drainage of Av. Angola (L=3.1 km) and Rua S. Cabral/Largo de Deta (L=0.6 km)
- To decrease Traffic Congestion through improvement of intersection

As for the project for Rehabilitation and Improvement of Av. Marien Ngouabi, followings are the project objectives and basic components:

- For smooth vehicle running, rehabilitation of pavement and drainage on a section from Av.Acordos Lusaka to Rue Joao Arbasini on Av. Marien Ngouabi (L=1.0 km)
- To decrease Traffic Congestion through improvement of intersections and Widening to dual-carriageway on a section from Av. Mau Tse Tung to Av. Acordos Lusaka on Av. Marien Ngouabi (L=0.9 km)

As for the project for Traffic Management Plan, followings are the project objectives and basic components:

Project Objectives:

- To smooth vehicle running;
- To decrease traffic congestion and
- To avoid large scale investment

Project Basic Components:

- Construction of Right-turn lanes and signals (14 intersections);
- Control of on-street parking in intersection areas

As for the project for Rehabilitation and Improvement of Bus Stops and Terminals, followings are the project objectives and basic components:

Project Objectives:

- To provide appropriate Bus Services and
- To settle Traffic Congestion

Project Basic Components:

- Provide suitable location and size of bus bays (22 bus bays) and one station and
- Equip required functions.

3. Alternatives

Basic policy of the selection of the alternatives on each project has been prepared as shown in Table 14.3.1. For the rehabilitation and improvement of the existing roads, no route and road functional alternatives are introduced due to respect the general strategies of the Master Plan.

As for the new construction of the priority projects, route, stage construction and right-of-way alternatives has been prepared. The detailed contents of the study are explained the following chapters.

4. Future Traffic Demand on the target year

Future Traffic Demand on the target year of 2010 has already been prepared as same of the mid-term traffic volume on the base plan in Chapter 12.

In case of the without project, the mid-term traffic volume on the Do Minimum case has also been prepared in Chapter 12.

Table 14.3.1 Objectives and Components of Feasibility Study

FS Project	Trunk Roads					Collector Roads		Residential Area Roads			Rehabilitation and Improvement of Traffic Management Facilities	Rehabilitation and Improvement of Bus Stops and Terminals
	1.Construction of Missing link on Av. Julius Nyerere	2.Improvement of Av. Vladinir Lenine	3.Rehabilitation and Improvement of Av. Acordos de Lusaka	4.Rehabilitation and Improvement of Av. Angola	5.Rehabilitation and Improvement of Av. Marien Ngouabi	1.Rehabilitation of Industrial and Commertial Area Roads	2.Rehabilitation of Port Area Roads	1.Rehabilitation of District 1 Area Roads	2.Rehabilitation of District 2 Area Roads	3.Rehabilitation of District 3 Area Roads		
1. General Target/Objectives, Target year: 2020	1. Protect/ improve Basic Human Needs and Community Environment 2. Contribute settlement of existing Road Ploblems 3. Enhance Future Traffic Efficiency 4. Promote the Metropolitan Development											
2. General Strategy for year 2020	1. Functional Classification of Road Network and Typical Closs-sections 2. Rehabilitation of Pavement and Drainage, Construction of Dual Carriageway (Lusaka, Angola and M. Ngouabi Rd.) and Improvement of Intersections in Central Area 3. Construction and Improvement of Dual Carriageway (Mozambiqu, Nyerere, Lusaka, Lenine, FPLM, M. Ngouabi Rd.) 4. Construction and Improvement of Outer and Middle Ring roads											
3. Project Objectives, Target year: 2010	1. Early Linking of Missing Link 2. Prevent Disaster 3. Basic Corridor for Future Extention	1. Decrease Traffic Congestion 2. Provide Better Public Transport	1. Smooth Vehicle Running 2. Decrease Traffic Congestion	1. -do- 2. -do-	1. -do- 2. -do -	1. -do-	1. -do-	1. -do-	1. -do-	1. -do-	1. -do- 2. -do- 3. Avoid Large-scale Investment	1. Provide Appropriate Bus Services 2. Settle Traffic Congestion
4. Project Measures/ Components for year 2010	1.Reconstruction of 2-lane Trunk Road 2.Measures for Land-slide and Drainage 3.Land Preparaion for Widening	1. Construction of Bus Bay 2. Improvement of Intersection	1. Pavement and Drainage Rehabilitation 2. Construction of Dual Carriageway	1. -do- 2. Intersection Improvement	1. -do- 2. -do- 3. Construction of Dual Carriageway	1. -do-	1. -do-	1. -do-	1. -do-	1. -do-	1. Installation of Right-turn lane and Signal 2. Control of On-street Parking 3. Traffic Control	1. Provide suitable location and size of bus bays/stations 2. Equip required Functions
Carriageway	Asphalt-concrete(As-con)	Concrete block (Block)	As-con	As-con	As-con	As-con	As-con	As-con	As-con	As-con	As-con	Block
Footpath	Bitumenous Surface Treatment(BST)	Block	Block	Block	Block	Block	Block	Block	Block	Block	Block	Block
Drainage	Open ditch	nil	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	Open ditch	Open ditch	U-shaped	U-shaped
5. Alternatives	1. Route Alternatives 2. Stage construction	nil	1. Widening of Right of Way	nil	nil	nil	nil	nil	nil	nil	nil	nil
Carriageway	Stabilized base/sub-base course (Stabilization)	Semi-rigid	Stabilization	Stabilization	Stabilization and BST	Stabilization and BST	Stabilization and BST	Stabilization and BST	Stabilization and BST	Stabilization and BST	Semi-rigid	Semi-rigid
Footpath	nil	BST	BST	BST	BST	BST	BST	BST	BST	BST	nil	BST
Drainage	nil	nil	L-shaped	L-shaped	L-shaped	Open ditch	L-shaped	L-shaped	nil	nil	L-shaped	L-shaped

CHAPTER 15

ENGINEERING SURVEY AND ANALYSIS

CHAPTER 15 : ENGINEERING SURVEY AND ANALYSIS

15.1 GENERAL

The engineering surveys, which are the Geological Investigation, the Material Investigation, Topographical Survey and the Utilities Investigation, should be carried out in order to define the design condition of the Preliminary Design. Each survey result should be analyzed to reflect the Preliminary Design.

15.2 GEOLOGICAL INVESTIGATION

15.2.1 Purpose of the Investigation

Purposes of geological investigation by better understanding geological conditions at the site are as follows.

- To properly estimate bearing strata to support foundations for structures.
- To design cost effective slope protection. Proposed structure/facilities are:
    - Bridge,
    - Road embankment,
    - Cut slope

15.2.2 Geological Characteristic

Basic formation at the site is Ponta Formation, which is predominantly consisting of coarse grained sandstone deposited in late Tertiary. The sandstone has been completely weathered at top tens of meters and changed into residual soil, such as sand, silty sand, coarse sand with gravel and so on. Constituent of Ponta Formation is summarized as shown in the Table 15.2.1.

Table 15.2.1 Summarization of Ponta Formation

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MnO	MgO
Proportion	80-90%	3-6%	1-5%	0.1-1%	0.01-0.05%	0– 0.5%

There is a fault along Av. J. Nyerere Road, running to north. The maximum differential level is about 30m as is estimated from geological section provided by the Ministry of Mineral Resources and Energy of Mozambique. East side of the fault is lowered and west side is elevated. East side is close to the sea and is covered with beach sand. West side is outcropped Ponta Formation, partially covered with Congolote Formation, unconsolidated

fine to coarse sand deposited in late Pleistocene.

15.2.3 Soil Investigation at Proposed Structure

Core drilling were performed at three locations as shown in the Figure 15.2.1. Detail of drilling are shown in drilling logs in appendix. Following is description of soil encountered at the site:

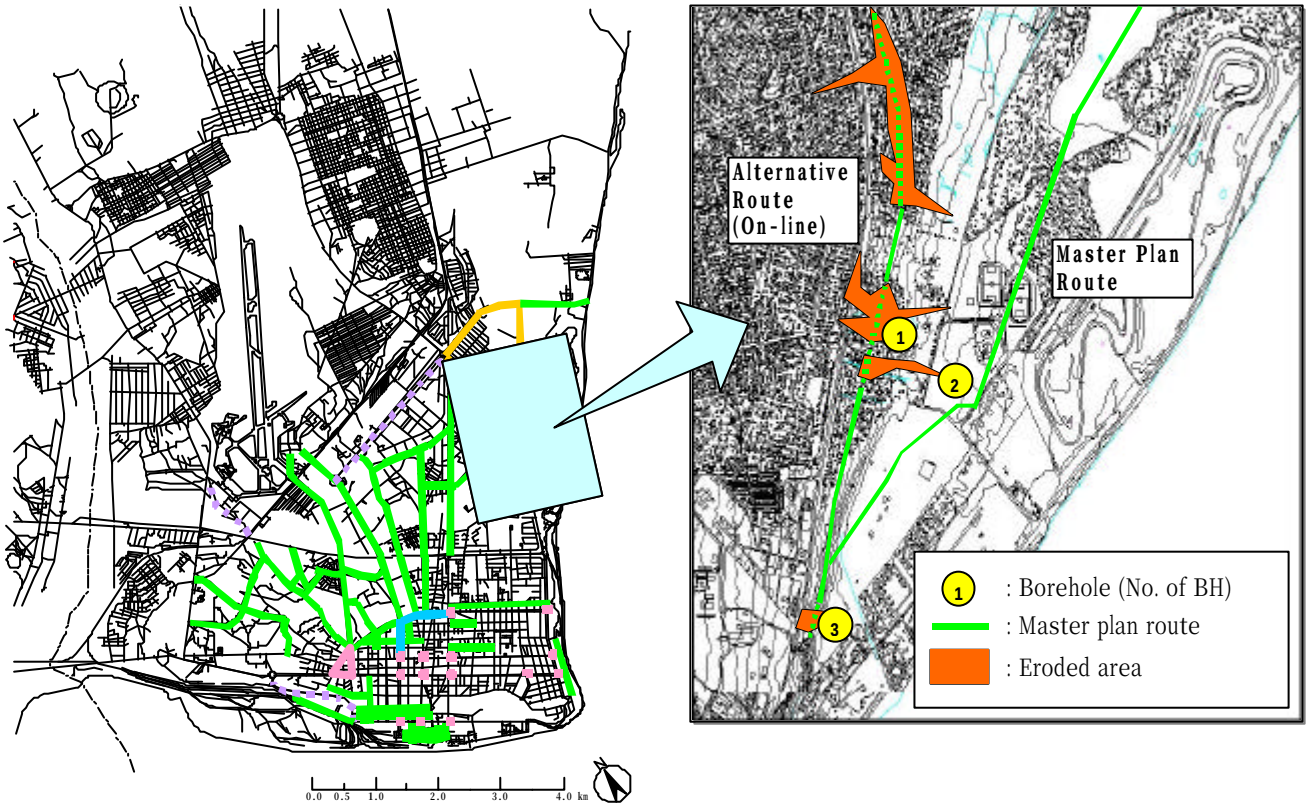


Figure 15.2.1 Location of Borehole

<Borehole No.1>

The borehole was carried out at the center of Av. J. Nyerere road in Ravine 3. The original ground level was same as the top of the Ravine 3 before. The groundwater level is about 3m below from ground level.
Subsoils encountered are:

GL-0 ～13m
Secondary deposit. Reddish brown, loose, fine to medium grained sand with trace of silt. Since plastic tube fragment was sampled from the depth GL-7m, we estimate that this layer is formed by backfilling of flooded soil from up stream.

GL-13～18m
Original ground. N-value by Standard Penetration Test is sharply increased with depth. From GL-12m, sandstone of fresh Ponta Formation is encountered. The particles are coarse grained with some fragment of igneous rocks.

<Borehole No.2>

This hole is located on the east side of the fault where beach sand is distributed and red sand has been flown over from around the location of borehole No.1. Purpose of this borehole is to confirm the ground condition for construction of culvert and small embankment.
Groundwater table was GL-1m, same as nearby surface water table. The subsoils are:

GL-0～3m
Secondary deposit., reddish brown, fine to medium sand

GL-3m～8m
Beach sand, brownish gray, very loose, medium to coarse grained sand, with a trace of shell fragment.

GL-8～13m
Ponta Formation, brownish gray, medium to coarse sand occasionally containing decomposed fragment of sandstone.

GL-13～14m
Decomposed sandstone, grayish brown coarse sand

GL-14～15m
Sandstone, light brown, with core recovery of 80% and RQD of 60%. Classified as moderately weathered.

<Borehole 3>

This borehole was sunk to evaluate the depth to the bearing strata for pile end for proposed abutment/pier of the bridge. The location is at washed away Av. J. Nyerere road, to the south of Borehole No.1.
Depth to the groundwater table is not confirmed. Subsoil embedded are:

GL-0～3m

Fill, light brown, coarse sand with boulders.

GL-3～6m

Ponta Formation, reddish brown fine to medium sand deprived from completely weathered sandstone

GL-6～10m

Reddish brown fine to medium sand sometimes with sandstone fragment

GL-16～20m

Weathered sandstone, grayish brown. Total length of rock confirmed is 4 m., in which top 3m is highly fractured into gravel or short-bar shaped cores while bottom 1m is slightly weathered with long-bar shaped cores.

15.2.4 Evaluation of Foundation

1) Bearing stratum for embankment

Most of the top soils distributed over the project site, including secondary deposited sand, beach sand and residual sand form a stable supporting ground for embankment. Top portion may be loose and a certain amount of settlement may be caused. However, the settlement of loose sand takes place immediately right after on-loaded and no long-term settlement which can affect the function of embankment is anticipated.

2) Bearing stratum for abutment and piers

Recommended is use of end bearing pile driven to the depth at which sandstone of minimum core recovery of 50% is confirmed or SPT N-Value greater than 50 blows are obtained for 2m continuously. Since unweathered sandstone fragment may be remained not in decomposed condition, which can damage the pile end if over-driven, bored type pile is preferred to the driven type.

3) Slope stability

Most of the soil at the project site is suitable for filling of embankment if properly compacted. However, both clay-cover and horizontal subsurface drains are necessary to prevent slope surface failure for filled embankment. And the slope angle should at least be equal or gentler than Vertical : Horizontal =1:1.5.

For cut slope, the slope angle is desirable to be equal to or gentler than Vertical : Horizontal =1:1.0 at the place where the groundwater level is high. Clay-cover or subsurface drains are also necessary to prevent slope surface failure.

15.3 MATERIAL INVESTIGATION

15.3.1 Purpose of the Investigation

Purposes of the material investigation are as follows.

- To evaluate existing subsurface soil conditions on Project roads,
- To confirm the quality and quantity of:
    - Subsoil at project site
    - Potential borrow soil
    - Coarse aggregate for potential quarry
    - Fine aggregate for concrete

15.3.2 Subsoil Conditions on Project Roads

Subgrade sampling and laboratory soil tests were performed at selected 36 locations on project as shown in the Figure 15.3.1.

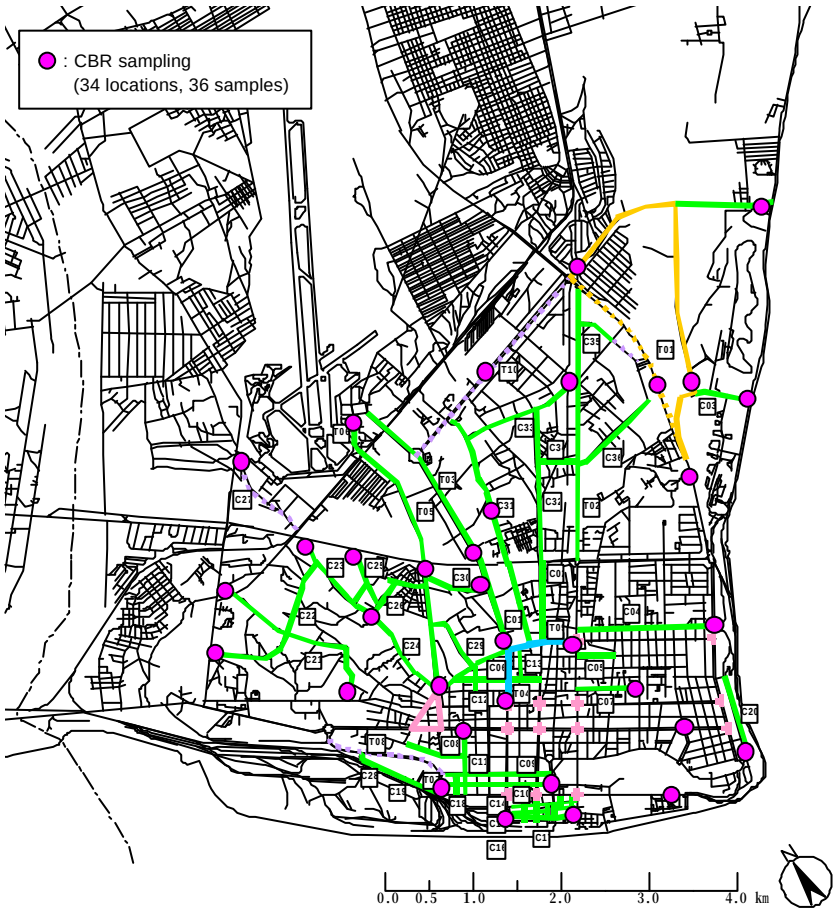


Figure 15.3.1 Location of CBR Sampling

Location of sampling is also shown in Appendix 15.2 together with sketches of test pits. On the basis of the results, we classified the soils encountered as following according to AASHTO system attached in appendix 15.2 and visual inspection:

1) Stone fragment, gravel and sand
2) Fine sand
3) Silty or clayey gravel and sand
4) Ash and burned waste

Detailed results is complied in the appendices and the Engineering properties can be tabulated as shown in the Table 15.3.1:

Table 15.3.1 Engineering properties of soils at the site

		Plas-ticity	Maximum dry density, kN/m3	Optimum moisture content, %	CBR, %	Cohe-sion, kN/m2	Fric-tion,	Location
Stone fragment, gravel and sand		NP	1.7 and1.9	7 and 10	24 and 48	-	-	T07 and T01/4
Fine sand	Red sand T01	NP	1.75 in average	8-9	20-25	2-7	28-25	Av24,C04,C07,C11,C16/1,C16/2, C21/1,C21/2,C24, C25,C27,C30,C31/1,C31/2,C33tT01/3,T01/5,T01/7,T03,T05,T06,T09/1, Y09/2
	Gray sand C27					0-8	33-37	
Silty or clayey gravel and sand		NP	1.80-1.95	10-11	30-35			AV25,C20,C22, C23,T01/1,T01/2T01/6 T04, T09/2

Basically, all material can be classified as excellent to good as per AASHTO.

<Stone fragment, gravel and sand>

Number of samples tested is only 2, and CBR were 20 % in the minimum.

<Fine sand>

Maximum dry densities obtained are 1.7 to 1.85 g/cm^3 in the most cases. Optimum moisture content is 7-10%. CBR ranges 15 % to 45% and is about 25% in the average.

Direct shearing test were carried out and the results are as shown in the Table 15.3.2.

Table 15.3.2 Test Results of Direct Shearing Test

		Fine content %	Shear Strength			
				Compaction Degree		
				80%	90%	100%
C27	Gray sand	8	C, kN/m2	0	2	8
			φ, °	33	33	37
T01/5	Red sand	9	C, kN/m2	2	2	7
			φ, °	28	30	35

Although shear strength fluctuates widely depending on the degree of compaction, we can expect $\phi = 30°$ if the fill is compacted at least 90% of maximum dry density, for both sands.

Followings are comment to earthwork on the basis of visual inspection at the site.

- The soil particles are somewhat fragile and, thus, can get high density with high strength when properly compacted.
- Earth work would not be a problem since adjustment of optimum moisture content is easy due to dry climate at Maputo.
- However, very severe erosion was caused in the past and enough precaution and measures have to be taken to prevent surface water or groundwater run on/through the slope/embankment.

<Silty or clayey gravel and sandv>

Fine (silt and clay) content is greater than 10% for this soil. Maximum dry densities are 1.8g/cm3 in the minimum. With higher density than 'Fine sand', CBR is also higher.

<Ash and burned waste>

Ash and cinders that were generated at incineration plant operating before are found to be sandwiched in the fill, about 0.5 to 1m bellow ground level at several location. Although they are almost same as sand in physical properties and not cause a major bearing capacity problem as subgrade, cinders are supposed to contain heavy metals and dioxins that are harmful to human health.

15.3.3 Potential Borrow Pit Areas

Soil borrow pit is located on a gently elevated hill at Marracuene, about 30km north to the Maputo city. Type of the soil is reddish brown, fine to medium sand derived from Ponta Foramtion. The type of soil is same as is commonly distributed at the project site according to our visual inspection and we believe that the quality of soil is as excellent as above-mentioned red sand. Vast quantity of soil was witnessed at the pit.

15.3.4 Potential Quarry Site for Aggregate

Most potential quarry is located about 30 km to the south of Maputo. There are two types of rocks: Rhyolite and Basalt:

<Rhyolite>

The quality of Rhyolite looks weathered and a little fragile by visual inspection and is not used for sea wall (breakwater) according to the local contractor. However, it has enough strength as coarse aggregate, base course and other building stones on the basis of visual inspection.

<Basalt>

The quality of basalt is excellent by visual inspection. However, the Basalt quarry is located relatively flat portion compared to Rhyolite quarry and it is necessary to dig downward to continue production of stones.

15.3.5 Investigation of Material for Structure

Other than borrow soil and coarse aggregate, availability of fine aggregate for concrete use was investigated through site reconnaissance and existing data collection. Predominantly fine aggregate is produced at crushing plant in the Rhyolite quarry. Minor amount is taken from river according to local subcontractor.

15.3.6 Evaluation of Aggregate and Materials

As coarse aggregates, both Rhyolite and Basalt are assumed to be excellent material from visual inspection. Following summarizes laboratory tests results performed by local contractor. As shown in the Table 15.3.3, Rhyolite tested is proved to be an excellent both as concrete aggregate and pavement material.

Table 15.3.3 Comparison of Properties of Rhyolite Quarry with AASHTO

	AASHTO: M 57-80	AASHTO: M 147-65	Test Results of Rhyolite	Comment
	Coarse Aggregate for Portland Cement Concrete	Aggregate and Soil-Aggregate Subbase, Base and Surface Courses		
Abrasion	50% in the maximum	50% in the maximum	21-22%	Accepted
Soundness	12% in the maximum	-	1.5%	Accepted

15.4 HYDROLOGICAL STUDY AND ANALYSIS

1) Rainfall Intensity

The rainfall intensity used to the drainage design should be corresponding to the time of concentration "t (min)", which means the flow time that the rainfall flow down from the farthest point of the catchment area. For that purpose, the rainfall intensity corresponding to "t" should be converted from the past rainfall data corresponding to the optional duration of rainfall.

The rainfall intensity corresponding to "t" in the Maputo city is being set up with the master plan in 1981. After that, it has been examined newly in the basic design study of the reconstruction of Av. Julius Nyerere in 2000. Through the comparison of these studies, it is revealed that the rainfall intensity adopted in these studies are not much different from the other in the short duration of "t".

Therefore, it is conceivable to adopt the rainfall intensity in the result of these studies to the drainage design.

Table 15.4.1 Rainfall Depths (mm) and Intensities (mm/h,l/s/ha) For Short Durations

Return Period T (year)	Duration t(min)	Depth h(mm)	Intensity I	
			(mm/h)	(l/s/ha)
2	15	25	100	278
	30	37	74	206
	60	49	49	136
5	15	32	128	356
	30	48	96	267
	60	64	64	178
10	15	37	148	411
	30	56	112	311
	60	73	73	204
20	15	42	168	467
	30	64	128	356
	60	83	83	231
50	15	48	192	533
	30	74	148	411
	60	94	94	261
100	15	53	212	589
	30	82	164	456
	60	103	103	286

Source: Scope Assessment and Preliminary Design Study of Repair of Avenida Julius Nyerere

2) Run-off Factor

The run-off factor is different corresponding to the rainfall intensity or characteristics of the site such as the condition of the ground surface, the land use pattern, the terrain and so on. Generally, the run-off factor is set up as it is high in the urbanized area and it is low in the un-urbanized area.

However, through the visual inspection of the road surface drainage situation in Maputo city, it is understood that the following conditions should be considered for determination of the run-off factor.

Urban Area

District 1 is being urbanized already and there are many gathering residences and even the population accumulation is high. Also the most of roads are paved. However the part of the unpaved is many by the damage of pavement, also the sidewalk is unpaved in a part of trunk roads. Outflow rate is not high at the usual rainfall.

Sub-urban Area

The most of roads in the suburbs area of District 2 and 3 are unpaved, and the outflow rate is not high except hilly areas. However it becomes to be impossible traffic at the usual rainfall by the defectives of water flow out due to inadequate of drainage facilities.

Through the evaluation of the above site conditions, the run-off factor determined for the drainage design is proposed as follows.

- Urban Area : 0.75
- Semi-urban Area (High Density Residential Areas) : 0.55
- Semi-urban Area (Other Areas) : 0.20

15.5 TOPOGRAPHIC SURVEY

The Topographic Survey was made to obtain topographic data of the existing ground for designing of the road alignment and geometrical detail on the feasibility study project roads.

The list and location of the Project Roads are as shown in the Table 15.5.1 and Figure 15.5.1.

The survey results are attached in the Appendix.

15.5.1 Scope of the Works

The works for the topographic survey was executed in accordance with the following terms under the supervision of the JICA Study Team. The surveys are composed of the following items :

Benchmark Control Survey

The Consultant shall establish an EDM traverse, in accordance with the Survey Regulations to provide a suitable foundation for the reliable mapping of features within the detail Survey. Beacons will be tied into the Existing Grid system via the prescribed monuments. The elevation of stations will also be compared to the triangulation point located at Project roads.

Traverse Survey

The coordination of the traverse points will be carried out using GPS. All ground control points will be tied to Existing Geodetic Network by use precise GPS method.

Cross section Survey

The cross section survey shall be conducted every 20m. The survey width shall be applied 15m from existing road centerline. Detail survey contents are as follows.

Plan Survey

The plan survey shall be conducted at peculiar points. For example catch-pit, electric-poles, flowerbeds, water taps etc.

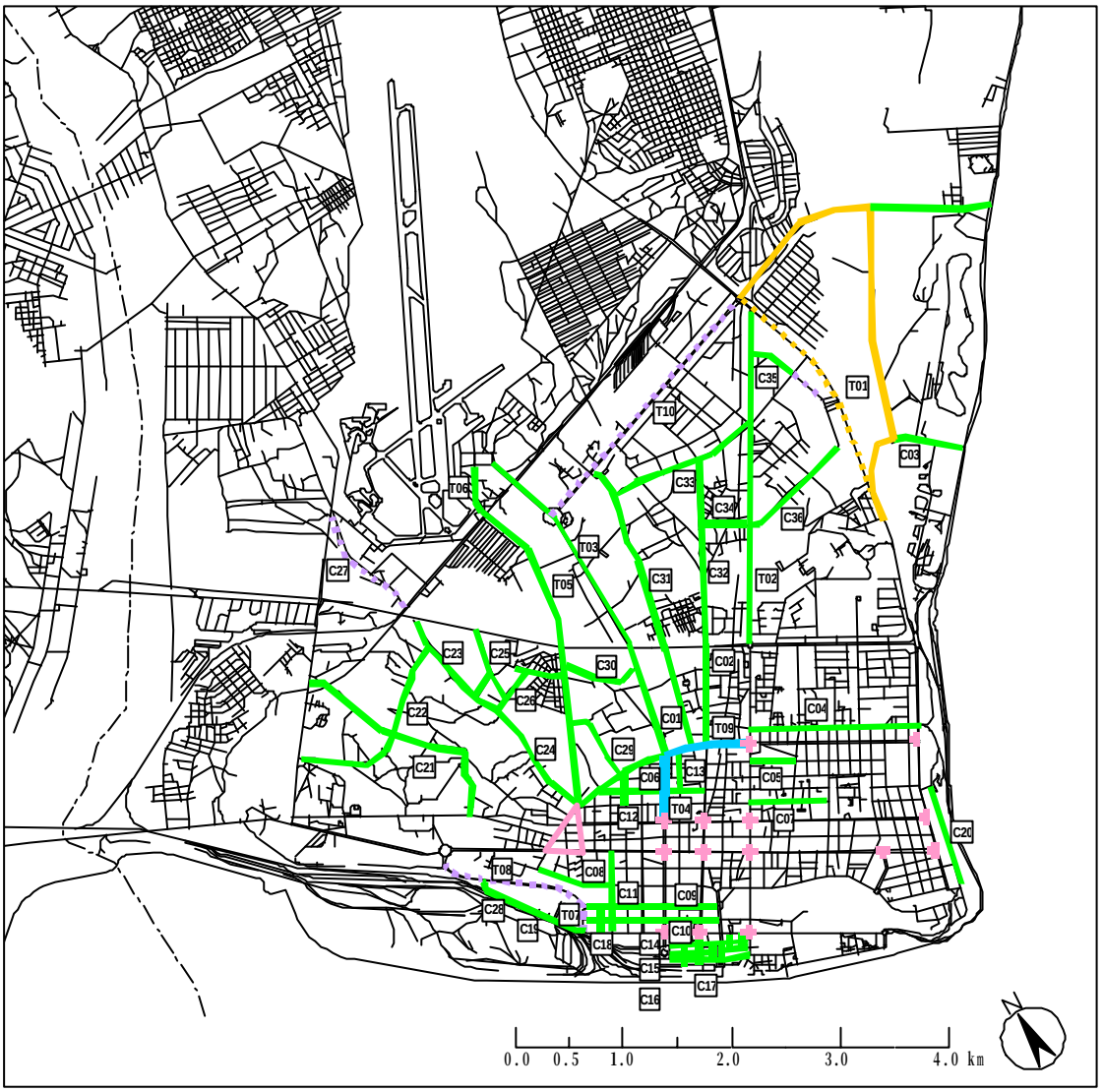
15.5.2 Computer Format

The data was collected as a digital 3-D ground model in a format compatible with

"MODELMAKER" computer software systems.

