No.

NATIONAL ROAD ADMINISTRATION
REPUBLIC OF MOZAMBIQUE

THE PREPARATORY STUDY ON ROAD IMPROVEMENT PLAN IN NACALA DEVELOPMENT CORRIDOR (N13: CUAMBA-MANDIMBA-LICHINGA) IN THE REPUBLIC OF MOZAMBIQUE

FINAL REPORT
2 of 3
MAIN TEXT

Volume 2 Cuamba-Mandimba Section
Part III Preliminary Engineering Design
Part IV Ec onomic Feasibility Study
Part V Cro ss-Border Facilities

February 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

Eight - Japan Engineering Consultants Inc.

Oriental Consultants Co., Ltd.

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The following foreign exchange rate is applied in the study

1 US dollar = 28.00Mtn = 91.36 JP Yen, or 1 MTn = 3.26 JP Yen (October 2009)

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PREFACE

In response to the request from the Government of the Republic of Mozambique, the Government of Japan decided to conduct the Preparatory Survey on Road Improvement Plan in Nacala Development Corridor (N13: Cuamba-Mandimba-Lichinga) and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA dispatched a Study Team headed by Mr. Hisashi MUTO of Eight-Japan Engineering Consultants Inc. and consist of Eight-Japan Engineering Consultants Inc. and Oriental Consultants Co., Ltd. to Mozambique, between March 2009 and December 2009.

The Study Team held discussions with the officials concerned of the Government of Mozambique and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Mozambique for their close cooperation extended to the study.

February 2010,

Kiyofumi KONISHI
Director General
Economic Infrastructure Department
Japan International Cooperation Agency

Mr. Kiyofumi KONISHI
Director General
Economic Infrastructure Department
Japan International Cooperation Agency

February 2010

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit to you the Final Report of the Preparatory Survey on Road Improvement Plan in Nacala Development Corridor (N13: Cuamba-Mandimba-Lichinga) in the Republic of Mozambique.

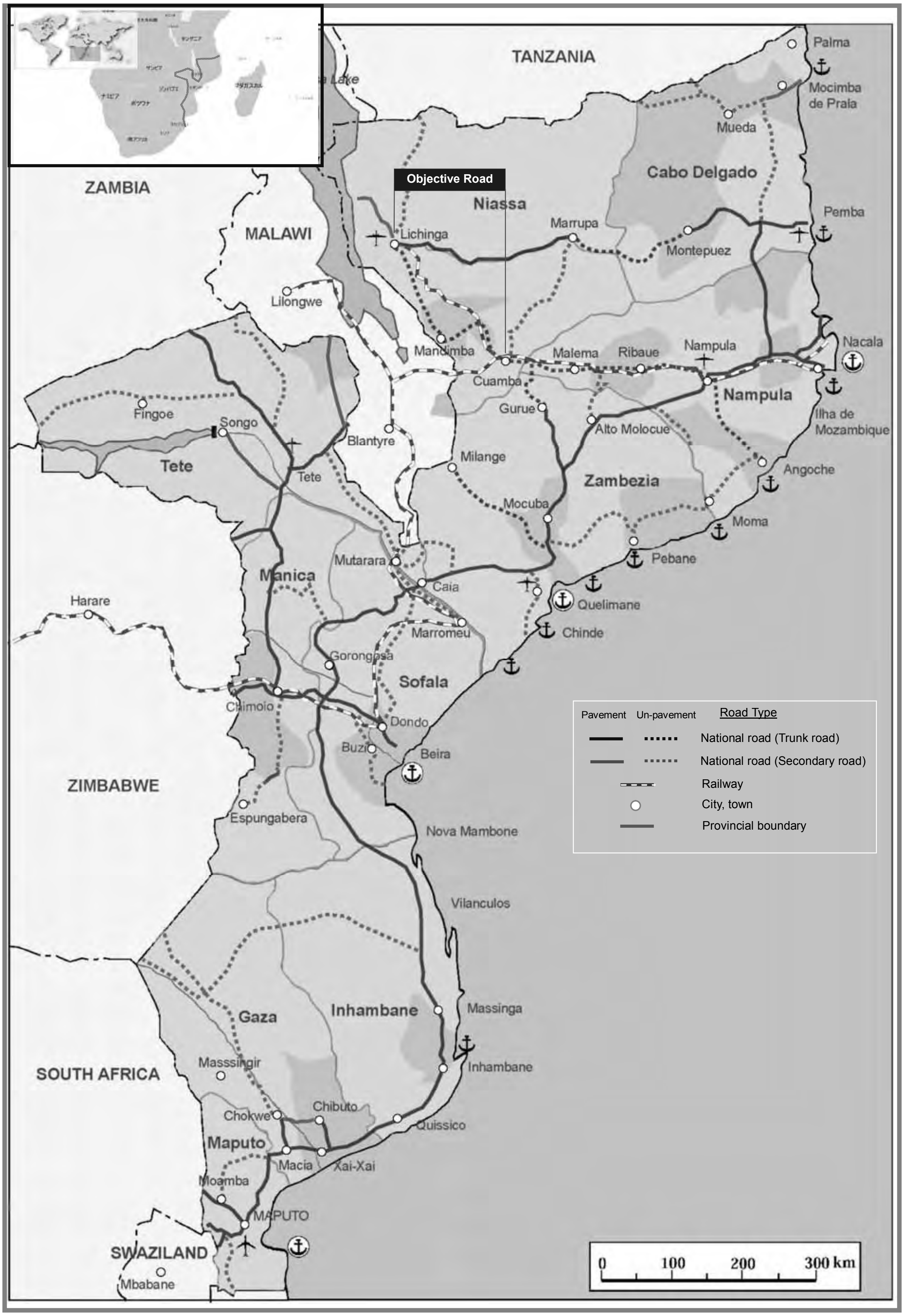
This study was conducted by Eight-Japan Engineering Consultants Inc. and Oriental Consultants Co., Ltd. under a contract to JICA, during the period from March 2009 to February 2010.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, Ministry of Foreign Affairs of Japan, National Road Administration, JICA Mozambique Office and Embassy of Japan in Mozambique for their cooperation assistance throughout the Study.

Finally, we hope this report will contribute to further promotion of the project.

Very truly yours,

Hisashi MUTO
Team Leader,
The Preparatory Survey on Road Improvement Plan in Nacala Development Corridor
The Consortium of Eight-Japan Engineering Consultants Inc. and Oriental Consultants Co., Ltd.



Project Location Map

Project Outline

1. Country	Republic of Mozambique
2. Name of Study	The Preparatory Survey on Road Improvement Plan in Nacala Development Corridor (N13: Cuamba-Mandimba-Lichinga) in the Republic of Mozambique
3. Counterpart Agency	National Road Administration (ANE), Ministry of Public Works and Housing(MOPWH)
4. Objectives of the Study	(1) The objectives of the Study are to determine the most technically feasible and economically viable, environmentally acceptable and socially optimal option of upgrading the existing Cuamba – Lichinga road to an all-weather road for easier transit. (2) Formulation and recommendation of the “Regional Development Program” intended for Niassa Province is also the objective of the Study.

1. The Study Area

- The Study Road, with a total length of approximately 302km including the Mandimba-Malawi Border road, traverses four districts having high agricultural potential, namely Cuamba, Mandimba, Ngauma and Lichinga in Niassa Province.
- The Cuamba-Mandimba-Malawi Border road is an important component within the Nacala Development Corridor, since it connects Niassa and Nampula Provinces, and in addition it serves to link landlocked Zambia and Malawi to the Mozambican coast.

2. Scope of the Study

(1) Economic Feasibility Study

1) Economic Analysis, 2) Traffic Analysis, 3) Economic Evaluation, 4) Risk Analysis

(2) Preliminary Engineering Design

1) Site Measurement (Natural Condition Survey), 2) Visual Site Survey, 3) Preliminary Design, 4) Cost Estimate

(3) One Stop Border Post (OSBP)

(4) Assistance for Execution of EIA by GOM (ANE)

(5) Regional Development Program

3. Narrative Description

Feasibility Study

The Study Road passes through many small villages. The road can be broadly divided into three terrains (0 – 148km: Flat terrain, 148 – 240km: Rolling terrain, 240 – 302km: Rolling with some mountainous terrain), and it undulates from a starting altitude of 560MASL reaching up to nearly 1,400MASL at Lichinga. The existing horizontal alignment and vertical alignment generally follow the watershed crest and the natural ground, respectively. The existing road is in fair to poor condition during the dry season and becomes impassable during the rainy season due to interaction between poor drainage and erodible soils. In addition the Study Road width varies between 5m and more than 10m and is generally lower than the surrounding ground.

As a result of the traffic demand analysis, future traffic volumes for both sections (Cuamba-Mandimba and Mandimba-Lichinga) in 2023 were estimated at about 1,481AADT and 1,732AADT, respectively. From the viewpoint of terrain, traffic safety, construction cost, social impacts, traffic management and operation, a design speed of 100km/hr was recommended for the section of Cuamba - Mandimba. Similarly, a design speed of 80km/hr was recommend for the section of Mandimba - Lichinga. And furthermore, the selection of the suitable pavement composition was evaluated based on the initial cost and its financial viability using the EIRR indicator. As a result of the analysis, a DBST surface on a granular base and cemented sub-base was selected as the most economically viable pavement composition. This composition was shown to have the lowest initial cost and the highest EIRR.

Regional Development Program

Niassa Province has the potential for various kinds of development. However, bad access conditions have hindered economic development in the province. Furthermore, huge areas, scattered population and low population density have made it difficult to deliver basic social services to the people. The Study Team formulated a regional development program so that the road improvements of Cuamba-Mandimba and Mandimba-Lichinga could generate synergistic effects on regional development. For the southern part of Niassa Province, such development measures included the support to smallholding farmers’ commercialization and agro-processing industries, and infrastructure development for improving logistic functions in the towns of Cuamba and Mandimba. For the middle to northern part of the province, high priority was given to the support of smallholding farmers’ commercialization, wood processing industries and tourism, as well as to improvement of social infrastructure and services.

4. Conclusion and Recommendations

(1) To authorize the regional development program proposed by the Study in conjunction with the road implementation plan.

(2) To advance the bilateral discussion for OSBP and to establish a policy relevant to the following issues:

- Types of operational system for OSBP scheme
- Layout and facility size
- Implementation program such as "Two-step upgrading," proposed by the Study

(3) To adopt the COI concept for minimization of social impacts such as resettlement.

(4) To start the detailed design for Cuamba - Mandimba Road (154km) as soon as possible.

(5) To execute a severe site survey (Topographic, Geological and Soil) for Mandimba - Lichinga Road.

5. Report Structure

Name of Report	Number of Volume	Main Contents of the Report		Language		
				Eng.	Por.	Jap.
1. Summary	-	-	-	✓	✓	✓
2. Main Text	Volume-1	Part I	Overall Approach & Work Procedure	✓	✓	
		Part II	General Appreciations			
	Volume-2 **Cuamba-Mandimba Section**	Part III	Preliminary Road Engineering Design			
		Part IV	Economic Feasibility Study			
		Part V	Cross Border Facilities			
	Volume-2 **Mandimba-Lichinga Section**	Part III	Preliminary Road Engineering Design			
		Part IV	Economic Feasibility Study			
	Volume-3	Part VI	Environmental and Social Considerations			
	Volume-4	Part VII	Regional Development Program			
3. Drawings	Cuamba-Mandimba Section	-	-	✓	✓	
	Mandimba-Lichinga Section	-	-			

Executive Summary

Part I Overall Approach & Work Procedure

Mozambique is located on the south-eastern coast of Africa and covers an area of 799,380 sq. km. It is bounded on the north by Tanzania; on the west by Malawi, Zambia, Zimbabwe, Swaziland and the Republic of South Africa (RSA); and on the entire eastern boundary by the Mozambican channel of the Indian Ocean. Mozambique's 17-year civil war, which lasted until 1992, ruined much of the country and destroyed key road infrastructure.

The Government of the Republic of Mozambique (hereafter referred to as the "GOM") assumed that the limited access to roads and other socio-economic services is a cause of the country's poverty and gave priority to improving infrastructures in areas with high potential for agricultural production, etc. in the Action Plan for the Reduction of Absolute Poverty (PARPA II: 2006 – 2009).

A main goal of the Road Sector Strategy 2007-2011 (RSS) is to serve the efficient road network to the prioritized economic areas such as agricultural areas, tourist sites and areas of industrial or natural-resource development that have the greatest potential to contribute to economic growth and PARPA II.

Given the above-mentioned situation, the GOM requested the Government of Japan (hereafter referred to as the "GOJ") to conduct a feasibility study (F/S) for the Upgrading of the Nampula - Cuamba Road. In response to this request from the GOM, the GOJ conducted "The Study on Upgrading of Nampula - Cuamba Road" from 2006 to 2007. In Nampula – Cuamba section, the detail design has been put forward for construction by the counter fund of GOJ.

The Study Road (N13: Cuamba – Mandimba – Lichinga), as part of the two Mozambican corridors (Nacala N13/N1 and Lichinga-Pemba N14/N1 corridors), provides a strategic link to the Malawi Border at Mandimba with the ports of Nacala and Pemba, in Nampula and Cabo Delgado Provinces respectively. Although the Study Road has much potential for stimulating development and reducing poverty throughout the entire northern area of Mozambique by enabling efficient connection, the section concerned is the only unpaved section.

Accordingly, the Japan International Cooperation Agency (hereafter referred to as "JICA"), the official agency responsible for the technical cooperation of the GOJ, undertook the Study including regional development program of Niassa Province along the Study Road in close cooperation with the concerned authorities of Mozambique.

The objectives of the Study are to determine the most technically feasible and economically viable, environmentally acceptable and socially optimal option of upgrading the existing Cuamba – Lichinga road to an all-weather road for easier transit. The Study also determines the impact of providing an all-weather road on poverty reduction and environment.

And establishment of the "Regional Development Program" intended for Niassa Province is also the objective of the Study. This program aims to extend the improvement effect to the wide area in conjunction with the road improvement (Nacala N13/N1 and Lichinga-Pemba N14/N1 corridors).

Part II General Appreciations

1. Government/Sectoral Policy

National policy and planning in Mozambique all have poverty reduction as a key objective. The Mozambique Government has been combating absolute poverty under the Poverty Reduction Strategy Paper (PARPA: 2001-2005) and PARPA II (2006-2009). The target of PARPA II is to reduce the incidence of absolute poverty from 54% in 2003 to 45% in 2009.

And Mozambique’s transport sector is governed by the following road sector policies and strategies:

- Road Sector Strategy 2007-2011 (RSS)
- Integrated Road Sector Program 2009-2011 (PRISE)
- Semi Annual Work Plan and Budget (SAWPB)

2. Responsible Institutions for the Sector

Mozambique’s road network is currently managed by the National Road Administration (ANE), which reports to the Ministry of Public Works and Housing. The Road Fund is responsible for managing the funds for the sector.

3. Traffic Modal Split

In Mozambique, the roads occupy a large share of both freight (58.2%) and passenger transport (96.1%) among all modes, particularly for passenger transport which is almost totally reliant on the road network. On the other hand, at 27.9%., contribution of the railway mode is relatively high for freight transport. Marine transportation (8.3%) also contributes towards transportation of freight. The air mode only shares a low ratio for both goods and passenger transport due to lower transport capacity.

4. Road Classification System and Conditions

Mozambique has classified roads which consist of national roads (primary and secondary) and regional roads (tertiary and vicinal roads). These roads are administrated by ANE. Urban roads and unclassified roads fall under the jurisdiction of the municipal councils and the district administrations respectively.

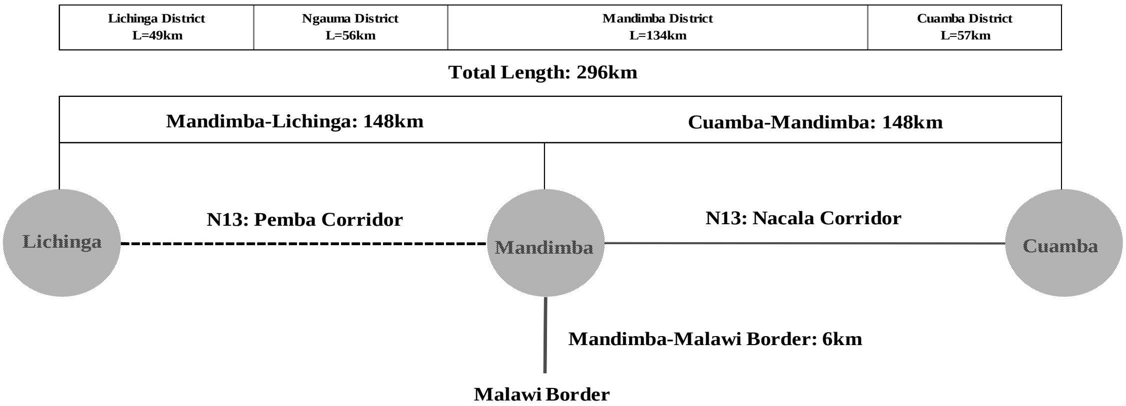
The current Mozambique classified road network is estimated at around 30,000km of which less than 20% is paved. Of the paved roads, the majority are estimated to be in good to fair condition (88%), however only 57% of the unpaved roads are estimated to be fully travelable. A key element of the RSS and of the Strategic Maintenance Plan (SMP) is the introduction of a Paved Road Management Programme (PRMP), which will be managed separately from the rest of the road network. SMP takes care of the 30,000km of classified roads and an additional 3,000km of urban roads.

[Cuamba-Mandimba Section]

Part III Preliminary Engineering Design

1. General Observations

The Study Road can be broadly divided into two sections (Cuamba-Mandimba Section and Mandimba-Malawi Border Section) and the road length of each section is indicated in the following figure.



Outline of the Study Road

2. Natural Condition Survey for the Study Road

The aim of the natural condition survey is to confirm the existing natural conditions for the Study Road with a view to making a road design. Natural condition survey is composed of the following three works.

1) Topographic Survey (Road alignment survey, Aerial survey, Bridge survey, Benchmark setting), 2) Geological Survey, 3) Soil & Material Survey

3. Hydrology and Hydrological Analysis

Following table shows the results of the flood level calculation by the HEC-Ras, which is based on the calculation for non-uniform flow.

Bridge	Return Period	Discharge (m3/s)	Calculated Flood Level (m)	Results of Field Survey (m)
Muambessi	50-Year	312.0	618.50	616.9
	100-Year	390.9	619.28	
Lussangassi	50 Year	589.9	639.42	637.5
	100 Year	731.4	639.92	
Ngolua	50-Year	246.4	704.16	706.2
	100-Year	307.9	704.85	
Ngame II	50 Year	243.7	708.61	709.2
	100 Year	301.7	709.15	

4. Applicable Design Standards

The application of a proper design standard will ensure that the following objectives are achieved:

- Ensure safety, a high standard service level and comfort for road users by the provision of adequate sight distance and roadway space,
- Ensure that the roadway is designed economically
- Ensure uniformity in the design
- Ensure safety of the structures (bridges and culverts).

For the design studies of the Nampula-Nacala Road and Nampla-Cuamba Road which are a part of Nacala Corridor, the Study Team proposed to use the Southern Africa Transport and Communications Commission (SATCC) design standards, as these were commonly used for other projects in the region.

5. Preliminary Engineering Design

Through discussions with ANE and the results of field surveys by the Study Team, the concept of the Project was confirmed as follows:

- To create an efficient primary road connection securing smooth traffic flow throughout the year corresponding to the future traffic demand
- To create a safe primary road connection by reducing the risk of accidents and the rate of injuries to pedestrians by motorized vehicles

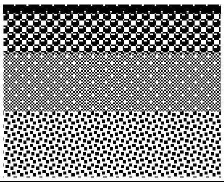
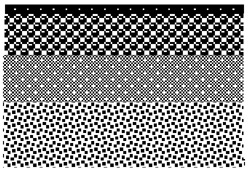
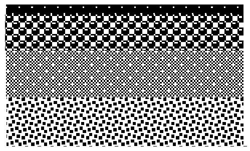
(1) Recommendable Alignment

The following table shows the improvement magnitude and effect of the recommended alignment. In regard to the section between Cuamba and Malawi Border, it was clarified by two indices (horizontal curvature and rise plus fall) that the existing alignments both horizontal and vertical almost meet criteria for a design speed of 100km/h. This means that improvement to the recommended alignment will basically be carried out on the existing road.

			Existing	Plan
Length (km)			153.8km	152.9km
Terrain			Flat	Flat
Design Speed			-	100km/h
Geometry	Horizontal Curvature	deg/km	22.4 (1.00)	21.2 (0.95)
	Rise + Fall	m/km	9.8 (1.00)	9.8 (1.00)
	No. of Rises + Falls	no./km	4.5	3.3
No. of Level Crossings			8	2

(2) Suitable Pavement Compositions

A mechanistic analysis using ELSYM5 was conducted according to the design CBR. The results of the analysis are as shown in following table.

S2 (3-4)	***S3 (5-7)***	***S4 (8-14)***
 200 / 250 / 250	 200 / 200 / 250	 150 / 200 / 200

: G4 Crushed or Natural Gravel Base Soaked CBR>80%@98% mod. AASHTO density

: C4 Cemented stabilized Sub-base 0.75-1.5Mpa@100% mod. AASHTO density

: G7 Selected Layer Soaked CBR>15%@93% mod. AASHTO density

Poisson's ratio & Elastic coefficient (Elastic coefficient = (10 x CBR)Mpa)

G4: 0.35, Phase-I: 400Mpa, Phase-II: 400Mpa, Phase-III: 300Mpa

C4: 0.25, Phase-I: 1500Mpa, Phase-II: 600Mpa, Phase-III: 300Mpa

G7: 0.35, Phase-I: 150Mpa, Phase-II: 150Mpa, Phase-III: 150Mpa

(3) Bridge Design

By the discussion with ANE, bridge inner width has been set as 9.2m for two-lane bridges. Those are summarized in following table.

General		Existing bridge			New bridge			
No.	name	width	length	existing	lane	width	length	from existing Br.
(Cuamba)								
1	Muambessi	4.8	14.3	demolish	2-lane	9.2	17	same position
2	Lussangassi	3.2	28.0	demolish	2-lane	9.2	34	down stream 8m
3	Ngolua	4.7	14.0	demolish	2-lane	9.2	17	same position
4	Ngame-II	4.9	28.0	demolish	2-lane	9.2	34	same position
(Mandimba)								

6. Construction Planning

The construction plan was proposed for improvement of Cuamba – Mandimba road on N13 including construction method, procurement of material and equipment, and construction schedule according to site condition, structural scale and work quantities.

7. Project Implementation Plan

Project implementation plan was proposed based on some constraints affecting the schedule as below:

- Selection of consultant for D/D will require four to five months procedure and preparation of D/D with tender documents will require minimum five months.
- Preparation of environmental impact assessment and RAP will require about eight to nine months and will be submitted to AfDB and JICA 120 days prior to the submission of the appraisal report and loan agreement of the Project, respectively.

- Tendering for construction contractor will require minimum nine to ten months procedure including pre-qualification, tender announcement, tender preparation limited to 90 days and tender evaluation and approval by ANE and lending agencies
- Construction work and supervision service will require about three years (33 months)

8. Project Cost Estimate

Basically unit construction cost of "Upgrading of Nampula – Cuamba Road" (hereinafter referred as "NCR") is utilized for the Estimate due to high similarities between the two projects as follows.

- Site location: The Project road is the extension of NCR beyond Cuamba in northern region.
- Time of estimate: Engineering estimate of NCR was finalized at its detailed design stage in April 2009.

The results of the Estimate are summarized in the following table.

Description		Final (USD)
		DBST
1000	General	21,773,229
2000	Drainage	6,205,937
3000	EW & granular layers	47,887,098
4000	AC & seals	13,525,335
5000	Ancillary	2,501,784
6000	Structures	6,051,036
7000	Test & QC	17,250
8000	Others	1,573,090
	Total (Bill A: Road)	**99,534,760**
	Bill B: Day works	855,999
	Bill C: Social issues	935,627
	Bill D: Environmental	248,837
	Total (Bill A to D)	**101,575,223**
	Contingencies (10%)	10,157,522
	IVA (6.8%)	7,597,827
	Total construction cost	**119,330,572**
	Engineering cost (5%)	5,586,637
	IVA (6.8%)	379,891
	Total project cost	**125,297,100**
	Compensation cost	156,103
	Project cost per km	**820,492**

9. Road Maintenance Systems

ANE's ten provincial delegations are responsible for the implementation of all maintenance works on classified roads. The Directorate of Maintenance has a crucial role in ensuring that the delegations in provinces are fully aware of and complying with the technical and operational guidelines for implementation of the annual maintenance plan; and that roads of all types (primary, secondary, tertiary, vicinal, paved, unpaved) are being maintained and provided .

Part IV Economic Feasibility Study

1. Existing Traffic Flow Patterns

The Study Team conducted the following surveys and research to recognize the characteristics of traffic flow patterns for each section.

- Previous traffic volume data in ANE
- Traffic volume and roadside OD survey in May and August, 2009 at three locations in Cuamba, Mandimba and Lichinga on the Study Road
- OD survey at four borders between Mozambique, Malawi and Zambia
- Interview survey of stakeholders both in Mozambique and Malawi

This section is used for passenger movement from Lichinga and other districts in Niassa to connect railway or Nampula province. Regarding goods transportation, some consumer goods are dispatched from Cuamba to Lichinga. On the other hand, most consumer goods for Cuamba city come from the Nampula side mainly by railway.

2. Methodology of Traffic Demand Forecast

The Study Team applied the socio-economic framework based on the development strategy in Niassa (PEP), and the concepts of forecast methodology as three different types of traffic;

Passenger traffic volume is estimated by “Gravity Model” with the variable index of potential population and road section impedance, developed by the actual number of passengers for each O-D trip.

Regional traffic volume is considered by dividing traffic as attraction and generation for each zone. Trip attraction is estimated by the consumption of daily goods, and trip generation is based on the agro-products from Niassa Province.

International traffic volume is thought to be generated after the road network is improved. It is estimated by the Malawi trade and railway capacity, and applies the corridor choice model, named lodgit model.

3. Results of Traffic Demand Forecast

Accumulating the results of each component, future traffic volume for both sections will be summarized. For the section of Cuamba – Mandimba, future traffic volume in AADT is estimated at about 457AADT in 2014, 1,481AADT in 2023 and 5,027AADT in 2033 in the “with” case.

The section of Cuamba - Mandimba is characterized by the numbers of trailers that will be diverted from Beira corridor and railway. It is evidenced that this section will be composed of a part of international corridor.

Compared with the previous feasibility study between Nampula and Cuamba, this estimated traffic volume is almost the same level of volume as for the previous section.

4. Economic Analysis

Economic analysis is conducted on the following assumptions:

Analysis Tool : HDM-4 (RED, Comprehensive for reference)
Project life : 20 years after the opening of the project road (2014)
Pricing date : as of October 2009
Social discount rate : 12%
Conversion Factor : Construction work (0.84), Maintenance work (0.75)
Exchange rate : US$1.00 = 28.00 Meticais (MT)

Results of analysis are tabulated as follows:

Sensitivity Analysis

Case	Assumptions	EIRR
Base	Upgrade to paved road with DBST with Lichinga-Mandinba intervention	19.5%
1	Decrease in traffic volume of -20%	16.6%
2	Increase in investment costs of +20%	16.9%
3	Combination of above as the worst case	14.3%

The Project scores an average level as an upgrade-to-paved intervention and its economic viability is acceptable, with an EIRR of over 12% of the opportunity cost among alternatives. Based on this result, the Project is evaluated as one of the prioritized projects to be implemented in the nation. The particular importance of this primary road and of bringing it to all-weather travelable condition is well established. The Study Team concludes that the road upgrading project is economically feasible in terms of the national economy of Mozambique.

Part V Cross Border Facilities

1. Baseline Study and Fact Findings for Upgrading Border Facilities:

Upgrading of facilities at Mandimba-Chiponde border post was assessed in terms of its needs and requirements in conformity with baseline study and facts found upon the following issues.

- Current Conditions of Borders at Mozambique-Malawi
  - Cross Border Traffic
  - Control System and Facility
- Characteristics of Mandimba-Chiponde Border
  - Geographical and Commercial Features
  - Interactions and Border Communities
  - Strategic Importance on Regional Corridor Development
  - Site Conditions and Facilities
- Strategy for Upgrading Border Control and Facility
  - SADC Regional Strategy
  - Mozambique-Malawi Bilateral Strategy

2. Implementation Approach for Upgrading Border Facilities:

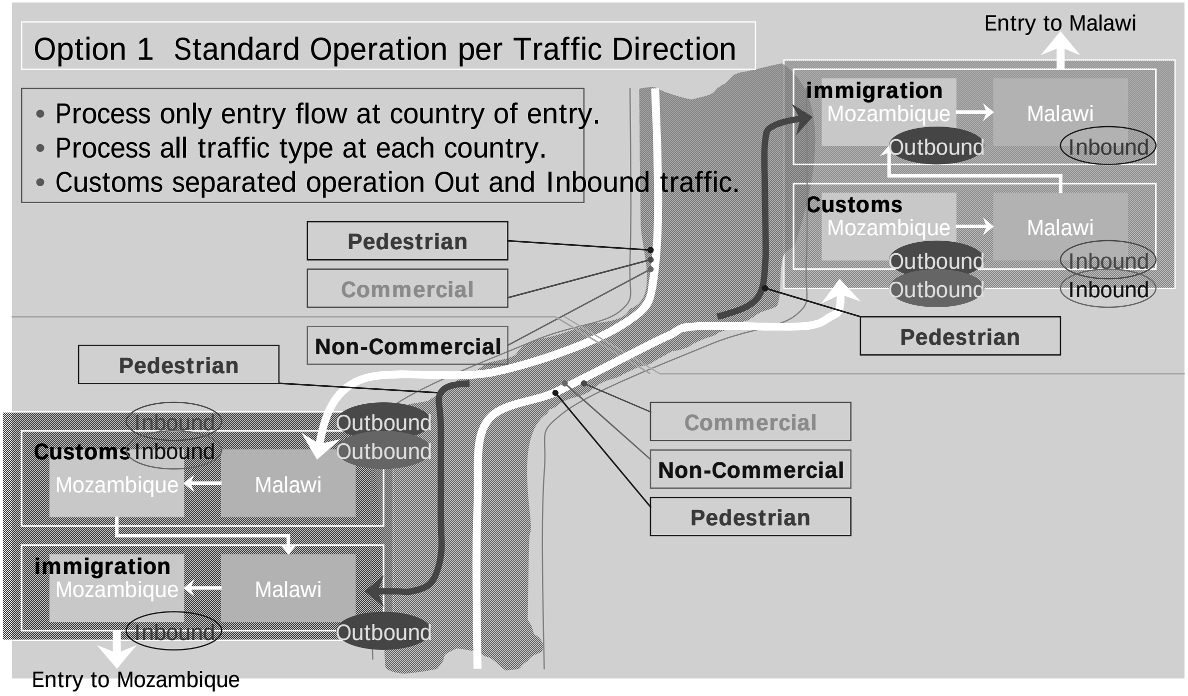
Implementation approach was formulated with the following proposals:

- Phased introduction for OSBP shall be employed,
- Existing facility shall be practically adapted and utilized under the environment of OSBP operation,
- Phased introduction shall be examined in line with: i) magnitude of future demands of cross border traffic and year forecasted, ii) time schedule of the bilateral discussion and the agreement, and iii) time schedule to introduce OSBP environment to other borders.