Table 15.5.1 Survey Route List

Classification	District	Road Name	Length (km)
Trunk Roads	-	T01) New Construction of Av. Julius Nyerere (incl. Rua 3867, 4500, 4683, 4685)	5.50
		T01) Av. Julius Nyerere (existing route)	2.80
		T02) Av. Vladimir Lenine	3.20
		T03) Av. Acordos do Lusaka	2.85
		T04) Av. Guerra Popular	0.70
		T05) Av. da Angola	3.10
		T06) Rua S. Cabral / Largo de Deta	0.60
		T07) Rua Paulino Santos Gil	-
		T08) Av. da ONU	-
		T09) Av. Marien Ngouabi Eastern Portion (Av.V.Lenine-Av.A.Lusaka)	0.90
		T09) Av. Marien Ngouabi Western Portion (Av. A.Lusaka-Av.Angola)	0.98
		T10) Av. da FPLM	2.85
Collector Roads	Dist 1	C01) Av. Milagre Mabote(1369)	1.00
		C02) Av. da Malhangalene(1357)	0.94
		C03) Av. Para O Palmar(1426)	1.40
		C04) Av. Kawame Nkrumah(1250)	1.61
		C05) Av. Paulo Samuel Kankhomba(1152)	0.55
		C06) Av. Emilia Dausse(1138)	0.85
		C07) Av. de Maguiguana(1130)	0.75
		C08) Av. Josina Michel(1070)	0.90
		C09) Av. Fernao de Magalhaes(1038)	1.30
		C10) Av. Zedequias Manganhela(1034)	1.30
		C11) Av. Mohamed Siad Barre(1203)	0.85
		C12) Av. RomaoFernandes(1199)	0.85
		C13) Av. Filipe Samuel Magaia(1183)	0.40
		C14) R. Consiglieri Pedroso(1022)/R. Joaquim Lapa(1020)	0.80
		C15) R. do Bagamayo(1016)/R. de Timor Leste(1014)	0.80
		C16) Av. Martires de Inhaminga(1006)	0.80
		C17) Port Area(6 roads)	1.50
		C18) Rua 1229	0.25
		C19) Av. das Estancias(1030)	0.58
		C20) Av. Friedrich Engels(1009)	1.20
	Dist 2	C21) Rua 2282/2265	2.36
		C22) Rua 2275	2.01
		C23) Rua de Xipamanine(2291)	1.13
		C24) Rua dos Imaos Roby(2289)	1.30
		C25) Rua 2315/2313	0.70
		C26) Rua 2309/2324	1.00
		C27) Rua 2522	1.25
		C28) Av. das Estancias(2000)	0.49
	Dist 3	C29) Rua da Goa(3027)	0.80
		C30) Rua da Lixeira(3030)	0.79
		C31) Av. Milagre Mabote(3001)	1.98
		C32) Av. da Malhangalene(3259)	1.83
		C33) Rua 1 de Maio(3374)	1.49
		C34) Rua 3306	0.49
		C35) Rua 3523	1.00
		C36) Rua 3576	1.10
Intersections		Int1) Av. Mao Tsé Tung x Av. Julius Nyerere	-
		Int2) Av. Eduardo Mondlane x Av. Julius Nyerere	-
		Int3) Av. 24 de Julho x Av. Julius Nyerere	-
		Int4) Av. 24 de Julho x R dos Lusiadas	-
		Int5) Av. 24 de Julho x Av. Vladimir Lenine	-
		Int6) Av. 24 de Julho x Av. Karl Marx	-
		Int7) Av. 24 de Julho x Av. Guerra Popular	-
		Int8) Av. Eduardo Mondlane x Av. Guerra Popular	-
		Int9) Av. Eduardo Mondlane x Av. Karl Marx	-
		Int10) Av. Eduardo Mondlane x Av. Vladimir Lenine	-
		Int11) Av. Karl Marx x Av. Marien Ngouabi	-
		Int12) Av. Vladimir Lenine x Av. Marien Ngouabi x Av. Mao Tsé Tung	-
		Int13) Av. Karl Marx x Av. 25 de Setembro	-
		Int14) Av. 25 de Setembro x Av. Samora Machel	-
		Int15) Av. 25 de Setembro x Av. Vladimir Lenine	-
		Int16) Av. 24 de Julho x Av. da Tanzania Int17) Av. Eduardo Mondlane x Av. do Rio Limpopo/ Av. da Tanzania x Av. Rau João Albasini Int18) Av. Eduardo Mondlane x Av. da Zambia Int19) Av. da Zambia x Av. da Maguiguana	-



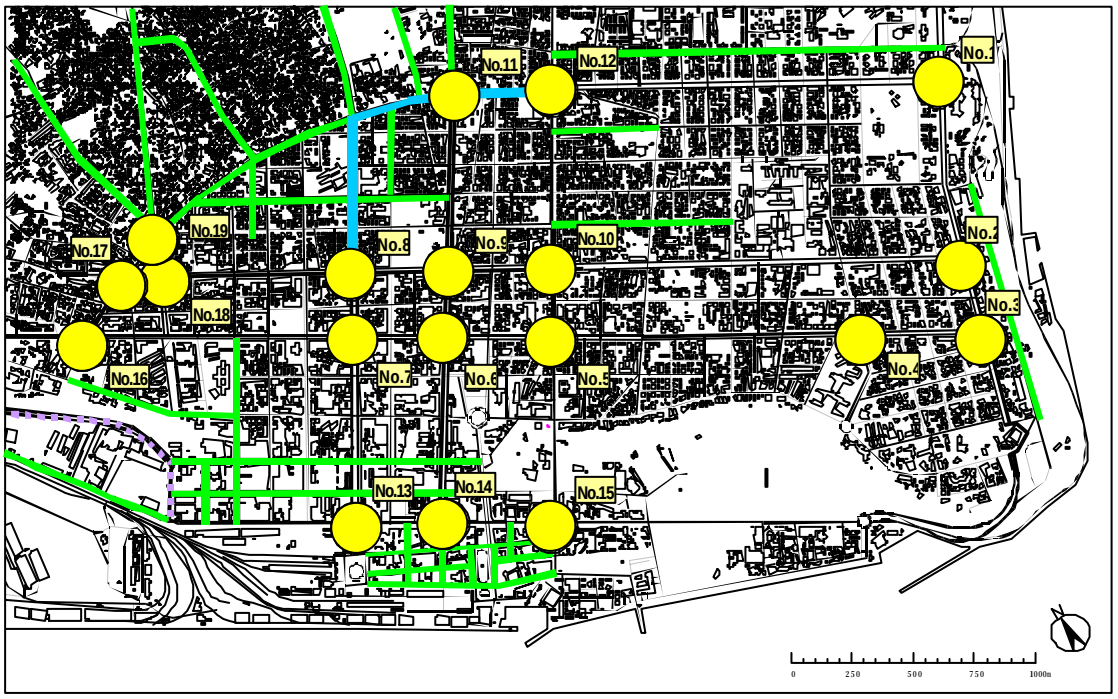


Figure 15.5.1 Survey Route Map

15.6 EXISTING CONDITIONS OF THE PROJECTS

The high priority projects consist of three categories; namely, road development plan, traffic management plan and public transport plan and the existing problems and issues of conditions are outlined as below:

15.6.1 Road Development Plan

1) Trunk Road Development Plan:

(1) Construction of Missing Link on Av. Julius Nyerere

Existing section, from the edge of the university of Mozambique to the intersection of Praca dos Combatentes, on Av. J. Nyerere has been corrupted and cut off by the heavy rain. In the Master Plan Study, the basic relief route for the connection of the Missing Link are recommended to the route which is running approximate 0.5 to 1.0km far from the existing route of Av. J. Nyerere due to cost-efficiency.

The proposed alignment is passing through the flat plain with 5.6 km long.

Although there is no clear Right-of-way authorized yet, there is a new access road with single carriageway to the new housing development and a rural earth road which could be applicable a part of the proposed road.

The proposed alignment is passing with a new temporary constructed canal and also passing at the edge of local community that will be required some housing compensations.

(2) Improvement of Av. Vladimir Lenine

Existing section, from the intersection with Av. Keneth Kaunda to the intersection with Av. Julius Nyerere, on Av. Vladimir Lenine has been reconstructed by Block Pavement recently. The pavement width of the section is only 6m of carriageway and 3m width of mounted foot pass on both side. Due to the limited space for stopping buses outside carriageway, the traffic always congested almost every day. The intersection with Av. J. Nyerere is also having problems of difficulty of through traffic, due to the shape of the intersection. The intersection with Rua da Soveste and Rua do Costa do Sol is six legs intersection with no priority direction being controlled. Therefore, both intersections are always congested.

(3) Rehabilitation and Improvement of Av. Acordos Lusaka and Av. G. Popular

The right-of–way of Av. A. Lusaka is 40 m width consisting with 6 m of 2 lanes single carriageway, 2 m width of shoulder, 4 m width of pedestrian way on one side, 2 m width of central strip and 2 m and 12 m of drainages outside pedestrian way. Existing problems on this road are pavement deterioration and poor design capacity on intersections lacking with proper right-turning lane.

The right-of-way of the section from the intersection with Av. M. Ngouabi to the intersection with Av. E. Mondlane on Av. G. Popular is only 20 m width consisting 4m width of single carriageway, 2m width of parking lane and 4m width of pedestrian way and forming bottleneck of the traffic. The intersections of both ends are controlled by signals but lacking right-turning lane. Another problem is bus stops. Buses are stopping on the parking lane with poor pavement and disturbing through traffic.

(4) Rehabilitation and Improvement of Av. Angola

The right-of-way of Av. Angola is 20m width consisting 4m width of single carriageway, 2m width of parking lane and 4m width of pedestrian pass. The pavement condition of this road is poor due to deterioration of thick asphalt pavement and no proper drainage installed. The other problems are lacking of bus bays and right-turning lanes on main intersections causing traffic congestion.

(5) Rehabilitation and Improvement of Av. Marien Ngouabi

The right-of-way of Av. M. Ngouabi is 20m width as same of Av. Angola and connecting with 4 lanes trunk road of av. M. T. Tung indirectly and Av. Lusaka causing bottleneck of smooth traffic.

The pavement condition is poor due to same reasons of Av. Angola The other problems are same of Av. Angola consisting of lacking of bus bays and right-turning lanes.

2) Collector Road Development Plan:

(1) Rehabilitation of Industrial and Commercial Area Roads

Existing condition of Industrial and Commercial Area Roads is heavy deterioration of pavement on carriageway and pedestrian pass due to not only poor maintenance and

drainage but also leaking of oil from parking heavy commercial vehicles and poor thickness of asphalt and gravel base course.

The existing right-of-ways are varied and buildings are developed. Therefore rehabilitation will be done within the existing right-of-ways

(2) Rehabilitation of Port Area Roads

Existing condition of Port Area Roads is deteriorated same as Industrial and Commercial Area Roads. The reasons of the deterioration are completely same. Existing right-of-ways are varied and buildings are developed. The required rehabilitation will be done within the existing right-of-ways.

3) Residential Area Collector Roads Development Plan:

(1) Rehabilitation of District 1 Area Roads

Existing right-of-ways are varied from 13m to 20m width consisting 4m width of carriageway, 1-2m width of parking lane and 1.5-4.0m width of pedestrian way. Existing asphalt pavements are deteriorated due to not only poor maintenance but also poor thickness of surface and base layer as well as poor drainage. The required rehabilitation will be done within the existing right-of-way.

(2) Rehabilitation of District 2 Area Roads

Existing right-of-ways of the objective roads are varied from at least 6m to 14m widths under the recommendable right-of-way width for the required function of collector road. Existing pavements are completely deteriorated with lack of drainage.
The required rehabilitation will include construction of pavement, drainage, pedestrian pass and utility space as well as land and properties compensation.

(3) Rehabilitation of District 3 Area Roads

Existing right-of-ways of the objective roads are varied from 6m to 15m widths and existing pavements are also heavily deteriorated. The required rehabilitation will include construction of pavement, drainage, pedestrian pass and utility space as well as land and properties compensation

15.6.2 Traffic Management Plan

Existing conditions of the 14 nos. of main intersections on trunk roads in the CBD are heavily congested due to luck of right-turning lanes and right-turning signals. There are enough space for the construction of right-turning lane either in central strip and service road on Av. Julius Nyerere, Av. Mao Tse Tung, Av. Eduardo Mondlane, Av. 24 de Julho, Av. 25 de Setembro, Av. Karl Marx and Av. da Zambia. But along Av. Vradimir Lenine, Av. Marian Ngouabi nd Av. Guerral Popural there are limited land only for singl-carriageway available, therefore land acquisition or property compensation will be required for construction of right-turning lane. Existing pavement conditions of the 14 nos. of the intersections are also deteriorated due to insufficient pavement structure and heavy traffic. Therefore pavement rehabilitation of the intersections is also required.

15.6.3 Public Transport Plan

Existing conditions of the Bus Stops on the trunk roads are congested due to lack of proper bus bays and facilities especially on Av. V. Lenine. The Bus Stops on the collector roads has no proper facilities at all. There are very congested Bus Station at the Plaza Combatentes on Av. J. Nyerere due to limited space and the congested market. The other Bus Station, which will be rehabilitated, is at the Plaza Trabalhadores due to increasing of the required functions. Therefore the rehabilitation and/or the improvement of Bus Stops and Terminals are necessary.

1) Bus Stops

Bus facilities in Maputo constructed for Buses are Bus shelters and information boards on the pedestrian ways. Bus Stops for TPM big buses are equipped with shelters but some of them are old and decrepit.

Other bus facilities such as rooms for waiting passengers and stopping Buses are in a part of pedestrian way and stopping lane. Buses stopping on carriageway and waiting passengers overflowing from pedestrian way cause traffic jams on such a road as Av. Vladimir Lenine, which has narrow pedestrian way and no stopping lane. Along the Trunk roads in C.B.D., Buses cannot stop on the stopping lanes and blockade carriageways as the stopping lanes are occupied by parking cars,

Number of existing Bus stops along the Trunk Bus Routes in F.S. Project are shown in the Table 15.6.1.Average Distance between Bus Stops along the Trunk Bus Routes is 480m.

Table 15.6.1 Existing Bus Stops on Trunk Roads

Road Name	Section	No. of Bus Stops		Distance km	Average Distance	
		Inbound	Outbound		Inbound	Outbound
Av. A. de Lusaka		5	6	2.5	0.5	0.42
Av. G. Popular		5	6	2.0	0.4	0.33
Av. A. de Angola	Inside of Av. Machava	2	2	1.5	0.75	0.75
	Outside of Av. Machava	5	4	1.6	0.32	0.4
Av. F.P.L.M.		6	6	2.6	0.43	0.43
Av. V. Lenine	Inside of Av. Machava	3	3	1.1	0.36	0.36
	Outside of Av. Machava	6	6	3.3	0.55	0.55
Av. E. Mondiane		7	8	3.5	0.5	0.44
Av. 24 de Junho		5	5	3.3	0.66	0.66
Av. K. Marx		3	4	1.7	0.57	0.43
Total		47	50	23.1		
Average			97	46.2		47.6

2) Bus Terminals

Placa dos Combatentes

Placa dos Combatentes is a roundabout at the intersection of Av. Julius Nierere and Av. P.F.L.M. On the roads at Placa dos Combatentes, usually 15～20 minibuses waiting for passengers are stopping, and in the rotary island and around the intersection, about 20 passenger cars and trucks are parking. Large market is surrounding the intersection and commercial activities of people and vehicles occupy right of way of the road. Cars passing thorough the intersection make long queue due to the traffic weaving.

Placa dos Trabalhadores

Placa dos Trabalhadores is located in down town of Maputo at the railway station and has square area of about 15,000 m^2. In front of the station 4 Bus Stops for big public buses are stationed. Each bus stop is equipped with a shelter and an information board that shows the bus route. At the center of the square is a island with a statue, and other area surrounding the island is used for car parking of about 100cars and 15trucks, servicing for the parking demand in down town commercial area. Minibuses are not allowed to enter the square and are parking along Av. Guerra Popular for passengers to board. Consequently, concentration of minibuses causes traffic congestion on Av. Guerra Popular.

15.7 UTILITIES INVESTIGATION

Utilities investigation was carried out through hearings to the relevant authorities.

Information of existing utilities condition, which may influence to the construction cost and execution of the project on the feasibility study project routes, were collected.

Information collected through hearings to the relevant authorities are as follows. Detail information and other information were collected through the topographic survey, site investigation and so on.

Table 15.7.1 Relevant Authorities of Utilities

Information		Authorities
Telephone line	Primary line Secondary line	Telecomunicações de Moçambique (TDM)
Electricity line	High voltage line Low voltage line	Electricidade de Moçambique (EDM)
Water service		Água de Moçambique
Sewerage system		Direcção Nacional de Água Direcção Municipal de Água e Saneamento

15.7.1 Telephone Line

Existing telephone line network is covering whole Maputo city. Primary telephone lines are running along the main street, secondary lines are distributed to local area roads. Telephone poles and lines positioned in the proposed width of right of way are the objective of shifting.

Detailed positions of telephone poles are plotted on the plan map by the topographic survey. The existing telephone line network located on the feasibility study project roads are shown in the Appendix.

The most of telephone poles are positioned on the boundary of the right of way. However, a lot of illegal house have been constructed within the right of way on collector roads and local area roads, telephone poles are taken in to those houses.

15.7.2 Electricity Line

Existing electricity line is over-hung line, it is divided to high-tension line, medium-tension line and low-tension line. High-tension line is recognized to influence to the alignment on the missing link of Av. Julius Nyerere, therefore careful consideration should be made. On the other roads, there are no high-tension lines influences to the alignment plan.

Detailed positions of electricity lines are plotted on the plan map by the topographic survey. The existing electricity pole located on the feasibility study project roads are shown in the Appendix.

Electricity lines are sometimes hung with telephone lines, situation caused of illegal housing are seen on collector roads as same as the telephone lines.

Photo 15.7.1 Illegal Housing on Collector Roads

15.7.3 Water Service

Detailed positions of valves are plotted on the plan map by the topographic survey. The existing tap water lines located on the feasibility study project roads are shown in the Appendix.

However, it is understood through the execution of the Pilot Project, the condition of network at site has been changed from such information due to inadequate maintenance of the record. Therefore detail site investigation such as trial dig etc. will be required prior to the detail design and the execution of construction.

15.7.4 Sewerage System

Detailed positions of water trap, manhole etc. are plotted on the plan map by the topographic survey. Meanwhile investigation through the relevant authorities are carried out. The existing sewerage system located on the feasibility study project roads are shown in the Appendix.

However, it is understood though the execution of the Pilot Project, the condition of network at site has been changed from such information due to inadequate maintenance of the record. Therefore detail site investigation such as trial dig etc. will be required prior to the detail design and the execution of construction.

15.8 EVALUATION OF THE PILOT PROJECT

Through the implementation of planning, design and construction work, the following items were evaluated. These should be basis of the master plan for the road development.

15.8.1 Contents of The Evaluation

Items to be evaluated through the implementation of the Pilot Project is as shown in the Table 15.8.1. Some items should be evaluated through enough years after opening to traffic, therefore the following evaluation is made preliminarily.

Table 15.8.1 Items to be Evaluated

Evaluation	Items
1) Economy	- Construction cost
2) Durability	- Structural life
3) Maintenance / repair	- Easiness of maintenance / repair
4) Other - Construction easiness - Availability	- Construction speed
	- Availability of material / equipment in and around Mozambique
	- Quality control
	- Special consideration

The evaluation has been made through the consideration as follows ;

1) Economy

Construction cost

Construction cost is the clearest indicator for evaluation of the project. It consists the material, equipment and operation cost.

2) Durability

Structural life

The structural life is normally defined as the design period, stipulated in relevant standard such as SATCC. It is 10-15 years for the pavement works and 100 years for the concrete works, however frequent maintenance or repair is required. Frequency of maintenance

will influence on the structural life, therefore the performance of road department on the maintenance works should be carefully considered.

3) Maintenance / repair

Easiness of maintenance / repair

Easiness of maintenance or repair depends on the performance of the road department and local contractor, availability of local materials and equipments and so on. Therefore the structural type should match to these situations in Mozambique.

4) Other

Construction speed

Construction speed is the clearest indicator for evaluation of the project.

The evaluation should be made through the comparing of the days to be required for the construction works.

Availability of material, plant and equipment in and around Mozambique

Construction, maintenance and repair should require the material and equipment, therefore the type of the structure or method should meet the local availability.

The quantified rating will be difficult, therefore the evaluation should be made through the comparing of the evaluation of availability, days to be required to purchase, and so on.

Necessity of skilled workers

Difficult works will require the skilled workers, therefore the type of the structure or method should meet the local availability.

Quality control at site

The special method or structure type may require the special care on the quality control. As such, the requirement should match to the local situation.

15.8.2 Evaluation

1) Pavement

The evaluation of the pavement structures should be made through the consideration of the economy, the durability and the easiness of maintenance and repair as well as the construction easiness or the existence of special considerations.

The selection of the pavement type should be much to the several site condition such as road classification, traffic condition, land use pattern and so on.
Result of the evaluation on the pavement structure was made as shown in the Table 15.8.2.

2) Drainage

The evaluation of the drainage structure should also be made through the consideration of the economy, the durability and the easiness of maintenance and repair.

Selection of the drainage type should be much to the several site condition such as road classification, traffic condition and so on, also it depends on the easiness of cleaning and right of way width.

Result of the evaluation on the drainage structure was made as shown in the Table 15.8.3.

Table 15.8.2 Evaluation for Pavement

Regend ---- ◎:Very good, ○:Good, △:Considerable, ×:unsuitable

Items		Case-0 Surface : Pre-mixed Asphalt Concrete (t=40mm) Base : Graded Crushed Stone (t=200mm)		Case-1 Surface : Double Bitumen Surface Treatment Base : Stabilized Soil (t=150mm base, 100mm sub)		Case-2 Surface : Concrete Block Base : Graded Crushed Stone (t=200mm)		Case-3 Surface : Inter-rocking Concrete Block Base : Stabilized Soil (t=150mm)	
1. Economy	1) Construction cost rate (surface)	○	1.00	◎	0.42	○	1.15	○	1.15
	2) Construction cost rate (base, subbase)	○	1.00	◎	0.46	○	1.00	◎	0.46
	3) Construction cost rate in total (surface + base)	○	1.00	◎	0.49	○	1.02	◎	0.89
2. Durability	1) Structural life	◎	- Generally 10-15 years (depending on the design period)	△	- Short(generally 2-5 years)	◎	- Generally 10-15 years (depending on the design period)	◎	- Generally 10-15 years (depending on the design period)
3. Maintenance / repair	1) Easiness of maintenance / repair	○	- Medium/careful	○	- Medium / careful	◎	- Easy	◎	- Easy
4. Other	1) Construction days (surface)	○	3 days	○	4 days	△	20 days	△	18 days
	2) Construction days (base, subbase)	○	1 day	△	- Stabilizing subbase : 1 day - Stabilizing base : 1 day - 7 days curing on each layer should be required	○	1 day	△	- Stabilizing base : 1 day - 7 days curing on each layer should be required
	3) Material, plant and equipment (surface)	◎	- Asphalt plants are available in Maputo, but quality should be carefully considered - Asphalt finisher is available in Mozambique	◎	- No special material or equipment are required	◎	- Concrete block products are available in Maputo	◎	<= ditto
	4) Material, plant and equipment (base, subbase)	○	- Quality of gravel should be carefully considered - No special equipment will be required	○	- No special material is required - Grader, but road stabilizer is preferable, establishment of pre-mix plant is the most preferable	○	<= ditto	○	<= ditto
	5) Skilled workers	○	- Operator of asphalt finisher should be required	◎	- Nil	○	- Skilled workers for block laying should be required	○	<= ditto
	6) Quality control at site (surface)	○	- Temparature at spreading - Pocedure at roller compaction	◎	- Nil	◎	- Nil	◎	- Nil
	7) Quality control at site (base, subbase)	○	- Procedure of compaction - Field density	△	- Cement content - Moisture content - Spacial care for scattering of mixing proportion and mixing procedure shoud be requirerd	○	<= ditto	△	<= ditto
	8) Special consideration	○	- Nil	△	- Adhesion of betuminous surface to stabilized base should be carefully considered	○	- Nil	○	- Nil
Conclusion	**1) Surface**	**- Trunk road - Collector road (heavy traffic section)**		**- Collector road (rural area) - Road shoulder**		**- Collector road - Bus stop, bus terminal**		**- Collector roads - Bus stop, bus terminals**	
	2) Base	**- Trunk road - Collector road (heavy traffic section) - Bus terminal**		**- Collector roads (semi-urbanized area, low traffic section) - Side walk**		**- Trunk road - Collector road (heavy traffic section) - Bus terminal**		**- Collector roads (semi-urbanized area, low traffic section) - Side walk**	

Table 15.8.3 Evaluation for Drainages

Regend ---- ◎:Very good, ○:Good, △:Considerable, ×:unsuitable

Items		Case-0-1 U-shaped Concrete Ditch (W=1,000mm, L=454.6m)		Case-0-1 K-shaped Ditch (Stabilized Soil) (W=1,000mm, L=428.1m)		Case-2 Concrete Lining Ditch (W=2,000mm, L=341.6m)		Case-3 Stone Pitching Ditch (W=2,500mm, L=343.6m)	
1. Economy	1) Construction cost rate (per length)	△	1.00	◎	0.09	△	1.08	○	0.65
2. Durability	1) Structural life	◎	- Nil	△	- Unknown, expected short - Special care for wearing should be paid	◎	- Nil	○	- Unknown, expected short - Special care for cracking etc. should be paid
3. Maintenance easiness	1) Easiness of maintenance / repair	◎	- Easy	○	- Frequent repair should be required	◎	- Easy	◎	- Easy
	2) Easiness of cleaning	◎	- Easy	△	- Frequent cleaning should be required	◎	- Easy	◎	- Easy
4. Other	1) Construction days	○	8 days/100m	○	- Nil	○	7 days/100m	○	11 days/100m
	2) Equipments / materials	○	- Equpments and materials for normal concrete works are available in Maputo	○	- No special material is required - Grader, but road stabilizer is preferable, establishment of pre-mix plant is the most preferable	○	- Equpments and materials for normal concrete works are available in Maputo	◎	- Nil, no mechanical execution required
	3) Skilled workers	○	- For normal concrete works	○	- Nil	○	- For normal concrete works	○	- Nil
	4) Quality control	○	- Quality control on concrete works should be required	△	- Cement content - Moisture content - Spacial care for scattering of mixing proportion and mixing procedure shoud be requirerd	○	- Quality control on concrete works should be required	◎	- Nil
	5) Road safety	◎	- Easy to cover for crossing of vehicle, or to avoid folling	△	- Vehicle will cross on the ditch, concrete structure is acceptable	○	- Long spanned bridge or culvert should be applied for crossing of vehicle - Guard barrier or kerb should be applied to avoid folling of pedestrian or vehicle	○	<= ditto
Conclusion		**- Suitable in urbanized area**		**- Unsuitable as the permanent structure, acceptable as the temporary measures - Concrete structure will be acceptable**		**- Suitable in rural / semi-urbanized area**		**- Easiest, cheapest type - Suitable in rural / semi-urbanized area - Special care for maintenance and repair should be paid**	

15.8.3 Conclusion and Suggestion for Highway Design and Planning

1) Highway design

Base course

Graded crushed stone is the most reliable method. All material and equipment for construction or repair are similar to ordinal road works. Quality control method is also established and recognized. Therefore these will be the most advantageous issues to adopt for maintenance and repair. However the cost is high, therefore benefit and cost should be carefully considered at planning stage.

Stabilized soil is easy to maintenance or repair. Any special material or equipment are not required, also the cost is low. Its durability, as shown in the Figure 15.8.1, the strength increases during normal curing period of approximately one week, after that it gently increases up to six month. However low adhesion to bituminous surface should be carefully considered on heavy traffic section at planning.

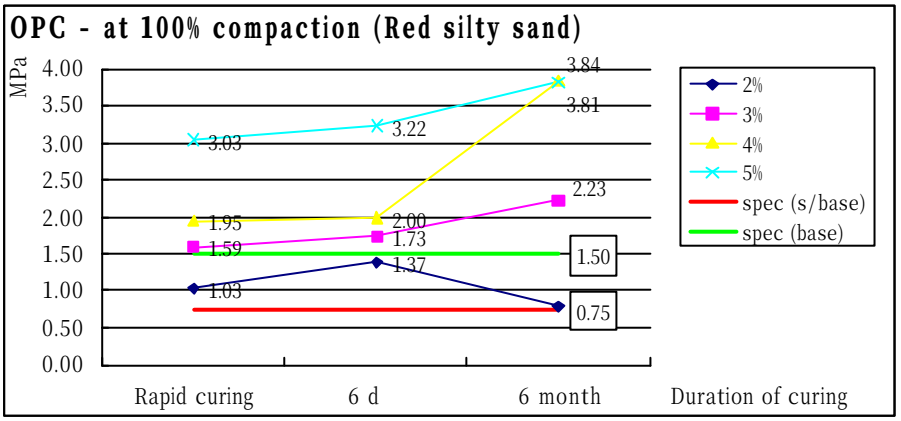


Figure 15.8.1 Strength of Stabilized In-situ Soil

Through these consideration, base type and adoption of conditions are as shown in the Table 15.8.4.

Table 15.8.4 Application of Base type

	Cost comparison	Road classification	Traffic condition	Other usage
Graded crushed stone	1.00	- Trunk road - Collector road (urbanized area)	- Heavy traffic	- Bus terminal
Stabilized soil	0.46	- Collector road (semi-urbanized area)	- Low traffic	- Side walk - Road shoulder

Surface course

Pre-mixed asphalt concrete is the most reliable method. All material and equipment for construction or repair are similar to ordinal road works. Quality control method is also established and recognized. Therefore these will be the most advantageous issues to adopt for maintenance and repair. However the special equipment such as asphalt plant and finisher will be required, skilled worker also, therefore cost is expected to be increased comparing to the other types.

DBST is known as the emergency or temporary method, but several results to be used as permanent pavement, are found in African or Asian countries due to low initial cost. Durability of DBST depends on the several conditions such as traffic or environmental characteristics. Therefore it should be adopted to low traffic section, and also semi-urbanized section. However the cost is very low comparing to the other type of pavement, therefore adopting to formation of road shoulder, and the emergency construction or repair is the most preferable.

Concrete block type is the easiest method for maintenance or repair. Concrete block is available from several products in and around Maputo city. Also the special equipment or skilled workers are not required. However the cost is almost equivalent to asphalt concrete surface course. Also the slowest construction speed among the several type of pavement should be carefully considered.

Through these considerations, the adequate types of surface course are concluded as shown in the Table 15.8.5.

Table 15.8.5 Surface course type

	Cost comparison	Road classification	Traffic condition	Other usage
Pre-mixed Asphalt Concrete	1.00	- Trunk road - Collector road (urbanized area)	- Heavy traffic	
DBST	0.42	- Collector road (semi-urbanized area)	- Low traffic	- Side walk - Road shoulder - Emergency repair
Inter-rocking Concrete Block	1.15	- Collector road	- Heavy traffic - Low traffic	- Bus stop - Bus terminal

Roadside drainage

U-shaped concrete drain is common method in urbanized area, its width is narrow and easy to cover with concrete lid. It will be the most advantageous issue to adopt to the urban area road. Pre-cast type will be more preferable for repair. However the cost is the highest among the other types, therefore combinational adoption with L-shaped drain will be

preferable on the viewpoint of the economy.

K-drain is easiest and cheapest drainage structure, also no requirement to consider falling pedestrian or any measures for crossing vehicle. In the Pilot Project, stabilized soil is adopted as in one body of sidewalk, it is epochal measure due to the cost, construction easiness etc. However wearing of stabilized soil is the problem, it should be adopted as temporary measure, otherwise increase of cement content or adoption of concrete structure should be considered as the permanent structure. Furthermore, it is inadequate measure at heavy traffic section due to unclear boundary between carriageway and pedestrian space. Therefore it should be adopted on low traffic section i.e., access road, or some special measure for pedestrian safety should be considered.

V-shaped open drain, it has large cross-sectional shape, is also common type in semi-urbanized area roads. It has of easiness to cleaning, maintenance etc., it will be the advantageous issue to adopt to the semi-urbanized area roads. Stone pitching type is the cheap measure comparing to the concrete type. But its durability is expected short. Therefore the small semi-urbanized section is more preferable. Wet masonry type, it has small gap on the wall, is also conceivable for discharging the ground water. It should be applied for the place where the ground water level is high, in order to avoid deterioration of subgrade by the ground water.

Through these consideration, the adequate adoption of roadside drainage structures are concluded as shown in the Table 15.8.6.

Table 15.8.6 Drainage type

	Cost comparison	Road classification	Traffic condition	Other usage
U-drain (Concrete)	1.00	- Trunk road (urbanized area) - Collector road (urbanized area)	- Much pedestrian and vehicle crossing in urban area	
K-drain (Stabilized soil)	0.09	- Collector road (temporary construction)	---	- Temporary construction
K-drain (Concrete)	---	- Collector road (narrow ROW)	- Pedestrian and vehicle use same road space	- Access road - Local area road
V-drain (Concrete)	1.08	- Trunk road (semi-urbanized area)	- Less pedestrian and vehicle crossing	
V-drain (Stone pitching) (Wet masonry)	0.65	- Trunk road (semi-urbanized area) - Collector road	- Less pedestrian and vehicle crossing	

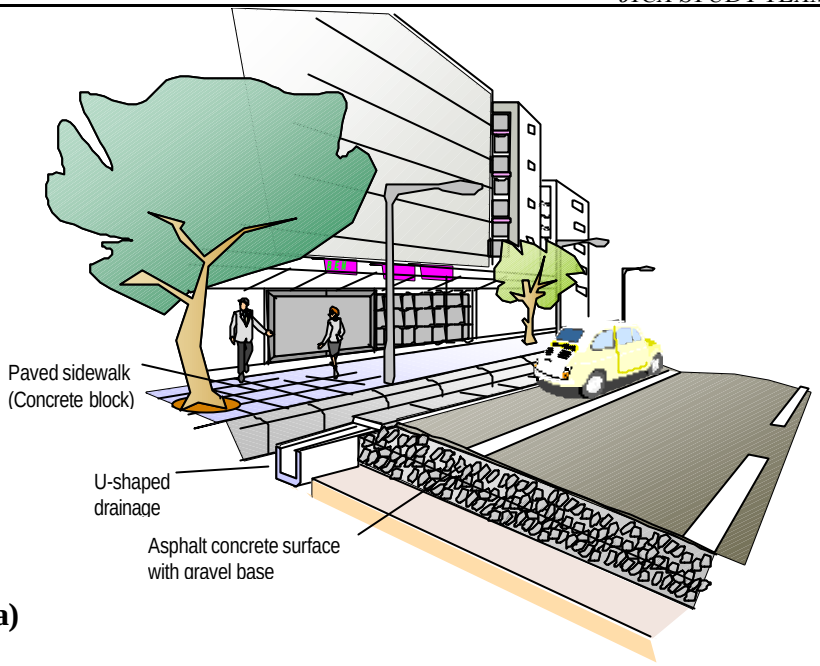


Figure 15.8.2 Road Image
(Trunk Roads / Urban Area)

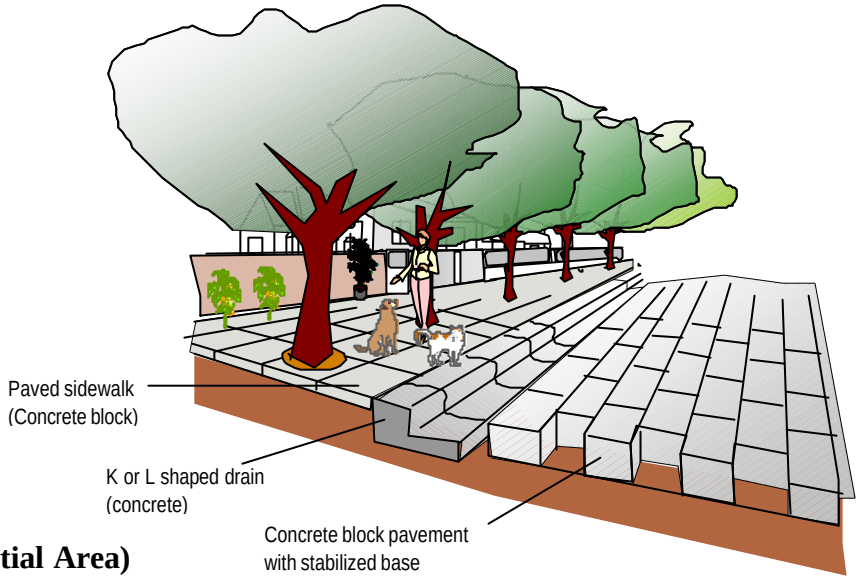


Figure 15.8.3 Road Image
(Collector Roads / Residential Area)

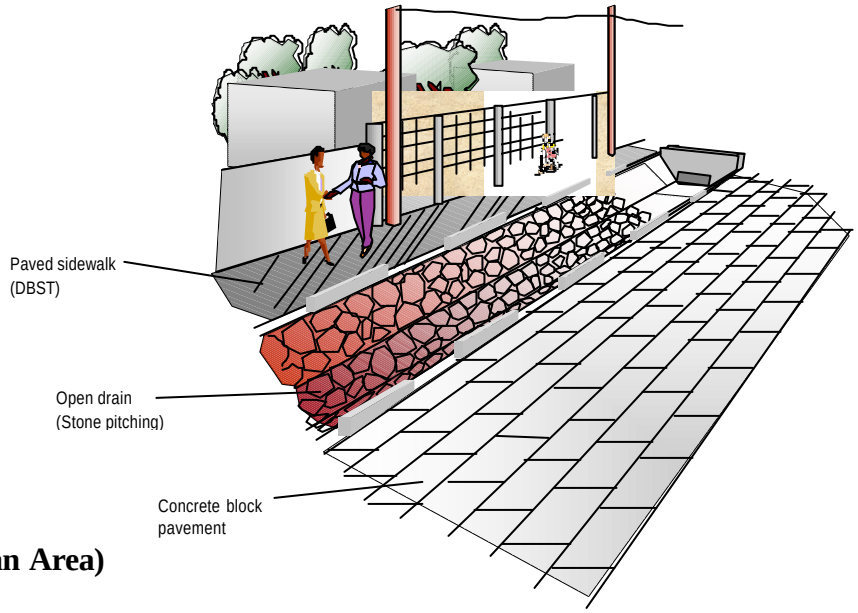


Figure 15.8.4 Road Image
(Collector Roads / Suburban Area)

2) Construction plan

Any special equipments or materials are not required at the construction of the above types of pavement and drainage. However, to secure adequate quality or speedy construction, there are some recommendations as follows.

- For stabilization of in-situ soil, rotary road stabilizer is preferable, establishment of central stabilization plant is the most preferable. Any of these, road stabilizer or plant will not be available in Mozambique, it will be subject to be imported.

- Concrete block pavement is the reasonable method coupling with stabilized base on the viewpoint of the low initial cost and the easiness of repair or maintenance. Also it is advantageous to create the job opportunity and stimulation of local industry. However construction speed should be carefully considered in the construction plan.

- For concrete works, quality of form works will be important subject, adoption of steel form is preferable. Also pre-cast products should be subject of comparison.

CHAPTER 16

ENVIRONMENTAL SURVEY

CHAPTER 16 : ENVIRONMENTAL SURVEY

16.1 GENERAL

In this chapter, existing environmental situations of the proposed high priority road development project of feasibility study were identified by field survey, literature survey, interviews and discussions with authorities. Environmental survey items are shown below:

◇Natural Environmental survey

- Flora and fauna
- Geology and soils
- Flood hazard
- Groundwater

◇Social Environmental survey

- Landuse
- Infrastructure
- Cultural properties
- Economic activities
- Household and business opinion surveys
- Resettlement compensation

◇Environmental Pollution survey

- Air pollution

16.2 SUMMARY OF THE PROPOSED PROJECTS

The proposed project involves the improvement and reconstruction of a number of trunk, collector and area roads in Maputo municipal area. A new section of road is proposed for Av Julius Nyerere in the wake of the destruction of sections of the current alignment in the Polano-Canoco quarter as a result of recent flooding, and the alternative plan is also proposed for the restoration of Av Julius Nyerere along original route site. The current upgrades and improvements under consideration form part of an overall 2020 strategy to upgrade the entire transportation network in Maputo. A summary of the high priority road development project of feasibility study for 2010 is shown in Table 16.2.1.

Table 16.2.1 Summary of Proposed High Priority Projects

F/S Project		Project Measures/Component
Trunk Roads	1.Construction of Missing Link on Av. Julius Nyerere	Early linking of the missing link on Av. Julius Nyerere through construction of two-lane trunk road
	2.Restoration of Av. Juluis Nyerere	Restoration of Av. Juluis Nyerere along original route site
	3.Improvement of AV.Vladimir Lenine	Construction of bus bays and improvement of intersections on AV.Vladimir Lenine
	4.Rehabilitation and Improvement of AV. Acordos de Lusaka and Av. Guerra Popular	Rehabilitation of pavement and drainage of AV. Acordos de Lusaka
		Widening of Av. Guerra Popular from 2 to 4 lane road
	5.Rehabilitation and Improvement of AV. Angola and Rua S. Cabral/Largo de Deta	Rehabilitation of pavement and drainage of AV. Angola
		Rehabilitation of pavement and drainage of Rua S. Cabral/Largo de Deta
	6.Rehabilitation and Improvement of AV. Marien Ngouabi	Widening of Av. Marien Gouabi (from Av. Mau Tse Tung to Av. Acordos Lusaka) from 2 to 4 lane road
		Reconstruction of pavement and drainage of Av. Marien Gouabi (from Av. Acordos Lusaka to Rue Joao Arbasini)
Collector Roads	1.Rehabilitation of Industrial and Commercial Area Roads	Rehabilitation of pavement and drainage of area roads
	2.Rehabilitation of Port Area Roads	Rehabilitation of pavement and drainage of area roads
Residential Area Roads	1.Rehabilitation of District 1 Area Roads	Rehabilitation of pavement and drainage of District 1 area roads
	2.Rehabilitation of District 2 Area Roads	Rehabilitation of pavement and drainage of District 2 area roads
	3.Rehabilitation of District 3 Area Roads	Rehabilitation of pavement and drainage of District 3 area roads
Rehabilitation and Improvement of Traffic Management Facilities		Construction of right-turn lanes and signals (14 intersections) and control of on street parking in intersection areas
Rehabilitation and Improvement of Bus Stops and Terminals		To Provide suitable location and size of bus bays (22 bus bays) and one terminal and to equip required function on to the bus terminal

Figure 16.2.1 Illustrates the location of the Trunk, collector and area roads for the high priority project of feasibility study.

Figure 16.2.1 Location of Proposed High Priority Projects

16.3 ENVIRONMENTAL SURVEY ALONG THE PROPOSED PROJECTS

16.3.1 Approach and methodology

(1) Approach

In the approach to this investigation, the term ***environmental*** was used in its broadest sense to encompass all components of the affected environment, including the biophysical, social, cultural and economic aspects.

During the impact prediction process, the negative impacts of upgrading the target roads have been balanced against the benefits which will accrue to the community and the city as a whole through an improved transportation network. A total of 53 households and 9 businesses were interviewed to gain an insight into the communities' attitude and concerns surround the conditions of the roads and their sentiments about the proposed upgrade.

The principals of integrated Environmental Management (IEM) have been adopted in the approach to this study. IEM is designed to ensure that the environmental consequences of a project are understood and adequately considered during the planning process. The purpose of this is to resolve and mitigate any negative impacts and enhance the positive benefits of the development proposal right at the outset of the project.

(2) Methodology

The following methodology was adopted in achieving the objectives of the survey:

◇ ***Field Surveys:***

- **Tree survey.** A detailed investigation of the trees in each road targeted for upgrading and/or widening, had to be undertaken. Each tree species was identified, either through a literature study or from the expertise from the Maputo National Botanical Garden's horticulturalists.

- **Flood hazard.** An investigation of the flood prone area and erosion area caused by lack of proper drainage system had to be undertaken.

- **Household option surveys**. Household opinion surveys were conducted for over 50 households. The detailed methodology employed in undertaking these surveys is included

in Section 16.3.10.

- **Business surveys**. Business surveys were undertaken of all target roads, detailing the number of business within the different sectors along each road.

- **Building surveys.** A detailed building survey was undertaken of the two roads affected by the proposed widening: Av. Guerra Popular and Av. Marien Ngouabi.

- **Environmental Pollution survey**. A specialist consultant, Ecoserv (South Africa) , was appointed to undertake the Air Pollution survey, which consisted of placing air pollution monitoring equipment at two sites around the city. Contents measured included NO_2 (Nitrogen Dioxide), SO_2 (Sulphur Dioxide) and CO (Carbon Monoxide). The methodology and results of this survey are detailed under Section 16.3.12.

◇ ***Literature survey:***

Information was gathered from existing literature on the natural and social environment of the Maputo area.

◇ ***Interviews and discussions with authorities:***

Interviews and discussions were held with a number of authorities and personnel in various government and council departments, the private sector and Non-governmental Organisations. A list of organisations consulted is included in Appendix 16.1, where applicable.

16.3.2 Flora and fauna

The natural conditions in and around Maputo have been modified over a long time period, mostly due to anthropogenic activity during the Maputo City expansion.

The unfavourable conditions of the mangrove salt marsh and coastal plain area for settlement, has led to this ecological area remaining moderately intact. Due to urban expansion, a surge of construction activities has taken place over the last five years. Other important degradation factors include wood collection for fuel, water contamination due to poor sanitation, and the use of the *Canniso* sp. (reed), for use as a building material/screen.

For ecological analysis, two main areas exist:

- The Maputo plateau (40m.a.s.l)
- The coastal plain (salt marsh/wetland)

The plateau consisted of an open forest, eventually destroyed through anthropogenic impacts, to become a savanna region. Towards the end of the 19th century, the area corresponding to the present Sommerschield and part of the Polana-caniço area was afforested with *Eucalyptus* species, which are exotic species that swiftly outcompeted the indigenous plant species.

The coastal plain corresponds to the southern limit of the Incomati river estuary, characterised by a dune corridor along the coast, creating an intertidal salt marsh/swamp, where a bountiful mangrove forest once thrived. The present natural vegetation consists mainly of dune scrub and floodplain communities such as mangroves, salt marsh species and reed beds – *Canisso* species.

The primary dune in Costa do Sol, was destroyed in the late 1950's, through the construction of the Marginal Road along the dune cordon. To reduce the movement of sand, some Casuarina species (*Casuarina equisetifolia*), were planted along the road on the beach side. Only herbaceous dune species now remain of the natural vegetation.
Wetlands area sensitive ecosystems of particular economic and environmental importance, fulfilling many roles:

- Natural water purification systems
- Providing recreational areas for bird or animal viewing
- Act as buffers against floods
- Protection from coastal erosion
- Preservation of biological diversity, by providing spawning grounds for many species

such as shrimps, fish, aquatic bird species etc.

Mangroves also play an important role in the production of valuable fish and prawns that use these habitats as spawning and nursery grounds, during the juvenile and adult stages of their growth and development.

Maputo Bay constitutes the lower latitudinal border from where mangrove diversity drops abruptly. It is also the second most important shrimp producing area in Mozambique. Semi-industrial and local fishermen using trawl nets fish for prawns. The prawn catches have progressively declined since 1973, when a total annual catch of 800 tons was recorded. There are estimates of catchments of 200 tons during 1994.

Mangroves near Maputo have almost vanished, with only vestiges remaining in Costo do Sol. Major impacts on mangrove forests include:

- Urban expansion
- Fuel-wood collection
- Changes in the salt water condition
- Water contamination by domestic waste water
- Solid waste disposal
- Siltation due to upstream erosion.

Costa do Sol area is presently in an urban/residential development process, although not following a structured urban development plan. This is impacting on the mangrove swamp at an alarming rate.

The recent Maputo Structure Plan (PROL, 1999), classifies the existing wetland/swamp area as a protected plan, with no construction allowed. However the Plan has not yet been approved, so development can still proceed, threatening the existence of the wetland (SWECO INTERNATIONAL, 2000).

Much of Maputo's central business district and the surrounding residential suburbs have been beautified by an abundance of exotic and indigenous trees planted to form dense avenues. The Maputo city council has a strict policy regarding the protection of street trees which are viewed as an integral part of the cities identity to the extent that heavy penalties are applied in the event of removing trees without the necessary permits.

Table 16.3.1 below shows the result of the tree surveys completed along the target roads.

Table 16.3.1 Tree List for Target Roads

Road	Number of Trees	Scientific Name	Common Name
Rua 4500	1	*Trichillia emetica*	Mafureira
Ave. Para O Palmar	20 2	• *Sclerocarya birrea* • *Eucalyptus Lehmanii*	• Amarula • Eucalyptus
Ave. Friedrich Engels	3 125 9 11 1 6 19 1 1 4 20 37 2	• *Cassia siamea* • *Delonix regia* • *Trichillia emetica* • *Cocus nucifera* • *Ficus natalensis* • *Pithecelobium dulce* • *Cheysalidocarpus* • *Jacaranda mimosifolia* • *Azelia quanzensis* • *Eucalyptus lehmanii* • • *Pinus radiata* • *Washingtonia felifera* • *Sclerocarya birrea* • *Washingtonia felifera*	• Acacia amarela • Acacia vermelha • Mafureira • Coquiera • Chilhamfana • Tamarindeiro esphinosa • Palmeira bambu • Jacaranda • Travencia • Eucalyptus • Amarula • Pine
Ave. Guerra Popular	60 21 4	• *Olarita sp.* • *Cassia siamea* • *Trichillia emetica*	• Olarita • Acacia amarela • Mafureira
Ave. Marien Ngouabi	1 86 96 1 11	• *Olarita sp* • *Cassia siamea* • *Azelia quanzensis* • *Grevillia robusta* • *Pongamia pinnata*	• Olarita • Acacia amarela • Chanfuta • Grevillia • Pongomia
Ave. Emily Dausse	1 12 1	• *Olarita sp* • *Delonix regia* • *Trichillia emetica*	• Olarita • Acacia vermelha • Mafureira
Ave. Samual Magaia	49 31 4	• *Olarita sp.* • *Trichillia emetica* • *Azelia quanzensis*	• Olarita • Mafureira • Chanfuta
Ave. Nkame Nkrumah	126 1 4	• *Olarita sp* • *Cocus nucifera* • *Azelia quanzensis*	• Olarita • Coqueira • Chanfuta
Ave. Martines de Inhaminga	83 13	• *Cassia siamea* • *Azelia quanzensis*	• Acacia amarela • Chanfuta
Ave. de Angola	46 17 67 1 4	• *Olarita sp.* • *Delonix regia* • *Cassia siamea* • *Trichillia emetica* • *Azelia quanzensis*	• Olarita • Acacia vermelha • Acacia amarela • Mafureira • Chanfuta

16.3.3 Geology and soils

The Maputo region is divided into two geomorphologic areas:

- The coastal plain area, comprising unstabilized dunes and recent alluviums, with tertiary deposits of sandstone found 20m below the surface and;

- A higher area, with inland dunes, which are older and stabilized.

The following formations can be recognised:

I. Tidal and beach deposits in the southern direction.
II. Coastal area, sloping into the sea, with a maximum height of 8m. This area is built up by moving dunes and alluviums. The Incomati river estuary creates tidal fluctuations in the plain area.
III. Plateau of 40 – 50m, consisting predominantly of stabilized interior dunes and some sheets of sand.
IV. Maputo hill, occurring 50 – 60m above sea level, consisting of fixed, consolidated dunes of the Ponta Vermelha formation. This formation shaped between the Superior and Mid Pleistocene Aeon. The red sands seem to originate from fluvial processes.

The red dune sands, which occur widely in most parts of Maputo, with a variable thickness of 30 – 40m, are very sensitive to flowing water. These soils are compact when dry (humidity below 5 %), but are easily moulded when wet (from 10% humidity). Above a humidity of 16%, the soils become liquid and could be transported by water runoff, as mud.

16.3.4 Flood hazard

In the 80's a drainage system was constructed. However, neglected maintenance of the system led to the destruction of almost all of it. In 1989 small ravines are formed between the plateau and the coastal area, and these became more and more developed after each heavy rain. In 1998 the erosion damages were very significant due to the heavy rain. Av. Julius Nyerere was cut and a lot of houses were destroyed. Especially, in February 2000, the intense and continuous rains caused an enormous increase to the craters.

There are flood prone area and erosion area caused by lack of proper drainage system, outlet and lack of drainage maintenance. The flood prone area and erosion area are illustrated in chapter 4.4.

16.3.5 Groundwater

The geological formation of Maputo City Plateau is characterised by the occurrence of groundwater between 7 – 15m in depth. Groundwater level within the coastal plains is close to the surface and subject to tidal influence.

16.3.6 Landuse

(1) Existing Land Use

Maputo City grew in the present central part of the city and expanded radially over the decades, along the present Avenues Julius Nyerere, Vladimir Lenine, Karl Marx, Angola, Trabalho. Expansion occurred mainly in a west – east direction. Initially these areas had low densities and assumed the characteristics of Mozambican rural settlements.

After independence, the Government provided some investment to improve living conditions, but the civil war and lack of funding led to an accelerated expansion without proper urban planning and infrastructure. District 1 and the north-eastern sections of District 3, now comprise mostly war refugees from the rural areas, and have become densely populated, unstructured areas with make-shift houses.

Sommerschield area is a planned urban area located towards the northern boundaries of the city. Upmarket houses built during the 1960's occupy this area, with the Eduardo Mondlane University forming the northern limits. North of the University is the Polana-Caniço area, which is being increasingly developed. Similarly in district 1, makeshift houses were replaced with iron and concrete houses, and encroachment on the original road reserve took place, leaving narrow, un-drained gravel roads in dire need of upgrading and rehabilitation.

The Town Plan approved for Maputo is the Urban Master Plan for Lourenço Marques, produced in 1969. It is an expended urban plan, which defines land use taking into account economical and administrative functions of the city, physical topographical aspects, social aspects, local constraints related to existing and approved occupation. The plan also includes a traffic study with traffic counts, assessments of road capacities, parking, accidents, traffic regulation, collective transports and future circulation.

Recently, in 1999, a new town plan was drawn up – "Structure Plan of Maputo Metropolitan Area." The Plan presents a proposal for future and use and demands that existing residential area should be infra-structured and consolidated. The mangrove swamp is deemed not

suitable for urbanisation. The Plan is presently in the process of approval by the Municipal Assembly. Therefore, the 1969 Urban Master Plan is still being used, but is inadequate due to the rapid changes which have since taken place.

According to the Urban Master Plan of 1969, the slope bordering onto Av. J. Nyerere, is classified for Low Density Residential Areas and Urban Green Areas (Public Open Spaces), and Dense Residential Areas northwards of the University. The coastal plain is classified as an Urban Green Belt and for Recreational and Tourism Equipment.

In terms of land use, the 1999 Structure Plan makes general proposals for city expansion:

- Consolidation of the existing residential area, in the surroundings of Av. J. Nyerere, slope and plain area,
- Maintenance of the existing recreational areas and social equipment
- Maintenance of the commercial centre in Praça dos Trabalhadores,
- Maintenance of a green belt in the present agricultural area, near Costa do Sol,
- No urban use in the mangrove swamp.

No net road system has been proposed, except for a few local situations (SWECO/CONSULTEC, 2000).

(2) Landuse along target roads

Detailed land use surveys were undertaken for all target roads.

Figures 13.3.1 and 13.3.2 show the street plans for Avenues G. Popular and M. Ngouabi, which are the two roads to be widened for the purposed of this study. Descriptions of economic activities for these roads are provided in section 16.3.9, and the details of survey of buildings are shown in Appendix 16.2.

The land use categories found in the two streets are predominantly residential for Av. G. Popular, with two supermarkets, a paint supply shop, a garage, school, restaurant, and a clothing store. Av. M. Ngouabi, is predominantly mixed residential and commercial, with a number of security firms, cafés and curio shop interspersed between the blocks and houses.

The harbour area, consisting of Rua do Bagamoya, C. Pedroso, J. Lapa, Marques, De Timor lest and Av. M. de Inhaminga is made up of commercial businesses and some retail, with light to heavy industrial activities and warehouses to banks, restaurants, bars, fast food outlets and

the Money Museum.

Av. F. Engels, is an upmarket residential area overlooking the coast, consisting of mixed residential properties – houses and flats.

Av. Emily Dausse consists of mixed residential, retail and business land uses whilst Avenues de Angola and de Lusaka, consist mostly of informal houses, small informal traders and restaurants, a shopping centre, government departments, service stations, light industry and a few double story flats and houses.

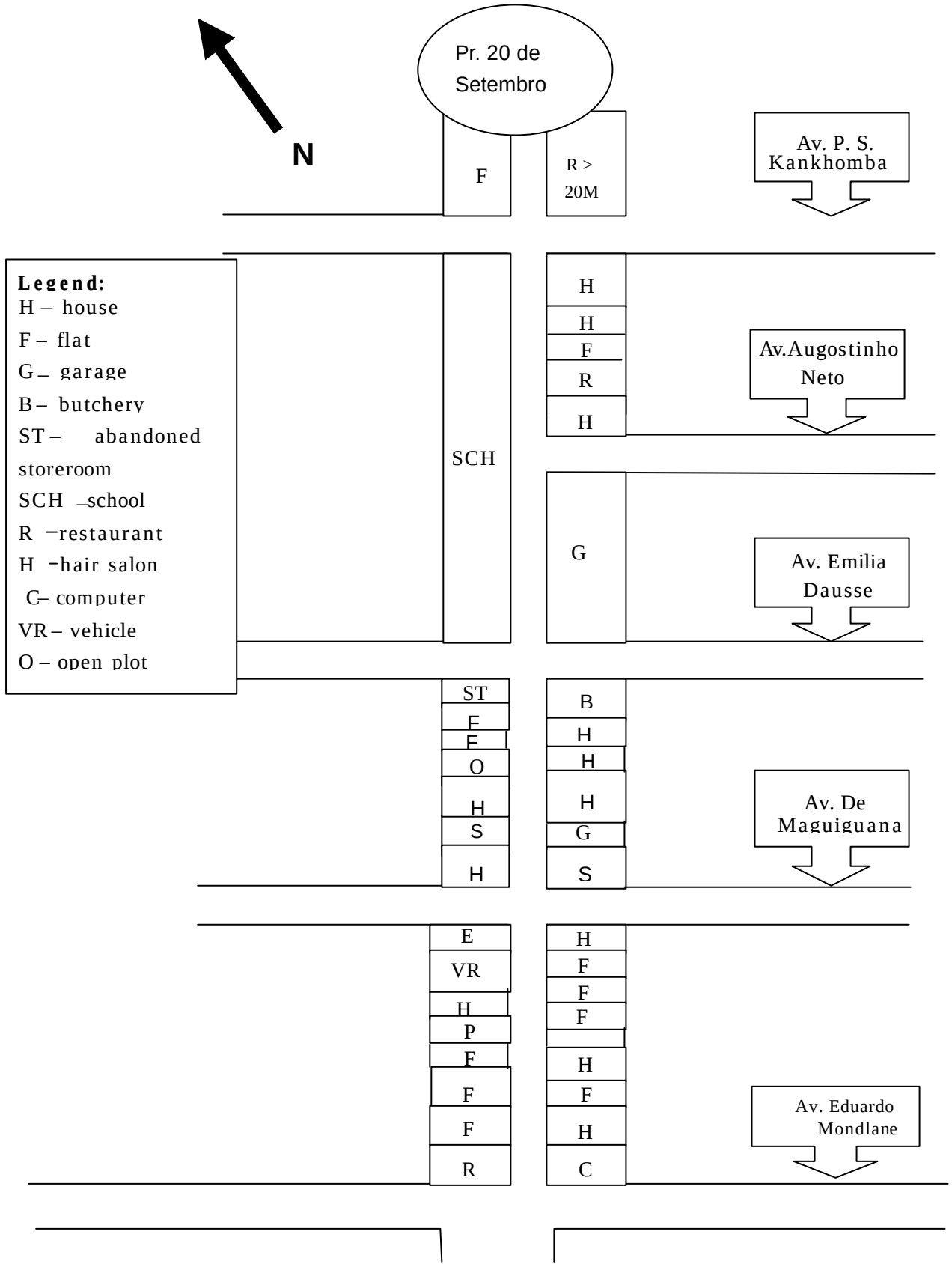


Figure 16.3.1 Street plan for Ave. Guerra Popular

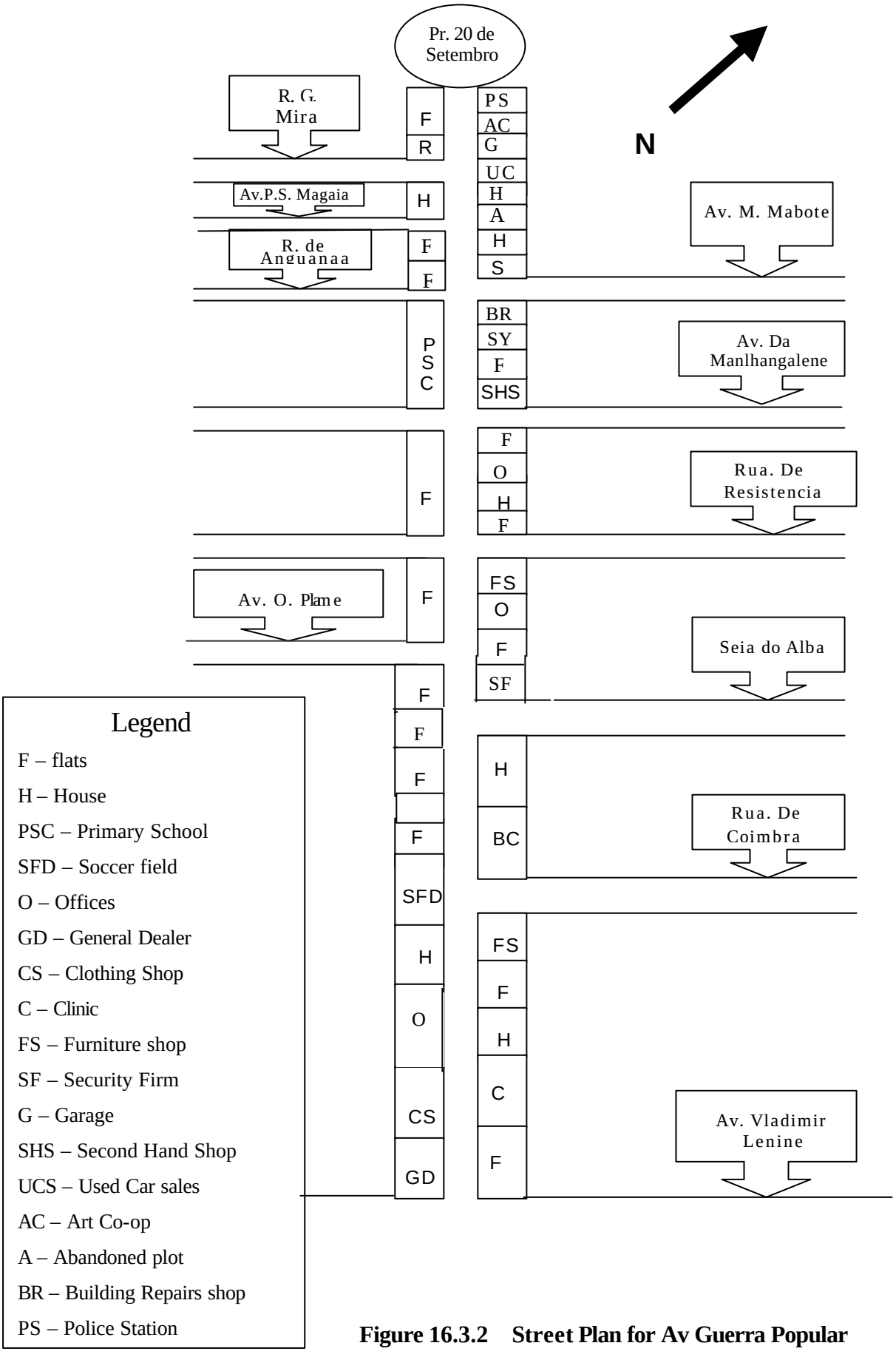


Figure 16.3.2 Street Plan for Av Guerra Popular

16.3.7 Infrastructure

(1) Roads and Transport

The condition of the Maputo road network is one of the main city problems. Basically only the roads within the city have a pavement but due to lack of maintenance, most of them are in a poor condition.