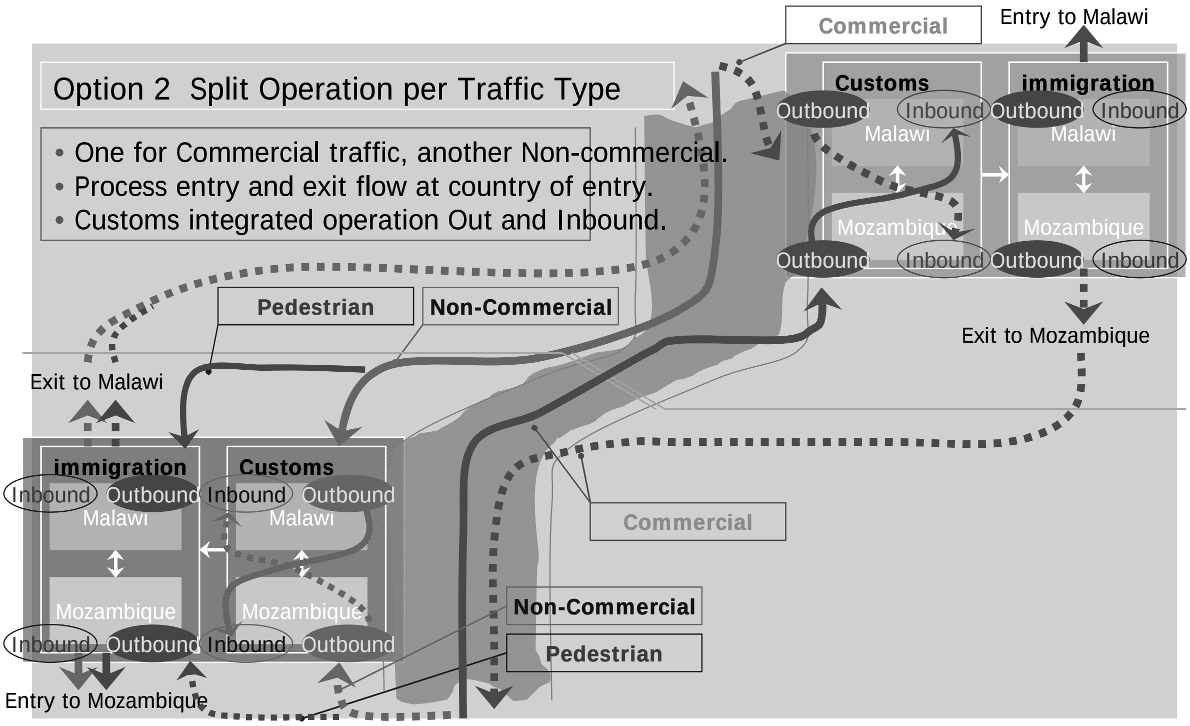
3. Implementation Policy for Upgrading Border Facilities:

"**Two-step upgrading**" as competitive scenario and "**Juxtaposed facility model**" were technically selected for the phased introduction of OSBP. And facility planning was preliminarily formulated estimating provisional conditions such as border control procedures and performance benchmarks (target time release, total processing time, unit workforce etc.) to be applied for OSBP operation.

Two types of operational options for OSBP scheme were proposed and preliminary layout and facility size were proposed for two target years according to "Two-step upgrading," that is, 2014 as the first step and 2024 as the second step introduction:



Option 1: Split Operation per Traffic Direction



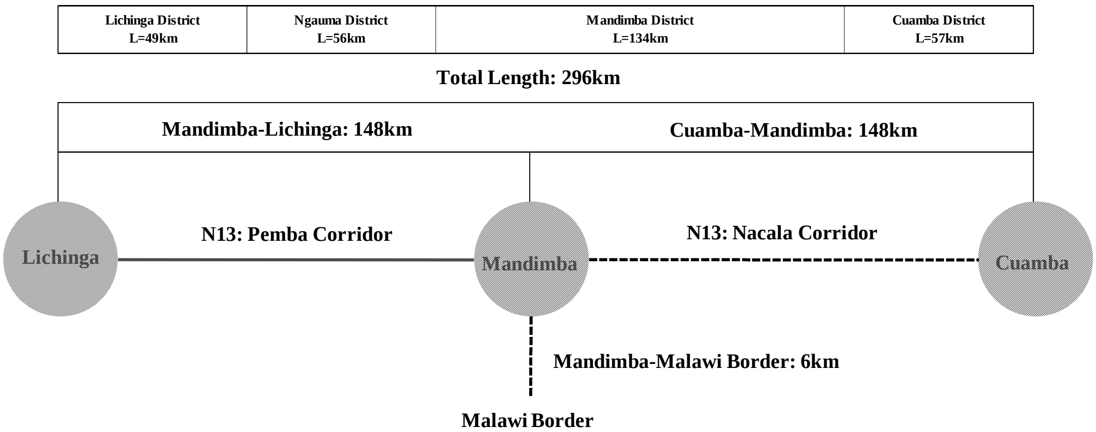
Option2: Split Operation per Traffic Type

[Mandimba-Lichinga Section]

Part III Preliminary Engineering Design

1. General Observations

As shown in Figure 1.1.1, the Study Road, with a total length of approximately 148km, traverses three districts having high agricultural potential, namely Mandimba, Ngauma and Lichinga in Niassa Province. The Mandimba-Lichinga road is part of the Pemba Corridor.



Outline of the Study Road

2. Natural Condition Survey for the Study Road

The aim of the natural condition survey is to confirm the existing natural conditions for the Study Road with a view to making a road design. Natural condition survey is composed of the following three components:

1) Topographic survey (Aerial survey, Bridge survey, Benchmark setting), 2) Geological survey, and 3) Soil & material survey.

3. Hydrology and Hydrological Analysis

Following table shows the results of the flood level calculation by the HEC-Ras, which is based on the calculation for non-uniform flow.

Bridge	Return Period	Discharge (m3/s)	Calculated Flood Level (m)	Results of Field Survey (m)
Ngame I	50-Year	225.6	731.10	732.9
	100-Year	278.9	731.68	
Lilasse	50 Year	277.3	892.76	893.2
	100 Year	342.7	893.01	
Ninde	50-Year	256.6	902.47	902.9
	100-Year	316.9	902.75	
Luculumesi	50 Year	716.2	992.98	990.0
	100 Year	885.0	993.63	
Lutembue	50-Year	310.9	1045.64	1043.9
	100-Year	384.7	1046.01	
Luambala	50 Year	463.2	1107.61	1105.5
	100 Year	576.5	1108.09	

4. Applicable Design Standards

The application of a proper design standard will ensure that the following objectives are achieved:

- Ensure safety, a high standard service level and comfort for road users by the provision of adequate sight distance and roadway space,
- Ensure that the roadway is designed economically
- Ensure uniformity in the design
- Ensure safety of the structures (bridges and culverts).

The Study Team proposed to use the Southern Africa Transport and Communications Commission (SATCC) design standards, as these were commonly used for other projects in the region. The Lichinga- Montepuez Road is also subject to the SATCC design standards.

5. Preliminary Engineering Design

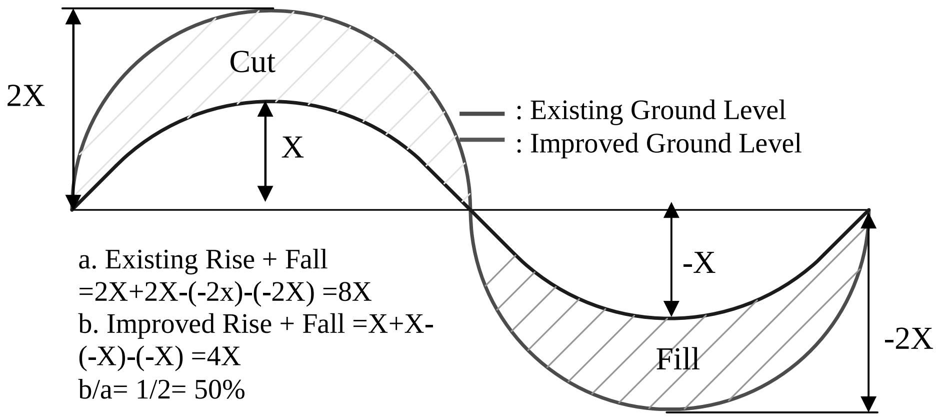
Through discussions with ANE and the results of field surveys by the Study Team, the concept of the Project was confirmed as follows:

- To create an efficient primary road connection securing smooth traffic flow throughout the year corresponding to the future traffic demand
- To create a safe primary road connection by reducing the risk of accidents and the rate of injuries to pedestrians by motorized vehicles

(1) Recommendable Alignment

The following table shows the improvement magnitude and effect of the recommended alignment. In regard to the section between Mandimba and Lichinga, although the horizontal alignment almost meets criteria for a design speed of 80km/h, the vertical alignment should be improved more than 50% for meeting a design speed of 80km/h as shown in following figure. This means that this section should be improved on large scale.

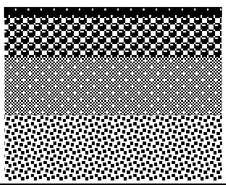
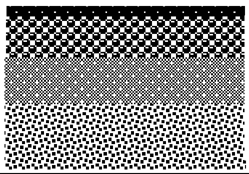
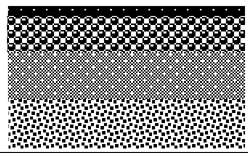
			Existing	Plan
Length (km)			148.1km	148.6km
Terrain			Rolling and mountainous	Rolling and mountainous
Design Speed			-	80km/h
Geometry	Horizontal Curvature	deg/km	164.1 (1.00)	174.8 (1.07)
	Rise + Fall	m/km	55.8 (1.00)	24.2 (***0.43***)
	No. of Rises + Falls	no./km	3.1	2.8



Improvement Image of the Vertical Alignment

(2) Suitable Pavement Compositions

A mechanistic analysis using ELSYM5 was conducted according to the design CBR. The results of the analysis are as shown in following table.

S2 (3-4)	*S3 (5-7)*	*S4 (8-14)*
 200 250 250	 200 200 250	 150 200 200

: G4 Crushed or Natural Gravel Base Soaked CBR>80%@98% mod. AASHTO density

: C4 Cemented stabilized Sub-base 0.75-1.5Mpa@100% mod. AASHTO density

: G7 Selected Layer Soaked CBR>15%@93% mod. AASHTO density

Poisson's ratio & Elastic coefficient (Elastic coefficient = (10 x CBR)Mpa)

G4: 0.35, Phase-I: 400Mpa, Phase-II: 400Mpa, Phase-III: 300Mpa

C4: 0.25, Phase-I: 1500Mpa, Phase-II: 600Mpa, Phase-III: 300Mpa

G7: 0.35, Phase-I: 150Mpa, Phase-II: 150Mpa, Phase-III: 150Mpa

(3) Bridge Design

By the discussion with ANE, bridge inner width has been set as 9.2m for two-lane bridges. Those are summarized in following table.

General		Existing bridge			New bridge			
No.	name	width	length	existing	lane	width	length	from existing Br.
(Mandimba)								
5	Ngame-I	4.2	28.0	demolish	2-lane	9.2	30	same position
6	Lilasse	4.0	10.0	demolish	2-lane	9.2	17	same position
7	Ninde	4.1	31.0	demolish	2-lane	9.2	34	down stream 8m
8	Luculumesi	4.4	22.0	demolish	2-lane	9.2	34	down stream 8m
9	Lutembue	4.1	34.0	demolish	2-lane	9.2	34	down stream 8m
10	Luambala	4.2	22.0	demolish	2-lane	9.2	30	up stream 8m
(Lichinga)								

6. Construction Planning

The construction plan was proposed for improvement of Mandimba - Lichinga road on N13 including construction method, procurement of material and equipment, and construction schedule according to site condition, structural scale and work quantities.

7. Project Implementation Plan

Project implementation plan was proposed based on some constraints affecting the schedule as shown below:

- Selection of consultant for D/D will require four months procedure and preparation of D/D and tender documents will require minimum six months.
- Preparation of environmental impact assessment and RAP will require about eight to nine months and will be submitted to a donor 120 days prior to the submission of the appraisal report and loan agreement of the Project.
- Tendering for construction contractor will require minimum nine to ten months procedure including pre-qualification, tender announcement, tender preparation of 90 days limitation and tender evaluation and approval by ANE and lending agencies
- Construction work and supervision service will require about three years (33 months)

The GOM/ANE is willing to make a request to apply for this Project as NEPAD project or component of the Cuanma-Mandimba Road Project. NEPAD project has to contribute to enhancing regional economic integration as a multinational project. However, the function of the Lichinga-Mandimba Road is not international trunk road linking other countries but rather essential road for regional development of Niassa Province.

For the reasons mentioned above, the possibility of applying this Project as NEPAD project will not be high. In that case, the GOM/ANE should consider a phased improvement in line with the existing road conditions and regional development program.

8. Project Cost Estimate

Basically unit construction cost of “Upgrading of Nampula – Cuamba Road” (hereinafter referred as “NCR”) is utilized for the Estimate due to high similarities between the two projects as follows.

- Site location: The Project Road is the extension of NCR beyond Cuamba in northern region.
- Time of estimate: Engineering estimate of NCR was finalized at its detailed design stage in April 2009.

The results of the Estimate are summarized in following tables.

Description		Final (USD)
		DBST
1000	General	28,083,346
2000	Drainage	11,519,383
3000	EW & granular layers	66,843,578
4000	AC & seals	14,259,205
5000	Ancillary	3,578,272
6000	Structures	5,797,170
7000	Test & QC	17,250
8000	Others	1,997,534
	Total (Bill A: Road)	**132,095,738**
	Bill B: Day works	1,136,023
	Bill C: Social issues	1,241,700
	Bill D: Environmental	330,239
	Total (Bill A to D)	**134,803,700**
	Contingencies (10%)	13,480,370
	IVA (6.8%)	10,083,317
	Total construction cost	**158,367,387**
	Engineering cost (5%)	7,414,204
	IVA (6.8%)	504,166
	Total project cost	**166,285,757**
	Compensation cost	199,391

	Project cost per km	**1,121,868**

9. Road Maintenance Systems

ANE’s ten provincial delegations are responsible for the implementation of all maintenance works on classified roads. The Directorate of Maintenance has a crucial role in ensuring that the delegations in provinces are fully aware of and complying with the technical and operational guidelines for implementation of the annual maintenance plan; and that roads of all types (primary, secondary, tertiary, vicinal, paved, unpaved) are being maintained and provided .

Part IV Traffic Demand Forecast and Economic Analysis

1. Existing Traffic Flow Patterns

The Study Team conducted the following surveys and research to recognize the characteristics of traffic flow patterns for each section:

- Previous traffic volume data in ANE
- Traffic volume and roadside OD survey in May and August, 2009 at three locations in Cuamba, Mandimba and Lichinga on the Study Road
- OD survey at four borders between Mozambique, Malawi and Zambia
- Interview survey with stakeholders in both Mozambique and Malawi

This section is the only route for delivering consumer goods to Lichinga, which is the provincial capital of Niassa, which is the base for distributing to the northern part. This section can be said to be the lifeline for the northern area. The majority of social and official movement is along the OD-pair between Lichinga and Cuamba.

2. Methodology of Traffic Demand Forecast

The Study Team applied the socio-economic framework based on the development strategy in Niassa (PEP), and the concepts of forecast methodology as three different types of traffic:

Passenger traffic volume is estimated by “Gravity Model” with the variable index of potential population and road section impedance, developed by the actual number of passengers for each O-D trip.

Regional traffic volume is considered by dividing traffic as attraction and generation for each zone. Trip attraction is estimated by the consumption of daily goods, and trip generation is based on the agro-products from Niassa province.

International traffic volume is thought to be generated after the road network is improved. It is estimated by the Malawi trade and railway capacity, and applies the corridor choice model, named lodgit model.

3. Results of Traffic Demand Forecast

Accumulating the results of each component, future traffic volume for both sections will be summarized. For the section of Mandimba – Lichinga, future traffic volume in AADT is estimated at about 467AADT in 2014, 1,732AADT in 2023 and 6,417AADT in 2033 in the “with” case.

The future AADT of section between Lichinga – Mandimba is more than Mandimba – Cuamba. It is because social communication will be more active by minibus and passenger car to the connection of provincial capital in Lichinga.

Compared with the previous feasibility study between Nampula and Cuamba, this estimated traffic volume is almost the same level of volume as for the previous section.

4. Economic Analysis

Economic analysis was conducted on the following assumptions:

Analysis Tool : HDM-4 (RED, Comprehensive for reference)
Project life : 20 years after the opening of the project road (2016)
Pricing date : As of October 2009
Social discount rate : 12%
Conversion Factor : Construction work (0.84), Maintenance work (0.75)
Exchange rate : US$1.00 = 28.00 Meticais (MT)

Results of analysis are tabulated as follows:

Sensitivity Analysis

Case	Assumptions	EIRR
Base	Upgrade to paved road with DBST (revised cost)	18.1%
1	Decrease in traffic volume of -20%	15.4%
2	Increase in investment costs of +20%	15.6%
3	Combination of above as the worst case	13.6%

The Project scores an average level as an upgrade-to-paved intervention and its economic viability is acceptable, with an EIRR of over 12% of the opportunity cost among alternatives. Based on this result, the Project is evaluated as one of the prioritized projects to be implemented in the nation. The particular importance of this primary road and of bringing it to all-weather travelable condition is well established. The Study Team concludes that the road upgrading project is economically feasible in terms of the national economy of Mozambique.

Part VI Environmental and Social Considerations

1. Environmental Law and Relevant Guidelines

The Government of Mozambique has issued laws relevant to the environment. According to the EIA Law, all project proponents must obtain environmental certification from the approval organization which is the Ministry of Environmental Coordination (hereinafter referred to as "MICOA"). This environmental law prescribes that rural road rehabilitation projects are classified as "category A" projects, which require an EIA basically. With regard to Malawi side, the Part V in Environmental Management Act 1996 says, "A4.5 construction new road / widening of existing road of highway / rural road" requires EIA process. On the other hand, construction of immigration facilities is not prescribed in the mandatory list for EIA.

The environmental and social consideration survey based on the JBIC and JICA guidelines indicated that it seems serious environmental impacts are not expected, so far, however some key issues such as resettlement, elephant migration corridor and infectious disease items were picked up, and some mitigation measures were recommended from the Study Team.

2. Environmental Recommendations

The Study Team recommends the following:

[Implementation of Mitigation Measure against Key Issues]

- With regard to African elephant migration routes in the Study Area, signboards should be set up to warn drivers and inhabitants and environmental education should be conducted for construction workers and inhabitants by the proponent.
- In terms of resettlement, adequate law-based process under land law, RPF and other relevant guidelines shall be conducted. Especially, sufficient discussion for negotiation of price determination shall be carried out with stakeholders because the GOM does not have a prescribed compensation price list for structures and assets at the moment.

[Implementation of Adequate EIA]

- ToR for EIA which will be prepared by ANE should consider relevant guidelines such as GOM, JBIC, JICA and AfDB.
- The Study Report shall be referred and incorporated into the EIA report which will be prepared by ANE, especially analysis of elephants and quantitative pollution forecast in air quality and noise pollution

[Implementation of Required Environmental Process during Construction]

- Appropriate law-based processes shall be adopted for development of quarries and borrow pits during construction. Generally, development of new quarry site shall take environmental certificate from Provincial MICOA.

Part VII Regional Development Program

1. Present Situation and Development Potential of Niassa Province

Niassa Province has inherent development potential in agriculture, forestry, mining and tourism. However, poor access conditions have hindered economic development in the province. Furthermore, its territorial size, scattered population and low population density have made it difficult to deliver basic social services to the people.

The majority of provincial population is rural and the majority of rural population is smallholding farmers (smallholders). They grow a variety of food crops including maize, cassava and beans. Poor access conditions increase transport costs. It is difficult for smallholders to transport their agricultural produce by car and sell them at market places. As a result, smallholders have to wait for middlemen to come to their villages or they need to bring produce to nearby buying places by bicycle or on foot. Moreover, in order to satisfy cash needs, they have to sell part of food crops for their own family consumption.

Some smallholders grow cash crops, such as tobacco and cotton. On the other hand, in recent years, in the southern part of Niassa Province, where access conditions are relatively good because of its railway linkage, some smallholders grow sesame for export in the activities of agricultural associations. However, these kinds of cash cropping are still limited in number and to certain areas.

Agriculture is a major and important economic sector, which provides food and cash for the majority of people in the province. In Niassa Province, there is much room for improvement of agriculture in technical production and commercialization. Furthermore, agro-processing industries are expected highly not only to increase the demand for local agricultural produce, but also to increase non-agricultural employment.

In the northern part of Niassa Province, since 2005, industrial tree plantations have been increasingly developed by foreign investments. Harvesting of trees will start at those plantations around 2013. Those harvested wood and/or locally processed wood products would be exported to other regions. In the short term, they rely on road transport from Lichinga to Cuamba to get railway at Cuamba. In the mid and long terms, it is expected that the railway line between Cuamba and Lichinga could be rehabilitated so as to transport unprocessed wood or processed wood products to Cuamba and further to Nampula or to Nacala, sometime to Malawi.

In Niassa Province, Niassa Lake in the north-western area and Niassa Reserve in the north-eastern area have tourism potential. Lichinga, provincial town of Niassa, has beautiful streetscape due to Portuguese colonial legacy. Lichinga has development potential to be a base for tourist accommodation. Such tourism potential including tourist resorts, water sports, ecotourism and game hunting has been hardly exploited yet.

It has been known that the north-western area of the province has mineral resources including coal. However, high transport costs have hindered exploration and development of mineral resources.

2. Regional Development Measures for Promoting Synergy Effect of Trunk Road Improvement and Regional Development

(1) Corridor along Cuamba-Mandimba Trunk Road: Southern Part of Niassa Province

Smallholder Agriculture and Agro-Processing Industries

The upgrading and pavement project of Cuamba-Mandimba Road could reduce transport costs, as well as improve road access along the corridor. As a result, regional potential to commercialize smallholder agriculture and to expand their production would be enhanced. However, such road upgrading alone cannot realize the enhanced regional potential and achieve smallholder commercialization and production expansion. Therefore, it is necessary to assist in strengthening their agriculture associations and securing market channels for their produce.

The upgrading and integration of Cuamba-Mandimba Road with already upgraded Nampula-Cuamba Road would substantially reduce long-distance transport costs by truck so as to reduce goods prices imported from other regions.

It is considered that such smallholder commercialization and agricultural production expansion would increase business potential of agro-processing industries along the corridor. However, such road upgrading alone is not enough to exploit improved opportunities in agro-processing industries. It is essential to assist in not only feasibility studies but also business development services, for providing information and support to private sectors. Such measures would help private sectors to actually invest in the field of agro-processing.

Urban Economy and Logistics Function

The integrated upgrading of trunk roads of Nacala Development Corridor would vitalize regional economy along the corridor. This could promote geographical expansion of commercial catchments Nampula Town and Nacala Town, resulting in upgraded commercial agglomeration.

Similarly the inland towns, such as Cuamba Town and Mandimba Town, would expand their commercial catchments and increase demands for transport and logistics sectors.

In addition to the upgrading of Nampula-Cuamba-Mandimba Road, development of bypass roads, logistics centers and loading-unloading facilities between roads and railways would be necessary for making regional transport more effective and efficient by taking advantage of upgraded trunk roads and rehabilitated railway of Nacala Development Corridor.

(2) Periphery of Nacala Development Corridor: Central and Northern Parts of Niassa Province

Smallholder Commercialization and Production Improvement

Commercialization of smallholders in the periphery of Nacala Development Corridor would be encouraged by the road improvement between Nampula, Cuamba and Mandimba. Due to the reduced long-distance transport costs, the farmers would be able to sell their agricultural products at higher prices. As the economic activities in Nacala Development Corridor are vitalized with the trunk road improvement, populations of Cuamba Town and Mandimba Town would increase. As a result, the amount of agricultural products to be dealt with by the middlemen would increase. Currently the support to the smallholder commercialization by organizing agricultural associations and by making linkage with marketing companies is provided in a limited number of villages in the southern part of the province. In order to make full use of the enhanced opportunities for smallholder commercialization, such support should be expanded to the central and northern parts. In addition, agricultural technical support should be introduced to improve their production.

Tourism Development

If the road between Nampula, Cuamba and Mandimba is improved, tourists visiting southern part of the Province from Malawi or Nampula by bus or car would increase. It is expected that Lichinga would be developed as a comfortable tourist base to provide accommodation to tourists, traveling along the route via Cuamba and Mandimba. Measures should be taken to improve the quality of tourism services in hotels, restaurants and car rentals, as well as to provide tourist information in Lichinga Town. Furthermore, efforts should be made to attract tourists to make trips from Lichinga to nearby tourist spots such as Niassa Lake and nature conservation areas.

In order to fully develop tourism in Niassa Province to such an extent that more international and domestic tourists would visit Niassa Lake and/or Niassa Reserve as popular tourist destinations, good access conditions should be ensured with improved Mandimba-Lichinga Road. In combination with the road improvement, it is necessary to make Lichinga Town an attractive tourist center, by providing small tourist-oriented facilities, such as tourist information centers, museums and sign boards. It is also necessary to start developing the capacity of local tourist industries by providing training programs. More tourist accommodations and attractions should be developed at Niassa Lake and Niassa Reserve. For facilitating tourism development at the provincial level and for promoting tourism in Niassa Province, it is also recommended to establish a local tourism board involving government and private sectors.

Development of Wood Processing Industry

Improvement of Mandimba-Lichinga Road is essential for promoting industrial development, such as wood-processing industries, in the central and northern part of Niassa Province. The road improvement would largely contribute to cost reduction of long-distance truck transport and furthermore to price reduction of imported goods, such as spare parts and fuels. This could lead to enhancement of basic conditions for attracting industries.

For actual promotion of wood-processing industries, business development services should be provided for foreign investors and companies. Furthermore, it is also necessary to develop small and medium scale enterprises (SMEs) of wood-processing for local employment generation.

Mineral Resources Development

The improvement of Lichinga-Mandimba Road is essential to realize mineral resources development in the north-western area of the province. Together with the road improvement, geological surveys and research is important to provide information on mineral resources availability to promote private investment in mineral exploration and furthermore in mineral exploitation. In the long term, rehabilitation of Lichinga-Cuamba Railway Line is highly expected for transporting exploited mineral resources through Cuamba, Nampula and Nacala.

Improvement of Social Services

In addition to the above-mentioned economic development measures, the improvement of social services, such as water, education and health, as well as the improvement of local roads are very important for the regional development in the central and northern parts of Niassa Province. In the decentralization policy of Mozambique, budgets for the development are allocated to district governments, and they are supposed to play central roles in planning and implementation for local development. However, their capacity is limited. In order to improve social infrastructure and services, assistance programs for capacity development of district governments are necessary.

The Preparatory Survey on Road Improvement Plan in Nacala Development Corridor (N13: Cuamba-Mandimba-Lichinga) in the Republic of Mozambique

Final Report

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Part III Preliminary Engineering Design

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Part V Cross Border Facilities

Abbreviation

AADT	Annual Average Daily Traffic
ACE	Competent Authority of Road Sector
ACV	Aggregate Crushed Value
ADT	Average Daily Traffic
AfDB	African Development Bank
ANE	National Road Administration
AU	Africa Union
BOO	Build Own Operate
BOT	Build Operate Transfer
BOOT	Build Own Operate and Transfer
CBR	California Bearing Ration
CDN	Northern Development Corridor
CFM	Mozambique Railway Authority
CLUSA	Cooperative League of the U.S.A.
COI	Corridor of Impact
COMESA	Common Market for Eastern and Southern Africa
DA	Directorate of Administration
DCP	Dynamic Cone Penetration
DIMAN	Directorate of Maintenance of ANE
DIPRO	Directorate of Project of ANE
DNEP	National Directorate of Roads and Bridges
DPANE	Provincial Delegation of ANE
DPOPH	Provincial Directorate of Public Works and Housing
DTI	Department of Trade and Industry
EAC	East African Community
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
ESCS	Environmental and Social Consideration Survey
EU	European Union
FDD	Full Due Diligence
FIP	Preliminary Information File
GAT	Cross Cutting Issues Unit (Environmental Unit in ANE)
GAS	Director of Assessor and Supervision Cabinet
GDP	Gross Domestic Product
GED	Cabinet for Development and Strategic Study
GOJ	Government of Japan
GOM	Government of the Republic of Mozambique
GPS	Global Positioning System
H.W.L	High Water Level
HDM-4	Highway Design and Maintenance Standards Model
HIV/AIDS	Human Immunodeficiency Virus /Acquires Immune Deficiency Syndrome
ICB	International Competitive Bidding
IDA	International Development Association
IND	National De-mining Institute
INE	National Statistics Institute
IRI	International Roughness Index
IRR	Internal Rate of Return
IUCN	International Union for the Conservation of Nature and Natural Resources
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
MASL	Meter Above Sea Level
MCA	Multi Criteria Analysis

MCC	Millennium Challenge Corporation
MICOA	Ministry for Coordination of Environmental Affairs
MOAF	Ministry of Agriculture & Fisheries
MODP	Ministry of Development & Planning
MOIC	Ministry of Industry & Commerce
MOPWH	Ministry of Public Works and Housing
MOTC	Ministry of Transport & Communication
MTEF	Medium Term Expenditure Framework
NCB	National Competitive Bidding
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization
NPV	Net Present Value
OSBP	One Stop Border Post
OD	Origin and Destination
PAC	Environmental Accompanying Plans
PAP	Project Affected Person(s)
PARPA	The Action Plan for the Reduction of Absolute Poverty
PEP	Provincial Strategic Plan
PES	Economic and Social Plan
PGA	Environmental Administration Plan
PPP	Public-Private Partnership
PRISE	Road Sector Integrate Program
RAP	Resettlement Action Plan
RECs	Regional Economic Communities
RED	Roads Economic Decision Model
RF	Road Fund
RMF	Regional Maximum Flood
ROW	Right of Way
RPF	Resettlement Policy Framework
RSS	Roads Sector Strategy 2007-2011
SADC	Southern African Development Community
SATCC	the Southern Africa Transport and Communications Commission
SAWPB	Semi Annual Workplan and Budget
SEA	Strategic Environmental Assessment
SDI	Spatial Development Initiatives
SISTAF	Ministries of Finance and Planning and Development in the Government’s financial management system
SIDA	Swedish International Development Cooperation Agency
SMEs	Medium-scale National Entrepreneurs
SMP	Strategic Maintenance Plan
SPT	Standard Penetration Test
STD	Sexually Transmitted Disease
SWOT	Strength, Opportunity, Weakness and Threat
TMH	Technical Measures for Highways
TRH	Technical Recommendations for Highways
TOR	Terms of Reference
VEF	Vehicle Equivalent Factor
VOC	Vehicle Operation Cost
WB	The World Bank

PART III

PRELIMINARY ENGINEERING DESIGN

Part III Preliminary Engineering Design

Chapter 1 Inventory Survey for the Study Road

1.1 General Observations

(1) Nacala Development Corridor

The Regional Economic Communities (RECs) of COMESA, SADC and EAC have long recognized the importance of improving trade facilitation (amongst other issues) in the context of deepening regional integration and reducing the costs of cross-border transactions and so improving economic livelihood. As such, the RECs have supported a number of trade facilitation instruments such as regional customs bond guarantee systems, a regional 3rd party vehicle insurance scheme, harmonized axle loads and vehicle dimensions, a single customs document, harmonized customs procedures, regional carrier’s license, etc. All RECs have also supported infrastructural development programs.

From the above, it would, therefore, seem appropriate to develop, through the COMESA-EAC-SADC Task Force, a joint multimodal transport program along one or more corridors which would have both hardware and software components.

The Nacala Corridor project is within the SADC’s priority projects and part of the Spatial Development Initiative (SDI) meant to unlock the development potential of the hinterland of Nacala Port in Mozambique, Malwai and Zambia. Further, the project is consistent with the African Development Bank’s and NEPAD strategy that puts emphasis on multinational projects that foster regional integration and economic development of sub-regional blocks and complies with the criteria set for the NEPAD STAP programme.

The concept of the Nacala Development Corridor (NDC) has been derived jointly by the governments of Mozambique, Malawi and Zambia to upgrade the historic transport route linking the deep water port of Nacala to Blantyre, Lilongwe and the eastern and northern provinces of Zambia. The Mozambican part of the road corridor is presently paved for only 200km of its 700km total length. The unpaved sections of the road become impassable during the rainy season from December to March, preventing the operation of a reliable road freight service.

The importance of the corridor to the region has been recognized by the Southern African Development Community and it is the subject of a Spatial Development Initiative signed by Malawi, Mozambique and Zambia to promote development. The road forms SADC Trunk Route Number 20.

(2) The Study Road

As shown in Figure 1.1.1, the Study Road, with a total length of approximately 154km including the Mandimba-Malawi Border road, traverses two districts having high agricultural potential, namely Cuamba and Mandimba in Niassa Province. The Cuamba-Mandimba-Malawi Border road is an important component within the Nacala Development Corridor, since it connects Niassa and Nampula Provinces, and in addition it serves to link landlocked Zambia and Malawi to the Mozambican coast. The Nacala

Corridor is important corridors in Mozambique for achievement of the policy of the PARPA and RSS.

The Study Road can be broadly divided into two sections (Cuamba-Mandimba Section and Mandimba-Malawi Border Section) and the road length of each section is indicated in Figure 1.1.1.

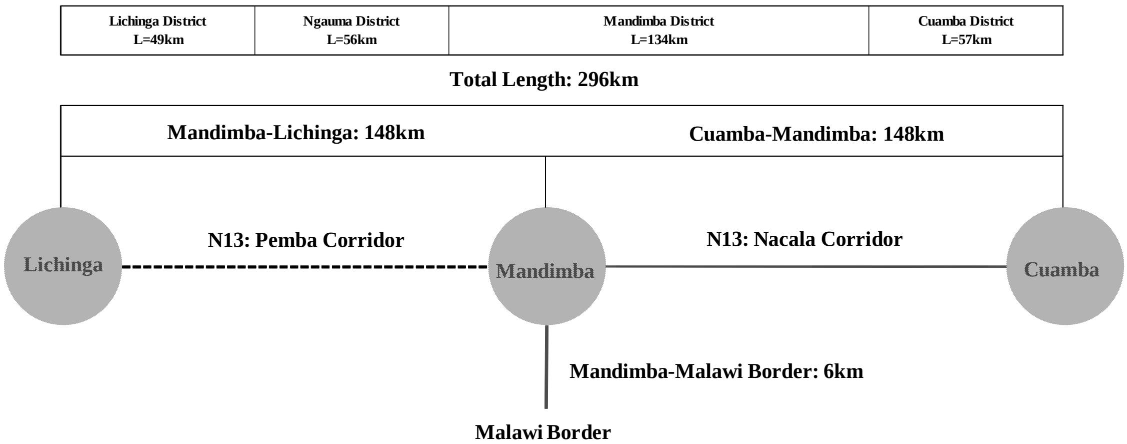


Figure 1.1.1 Outline of the Study Road

The referencing system for the study road used in this report is based on follows;

(3) Cuamba-Mandimba Section

- Chainage increases from Cuamba towards Mandimba.
- The starting point of the study road is at the intersection of the N13 and the railway bridge in Cuamba town
- The end point is at the N13/ Mandinba-Malawi Border road junction in Mandimba.

(4) Mandimba-Malawi Border Section

- Chainage increases from Mandimba towards Malawi Border and continued chainage is used from Cuamba-mandimba section.
- The starting point of the Study Road is at N13/ Mandinba-Malawi Border road junction in Mandimba.
- The end point is at the Malawi Border Post.

1.2 Existing Road Conditions

1.2.1 Methodology of Inventory Survey

A road inventory survey was carried out to assess the present conditions of the Study Road and to determine upgrading concepts. The road inventory survey included:

- ***Road Condition Assessment***: terrain, geometry, road surface type and conditions.
- ***Drainage Condition Assessment***: culvert type, size, cell number, length, materials flow direction and conditions.

- ***Road features and furniture***: level crossings, major and minor junctions, towns, villages and road signs, bus stops.
- ***Control Points Assessment***: cemeteries, religious facilities, sacred trees, historical facilities, schools, hospitals and water wells.

The results of the inventory survey are shown in the following sub-chapter.

1.2.2 Existing Road Condition by Section

(1) Cuamba-Mandimba Section

The Study Road passes through many small villages. The terrain is mostly flat, starting at an altitude of about 560 MASL climbing towards Mandimba, located at an altitude of approximately 760 MASL. The Study Road steadily climbs at a gradient of 0.13% on average.

The existing road alignment generally follows the watershed crest, and its horizontal alignment is characterized by straight line, large and/or medium size curves apart from a few sections such as the level crossing. The Study Road runs parallel with the railway line and crosses the railway line on eight occasions within a short length. At the crossing points, the existing alignment of the Study Road usually crosses over the railway line at a skewed angle. These types of crossing are unacceptable geometrically. In addition, it is dangerous in terms of traffic safety because firstly it is difficult for drivers to confirm whether or not a train is coming, and secondly, the sharp crossing of vehicles sometimes causes slippage particularly on rainy days.

Table 1.2.1 Crossing Angle of Each Level Crossing

Location	Angle	Location	Angle
17+620	49	30+724	19
24+311	11	61+407	26
27+084	8	65+660	8
28+411	15	74+353	36

Overall, the Study Road width varies between 7.0m and over 10m with an earth/gravel surface excluding the section between 145km+419 and 147km+881 which is surfaced with sand seal. The existing vertical alignment follows the natural ground. Regardless of the flat terrain, fills are not common. Accordingly, the Study Road is generally lower than the surrounding ground. In consequence, in many sections, water is confined on the road after rainfall and causes concentration of run-off water and erosion on the carriageway.

The existing transversal drainages shown in the Appendix are set in reasonable intervals (1/1.1km). The locations of the drainage structures are hydraulically adequate to accommodate the stream flows, which cross the road. In addition, the existing culverts and their inlets and outlets are generally in a good condition. However the width between culvert headwalls varies according to the existing road width and ground terrain conditions, etc.

Photo 1.2.1 Typical Cross Section (76km)

Photo 1.2.2 Market on the Road (118km)

(2) Mandimba-Malawi Border Section

Mandimba-Malawi Border road which has a length of 6km leads up to Malawi after bisecting from N13 in Mandimba. This road undulates at nearly 760 – 800 MASL while passing three minor rivers and rolling terrain. The road has an earth surface and is significantly deteriorated by lack of maintenance activities and heavy rains. Typically, the road width varies between 6m and 7m (between the edge of road), and is not generally adequate for two-lanes of heavy trucks.

And, trees line the road in many places giving an attractive avenue effect. However, the distance between the trees is unlikely to be sufficient for an improved road cross section and either a compromise with respect to standard will have to be made or one side of the avenue must be removed.

In addition, many small houses and schools are to be found on both sides of the road. The road serves many pedestrians and bicycle users making market deliveries and traders, as it also provides an area for market storage when on holiday.

Drainage provisions are not good, in particular, a drift which allows that water pass through on the road is built between Mozambique's border facility and Malawi's border facility. Accordingly, the existing road becomes impassable during heavy rains.

Photo 1.2.3 Road Lined with Trees (149km)

Photo 1.2.4 Transversal Structure "Drift" (153km)

1.2.3 Consideration Facilities for the Road Planning

In the stakeholder meeting, existence of some facilities for consideration such as cemeteries was noted by the residents. Therefore, the Study Team specified the facilities for consideration in the road widening and the re-alignment plan by a visual survey and an interview with residents on site. Locations of these facilities surveyed by the Study Team were mapped by use of the GPS. These facilities mean public facilities, social facilities, religious facilities, historical facilities and important project areas such as Tobacco Plantation Project by the Government. The results of the survey are summarized as follows:

(1) Cuamba-Mandimba Section

In the section between Cuamba and Mandimba, wells are the most numerous facilities for consideration, followed next by schools.

Table 1.2.2 Summary of Facilities for Consideration Between Cuamba and Mandimba

Facility	Number	Facility	Number
School	20	Monument	0
Hospital	3	Factory	1
Church	2	Project Site	5
Mosque	0	Pylon	2
Cemetery	13	Petrol Station	0
Well	79		

(2) Mandimba-Malawi Border Section

In the section between Mandimba and Malawi Border, wells are the most numerous facilities for considerations, and schools come next as well as Cuamba-Mandimba section.

Table 1.2.3 Summary of Facilities for Consideration Between Mandimba and Malawi Border

Facility	Number	Facility	Number
School	3	Monument	0
Hospital	0	Factory	0
Church	2	Project Site	0
Mosque	2	Pylon	0
Cemetery	3	Petrol Station	0
Well	9		

1.2.4 Black Spots on N13

According to the interview survey with the traffic police in Niassa Province, the following spots were reported as areas of high traffic accident risk. The Study Team investigated causes of traffic accident at each spot. The following table shows black spots and investigation results.

Table 1.2.4 Black Spots and Causes of Accidents

Km from Cuamba	District	Location	Hour	Cause
28km	Caumba	Macau	9:00-24:00	- Populated Area - Inadequate Alignment
30km	Cuamba	Mepica	12:00-15:30	- Populated Area - Inadequate Alignment
50km	Cuamba	Mabulacha (Meplage)	15:00-21:00	- Populated Area
75km	Mandimba	Mississi (Mucovola)	6:00-24:00	- Populated Area - Inadequate Alignment
115km	Mandimba	Comjerenje	9:00-15:00	- Populated Area

1.2.5 Analysis and Findings

(1) Necessity for Improvement of Road Alignment

Both the existing horizontal alignment and the existing vertical alignment are not appropriate for “high” speed driving required as the international corridor. The length and radius of horizontal curves, and K values are unacceptable with a view to road safety such as sight distance. And steep gradient should accelerate road surface erosion.

In particular sharp angled crossings of railway lines and the elevation gap between the road alignment and the railway crossing should be improved from the aspect of road safety.

However, unreasonable adoption of high-speed design standard would mean not only substantial increase in construction cost but also increase in affected area. Accordingly, adoption of high-speed design standard needs to be addressed based on the road functions, local circumstance and natural conditions such as terrain.

(2) Necessity of Improvement of Road Surface

During the rainy season, most sections of the Study Road suffer from erosion by heavy rainfall and uncontrolled surface run off. The erosion makes driving conditions difficult. The erosion issue is a result of various problems such as the road being lower than the surrounding area, steep gradients, improper or defected drainage, and the use of road materials with high Plasticity Index (PI).

In addition, during the dry season, the road surface is corrugated as a result of substandard material characteristics and car driving forces. Driving on corrugated road is very uncomfortable for drivers and passengers.

Based on the issues presented on alignment and road surface condition, the Study Team recommends surfacing the road with, for instance, a bituminous surface treatment to allow for comfortable trafficking all year long.

(3) Necessity for Improvement of Drainage Facilities

The culverts and their respective inlets and outlets are generally in good condition. However the width between culvert headwalls is very narrow. In addition, it is reported that a fair amount of earth and sand accumulate inside the culverts during the rainy season probably due to the use of corrugated steel-pipes and flat gradients. Therefore, existing culverts should be replaced with concrete pipe/box culverts with sufficient capacity and appropriate gradients to prevent silting up.

Existing earth drains are not functional due to accumulated earth and soil and eroded road surfaces. These problems are particularly notable on sections with steep gradient, in “cut and fill” and those that are lower than the surrounding ground level. On such sections, an appropriate drainage system should be designed. Furthermore, drainage structures should be connected and discharged through suitable and regular outlets.

(4) Necessity to Consider Bypasses

As a result of the site survey, the Study Road passes through many villages and populated areas. On such sections, stores, vendors, religious facilities and public facilities such as schools, hospitals and town halls are located close to the road. Thus, on such sections, bypass routes need to be addressed based on the road functions, local circumstance and traffic volume.

In addition, bypasses for decreasing the number of level crossings should be considered from the viewpoint of road safety in conjunction with the bypasses for the populated areas as discussed above.

1.3 Existing Bridge Conditions

1.3.1 Introduction

A bridge inventory survey was executed to assess the present conditions of bridges. The information obtained will be utilized for diagnosing damage of the existing bridges and proposing improvements to those bridges. A list of bridges was obtained from ANE before starting the bridge survey.

All waterways with approximately more than 10m in width on the Study Road were the subject of investigation as part of the bridge inventory survey. As a result, 14 bridges were identified. All waterways had structures, including some multi-cell pipe culverts. The survey mainly focused on gathering general information about the bridge and waterway, including flood records, and in assessing any damage to the bridge.

1.3.2 Bridge Survey Works

<u>Survey Items</u>

The following information was gathered at the bridge sites:

- Bridge Location: River and bridge name, Station km
- Bridge General Information: Total length, span arrangement, carriageway and pedestrian width, superstructure type, load capacity if possible, girder information (depth, arrangements), substructure type (pier and abutment), protection work
- Damage Conditions: Girder, slab, substructure, bank protection, others (ancillary facilities)
- River Conditions: Yearly Low Water Level, Yearly High Water Level, Highest Water Level (HWL), river width, riverbed material, river gradient, river depth, which are done basically by hearing from local people
- Surrounding Conditions: Land use, potential number of houses to be affected by a new bridge
- Other Information: Observation at the site, information from project documents
- Engineer's Comments: Necessity for replacement, points to be considered in a new bridge plan

<u>Survey Method</u>

The bridge inventory and relevant information were collected mainly by on-site investigations, and checked with the topographical survey. In addition, flood record information including the flood H.W.L. was gathered from the Department of Water Resources and Control as well as by interviewing local people living near the existing bridge.

1.3.3 Survey Result

In this Cuamba – Mandimba road section, total 14 bridges were investigated. The survey results and possible three (3) alternatives of bridge improvement plan are summarized in Table 1.3.1.

The important three (3) items of bridge survey are specially described here for further analysis.

(1) Bridge Condition and Damage

The bridge conditions are relatively fair even after being constructed 40-60 years ago. The main reason is that earthquakes and river flooding seldom occur, and the hilly atmosphere is good for steel bridges.

The investigated 14 bridges are grouped in three (3) categories as follows.

<u>Category Good [3]</u>: Strong or new bridge that will remain in use

These are structurally strong continuous RC-T bridge [1], road-railway bridge [1], and a newly completed bridge granted by GOJ [1].

<u>Category Fair [5]</u>: Bridges that will remain in use for the next 20 years approximately

These are simple RC-T bridges [5].

<u>Category Poor [6]</u>: Bridges that will be replaced by new structures

These are non-girder bridges such as RC-slab bridges [4] and H-beams [2], in which slab and gird post are damaged.

(2) Bridge Inner Width

The bridge inner width for road traffic varies between 3.2 – 6.5 m on the old constructed bridges, while the newly constructed bridge granted by GOJ has 7.2 m inner width.

Even though 7.0 - 8.0 m inner width is minimum required for new 2-lane bridge construction, the existing bridges with inner 6.0 m width or more are recognized as possible 2-lane bridge.

(3) River Flooding and High Water Level

For the 14 bridge locations, high water level (HWL) is sufficiently below bridge girders according to the local people, but theoretical HWL and discharge are calculated by hydrological analysis with collected river and rainfall data.

Table 1.3.1 Bridge Survey Result

General information				Length and width		Super-structure			Sub-structure			Structure	River information		Remarks	Alternatives of Improvement Plan				
																Alt-1	Alt-2		Alt-3	
No.	Sta	Sta	name	length (span)	width	rail	slab (cm)	girder	abutment	pier	foundation	condition	flow (w)	H.W.L.		reuse existing	reuse existing	add 1-lane bridge	new 2-lane structure (demolish existing)	
	0.0	153.0	(Cuamba)																	
1	0.5	152.5	Muanda	70 (14 * 5)	6.0 + 3.0	rail	30	RC-T (n=5, h=1.2m)	Rev-T (h=8m)	wall (h=10m)	spread	good	left (60m)	ok	Good condition, Road+Rail bridge	2-lane	—	—	—	—
2	8.4	144.6	Ningare	22 (11+11)	7.2	rail	80	Hollow Slab (Continuous)	Rev-T (h=5m)	wall (h=6m)	spread	good	left (5m)	ok	Good condition, Japan Grant Bridge	2-lane	—	—	—	—
3	43.0	110.0	Manjamanja	8.8	4.1	post		RC-slab (h=0.6m)	Rev-T (h=4m)		spread	poor	left (7m)	ok		1-lane	—	—	—	culvert
4	44.0	109.0	Namicango	10.6	4.2	post		RC-slab (h=0.6m)	Rev-T (h=4m)		spread	poor	left (7m)	ok		1-lane	—	—	—	culvert
5	49.0	104.0	Muambessi	14.3	4.8	rail	30	RC-T (n=3, h=0.8m)	Rev-T (h=6m)		spread	fair	left (8m)	ok	constructed 1966	1-lane	1-lane	1-lane	bridge	—
6	112.0	41.0	Lugenda	34 (17+17)	0.4+5.3+0.4	rail	30	continuous RC-T (n=3, h=1.2m)	Rev-T (h=7m)	wall (h=7m)	spread	good	left (30m)	ok	good condition by continuous girder, even constructed in 1940	2-lane	—	—	bridge	—
7	114.9	38.1	Tarikajao	6.0	4.0	post	40	H-beam (n=2, h=0.3m)	Rev-T (h=3m)		spread	poor	right	ok		1-lane	—	—	—	culvert
8	117.5	35.5	Pimbinu	8.8	4.1	post	60	H-beam (n=2, h=0.3m)	Rev-T (h=3m)		spread	poor	right	ok		1-lane	—	—	—	culvert
9	119.7	33.3	Lussengessi-II	8.8	4.0	post		RC-slab (h=0.5m)	Rev-T (h=4m)		spread	poor	right	ok		1-lane	—	—	—	culvert
10	119.8	33.2	Lussengessi-I	28 (14+14)	6.0	rail	25	RC-T (n=4, h=1.1m)	Rev-T (h=4m)	wall (h=5m)	spread	fair	right	ok	good condition, even constructed in 1963	2-lane	—	—	bridge	—
11	124.3	28.7	Kadawada	8.7	3.3	post		RC-slab (h=0.5m)	Rev-T (h=3m)		spread	poor	right	ok		1-lane	—	—	—	culvert
12	129.5	23.5	Lussangassi	28 (7+7+7+7)	3.2	post	30	RC-T (n=3, h=1.0m)	Rev-T (h=5m)	3-colum (h=6m)	spread	fair	right (15m)	ok	many accident by winding approach road	1-lane	1-lane	1-lane	bridge	—
13	148.8	4.2	Ngolua	14.0	4.7	post	30	RC-T (n=3, h=1.0m)	Rev-T (h=7m)		spread	fair	right (14m)	ok	constructed 1964	1-lane	1-lane	1-lane	bridge	—
14	150.5	2.5	Ngame-II	28 (14+14)	4.9	post	30	RC-T (n=3, h=1.0m)	Rev-T (h=6m)	3-colum (h=6m)	spread	fair	right (25m)	ok	constructed 1964	1-lane	1-lane	1-lane	bridge	—
	153.0	0.0	(Mandimba)																	

1.3.4 Findings by Site Survey

In this road section 14 bridges were investigated. The road goes in almost same elevation from east (Cuamba, El. 559) to west (Mandimba, El. 764m), and the middle of this road section is marshy area without any bridge.

No.1-Muanda Bridge is road/railway bridge with 2-lane 6m width for road traffic. This bridge was constructed as very stiff structure system because of safe railway transportation.


Photo 1.3.1 No.1-Muanda Bridge

No.2-Ningare Bridge was constructed by the grant fund of GOJ in 2004. It has 7.2m road width and is kept in very good condition.


Photo 1.3.2 No.2-Ningare Bridge

No.6-Lugenda Bridge is constructed by RC-T continuous girder with 2-lane width, which has been kept in good condition because of the continuous girder system which is stronger than simple girders.


Photo 1.3.3 No.6-Lugenda Bridge

No.10-Lussengessi-I Bridge is constructed by RC-T simple girders, its condition is structurally fair and it has 2-lane road width.


Photo 1.3.4 No.10-Lussengessi-I Bridge

No.5-Muambessi, No.12-Lussangassi, No.13-Ngolua and No.14-Ngame-II Bridges are constructed by RC-T simple girders, their condition is structurally fair but they have only 1-lane road width.


Photo 1.3.5 No.5-Muambessi Bridge (left) and No.12-Lussangassi Bridge (right)


Photo 1.3.6 No.13-Ngolua Bridge (left) and No.14-Ngame-II Bridge (right)

No.3-Manjamanja, No.4-Namicango, No.9-Lussengessi-II and No.11-Kadawada Bridges are constructed by RC-slab with 1-lane width, but there is damage to slabs, gird posts and abutments.


Photo 1.3.7 No.3-Manjamanj Bridge (left) and No.4-Namicango Bridge (right)


Photo 1.3.8 No.9-Lussengessi-II Bridge (left) and No.11-Kadawada Bridge (right)

No.7-Tarikajao and No.8-Pimbinu Bridges are constructed by H-beam with 1-lane width, but there is damage to slabs and gird posts.


Photo 1.3.9 No.7-Tarikajao Bridge (left) and No.8-Pimbinu Bridge (right)

Chapter 2 Natural Condition Survey for the Study Road

2.1 Natural Conditions

2.1.1 Location and Area

Niassa Province is located on the north-western part of Mozambique, between latitude 11° 25' north and 15° 26' south and longitude 38° 21' east and 34° 30' west, and it is the largest province with an area of 129,000 km^2. It is bounded on the north by Tanzania, on the west by Malawi, on the east by Cabo Delgado Province and on the south by Nampula and Zambezia Provinces.

The provincial capital and commercial centers are Lichinga and Cuamba. Cuamba is located along the Nacala corridor to the port of Nacala. Location map is shown in Figure 2.1.1.

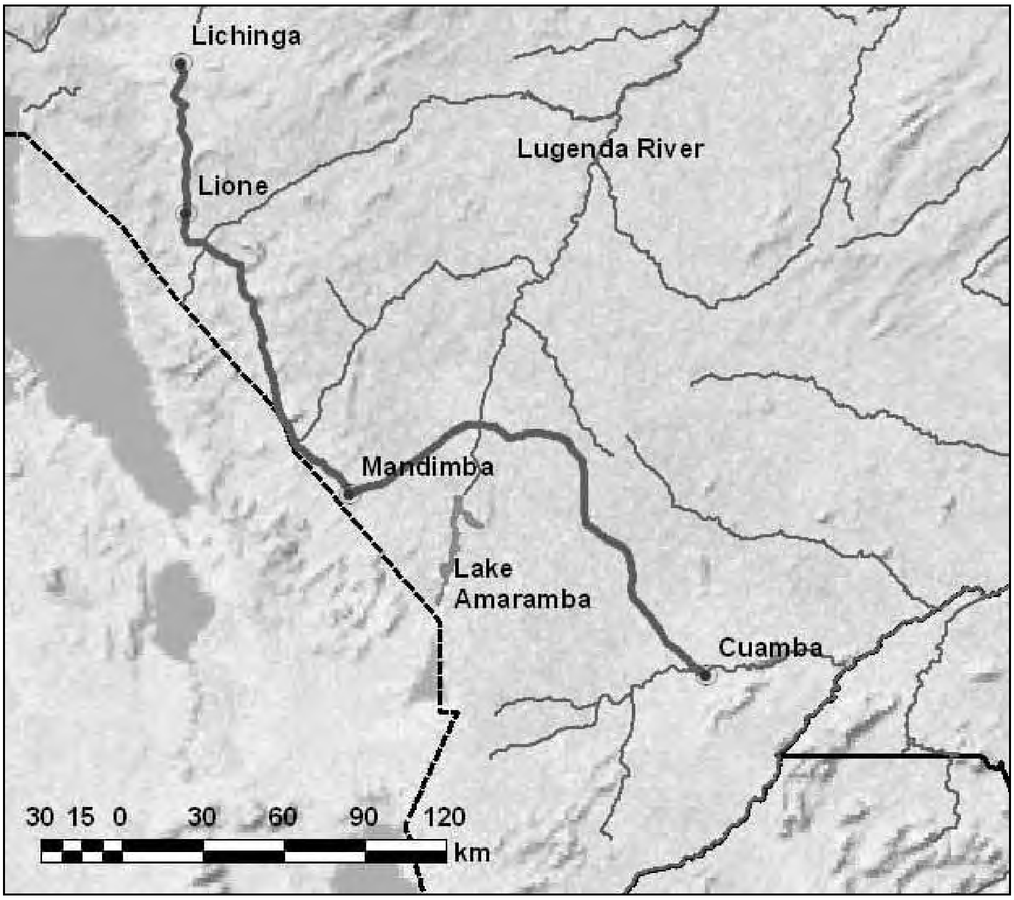


Figure 2.1.1 Location Map of Study Area

2.1.2 Topography

Altitude ranges from 600m above sea level to the high plateau of Lichinga, 1400m above sea level. Most of the undulating plains and mountains are covered in indigenous subtropical forest.

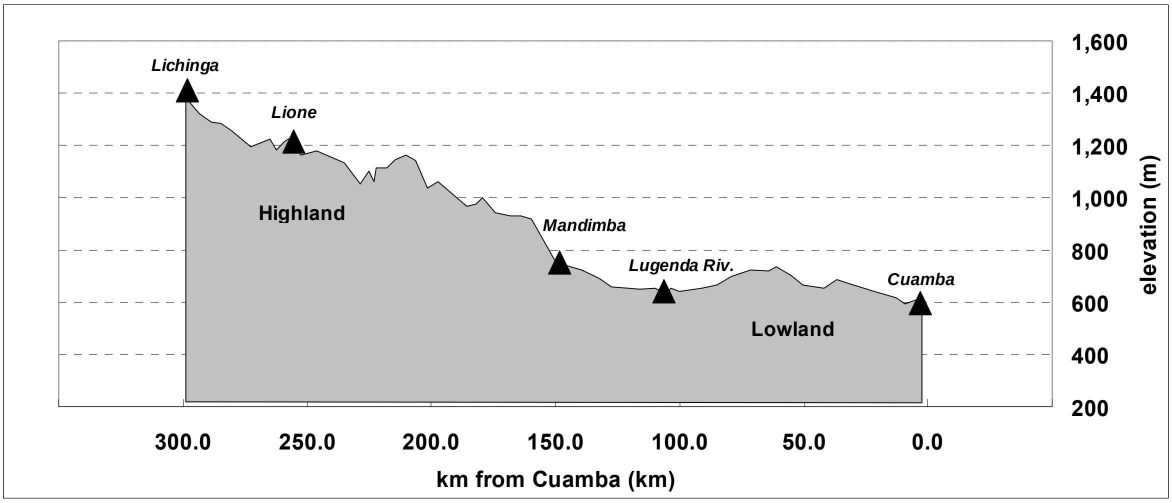


Figure 2.1.2 Topographic Section of the Study Area

Topographic section of the Study area is shown in Figure 2.1.2. Between Lichinga to Mandimba, the elevation decreases from 1400m to 700m. The gradient in this area shows 0.43%. On the other hand, between Mandimba to Cuamba, topography is slightly flat and the gradient only shows 0.12%.

Between Lichinga and Lione, the road does not cross any river, however from Lione to Mandimba and Mandimba to Cuamba, the road crosses various rivers. The flow direction of most rivers is from south to north, although some rivers between Mandimba and Cuamba do not exist currently because of the quite flat topography. The biggest river in study area is Lugenda River which comes from Amaramba Lake. Lugenda River goes along the border between Mozambique and Tanzania and flows into the Indian Ocean.

2.1.3 Climate

From the meteorological point of view, the province is categorized as follows:

(1) Lowland area around Cuamba (600m alt.).

Cuamba has an average annual temperature of 24°C in the lowlands hot. In colder months, in June, the temperature can drop to 14°C at night and reach a maximum of 30°C during the day. In the warmer months of the year, October and November, the average daily maximum temperature can reach 35°C and the lowest temperature at night is around 22°C. Temperature and precipitation in Cuamba are shown in Figure 2.1.3.

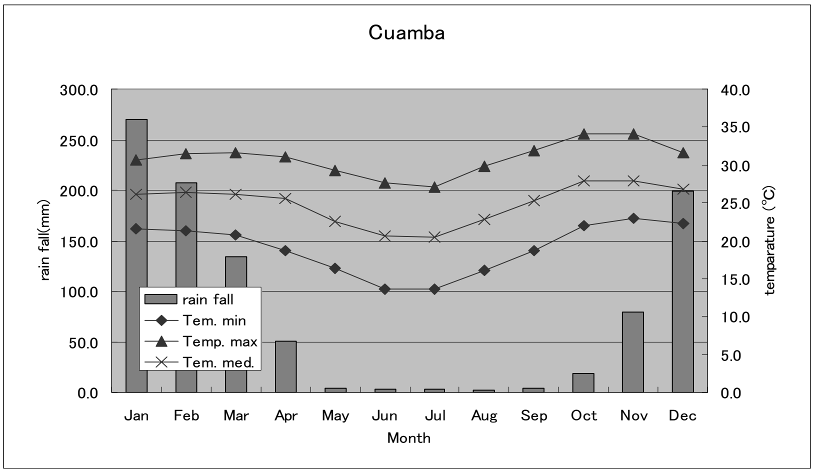


Figure 2.1.3 Temperature and Precipitation in Cuamba

(2) Highland area around Lichinga (1300m alt.)

The provincial capital, Lichinga, has an average annual temperature of 19°C in the high plateau. In July, the lowest average temperature at night is 10°C and the highest during the day is 22°C. In November, the hottest month of the year, the lowest average temperature during the night is 15°C and highest average temperature during the day is 28°C. Temperature and precipitation in Lichinga are shown in Figure 2.1.4.

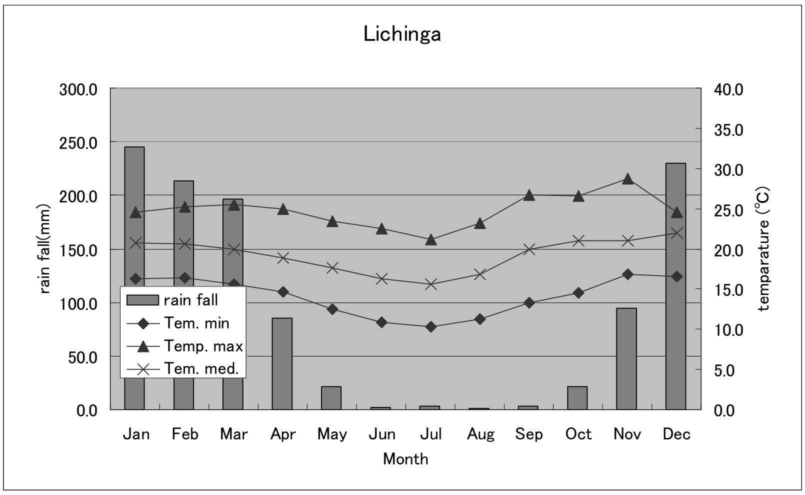


Figure 2.1.4 Temperature and Precipitation in Lichinga

The average rainy season on the high plateau and in surrounding areas varies from 18 to 21 weeks. The southern and central regions of the province have a rainy season from 13 to 18 weeks. The rainy season begins in December and ends in April. In the high plateau and along the shores of Lake Niassa you can expect an average rainfall of 1300 mm. In more arid areas in southern Niassa near Cuamba, rainfall is more normal at between 800~1000 mm. Due to extension of the period of medium rain actually available, the amount of precipitation and temperature limits, you can expect a growth period from 180 to 210 days for crops dependent on rain. The growing season begins in November and without irrigation can only be a certain period every year.

2.1.4 Geology

Geological map of study area is shown in Figure 2.1.5

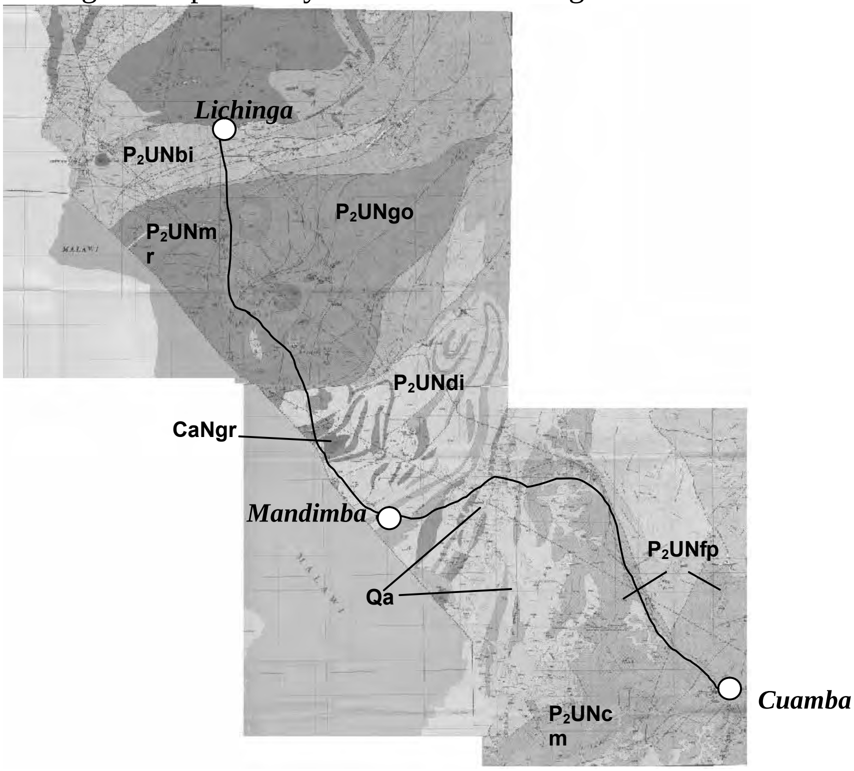


Figure 2.1.5 Geological map of study area

Source; Ministério dos Recursos Minerais /Direcção Nacional de Geologia, 2007

The geology of the Study area consists of the following three types.