In Polana-Caniço, only Av. V. Lenin is paved and in good condition. The unpaved roads have all been eroded. The damage caused by the floods to Av. J. Nyerere has led to temporary roads being constructed for traffic. This has affected the collective transport routes, resulting in circulation along Av. V. Lenin, instead of Av. J. Nyerere. At present, Av. V. Lenine encounters huge traffic problems.

(2) Water Supply

Since 1999, a private company "Agua de Maputo" has been responsible for facilitating the Maputo water supply. This company supplies about 50000 users in Maputo, with half from District 1. The supply to the surrounding areas is provided mainly by smaller supply systems. The water supply in the Sommerschield area is reasonable, with some restrictions during the day. In the Polana-Caniço area, the supply is insufficient. Due to erosion, the net supply to this area has been affected since 1998. Presently, the water supply is cut off, resulting in public health consequences from water-born diseases.

Water supply in the Chamanculo, Xipamanine, Aeroporto and Maxaquene and much of the Polana-Caniço is via a system of communal standpipes.

(3) Drainage and Sewage Systems

The Maputo drainage and sewage system is based on the topography of the surroundings. Included in the study area, are a central catchment and a few smaller catchments in the east towards the bay, with no treatment taking place.

Only the Sommerschield area is served by a sewage system, which is presently discharging directly into the sea, from the Av. Kenneth Kuanda end. In the Polana-Caniço area, the sewage system consists of pit latrines and septic tanks.

(4) Solid Wastes

The municipality is the unique entity responsible for solid waste management. Only the central city has a collection system. There is no waste separation system, nor any policy for waste reduction, recycling or recovery. Even medical and hazardous waste is disposed of in the Lixeira do Hulene – a disposal site without proper conditions.

In the Polana-Caniço area, the population usually disposes garbage in holes in each yard, or dumps in any depression/ravine or abandoned area.

There are plans for a municipal landfill site. Alternative sites have been identified, although there has not been a decision taken regarding the location or time of executing the feasibility studies.

MICOA has begun drafting a National Waste Management Strategy for the city and surroundings, and is still in the process of being finalised.

It has to be noted that the expansion of urban development will lead to an increase in solid waste generation, therefore a better waste collection system is of high importance (SWECO/CONSULTEC, 2000).

16.3.8 Cultural properties

There are 3 items of cultural property under state protection that are near the target roads. Name and location are listed in Table 16.3.2.

Table 16.3.2 List of Cultural Properties near the Target Roads

Road	Cultural Property		
	Item	*Location*	*Distance from road (m)*
Rua Timor Leste	Fort	Between T. Leste and Ave. Inhaminga	3
Rua Consiglieu Pedrosa	National Money Museum	Corner C. Pedrosa and R. Praza	5
Praza Workers	Pioneer Portuguese Women	Praza Workers Circle	30

16.3.9 Economic activities

In Maputo city, the majority of GDP is depending on commerce and other urban-related economic activities such as construction, transport and manufacturing. Table 16.3.3 shows commercial activities along upgraded and widened roads.

Table 16.3.3 Commercial Activities of Target Roads

Commercial Activity	ROAD NAME								
	Rua Joaquim Lapa	Rua Timor Leste	Rua Consiglien Pedrosa	Ave. Guerra Popular	Ave. Zedequias Manganhala	Ave. Fermas Mahalhaes	Ave. Mohammed Said Barra	Rua. De Bagamoya	Ave. Martines de Inhaminga
Petrol Station							1		1
Vehicle Repair Shop	1	1	2	2	4	4	4		1
Tires Repair Shop									
Food Sales			3	3	3		2		
Supplies Shop	9		6	5	28	26			
Medical Clinic	1				1			1	
Lodge (hotel)			1						
Drugstore (Pharmacy)	2	1	1						
Restaurant			2	1		6		7	1
Building Materials Shop	2		3		4	4	1		
Warehouse				1	4	4	12	2	3
Beauty Parlor & Hairdresser				1	1	1		1	
Service Supplier	2	2	1		2		2	1	
Bank	5	2	2		4	2	2	1	
Clothing Shop	4		5		1	1		2	
Travel Agent	2								
Lottery Office	1					1			
Newspaper Printers	1								
Offices		2	2		1		2	5	2
Government Departments			3		1	3	4	4	2
Driving School		1							
Police Station		1	1						
General Hardware Store			7	1	3	4			
Car Dealers						2			
Parking Lots & Open plots					4	1	1	1	
Markets					2				
Beer Brewery					1				
Soccer Stadium					1				
Wholesale					7	2	1		
Agricultural Machinery Supplier					2	2			
Factory					1				
Petrol Depot					1				
School						1	1		
cinema							1		1

16.3.10 Household and business opinion survey

(1) Household opinion survey

The objectives of the household opinion survey were as follows:

- To develop a profile of the community affected by the proposed upgrade
- To obtain insight into their concerns regarding the condition of the roads
- To ascertain whether they would support the upgrade, and if they would be prepared to relocate or receive compensation in the event of their being directly affected by the upgrade.
- To establish their requirements for a new house in terms of services and location.

1) Methodology

A total of 54 household members were interviewed during the course of the study. The Number of households surveyed per street is presented in Table 16.3.4. The sampling strategy was decided based on the following factors:

- **Level of impact.** Preference was given to areas which would be directly affected by the proposed upgrading. This included the Chamanculo, Xipamanine, Maxaquene, Minkadjuine, Polana-Caniço and Aeroporto districts, where the upgrading of collector roads will involve some relocation of households adjacent to the road. The second focus of the survey were the roads of Av Guerra Popular and Av Marien Ngouabi which will be widened to accommodated two-lane traffic.

- **Population density.** More interviews were conducted in areas of highest population density in order to gain an accurate view of the residents' views and attitudes surround the roads.

The surveys were conducted on foot with the assistance of an interpreter. Residents were approached at regular intervals along the roads. After it was ascertained whether the person in fact lived adjacent to the road, permission would be sought for the interview to be undertaken. In some cases, the person would decline and the process would need to be repeated further along the road. Each interviewee was assured that neither their name nor address would be recorded. This was done to allay fears of repercussions from the council/government authorities. An attempt was made to interview roughly equal numbers of men and women, although less men were general available during the day. No children under the age of 18 were interviewed.

Table 16.3.4 Households Sampled per Street

STREET NAME	No OF HOUSEHOLDS
Rua 4500	2
Rua 3867	3
Rua 2265	5
Rua 2275	5 to intersection with Rua 2282
Rua 2275	4 to intersection with Rua de Xipamanine
Rua de Xipamanhle	9 to 21 de Outubro
Rua 2522	3
Av. Milagre Mabote	8
Av. De Malhangalene	5
Av. Friedrich Engels	1
Av. Guerra Popular	5
Av. Marien Ngouabi	4
Total	54

2) Findings

a) Profile of interviewee

- 57% of the respondents were women
- The average age of respondents was 38 years old
- 57% of families had more than 5 family members
- 64% claim to have been settled in their house for over 20 years
- 36% were unemployed (see figure 16.3.3)
- 59% received an average household monthly income of less than 1 million Mt. (refer to figure 16.3.4)

b) Living environment

- 77% owned the house they were in.
- In the Chamanculo, Xipamanine, Maxaquene, Minkadjuine, Polana-Caniço and Aeroporto districts, 65% of the houses consisted of concrete blocks and iron roof, with the remained constructed of wood, iron and reeds.
- The level of services within the Chamanculo, Xipamanine, Maxaquene, Minkadjuine, Polana-Caniço and Aeroporto districts was relatively low with only 23% having household water supply and 35% electricity. Houses in the Av Guerra Popular and Av Marien Ngouabi are serviced with water, electricity and sewage system.

c) Actual condition of use of roads

- Bad pavement conditions, lack of signals and lack of public transport services were cited as the major problems related to the traffic (refer to figure 16.3.5)

d) Social consideration on the road upgrade

- The respondents voted overwhelmingly in favour of the road upgrade – particularly in the Chamanculo, Xipamanine, Maxaquene, Minkadjuine, Polana-Caniço and Aeroporto districts (100%). The main motivations for supporting the upgrade were improved access in and out of the area and increased safety and comfort (refer to figure 16.3.6). Residents in Av Guerra Popular and Av Marien Ngouabi were more reticent about approving the roadworks as it might mean being displaced to another location.
- 86% preferred to be provided with an alternative house, rather than receiving compensation.
- Water supply, electricity supply, access to medical facilities and schools were cited as the main requirements of relocating to an alternative location (refer to figure 16.3.7)

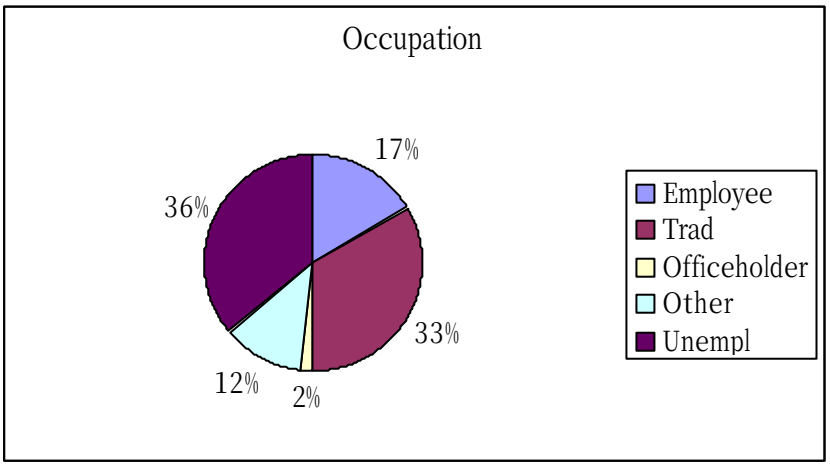


Figure 16.3.3 Occupation of Respondents

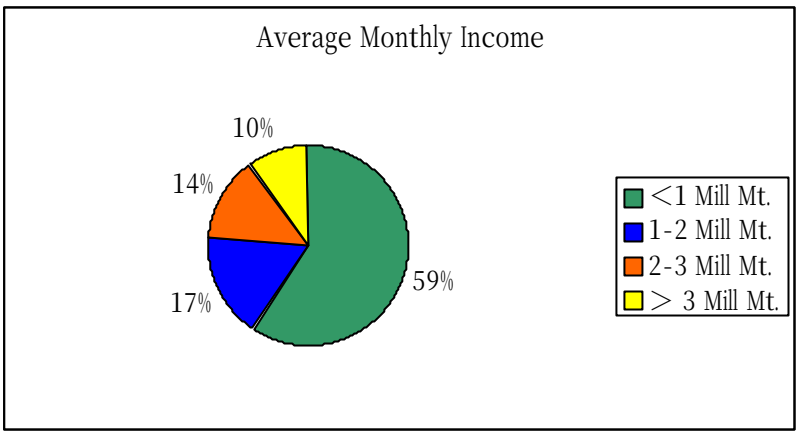


Figure 16.3.4 Average Monthly Household Income in Mt.

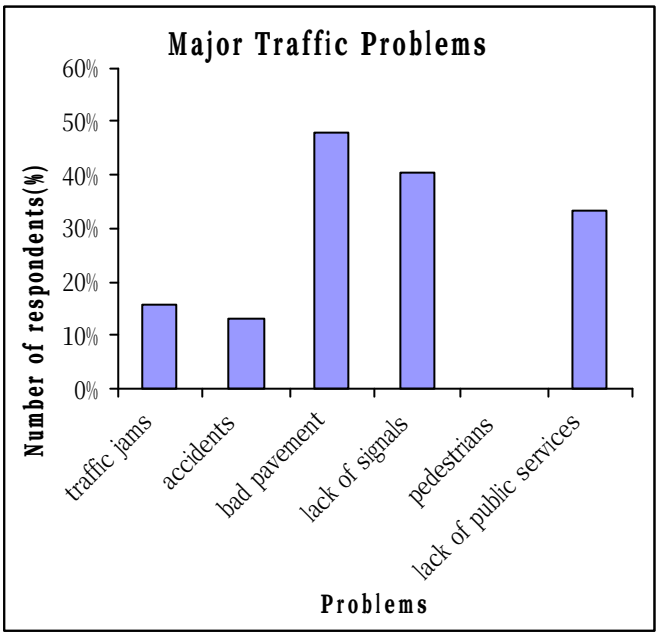


Figure 16.3.5 Major Traffic Problems Identified by Respondents

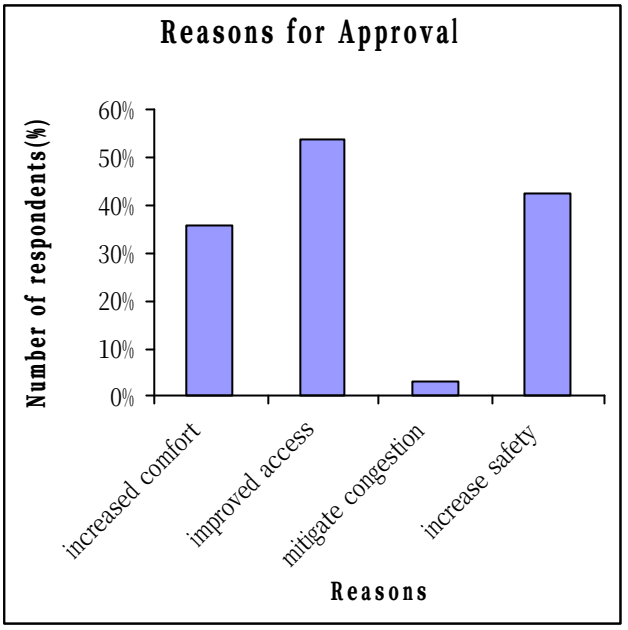


Figure 16.3.6 Reasons for Approving Upgrade

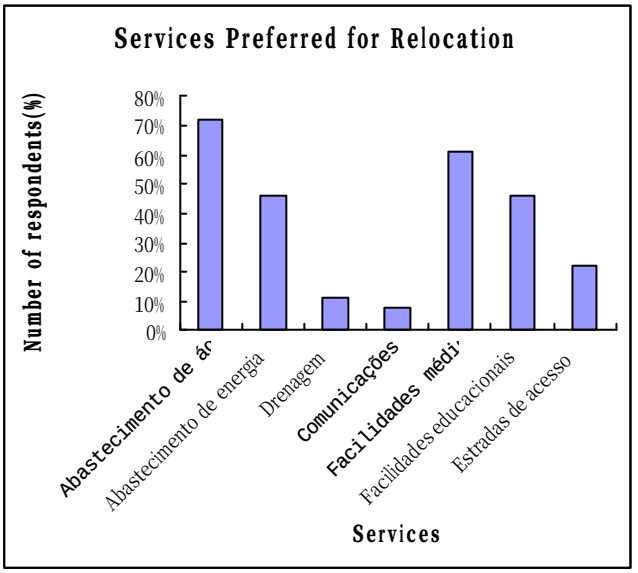


Figure 16.3.7 Services Preferred for Relocation

3) Discussion

a) Low Income Areas

The majority of residents interviewed within the Chamanculo, Xipamanine, Maxaquene, Minkadjuine, Polana-Caniço and Aeroporto districts fell within a low-income bracket (less than 1 million meticas/household/month). A large percentage were unemployed or earning a living from vending of food and goods from outside their yard. Although there was evidence of telecommunication and powerlines within the districts, most of the households could not afford to pay the connection fees.

There was a high level of awareness regarding the condition of the roads, and most expressed concern for the pavement condition and the safety of their families. It was from these interviews that it was revealed that the roads were originally paved and far wider than is currently the case. Many of the residents expressed dissatisfaction with the city council in their attitude to upgrading and maintaining these districts. They supported the upgrade as it would mean improved access to the area and therefore increased trade, access to public transport and to markets, hospitals and schools.

The general impression of interviewing people within the lower income areas was that they had very little to lose by the upgrade. At best, they would be relocated and presented with a superior house with connection to basic services. At worst, they could find themselves located elsewhere in similar conditions to what they are currently experiencing.

b) Middle Income Area

Middle-income applies to homeowners and tenants in Av Guerra Popular and Av Marien Ngouabi. All lived in well-established accommodation consisting of houses or flats built over 30 years ago. The respondents highlighted accidents, the condition of the road surface and lack of signals as their main concerns regarding the road.

Homeowners interviewed were reluctant to support the road upgrading since it meant that they could be relocated elsewhere. Most felt that they would only accept an alternative house if they could be provided with the exact same services and access to facilities (such as schools, shops, places of work etc) that they currently enjoy. Residents interviewed that are currently renting accommodation were less hesitant about accepting the concept of alternative accommodation.

(2) Business opinion survey

A total of nine businesses were surveyed out of a possible 15. The businesses found along the two roads are a mixture between restaurants, clothing shops, supermarkets, security firms, an art co-op and a curio shop. The general impression portrayed by the business sector along Avenues G. Popular and M. Ngouabi, was one of approval for the road widening and upgrade.

The majority of the businesses approved (89%) whilst 11% disapproved. The reason for disapproval was given that it would be difficult to re-establish the same business elsewhere.

The majority of the businesses felt that it would be preferable to receive financial compensation (66%) rather than an alternative building (33%).

All the businesses surveyed felt that the road widening would be beneficial to their business ventures, as well as being an improvement to the present traffic situation, of negligent driving predominantly by taxis and fewer sidewalk traders.

16.3.11 Resettlement compensation

(1) Approach and Assumptions

An estimation of costs for resettlement compensation has been made. Relocating households are caused by roads widening, construction of missing link on Av. Julius Nyerere, Restoration of original Av. Julius Nyerere and improvement of bus terminals.

In order to reach an estimation of the costs, the following assumptions have been made:

- Families displaced by the project will be provided with low-cost housing as per the City Council standard. This consists of a 2-3-room brick "starter" house with basic services. The average cost of building such a dwelling is in the region of 1500 USD.

(2) Results of cost estimation

The results of cost estimation on families displaced are shown in table 16.3.5.

Table 16.3.5 Costs Estimates for Families Displaced

Name of Road/Project	NO. of Resettlement	Cost (US$)
Construction of Missing Link on Av. Juluis Nyerere	350	525,000
Restoration of Av. Juluis	215	322,500
Rehabilitation of District 2 Area Roads	53	79,500
Rua 2282/2265	17	25,500
Rua 2275	23	34,500
Rua de Xipamanine(2291)	2	3,000
Rua 2315/2313	5	7,500
Rua 2309/2324	6	9,000
Rehabilitation of District 3 Area Roads	34	51,000
Rua da Goa(3027)	1	1,500
Av. Milagre Mbote(3001)	3	4,500
Av. Da Malhangalene(3259)	13	19,500
Rua 1de Maio(3374)	17	25,500
Improvement of Bus Terminals	92	138,000

16.3.12 Air pollution survey

(1) General

Field survey was carried out to confirm present conditions related to air pollution in the project area. The target pollutants are NO_2, CO and SO_2. The sampling points were undertaken in the vicinity of the university and in the residential suburb of Chamanculo where the effects caused by traffic vehicles are considered as few. The sampling sites are shown in Figure 16.2.1.

(2) Sampling Methodology

It was proposed to sample for SO_2 and NO_2 using passive samplers supplied by O*gawa* and for CO using pressurised stainless steel canisters supplied by the *National Energy Corporation of South Africa (NECSA).* An advantage of passive methods is that they require minimal equipment and there is no need for power at sampling sites. This method and equipment is simple and relatively inexpensive, and provides an acceptable range and detection limit for ambient environments. The passive samplers were to be deployed over two, two weekly periods for comparison to monthly guideline values.

(3) Method of Analyses

1) Passive Filters

After exposure the NO_2 filters were analysed by Durban Metro Water Services Laboratory (South Africa) using UV/VIS spectrophotometry. In this process, the NO_2 is extracted from the filter element with water. Two colour producing reagents are then added - these react with NO_2 to form a red colour - the intensity of which is proportional to the concentration that the element was exposed to in the field.

The SO_2 samples were analysed by Umgeni Water in Pietermaritzburg using ion chromatography. The filters are treated with a solvent and then converted to a sulphate with the use of an oxidising agent. The SO_2 is then determined as sulphate.

2) Canisters

The gas samples were analysed using a gas chromatographic technique, which is equipped with a gas inlet system. The sample connection was leak checked prior to analysis.

(4) Results

Table 16.3.6 Results of the SO_2 Passive Sampling Programme

Filter Number	Filter Type	Location	Result (ppb)	WHO 24 hr. avg.	US EPA 24 hr. avg.	South African 24 hr. avg.
JG 1	SO_2	University	1,1 ppb	48 ppb	140 ppb	100 ppb
JG 3	SO_2	Chamanculo	0,9 ppb			

Table 16.3.7 Results of the NO_2 Passive Sampling Programme

Filter Number	Filter Type	Location	Result (ppb)	WHO 24hr. avg.	US EPA 1 hr. avg.	South African Monthly Standard
JG 2	NO_2	University	6,0 ppb	80 ppb	128 ppb	80 ppb
JG 5	NO_2	Chamanculo	12,0 ppb			
Wentworth Ref.	NO_2	Durban	23,0 ppb			
Analyser	NO_2	Durban	21,8 ppb			

Table 16.3.8 Results of the CO Canister Sampling Programme

Sample No.	Sampler	Location	Result		
			CO	CO, WHO 1 hr. avg.	CO, US EPA 1 hr. avg.
CO 1	Canister	University	< 500 ppb*	26 198 ppb	35 000 ppb
CO 2	Canister	Chamanculo	< 500 ppb*		
CO 3	Canister	University	< 500 ppb*		
CO 4	Canister	Chamanculo	< 500 ppb*		

* Detection limit = 500 ppb

(5) Discussion

From the results of the sampling programme it is evident that:

- SO_2, NO_2 and CO concentrations in the study area appear to be low relative to a range of guidelines.
- The concentration recorded for NO_2 was below the South African monthly guideline level of 80 ppb.
- The concentration recorded for SO_2 was below the South African annual guideline level of 30 ppb.
- This does not necessarily mean that guidelines for the shorter averaging periods, such as the guidelines for instantaneous peaks were not exceeded during the sampling period.
- There was a reasonable correlation between the concentration recorded by the continuous analyzer and the quality control NO_2 passive filter, which were both located at the Wentworth monitoring station in Durban, South Africa. For the same period the passive filter recorded a concentration of 23 ppb and the analyzer a concentration of 21,8 ppb.
- The results measured for CO were less than 500 ppb.

CHAPTER 17

BASIC DESIGN STANDARD

CHAPTER 17 : BASIC DESIGN STANDARD

17.1 GENERAL

In this chapter, the basic engineering aspects including design standards and standard cross-sections to be applied for the proposed roads have been studied. The basic plan for the right-of-way (ROW) was also also studied taking into consideration the present ROW, road area and the land-use situation along the proposed roads.

17.2 DESIGN STANDARD

As described in Section 4.4,11.2 and 11.4, Chapter 4 and 11, Part A: Master Plan Study, the recommendable Road Classification and Road Design Standard have been evaluated based on ANE's and SATCC design standards. The followings are the road classification and design standards for high priority projects.

17.2.1 Functional Classification of the High Priority Roads

The functional classification of each Proposed road has been studied referring to the recommendable road classification prepared by the Study Team as follows:

- Trunk Road:

1. Missing Link on Av. Julius Nyerere:
2. Av. Vladimir Lenine:
3. Av. Acordos Lusaka and Av. Guerra Popular:
4. Av. Angola and Rua S. Cabral/Largo de Deta:
5. Av. Marien Ngouabi:

- Collector Road:

1. Industrial and Commercial Area Roads (total length= 6.03 km):
   Av. Josina Michel (1070, L=0.9km), Av. Fernao de Magalhaes (1038, L=1.3 km), Av. Zedequias Manganhela (1034, L=1.3 km), Av. Mohamed Siad Barre (1203, L=0.85 km), Av. Romao Fernandes (1199, L=0.85 km), Rue 1229 (L=0.25 km) and Av. As Estancias (1030, L=0.58 km).
2. Port Area Roads (total length =3.9 km):
   Rue Consiglieri Pedroso (1022)/ Rue Joaquim Lapa (1020, L=0.8 km), Rue do Bagamoyo (1016)/ Rue de Timor Leste (1014, L=0.8 km), Av. Martires de Inhaminga (1006, L=0.8 km) and the other six port area roads (L=1.5 km).

- Local Area Road:

1. District 1 Area Roads (total length = 8.7 km):

Av. Milagre Mabote (1369, L=1.0 km), Av. da malhangalene (1357, L=0.94 km), Av. Para O Palmar (1426, L=1.4 km), Av. Kaweme Nkrumah (1250, L=1.61 km), Av. Paulo Samuel Kankhomba (1152, L=0.55 km), Av. Emilia Dausse (1138, L=0.85 km), Av. de Maguiguana (1130, L=0.75 km), Av. Filipe Samuel Magaia (1183, L=0.4 km) and Av. Friendrich Engels (1009, L=1.2 km).

2. District 2 Area Roads (total length = 10.2 km):

Rua 2282/2265 (L=2.36 km), Rua 2275 (L=2.0 km), Rua de Xipamanine (2291, L=1.13 km), Rua dos Imaos Roby (2289, L=1.3 km), Rua 2315/2313 (L=0.7 km), Rua 2309/2324 (L=1.0 km), Rua 2522 (L=1.25 km) and Av. das Estancias (2000, L=0.49 km).

3. District 3 Area Roads (total length =9.5 km):

Rehabilitation of pavement and drainage on Rua da Goa (3027, L=0.8 km), Rua da Lixera (3030, L=0.79 km), Av. Milagre Mbote (3001, L=1.98 km), Av. da Malhangalene (3259, L=1.83 km), Rua 1 de Maio (3374, 1.49 km), Rua 3306 (L=0.49 km), Rua 3523 (L=1.0 km) and Rua 3576 (L=1.1 km).

17.2.2 Design Standards

In order to clarify the urban road designing to be applied to this study, a new design standard width and a new geometric design stand have also been proposed by the study team based on ANE's design standard as well as SATCC design standard.

The main point of the newly proposed standards is as follows:

- Standard width is classified by four classifications of roads, two types of roads where the roads are passing and by numbers of lone.
- Standard width is showing each component of typical cross-sections and recommended right of way.
- Geometric design standard is classified by design speed and is consisting of horizontal and vertical alignment.

Table 4.2.3 and 4.2.4 in the Chapter 4 shows the components of the proposed standard width and the geometric design standard to be applied for the study of urban roads in Maputo.

17.2.3 Design Speed

Design Speed is a fundamental factor for road design and is directly related to the geometric elements of the road design including carriageway width, horizontal and vertical alignments, etc.

The design speed to be applied for each proposed road was established taking into account the road classification, type of road and land-use situation along the proposed roads as shown in Table 17.2.1.

Table 17.2.1 Proposed Design Speeds

Project Road	Classification	Type of Road	Terrain Condition	Land-use Situation	Proposed Design Speed (km/hr)
Missing Link of Av. Julius Nyerere	Trunk Road	Street	Flat/Rolling	Urban Area	60
Av. Vladimir Lenine	Trunk Road	Street	Flat	Urban	50
Av. Acordos do Lusaka	Trunk Road	Street	Flat	Urban	60
Av. Guerra Popular	Trunk Road	Street	Flat	Urban	50
Av. Angola and Rua S. Cabral/Largo de Deta	Trunk Road	Street	Flat	Urban	50/40
Av. Marien Ngouabi	Trunk Road	Street	Flat	Urban	50/40
Industrial and Commertial Area Roads	Collector Road	Street	Flat	Urban	40
Port Area Roads	Collector/ Local Area Road	Street	Flat	Urban	40/30
District 1 Area Roads	Collector Road	Street	Flat/Rolling	Urban	40/30
District 2 Area Roads	Collector Road	Road	Flat	Semi-urban	40
District 3 Area Roads	Collector Road	Road/Street	Flat	Semi-urban	40

17.2.4 Pavement Design Standard

The Pavement Design methodology in Mozambique and SATCC is based on the "AASHTO Guide for Design of Pavement Structures", 1993.

The Pavement Design Standard in this study should be applied AASHTO.