A	Quaternary (Recent)	**Qa**		Alluvium deposit
B	Cambrian	**CaNgr**		Gneissic granite
C	Proterozoic (Pre-Cambrian)	**P_2UNgo**		Granitic to granodioritic migmatitic gneiss
		P_2UNmr		Chala gneiss(banded mafic granulitic gneiss
		P_2UNdi		Granitic to granodioritic gneiss
		P_2UNbi		Biotite gneiss, partly mylonitic
		P_2UNcm		Charnokitic gneiss, partly migmatitic
		P_2UNfp		Monte Elinasse Charnoclitic granofels and gneiss

A: Alluvium deposits of Quaternary

Alluvium deposits of Quaternary age are seen near Lugenda River between

Mandimba and Cuamba. This deposit is characterized as the swamp deposit composed of mud, very fine to medium sand. However, black cotton soil which affects the road design is not common in the Study area.

B: Gneissic granite of Cambrian

Gneissic granite of Cambrian age is partly seen as intrusion rock. This intrusion rock remains as the mountain/hill known as “Lissiete Mountain” between Lichinga and Mandimba.

C: Metamorphic rock of Precambrian

Most of the geology in the Study area consists of metamorphic rock such as gneiss of Precambrian age. These metamorphic rocks consist of schist, gneiss and granulite, which was formed by Pan-African organic belt (Mozambique organic belt). As the result of the long-term orogenic cycle, the geological aspect of these rocks is highly metamorphosed and characterized by compositional banding of dominated strike in the N-S direction. Normally the rock is covered by top soil layer, however, near the existing bride and hill site, the outcrop can be seen.

2.1.5 Earthquake

Seismic epicenters are shown in Figure 2.1.6 According to this figure, the earthquake of more than magnitude 5 did not occur in Niassa Province in the period of 1963 to 2007 (34years). Epicenters are concentrated near the Niassa Lake along the African Great Rift Valley and Mozambique channel in the Indian Ocean. The depth of epicenters ranges from minimum10km to maximum 33km, while average depth is 18km. From above mentioned information, earthquakes which affect structures such as bridges and roads have not occurred in the past in Niassa Province.

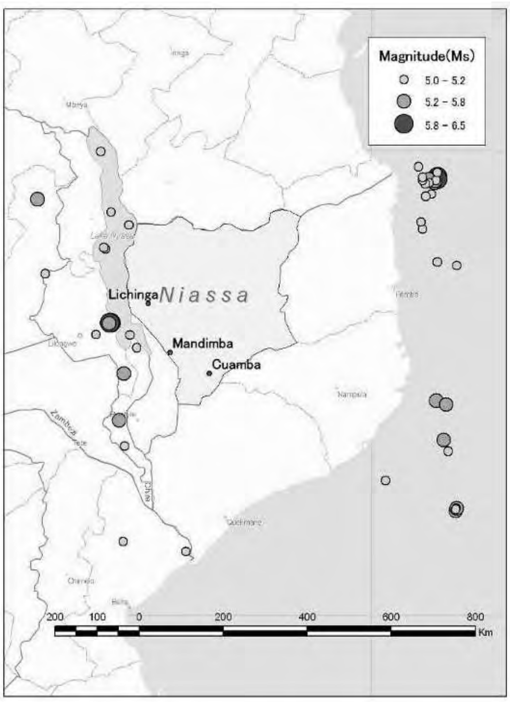


Figure 2.1.6 Map of Earthquake Distribution (1963-2007) :
Source: Institute Nacional de Meteorologia

2.1.6 Erosion

Condition of erosion in the Study area are shown in Figure 2.1.7. In the Study area, the erosion hazard categories vary from 2 (low) to 6 (high) level. The lowland which is covered by the recent alluvium deposit between Cuamba to Mandimba has low erosion hazard (category 2) due to the flat topographical condition. The highland which is exposed weathered rocks and soil with high gradient between Mandimba to Lichinga has high erosion hazard (category 6) and is affected by erosional surroundings.

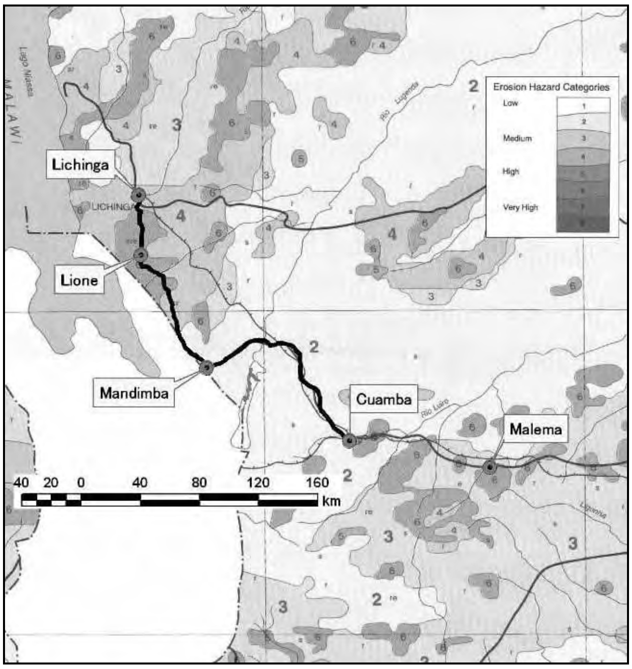


Figure 2.1.7 Erosion Hazard Map

2.2 Topographic Survey

2.2.1 General

The aim of the topographic survey is to confirm the existing topographic condition for the Study Road with a view to making a road design. Topographic survey is composed of the following four works.

- Road alignment survey (center line survey, longitudinal survey, cross section survey)
- Aerial survey
- Bridge survey
- Benchmark setting

2.2.2 Road Alignment Survey

(1) Scope of the work (First Stage)

- 150km between Cuamba and Mandimba: 50m interval.

- 6km between Mandimba and Malawi border: 50m interval

Survey width for the cross section survey shall cover 30m width toward outside on both sides of the centerline (total 60m)

(2) Scope of the work (Second Stage)

- Section -1: 22km from Cuamba (L=7.1km)
- Section -2: 60km from Cuamba (L=7.8km)
- Section -3: Mandimba (L=4.1km)

(3) Survey method

The survey was done on the WGS 84 UTM Zone 37 System. From the previous survey of Nampula-Cuamba benchmarks were placed every 1km.

The difference between GPS heights and leveling heights comes from the ellipsoidal height and a geoids height. The GPS is based on the geoid, which is a curved ellipsoid and the level height is the orthometric height, which is the height on the ellipsoid and is the height above mean sea level.

(4) Survey Results

All of the above results are processed into drawing and digital data using AUTOCAD and Microsoft Excel.

2.2.3 Aerial Survey

(1) Scope of the work

The scope of the work of aerial survey is the following items.

A: Photography: Total length 311km (Cuamba- Lichinga: 305km, Mandimba-Malawi border: 6km, the width of the photograph is 5km)

B: Taking aerial photos: scale is 1/10,000 with “tif” file format.

C: Making the base map for design (scale is 1/10,000 with “dwg” file format)

(2) Equipment

The following equipment was used for the aerial survey
Aircraft: 402B
Camera: RMK TOP105
Film: Agfa x 100
Exposure: Auto
Chemicals: C41 Process
Processing machine: Hope

(3) Results

The best time for aerial photography in the Northern Regions of Mozambique is during June and July, when cloud cover is at the minimum expected for the year. The flying was done above cloud level, so close monitoring of the weather conditions was essential to achieve clear photography without the presence of clouds and cloud shadows.

The best time for flying is between 09:00 and 15:00, as before, but after these times the sun is too low. A low sun causes undesirably long shadows in the photography.

Although the aerial survey was delayed from the original schedule due to the poor climate condition, the work was done from 29 to 31 of July. As a result, The aerial photography was done on a scale of 1:10,000. And the base map was done on a scale of 1:10,000 in AutoCAD format.

2.2.4 Bridge Survey

(1) Scope of the work

Ten bridges are located to survey. Survey area of each bridge is 100m x 100m (10,000m^2).

Topographical surveys at the following bridge sites were performed as follows;

Cuamba – Mandimba

Muambessi River	S14 28.907 E36 17.653
Lussangassi River	S14 16.434 E35 49.764
Ngolua River	S14 21.202 E35 41.010
Ngame II River	S14 21.549 E35 40.041

(2) Results

All of the above results are made to the drawing and digital data using the AUTOCAD and Microsoft Excel.

2.2.5 Benchmark setting

(1) Scope of the work (First Stage)

The scope of the work of benchmark setting is the following items.

- 150km between Cuamba and Mandimba: 1km interval
- 6km between Mandimba and Malawi border: 1km interval

(2) Scope of the work (Second Stage)

- Section -1: 22km from Cuamba (6 points)
- Section -2: 60km from Cuamba (6 points)
- Section -3: Mandimba (4 points)

(3) Results

All the above results are set at site and the detailed coordination of each benchmark is shown in the Appendices.

2.3 Geological Survey

2.3.1 Boring Survey and Standard Penetration Tests (SPT)

(1) Scope of Work

The aim of the boring survey and SPT is to confirm the boundary between weathered layer and hard basement rock layer and the depth of foundation for the four bridges in the Study area. Two boreholes are performed for each bridge site. The Location of target bridges is as follows;

Cuamba-Mandimba section

- Muambessi bridge
- Lussangassi bridge
- Ngolua bridge
- Ngame II bridge

(2) Survey Results

Total twenty boreholes were drilled near the bridges at the points defined by consultants. Location of the each bridge is shown in Figure 2.3.1.During the drilling work, SPTs were carried out at regular intervals of approximately 1m. Other information such as top elevation of borehole, description of soil layers, depth of water table, depth of weathered rock, depth of hard rock, internal angle of friction and undrained compressive strength were also surveyed. Table 2.3.1 shows the summary of mechanical boring survey.

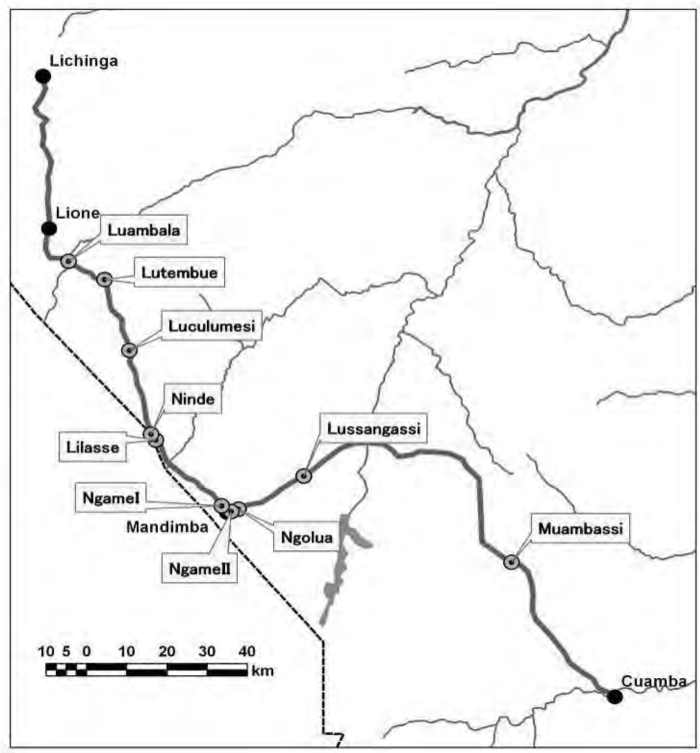


Figure 2.3.1 Location of the Mechanical Boring Points.

Table 2.3.1 Location and Summary of Mechanical Boring Survey

Bridge Name	Boring Number	Depth to Soil layer (m)	Drilling Depth (m)
Muambassi bridge	BH01	6.50	21.50
	BH02	7.50	22.00
Lussangassi bridge	BH03	3.00	15.00
	BH04	3.25	17.00
Ngolua bridge	BH05	5.00	15.75
	BH06	7.50	21.50
Ngame II bridge	BH07	18.00	28.50
	BH08	18.50	27.00

2.4 Soil & Material Survey

2.4.1 CBR and DCP Test

(1) Scope of Work (First Stage)

The aim of the California Bearing Ration (CBR) and Dynamic Cone Penetration (DCP) test is to confirm the bearing capacity of the in-situ sub-grade material so that the pavement will be able to fulfill the service objective over the design period. The sub-grade strength is usually evaluated by means of soaked CBR test results. At the same time, DCP test is also considered rather than the soaked CBR test, due to the fact that it is easier and quicker. In this study, the soaked CBR tests were carried out at the following intervals, while the DCP tests were also carried out for filling the gaps.

Cuamba-Mandimba-Malawi Border Road

- CBR Test: 10km interval
- DCP Test: 1km interval

(2) Scope of Work (Second Stage)

- CBR Test:
  Section -1: 22km from Cuamba (L=7.1km,1 point)
  Section -2: 60km from Cuamba (L=7.8km,1 point)
  Section -3: Mandimba (L=4.1km, 1 point)
- DCP Test:
  Section -1: 22km from Cuamba (L=7.1km,8 points, 1km interval)
  Section -2: 60km from Cuamba (L=7.8km,9 points, 1km interval)
  Section -3: Mandimba (L=4.1km, 5points, 1km interval)

(3) Sampling and Test Results

CBR tests were performed according to the TMH1 Test A8 procedures. Sub-grade CBR is usually decided based on the strength of soil at a point 1.0m below the surface. The tested materials were sampled at points 0.0-0.5m and 0.5-1.0m below the existing road surface, so that an appropriate design CBR is defined for in situ sub-grade unit.

The underlying principle of DCP test is the measurement of the penetration of the cone into the soil being tested. This rate of penetration gives an indication of the soil bearing capacity. Results of DCP tests were converted to in-situ CBR values based on the CICTRAN DCP/CBR relationship used commonly in South African countries.

Both results of CBR and DCP should be mentioned in Chapter 5 and discussed.

2.4.2 Borrow-Pit's Material Survey for Pavement Layer and Fill

(1) Scope of Work (First Stage)

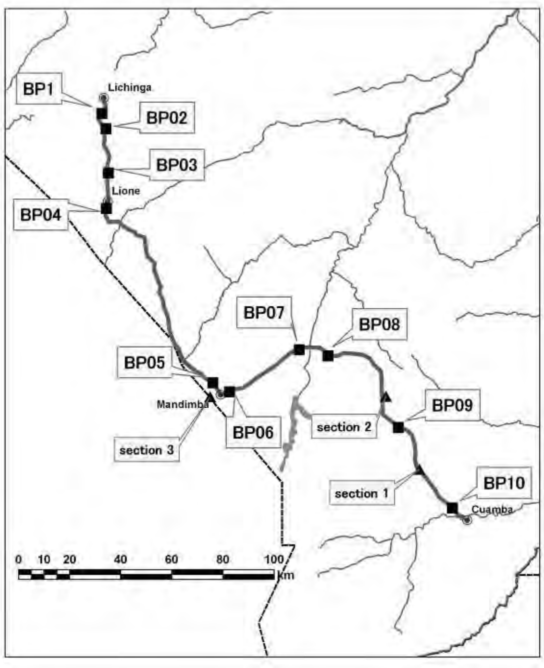
Some borrow-pit's material from appropriate spots along the Study Road were sampled by the Study Team for testing of fill and pavement layer materials Numbers of sampling are as follows:

- Cuamba-Mandimba section: 5 samples

Each borrow pit site is shown in Fig 2.4.1

(2) Scope of Work (Second Stage)

- Section -1: 28km from Cuamba (1point)
- Section -2: 64km from Cuamba (1point)
- Section -3: Mandimba (1point)



No.	Coordination	
	S	E
First Stage		
BP10	14.76301	36.47343
BP9	14.47824	36.28293
BP8	14.22408	36.03554
BP7	14.20252	35.93399
BP6	14.35218	35.68965
Second Stage		
Section 1	14.62628	36.35617
Section 2	14.36731	36.23836
Section 3	14.36933	35.62042

Figure 2.4.1 Location of the Borrow Pit

(3) Acceptable Material Quality

The recommendation stated are based on the SATCC requirements for road construction, as per Section 3300 and 3400 of Technical Specifications, and are given in Table 2.4.1:

Table 2.4.1 Recommended Material Qualities Based on the SATCC

Structure Location	Requirements
Fill	Depth below final surface 0.0m – 1.2m: Minimum soaked CBR = 3% at 90% modified AASHTO density 1.2m – 9.0m: Minimum soaked CBR = 3% at 100% modified AASHTO density
Selected layer	Lower: Minimum soaked CBR = 10% at 93% modified AASHTO density Upper: Minimum soaked CBR = 15% at 93% modified AASHTO density Maximum PI = 3 x Grading modulus (GM*) + 10
Sub base	Minimum soaked CBR = 30% at 95% modified AASHTO density Maximum PI for natural material = 10. For stabilized soil shall not exceed 6% after treatment GM minimum 1.5. A minimum of 1.2 can be authorized by the engineer
Base	Minimum soaked CBR = 80% at 98% modified AASHTO density Maximum PI for natural material = 6. For stabilized soil shall not exceed 6% after treatment GM minimum 2.0 for unstabilized material or 1.7 if the materials are to be chemically stabilized

*$GM=(300-(P_{2.00mm}+P_{0.425mm}+P_{0.075mm}))/100$

$P_{2.00mm}$, etc., denotes the percentage passing through the sieve size.

(4) Results of the Material Survey

Table 2.4.2 summarizes the results of the borrow-pit's materials between Cuamba-Mandimba. And Photos 2.1.1 to 2.1.5 show the borrow pit sites. All of the tests are based on SATCC, TRH or equivalent.

According to the results of the tests for fill and pavement layer materials, fill and selected layer material should be distributed over a wide area and readily obtained at the periphery of the Study Road. In contrast, natural material for sub-base is quite limited, and natural material for base should not be supplied from the target area.

However, in case that crushed stone for base and sub-base is in short supply, natural material stabilized with cement can be considered as sub-base course material.

Crushed stone for use as both base and sub-base is in short supply, thus use of natural gravel should be considered because it generally is distributed over a wide area. The quality of the natural gravel also tested for use of the sub-base with several mixture compositions.

Table 2.4.2 Results of the Borrow-pit's Material Tests for Cuamba-Mandimba

Km* (BP No.)	GM	PI	OMC	CBR (%)			BP Utilization
				90%	95%	100%	
8.0km+000 (BP10)	1.8	11%	7.2%	6	21	97	Fill/Selected/ (Cemented sub-base**)
51km+700 (BP9)	1.8	11%	6.8%	67	72	69	Fill/Selected/ (Cemented sub-base**)
105km+000 (BP8)	1.4	5%	6.8%	2	12	16	Fill/Selected
111km+000 (BP7-3rd Lyr)	2.2	9%	7.6%	15	21	19	Fill/Selected/ (Cemented sub-base**)
111km+000 (BP7-2nd Lyr)	1.9	14%	9.5%	13	10	7	Fill/Selected
145km+000 (BP6-2nd Lyr)	2.6	7%	6.8%	21	43	112	Fill/Selected/Sub-base
145km+000 (BP6-1st Lyr)	1.9	15%	9.3%	6	5	5	Fill
28km+000 Section -1	1.3	4%	6.7%	37	45	60	Fill/Selected/Sub-base
64km+400 Section -2	2.1	-	8.5%	20	22	23	Fill
Mandimba Section-3	0.9	18.8%	18.6%	1	5	9	Fill

*Km starts from Cuamba.
**It denotes a possibility to use as sub-base material by stabilization with cement.

Photo2.1.1 B.P.10 (Borrow Pit)

Photo2.1.2 B.P.9 (Borrow pit)

Photo2.1.3 B.P.8 (Borrow Pit)

Photo2.1.4 B.P.7 (Borrow pit)

Photo2.1.5 B.P.6 (Borrow Pit)

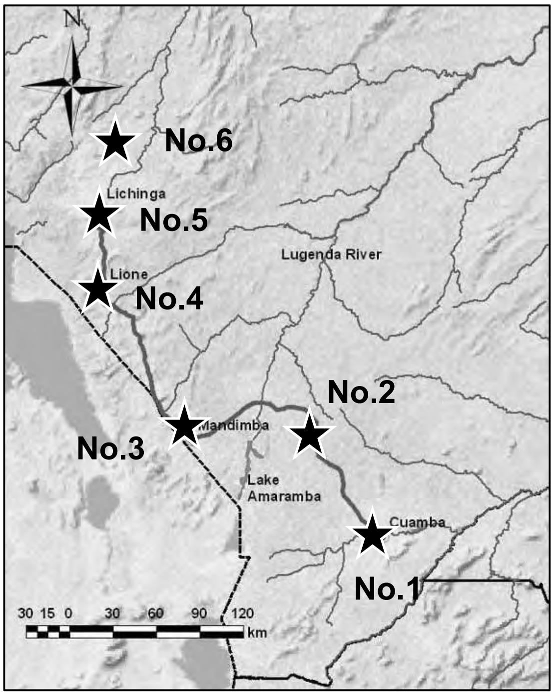
2.4.3 Quarry's Material Survey for Pavement Layer and Concrete Work

(1) Scope of Work

Some quarry materials were sampled to confirm the possible positions of materials to be used in both pavement and concrete work. And each estimated available volume of the quarry site was also surveyed. Number of sampling locations is as follows:

Cuamba-Mandimba-Lichinga section: 6 samples (5 samples for original contract and 1 sample for additional contract)

Each quarry site location is shown in Figure 2.4.2



No.	Coordination	
	S	E
Cuamba – Mandimba		
1 Cuamba	14.76301	36.47343
2 Manhumar	14.47824	36.28293
Mandimba - Lichinga		
3 Chanica	14.32012	35.63077
4 Lione	13.70239	35.25617
5 Lichinga City	13.57707	35.26247
6 Bangalira	13.41993	35.25448

Figure 2.4.2 Location of the Quarry Sites

(2) Acceptable Material Quality

In this survey, two tests were performed to confirm material quality. One is Aggregate Crushing Value (ACV), and the other is the Aggregate Crushing Strength (10% FACT). As shown in Table 2.4.3, according to ANE standards, the maximum ACVs required for surfacing and base-course are 25% and 28%, respectively. Acceptable value of the quality of the crushed stone is shown in Table 2.4.3. And according to SATCC specifications, the aggregate crushing strength (10% FACT) for the various road applications shall not be less than the values shown in Table 2.4.4.

Table 2.4.3 Acceptable Values for the Quality of the Crushed Stone

Utilization	Wearing Course	Base Course	Concrete
ACV (%)	25 (32) or below	28 (32) or below	45 or below

Note: ( ); Exceptional Values

Table 2.4.4 Acceptable Minimum Values of 10% FACT

Rock Road Application	Force that Produces 10% FACT (KN)
Crushing stone (section 3702 of SATCC Specs)	110KN
Surfacing (section 4202 of SATACC Specs)	180KN
Seals (section 4302 of SATACC Specs)	210KN

(3) Sampling Location and Results of Quarry Survey

The results of the quarry survey are shown in Table 2.4.5. Moreover, Photos 2-1-6 to 2-1-11 show the photos of each quarry site. From the test results, between Cuamba and Mandimba, quarry sites can be used for road construction materials such as seals or crushed stone for base course. On the other hand, between Mandimba and Lichinga, the material of quarry sites is not available for road construction. The only quarry site which is used for road construction such as seals or crushed stone for base course is located approximately 30km north of Lichinga city.

Table 2.4.5 Results of Quarry Site Survey

No.	Quarry site location and Name	Mechanic Strength		Estimated Available Value(m^3)	Remarks
		ACV (%)	10% FACT (KN)		
1	Cuamba/Mandimba section – Cuamba R720	26.0	187	800,000m^3	This quarry site is planning to use for Nampra-Cuamba road construction work
2	Cuamba/Mandimba section – Munhumar	25.3	191	540,000m^3	Can be used for seals and crushed stone for base course
3	Lichinga/Mandimba section – Chanica Village	30.3	163	70,000m^3	Can be used as crushed stone for base course
4	Lichinga/Mandimba section – Lione Village	46.7	-	10,550m^3	Not suitable for use in road construction
5	Lichinga/Mamdimba section –Lichinga city	32.6	-	122,500m^3	Not suitable for use in road construction
6	Lichinga/Mamdimba Section- Bagarila	17.7	235	630,000m^3	Can be used as crushed stone for seals

Photo 2.1.6 Quarry site 1 (Cuamba)

Photo 2.1.7 Quarry site 2 (Munhumar)

Photo 2.1.8 Quarry site 3 (Chanica)

Photo 2.1.9 Quarry site 4 (Lione)

Photo 2.1.10 Quarry site 5 (Lichinga city)

Photo 2.1.11 Quarry site 6 (Bagarila)

Chapter 3 Hydrology and Hydrological Analysis

3.1 Hydrological Analysis

3.1.1 Catchment Area

The delimitation and determination of the catchment areas and river lengths were initially made using topographical maps at a 1:50.000 scale. A map with the catchment areas is shown at the close of the chapter (Figure 3.1.1).

The use of the above referred maps did not allow for the identification of the small catchments. To solve this problem, during the field visit identification was made of all existing drainage structures and low spots where a visual inspection indicates the need for transversal drainage.

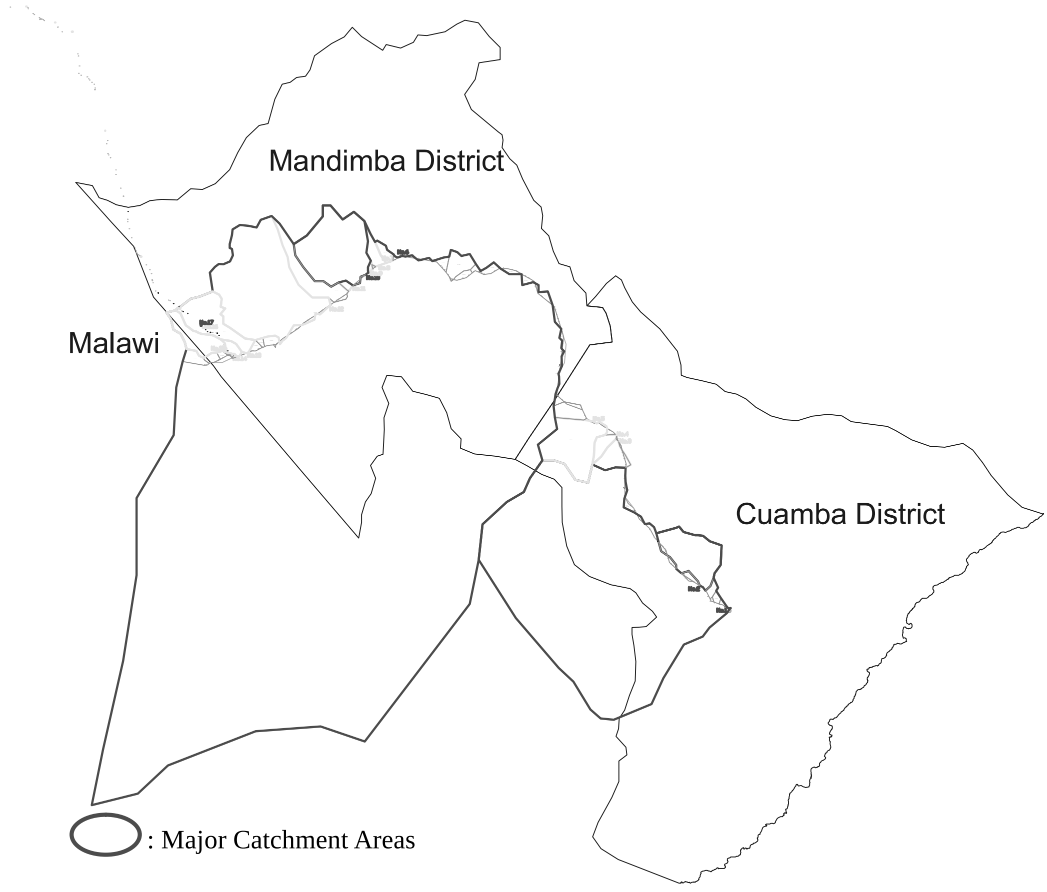


Figure 3.1.1 Major Catchment Areas for the Study Road

3.1.2 Rainfall Analysis

Daily rainfall data were supplied as below from two rainfall stations.

Table 3.1.1 Rainfall Data Supplied

Rainfall Station	Start Date of Data	End Data of Data	Missing Record
Cuamba	1960	2008	1975-1976
Mandimba	1973	1983	1979,1981

A statistical analysis was done on the rainfall data at stations Cuamba and, Mandimba. Two statistical distribution methods (Iwai Method and Log Pearson III) were applied to the observed rainfall records.

Table 3.1.2 Day Design Rainfall at each of the Rainfall Stations

Duration	1 Day Return Period Rainfall (mm)					
	2	5	10	20	50	100
Cuamba	75.7	97.9	111.4	123.5	138.2	148.7
Mandimba	82.2	101.9	113.1	122.9	134.3	142.2

The statistical rainfall at Mandimba is not supplied with a high confidence due to the short records. The calculated design rainfall may prove to be more conservative than necessary. Hence an average of the design rainfall experienced at Cuamba may prove sufficient for the purposes of the Study.

3.2 Flood Hydrology

3.2.1 Determination of the Run-off Modeling

Flood hydrological methods used in this Study include the Rational method and Regional Maximum flood. Not all methods could be applied to calculating the flood peaks at each catchment. The Rational method can be applied to catchments up to $500km^2$.

The Regional Maximum Flood (RMF) can only be applied to large catchments and is based on a regional K factor. There has been work done in southern Mozambique where the K factor varies from 5 - 5.6. A sensitivity analysis will be performed to compare the flood peaks.

Table 3.2.1 Limitation of Flood Calculation Method

Method	Maximum Area (km2)
Alternative Rational Method	No limitation (0 to 500: Study Team Recommendation)
Empirical Method (RMF)	No limitation

Source: Drainage Manual 5th Edition (SA National Road Agency)

3.2.2 Alternative Rational Method

The Rational formula is defined as:

Q = 0.278 c I A

Where,

Q: Discharge (m3/s)

c: Runoff coefficient

I: Average rainfall intensity over the whole catchment for a duration corresponding to the time of concentration

A: Catchment area (km^2)

Note: In Alternative Rational Method, rainfall intensity is derived from following formula.

IT = (PT/Tc) x ARF

The Rational formula has the following assumptions:

- The rainfall has a uniform area distribution across the total contributing catchment
- The rainfall has a uniform time distribution for at least a duration equal to the time of concentration
- The peak discharge occurs when the total catchment contributes to the flow occurring at the end of the critical storm duration, or time of concentration.
- The runoff coefficient, C remains constant for the storm duration, or time of concentration
- The return period of the peak flow, T, is the same as that of the rainfall intensity

It was assumed that the flows in the various catchments were in a defined water course. Time of concentration was hence calculated using the following formula:

Tc = ((0.87×L2)／(1000×S))0.385: Defined Watercourse

Tc = 0.604(rL/(S1/2))0.467: Overland Flow

Where,

Tc: Time of concentration (hour)

L: Hydraulic length of catchment, measured along flow path from the catchment boundary to the point where the flood needs to be determined (km)

S: Average slope (m/m)

In this Study, an "alternative" Rational application is used (as applied in the Universal Programs for Discharge and explained in the Roads Design Manual - South Africa - 5th edition)

The modified recalibrated Hershfield relationship could be used to determine point rainfall, which is then converted to intensity by dividing the point rainfall by the time of concentration for storm durations of up to 6 hours. For durations between 6 and 24 hours, linear interpolation is used between the calculated point rainfall from the modified Hershfield equation and the 1 day point rainfall. The Modified Hershfield relationship is given as:

PT = 1.13 x (0.41 + 0.64 x log(T)) x (-0.11 + 0.27 x log(t)) x (0.79 x M0.69 x R0.20)

Where,

PT: Precipitation depth for a duration of t minutes and return period of T years

t: Duration in minutes

T: Return period

M: 2-year return period daily rainfall

R: Average number of days per year on which thunder was heard

Note: it was assumed that that the average number of days on which it stormed was 80.

The point rainfall above is still subject to a areal reduction factor (ARF). Rainfall from flood producing storms is generally not evenly distributed temporally and spatially in a catchment. For this reason it is necessary to reduce the rainfall depth according to the catchment size and storm duration.

The ARF can be calculated using equation:

ARF = (9000-12800 x log(A) + 9830 x log(60 x Tc))0.4

3.2.3 Empirical Method (Regional Maximum Flood: RMF)

The Regional Maximum Flood (RMF) (Department of Water Affairs and Forestry, South Africa, TR137) approach was developed for southern Africa in the late 1980's and estimates flood peak discharges for the 1:50, 1:100 and 1:200 flood peaks. The RMF is calculated using the Francou-Rodier formula on the basis of the catchment area and a regional K factor. The Francou-Rodier relationship reads:

QRMF=106 x (A/108)1-0.1xk

Where,

QRMF: regional maximum flood peak flow rate (m3/s)

K: Regional constant

10^6: Total world MAR (m3/s)

10^8: Total world catchment area (km2)

The Regional Maximum Flood (RMF) can only be applied to large catchments and is based on a regional K factor. Report - TR137 - Regional Maximum Flood Peaks in South Africa (Department Water Affairs and Forestry) also included work done in southern Mozambique where the K factor varies from 5.0 -5.6. A sensitivity analysis was done to compare the flood peaks.

3.3 Design Discharge

3.3.1 Design Discharge for 4 New Bridges

The following 4 bridges will be replaced in this Study.

Table 3.3.1 Summary of Catchment Characteristics

Bridge	Catchment area (km2)	River Length (km)	Slope (m/m)	Time of Concentration (hours)
Muambessi	93.1	10.05	0.004	3.15
Lussangassi	300.1	29.60	0.008	5.90
Ngolua	67.4	17.09	0.009	3.65
Ngame II	44.2	17.20	0.012	3.23

The methods of analyses as described above were used to determine the capacity of each bridge structure. The design discharge for each bridge is determined by both the Rational Method and the Regional Maximum Flood (RMF).

The calculation results for each bridge are shown in Table 3.3.2 as below. As the result of calculation, the average between the Rational Method and the Regional

Maximum Flood (at K=5.0) is suggested for application as the flood peak, because it is more conservative.

These results are reviewed and compared by the site investigation results in sub-chapter 3.4.

Table 3.3.2 Calculation Results for Design Discharge for each Bridge

Bridge	Return Period	Flood Peak (m3/s)					
		Rational	RMF				Average
			K=5.0	K=5.2	K=5.4	K=5.6	
Muambessi	1:20	143.0	-	-	-	-	-
	1:50	253.8	370.1	488.6	645.0	1059.7	312.0
	1:100	307.8	474.0	633.5	832.8	1375.8	390.9
	RMF	-	964.9	1273.8	1681.6	2219.9	-
Lussangassi	1:20	263.4	-	-	-	-	-
	1:50	467.7	712.0	918.2	1184.1	1868.9	589.9
	1:100	567.2	895.6	1170.7	1506.8	2377.9	731.4
	RMF	-	1732.3	2234.0	2881.0	3715.3	-
Ngolua	1:20	94.1	-	-	-	-	-
	1:50	167.0	325.7	432.8	575.1	943.3	246.4
	1:100	202.5	413.3	556.1	735.4	1213.3	307.9
	RMF	-	821.0	1090.8	1449.4	1925.8	-
Ngame II	1:20	154.1	-	-	-	-	-
	1:50	215.6	271.7	364.1	487.9	801.5	243.7
	1:100	261.5	341.9	464.2	618.7	1022.6	301.7
	RMF	-	664.8	890.8	1193.7	1599.5	-

3.4 Flood Level Estimation for Bridges

3.4.1 Flood Level Analysis

As discussed above, the flood peaks for the 50 and 100 year return period from Table 3.3.1 should be determined by comparison of adequate method and result of site investigation.

Table below gives details of the existing bridges including the maximum water level recorded at each bridge.

Table 3.4.1 Deck Elevation and Water Level from the Site Survey

Bridge	Deck Elevation* (m)	Maximum Water Level Obtained by Field Survey (m)	Minimum Channel Elevation (m)
Muambessi	618.2	616.9	611.5
Lussangassi	639.4	637.5	633.3
Ngolua	706.5	706.2	699.0
Ngame II	710.9	709.2	704.5

* Deck elevations and minimum channel elevations were extracted from the topographic survey data.

3.4.2 Suggested Flood Level for 4 Bridges

The software used to model for the flood level calculation is HEC-Ras in which primary input is cross-sectional data, Manning's roughness and the flood peaks. Cross sections were extracted from the topographic survey. A Manning's roughness of 0.035 was assumed.

Table 3.4.2 shows the results of the flood level calculation by the HEC-Ras, which is based on the calculation for non-uniform flow.

Table 3.4.2 Suggested Flood Level for Return Period of 50-years and 100-years

Bridge	Return Period	Discharge (m3/s)	Calculated Flood Level (m)	Results of Field Survey (m)
Muambessi	50-Year	312.0	618.50	616.9
	100-Year	390.9	619.28	
Lussangassi	50 Year	589.9	639.42	637.5
	100 Year	731.4	639.92	
Ngolua	50-Year	246.4	704.16	706.2
	100-Year	307.9	704.85	
Ngame II	50 Year	243.7	708.61	709.2
	100 Year	301.7	709.15	

Chapter 4 Applicable Design Standards

4.1 General

The application of a proper design standard will ensure that the following objectives are achieved:

- Ensure safety, a high standard service level and comfort for road users by the provision of adequate sight distance and roadway space,
- Ensure that the roadway is designed economically
- Ensure uniformity in the design
- Ensure safety of the structures (bridges and culverts).

This Study aims to upgrade the Cuamba-Mandimba-Malawi Border Road which has a length of 153km. The Cuamba-Mandimba-Malawi Border road is a part of the Nacala Corridor. This road is the most important major corridor for achievement of the objectives of the PARPA and RSS.

For the design studies of the Nampula-Nacala Road and Nampla-Cuamba Road which are a part of Nacala Corridor, the Study Team proposed to use the Southern Africa Transport and Communications Commission (SATCC) design standards, as these were commonly used for other projects in the region.

Accordingly, the SATCC standards are the most appropriate standards to be applied for the Cuamba-Mandimba-Malawi Border Road.

The SATCC Standards prepared a set of standard documents for the design and construction of roads and related infrastructure. The documents are derived from mostly American and British practices but were specifically adapted for local conditions. These documents and codes are thus ideally suited for use on road projects.

4.2 Applicable Design Standards for Road Design

4.2.1 Geometric Design Parameter

(1) Applicable Design Standards

The road geometric design is based on the “SATCC Code of Practice for the Geometric Design of Trunk Roads”, September 1998.

(2) Sight Distance

Stopping and passing sight distance

Design speed	Stopping sight distance	Passing sight distance
100km/h	155 m	670 m
80 km/h	115 m	540 m
70 km/h	95 m	-
60 km/h	80 m	410 m
50 km/h	65 m	-
40 km/h	50 m	290 m

(3) Horizontal Alignment

Minimum radius & maximum super-elevation

Design Speed 100 kph		**Design Speed 80 kph**	
Minimum radius	Max. super-elevation	Minimum radius	Max. super-elevation
420-380-350	6%-8%-10% respectively	250-230-210	6%-8%-10% respectively
Design Speed 70 kph		**Design Speed 60 kph**	
Minimum radius	Max. super-elevation	Minimum radius	Max. super-elevation
190-175-160	6%-8%-10% respectively	140-125-110	6%-8%-10% respectively
Design Speed 50 kph		**Design Speed 40 kph**	
Minimum radius	Max. super-elevation	Minimum radius	Minimum radius
90-85-80	6%-8%-10% respectively	55-50-50	6%-8%-10% respectively

Minimum length of curve

Suggested (m)	Absolute (m)	
	DA > 5	DA < 5
300	150	150+30(5-DA)

*DA: Deflection Angle

Maximum length of curves

Suggested (m)	Absolute (m)
800	1,000

Super-elevation

The Study Team recommends the maximum super-elevation of 8% for design speed of 80km/h and 100km/h in consideration of the bicycle users and heavy vehicles with low speed. In town sections with low design speed, the maximum super-elevation of 6% is recommended.

Design Speed	Minimum radius	Maximum super-elevation
100km/h	380 m	8%
80 km/h	230 m	8%
70 km/h	190 m	6%
60 km/h	140 m	6%
50 km/h	90 m	6%
40 km/h	55 m	6%

Normal camber

The following are recommended as normal camber values by SATCC. The normal camber of 3% is adopted, because the Cuamba-Mandimba-Malawi Border Road is located in an area of heavy rain.

Low Rainfall	Heavy Rainfall
2%	3%

However, the Study Team recommends the normal camber of 2.5% in consideration of the bicycle users, low-speed traffic and drainage.

Minimum radius of curve with adverse cross-fall

Based on a 2.5% normal camber:

Design Speed	Calculated Value	SATCC Recommendations (SATCC Technical Unit, 1995)
100km/h	4100 m	4500 m
80 km/h	2700 m	3000 m
70 km/h	2100 m	2500 m
60 km/h	1600 m	1800 m
50 km/h	1100 m	1800 m
40 km/h	700 m	- m

$R=V^2/127(100e+fs)$

R: Radius of circular curve (m)

V: Design speed (km/h)

e: Normal Camber (-2.5%)

fs: Side Friction (fs = 0.19 – V/1600)

Maximum radius for use of a spiral curve

Design Speed	Maximum radius for use of a spiral
100km/h	1500 m
80 km/h	900 m
70 km/h	700 m
60 km/h	500 m
50 km/h	350 m
40 km/h	250 m

R＝0.145V2

Super-elevation rate

The following table is recommended for super-elevation rate values by SATCC. However, the design speed of less than 60km/h is out of scope, because applicable range of SATCC is trunk road with high design speed. Therefore, the Study Team recommends to apply the SANRAL manual of South Africa.

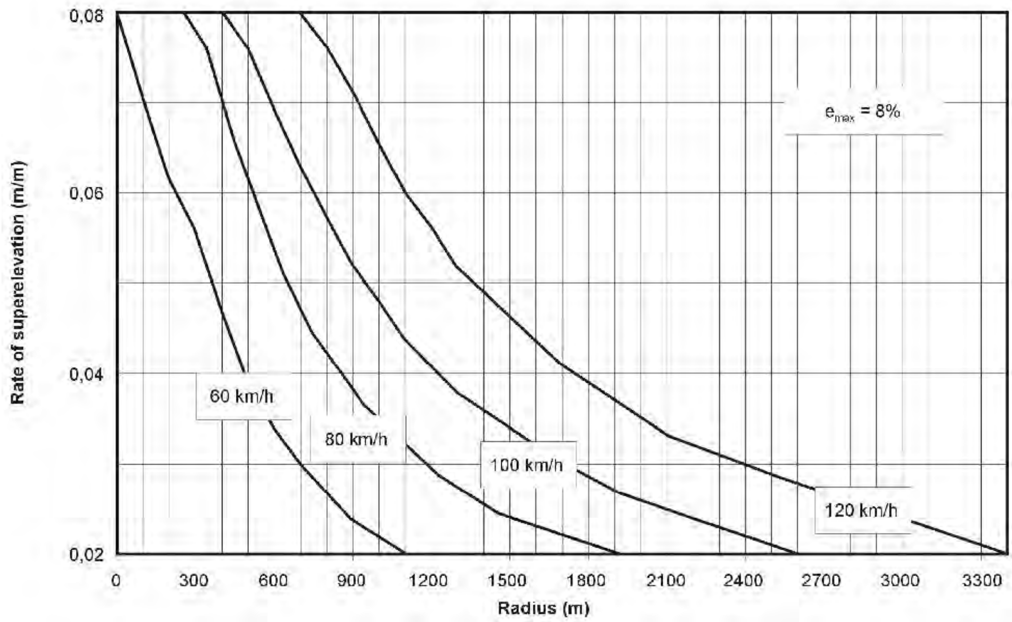


Figure 4.2.1 Super-elevation rates by SATCC standard

Table 4.4 Values of superelevation for above min radii of curvature (%): e_{max} = 6 %

RADIUS (m)	DESIGN SPEED (km/h)									
	40	50	60	70	80	90	100	110	120	130
7000	NC	NC	NC	NC	NC	NC	NC	NC	RC	RC
5000	NC	NC	NC	NC	NC	NC	NC	RC	RC	RC
4000	NC	NC	NC	NC	NC	NC	RC	RC	RC	2,3
3000	NC	NC	NC	NC	NC	RC	RC	2,0	2,4	3,5
2000	NC	NC	NC	RC	RC	2,3	2,2	2,9	3,4	4,0
1500	NC	NC	RC	RC	2,4	2,9	2,9	3,6	4,2	4,9
1400	NC	NC	RC	RC	2,5	3,1	3,1	3,8	4,4	5,1
1300	NC	NC	RC	2,1	2,6	3,2	3,3	4,1	4,6	5,3
1200	NC	NC	RC	2,3	2,8	3,3	3,4	4,3	4,8	5,5
1000	NC	RC	2,1	2,7	3,2	3,7	4,0	4,8	5,4	5,8
900	NC	RC	2,3	2,9	3,4	3,9	4,3	5,1	5,7	6,0
800	NC	RC	2,5	3,1	3,6	4,2	4,6	5,4	5,9	
700	NC	2,1	2,7	3,4	3,9	4,5	5,0	5,8	6,0	
600	NC	2,4	3,0	3,7	4,2	4,8	5,4	6,0		
500	RC	2,7	3,4	4,1	4,8	5,2	5,9			
400	2,3	3,1	3,8	4,5	5,1	5,7	6,0			
300	2,8	3,7	4,4	5,1	5,7	5,9				
250	3,1	4,0	4,8	5,5	6,0	6,0				
200	3,6	4,5	5,2	5,9						
180	3,8	4,7	5,4	6,0						
160	4,0	4,9	5,8							
140	4,3	5,2	5,9							
120	4,6	5,5	6,0							
100	4,9	5,8								
90	5,1	6,0								
80	5,4									
70	5,6									
60	5,9									
50	6,0									

Figure 4.2.2 Super-elevation Rates by SANRAL Standard (For Urban Area)

Spirals lengths (SATCC 1998):

L (spiral) =0.0702V3/ (RC)

V: Design speed (km/h)

R: Radius of circular curve (m)

C: Rate of increase in centripetal acceleration (m/s3); 1<C<3

Design Speed=	100
C (SATCC)=	1.438
R	L spiral (m) SATCC 1998
380	128
500	98
600	81
700	70
800	61
900	54
1000	49
1200	41
1400	35
1500	N/A

Design Speed=	80
C (SATCC)=	1.438
R	L spiral (m) SATCC 1998
230	109
300	83
400	63
500	50
600	42
700	36
800	31
900	N/A

Design Speed=	70
C (SATCC)=	1.438
R	L spiral (m) SATCC 1998
190	88
200	84
300	56
400	42
500	33
600	28
700	N/A

Design Speed=	60
C (SATCC)=	1.438
R	L spiral (m) SATCC 1998
140	75
200	53
250	42
300	35
350	30
400	26
450	23
500	N/A

Design Speed=	50
C (SATCC)=	1.438
R	L spiral (m) SATCC 1998
90	68
150	41
200	31
250	24
300	20
350	N/A

Design Speed=	40
C (SATCC)=	1.438
R	L spiral (m) SATCC 1998
55	57
100	31
150	21
200	16
250	N/A

Run-out & run-off lengths:

L (run-off) = ewl/(s x 150%) where:

w: Lane width (m)

e: Super-elevation at the start of the circular curve (%)

s: Relative slope factor (%); s = 0.5 or 0.4 (respectively design speed = 80 or 100 km/h)

l: Lane factor (= 1 in case of undivided two lanes)

The same formula is used for run-out, but super-elevation goes from 2.5% (recommended camber by the Study Team) to 0%.

(4) Vertical Alignment

Minimum values of K for vertical curves

Design speed	Crest curve	Sag curve	Absolute
100 km/h	60	36	Lv =(V^2/360) x D*
80 km/h	33	25	
70 km/h	23	20	
60 km/h	16	16	
50 km/h	11	12	
40 km/h	6	8	

*D: absolute value of algebra of vertical gradient (necessary length for impact alleviation)

Strict acceptance of the K value would mean a substantial increase in earthworks in this project area with hilly and mountainous terrain, with corresponding increase in costs as well as the design speed.

As a general rule, at least the absolute value (minimum requirement length for impact alleviation) has to be secured for comfortable driving. At the same time, since the K value does not meet the required parameters, appropriate traffic operations such as markings and warning signs shall be installed for the safety of all road users.

Minimum lengths of vertical curves

Design speed	Curve length (m)
100km/h	180
80 km/h	140
70 km/h	-
60 km/h	100
50 km/h	-
40 km/h	80

Maximum gradients

Design speed	Maximum gradient (%)		
	Flat	**Rolling**	**Mountainous**
100km/h	4	5	6
80 km/h	5	6	7
70 km/h	-	-	-
60 km/h	6	7	8
50 km/h	-	-	-
40 km/h	7	8	9

Critical lengths of grades

Gradient	Length of grade (m)
3 %	500
4 %	300
5 %	240
6 %	200
7 %	170
8 %	150

Acceptance of the above tables would mean a substantial increase in earthworks, with corresponding increase in costs and additional risks to the destabilization of the local soil strata. Thus the Study Team reviewed the climbing ability for the large trucks. Based on that result, the Study Team recommends applying the following table as adequate critical length of grades:

Recommendable critical lengths of grades

Gradient	Length of grade (m)
3 %	N/A
4 %	N/A
5 %	1500
6 %	700
7 %	500

4.2.2 Typical Cross Sections

For the Nampula-Nacala road and Nampula-Cuamba road, a 7.0m carriageway width and 1.5m shoulder width (1.0m paved shoulder and 0.5m soft shoulder) were adopted as the typical cross section. The Lichinga-Montepuez road also adopted a 7.0m carriageway width and a 1.5m paved shoulder as recommended in SATCC 1998.

The Study Team recommends that the same typical cross section as the Nampula-Nacala road and Nampula-Cuamba road is adopted to ensure consistency in the design standard. In addition, the risk of traffic accidents is likely to increase with increased volume of traffic and higher driving speeds. Therefore, a 2.5m shoulder width (2.0m paved shoulder and 0.5m soft shoulder) is proposed in populated areas, as a large number of pedestrians use the road. Proposed typical cross sections are follows:

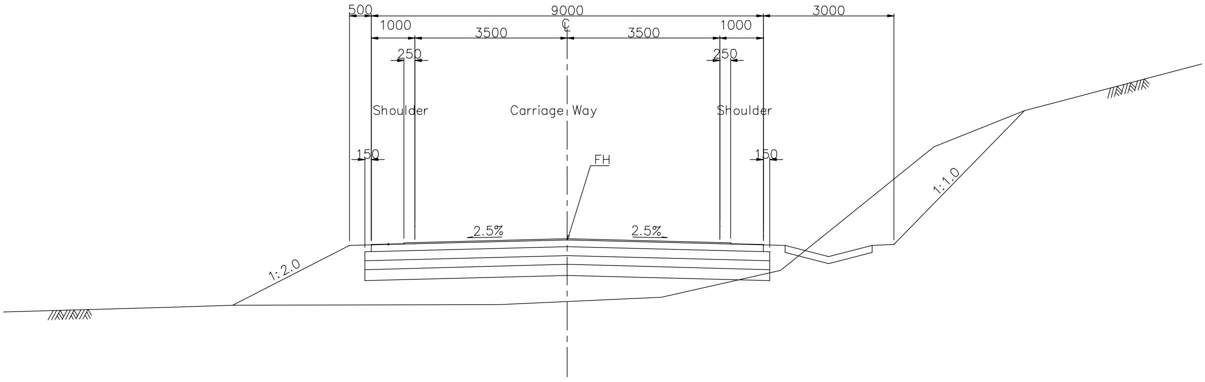


Figure 4.2.3 Proposed Typical Cross Section (Unpopulated Area)

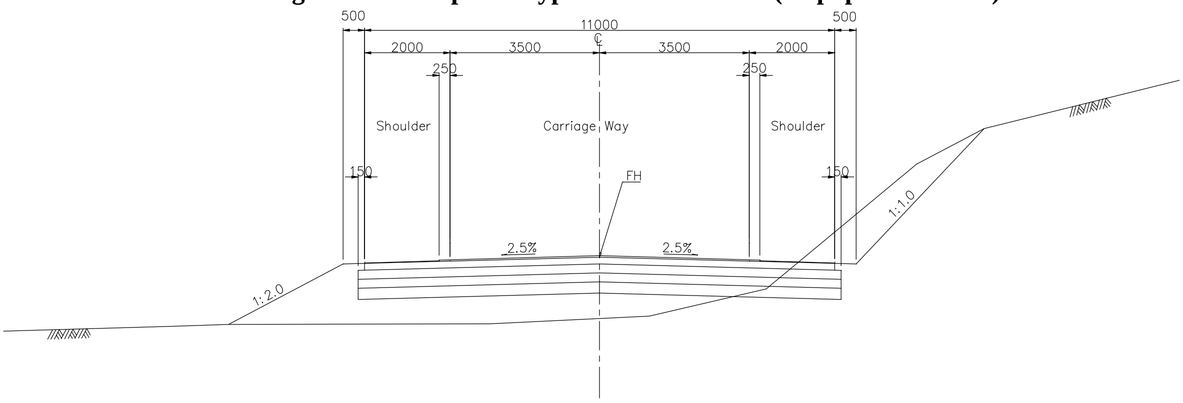


Figure 4.2.4 Proposed Typical Cross Section (Populated Area)

4.2.3 Pavement Design

(1) Applicable Design Method

The design of pavement structures is based on the methods given by the "SATCC Practice for the Design of Road Pavements". In addition to the SATCC standard, other design methods such as "Road Notes 31" and "TRH4 of South Africa" are also considered as reference.

Both SATTC and Road Notes 31 are selected as pavement composition from the attached appendix after determination of the several conditions, respectively. These methods have been known and described as empirical methods, and are convenient for the selection of the pavement composition. At the same time, theoretical methods such as multi-layer elasticity method are globalizing and becoming common standard for the pavement design.

In this Study, pavement composition determined by the empirical method shall be reviewed based on the South African Mechanistic Pavement Rehabilitation Design Method.

(2) Pavement Design Life

The design life of a road can have a large impact on the design specifications of its pavement structure and it is therefore important to decide on an appropriate period. Usually, a 10-, 15-, or 20-year period is adopted, with the selection of an appropriate design life being dependent on the unique circumstances of the individual project. The following table from the SATCC standard provides some guidance on the selection.

Table 4.2.1 Pavement Design Life Selection Guidance

		Importance/Level of Service	
		Low	High
Design Data Reliability	Low	10 – 15 Years	15 years
	High	10 – 20 Years	15 – 20 Years

The Study road is mostly located in poor areas with no reliable historic traffic data being available and runs parallel to an existing railway line. In such cases, the potential for making significant errors in long-term traffic forecasting is significant. Given this, a 15-year design life is recommended.

(3) Vehicle Equivalent Factor (VEF)

The damaging effect of all axles expected to traverse the road is converted into Equivalent Standard Axle (E80) and added up over a chosen design period to become the basis for the structural pavement design. This figure is termed the design traffic loading and expressed in million E80. The design traffic loading is the cumulative traffic expected to use the heaviest loaded lane during the design period.

Equivalent Standard Axle (E80) for design of bitumen surface road pavements shall be based on project-dedicated axle load surveys. Hence the axle load surveys were conducted following locations and conditions by the Study Team.

- Survey Date: 20 May 2009 – 22 May 2009 (3days)

- Survey Time: 7:00 – 19:00 (12hr)
- Survey Locations: N13 on Cuamba, Lichinga and Mandimba (Both direction)

The required minimum information from the axle load survey included the following:

- Axle loads of heavy vehicles whether they are empty or loaded.
- Vehicle category
  1: Medium Passenger Car
  2: 4-Wheel Vehicle
  3: Minibus and Light Bus
  4: Medium / Large Bus
  5: Light Goods Vehicle
  6: Medium Goods Vehicle
  7: Heavy Goods Vehicle
  8: Very Heavy Goods Vehicle
- Loading in each lane (direction) of the road

Each axle in a multi-axle combination (e.g. bogie, triple, etc) was measured separately.

The damaging effect of an axle passing over the pavement is expressed by the equivalent factor related to an equivalent standard axle (E80) of 8,160kg load:

Equivalent factor = $[\text{Axle Load (kg)} / 8160]^{4.5}$

The Vehicle Equivalent Factor (VEF) for every vehicle in the axle load survey was determined and an average value is subsequently calculated for each heavy vehicle category. The results of Vehicle Equivalent Factor (VEF) derived from the axle load survey are shown in Table 4.2.2.

The number of medium/large buses is quite limited due to the poor road condition, and this figure is not supplied with high confidence. Hence the Study Team recommends applying the value of “1.02” used in detail design for the Nampula – Cuamba road. And the average value is suggested for application as the Vehicle Equivalent Factor (VEF), because it is more conservative.

Table 4.2.2 VEF by Vehicle Category and Survey Points

Vehicle Category	Cuamba	Mandimba	Lichinga	Average
4: Medium / Large Bus	-	-	0.008	0.008
6: Medium Goods Vehicle	0.415	0.080	0.390	0.401
7: Heavy Goods Vehicle	0.016	-	11.174	4.798
8: Very Heavy Goods Vehicle	11.194	10.509	21.496	13.338

Note: Vehicle category 1, 2, 3, 5 are not applicable for the pavement design.

4.2.4 Level Crossing Design

(1) Applicable Design Standard

The section between Cuamba and Mandimba crosses the railway on a skew at 8 points, and these crossing angles reduce the safety such as visibility. In this Study, these level crossings should be improved from the aspect of safety in accordance with the following standard applied in Nampla-Cuamba road project.

(2) Classification of Level Crossing and Railway Reserve Area

The CFM North classifies the level crossing as follows:

- Level crossing that invites drivers attention by warning signs
- Level crossing that controls by crossing gate

And proposed railway reserve area by the CFM is as indicated below:

Table 4.2.3 Railway Reserve Area Proposed by the CFM

	Unpopulated Area	Populated Area	Absolute
CFM HQ	200m	100m	20m
CFM North	100m	50m	10m

(3) Angle of the Level Crossing

The CFM doesn't have the standard for the level crossing. However, in verbal explanation, they have kept following standard values for angle of the level crossing:

Table 4.2.4 Angle of the Level Crossing

Desirable	Absolute
Degree of 60 - 90	Up to degree of 45

4.2.5 Road Safety Facilities

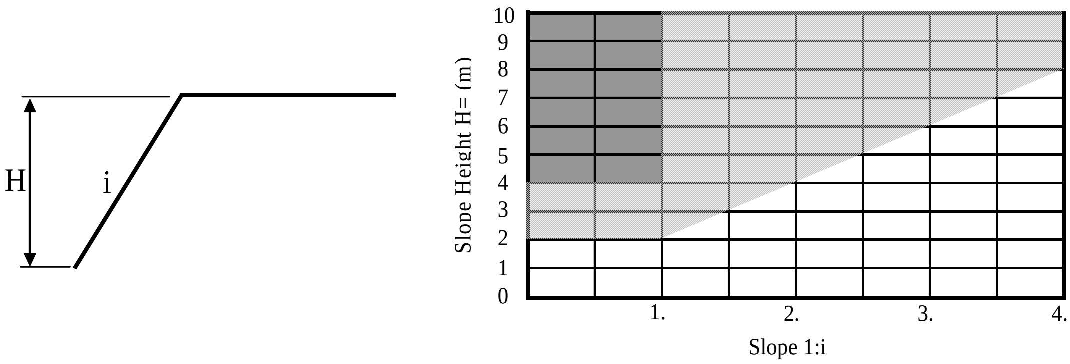
(1) Road Traffic Signs

The Study Team follows the SATCC manuals of November 1997 for specifying the road signs and road markings. As a general rule, road traffic signs give warning to the drivers, and increase the safety of all road users including pedestrians. Road markings consist of horizontal reflective painting on the road surface, whilst road signs contain vertically displayed sign posts. The different types of road signs are:

- Danger warning signs
- Regulatory signs
- Priority signs
- Prohibitory signs
- Mandatory signs
- Informative signs

(2) Guardrail

Setting of guardrails is also included in this project as traffic safety facilities. Guardrails are set at backward and forward of new bridges and fills higher than 4 meters according to the illustration below:



: High Risk Area with Injury

: Middle Risk Area with Injury

Source: Standard for the setting of the road safety facilities (Japan Civil Engineering Association)

Figure 4.2.5 Risk of Injury due to Downfall

4.3 Applicable Design Standard for Bridges and Culverts

4.3.1 Applicable Design Standards

For a long time in Mozambique, Portuguese standards and specifications were widely used for the design of highway bridges and culverts. After SATCC "Code of Practice for the Design of Highway Bridges and Culverts in South Africa" were introduced in 1981, this became the principal design standard and specification although it still remains a provisional status.

Since the SATCC codes are formulated on the basis of British Design Codes, ANE staff still uses the Portuguese codes for checking the design done by SATCC codes. The latest SATCC code (September 1998, reprinted July 2001) should be adopted as the standards and specifications for bridge and culvert design for this Study road. The relevant specifications published by AASHTO, British Standard (BS) and the Portuguese Bridge Code are also used.

4.3.2 Cross-sections for Bridges and Culverts

(1) Bridge Cross-section

The selection of road lane width is based on traffic volume, vehicle type, design speed and project location (rural or urban area). Therefore the lane width is recommended between 3.1m to 3.7m by SATCC Code of Practice and the shoulder width is recommended between 0.5m to 1.0m.

But there is no applicable rule of cross section and width for bridges in SATCC design codes. Accordingly previous bridge projects have applied different bridge widths depending on the conditions surrounding the areas where the bridges are located.

It is recognized that a difference in cross-section width between bridges and approach roads would affect traffic safety, and that the bridge width affects the construction costs, even not so high portion of the total project cost. Considering these aspects, the Study Team discussed with ANE staff and decided the bridge cross section to apply in this Study as shown below.

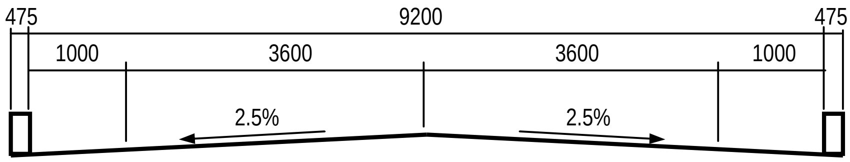


Figure 4.3.1 Bridge Cross-section

(2) Culvert Cross-section

The construction cost of culverts is not as high as that of bridges, therefore the cross-sections of culverts will be selected the same as the road cross-section on the basis of the traffic safety aspect rather than the cost aspect.

4.3.3 Design Criteria

(1) Design Methodology

All structure members are designed to the limited state methods under the most adverse loading conditions and the defined load combinations in accordance with the SATCC code. The limit states design criteria are applied to the following:

- Ultimate Limit States, which correspond to the maximum load carrying capacity
- Serviceability Limit States, which are related to the criteria governing normal use and durability deflection

(2) Loading Criteria for Bridges

Live Load

The following three types of live loading due to traffic will be considered as per the SATCC codes:

- NA loading: representing normal traffic
- NB loading: a unit loading representing a single abnormally heavy vehicle
- NC loading: representing a multi-wheeled trailer combination

These loadings will be applied separately, in a way that will cause the most severe effects in the elements of the structure under consideration. The live load will be increased due to dynamic and vibration effects in accordance with the SATCC codes.

Dead Load

The dead load is a main component in determining the weight of a bridge structure. The dead load can be calculated on the basis of the unit weights specified in the SATTC codes. The major unit weights for materials are as follows:

- Steel : 7.850 tf/m3
- Reinforced concrete: 2.600 tf/m3
- Pre-stressed concrete: 2.600 tf/m3
- Plain concrete: 2.400 tf/m3

Other loads

The following loads will be considered for the bridge designs:

- Earth pressure
- Wind loads
- Braking forces
- Thermal effects
- Seismic forces

It is understood that seismic forces have generally not been considered in previous bridge designs in Mozambique. However seismic forces will be considered at the minimum level in line with the new ANE policy.