1) To Confirm Required Rehabilitation Measures of Pavement

Different stages of damaged roads demand different paving improvement measures. For this purpose, an appropriate improvement measure should be selected based on the survey results on the Pavement Serviceability Index (PSI) for each existing road as shown in Table 17.2.2.

Table 17.2.2 Required Rehabilitation Measures of Pavement

PSI	Improvement Measure
Very Bad	Reconstruction from Subbase Course
Bad	Reconstruction from Base Course
Fair	Overlay
Good	Pot-hole patching
Very Good	Ordinary maintenance work

2) To Introduce Sustainable Design Life of Pavement by Road Function

The design period is the period during which the road will accommodate the traffic at a satisfactory level of service without requiring capital intervention in the form of rehabilitation or strengthening.

During the design period only ordinary routine maintenance and periodic maintenance will be carried out. At the end of the design period the pavement shall not have deteriorated to the extent that reconstruction is needed, but the pavement will require a strengthening in order to carry the traffic for a further period.

In this study, Study Team recommended that the road maintenance works should be transfer from by MCM to by private enterprise.

Given the prospect of the implementation of the periodic maintenance in the coming years, it is now deemed more rational to decide the design life for pavement rehabilitation from a more realistic economic point of view.

The design period for pavement design under the Project should be 10 years for the project roads by considering the follows items.

(i) the road maintenance regime of the MCM will be strengthened,
(ii) possible transfer of the road maintenance responsibility from the public sector to the private sector.

17.2.5 Drainage Design Standard

Drainage design standard has not been prepared in Maputo City; therefore, design standard should be determined referring with existing plans, and also comparing with Japanese standard.

1) Return Period

Base on evaluation of the each proposed basin and referring with existing study (Preliminary Design Study of Repair of Avenida Julius Nyerere), return period has been determined as 2 years, respectively, except Av.J.Nyerere and outlet of port area road.

Av.J.Nyerere and Outlet of Port Area Road
Road drainage: 10 years
Box culvert to Outlet: 50 years
Outlet: 50 years

2) Run-off Factor

Proposed run-off factor has also been determined based on the evaluation of the existing land use as follows.

- Urban Area:0.75
- Semi Urban Area (High Density Residential Areas) :0. 55
- Semi Urban Area (Other Areas):0. 20

3) Calculation of Discharge

Calculation of the proposed discharge are depending on following formula:
(Rational Formula)

$Q=1/360 \cdot C \cdot I \cdot A$

C: Run-off Factor
I: Intensity (mm/hr)
A: Catchment Area (ha)
Q:Volume of Discharge(cu・m)

4) Calculation of Channels

Calculation of the proposed channels are depending on following formula:

(Manning Formula)

$V=1/N \cdot R^{2/3} \cdot I^{1/2}$

N: Coefficient of Roughness

R: Hydraulic Radius

I: Incline

V:Water Velocity(m)

Regarding Japanese standard, Water Velocity should be designed from 0.6m/sec to3.0m/sec.

$Q=A \cdot V$

V:Water Velocity(m)

A: Area of Flow Water (sq.m)

Q: Capcity of Channel (cu.m/sec)

17.2.6 Structure Design Standard

1) Structure Design Policy

The following structures are supposed Julius Nyerere including the alternative route. Therefore each type of structure is presented in Chapter 18.

(a) Bridge for crossing the damaged part near Eduardo Mondlane University
(b) Culverts for cross under the road

2) Bridge Design standard

Maputo City has never constructed the bridges in the city area. All of the bridges were constructed by Ministry of Public work, especially, which is ANE. ANE is applied their own standard as well as SATCC design standard. Maputo City has no Design Standards regarding the Bridge Design. Therefore Bridge Design Standard should be applied ANE's design standard.

(1) Cross Section

The typical cross section is shown in Figure 17.2.1. The existing 2 lanes will be widened to 4 lanes in the future. But the bridge design on the Feasibility Study should be considered with 2 lanes.

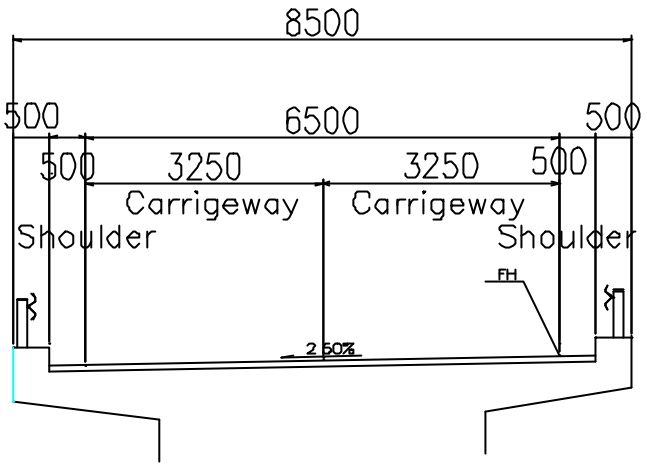


Figure 17.2.1 Typical Cross Section

(2) Load

The following loads are considered in the design of the bridge in accordance with ANE's Design Standard.

a) Dead Loads
b) Earth Pressure
c) Live Loads & impact
d) Braking & Traction of vehicle
e) Buoyancy
f) Wind
g) Temperature
h) Shrinkage

(3) Crossing Condition

For the designing of the bridge crossing over the damaged part, the following items are required for the design conditions as the drainage.

a) Width and cross section of the damaged part
b) Maximum velocity of the current and Maximum volume of the flood discharge

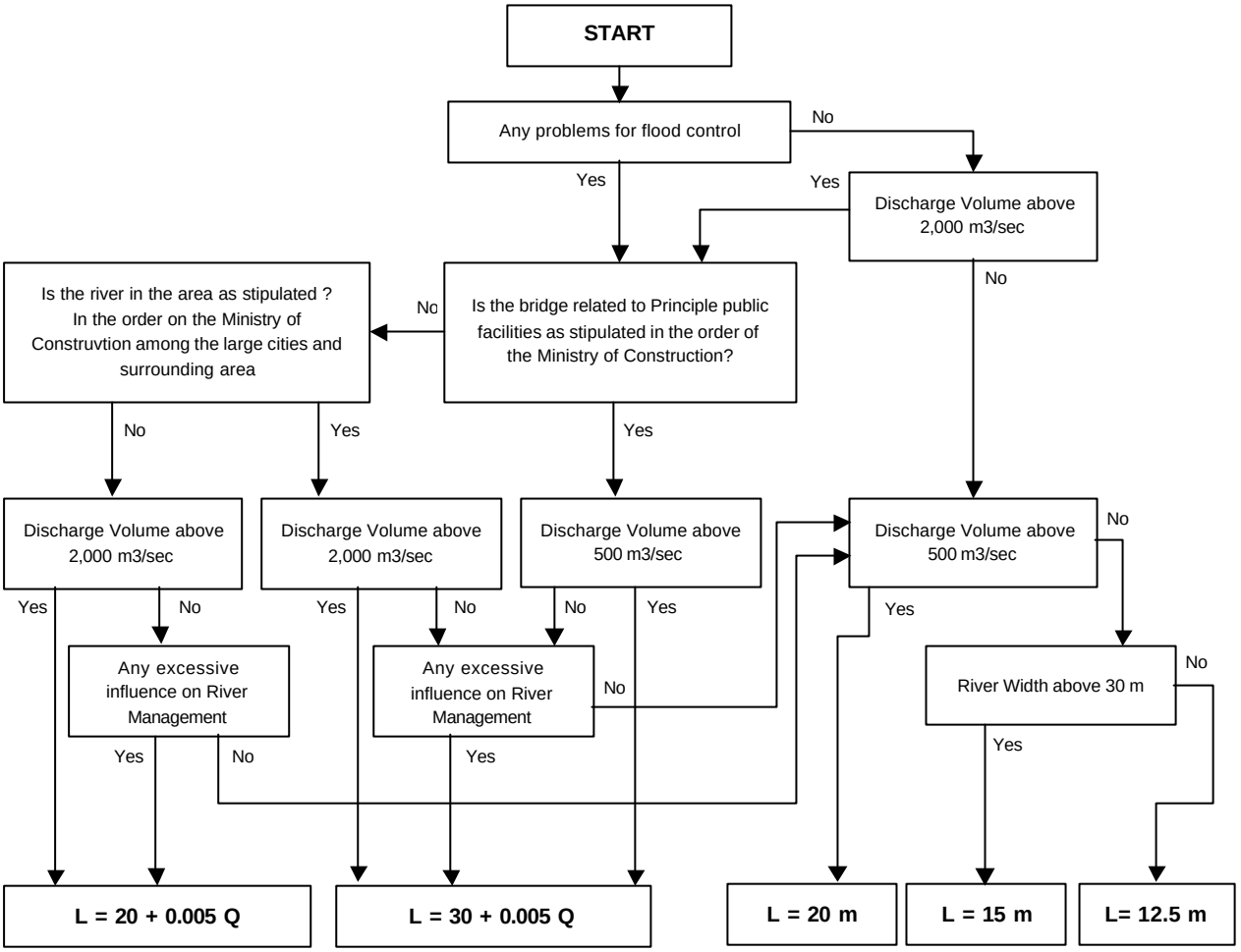
For instance, in Japan the plan height and minimum span length of the bridge crossing over river are decided from a clearance under the girder and standard span length which are prescribed based on the volume of the flood discharge. (See Table 17.2.3, Figure 17.2.2)

Table 17.2.3 Minimum Clearance under the Girder (Japan)

Design flood Discharge Q (m^3/s)	Q < 200	200 <= Q < 500	500 <= Q < 2,000	2,000 <= Q < 5,000	5,000 <= Q < 10,000	10,000<= Q
Clearance under Girder (m)	0.6	0.8	1.0	1.2	1.5	2.0

(4) Discharge Volume

Discharge volume should be calculated and used fifty years return periods. JICA Study Team has gotten much data from the Institute of National Meteorology. Discharge volume is presented in Section 15.4



L: Bridge length

Figure 17.2.2 Minimum Span Length related Discharge (Japan)

3) Box Culverts Design standard

For box culverts, sectional dimensions will be determined from the dimensions of internal hollow spaces (internal hollow width x internal hollow height) and the overburden of culverts while referring to the Standard Box Culvert Design Drawings established by the Ministry of Land and Transport of Japan.
Table 17.2.4 and Figure 17.2.3 show typical sectional dimensions.

Table 17.2.4 Box Culvert

Inner section W (m) x H (m)	Over burden (m)	Top slab (mm)	Floor slab (mm)	Side wall (mm)	Remarks
5.0×5.0	0.20 - 1.00	400	500	450	Haunch size 300×300
	1.00 - 2.00	450	550	500	
	2.00 - 2.75	500	600	550	
	2.75 - 3.50	550	650	550	
	3.50 - 4.50	600	700	600	
	4.50 - 5.50	650	750	650	
6.0×5.0	0.20 - 0.75	400	500	450	
	0.75 - 1.75	500	600	500	
	1.75 - 3.00	600	750	600	
7.0×5.0	0.20 - 0.75	450	550	500	
	0.75 - 2.00	600	700	600	
	2.00 - 3.25	700	850	650	

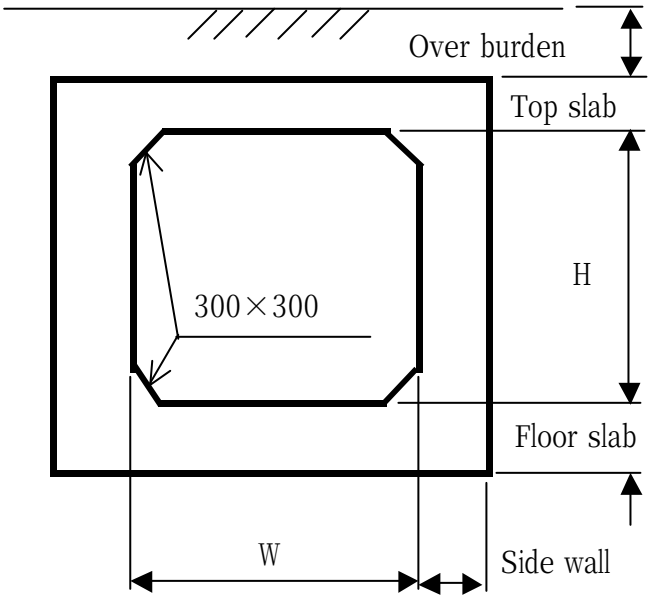


Figure 17.2.3 Typical Cross section

17.3 STANDARD TYPICAL CROSS-SECTIONS AND RIGHT-OF-WAY

Typical cross-sections for each road-type have been developed for the year 2010 along with traffic lane numbers determined taking into consideration road classification, type of road (Street and Road), land-use pattern and existing right-of-way conditions.

Figure 17.3.1 shows proposed typical cross-sections as well as required right-of-way width for each proposed road.

1) Number of Lane

Number of lane of each proposed road has been studied in Chapter 12 and proposed 4-lane Roads are Av. Acordos do Lusaka, Av. Guerra Popular and a part of Av. Marien Ngouabi. Others are proposed as 2-lane roads.

2) Carriageway Width

The proposed Carriageway Width of 1 lane has been evaluated as 3.25m, 3.00m and 3.00m for Trunk, Collector and Local Area Roads respectively. In case of Av. Guerra Popular, Av. Marian Ngouabi and Av. Acordos de Lusaka, the proposed width of each carriageway will be reduced to 3.00m due to limitation of land and difficulty of acquisition of properties.

3) Shoulder Width

Proposed Shoulder Width for 2-lane Trunk Road has been evaluated as 0.5m for Street type and 0.75m for Road type. Shoulder Width of Collector and Local Area Road are 0.5m and 0m respectively.
In case of street type of Trunk Road, 1.5-2.0m of parking space will be prepared depending on the roadside condition.

4) Median Strip

Typical median strip of 6.0m widths will be prepared on the proposed 4-lane Trunk road and it's varied depending upon availability of space.

5) Sidewalks

Sidewalk should be equipped on Trunk Road and Collector Road. Proposed minimum width

of sidewalk are 2.0m for Street Type of Trunk Road, 1.5m for Street Type of Collector Road and 1.5m for Road Type of Collector Road.

6) Drainage Type

Roadside Drainage should be prepared all of the proposed roads. Proposed type of drainage will be L or U-shaped ditch for Street Type of Trunk and Collector Roads and the others are recommended Open Drain.

7) Utility Space

Standard Width of utility space of Trunk, Collector and Local Area Road are 2.0m, 1.0m and 1.0m respectively depending on availability of space.

8) Total Road Width and Right-of-way

Standard widths of Right-of-way for 2-lane Trunk, 4-lane Trunk, collector and Local Area Road are 20.0m, 40.0m, 14-20m and 6-10m respectively depending upon availability of land and difficulty of acquisition of properties.

Table 17.3.1 Proposed Standard Width and Right-of-way

Project Road	Classification	Road Type	Lane No.	Design Traffic Volume (pcu/day)	Design Speed (km/hr)	Lane width (m)	Carriageway Width(m)	Shoulder (m)		Paking Lane both side(m)	Central Strip (m)	Sidewalk both side (m)	Drainage System	Utility Space both side(m)	Total Road Width (m)	Recommended Right of way (m)	Pavement Type	
								Left side	Right side								Recommend	Alternative
Missing Link of Av. J. Nyerere	Trunk Road	Road	4	< 40,000	60	3.25	13.00	1.25	0.25	-	8.00	4.00	OD	2.00	40.00	40	AC	-
			2	< 13,000	60	3.25	6.50	1.25	1.25	-	-	4.00	OD	2.00	23.50	40	AC	-
Av. V. Lenine	Trunk Roadl	Street	2	< 13,000	50	3.50	7.00	0.50	-	-	-	2.00	L,U	2.00	16.00	20	Concrete Block	-
Av. A. Lusaka	Trunk Road	Street	4	< 40,000	50	3.00	12.00	0.50	-	1.50	2.00	4.00	L,U	1.00	28.00	30	AC	DBST
Av. Guerra Popular	Trunk Road	Street	4	< 40,000	40	3	12.00	0.50	-	-	-	3.50	L,U	-	20.00	20	AC	-
Av. Angola	Trunk Road	Street	2	< 13,000	50/40	3.50	7.00	0.50	-	2.00	-	4.00	L,U	-	20.00	20	AC	-
Av. M. Ngouabi	Trunk Road	Street	4	< 40,000	50/40	3.00	12.00	0.50	-	-	-	3.50	L,U	-	20.00	20	AC	DBST
			2	< 13,000	50/40	3.50	7.00	0.50	-	2.00	-	4.00	L,U	-	20.00	20	AC	DBST
Industrial and Commert	Collector Road	Street	2	< 8,000	40	3.50	7.00	0.50	-	2.00	-	4.00	L,U	-	20.00	20	Concrete Block	DBST/Stab.M
Port Area Roads	Collector Road	Street	2	< 8,000	40/30	3.00	6.00	0.50	-	2.00	-	1.50	L,U	0	14.00	14-20	Concrete Block	DBST/Stab.M
District 1 Area Rds	Collector Road	Street	2	< 5,000	20-40	3.00	6.00	0.50	-	2.50	-	2.00	L,U	0	16.00	16-20	Concrete Block	DBST/Stab.M
District 2 Area Rds	Collector Road	Road	2	< 5,000	20-40	3.00	6.00	-	-	-	-	2.00	OD	1.00	14.00	14	Concrete Block	DBST/Stab.M
District 3 Area Rds	Collector Road	Road	2	< 5,000	20-40	3.00	6.00	-	-	-	-	2.00	OD	1.00	14.00	14	Concrete Block	DBST/Stab.M

L,U: L-side ditch , U-Shaped drain(W=0m, both side)
OD : Open Drain (W=1.0m,both side/ except Local Area)
OD : Open Drain (W=1.0m,Local Area Road 2lane-both sode, 1 lane-one side))

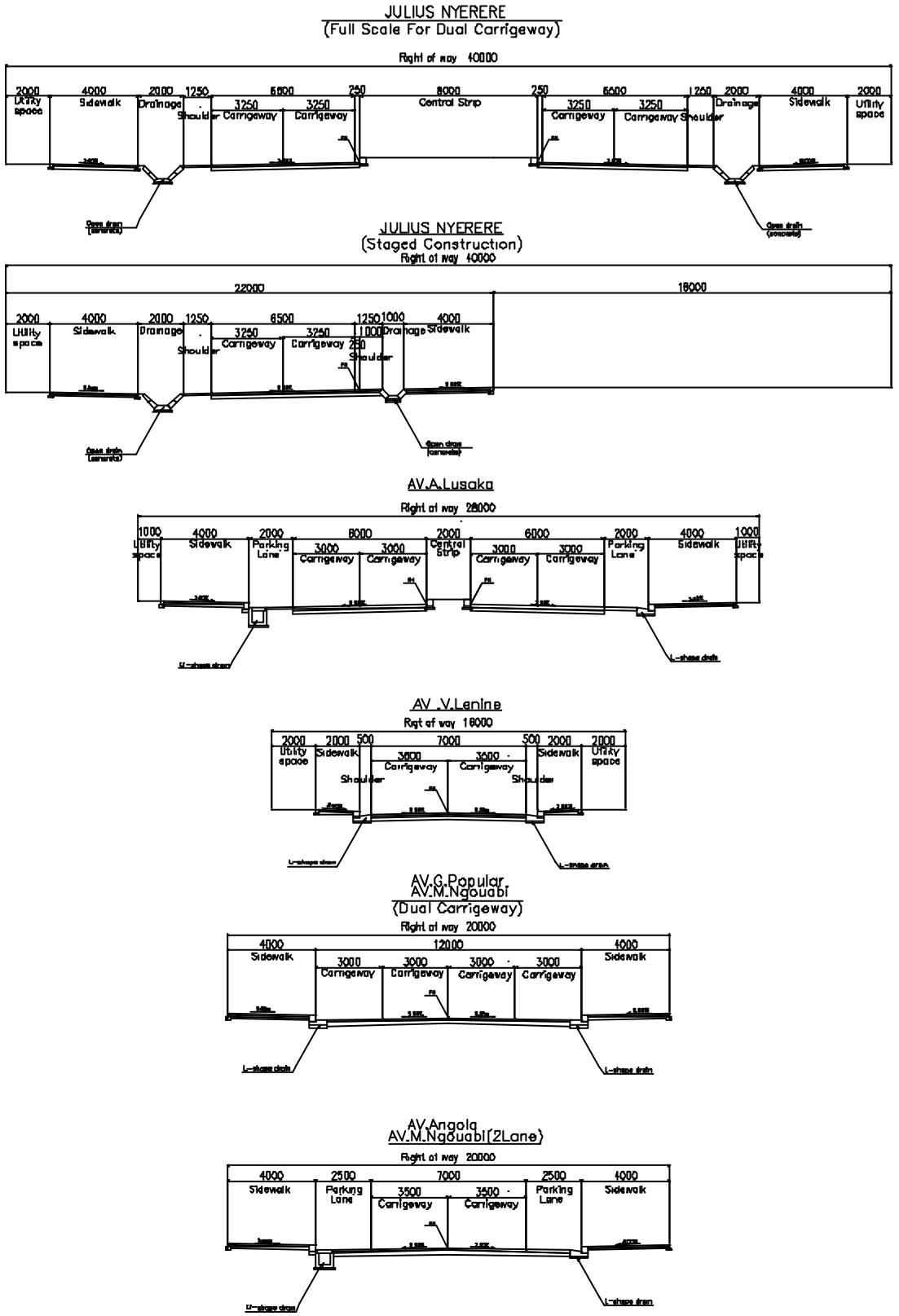


Figure 17.3.1 (1) Proposed Typical Cross-sections (Trunk Roads)

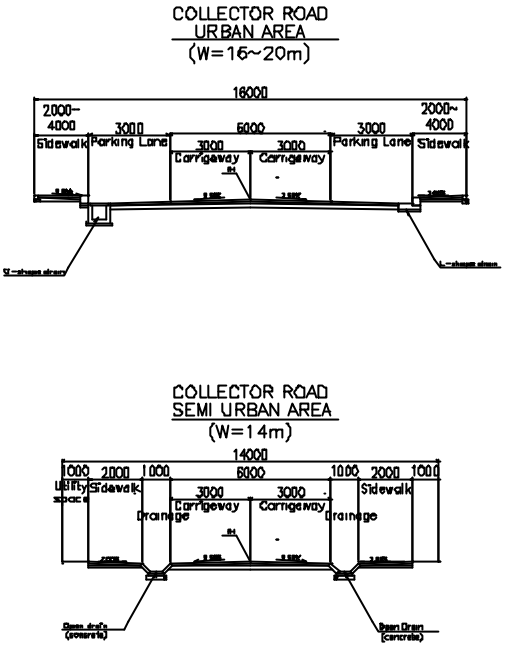


Figure 17.3.1 (2) Proposed Typical Cross-sections (Collector Roads)

CHAPTER 18

PRELIMINARY ENGINEERING DESIGN

CHAPTER 18 : PRELIMINARY ENGINEERING DESIGN

18.1 GENERAL

In this chapter, the preliminary engineering designing on the Projects have been studied including application of the design standards and the proposed standard cross-sections as well as evaluation of trade-off relation between expectable right-of-way and amount of land acquisition. The contents of the preliminary engineering design composed of an alternative route study on the missing link of Av. Julius Nyerere, highway design, intersection design, bridge and structure design, drainage design, pavement design and road facilities design as well as relocation and protection of public utilities.

18.2 ALTERNATIVE ROUTE STUDY

The missing link of Av. J. Nyerere was caused by the flood and the erosion in February 2000. Av. J. Nyerere has been identified as one of the main corridors connecting the north area and the CBD and the construction of the missing link has also identified as one of the urgent project among the others. The basic route for the missing link has been studied in the master plan study and the route is recommended to pass the flood plain comparing the original route of the missing link through the evaluation of the costs and the benefits.

Based on the above, the alternative route study on the missing link of Av. J. Nyerere has been carefully done in order to identify the appropriate alternative route to be analyzed during the feasibility study.

18.2.1 Objectives and Policies

In order to solve the subject, the objectives of the feasibility study on the construction project of the missing link has been identified in Chapter 14 as follows:

- Early linking of the missing link through construction of **two lane trunk road**
- To prevent Disaster through introduction of the required measures for the **land-slide and the storm drainage**
- To function as a basic corridor for future extension through preparation of land for **future widening.**

The function of the trunk road has been identified in Chapter 4 and 11 and the main points are summarized as follows:

- **No school zone and community cutting** should be planned
- **The traffic capacity and the design speed** should be **high**
- **Access control to each housing** should be introduced

Regarding the protection of the landslide and the storm water drainage, an emergency protect ional work has been done by the supporting of the international donors. A new storm water system for this eroded area (named 'Polana Canico') has also been proposed in the SIDA's feasibility study. The main idea of the system consists of the changing from one single discharge point to the four outlets system into the sea and introduction of open channel system.

After evaluation of the proposed drainage system, the study team also recommends to introduce the same drainage system basically in addition to some modification of the system due to the introduction of the different alignment in this study comparing to the SIDA's study.
In case of the basic route of the missing link which will be running though the flood lain with parallel to the new storm water system, a protect ional work of the new system should be considered due to a heavy erosion of the river bank of the system to be becoming affection to the basic route.
The slope protection will also be required including construction of vertical and side drain at the edges of gentle slop.

The right-of-way width of the missing link section will be basically 40m composing of approximate 23m widths for single carriageway and remaining 17m widths for future widening space of dual carriageway. Some modification will be required in the section of a new construction of bridge, large size of culvert, embankment and cutting as well as to reduce a number of resettlement required.

An access control should be introduced to both of the basic route and the alternatives in order to maximize the required traffic function of the trunk road and to reduce traffic accident. A limited number of access roads directly connecting to the missing link will also be introduced.

The location of the proposed alignment of the missing link should be carefully determined considering the protection of existing community based on the viewpoint of environment and safety. Therefore the proposed route alignment should be outside the existing communities.

18.2.2 Characteristics of the Candidate Routes

Based on the above objectives and policies, the study team has selected four (4) candidates to the basic route as shown in Figure 18.2.1. The following three points have made for the selection of the candidates:

- Short distance linking
- To connect with the collector roads
- To use a land of existing road

1) Plan 1

Plan 1 route is to use the existing roads, which is Rua 3523 and Rua 3641, with approximate 3.1 km length. A part of Rua 3523 was also damaged by the flood in 2000 and this was rehabilitated with concrete block pavement and open ditch by the support of donor community in June 2001 (see Photo 18.2.1 and 18.2.2). The damaged part of Rua 3641 is scheduled to fill by soil up to the existing ground level height within very near future.

Photo 18.2.1 Road Surface

Photo 18.2.2 Plan Part for Filling Up

The existing road width of Rua 3523 is approx. eighteen (18) meters with single carriageway. And the width of Rua 3641 is only eight (8) meters. The both of the roads are used as either collector road or local area road in the community with full development of local houses along side the roads.

The proposed alignment should cross a part of residential area connecting with the original route of Av. J. Nyerere keeping a distance from the eroded ravines.

2) Plan 2

Plan 2 route is used a part of Av. Pala o Palmar (rua 1426), which is reconstructed as an access road for new housing area by the private company as shown in Photo 18.2.3 and 18.2.4, and running the west side of the golf course, and finally connecting with Rua 4683 with a total length of approx. 5.1 km long. For the connection with Rua 4500, new construction of an access road will be necessary crossing fruit plantation and paddy field.

Av. P. Palmar is constructed by concrete surface with approx. thirteen (13) meters width. The storm water drainage main has already been constructed beside the road but not for the collection of the road surface water.

This route is passing near to the eroded ravines and will be nominated as one of the candidates after completion of the total rehabilitation of the damaged parts of Av. J. Nyerere.

Photo 18.2.3 Seeing toward Rua 1426

Photo 18.2.4 Seeing toward Av. J. Nyerere

Figure 18.2.1 Candidate Route for Alternative Route

3) Plan 3

Plan 3 route is starting from the same of Plan 2 and passing the road space of Rua 3862 and 3866 and finally connecting with the Combatentes Plaza with approx. 3.4 km long. The surrounding environment is local residence and some fruit plantation and paddy field.

The existing roads are earth road without drainage within approx. 3 meters width resulting amount of house compensation and resettlement required.

Almost alignment of this route is located near the eroded sections and will be nominated as one of the candidates after completion of the total rehabilitation of the damaged parts of Av. J. Nyerere.

4) Plan 4

Plan 4 route is just same of Av. J. Nyerere with total length of approx. 3.1 km. The original Right-of-way width is planned for dual carriageway and the existing road is 2-lane trunk road.

The proposed vertical alignment will be also the same as the original one for future dual carriageway and environment.

5) Master Plan

Master Plan route is starting from the same road of Plan 2 and using Rua 3867 passing the east side of the golf course and finally connecting with Rua 4683. The total length will be approx. 5.6 km long. The existing Right-of-way width of Rua 3867 is consisting approx. 30 metes to the edge of the golf course and becomes approx. 10 meters up to the entrance of the golf course.

The route is passing far from the eroded parts and passing parallel with the eroded storm water main that is requiring a protection or a re-alignment of the drainage main.

18.2.3 Selection of Alternative Route

The evaluation of each candidate route has been conducted based on the fitness in the objectives.

1) No school zone/community cutting

- **Plan 1 : Negative**. Because of the function of the proposed trunk road is high level; the environmental and social influence to the community will become huge problem during construction and after construction. Therefore this route will be useful as a temporary relief measure.

- **Plan 2 : Positive.** Due to the proposed alignment passing outside the existing community; there will not be the negative influence by the project.

- **Plan 3 : Negative.** Due to the direct cutting of the existing communities.

- **Plan 4 : Positive.** The proposed alignment will pass through the existing boundary of the communities.

- **Master Plan : Positive.** The route will pass through the existing boundary of the communities.

2) Countermeasures of Damaged Area

- **Plan 1 : Positive.** Because of that the emergency protection has been done and the damaged area will be filled up with a rehabilitation of drainage in near future, the countermeasure will be minimum except the rehabilitation of the drainage mains.

- **Plan 2 : Negative.** Due to the close location of the alignment to the damaged areas, huge amount of countermeasures for the damaged areas should be done by this project in order to protect the proposed road.

- **Plan 3 : Negative.** The same as Plan 2

- **Plan 4 : Positive.** It is not the direct countermeasure as the ravines will be filled with soil to the original ground level after removed the existing gabions.

- **Master Plan : Considerable.** The rehabilitation of the drainage main should be included in this project.

3) To secure the Right-of-way for Future Dual Carriageway

- **Plan 1 : Negative.** The existing Right-of-way is limited only for single carriageway and the function of the existing road is community road. Very huge numbers of resettlements will again be required.
-
- **Plan 2 : Considerable.** The areas are mainly shared by paddy fields and some local housing.