(3) Flood, Navigation and Other Clearances

Frequency of Design Flood

The selection of the return period for bridge or culvert design will have a large impact on the size of the structures which will affect the total cost involved. The adoption of a higher return period would decrease the probability of flooding on the road, damages to the road and other facilities as well as result in a more reliable road connection for the road users. However, this could also cause a substantial increase in the initial capital and future maintenance costs.

The ANE guidelines in the National Roads Strategy propose a return period appropriate to the design discharge. The return periods for bridge and culvert design are proposed to be selected as in the following table.

But the Study Team recommends that recurrence interval of 100 years shall be used for the bridge design because of the recent heavy rain and climate change.

Table 4.3.1 Design Return Period for Crossing Structure by Design Discharge

Peak Discharge T=20year	Recurrence Interval (yrs)			
	Pipe	Culvert	Low Level Structures	High Level Structures
$20m^3/s > Q$	5	10	10	20
$20m^3/s < Q < 250m^3/s$	10	20	20	50
$Q > 250m^3/s$	30	30	30	100

Design Discharges

The design discharges shall be calculated by two methods for comparison, namely the Rational Method and the Regional Maximum Flood Method, and checked by interviews with local residents.

As well as design discharge, high water level (H.W.L.) for bridge and culvert design is also calculated by hydrological analysis.

Flood Clearance

There is no standard for flood clearance (free board) in the SATCC codes. Flood clearance is normally determined taking into consideration the presence of debris such as drifting timber in a river during flood as well as the flood discharge volume.

Although previous bridge projects applied a clearance ranging from 1.5 to 2.0m, the design specifications of the South African Road Board will be applied for the new bridges on the Study Road considering the similarity of the region. This specification determines clearance from the girder bottom based on the design flood discharge shown in Table 4.3.2.

Table 4.3.2 Flood Clearance for Bridge Design

Design Discharge V (m3/m)	V<100	100<V<200	200<V<400	400<V<1000	1000<V
Clearance (m)	0.3	0.5	0.7	1.0	0.6 + HWL/15

Source: Code of procedures for the planning and design of structures, South African Road Boards

For culvert design, an additional flow of 20% will be considered when determining culvert size, to allow for flood clearance.

Navigation Clearance

There is no river that requires clearance for navigation on the Study Road. Accordingly, forces due to ship collision will not be considered in the bridge design.

Chapter 5 Preliminary Engineering Design

5.1 Introduction

5.1.1 Introduction

This chapter discusses the upgrading concept, alternative routes and design for the Study Road, all as derived from the site survey results i.e., road inventory, natural condition and hydrological survey, and bridge inventory survey. The principal purpose of this chapter is to determine whether the respective upgrading scenarios are feasible.

5.1.2 Concept of the Project

The road upgrading concept, which is dictated by the road function, will influence the final construction cost of the Project. Accordingly, the upgrading concept should be determined in accordance with the road function, importance, etc.

Through discussions with ANE and the results of field surveys by the Study Team, the concept of the Project was confirmed as follows:

- To create an efficient primary road connection securing smooth traffic flow throughout the year corresponding to the future traffic demand
- To create a safe primary road connection by reducing the risk of accidents and the rate of injuries to pedestrians by motorized vehicles

5.2 Screening of Conceivable Alternative Routes and Pavement Design

5.2.1 Geometric Design Process

(1) Design Policy and General Rules

The upgrading of the Study Road will satisfy the geometric standards of SATCC for road safety. However, it is important that the impacts to both social and natural environmental are minimized. Accordingly, the following concepts of road alignment were discussed and agreed upon between ANE and the Study Team. As a general rule:

- Re-alignment plan is based on the upgraded road keeping to its existing alignment (except where minor realignment is required for rectifying bends) to accommodate the design speed.
- Re-alignment plan should minimize the number of affected houses and people.
- Re-alignment plan should give consideration to minimizing the negative impacts to public facilities (schools, hospitals, etc), sanctuaries (church, mosque, cemeteries, etc), historical facilities (historical monuments, etc) and social facilities as well.
- Re-alignment plan should be considered to minimize the negative impacts to the living environment of residents by the use of appropriate way such as bypass.
- Re-alignment plan should give consideration to reducing the number of level crossings from aspect of road safety.

(2) Setting of Re-alignment

First of all, both the existing horizontal alignment and the vertical alignment should be traced for verification of the adequateness to the adopted design parameter. As mentioned above, the alignment basically follows the existing road, but re-alignment that accommodates the design speed is required at sub-standard sections such as small curves, steep slopes and skew crossings of the railway line. Additionally, the following conditions should be reflected in the re-alignment plan.

- Bridges as evaluated in sound condition by the bridge inventory survey should continue to be used to minimize initial capital costs. (see Table 5.2.1)
- The COI (Corridor of Impact: see below) should be set out of the considerable areas such as school compounds.
- The road (required cross section) should not move in on the railway reserve area proposed by CFM. (see Chapter-3)
- The new vertical alignment should be kept at the existing ground level in urban areas.
- High water level for the new bridges replaced in this Project should be reflected in the new vertical alignment.

Table 5.2.1 Reused Bridges on the Study Road

No.	Bridge Name	Station	Remarks
1	Muanda	0+437	Combine road and railway
2	Ningare	8+072	Japan's Grant Aid
3	Lugenda	108+293	
4	Lussengessi-I	115+808	

(3) Corridor of Impact (COI)

Corridor of Impact (COI) is necessary area for construction activities and means the minimum area needed for resettlement and compensation. In the Nampula – Cuamba road project, the GOM is going forward the compensation in keeping with the COI concept and will follow this concept to the Study Road.

During the construction, the contractor has to provide a diversion for road users. In the rural sections of the road, the minimum clearance width from the road edge should be approximately 7m (see Figure 5.2.1) including a diversion, typically. In the town sections, basically construction activities should be carried out within the present road width.

In general, it is not permitted for a diversion to pass a school site and/or a hospital site from the viewpoint of safety. In addition, passing in a cemetery is not permitted, because a diversion is also evaluated as intended land for compensation and land acquisition even if it is for a short period.

Hence, in cases where the space between road edge and considerable boundary (e.g. cemetery) is not enough for construction activities, the road center line should be shifted as shown below:

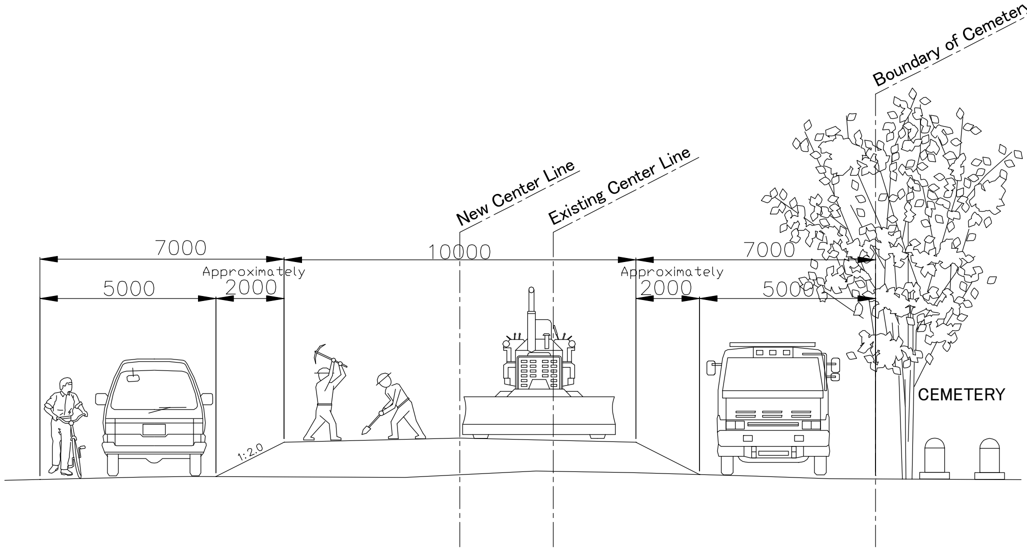


Figure 5.2.1 Construction Area Concept (e.g. Cemetery)

5.2.2 Screening of Conceivable Alternatives

(1) Procedure of the Preferable Route and Design

Alternatives for the road alignment and design should be determined and compared in accordance with the concept. The “Do nothing” option is not appropriate to the stated upgrading concept described above. In this Study, the preferable route and design should be selected in accordance with the following procedure.

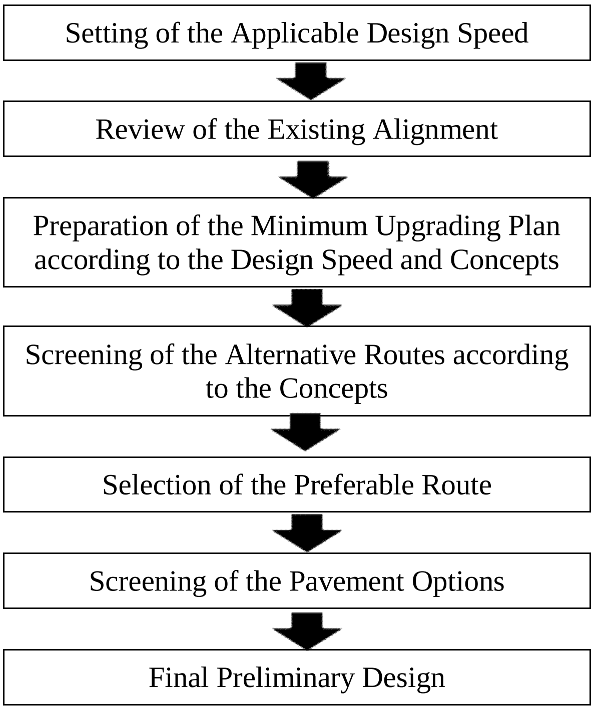


Figure 5.2.2 Procedure of the Preferable Route and Design

(2) Applicable Design Speed

The SATCC standards recommend a design speed of 120km/h for trunk roads if the topography permits. In case of rolling or mountainous terrain, the design speed should be reduced to 100km/h or 80km/h, respectively. Meanwhile, ANE's Design Standards (Draft) recommend a design speed of 100km/h for primary road with asphalt pavement and 60km/h for primary road with surfaced road.

Observations during the field survey indicate that the Study Road lies in various topographical conditions. In addition, the existing alignment both horizontal and vertical does not accommodate high-speed driving. Thus, improvements to a constant design speed of 120 km/h would mean a substantial increase in construction cost with the commensurate increase in affected area. This means to deviate from concepts discussed and decided above. In particular, topographic factor should be absolutely considered to determine the design speed.

Therefore, based on above concepts such as minimization of affected areas and consistency with the Nampula-Cuamba road, and from the viewpoint of traffic management and operation, the following design speed is recommended as a general rule.

Table 5.2.2 Recommendable Design Speed

Terrain	Flat	Rolling	Mountainous	Populated Area
Desire	100km/h	80km/h	60km/h	40 to 60km/h
Minimum	80km/h	60km/h	40km/h	

(3) Screening and Selection of the Preferable Route

The most preferable route is examined in this section. As a general rule, the new alignment for the Study Road should follow the existing alignment. However, some resettlements or land acquisitions are required due to keeping the minimum design requirement. Hence route selection should be considered not only from the economic viewpoint but also taking into account environmental impacts. For this reason, based on the following criteria, the most preferable route is selected.

Table 5.2.3 Criteria and Rating for Evaluation of Alternatives

Criteria		***Detail***	***Rating***
Construction Cost		• The lowest cost • Higher (0 – 10%) than the lowest cost • Higher (10 – 20%) than the lowest cost • Higher (20 – 30%) than the lowest cost • Higher (30 – 50%) than the lowest cost • More than 50%	5 4 3 2 1 0
Effect of Reduction on Social Impact (Number of affected houses)		• 0 –10 • 10 – 20 • 20 – 30 • 30 – 40 • 40 – 50 • More than 50	5 4 3 2 1 0
Effect of Reduction on Natural Impact		• Small impact • Significant Impact	2 0
Road Safety	Design Speed	• Consistent design speed • Different design speed	2 0
	- Horizontal Curvature (deg/km) - Rise + Fall (m/km) - No. of Rises + Falls (No./km) - Number of level crossings	• High improvement effect • Medium improvement effect • Low improvement effect	3 2 1

From the design policy discussed above, the following alternatives are considered.

Alternative-1: Minimum Upgrading: Alternative-A is to rectify only the substandard sections to accommodate the minimum requirements mentioned below:

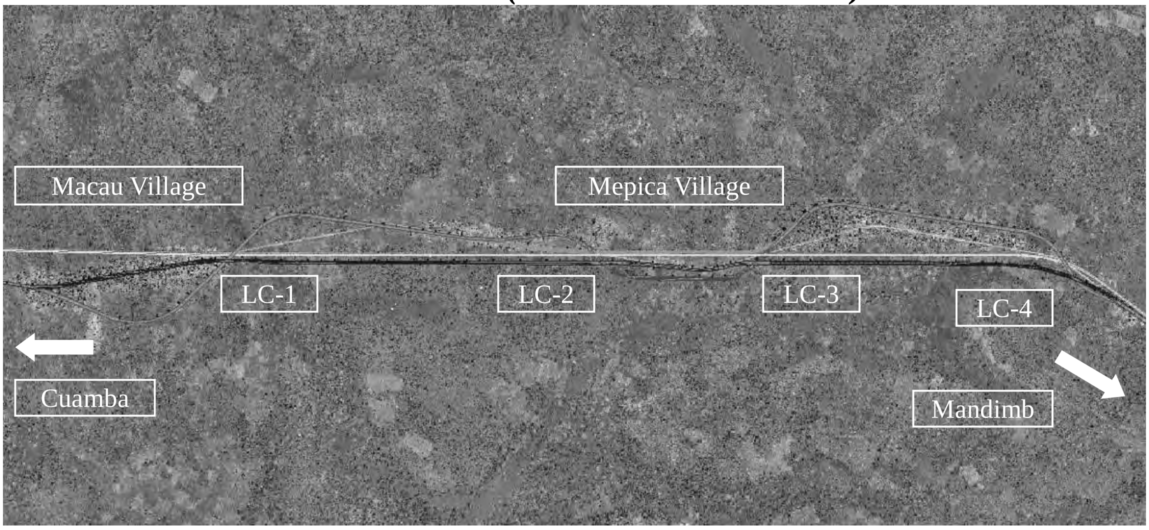
- Application of the geometric standard in accordance with the design speed
- Continued utilization of the sound bridges
- Acquisition of the COI and the railway reserve area
- Improvement of level crossings from the safety viewpoint
- Application of the calculated high water level for the new bridges

Alternative-2: Drastic Upgrading: Alternative-B considers the following conditions in addition to those in Alt.-A:

- Consideration of bypasses in populated areas
- Consideration of reduction of the number of level crossings
- Adoption of high design speed in mountainous terrain sections

From the results of the site survey by the Study Team, the following sections should be compared in accordance with above alternative concepts.

Section-1: Cuamba-Mandimba Road (K.P.22+600 – K.P.31+300)



LC: Level Crossing :Railway :Alt.-1 :Alt.-2-1 :Alt.-2-2

Reasons for Comparison:

The Study Road crosses the railway line at four points with a skew angle. In addition there are major populated areas in this section. Alt.-1 is to be rectified in only the substandard sections including the crossing angle with railway. Alt.2-1 and 2-2 are considered for bypass function and reduction of the number of level crossings from the viewpoint of road safety.

Figure 5.2.3 Comparison Route for Section-1 (k.p.22+600 – k.p.31+300)

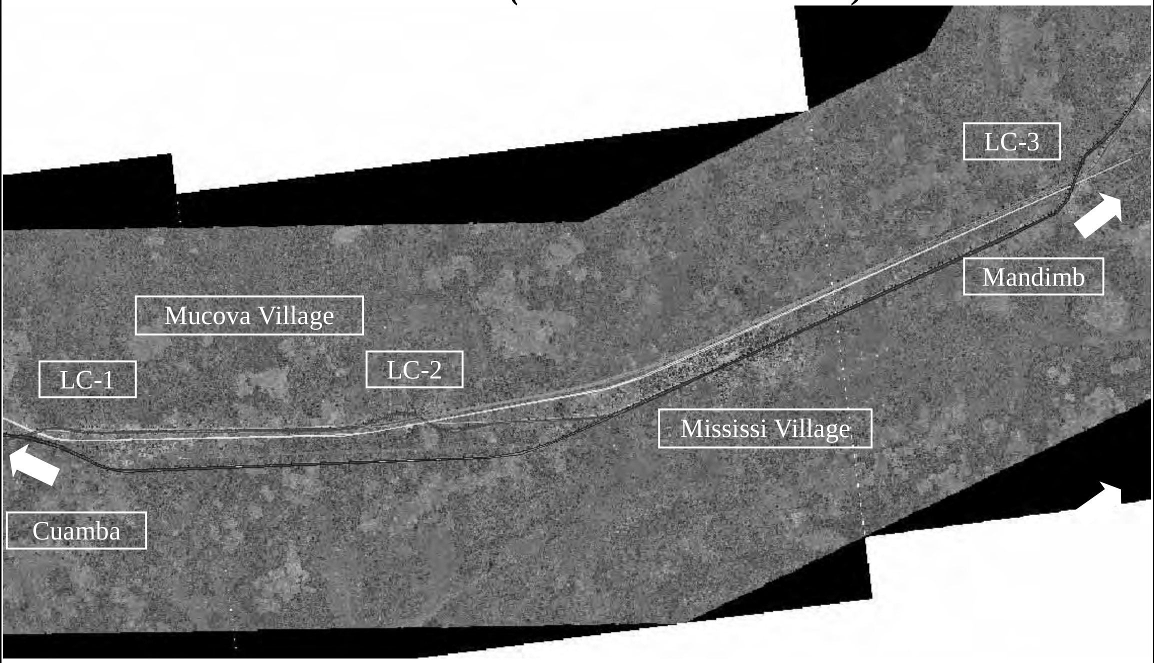
Table 5.2.4 Comparison Table for Section-1 (k.p.22+600 – k.p.31+300)

Items		Alt.-1		Alt.-2-1		Alt.-2-2	
Length (km)		9.53km		8.72km		9.34km	
Design Speed		100km/h	**2**	100km/h	**2**	100km/h	**2**
Construction Cost* (USD)		4,740,109 (1.15)	***3***	4,115,079 (1.00)	***5***	4,516,315 (1.10)	***3***
Effect of Reduction on Social Impact (Number of Affected Houses)		98	***0***	30	***2***	72	***0***
Road Safety	Horizontal Curvature (deg/km)	172.3	***1***	13.9	***3***	142.5	***2***
	Rise + Fall (m/km)	7.1	***1***	6.9	***2***	6.6	***3***
	No. of Rises + Falls (No./km)	3.5	***2***	3.9	***1***	3.7	***3***
	Number of level crossings	4	***1***	0	***3***	2	***2***
Evaluation		***3***	***10***	***1***	***18***	***2***	***15***

*: Direct Construction Cost

Note: Applicable Sub-grade Strength Alt.-1 (S2), Alt.-2-1 (S2), Alt.-2-2 (S2)

Section-2: Cuamba-Mandimba Road (K.P.59+750 – K.P.75+350)



LC: Level Crossing :Railway :Alt.-1 :Alt.-2-1 :Alt.-2-2

Reasons for Comparison:

The Study Road crosses the railway line at four points with a skew angle. In addition there are major populated areas in this section. Alt.-1 is to be rectified in only the substandard sections including the crossing angle with railway. Alt.2-1 and 2-2 are considered for bypass function and reduction of the number of level crossings from the viewpoint of road safety.

Figure 5.2.4 Comparison Route for the Section-2 (k.p.59+750 – k.p.75+350)

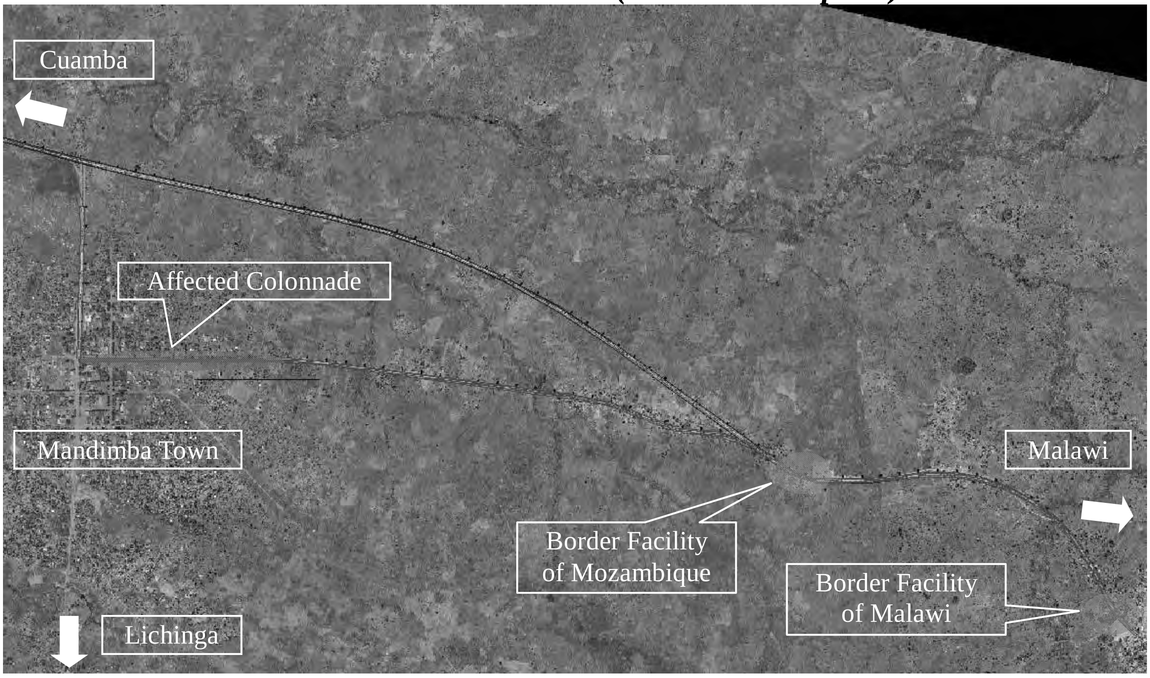
Table 5.2.5 Comparison Table for the Section-2 k.p.59+750 – k.p.75+350)

Items		Alt.-1		Alt.-2-1		Alt.-2-2	
Length (km)		15.56km		15.60km		15.26km	
Design Speed		100km/h	***2***	100km/h	***2***	100km/h	***2***
Construction Cost* (USD)		7,497,857 (1.02)	***4***	7,754,522 (1.06)	***4***	7,331,453 (1.00)	***5***
Effect of Reduction on Social Impact (Number of Affected Houses)		48	***1***	13	***4***	57	***0***
Road Safety	Horizontal Curvature (deg/km)	159.7	***1***	31.8	***3***	73.5	***2***
	Rise + Fall (m/km)	7.9	***1***	6.8	***2***	6.5	***3***
	No. of Rises + Falls (No./km)	2.8	***2***	2.2	***3***	3.5	***1***
	Number of level crossings	3	***1***	1	***2***	1	***2***
Evaluation		***3***	***12***	***1***	***20***	***2***	***15***

*: Direct Construction Cost

Note: Applicable Sub-grade Strength Alt.-1 (S3), Alt.-2-1 (S2), Alt.-2-2 (S2)

Section-3: Mandimba – Malawi Border Road (K.P.146 – End point)



Reasons for Comparison:

The Study Road passes through the center of Mandimba Town. In addition there are many considerable facilities such as schools along the Study Road. Alt.-1 is to be rectified in only the substandard sections to accommodate the design speed. Alt.-2 is a completely different route considering bypass function for minimization of the impact on the town.

Figure 5.2.5 Comparison Route for the Section-3 (k.p.146 – End)

Table 5.2.6 Comparison Table for the Section-3 (k.p.146 – End)

Items		Alt.-1		Alt.-2	
Length (km)		7.38km		6.72km	
Design Speed		100km/h	***2***	100km/h	***2***
Construction Cost* (USD)		3,634,911 (1.07)	***4***	3,404,192 (1.00)	***5***
Effect of Reduction on Social Impact (Number of Affected Houses)		24	***3***	25	***3***
Effect of Reduction on Natural Impact (Length of Affected Colonnade)		0+0 – 0+180 (180m) 0+400 – 1+200 (800m) Total: 980m	***0***	0m	***2***
Road Safety	Horizontal Curvature (deg/km)	43.8	***1***	24.8	***3***
	Rise + Fall (m/km)	22.2	***1***	16.1	***3***
	No. of Rises + Falls (No./km)	3.2	***1***	1.6	***3***
Evaluation		***2***	***12***	***1***	***21***

*: Direct Construction Cost

Note: Applicable Sub-grade Strength Alt.-1 (S2), Alt.-2 (S2)

(4) Recommendable Alignment

The following table shows the improvement magnitude and effect of the recommended alignment. In regard to the section between Cuamba and Malawi Border, it was clarified by two indices (horizontal curvature and rise plus fall) that the existing alignments both horizontal and vertical almost meet criteria for a design speed of 100km/h. This means that improvement to the recommended alignment will basically be carried out on the existing road excluding the bypass sections discussed above.

Table 5.2.7 Improvement Magnitude and Effects

<table>
<tr><th colspan="3"></th><th>Existing</th><th>Plan</th></tr>
<tr><td colspan="3">Length (km)</td><td>153.8km</td><td>152.9km</td></tr>
<tr><td colspan="3">Terrain</td><td>Flat</td><td>Flat</td></tr>
<tr><td colspan="3">Design Speed</td><td>-</td><td>100km/h</td></tr>
<tr><td rowspan="3">Geometry</td><td>Horizontal Curvature</td><td>deg/km</td><td>22.4
(1.00)</td><td>21.2
(0.95)</td></tr>
<tr><td>Rise + Fall</td><td>m/km</td><td>9.8
(1.00)</td><td>9.8
(1.00)</td></tr>
<tr><td>No. of Rises + Falls</td><td>no./km</td><td>4.5</td><td>3.3</td></tr>
<tr><td colspan="3">No. of Level Crossings</td><td>8</td><td>2</td></tr>
</table>

5.2.3 Preliminary Design for the Pavement Options

(1) Road Category and Design Depth

According to the Draft TRH4, the Study Road is categorized as a Category B road. This category is decided by road function, traffic volume and so on. Additionally, this road category points out the typical pavement characteristics including design depth as indicated below.

Table 5.2.8 Definition of the Road Categories

ROAD CATEGORY				
Service Level	A	B	C	D
	Very high level of service	High level of service	Moderate level of service	Moderate to low level of service
TYPICAL PAVEMENT CHARACTERISTICS				
RISK	Very low	Low	Medium	High
Design Reliability (%)	95	90	80	50
Total Equivalent Traffic Loading (E80/lane)	$3 – 100 \times 10^6$ Over 20 years	$0.3 – 10 \times 10^6$ Depending on design strategy	$< 3 \times 10^6$ Depending on design strategy	$< 1 \times 10^6$ Depending on design strategy
Typical Pavement Class	ES10-ES100	ES1-ES10	ES0.003-ES3	ES0.003-ES1
Daily Traffic (e.v.u.)*	>4000	600 - 10000	< 600	< 500
Warning Rut Level (mm) Terminal Rut Level (mm)	10 20	10 20	10 20	10 20
Design Period (years)	15 -30	15 - 25	10 - 20	7 - 15
Design Depth (mm)	1000 - 1200	800 - 1000	800	700

*:e.v.u.: Equivalent vehicle unit (1.25 vehicle = 1 e.v.u.)

(2) Design Traffic Loading for the Design Life

Traffic load is expressed as the cumulative equivalent standard axle load (ESAL) for the design life of a road and is calculated by the following process:

- Determine daily traffic flows for each relevant vehicle class.
- Determine average daily one-directional traffic flows.
- Forecast one-directional traffic flows.
- Determine the mean equivalence factor for each class of vehicle.
- Sum the products of the cumulative one-directional traffic flows for each vehicle class over the design life of the Study Road and the mean equivalence factors to obtain the cumulative ESAL for deciding the pavement structure.

Equivalency factors, which convert heavy vehicle traffic into vehicle equivalent factor (VEF), were derived applying the survey results as discussed in Chapter 4.

The formula that is applied to calculate ESAL is as follows:

$$\text{Cum. ESAL}_t^{y} = HV_t^{y_0} \times 365 \times ((1+\Upsilon)^y - 1)/\Upsilon \times HVF_t \times LF_t$$

Where,

Cum. ESAL_t^y = Cumulative ESAL for a design lane in a single direction for heavy vehicles of type t after y years.

$HV_t^{y_0}$ = Average daily traffic for heavy vehicle type t in initial year y0 for both directions.

ϒ = Average annual growth rate for heavy vehicle type t.

y = Design life of project road.

HVFt = Equivalency factor to convert heavy vehicle type t into ESA.

LFt = Factor to convert bi-directional traffic to traffic for a design lane per direction.

Table 5.2.9(1) Design ESAs Value for Cuamba-Mandimba Section

		Medium / Large Bus	Medium Goods Vehicle	Heavy Goods Vehicle	Very Heavy Goods Vehicle	Total
VEF		***1.02***	***0.401***	***4.798***	***13.338***	
1	2014	217	2,386	6,476	398,059	407,137
2	2015	243	2,712	7,315	440,124	450,394
3	2016	266	3,038	8,145	474,622	486,071
4	2017	295	3,435	9,154	511,125	524,008
5	2018	326	3,882	10,279	534,014	548,501
6	2019	361	4,389	11,546	556,911	573,207
7	2020	400	4,963	12,967	574,128	592,458
8	2021	443	5,613	14,560	596,784	617,400
9	2022	490	6,350	16,345	614,605	637,791
10	2023	542	7,185	18,345	662,529	688,601
11	2024	600	8,131	20,585	695,818	725,134
12	2025	663	9,205	23,091	722,497	755,456
13	2026	733	10,424	25,895	750,966	788,017
14	2027	809	11,808	29,030	781,528	823,175
15	2028	894	13,382	32,534	809,159	855,968
						9.5E+06

Table 5.2.9(2) Design ESAs Value for Mandimba-Malawi Border Section

		Medium / Large Bus	Medium Goods Vehicle	Heavy Goods Vehicle	Very Heavy Goods Vehicle	Total
VEF		***1.02***	***0.401***	***4.798***	***13.338***	
1	2014	0	586	413	209,923	210,923
2	2015	0	719	455	225,016	226,190
3	2016	0	857	500	237,740	239,097
4	2017	0	1,038	550	248,718	250,306
5	2018	0	1,253	605	257,854	259,712
6	2019	0	1,517	666	266,218	268,400
7	2020	0	1,837	732	273,911	276,480
8	2021	0	2,225	805	281,226	284,257
9	2022	0	2,698	886	288,406	291,990
10	2023	0	3,274	975	295,656	299,904
11	2024	0	3,974	1,072	303,153	308,198
12	2025	0	4,826	1,179	311,051	317,056
13	2026	0	5,865	1,297	319,492	326,655
14	2027	0	7,132	1,427	328,610	337,169
15	2028	0	8,676	1,570	338,536	348,782
						4.2E+06

In the results of the ESA's calculation, Mandimba-Malawi border section is classified into T5. However it is a sensible proposal that Mandimba - Malawi border section is equated with Cuamba - Mandimba section as consecutive road. Hence ESAs for Cuamba – Mandimbai is classified into T6 categories depending on the SATCC manual as shown below.

Table 5.2.10 Traffic Classes by SATCC Manual

Traffic Class Designation								
Traffic Range (million ESAs)	T1	T2	T3	T4	T5	T6	T7	T8
	< 0.3	0.3 –0.7	0.7-1.5	1.5-3.0	3.0-6.0	6.0-10	10-17	17-30

(3) Material Re-utilization

The pavement layers of the existing road were investigated to determine their potential for use in new construction. For this purpose, 3 samples of existing road material located from 0.0m to 0.3m in depth were tested in this Study. The results of these tests were as below:

Table 5.2.11 Results of Material Test for Re-utilization (0-30cm)

Sample No.		GM	ATTERBERG LIMITS			CBR (%)		
Sta. (km)	Section		LL	PI	LS	MOD	NBR	PROCTOR
						100%	95%	90%
90+000	Cuamba - Mandimba	1.9	23	7	5.5	81.00	29.00	10.00
110+000	Cuamba - Mandimba	1.6	27	10	5.5	103.00	38.00	19.00
120+000	Cuamba - Mandimba	1.6	19	11	3.6	19.00	5.00	1.00

Criteria for suitability of materials in sub-base are specified by GM, CBR and PI. Specification for the sub-base's CBR is more than 30% at 95% AASHTO density, Maximum PI is 10, and Minimum GM is 1.5. According to the test results above, only 1 sample was found to be suitable material satisfying both CBR and PI for sub-base.

Additionally, as already mentioned in Chapter 1, the Study Road is generally lower than the surrounding ground. In consequence, in many sections, water is confined on the road after the rains and causes concentration of run-off water and erosion on the carriageway. For this reason, it is recommended to raise the road surface more than the surrounding ground level (at least 0.5m).

From the two reasons discussed above, the existing pavement layers are not used as a sub-base for the new road. Hence, new sub-base materials have to be obtained from borrow pit along the Study Road.

(4) Sub-grade CBR

For the purpose of pavement design, the sub-grade was classified into classes of soil based on CBR. The sub-grade classification is proposed by SATCC manual as shown below.

Table 5.2.12 Sub-grade Classes

Sub-grade Class Designation						
Sub-grade CBR Range (%)	S1	S2	S3	S4	S5	S6
	2	3-4	5-7	8-14	15-29	30+

As is mentioned in Chapter 2, the soaked CBR test and the Dynamic Cone Penetration (DCP) test were carried out for the Study Road.

The sub-grade CBR is usually evaluated by means of soaked CBR testing results. Due to the fact that DCP tests are considerably easier and quicker (therefore enabling many tests to be executed) to carry out than soaked CBR, it is common practice to evaluate the strength of the sub-grades by means of in-situ CBR. The following relationship between a DCP value and the in-situ CBR, commonly used in Mozambique, is applied to convert DCP readings into an in-situ CBR value.

DN (mm/blow) > 2: 410xDN-1.27 = in-situ CBR

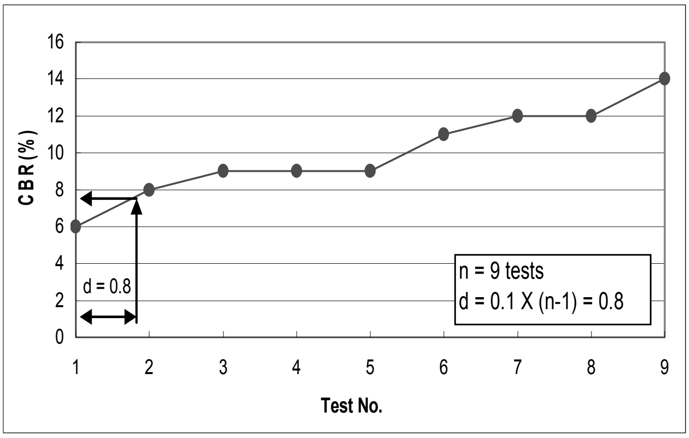
DN (mm/blow) < 2: 66.66xDN2- (330xDN) + 563.33 = in-situ CBR

In order to establish a relationship between the in-situ CBR (obtained through the DCP tests) and soaked CBR, 25 samples of existing road material located from 0.0m to 0.3m and 0.5 to 1.0m in depth were tested. After analyzing the soaked CBR and the DCP tests, it seems that 20% of the in-situ CBR indicates a soaked CBR value.

The Design CBR for a section is usually determined by the 90 percentile (same as reliability for category B road) value of the CBR test results. The method illustrated in following Figure is used for determination of the design CBR.

CBR values plotted in ascending order

Example CBR data	
6	
8	
9	
9	
9	
11	90 percentile 7.6%
12	
12	CBR design 8%
14	



The design CBR normally depends on the new road profile and embankment or cut depth. In this Study, the following cross section was assumed as the typical cross section.

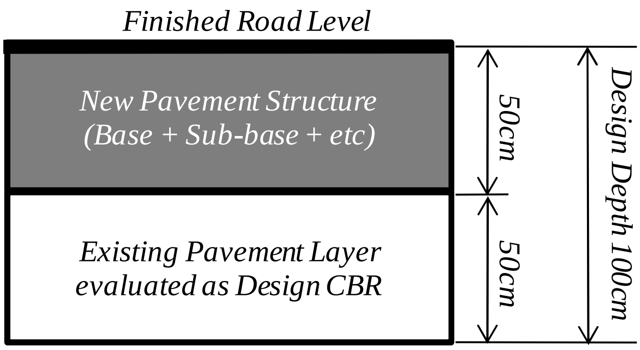


Figure 5.2.6 Assumed Typical Cross Section

In consequence, the design CBR's for the Study Road were classified as follows:

Table 5.2.13(1) Sub-grade Classes for the Study Road (Cuamba-Malawi Border)

Section (km)	0-10	10-20	20-30	30-40	40-50	50-60
90%-tile	6.0	6.0	3.0	5.0	8.0	5.0
Class	S3	S3	S2	S3	S4	S3
Section (km)	60-70	70-80	80-90	90-100	100-110	110-120
90%-tile	5.0	7.0	7.0	4.0	5.0	4.0
Class	S3	S3	S3	S2	S3	S2
Section (km)	120-130	130-140	140-150	150-156		
90%-tile	6.0	4.0	5.0	4.0		
Class	S3	S2	S3	S2		
The 90%-tile value for whole length is 4.0 (Class S2).						

Table 5.2.13(2) Sub-grade Classes for the Bypass Sections (Cuamba-Malawi Border)

Section (km)	24+000-31+100	60+600-68+100	146+200-152+900
90%-tile	3.0 (Fill)	3.0 (Fill)	3.0 (Fill)
Class	S2	S2	S2

(5) Screening of the Pavement Options

From the experience of past and ongoing projects, it was decided that there are three possible scenarios regarding the upgrading of the Study Road:

Alternative-A: Asphalt Concrete based on the SATCC Standard

Alternative-B: Double Surface Treatment based on the Road Note 31

Alternative-C: Gravel Surfacing requested by the AfDB as reference

As discussed in Chapter 2, sufficient natural gravels or soils for the sub-base cannot be supplied because the distribution of adequate natural materials is limited. Also it is difficult to supply good rock materials for the sub-base due to shortage of available quantity.

Available good rock quarry material for Cuamba-Mandimba Section:

Munhumar quarry	:	Approx. 540,000 m3
Chanica quarry	:	Approx. 70,000 m3
Total:		Approx. 610,000 m3

The approximate required quantity for base, surfacing and concrete will be:

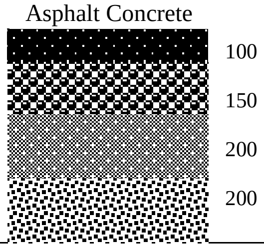
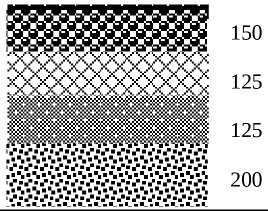
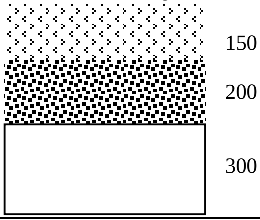
For base-course:	Approx. 280,000 m3
For DBST and concrete:	Approx. 220,000 m3
Total:	Approx. 600,000 m3 (inc.20% loss)

Hence, stabilized sub-base will be recommended. And stabilized sub-base layers in granular base pavements generally increase the load carrying capacity of the pavement. In consequence, a cemented sub-base will be applied to the Study Road.

The pavement type has a significant impact on the initial investment cost and future maintenance cost of the Study Road. It is therefore important to decide using the concept of a life cycle costing. The Study Team calculated the construction costs for the following pavement types and evaluated their economic viability with the

HDM-4 model.

Table 5.2.14 Comparison of Pavement Types for Cuamba-Malawi Border Section (Traffic Class: T6, Sub-grade Class: S2*)

Alternative-1 Asphalt Concrete	Alternative-2 Double Surface Treatment	Alternative-3 Gravel Surfacing (Maximum AADT=300)
Asphalt Concrete 	Double Surface Treatment 	Gravel Wearing 
: G4 Crushed or Natural Gravel Soaked CBR>80%@98% mod. AASHTO density *: C3 Cemented stabilized Sub-base 1.5-3.5Mpa@100% mod. AASHTO density* *: Selected Layer Soaked CBR>15%@93% mod. AASHTO density*	*: G4 Crushed or Natural Gravel Soaked CBR>80%@98% mod. AASHTO density* *: C2 Cemented stabilized Sub-base 3.5-6.0Mpa@100% mod. AASHTO density* *: C3 Cemented stabilized roadbase 1.5-3.5Mpa@100% mod. AASHTO density* *: Selected Layer Soaked CBR>15%@93% mod. AASHTO density*	*: Gravel Wearing Soaked CBR>25%@95% mod. AASHTO density* *: Selected Layer Soaked CBR>15%@93% mod. AASHTO density* *: Soaked CBR>7%@100% mod. AASHTO density*

The design CBR of whole length (Cuamba-Malawi border) is used for comparison of the pavement type.

Table 5.2.15 Economic Analysis for Selection of the Pavement Type

Pavement Type	Construction Cost		NPV (USD Mil.)	B/C	EIRR
	US$ Mil.	US$/km			
Alt.-1 Asphalt Concrete	197.4	1,281,659	-1.2	1.0	11.9%
Alt.-2 Double Surface Treatment	120.6	783,391	62.9	1.7	19.0%
Alt.-3 Gravel Wearing	54.2	351,863	-44.8	-0.2	-30.0%

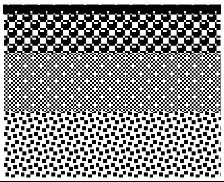
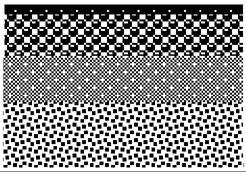
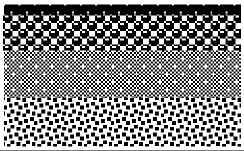
The selection of the suitable pavement type is evaluated based on the initial cost and its financial viability using the EIRR indicator. The result of the cost estimates and the economic analysis, the Alt-2 which constitutes a double surface treatment, is selected as the most economically viable pavement composition. Further details about economic analysis are shown in Part 4.

(6) Suitable Pavement Compositions

The proposed pavement type (double surface treatment) was defined to be the most effective and economical. However its pavement composition can be expensive in construction because the necessary care, construction method and also curing of the two cemented layers with thin thickness (125mm) can contribute to a longer construction period and consequently increase in costs.

Thus the pavement composition discussed above should be modified into more economical and effective composition based on the cemented sub-base in granular base. For this purpose, a mechanistic analysis using ELSYM5 was conducted according to the design CBR. The results of the analysis are as shown in Table 5.2.16. At the moment, there are some ideas and opinions relevant to determine pavement capacity. In this Study, the structural life of pavement was evaluated in two common ways. These approach methods are derived from the RR91/242 and the report written by Mr. H L Theyse, respectively. Calculation process and spread sheet are attached in Appendix-E.

Table 5.2.16 Recommendable Pavement Compositions based on the Mechanistic Analysis

S2 (3-4)	***S3 (5-7)***	***S4 (8-14)***
 200 250 250	 200 200 250	 150 200 200

: G4 Crushed or Natural Gravel Soaked CBR>80%@98% mod. AASHTO density

: C4 Cemented stabilized Sub-base 0.75-1.5Mpa@100% mod. AASHTO density

: G7 Selected Layer Soaked CBR>15%@93% mod. AASHTO density

Poisson's ratio & Elastic coefficient (Elastic coefficient = (10 x CBR)Mpa)

G4: 0.35, Phase-I: 400Mpa, Phase-II: 400Mpa, Phase-III: 300Mpa

C4: 0.25, Phase-I: 1500Mpa, Phase-II: 600Mpa, Phase-III: 300Mpa

G7: 0.35, Phase-I: 150Mpa, Phase-II: 150Mpa, Phase-III: 150Mpa

Table 5.2.17 Summary of the Pavement Capacity

Sub-grade Class	Method	Structural Life	Calculated Design ESA for 15 years
S2 (3-4)	RR91/242	2.22E+07 (wet)	9.5E+06 (Cuamba-Mandimba)
	H L Theyse	1.01E+07 (wet)	
S3 (5-7)	RR91/242	4.12E+07 (wet)	9.5E+06 (Cuamba-Mandimba)
	H L Theyse	1.78E+07 (wet)	
S4 (8-14)	RR91/242	2.64E+07 (wet)	9.5E+06 (Cuamba-Mandimba)
	H L Theyse	1.13E+07 (wet)	

5.3 Hydraulic Design

5.3.1 Background and Design Concepts

Most of the existing transversal drainage structures shown in Appendix-A are hydraulically adequate to accommodate the stream flows, which cross the road. As already mentioned, existing culverts and their inlets and outlets are generally in a good condition. However, the width between culvert headwalls varies according to the existing road width, ground terrain conditions, etc. Furthermore, not all existing culverts can be extended due to their inadequate strength, and most traversal structures are composed of the corrugate pipe that is apt to block up with soil. Therefore, it is proposed that all existing culverts be replaced by new “Concrete pipe and box culverts” with sufficient capacity and strength. Design policies for the provision of new pipe and box culverts are given blow.

- To replace all existing traversal structure excluding the bridges with new concrete pipe and box culverts.
- Capacity of the replaced traversal structures should be applied bigger from comparison between existing capacity and required capacity based on the hydraulic calculation.
- Proper transversal structures should be installed in absent sections identified by site investigation and air photos.

5.3.2 Catchment Areas and Discharge Volume

The determination of the catchment areas for the small culverts was initially made using topographical maps on 1:50,000 scale. The use of these maps doesn't allow for the identification of small catchments. To solve this problem, during the field visit identification was made of all existing drainage structures and low spots where a visual inspection indicates the need for transversal drainage.

A total of 76 catchment areas have been determined based on the topographical maps and flow directions identified by the site investigation. Most catchment areas are very small because the existing road alignment generally follows the watershed crest.

Design discharge volumes for the transversal structures were calculated by rational method, because these catchment areas are the aggregate of small catchment areas for pipe culverts. Time of concentration for small catchment areas which are less than $2.0km^2$ was set at 10 minutes. The discharge volumes for each catchment area are shown in Appendix-F.

5.3.3 Schedule of the Minor Traversal Structures

Transversal drainage is required to ensure the flow of natural streams crossed by the road, to avoid flooding of the road and surrounding areas and possible consequent damages. For this purpose, the hydraulic design is to determine the location and the necessary size of the traversal structures.

The capacity of the traversal structures is determined by the "Manning formula" used throughout the world.

$$Q = (1/n)\, A\, R2/3\, S½ \quad \text{(Manning formula)}$$

Where,

Q: Discharge (m3/s)

A: Cross-sectional flow area (m2)

R: Hydraulic radius (m)

S: Bed slope or hydraulic gradient (m/m)

N: Manning roughness coefficient

In a general way, the bed slope is determined within the parameter of 1% to 3% in accordance with the site condition. However, it is difficult to determine the bed slope for each structure. Therefore, the bed slope of 1% was adopted as safe bed slope for the review of the capacities.

From the results of the computation shown in Appendix-G, 168 traversal structures including bridges are required for the Study Road. The traversal structures will be installed in accordance with the design concepts discussed above.

5.3.4 Longitudinal Drainage

The existing road is lower than the surrounding ground and this topographic condition has resulted in erosion of the side drains and road surface. Causes of the erosion problem consist of various factors such as the materials and the accepted flow velocities. In this Project, the proposed height of the Study Road is basically set at higher position in comparison with the surrounding ground. However, occurrence of some cut slopes is unavoidable due to the topographic condition. The adequate longitudinal drainage should be installed in these sections with cut slope for road protection.

The SATCC Standard has a reference value of the maximum flow velocity for the prevention of scouring (erosion) as follows.

Table 5.3.1 Scour Velocities for Various Materials

Material	Maximum Permissible Velocity (m/s)
Fine Sand	0.6
Loam	0.9
Clay	1.2
Gravel	1.5
Soft Shale	1.8
Hard Shale	2.4
Hard Rock	4.5

Source: Code of Practice for the Geometric Design of Trunk Road (SATCC)

The laterites soil will be used as the principal material for the earth lined ditch because this soil is broadly distributed along the Study Road. The laterites soil is classified into the “Fine Sand” for which a maximum velocity of 0.6m/s is recommended.

The table below shows the flow velocities according to the gradients of the earth lined ditch.

$V = 1/n \times R^{2/3} \times I^{1/2}$

Where,

N: Roughness coefficient = 0.027 (for earthen drain)
R: Hydraulic radius = 0.167
I: Grade

Table 5.3.2 Permissible Maximum Grade for an Earthen Side Drain

I (%)	V (m/s)
0.1	0.35
0.2	0.50
0.3	0.61
0.4	0.71
0.5	0.79
0.6	0.87
0.7	0.94

In order to ensure good drainage, the minimum longitudinal gradient for road is recommended to be 0.3%. It means that the flow velocity exceeds 0.6m/s. Thus concrete lined ditch as mentioned below is recommended to prevent damage to the road structure from erosion.

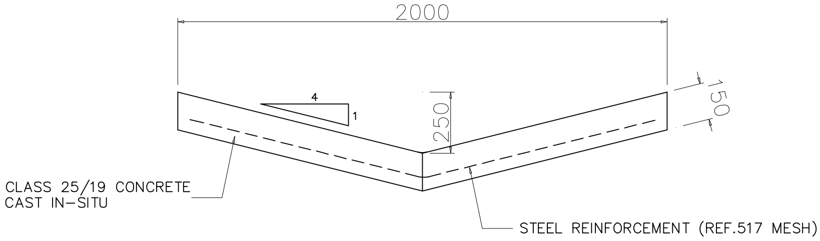


Figure 5.3.1 Proposed Concrete Lined Ditch for Cutting Sections

5.4 Road Incidental Facilities

5.4.1 Level Crossing Design

(1) Number of Level Crossings

As mentioned above, the Study Road is currently crossing the railway at 8 points. In general, since level crossings increase the risk of traffic accidents, the Study Team planned to eliminate 6 level crossings in conjunction with consideration of the bypass route in populated areas.

Table 5.4.1 Location of the Eliminated Level Crossing

Existing Km	New Km	Existing Km	New Km
17+620	17+619	30+724	Eliminated
24+311	Eliminated	61+407	Eliminated
27+084	Eliminated	65+660	Eliminated
28+411	Eliminated	74+353	74+109

(2) Safety Facilities and Crossing Angle

The CFM North classifies the level crossing as follows:

A: Level crossing that invites driver’s attention by warning signs

B: Level crossing that controls by crossing gate

The remaining two level crossings are classified into “A” because they are in unpopulated areas. Therefore, the following two safety facilities (crash barrier and warning sign) should be recommended for road safety.

Table 5.4.2 Proposed Safety Facilities for the Level Crossing

Location	Angle		Crash Barrier	Traffic Sign
	Existing	Plan		
17+619	49	49	x	x
74+109	36	45	x	x

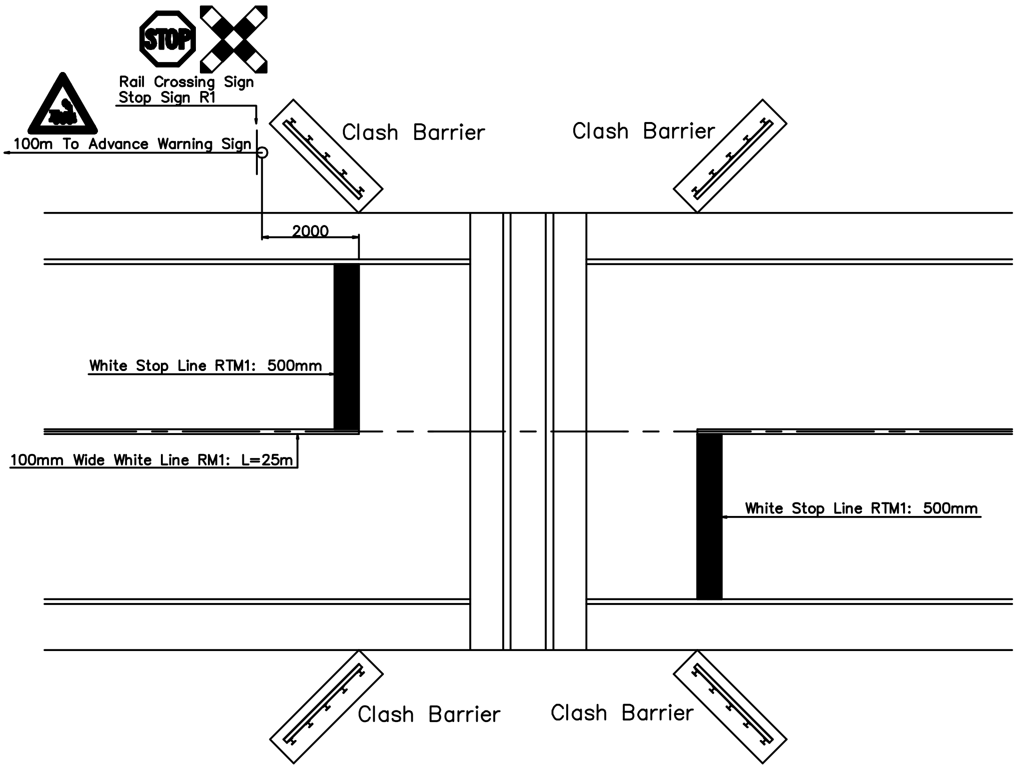


Figure 5.4.1 General Layout of the Safety Facilities for the Level Crossing

(3) Crossing with an Overpass or Underpass (as a reference)

Remained two level crossings still stand for the risk of the traffic accident. However, from situation of the railway operation and traffic demand, rapid improvement from level crossing to an overpass is not required.

Flowing figure shows an idea of overpass as a future possibility.

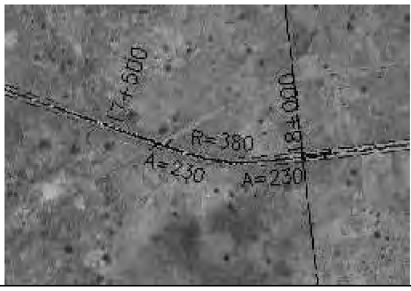
17+619	74+109
	
L=750m (Br. L=10m) Construction Cost: 996,410 USD	L=900m (Br. L=15m) Construction Cost: 1,310,000 USD

Figure 5.4.2 Crossing with an Overpass (as a reference)

5.4.2 Road Traffic Signs

The Study Team used the SATCC manuals of November 1997 for specifying the road signs and road markings. As a general rule, road traffic signs give warning to drivers, and increase the safety of all road users including pedestrians. Road markings consist of horizontal reflective painting on the road surface, whilst road signs contain vertically displayed sign posts. The different types of road signs are:

- Danger warning signs
- Regulatory signs
- Priority signs
- Prohibitory signs
- Mandatory signs
- Informative signs

5.4.3 Other Facilities

Guardrails are provided in accordance with the standard as discussed in Chapter 4. In addition kilometer posts are set along the entire route.

5.5 Bridge Design

5.5.1 Introduction

The result of site survey of existing 14 bridges are described in Table 1.3.1, and also 3 possible alternatives of the improvement plan for each bridge and culvert are summarized in the same table.

The site information of river condition (flooding, HWL, discharge) was collected from the local residents, and hydrological analysis was conducted to back up site information and to give river design condition (HWL, discharge) for new bridge.

By setting the concept of improvement plan for the bridges in this Study Road as follows, the best alternative shall be selected from the possible alternatives in Table 1.3.1.

5.5.2 Concept of Improvement Plan

The 4 concepts of improvement plan have been set up for Cuamba-Mandimba section.

(1) If the bridge width is for 2-lanes (assume minimum 6.0 m width) and the bridge condition is good or fair, the existing bridge remains to be used.

(2) If the bridge condition is poor, the existing bridge is replaced by new 2-lane bridge (or 2-lane culvert when the existing bridge length<12m).

(3) If the river flooding over road surface is reported at the bridge or culvert, the structure is replaced by 2-lane bridge to clear enough HWL and discharge.

(4) If the bridge width is for 1-lane and the bridge condition is good or fair, the existing bridge is replaced by new 2-lane bridge.

5.5.3 Selection of Best Alternative

According to the concept of improvement plan described above, the best alternatives for each bridge are selected as shown in Table 5.5.1. As a result, 4 bridges are selected for preliminary design.

Table 5.5.1 Selection of Best Alternative

unit (m)

General information		Condition of existing structures					Alt-1	Alt-2		Alt-3		remarks
No.	name	length	width	type	HWL	condition	reuse existing	reuse existing	add 1-lane bridge	new 2-lane structure (demolish existing)		
	(Cuamba)											
1	Muanda	70.0	6.0	RC-T	ok	good*	2-lane	–––	–––	–––	–––	*with railway
2	Ningare	22.0	7.2	Hollow	ok	good**	2-lane	–––	–––	–––	–––	**Japan Grant in 2004
3	Manjamanja	8.8	4.1	RC-slab	ok	poor	1-lane	–––	–––	–––	culvert	
4	Namicango	10.6	4.2	RC-slab	ok	poor	1-lane	–––	–––	–––	culvert	
5	Muambessi	14.3	4.8	RC-T	ok	fair	1-lane	1-lane	1-lane	bridge-1	–––	in 1966
6	Lugenda	34.0	6.1	RC-T	ok	good	2-lane	–––	–––	bridge	–––	continuous girder, 1940
7	Tarikajao	6.0	4.0	H-beam	ok	poor	1-lane	–––	–––	–––	culvert	
8	Pimbinu	8.8	4.1	H-beam	ok	poor	1-lane	–––	–––	–––	culvert	
9	Lussengessi-II	8.8	4.0	RC-slab	ok	poor	1-lane	–––	–––	–––	culvert	
10	Lussengessi-I	28.0	6.0	RC-T	ok	fair	2-lane	–––	–––	bridge	–––	in 1963
11	Kadawada	8.7	3.3	RC-slab	ok	poor	1-lane	–––	–––	–––	culvert	
12	Lussangassi	28.0	3.2	RC-T	ok	fair	1-lane	1-lane	1-lane	bridge-2	–––	winding road
13	Ngolua	14.0	4.7	RC-T	ok	fair	1-lane	1-lane	1-lane	bridge-3	–––	in 1964
14	Ngame-II	28.0	4.9	RC-T	ok	fair	1-lane	1-lane	1-lane	bridge-4	–––	in 1964
	(Mandimba)											

5.5.4 Preliminary Bridge Design

For the preliminary design of 4 bridges in Cuamba-Mandimba section, some design conditions such as bridge length and bridge position shall be decided by sight investigation of existing bridge and river. By the discussion with ANE, bridge inner width has been set as 9.2m for 2-lane bridge. Those are summarized in Table 5.5.2.

Table 5.5.2 New Bridges to be Designed

unit (m)

General		Existing bridge			New bridge			
No.	name	width	length	existing	lane	width	length	from existing Br.
(Cuamba)								
1	Muambessi	4.8	14.3	demolish	2-lane	9.2	17	same position
2	Lussangassi	3.2	28.0	demolish	2-lane	9.2	34	down stream 8m
3	Ngolua	4.7	14.0	demolish	2-lane	9.2	17	same position
4	Ngame-II	4.9	28.0	demolish	2-lane	9.2	34	same position
(Mandimba)								

5.5.5 Elevation of New Bridge Deck

The elevation of new bridge will be set as design H.W.L plus structure height (1.60m) plus flood clearance (0.7m or 1.0m, by design discharge). The design H.W.L is a maximum of "calculation result of 100-year return period" or "hearing result from residents in the field survey" and the design discharge is by 100-year return period.

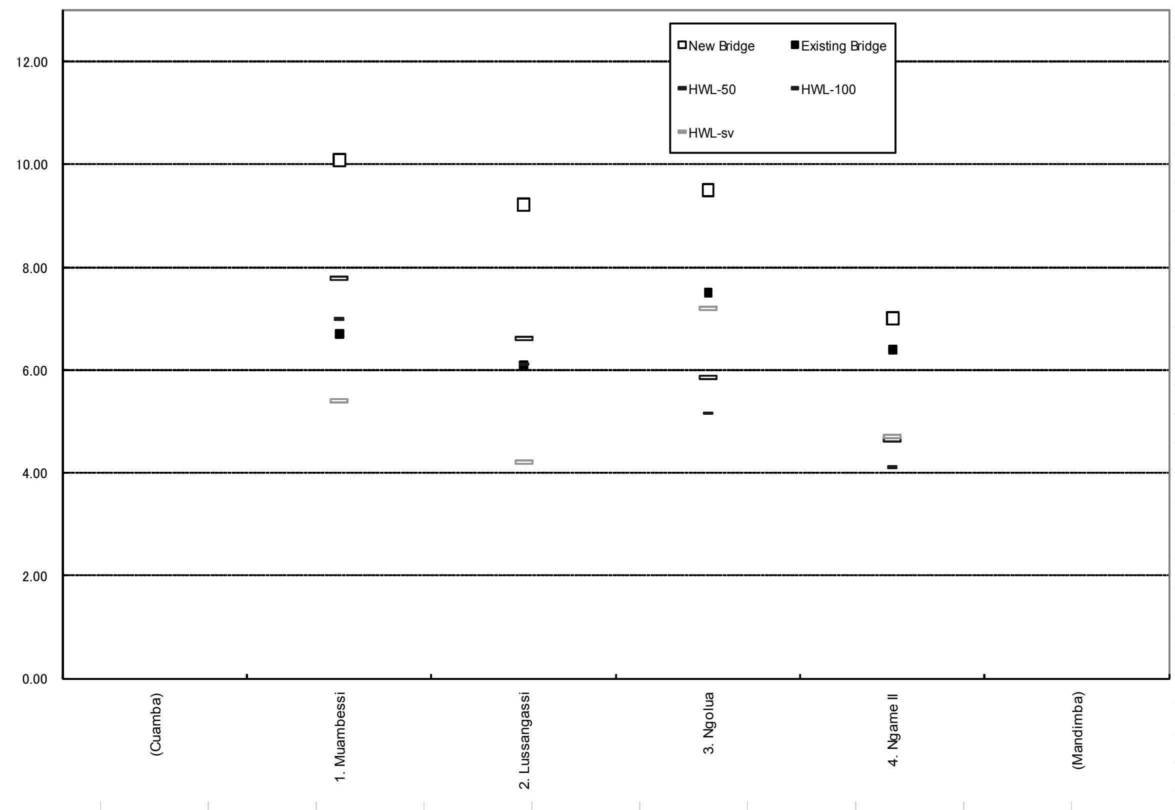
Table 5.5.3 Elevation of New Bridge Deck

Absolute Elevation (unit : m, m3/sec)

Bridge Name	New Bridge Deck Elevation	Structure Height	Flood Clearance	Existing Bridge Deck Elevation	Design HWL. Max(Hwl100, -sv)	HWL-50 for 50-year	HWL-100 for 100-year	HWL-sv by field survey	Channel Bottom by toposurvey	Design Discharge
(Cuamba)										
1. Muambessi	621.58	1.60	0.70	618.2	619.28	618.50	619.28	616.9	611.5	390.9
2. Lussangassi	642.52	1.60	1.00	639.4	639.92	639.42	639.92	637.5	633.3	**731.4**
3. Ngolua	708.50	1.60	0.70	706.5	706.20	704.16	704.85	706.2	699.0	307.9
4. Ngame II	711.50	1.60	0.70	710.9	709.20	708.61	709.15	709.2	704.5	301.7
(Mandimba)										

Height from Channel Bottom (unit : m, m3/sec)

Bridge Name	New Bridge Deck Elevation	Structure Height	Flood Clearance	Existing Bridge Deck Elevation	Design HWL. Max(Hwl100, -sv)	HWL-50 for 50-year	HWL-100 for 100-year	HWL-sv by field survey	Channel Bottom by toposurvey	Design Discharge
(Cuamba)										
1. Muambessi	10.08	1.60	0.70	6.70	7.78	7.00	7.78	5.40	0.0	390.9
2. Lussangassi	9.22	1.60	1.00	6.10	6.62	6.12	6.62	4.20	0.0	**731.4**
3. Ngolua	9.50	1.60	0.70	7.50	7.20	5.16	5.85	7.20	0.0	307.9
4. Ngame II	7.00	1.60	0.70	6.40	4.70	4.11	4.65	4.70	0.0	301.7
(Mandimba)										



5.5.6 Bridge Superstructure

The superstructures of new bridges on this Study Road are designed to meet the following general requirements.