- **Plan 3 : Negative.** The route is passing through the residential areas with huge amounts of resettlement.

- **Plan 4 : Positive.** The existing Right-of-way width is secured for dual carriageway.

- **Master Plan : Considerable.** The areas are mainly shared by paddy fields and some local housing.

4) Selection of Alternative Routes

Based on the above mentioned evaluations, the Master Plan Route and the Plan 4 Route are selected as the alternative route for the further feasibility study as shown in Table 18.2.1.

Table 18.2.1 Alternative Route for Av. Julius Nyerere

Objectives	Master Plan	Plan 1	Plan 2	Plan 3	Plan 4
Trip length (km)	5.6	3.1	5.1	3.4	3.1
Impact to daily life (community cutting)	○ (350)	× (550)	○ (280)	× (650)	○ (210)
Countermeasure for damaged area	○	○	×	×	△
Right of way for 4 (resettlement houses)	△	×	△	×	○
Result	△	×	×	×	△

○: No problem △: Acceptable ×: Unacceptable

18.2.4 Longitudinal Alignment Plan

Based on the each route alignment, the longitudinal alignment should be considered to influence of the running safety of cars and the construction cost for the eroded part. But the eroded part of near the University of Eduardo Mondlane (Ravine 1) is going to be carried out the back filling by private company. Therefore this eroded part will be planned the box culvert the Study.

1) Master Plan Route

The longitudinal alignment of the Master Plan route should be basically connected to the elevation of the existing roads. The existing roads are relatively the flat longitudinal alignment except the beginning (Rua 1426) and the ending section (Rua 4685). Especially a part of Av. Para o Palmar (1426) is newly going to be reconstructed by private company. Therefore the vertical grade of the beginning and the ending section should be determined based on the total amount of cut and fill volume.

If a gentle grade of the beginning and the ending section will be constructed with high banking. It will cause costly and the negative influence for environment. Therefore the existing vertical grade is a suitable one of this plan. The beginning section will be desirable to be planed with approximately 2.5 % downhill grade and the ending section will be planed with approximately between 4 % and 1.5 % gradient. And the vertical grade of the section between Roundabout A and Priority Junction B will be planed with almost flat elevation.

The eroded part is nearly as following situation.

Place	Eroded length (m)	Eroded depth (m)
• Ravine 5: Front of Rua 4685	400.0	4.0

In case of the vertical plan, a volume of cutting and banking is as follows.

- cutting volume : 80,000 m^3
- banking volume: 82,000 m^3

2) Plan 4 Route

The longitudinal alignment plan of the Plan 4 will be the same alignment as original ground level. Because it is too difficult and uneconomical that the damaged slopes will be completely

protected against heavy rain such as February 2000. Therefore it is the best solution to fill with soil in the ravines. The eroded height is approximately 3 m depth to 10 m depth. The eroded parts are approximately as follows.

Place	Eroded length (m)	Eroded depth (m)
• Ravine4: Along Rua 3519	640.0	16.0
• Ravine 3: Along Rua 3519	220.0	14.0
• Ravine 2: Along Rus 3515	60.0	3.0

The total backfilling volume will be 320,000 cubic meters for every ravines and other eroded parts.

18.2.5 Cross Section Plan

1) Master Plan Route

The cross section of Master Plan Route should be planed and considered the topographic condition, geological condition, land use condition and so on for each section. The section of Porana Canico is running through each stream that is going down the streams from each ravine. And the end of steam is flowing to the north area. The right bank of existing stream is banked by the natural soil. The embanked height will be approximately 2 m. The Master Plan Route should use the existing banking for embankment section and consider the reduction of banking volume. Therefore the completed road should keep for the revetment of stream as shown in Figure 18.2.2.

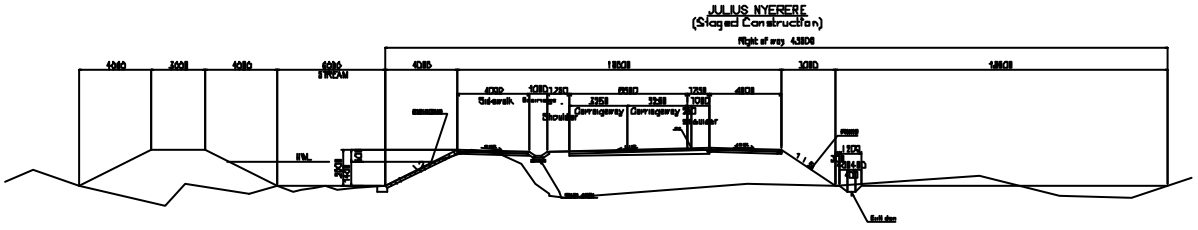


Figure 18.2. 2 Revetment of the Stream

The section of Ravine 5 will cut the existing slope and will construct the slope protection. Furthermore the canal and the space for utilities should be set on the slope shoulder of the cutting slope.

2) Plan 4 Route

The characteristic cross section is nothing.

18.2.6 Structures on the Road

Based on the above clauses, each route should be installed some structures for drainage at eroded parts.

1) Master Plan Route

The existing structure around Roundabout A is the box typed culvert, which size of inner section is 1.0 m width and 1.0 m height to one box. And there is a box typed culvert at entrance of the golf course, which size of inner section is 2.0 m width and 1.0 m height.

In order to drain from the eroded parts and circumference, the box typed culvert having appropriate sized for drainage should be installed around Roundabout A and Junction B for Master Plan Route. Two types of box culvert are determined in order to drain the each upstream discharge volume. The inner size of box culvert of Roundabout A and Junction B will be as follows.

- Roundabout A: 3.0 m width and 3.0 m height
  (Discharge : 17.7 cu. m/sec., Capacity : 18.2 cu. m/sec.)
- Junction B : 2 @ 3.5 m width and 2 m height
  (Discharge : 35.7cu.m/sec, Capacity : 41.9 cu.m/sec.)

In order to protect the road from stream flooding, the existing streams should be improved from the exit of Ravine 3 and 4 to the Junction B, which length will be approximately 1.7 km. The cross section of stream will be proposed as shown in Figure 18.2.3.

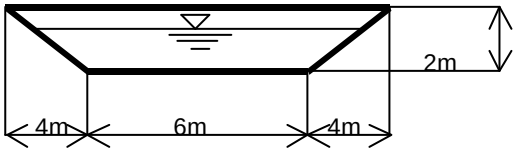


Figure 18.2.3 Cross Section

2) Plan 4 Route

(1) Ravine 4

There is no box culvert at Ravine 4. But there is canal made from mat gabions in the eroded ravine. This canal is used to drain for Rua do Costa do Sol (3704) and existing eroded road area.

Plan 4 Route is proposed to pass through in the Ravine 4. The drainage structures composed of two side ditches will be installed along the road after filling up completely to the proposed height in the Ravine 4. Therefore as the surface drainage of ground and road will be drained through the side ditch.

But in order to cross under the drainage of Rua do Costa do Sol (3704) at existing drain exit, box culvert should be installed at ravine 4. The inner size of box culvert will be 3.5 m width and height.

(2) Ravine 3

There are three eroded portions. Each eroded width will be 10 meter at Sta. 300, 30 meter at Sta. 360 and 30 meters at Sta. 400. Three pipe culverts, which size are diameter 0.6 meter all, are installed to lead the drain of Rua 3523 at near Sta. 400.

Ravine 3 was eroded at wide area including Rua 3523. In order to use this part more effectively, the eroded wide part should be planed to cut and fill up to the proposed road elevation. In order to cross the extended drainage of Rua 3523 under the planned route, it is possible to install either the box culvert or bridge at Sta. 400. Comparison of each structure is presented in the latter Clause 18.2.7.

(3) Ravine 2

The eroded part will be approximately 20 m length, 8 m width and 2 m depth partly. But fill up of eroded part is economically recommended with installation of the culvert clearly. Therefore two box culverts will be installed at Ravine 2. The inner size of box culveryt will be 2.5 m width and height and 3.0 m width and height respectively.

18.2.7 Comparison of Each Structure

1) Bridge Structure

Bridge structures are divided into three parts: superstructure, sub-structure and foundation. Each of these parts is described below.

(1) Superstructure

The superstructure is largely either concrete or steel. Concrete bridges are classified into RC and PC structures. For this Study, concrete bridge is selected for superstructure as following reasons:

<Easy maintenance>

- Steel bridges may suffer shortened service life due to corrosion.
- Painting of steel materials require periodical treatment, resulting in increased maintenance costs.
- Concrete bridges are free from surface corrosion and maintenance costs can be reduced.

<Low cost and superior economical feasibility>

- Generally, steel bridges tend to be higher in unit price than concrete bridges for short spans. Especially, in Mozambique, it is very difficult to construct a steel bridge and materials need to be imported from South Africa or other countries.

<Employing materials procurable in Mozambique>

- Principal materials (aggregates, cement and reinforcing bars) must be easily available.
- The use of domestically produced materials will reduce the standard costs.

(a) Applicable span for each type of bridge

The type of superstructure selected depends roughly on the span length of the bridge. Table 18.2.2 shows the standard applicable span for each type of superstructure in Japan. Span length of bridge is economically expected to be shorter than 30m. Generally, a concrete bridge is less expensive than a steel bridge for construction and maintenance. Concrete girder and slab are selected for this Study to take into consideration economy, construction, maintenance and domestic material availability.

(b) Recommended RC Slab

Most bridges in Maputo are concrete bridges except the pedestrian bridges on National Route (EN4). Reinforcements and concrete materials are arranged at site and cast-in-situ concrete is carried out to a bridge form.

On the understanding that performance is substantially improved and that future enhancement of technical conditions and maintenance work will be achieved, it is recommended that RC slab bridge will be less expensive than PC bridge.

Table 18.2.2 Standard Applicable Span

TYPE		SPAN (50m / 100m / 150m)	Girder Height/Span ratio
Steel bridge	Simple composite girder		1/18
	Simple girder		1/17
	Continuous girder		1/18
	Simple box girder		1/22
	Continuous box girder		1/23
	Simple truss		1/9
	Continuous truss		1/10
	Deck langer girder		1/6.5
	Deck lohse girder		1/6.5
	Arch		1/6.5
Concrete bridge	Pretensioning girder	(applicable span for RC bridge: less than 15m)	1/15
	Hollow slab		1/22
	Simple T girder		1/17.5
	Simple composite girder		1/15
	Connected continuous		71/15
	Continuous composite		1/16
	Simple box girder		1/20
	Continuous box girder		1/18
	Continuous box girder		1/18
	T type rigid frame		1/32
	Hollow slab		1/20
	Continuous spandrel - filled arch		1/2

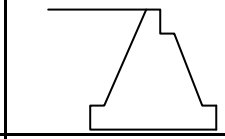
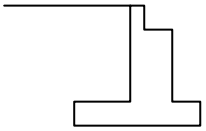
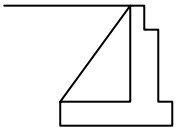
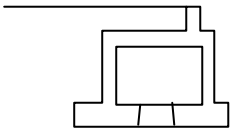
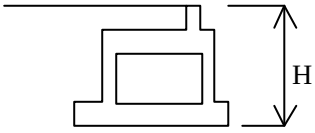
(2) Substructure

Abutments and piers shall be designed for bridge substructures. The types of abutments and piers are selected dependent on structural height, location (on land or in water), acting force (vertical and horizontal), and foundation type.

(a) Abutment

The types of abutments selected based on structural height are as shown Table 18.2.3.

Table 18.2.3 Abutment Types for the Height

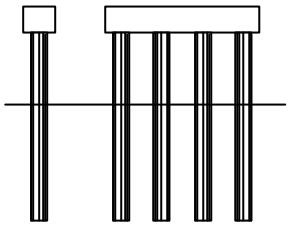
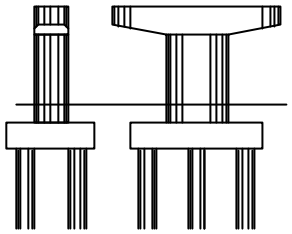
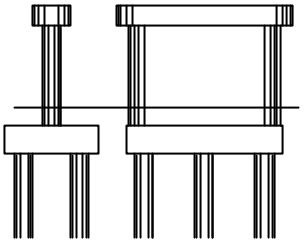
Tape and Shape		Applicable Height H (m)	Characteristic
Gravity-type		H <= 5	- Simple structure - Easy construction - Heavier weight
Reversed T Type		5 < H < 12	- Economic - Easy construction
Buttressed Type		12 <= H	- Economic - Intricate construction - Difficulty in buck filling
Rigid-framed Type		12 <= H <= 15	- Complicate structure - Expensive
Box Type		15 <= H	- Large scale structure - Complicate structure - Intricate construction - Expensive

The reversed T type is selected for economical reason, simple structure and easy construction.

(b) Pier and Foundation Type

According to explain the former section, as the bearing stratum is elevated deeply, the pile bent piers and pile foundation should be considered for the pier foundation at eroded part. On this study, the Study Team recommends the type of the substructure and foundation as shown in Table 18.2.4.

Table 18.2.4 Alternative table for Pier and Foundation

	Alternative 1 Pile bent type Pier	Alternative 2 Cylinder type Pier	Alternative 3 Wall type Pier
Shapes			
Structure Characteristics	• The structure is most simple. • The structure is suitable for deep bearing stratum. •	• The piles should support the footing, column and beam. • Total weight will be heavy.	• Same as Alternative 2
Construction Characteristics	• Piles are constructed by cast-in place concrete. • Construction work is easy. • Construction facilities are simple.	• Piles work will be the same as Alternative 1. • Substructure work shall be constructed by using sheet pile cofferdam.	• Same as Alternative 2
Economic	○	△	△
Total Evaluation	○	△	△

○: Suitable △: Unsuitable

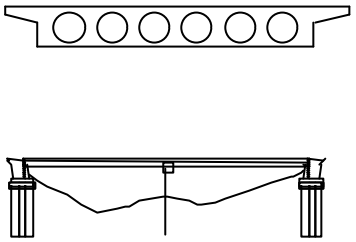
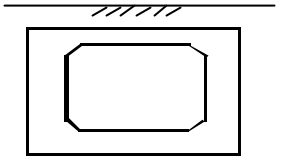
2) Box Culvert Structure

Each size of box culverts is presented the former Clause 18.2.6.

3) Comparison of Each Structure

Comparison of bridge and box culvert is shown in Table 18.2.5. Box culvert is selected at Ravine 3 in this Study as a result of the comparison.

Table 18.2.5 Comparison of Bridge and Box Culvert

	RC hollow slab bridge	RC box culvert
Side View		
Structural Characteristics	◆ The set elevation of both abutments is suitable under the eroded slope line due to the increase of the structure stability. ◆ The substructure foundation should be set the piles into the rock layer. ◆ Superstructure should be used the reinforced concrete type for economic. ◆ The structure scale will be larger than box culvert. △	◆ The set elevation is desirable to drain the drainage of the side ditch. ◆ The structure height will be 2.5 m height. ◆ No need piles for the structure stability. ◆ Banking height will be less than 7 m. ◆ The structure scale will be smaller than bridge. ○
Construction Characteristics	◆ The existing drainage will not be detoured because of the pile foundations. ◆ Foundation work is easy as using the pile type. ◆ Construction period will be longer than box culvert. △	◆ The existing drainage should be detoured the other direction while working. ◆ Concrete volume will be less than the bridge. ◆ Construction work is easy than bridge ◆ Construction period will be shorter than bridge. ○
Maintenance	It is easy because of concrete material	Same as Bridge
Economic	△	○
Total Evaluation	△	○

○: Suitable △: Unsuitable

18.2.9 Countermeasure for Cut Slope Protection

In order to stabilize permanently the cut slope of Plan 4 Route and a part of Master Plan Route, the countermeasure of the cut slope protection will be effective to construct the concrete wall on the slope surface. Because other countermeasures, vegetation work will be ineffective and barren due to the fine-grained sand, gabion work will be uneconomical due to the expensive method and wide area, respectively.

Therefore concrete wall will be economical and effective.

18.2.10 Road Construction Work Items to be Needed

Road construction work items are shown in Table 18.2.6. Master Plan Route is needed more items for construction work than Plan 4 Route.

Table 18.2.6 Road Construction Work Items

Item	Master Plan Route	Plan 4 Route
Road length	5.6 km	3.1km
Public facilities relocation • Telephone line • Electric power line • Water supply pipe	 Need to relocate partly Need to relocate widely Need to relocate partly	 Need to relocate partly Need to relocate partly No need
House relocation	Need to relocate (Number of houses: 350)	Need to relocate slightly (Number of houses: 210)
Removal of the installed gabions	No need	Need to remove (1,300m^3)
Earth work • Cutting volume • Banking volume	 80,000 m^3 82,000 m^3	 Nothing 320,000 m^3
Pavement Work	87,500 m^2	58,000 m^2
Structure work • Box culvert • Countermeasures of cut slope	 Roundabout A: 3.0m×3.0m Junction B:2@3.5m×2.0m Ravine 1: 5.0m×5.0m Concrete wall: partly (1,820m^2)	 Ravine 4: 3.5m×3.5m Ravine 3: 4.0m×4.0m Ravine 2: 3.0m×3.0m Ravine 1: 5.0m×5.0m Concrete wall: Nothig
Stream improvement	Need to improve: 1.7km	No need

18.3 TRAFFIC FORECASTS

18.3.1 Test Programme

Traffic forecasting for the Feasibility Study involved a number of tests to consider the relative performance of the constituent packages. The 12 packages that constitute the feasibility study road programme are summarized in Table 18.3.1.

Table 18.3.1 Feasibility Study Road Programme

Package	Components
1	Re-construction of Av Julius Nyerere
2	Junction improvements and installation of bus bays on Av Vladimir Lenine
3	Widening and junction improvements on Av Accordos de Lusaka
4	Widening of Av. de Angola
5	Re-habilitation of, and junction improvements on Av Marien Ngouabi
6	Rehabilitation of roads in the industrial/commercial area
7	Rehabilitation of roads in the port area
8	Rehabilitation of other roads in District 1
9	Rehabilitation of roads in District 2
10	Rehabilitation of roads in District 3
11	Central area traffic management
12	New bus terminals

The Feasibility Study package was tested in its entirety for the years 2005 and 2010, according to the test programme set out in Table 18.3.2

Table 18.3.2 Feasibility Study Test Programme

	2005	2010
Do-Minimum	05Dmin	01Dmin
Feasibility Study	2005FS	2005FS

For Package 1 two options were tested :

- The re-construction of Av Julius Nyerere on-line
- The construction of an off-line eastern alternative route

The Feasibility Study tests referred to in Table 18.3.1 were carried out the second variant above.

Packages 2 to 10 were tested using the model developed for the Master Plan. Each package was excluded in turn form the Feasibility Study programme in order to assess individual benefits.

18.3.2 Overall Feasibility Study Programme Results

Figure 18.3.1 shows the forecast traffic volumes on the network in 2005 for the Do-minimum and Feasibility Study cases. By 2005, in the Do-minimum case traffic congestion is forecast on Av de Moçambique and Av Julius Nyerere following the growth in development in the north of the city. Av Vladimir Lenine will become more congested leading to the use of AV FPLM as a main north-south artery. This, in turn, will place pressure on Av Acordos de Lusaka which will become congested, particularly on the section north of Rua da Machava. In the city centre severe congestion is expected on the main north-south roads of Av Guerra Populare, Av Karl Marx and Av Vladimir Lenine, as well east-west on Av 25 de Setembro.

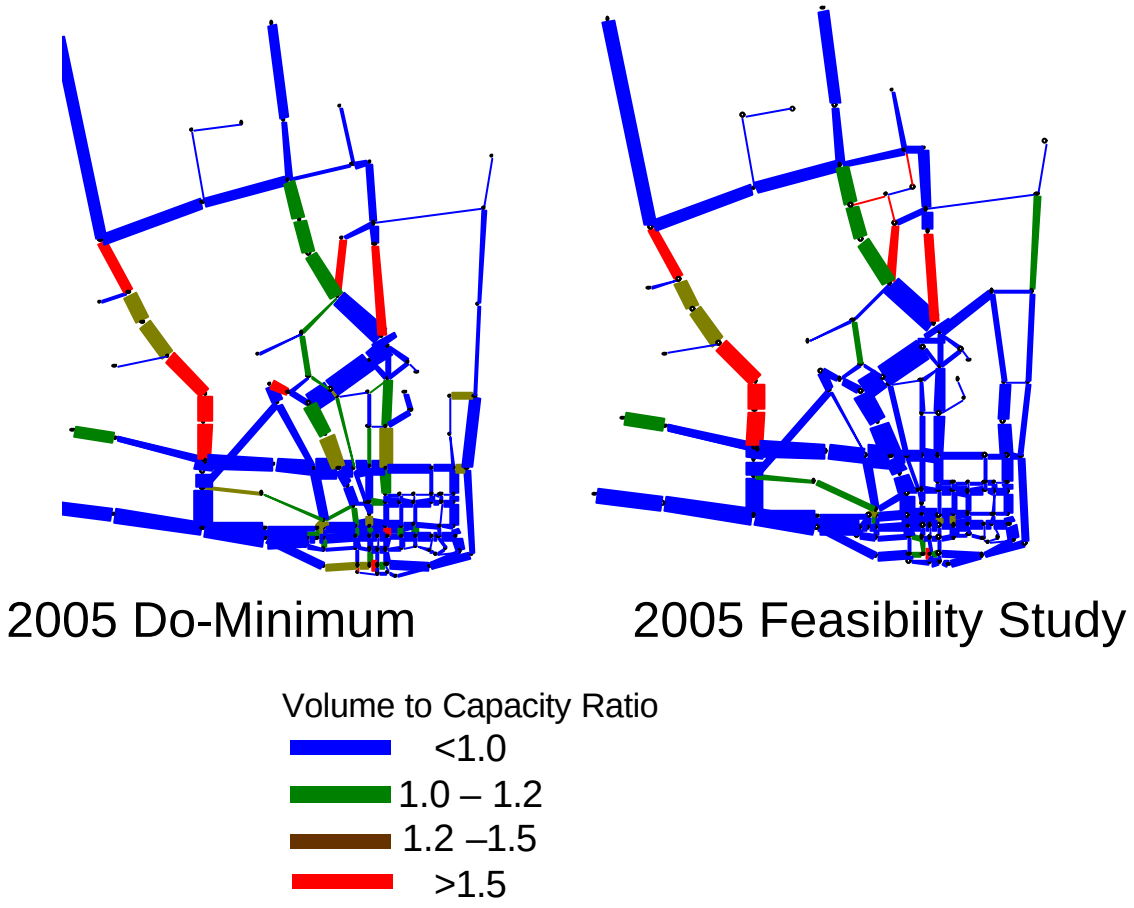


Figure 18.3.1 2005 Traffic Forecasts

Figure 18.3.2 shows traffic forecasts for the year 2010.

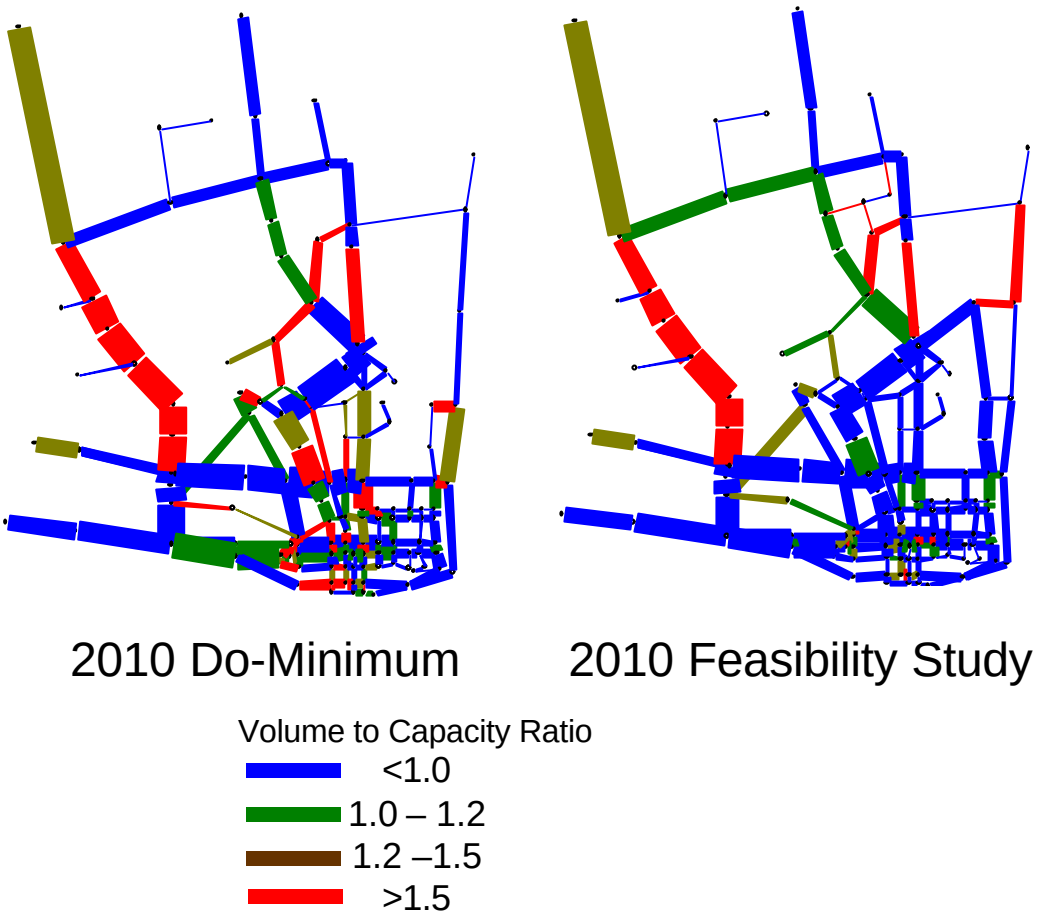


Figure 18.3.2 2010 Traffic Forecasts

By 2010 the forecast is that congestion will be even more severe. This is particularly true on Av de Mozambique, Av Acordos de Lusaka and Av Vladimir Lenine. In the city center it is extremely likely that all the major north south arteries will be congested over most of the day, and congestion on the east-west links will spread to Av 24 de Julho. The area around Alto Maé will become especially congested

The proposals contained in the feasibility Study programmes will address most of these problems in the year 2005, and also provide considerable relief by 2010. In both 2005 and 2010 congestion on Av de Mozambique and on Julius Nyerere, north of Praça Dos Combatentes is not addressed by these plans and congestion on these roads will persist. If growth in the north of the city occurs as expected then there will be a strong case for augmenting the road programme in the Feasibility Study to cope with the increased traffic. Should the Feasibility Study schemes be in place, then congestion in the south of the city ought to fairly limited. Even by 2010, congestion in the city will be limited to the Alto Mae area, and some of the junctions on Av 24 de Julho. However, it is anticipated that congestion will re-occur on Av Acordos de

Lusaka, especially at the junction with Rua da Machava. The forecasts also suggest that there might be congestion on Av Julius Nyerere on the section north of Av Mao Tsé Tung, unless improvements are made that junction.

Table 18.3.3 shows summary network statistics for the Feasibility Study tests

Table 18.3.3 Forecast Network Statistics, 2005 and 2010, 16 Hour Traffic Demand

	2005		2010	
	Do Minimum	Feasibility Study	Do-minimum	Feasibility Study
PCU Hours	74,537	66,621	134,393	118,496
Average Speed	30.3	34.0	23.3	26.9

The Do-Minimum networks for 2005 and 2010 are the same comprising the present day network plus

- Improvement of Rua da Machava to Dual-2 lane standard between Av Vladimir Lenine and the City boundary at Machava, with high capacity at grade junctions at Av de Angola and Av Acordos de Lusaka, and an all movement junction at Av de Mozambique, with grade separation maintained.

- The completion of the improvement to EN4 from the city boundary to Av de Trabalho (in the base year network the capacity of these links was reduced to reflect the fact that traffic was surveyed during the construction period)

- The full rehabilitation to Dual-2 standard of Av Organazação dos Nações Unidas, which was flood damaged in February 2000.

By the 2005 the average network will have fallen from 31.3 km per hour to 30.3 km per hour under Do-Minimum conditions. In the next five years there would be a rapid determination in average speed to 23.3 km per hour. The implementation of the Feasibility Study works would result in an average speed of 34.0 km per hour in 2005, higher than present, but by 2010 this would have deteriorated to 26.9 km per hour.

18.3.3 Alternative Alignments for the Re-instatement of Av. Julius Nyerere

As noted above, the alignments were tested for the re-instatement of Av Julius Nyerere, one off-line, included in the Feasibility Study package, and an on-line variant. The importance of this trunk road means that there are significant difference between the performance of the network under each option. Table 18.3.4 lists network statistics for these tests.

Table 18.3.4 Network Statistics for Av Julius Nyerere Link, 16 Hour Demand

		2005	2010
PCU Hours	No Missing Link	68,575	122,417
	Off-line	66,621	118,496
	On-Line	66,821	117,121
Average Speed (km per hour)	No Missing Link	32.7	25.4
	Off-line	34.0	26.9
	On-Line	33.5	26.6
Network Time Savings (PCU Hours)	Off-line	1954	3921
	On-Line	1754	5296
% of Feasibility Study Time Savings	Off-line	24.7	24.7
	On-Line	22.7	30.7

Table 18.3.4 reveals the importance of the missing Av Julius Nyerere link in the Feasibility Study Packages. In 2005 it is forecast to contribute almost one-quarter of the total time savings of the investment package, and this would rise to over 30% with the on-line option. In the early years it appears that the off-line option will produce marginally higher time savings. In the longer term, however, the on-line variant will produce much higher time savings than the off-line option. By 2010 network time savings from the on-line option are forecast to be 35% higher than for the off-line option.

Figure 18.3.3 shows forecast traffic volumes on the four north south roads in the vicinity of Av Julius Nyerere.

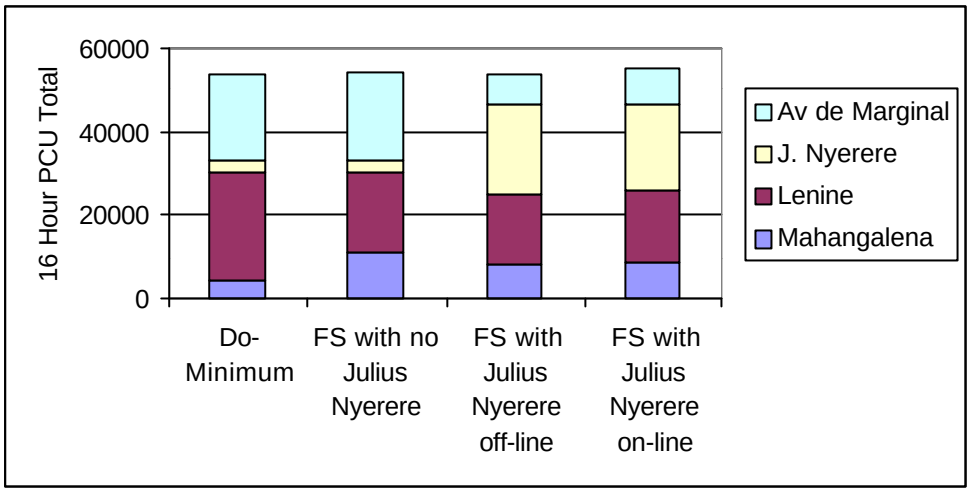


Figure 18.3.3 Forecast Traffic Volumes north of Av Kenneth Kaunda, 2005

Figure 18.3.3 reveals the potential effect of the re-instatement of the missing link. By 2005 the bulk (86%) of north-south traffic on these four roads will be borne by Av Vladimir Lenine and Av Marginal, leading severe congestion on the former. The Feasibility Study package, without re-instatement of the missing link, will offer relief to Av Vladimir Lenine through the improvement of capacity and speed on the parallel Av Malhangalena. However, the re-instatement of the missing link will not only relieve Av Vladimir Lenine further; it will offer significant congestion relief to Av Marginal, and a reduction in traffic on Av Malhangalena.

18.3.4 Consideration of Other Packages in the Feasibility Study

Improvement of Av Vladimir Lenine (Package 2)

Congestion on Av. Vladimir Lenine is to rise to serious levels under the Do-minimum forecasts. There are severe constraints to any major widening of this road, and the Feasibility Study package proposes only limited junction improvements at :

- Av. Mao Tsé Tung
- Rua da Soveste
- Av Julius Nyerere

In addition, measures for dealing with delay caused by buses are proposed. The current problem stems form the fact Av Vladimir Lenine is a single carriageway and heavily used by buses, which stop frequently in the carriageway, slowing down general traffic flow. The proposal is to introduce bus lay-bys, where possible, so that stopping buses do not interrupt general traffic flows. The junction improvements are synthesized in the model through capacity increases on the highway. It is more difficult to synthesise in the model the

implementation of bus bays and hence any benefits have been calculated exogenously, and are set out in the Appendix. Vehicle hour savings due the improvements in Package 2 are set out in Table 18.3.5

Table 18.3.5 Estimated Time Savings (pcu hours per 16 hour day) in 2005 due to Package 2

	Car	Truck	Buses	Total
Junction Improvements	170	57	68	295
Bus Bays	288	133	-142	279
Total	458	190	-74	574

Whilst there are potential disbenefits to buses, these are outweighed by time savings to cars and trucks.

The overall network effects of Package 2 are very limited. However, this package is only effective in absolute terms if implemented in conjunction with Package 1 (re-instatement of missing Av Julius Nyerere link), as shown in Figures 18.3.1 to 18.3.3.

The junction of Av Vladimir Lenine and Av Kenneth Kaunda is also constrained by adjacent development. The efficient operation of this junction in the longer term is very dependant on the design for the widening of Av Kenneth Kaunda at this point, which are currently unknown If the dualling of Av Kenneth Kaunda (on the north side) is able to taken as far as the junction it will probably require the partial acquisition of the Shell filling station. If this is possible, then the current roundabout configuration will not be appropriate and the introduction of high capacity signals will provide sufficient capacity. The signals should include right turning lanes on Av Kenneth Kaunda.

Improvement of Av Acordos de Lusaka (Package 3)

The need for the improvement of Av Acordos de Lusaka is highlighted in Figures 18.3.1 and 18.3.2, because of serious congestion in 2005 and acute congestion by 2010. The proposed widening has been incorporated in the Feasibility Study tests as increases in capacity on the road between Largo de Deta and Av Marien Ngouabi. It is assumed that the junction with Rua da Machava will be improved as part of the dualling of that road, and any further junction improvements will be compatible with that design.

The impact of removing the Av Acordos de Lusaka improvements form the Feasibility Study

programme is shown in Figure 18.3.2. The section between Rua da Machava and the Shoprite access road will become congested by 2005, and such congestion will grow in the following years. Figure 18.3.2 also reveals that the problem will occur again by 2010, even with improvements, and some form of grade-separation at Rua da Machava as proposed in the Masterplan, will be necessary.

Figure 18.3.5 shows the forecast traffic volumes on Av de Angola, Av Acordos de Lusaka, and Av Milagre Mabote, with and without the proposed improvements on Av Acordos de Lusaka, with all other Feasibility Study programmes in place. The impact of the improvements is a 36% increase in volume on Av Acordos de Lusaka, and relief on Av de Angola and Av Milagre Mabote. The total network time savings in 2005 are forecast to be 767 pcu–hours over the 16-hour day.

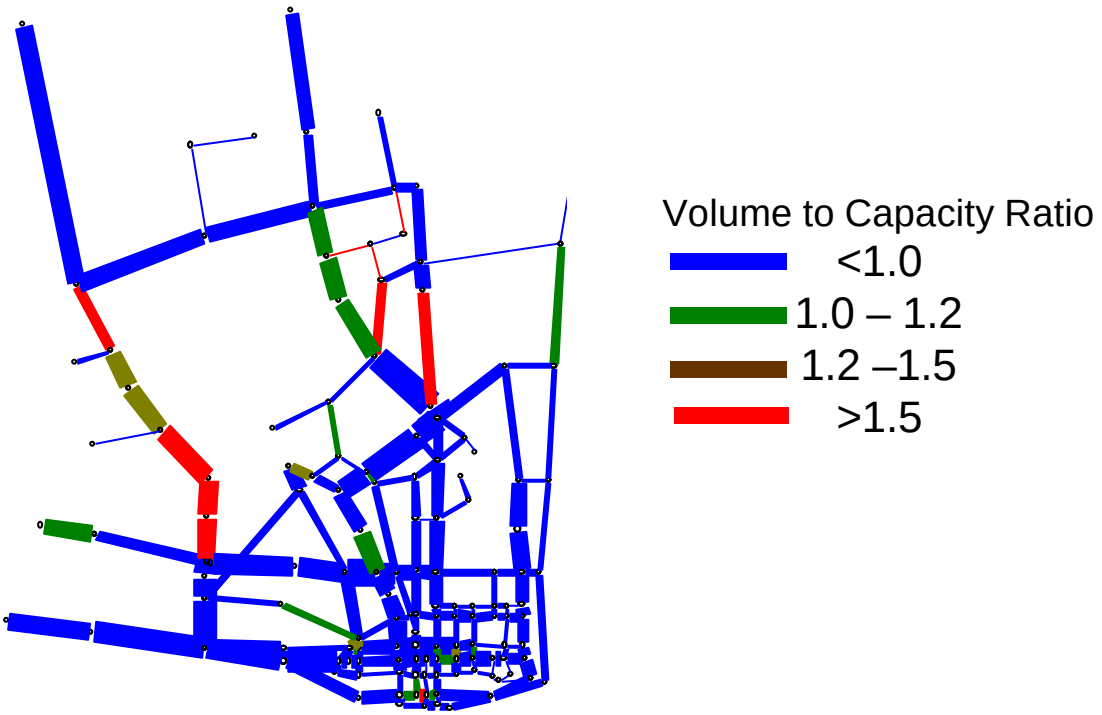


Figure 18.3.4 16 Hour Traffic Volumes with improvements to Av Accordos de Lusaka

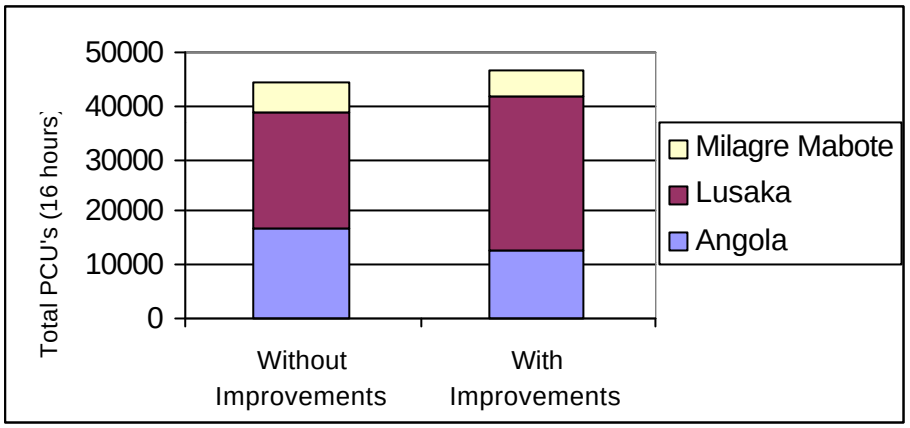


Figure 18.3.5 Traffic Volumes Variation with Av Accordos de Lusaka improvements, 2005

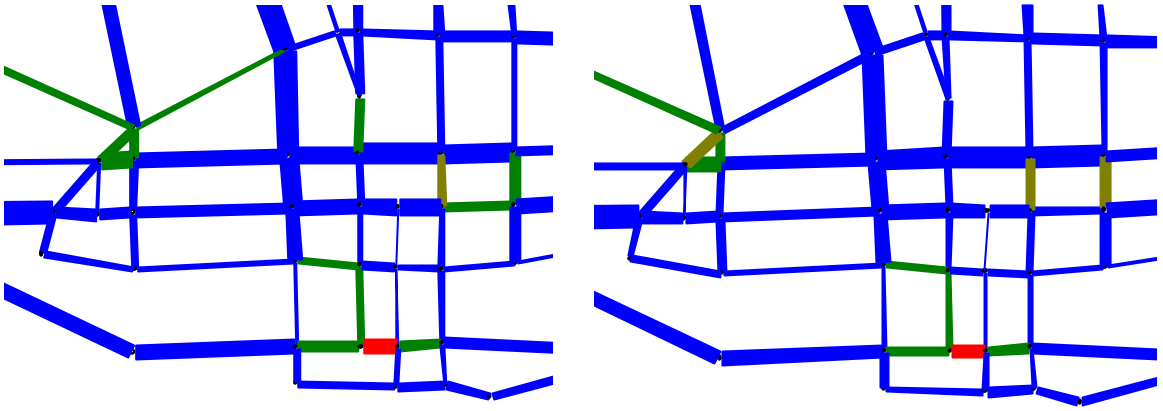
Improvement of Av de Angola (Package 4)

The overall effect on the network of this package is relatively small. If the scheme were removed forecast traffic volumes plotted would look exactly the same as those for the Feasibility Study in 2005, as shown in Figure 18.3.1. Time savings due to the improvements are forecast to be 109 pcu-hours in 2005.

Improvements to Av Marien Ngouabi (Package 5)

The section of Av Marien Ngouabi between Av de Tanzania and Av Mao Tsé Tung is extremely poor repair, which limits capacity and speed. Rehabilitation of this road and complementary junction improvements will add to east-west capacity and speed. Figure 18.3.2 shows that with the Do-minimum case this section of highway would be become extremely congested, even under low flows because of the poor condition of the road.

Figure 18.3.6 shows traffic volumes in the central area with and without the Marien Ngouabi improvements. Without the proposed improvements there would be significant congestion on Av Marien Ngouabi itself, as well as on Av Karl Marx and part of Av 24 de Julho. Time savings are forecast to be 277 pcu-hours per 16-hour day as a result of the improvements.



2005 without improvement of Marien Ngouabi 2005 with improvement of Marien Ngouabi

Figure 18.3.6 2005 Traffic Volumes (16 hour) with Feasibility Study Packages, central Maputo

Area Based Packages (6 to 10)

Packages 6 to 10 are road re-habilitation programmes for 5 areas of the city:

- Industrial and commercial area
- Port area
- Remainder of District 1
- District 2
- District 3

These programmes allow for the creation of new secondary and collector roads where there is currently effectively little passage. These lead to time savings for existing road users and those who divert to take advantage of the better quality surfaces. In the traffic model these roads are synthesised without restrictions, but in reality they may be built with limits, e.g. speeds humps, to protect residential amenity. It is possible that some of the benefits of these programmes are slightly over-estimated, but this cannot be proved until detailed design. Table 18.3.6 shows the time savings resulting from these programmes.

Table 18.3.6 Pcu-hours saved by road r-habilitation programmes, 16 hours, 2005

Package No.	Area to be re-habilitated	Pcu-hours saving
6	Industrial and Commercial Area	328
7	Port Area	365
8	District 1	453
9	District 2	284
10	District 3	1043

18.3.5 Benefits of the Feasibility Study Packages

Figure 18.3.7 shows the relative time savings afforded by the ten packages contained in the Feasibility Study programme. The contribution of the re-instatement of Av Julius Nyerere to overall benefits is very significant, although the are other benefits from the rehabilitation of the local roads not included in the figure.

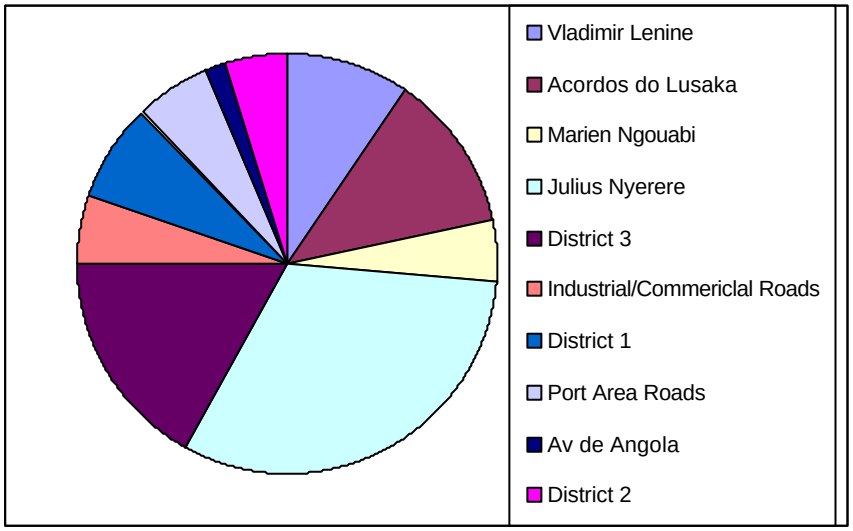


Figure 18.3.7 Distribution of Time Saving Benefits of Packages in the Feasibility Study Programme

18.3.6 Growth 2010 to 2020

Total traffic is forecast to grow by 58% in the period 2010 to 2020, under the medium growth scenario. The would give an annual growth rate of around 4.6%.

The 2020 assignments revealed pcu-hour savings of 21,372 (per 16 hours) for the Feasibility Study, compared to 15,897 pcu-hours in 2010. The increase in benefits, at 34% for the ten years, is less than traffic growth. This is because by 2020 the network will be very congested in

certain areas, even under the Feasibility Study plan. This is due the high population growth forecast for the north of the city, and the fact no capacity increases in the two major north-south arteries are included in the Feasibility Study.

When the network becomes very congested, the flat section A of the QV curve (Figure 18.3.8) is reached. Capacity increases will move the point on the curve to the left, but so long as it remains in section A there is no consequent increase in speed. Only when section B is reached will there be an increase in speed, corresponding to a reduction in flow to capacity,

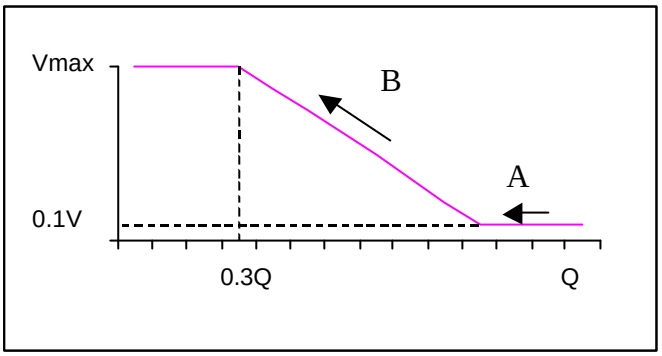


Figure 18.3.8 Speed-Flow Curve

Thus benefits tend to be lower in extremely congested networks. Although modelling is less reliable it seems reasonable to accept network forecasts as being potentially pessimistic.

18.4 HIGHWAY DESIGN

18.4.1 Design Speed

The design speed of each project road has already been determined in Chapter 17. Application of each design speed on each section of road should be done based on the condition of existing alignment and availability of land for typical cross-sections by each road function. The detailed design speed of each project road is shown in **Table 18.4.1**.

18.4.2 Proposed Alignment

The proposed alignment of each project road should be determined by considering the appropriate vertical alignment for drainage and easy access to housing. Except for Av. J. Nyerere that is already discussed, the other road development projects are basically the rehabilitation of existing roads. Therefore the horizontal and vertical alignments of each road will be almost same as the existing, except some sections where there is a drainage difficulty or steep alignment compared to the required road function. The alignment of each project road is shown in the Drawings.

18.4.3 Proposed Cross-section and Right-of-way

Typical cross-sections of each project road have been determined in Chapter 17 considering the required function and design speed. Although the typical cross-section is recommended, application of the typical cross-section and determination of actual cross-section should be carefully analyzed especially in case of the rehabilitation of collector roads in District 2 and 3.
Table 18.4.2 shows where typical cross-sections and alternative modifications have been examined. There is a clear relation between the number of resettlements and cases of proposed for modification. Although this is a social and political issue, the study team recommends the modification cases for the proposed cross-sections and Right-of-way because of the difficulty of entire land acquisition, as opposed to a modest reduction in the required function.

Table 18.4.1 Highway Design

Project Road			Traffic Voliume (vehicle/day)		Road Length (m)	Existing Nos. of Lane	Poposed Nos. of Lane	Existing						Poposed							Landaquisition	Design Speed (km?h)
			Existing	2010				Carriageway Width	Shoulder/ Parking Lane Width	Drainage Type	Sidewalk Width	Median Strip	Total Width	Carriageway Width	Shoulder/ Parking Lane Width	Drainage Type	Sidewalk Width	Utility Space	Median Strip	Total Width		
1	1	Av. J. Nyerere	-	16,944	4.80	-	2	-	-	-	-	-	-	3.25	1.25	OD	4.00	2.00	-	22(40)	required	60
2	2	Av. V. Lenine	20,213	19,189	0.00	2	2	3.50	0.50	L	2.00	-	23	3.50	0.50	L	2.00	2.00	-	16	required	50
3	3-1	Av. A. Lusaka	29,318	30,489	2.80	4	4	3.00	2.00	L/OD	4.00	2.00	28	3.00	2.00	L/OD	4.00	1.00	2.00	28	None	60
4	3-2	Av. G. Popular	11,965	36,012	0.70	2	4	3.50	2.50	L	4.00	-	20	3.00	0.50	L	3.50	-	-	20	required	50
5	4-1	Av. Angola			3.10	2	2	3.00	2.50	L	4.00	-	20	3.50	2.50	L	4.00	-	-	20	None	50
6	4-2	Rua S. Cabral/Largo de Deta	13,448	23,799	0.60	2	2	3.00	2.50	L	4.00	-	20	3.50	2.50	L	4.00	-	-	20	None	50
7	5	Av. Marien Ngouabi(4 lane)	4,478	11,988	1.90	2	4	3.50	2.50	L	4.00	-	20	3.00	0.50	L	3.50	-	-	20	required	50
						2	2	3.50	2.50	L	4.00	-	20	3.50	2.50	L	4.00	-	-	20	None	50
8	6-1	Av. J. Michel	8,459	10,884	0.90	2	2	3.00	1.00	L	4.00	-	16	3.00	1.00	L	4.00	-	-	16	None	40
9	6-2	Av. F. de Magalhaes	8,413	10,884	1.30	2	2	3.00	3.00	L	4.00	-	20	3.00	3.00	L	4.00	-	-	20	None	40
10	6-3	Av. Z. Magalhaela	10,712	12,439	1.30	2	2	3.00	3.00	L	4.00	-	20	3.00	3.00	L	4.00	-	-	20	None	40
11	6-4	Av. M. Siad Barre	17,975	23,128	0.85	2	2	3.00	2.00	L	3.00	-	16	3.00	2.00	L	3.00	-	-	16	None	40
12	6-5	Av. Romao Fernandes	5,287	6,802	0.85	2	2	3.00	1.00	L	4.00	-	16	3.00	1.00	L	4.00	-	-	16	None	40
13	6-6	Rue 1229			0.25	2	2	3.00	3.00	L	3.00	-	16	3.00	3.00	L	3.00	-	-	16	None	40
14	6-7	Av. As Estancias			0.58	2	2	3.00	1.00	L	3.00	-	12	3.00	1.00	L	3.00	-	-	12	None	40
15	7-1	Rue Consigglieri Pedroso			0.00	2	2	3.00	1.00	L	2.50	-	13	3.00	1.00	L	2.50	-	-	13	None	30
16	7-2	Rue Joaquim Lapa			0.24	2	2	3.00	1.00	L	3.00	-	14	3.00	1.00	L	3.00	-	-	14	None	30
17	7-3	Rue do Bagamayo			0.44	2	2	3.00	0.00	L	3.00	-	12	3.00	0.00	L	3.00	-	-	12	None	30
18	7-4	Rue de Timor Leste			0.23	2	2	3.00	1.50	L	2.00	-	13	3.00	1.50	L	2.00	-	-	13	None	30
19	7-5	Av. Martires de Inhaminga	5,174	11,748	0.80	2	2	3.00	4.00	L	2.50	-	19	3.00	4.00	L	2.50	-	-	19	None	30
20	7-6	Other 6 roads			1.50	2	2	3.00	0.00	L	2.00	-	10	3.00	0.00	L	2.00	-	-	10	None	30
21	8-1	Av. Milargre Mabote	6,011	10,668	1.00	2	2	3.00	1.50	L	3.50	-	9	3.00	1.50	L	3.50	-	-	16	None	40
22	8-2	Av. da Malhangalene	3,307	10,776	0.94	2	2	3.00	1.00	L	2.00	-	12	3.00	1.00	L	2.00	-	-	12	None	40
23	8-3	Av. Para O Parmar			1.40	2	2	3.00	1.00	L	2.00	-	12	3.00	1.00	L	2.00	-	-	12	None	40
24	8-4	Av. Kaweme Nkrumah	2,691	6,747	1.61	2	2	3.00	1.00	L	2.00	-	12	3.00	1.00	L	2.00	-	-	12	None	40
25	8-5	Av. Paulo Samuei Kankhomba			0.55	2	2	3.00	1.00	L	6.00	-	20	3.00	1.00	L	6.00	-	-	20	None	40
26	8-6	Av. Emilia Dausse			0.85	2	2	3.00	1.00	L	6.00	-	20	3.00	1.00	L	6.00	-	-	20	None	40
27	8-7	Av. de Maguiguana			0.75	2	2	3.00	1.00	L	6.00	-	20	3.00	1.00	L	6.00	-	-	20	None	40
28	8-8	Av. Filipe Samuel Magaia			0.40	2	2	3.00	3.00	L	4.00	-	20	3.00	3.00	L	4.00	-	-	20	None	40
29	8-9	Av. Friendrich Engels			1.20	2	2	3.00	1.00	L	2.00	-	12	3.00	1.00	L	2.00	-	-	12	None	40
30	9-1	Rua 2282/2265			2.36	2	2	-	-	-	-	-	5	3.0(5.0)	-	LU/OD/U	2.00	0.5～1.0	-	8～14	required	40
31	9-2	Rua 2275			2.00	2	2	-	-	-	-	-	5	3.00	-	OD/U	2.00	1.00	-	14	required	40
32	9-3	Rua de Xipamanine	6,184	10,768	1.13	2	2	-	-	-	-	-	6	3.00	-	LU/OD/U	1.50	0.5～1.0	-	10～14	required	40
33	9-4	Rua dos Imaos Roby			1.30	2	2	3.00	1.50	-	1.50	-	12	3.00	1.50	OD/U	1.50		-	12	required	40
34	9-5	Rua 2315/2313			0.70	2	2	-	-	-	-	-	6	3.00	-	LU/OD/U	1.5～2.0	0.5～1.0	-	10～14	required	40
35	9-6	Rua 2309/2324			1.00	2	2	-	-	-	-	-	5	3.00	-	OD/U	2.00	1.00	-	14	required	40
37	9-7	Av. das Estancias			0.49	2	2	3.00	1.00	-	2.00	-	12	3.00	-	OD/U	1.50	0.50	-	12	required	40
38	10-1	Rua da Goa			0.80	2	2	-	-	-	-	-	6	3.00	-	LU	1.50	0.50	-	10	required	40
39	10-2	Rua da Lixera			0.79	2	2	-	-	-	-	-	7	3.00	-	LU	1.50	0.50	-	10	required	40
40	10-3	Av. Milagre Mbote	6,011	10,668	1.98	2	2	-	-	-	-	-	7	3.0(5.0)	-	LU	1.50	0.50	-	8～10	required	40
41	10-4	Av. da Malhangalene	3,307	10,776	1.83	2	2	-	-	-	-	-	6	3.0(5.0)	-	LU/OD/U	1.50	0.50	-	8～12	required	40
42	10-5	Rua 1 de Maio			1.49	2	2	-	-	-	-	-	6	3.00	-	OD/U	2.00	1.00	-	14	required	40
43	10-6	Rua 3306			0.49	2	2	-	-	-	-	-	14	3.00	-	OD/U	2.00	1.00	-	14	required	40
44	10-7	Rua 3523			1.00	2	2	-	-	-	-	-	14	3.00	-	OD/U	2.00	1.00	-	14	required	40
45	10-8	Rua 3576			1.10	2	2	-	-	-	-	-	14	3.00	-	OD/U	2.00	1.00	-	14	required	40

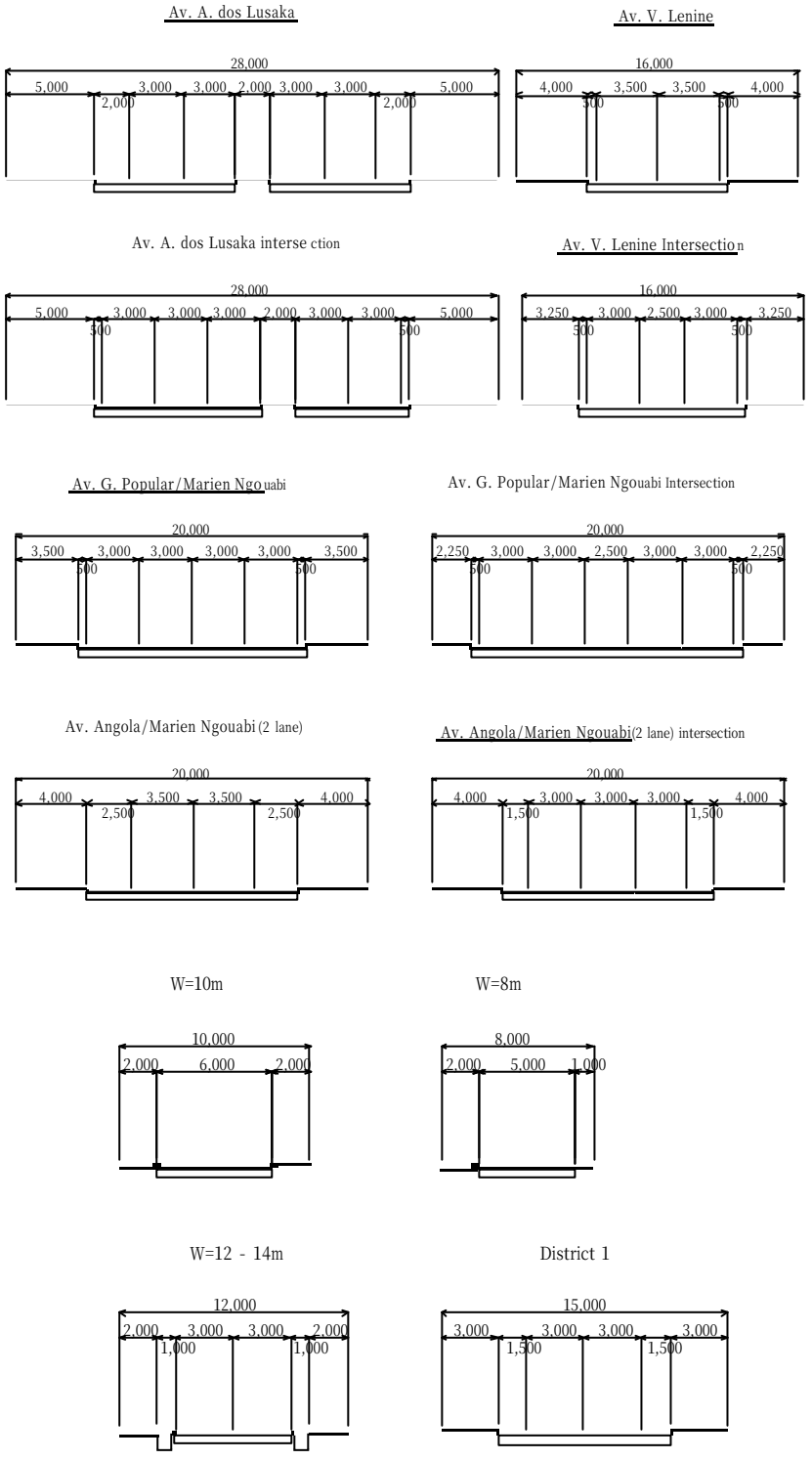


Figure 18.4.1 Typical Cross Section

Table 18.4.2 Comparison of Application of Typical Cross Section and Proposed Modifications

Group No	Existing minimum road width (m)	Proposed road width (m)	nos. of resettlement: Desirable Road Width=14m	nos. of resettlement: Proposed Minimum Road Width	Unit Price (USD/no)	House compensation cost(USD): W=14m	House compensation cost(USD): House Compensation Cost(USD)
9. Rehabilitation of District 2 Area Roads			216	53		**324,000**	**79,500**
9.1 Rua 2282/2265	6	8,10,14	98	17	1,500	147,000	25,500
9.2 Rua 2275	6	8,10,12,14	82	23	1,500	123,000	34,500
9.3 Rua de Xipamanine(2291)	6	10,12	16	2	1,500	24,000	3,000
9.4 Rua dos Imaos Roby(2289)	12m (street type)	12m (street type)	0	0	1,500	0	0
9.5 Rua 2315/2313	6	10,14	12	5	1,500	18,000	7,500
9.6 Rua 2309/2324	6	14	8	6	1,500	12,000	9,000
9.7 Av. das Estancias(2000)	12m (street type)	12m (street type)	0	0	1,500	0	0
10. Rehabilitation of District 3 Area Roads			188	34		**319,600**	**57,800**
10.1 Rua da Goa(3027)	5	10	8	1	1,700	13,600	1,700
10.2 Rua da Lixera(3030)	7	10	23	0	1,700	39,100	0
10.3 Av. Milagre Mbote(3001)	8	8,10	63	3	1,700	107,100	5,100
10.4 Av. da Malhangalene(3259)	6	8,10,12	70	13	1,700	119,000	22,100
10.5 Rua 1 de Maio(3374)	6	8	24	17	1,700	40,800	28,900
10.6 Rua 3306	14	14	0	0	1,700	0	0
10.7 Rua 3523	14	14	0	0	1,700	0	0
10.8 Rua 3576	14	14	0	0	1,700	0	0
Construction of Missing Link on Av. Julius Nyerere(On Line)				251	2,000		**502,000**
Construction of Missing Link on Av. Julius Nyerere(Off Line)				352	1,500		**528,000**
Construction of Bus Terminal(Combatentes)				92	1,500		**138,000**

18.5 INTERSECTION DESIGN

Most intersections in Maputo city do not have dedicated turning lanes. In order to secure the traffic capacity against the future traffic demand, turning lane should be established, and traffic management methods should be adequately planned.
Furthermore, intersections are danger spots, especially to pedestrians and traffic safety facilities should also be established.

The following are the plans for design and facilities for the intersections in Maputo city.

18.5.1 Location of Intersections to be Improved

Figure 18.5.1 shows the intersections to be improved. 9 intersections will be improved by the road development project, and 14 intersections will be improved by the traffic management project.

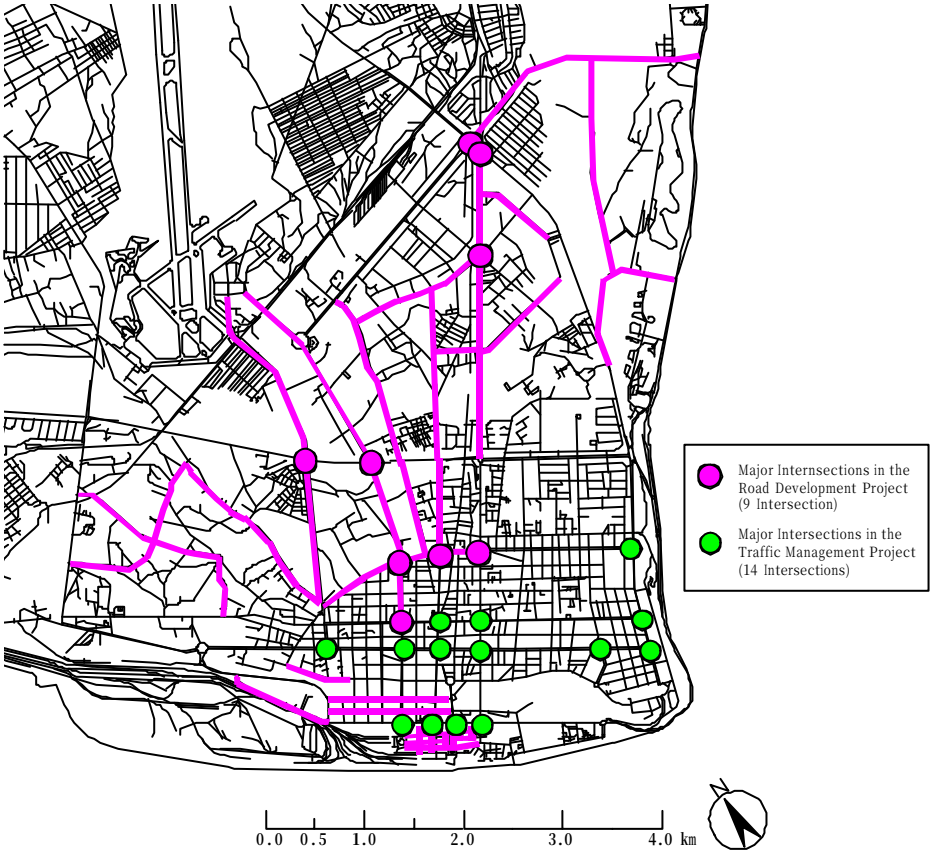


Figure 18.5.1 Location of Intersections to be Improved

18.5.2 Design Policy

All geometric design of highways and intersections will be established according to the SATCC standard in the feasibility study. However there are no standards stipulating road design in urban areas, therefore necessary items missing from the above standard should be applied based on the relevant standards such as Japanese Road Structural Ordinance, etc.

The design criteria are as follows.

1) Geometric Design Criteria

Design speed

According to the design policy shown in the chapter 17.2.3, design speed in urbanized area should be 50 km/h. However in high-urbanized area, it should be considered to reduce design speed to 30-40 km/h at locations with the following conditions.

- Narrow ROW
- Insufficient sight distance
- High level of pedestrian activity
- Environmentally sensitive areas

Lane width

Existing lane widths are typically 3.5m. In order to establish additional turning lanes, lane width should be reduced to 3.0m. However in high-urbanized area, it may be possible to reduce lane widths slightly more in order to avoid land acquisition.

Number of lanes

The median width should be reduced due to increase number of lanes at intersections. It also means to reduce the shift width between in and out at the intersection.
If the existing carriageway has enough width, establishment of left-turning lanes should also be considered.

Storage lane length

The length of 50m should be secured corresponding to the future queue demand.

Shift length

Policy of shift length is different from the highway design and urban road design. In urbanized area, minimum shift length of 20m should be secured according to the Japanese standard.

Corner cutting

The radius of corners are restricted by the sidewalk width in urban areas due to difficulties of additional land acquisition. As shown in the Figure 18.5.2, the maximum turning radius within this restriction should be secured. Therefore inadequate corners should be corrected.

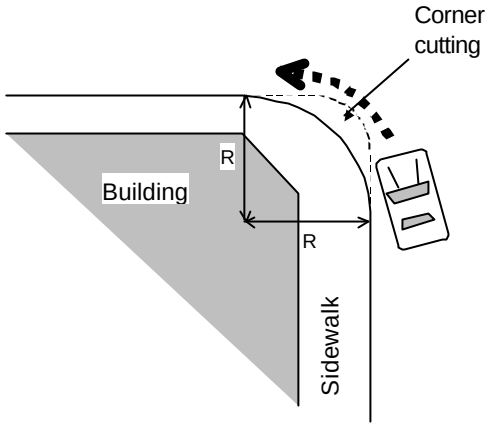


Figure 18.5.2 Corner Cutting at Intersections

2) Shape of Intersections

Crossing angle

Crossing angle should be suitable for smooth traffic movement. The acceptable angle of crossing is stipulated by the Japanese standard minimum of 60 degrees, and preferably it should be more than 75 degrees.

Most intersections adhere to this policy, expect at the north end of Av. Vladimir Lenine, there is angled at about 45 degrees. Therefore this intersection should be corrected, to connect at 90 degrees with Av. Julius Nyerere.

Figure 18.5.3 Draft Plan of T-shaped Intersection at North end of Av. Vladimir Lenine

Number of leg

On Av. Vladimir Lenine, there is a 6 legged intersection. In Japanese Road Structural Ordinance, connection more than 5 legs are prohibited. In such cases, measures for changing shape of intersection including changing of existing road alignment, changing of connection point and re-coordinate of traffic management system is recommended.

However, it is very difficult to change the road alignment at the intersection due to difficulties of land acquisition on Av. Vladimir Lenine. Therefore the intersection above shall be changed to a roundabout type intersection.

The scale of new roundabout should be as much as possible within the constraints of additional land acquisition. In order to avoid reduction of traffic capacity on the trunk road, a diameter of 30m is expected.

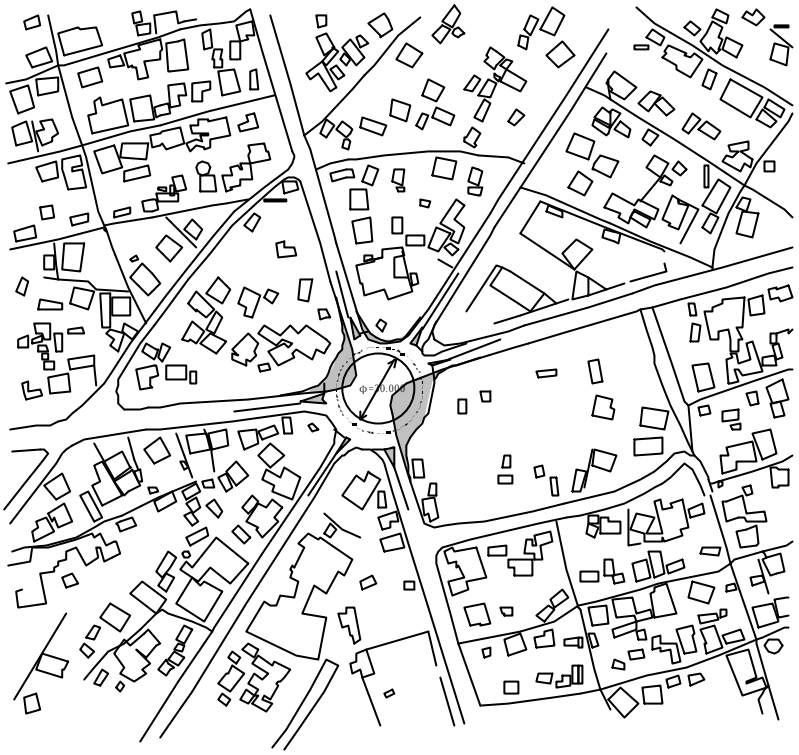


Figure 18.5.4 Draft Plan of Roundabout on Av. Vladimir Lenine

Type of intersection (Roundabout and cross-shaped intersection)

As shown in the Figure 18.5.5, inner circulation turning is recommendable in the opinion of traffic smoothability and traffic safety. Therefore small roundabouts in diameter of less than 10m should be changed to the normal cross-shaped intersection on trunk roads or major intersections.

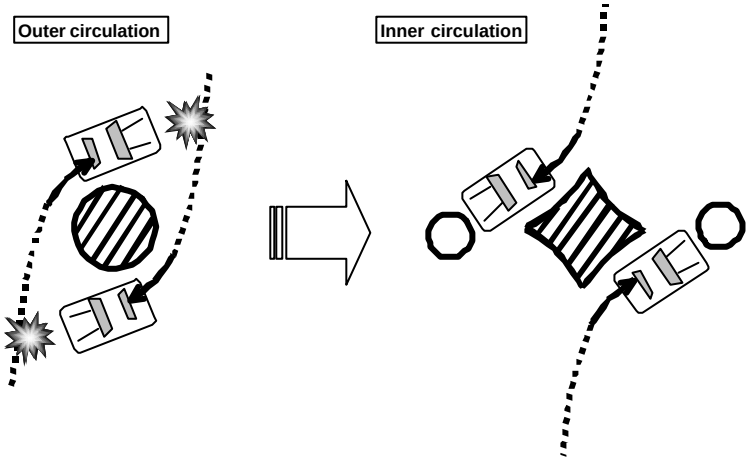


Figure 18.5.5 Turning Movement at Intersection

However small roundabouts work as a kind of speed reduction device. In order to avoid dangers caused by over speeding on narrow collector roads, small roundabouts are recommended to be applied at intersections on collector roads and local area roads in suburban areas.

3) Road Facilities Design

Lane marking

In order to prohibit lane change near the intersection, solid line should be applied on the storage lanes.

Stop line should be applied 1-2m before the pedestrian crossing strip.

Direction arrow markings should be applied on each lanes, it is established in interval of 25m including at the entrance of turning lane.

Channelization

Channelization zebra marking should be applied on the centre of intersection, to show the adequate turning movement to drivers as mentioned on the above.

Pedestrian crossing and road safety facilities

Crank-shaped pedestrian crossing strip is suitable to the pedestrian to confirm their safety at the centre median, also to give the time to the driver to find the crossing pedestrians at the exit of the intersection.

Meantime the safety guard fence should be established on the median and corner to secure their safety, also to prohibit reckless pedestrian crossing.

Parking control

As mentioned in the Chapter 11.8, car parking and stopping including buses should be strictly prohibited near intersections. Some of the major intersections are located at the crossing of major bus routes. In such cases, bus stops should be relocated an adequate distance, minimum 30m from the intersections.

Road lighting, trees etc.

In order to establish turning lanes, some of road lights should be relocated, or newly to be established.

Trees reduce sight lines at intersections should be cut.

4) Plan of Intersection

Through the above consideration, the design and facility plan of intersections are made as shown in the Appendix.

18.5.3 Traffic Signal Improvement Plan

1) General Requirement for Traffic Signal Design

Traffic management measures at intersections should include the following items.

- New signal heads to control right turns
- Provisions of secondary signal heads
- Improved signal timing
- Traffic detectors and dynamic control
- Monitoring through CCTV
- Linking signals to maximize effective capacity
- The control centre to plan, monitor and control signals and traffic

2) Recommended Intersections to be Improved

Table 18.5.1 Intersections Recommended for Traffic Improvements

Junction of	With	Signals	Physical Works
Eduardo Mondlane	Vladimir Lenine	Improved	No
24 de Julho	Vladimir Lenine	Improved	Yes
Eduardo Mondlane	Karl Marx	Improved	No
24 de Julho	Karl Marx	Improved	Yes
Eduardo Mondlane	Guerra Popular	Improved	Yes
24 de Julho	Guerra Popular	Improved	Yes
Eduardo Mondlane	Albert Lithuli	Improved	No
24 de Julho	Albert Lithuli	Improved	Yes
24 de Julho	Av de Zambia	New	Yes
Julius Nyerere	Mao Tse Tung	Improved	Yes
Julius Nyerere	Eduardo Mondlane	Improved	Yes
Julius Nyerere	24 de Julho	Improved	Yes
Martires de Machava	24 de Julho	Improved	Yes
25 de Setembro	Vladimir Lenine	Improved	Yes
25 de Setembro	Samora Machel	Improved	Yes
25 de Setembro	Karl Marx	Improved	Yes
25 de Setembro	Guerra Populare	Improved	Yes
Marien Ngouabi	Accordos de Lusaka	Improved	Yes*
Marien Ngouabi	Milagre Mabote	New	Yes*
Marien Ngouabi	Karl Marx	Improved	Yes*
Marien Ngouabi	Vladimir Lenine	Improved	Yes*

* Included as part of Marien Ngouabi works

3) Establishment of Linked Signal System

Linked traffic signal system will be established to the intersections shown in the Figure 18.5.6, to avoid traffic congestion at the major intersections by increasing of its traffic capacity.

Grouping of Traffic Signals

These intersections should be divided into 3 groups ; on Av. 24 de Julho, Av.25 de Setembro and Av. Julius Nyerere. These intersections are close to each other, the signal pattern should be connected with the others in order to secure smooth traffic and to avoid traffic congestion.

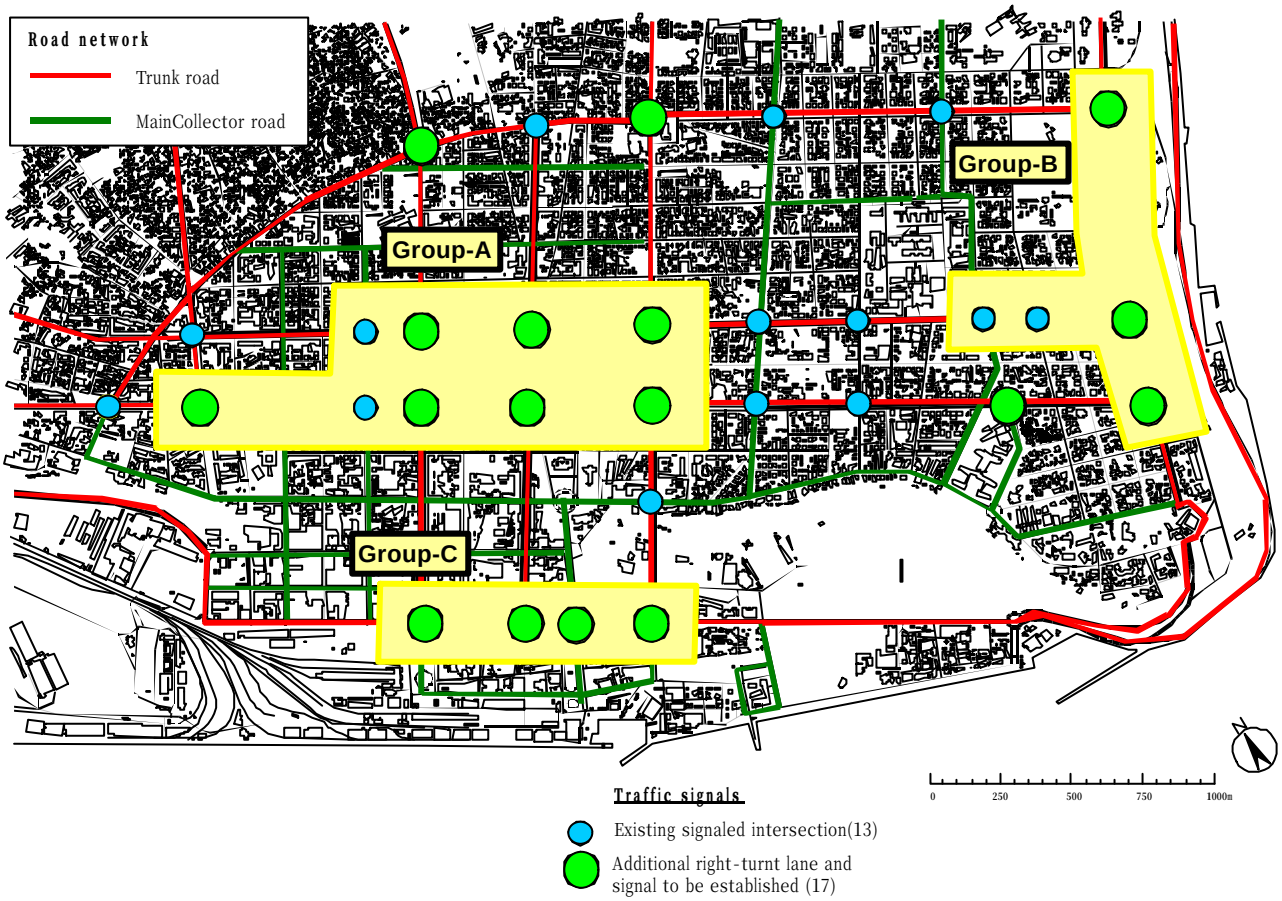


Figure 18.5.6 Location of Linked Traffic Signal System to be Applied

System components

Conceptual system components for each linked signal systems is as shown in the Figure 18.5.7. The system consists of vehicle detector, signal controller and information processing module.

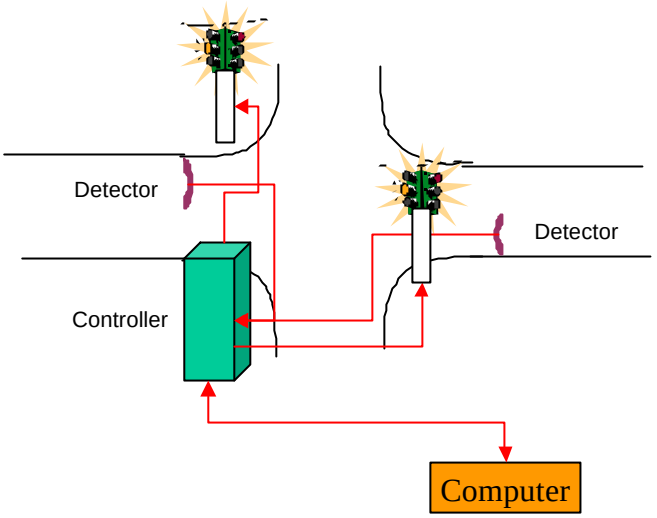


Figure 18.5.7 System Composition of Linked Traffic Signal

4) Benefit by the Improvements of Intersections

Following to the installation of linked traffic signal systems, unlinked traffic signals also to be subject to correct traffic signal pattern adequately.

Through the calculation of existing traffic capacity and result of the traffic demand forecasting, required future traffic signal pattern is calculated as follows. These calculation are made in the presupposition that the all improvement programme will be completed.

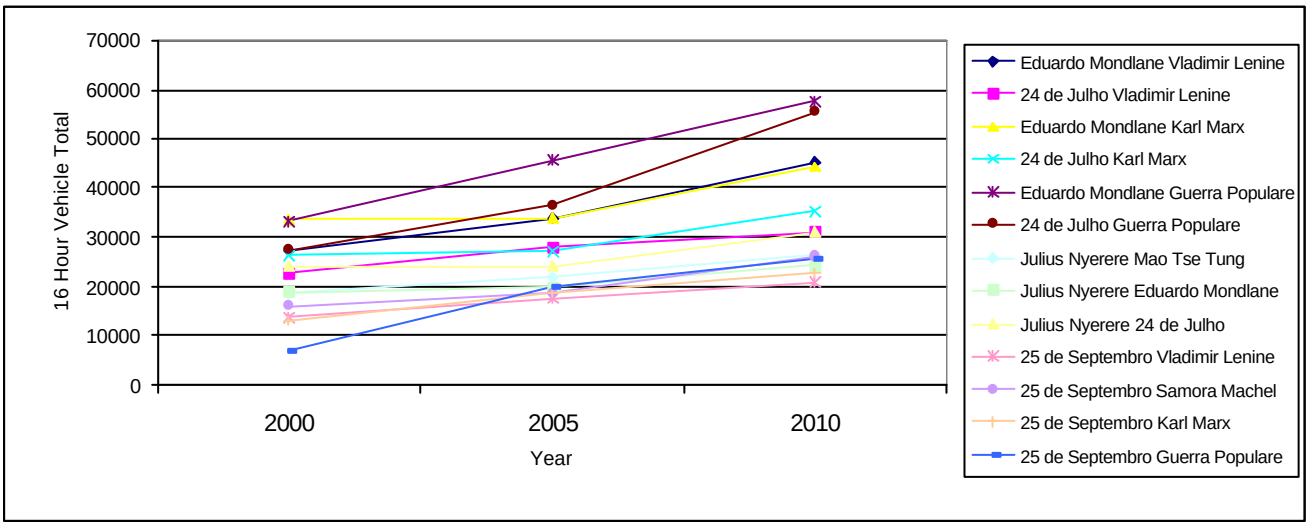


Figure 18.5.8 Future Traffic Demand on Major Intersections

Table 18.5.2 An Example Traffic Signal Pattern to be Applied

Future Capacity Calculation

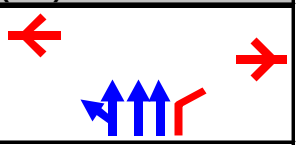
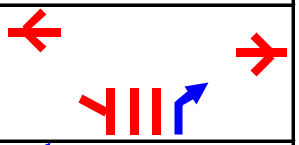
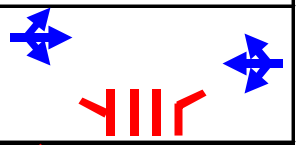
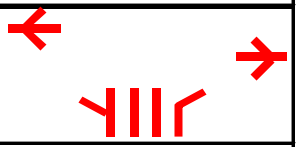
		Green (sec)		
Arm 1	4 lane approach	Stage 1 S/L	20	
		Stage 2 R	8	
Arm 2	1 lane approach	Stage 3	24	
		Inter Greens	13	
Cycle Time		65		

Table 18.5.3 Estimated Traffic Capacity Increase

Capacities per lane

	Lanes		Capacity pcu/hr	
Arm 1	1	S/L	1650	
	2	S	4000	
	1	R	1800	
Arm 2	1.5	S/L/R	1950	Opposed

Actual Capacities

	Lanes		Capacity pcu/hr
Arm 1	1	S/L	533
	2	S	1292
	1	R	249
Arm 2	1	S/L/R	750

Totals

	Existing	Future	Increase %
Arm 1	1167	2075	77.7
Arm 2	728	750	3.0
Total	1895	2825	49.0

5) Traffic Management Package

Costs for the installation of improved traffic management facilities in central Maputo have been estimated by aggregating unit costs for items needed to be supplied for each junction. For costing purposes 21 junctions are considered as listed in the Table 18.5.1.

Traffic management measures at these junctions will include :

- Removal of kerbside parking close to the junction
- Creation of right turning lanes, where feasible
- Better pedestrian facilities
- New signal heads to control right turns
- Provision of secondary signal heads
- Improved signal timings

The following issues should be considered in the long-term programme.

- Traffic detectors and dynamic control
- Monitoring through CCTV
- Linking signals to maximize effective capacity
- A central control center to plan, monitor and control signals and traffic

18.5.4 Intersection Improvement Plan

1) Major Intersection Design for Trunk Road Development Projects

On the following five trunk roads, there are nine (9) intersections identified as major and congested intersections required improvement by the trunk road development projects. Proposed plans of each intersection are shown in **the Drawings**. And the design policy of each intersection is studied as shown below by each trunk road development project.

(1) Missing Link on Av. Julius Nyerere:

Only one major intersection is 'Combatentes Plaza'. This intersection is well-designed roundabout but having some confusion of traffic flow and penetration of market and stopping of mass of vehicles. The design policy on this intersection is introducing proper rule of traffic control and to simplify the traffic flow as well as demolishing of the penetration.

(2) Av. Vladimir Lenine:

There is identified two (2) major intersections having confusion and congestion on traffic flow.

The intersection with the existing missing link on Av. J. Nyerere is very close to the Combatentes intersection and is also indirectly connected by the central strip on Av. J. Nyerere. Improvement of the shape of the strip and relocation of the intersection is necessary.
The other intersection having problematic shape is the one with Rua do Costa do Sol that has six (6) legs and no traffic control have been done. Considerable measures for this intersection will be either priority junction or small roundabout due to limitation of land. After preliminary studying on this intersection, a small roundabout with strict traffic control will be recommendable.

(3) Av. Acordos Lusaka and Av. Guerra Popular:

Along Av. A. Lusaka and Av. G. Popular, there are three (3) major intersections having confusion and congestion of traffic flow identified.

One major intersection with Via Rapida is controlled by signal but no right-turning lanes are equipped. Therefore installation of right-turning lanes with right-turning signal on Av. A. Lusaka should be necessary. On the other hand, the government intends to widen Via Rapida as dual carriageway. Therefore the study team recommends installing right-turning lane with

right-turning signal on the section of widening Via Rapida.

The other two (2) major intersections are one with Av. Marien Ngouabi and the other with Av. Eduardo Mondlane. The intersection crossing with Av. M. Ngouabi is signal-controlled roundabout and no right-turning lanes with right-turning signals are equipped within limited Right-of-way of 20m width. And also the existing Av. M. Ngouabi and Av. Guerra Popular are intended to be dual carriageway within the limited Right-of-way. Therefore Widening of some stretch and land acquisition on Av. M. Ngouabi and Av. Guerra Popular are necessary not only for installation of right-turning lanes with right-turning signals but-also for installation of bus bays.

Some confusion and congestion are identified on the intersection with Av. Eduardo Mondlane. Therefore Widening of some stretch and land acquisition on Av. Guerra Popular and modification of carriageway shape and traffic control on the section of Av. Eduardo Mondlane is necessary not only for installation of right-turning lanes with right-turning signals but-also for installation of bus bays.

(4) Av. Angola and Rua S. Cabral/Largo de Deta:

There is one major intersection with Via Rapida having confusion and congestion of traffic flow. This is controlled by signal but no right-turning lanes are equipped. Therefore installation of right-turning lanes with right-turning signal on Av. Angola should be necessary. On the other hand, the study team recommends installing right-turning lane with right-turning signal on the section of widening Via Rapida.

(5) Av. Marien Ngouabi:

The project of improvement of Av. M. Ngouabi is intended to open dual carriageway between Av. A. Lusaka, Av. Guerra Popular, Av. K. Marx and Av. M. T. Tung within the limited Right-of-way of 20m widths.

There are two (2) major intersections having confusion and congestion of traffic flow. The one is an intersection with Av. K. Marx controlled by signal without right-turning lane and right-turning signal. Therefore Widening of some stretch and land acquisition on Av. M. Ngouabi are necessary not only for installation of right-turning lanes with right-turning signals but-also for installation of bus bays.

The other is an intersection with Av. M. T. Tung, which is controlled by signal but the

right-turning traffic from Av. M. Ngouabi and through traffic from Av. M. T. Tung are controlled due to the shape of this intersection. The one of the objective of this project is to open dual carriageway between Av. M. Ngouabi and Av. M. T. Tung. Therefore Widening of some stretch and land acquisition on Av. M. Ngouabi and Av. M. T. Tung are necessary not only for installation of right-turning lanes with right-turning signals but-also for installation of bus bays as well as to open through traffic.

2) Minor Intersection Design

Designing of minor intersection on the road development project for collector roads or minor intersection along trunk roads will be done introducing either priority intersection or channelized intersection depending upon the traffic volume. Typical intersection shapes are shown in the drawing. A detailed design of each intersection will be done at Detailed Design stage.

3) Intersections Improved by Traffic Management Project

On the following trunk roads in the CBD of Maputo city, there are 14 intersections identified as major and congested intersections required improvement by the traffic management projects. Proposed plans of each intersection are shown in **the Drawings**. And the design policy of each intersection is studied as shown below by each traffic management project.

(1) Av. 25 de Setembro

Av. 25 de Setembro typically has 24.5m widths carriageway with 2.5m widths central parking strip and 4m widths shoulder. Shoulder is used as the roadside parking strip.
Right-turn lane and left-turn lane is possible to be established by reducing the central and roadside parking strip. Mounted median will not newly be established but chatter-bar should be installed on the 1.5m widths of centre strip.

(2) Av. 24 de Julho

Av. 24 de Julho typically has 24m widths carriageway with 8m widths median and 2m widths shoulder.
Right-turn lane is possible to be established by reducing the median. Shoulder width should not be reduced in order to avoid shifting movement at the exit of the intersections.

(3) Av. Julius Nyerere

Av. Julius Nyerere typically has 20-22m widths carriageway with 6-8m widths median. Right-turn lane is possible to be established by reducing the median and shoulder.

(4) Av. Eduardo Mondlane

Av. Eduardo Mondlane typically has 24m width carriageway. It is characteristic of having side road on the both side of the road, separated by mounted median.
In order to establish right-turn lane and left-turn lane, median will be removed in whole length of shifting section. Furthermore, 3m widths of central median should newly be established which will provide with a safety zone to pedestrians.

(5) Av. Vladimir Lenine

Av. Vladimir Lenine typically has 12m widths carriageway with 2.5m width shoulder.
Right-turn lane is possible to be established by reducing the shoulder. On the exit side of intersections will have 1 lane and 1.5m widths of shoulder should be secured in order to minimize shifting movement at the exit of the intersections.

(6) Av. Guerra Popular

Av. Guerra Popular typically has 26m widths carriageway with 6m widths median and 3m shoulder.
Right-turn lane is possible to be established by reducing the shoulder.

(7) Av. Karl Marx, Av. da Zambia

Av. Karl Marx and Av. da Zambia have similar geometry to Av. 24 de Julho. Therefore the policy of design should be in accordance with Av. 24 de Julho.