(1) Structural requirements

The general relationship between span length and girder type, as economical aspect, is shown in Table 5.5.4. The minimum bridge length of a bridge is generally determined by the nature of the river over which the bridge is required, the soil conditions (type of foundations), and factors relating to the surroundings of the bridge (available space for construction). The choice of span length is one of the most important factors in determining the type of girder.

Table 5.5.4 Type of Girder

Span Length (m)	**Girder Types**	**Remark**
L<=10	RC Slab	Supporting required
10< L<18	RC I – Girder (in-situ) RC I – Girder (pre-cast) RC Hollow Slab	Supporting required Supporting **NOT** required Supporting required
18=<L<=33	PC I - Girder	Supporting **NOT** required

A superstructure with girders has a desirable ratio of girder height to the length of span, which will result in minimizing construction cost. Such height – length ratios are standardized. However, for the main span of a bridge where the height is a critical factor for determining the vertical alignment of the road (HWL + clearance + girder height + deck), this will affect the total cost of the structure, and a bridge having a minimum allowable girder height is to be preferred.

(2) Environmental requirements

The type of bridge selected should harmonize with the surrounding environment. Other environmental considerations that need to be taken into account when selecting the bridge type are the preservation of existing man-made facilities such as irrigation systems, public facilities and to avoid substantial changes in the hydrological conditions of the rivers.

(3) Construction requirements

If the construction period is limited to such as rainy season, the type of bridges to be selected is determined by the speed of construction. The use of pre-cast concrete is an effective way to shorten the construction period.

(4) Construction economy

The most economical type of bridge will ultimately be selected from the various alternatives available, which satisfy the conditions as mentioned above. To compare the costs of the various types of bridges, the total construction costs need be considered which include the superstructure, substructure, approaches and the auxiliary works.

(5) Girder type selection and bridge length/span

The bridge length and span will be decided to keep enough space for the river width and the calculated river discharge. Therefore, new bridge length will be longer than existing bridge and new bridge span will be decided to follow the concept of minimum span requirement in "Japanese Specification for River Structures".

The decided bridge span is 17m as shown in Table 5.5.5 and the most suitable girder type has been selected as RC I – Girder (pre-cast) from Table 5.5.4.

Table 5.5.5 Bridge Length and Span

(unit : m, m3/s)

Bridge Name					New Bridge				Minimum	Design
	Width	Length	Span(s)	Girder	Sta	Length	Span(s)	Girder	Span	Discharge
					river center				Smin	
(Cuamba)										
1. Muambessi	8.0	14.3	14.3	RC-T	Sta 047+094.0	17.0	17	RC-I	12.5	390.9
2. Lussangassi	15.0	28.0	7+7+7+7	RC-T	Sta 125+161.1	34.0	**17+17**	RC-I	**14.8**	**731.4**
3. Ngolua	14.0	14.0	14.0	RC-T	Sta 143+520.5	17.0	17	RC-I	12.5	307.9
4. Ngame II	25.0	28.0	14+14	RC-T	Sta 145+369.9	34.0	17+17	RC-I	12.5	301.7
(Mandimba)										

Minimum Span Regulation by "Japanese Specification for River Structure"

Genetal condition	Smin = 20 + 0.005*Discharge	applied for larger river and longer bridges
Special condition-1	Smin = 12.5m	if Discharge < 500 m3/sec and River width < 30m
Special condition-2	Smin = 15.0m	if Discharge < 500 m3/sec and River width > 30m
Special condition-3	Smin = 20.0m	if 500 m3/sec < Discharge < 2000 m3/sec (no regulation of river width)

For the study road, 278.9<Discharge<885.0 and river width<30m, then make reasonable interpolation of formula as;

Discharge	<500	500	interporation formula	1,500
Smin	12.5	12.5	Smin = 12.5 + 7.5/750 * (Discharge - 500)	20.0

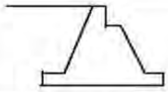
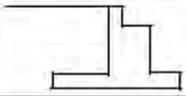
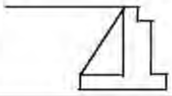
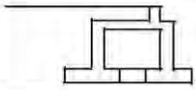
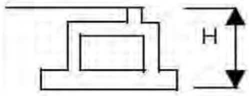
5.5.7 Bridge Substructure

The substructure of new bridges is designed to meet the following general requirements.

(1) Abutment

Reinforced concrete will be used for the common abutment. The type of abutment is basically selected based on the relationship between the height of the bridge structure and the suitability of the respective abutment as shown in Table 5.5.6. For the bridges of this Study Road, reversed T type will be selected as the most suitable abutment type.

Table 5.5.6 Type of Abutment

Tape and Shape		Applicable H (m)	Characteristic
Gravity-type		H<= 5	- Simple structure - Easy construction - Heavier weight
Reversed T Type		5< H <=12	- Cost effective - Easy construction
Counterforted Buttresseds type		10 <= H	- Intricate constrution - Difficulty in back filling
Rigid-framed Type		10<= H <= 15	- Complicated structure - High cost
Box Type		12<= H	- Complicated structure - Intricate construction - High cost

(2) Pier

Reinforced concrete piers will be used unless special conditions must be met. A wall-type pier having sharp edges is recommended in the rivers in order to allow smooth flow of water.

5.5.8 Bridge Foundation

The foundation type is mainly determined by the subsoil conditions, which need to support the total load of bridge, and by the economic criteria. A spread foundation is generally utilized where the depth of the supporting strata is obtained at less than 12m, whereas a piled foundation is employed for depths of more than 12m.

The geo-survey was conducted on all 4 new bridge locations, where 2 bore-hole data for each bridge location were given. The elevation of bearing strata is summarized in Table 5.5.7.

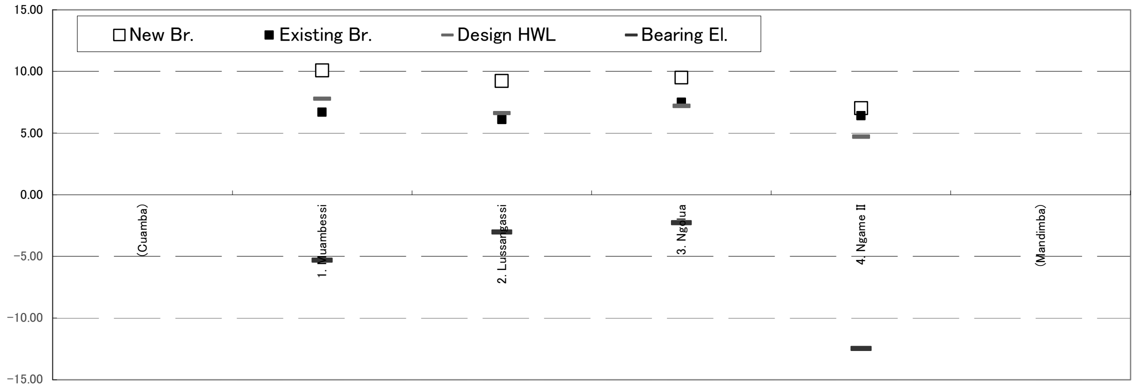
Table 5.5.7 Elevation of Bearing Strata

Absolute Elevation (Depth = New Br. El - Bearing El.)

Bridge Name	New Br.	Existing Br.	Design HWL	Channel	Bearing El.	BH-left				BH-right			
	Deck E.	Deck El.		Bottom	Average	Ground El.	BH	Depth	Bearing El.	Ground El.	BH	Depth	Bearing El.
(Cuamba)													
1. Muambessi	621.58	618.2	619.28	611.5	606.2	617.431	1	14.6	606.9	616.433	2	16.1	605.4
2. Lussangassi	642.52	639.4	639.92	633.3	630.3	637.604	3	10.4	632.1	637.837	4	14.1	628.4
3. Ngolua	708.50	706.5	706.20	699.0	696.7	705.221	5	8.3	700.2	705.230	6	15.3	693.2
4. Ngame II	711.50	710.9	709.20	704.5	692.0	711.517	7	18.0	693.5	709.026	8	21.0	690.5
(Mandimba)													

Height from Channel Bottom

Bridge Name	New Br.	Existing Br.	Design HWL	Channel	Bearing El.	BH-left				BH-right			
	Deck E.	Deck El.		Bottom	Average	Ground El.	BH	Depth	Bearing El.	Ground El.	BH	Depth	Bearing El.
(Cuamba)													
1. Muambessi	10.08	6.70	7.78	0.00	-5.32	5.93	1	14.6	-4.57	4.93	2	16.1	-6.07
2. Lussangassi	9.22	6.10	6.62	0.00	-3.03	4.30	3	10.4	-1.20	4.54	4	14.1	-4.86
3. Ngolua	9.50	7.50	7.20	0.00	-2.27	6.22	5	8.3	1.22	6.23	6	15.3	-5.77
4. Ngame II	7.00	6.40	4.70	0.00	-12.48	7.02	7	18.0	-10.98	4.53	8	21.0	-13.97
(Mandimba)													



From the possible 4 pile types below, 3) Driven pile (steel tube) has been selected as the most suitable type.

(1) Cast-in RC pile (Auger pile)

Due to the nature of the relatively hard soil conditions with difficulty of digging, and the fact that these are all river bridges, the use of auger pile was not recommended based on the risk of collapse of walls by water. This pile type would require temporary casing or drilling under slurry which makes the construction cost higher.

(2) Driven pile (pre-cast PC pile)

Driven pile with pre-cast PC pile is usually the most economical pile type for short-middle pile length, if PC pile can be fabricated in the local construction market. But unfortunately in Mozambique, this pre-cast PC pile has not been fabricated because not enough demand has been developed in local construction works.

(3) Driven pile (steel tube pile)

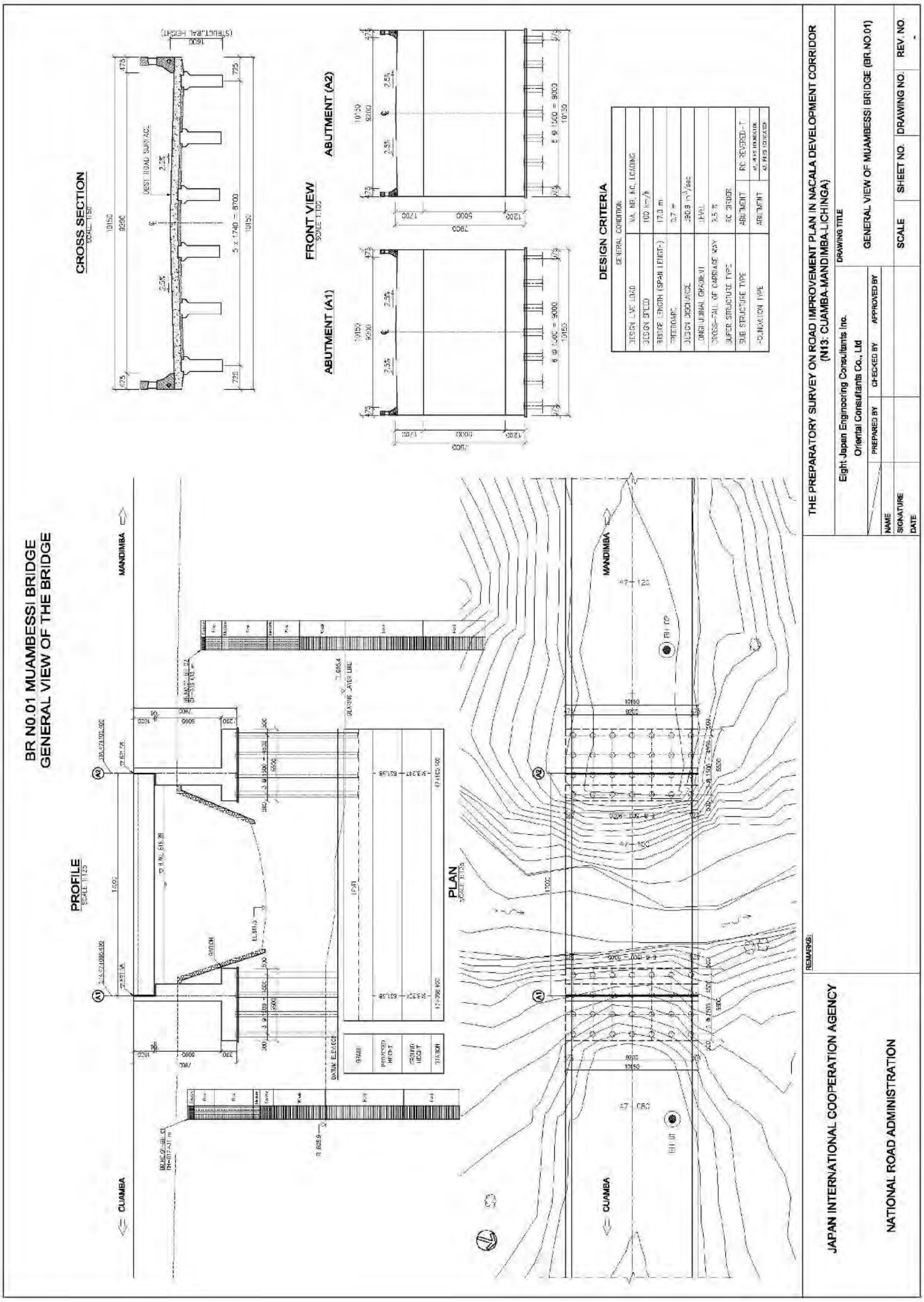
Driven pile with steel tube has been chosen as the best pile type which can achieve the required depth, can penetrate through the strata shown in the geo-technical report and has no risk of collapse or quality issues. Even the material/fabrication costs of steel tube are expensive, and it is easy for transportation and installation. Therefore, as total construction cost, this pile type is the best selection for this project.

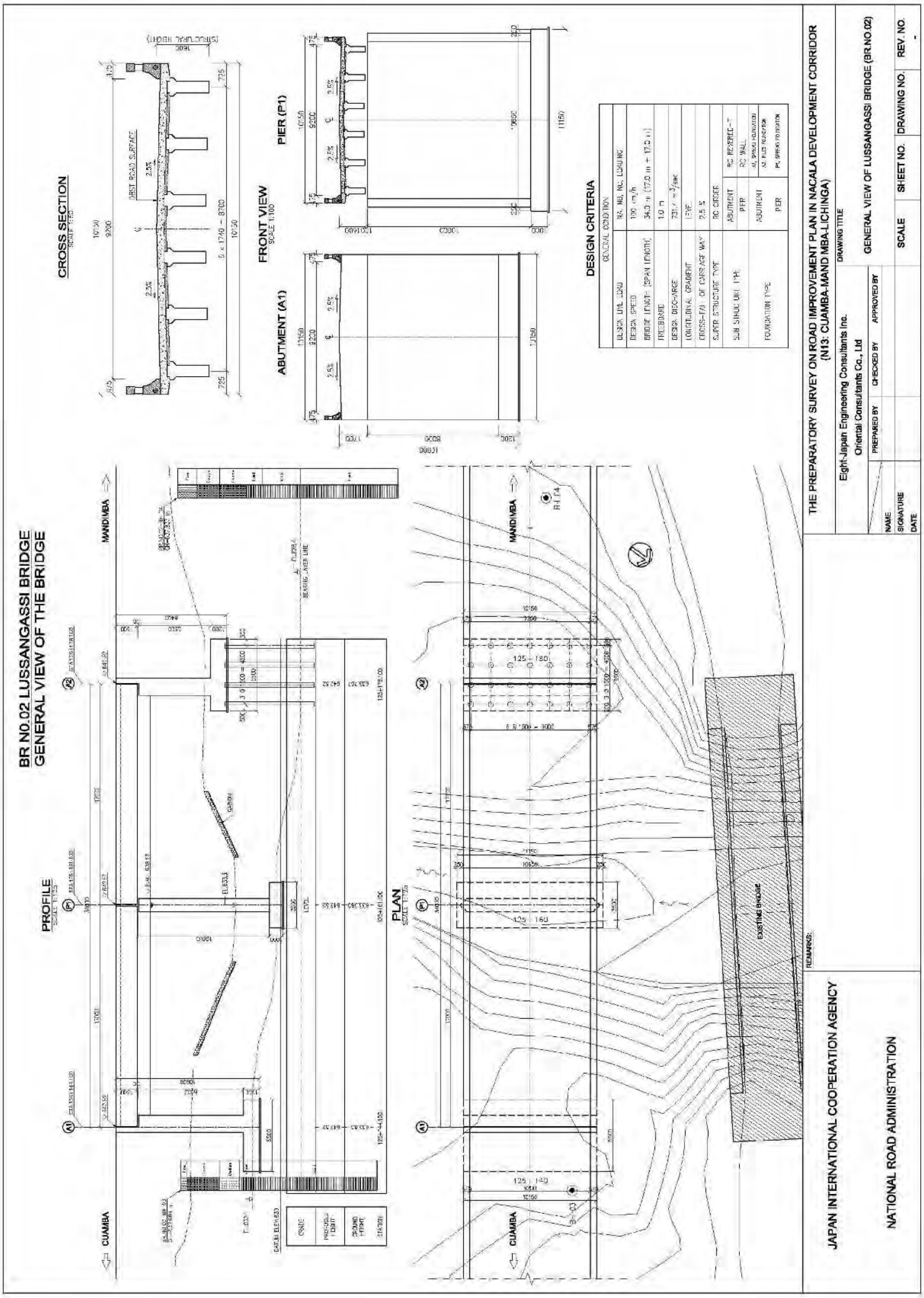
(4) Caisson

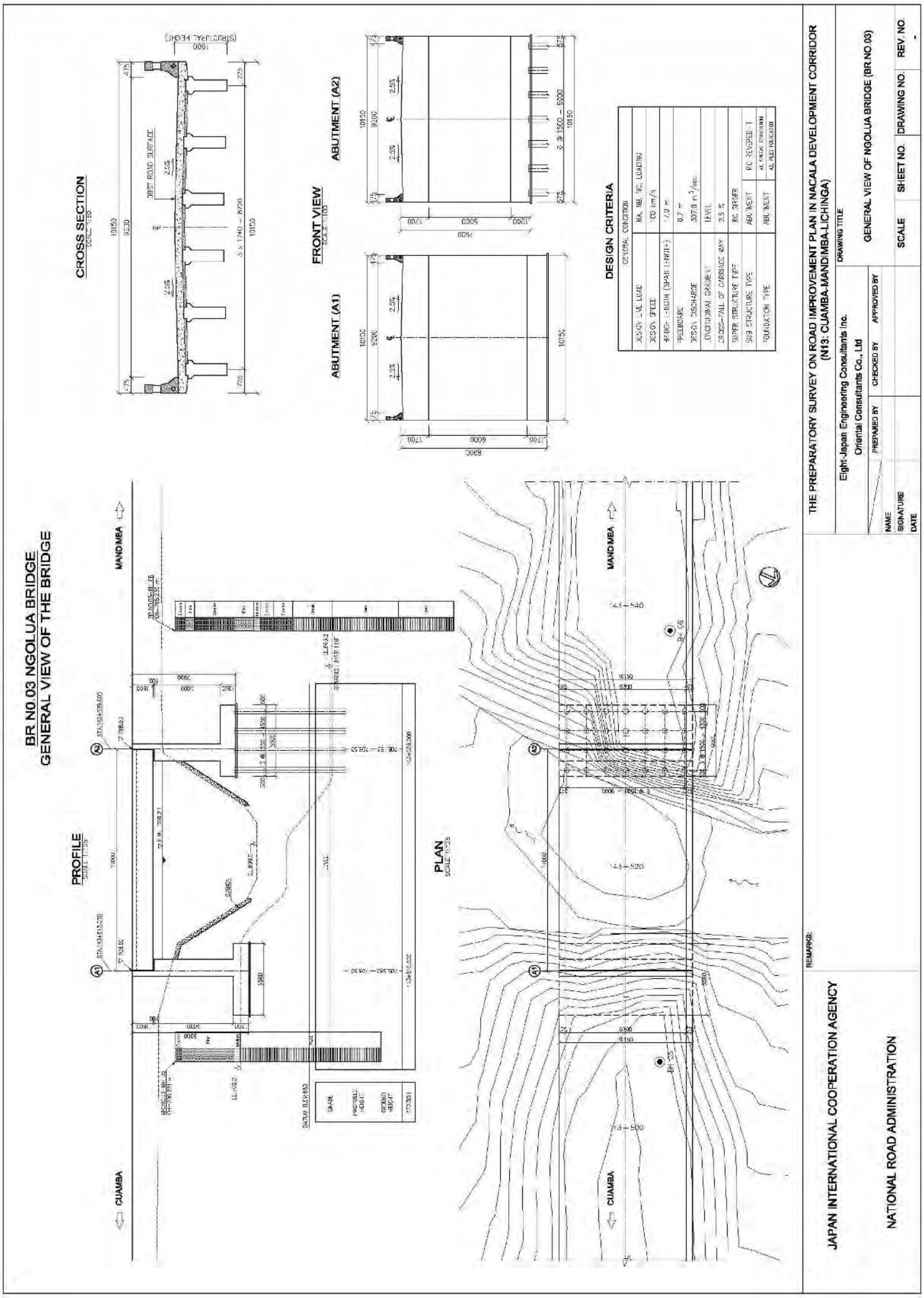
Caissons are generally suited to dry foundations where the depth to rock is less than 8m, just between direct foundation and pile foundation. For this project site some bridges have the depth to rock of about 8m but all bridges are crossing rivers and caissons have to satisfy same requirement as cast-in RC pile. Therefore, this pile type is not adopted.

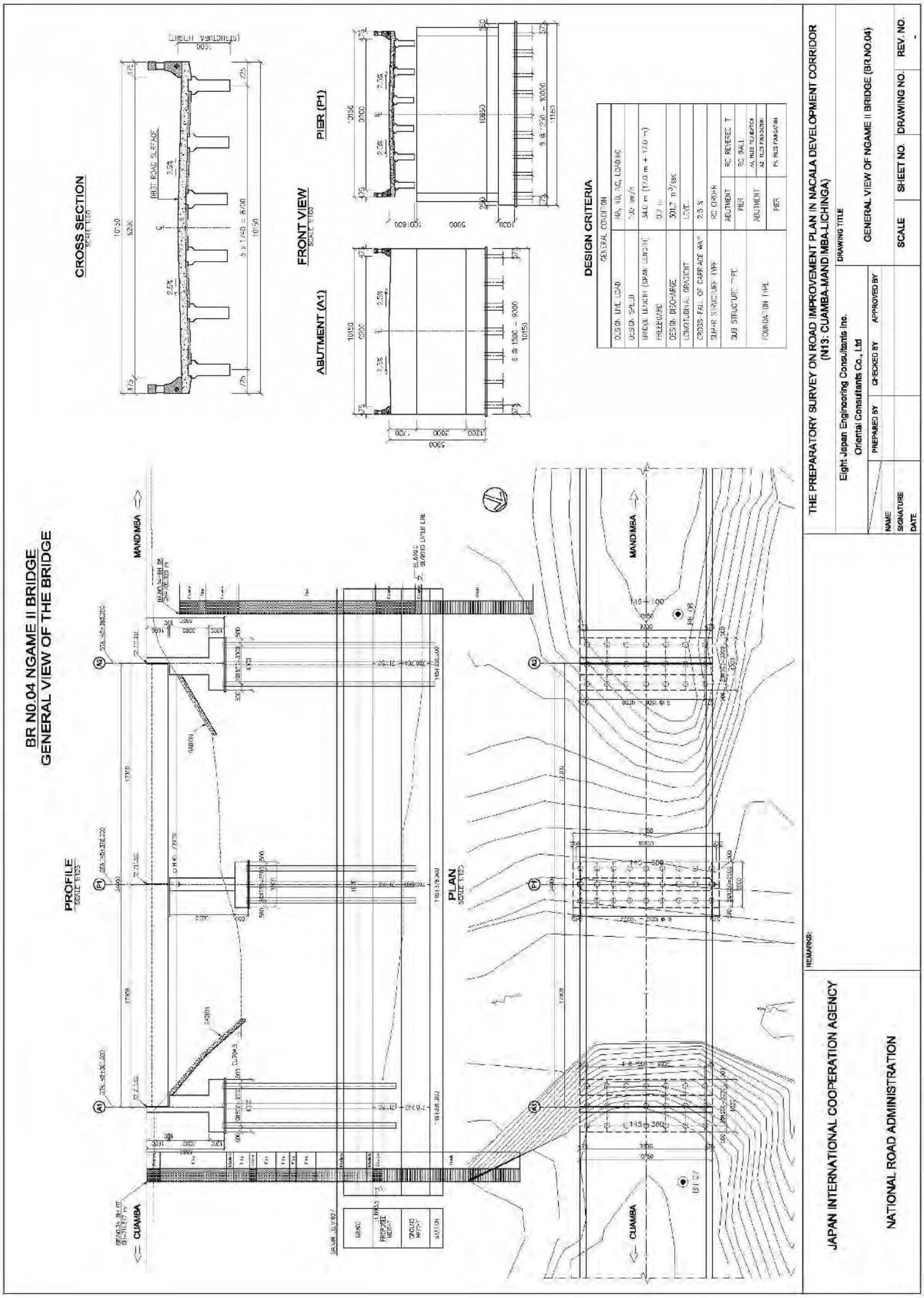
5.5.9 General View Drawings

By the preliminary design above, the general view drawings of all new bridges have been prepared as shown in the following pages.


BR N0.01 MUAMBESSI BRIDGE
GENERAL VIEW OF THE BRIDGE
PROFILE
PLAN
CROSS SECTION
FRONT VIEW
ABUTMENT (A1)
ABUTMENT (A2)
DESIGN CRITERIA
CUAMBA
MANDIMBA
JAPAN INTERNATIONAL COOPERATION AGENCY
NATIONAL ROAD ADMINISTRATION
THE PREPARATORY SURVEY ON ROAD IMPROVEMENT PLAN IN NACALA DEVELOPMENT CORRIDOR (N13: CUAMBA-MANDIMBA-LICHINGA)
Eight-Japan Engineering Consultants Inc.
Oriental Consultants Co., Ltd
GENERAL VIEW OF MUAMBESSI BRIDGE (BR.NO.01)
SCALE
SHEET NO.
DRAWING NO.
REV. NO.


BR NO.02 LUSSANGASSI BRIDGE
GENERAL VIEW OF THE BRIDGE
PROFILE
PLAN
CROSS SECTION
FRONT VIEW
ABUTMENT (A1)
PIER (P1)
DESIGN CRITERIA
CUAMBA
MANDIMBA
EXISTING BRIDGE
THE PREPARATORY SURVEY ON ROAD IMPROVEMENT PLAN IN NACALA DEVELOPMENT CORRIDOR (N13: CUAMBA-MANDIMBA-LICHINGA)
Eight-Japan Engineering Consultants Inc.
Oriental Consultants Co., Ltd
GENERAL VIEW OF LUSSANGASSI BRIDGE (BR.NO.02)
JAPAN INTERNATIONAL COOPERATION AGENCY
NATIONAL ROAD ADMINISTRATION


BR N0.03 NGOLUA BRIDGE
GENERAL VIEW OF THE BRIDGE
PROFILE
PLAN
CROSS SECTION
FRONT VIEW
ABUTMENT (A1)
ABUTMENT (A2)
DESIGN CRITERIA
CUAMBA
MANDIMBA
JAPAN INTERNATIONAL COOPERATION AGENCY
NATIONAL ROAD ADMINISTRATION
THE PREPARATORY SURVEY ON ROAD IMPROVEMENT PLAN IN NACALA DEVELOPMENT CORRIDOR
(N13: CUAMBA-MANDIMBA-LICHINGA)
Eight-Japan Engineering Consultants Inc.
Oriental Consultants Co., Ltd
GENERAL VIEW OF NGOLUA BRIDGE (BR.NO.03)


BR NO.04 NGAME II BRIDGE
GENERAL VIEW OF THE BRIDGE
PROFILE
PLAN
CROSS SECTION
FRONT VIEW
ABUTMENT (A1)
PIER (P1)
DESIGN CRITERIA
CUAMBA
MANDIMBA
JAPAN INTERNATIONAL COOPERATION AGENCY
NATIONAL ROAD ADMINISTRATION
THE PREPARATORY SURVEY ON ROAD IMPROVEMENT PLAN IN NACALA DEVELOPMENT CORRIDOR
(N13: CUAMBA-MANDIMBA-LICHINGA)
Eight-Japan Engineering Consultants Inc.
Oriental Consultants Co., Ltd
GENERAL VIEW OF NGAME II BRIDGE (BR.NO.04)

Chapter 6 Construction Planning

6.1 Introduction

This chapter shall describe the construction plan proposed for improvement of Cuamba – Mandimba – Lichinga road on N13 (hereinafter referred as "the Project") including construction method, procurement of material and equipment, and construction schedule according to site condition, structural scale and work quantities. The improvement work shall be divided into two major components namely road and bridge, for which discussion is made separately. Further the Project Road has approximately 300km length between Cuamba and Lichinga. Then the road shall be divided into following two construction sections to discuss design, construction plan and cost estimate.

Section 1: Cuamba – Mandimba (Length = 152.9km)

Section 2: Mandimba – Lichinga (Length = 148.4km)

Total: (301.3km)

This chapter shall focus on Section 1 (Cuamba – Maidimba) as follows.

6.2 Work at Pre-Construction Stage

The following activities must be completed in the pre-construction stage; otherwise the implementation schedule will be affected resulting in a possible delay in conclusion of works and the opening of the road.

(1) Land Acquisition and Resettlement

The land acquisition and resettlement shall be implemented by the GoM. Land area and structures to be relocated shall be finalized at detailed design.

(2) Survey and Clearance of Land Mines

Land mines along the Project Road must be identified and cleared at this stage. The work is an obligation of the contractor who has been awarded the job. Cost of the work shall be included in the Project cost in the same way as previous highway projects. National De-mining Institute (IND) has a registration system for de-mining organization (i.e. enterprise, NGO). IND's list shows detailed information of the registered organizations. The contractor shall then select the appropriate organization from the list.

(3) Relocation of Public Utilities

Public utilities (e.g. electric poles and lines, telephone cables, water pipes, etc.) shall be relocated by the GoM before commencement of the site works.

6.3 Construction Plan for the Project

6.3.1 Availability of Material and Equipment for the Project

(1) Construction Material

1) Material from Natural Source

Generally construction materials such as soil, aggregate and sand are available along and/or suburbs of the Project Road. The Team conducted material survey and laboratory test to confirm qualities and potential quantities of the materials. Detailed analysis of the survey is discussed to meet demand of the design result of the Project in Chapter 2 "Natural Condition Survey".

2) Material from Industrial Source

Local suppliers around the Project are not able to supply large amounts of construction materials (e.g. cement, re-bar, bitumen) due to their limited business scale. The contractor has to secure reliable and sustainable sources such as Maputo, Beira, Nampula, Nacala and/or overseas at the construction stage. Potential sources of major materials are as follows:

Cement : Nacala

Re-bar : Beira, Maputo and/or overseas

Bitumen : Beira, Maputo and/or overseas

(2) Construction Equipment

The local market of the leasing business is still too immature to provide construction equipments with sufficient types, numbers and performance to meet demands of the contractor. Therefore, the contractor has to outsource the equipments from Maputo, Beira, Nampula, Nacala and/or overseas unless bringing in his own equipments.

(3) Transportation Method of Material and Equipment

Currently railway service is operational from Nacala to Lichinga by Corredor de Desenvolvimento do Norte (CDN). However, only the line between Nacala and Entre-Lagos (aka border with Malawi) has a regular service (six round trips per week). Moreover cargo service of this line is unable to fully meet requirements of the users due to shortages of locomotives and wagons according to interview and study with relevant persons/organizations. Therefore, the contractor shall use the railway service between Nacala and Cuamba for transportation of material and equipment while adjusting with other users.

Currently the line between Cuamba and Lichinga has no regular service because of frequent damage of structures (e.g. track, sleeper and roadbed) due to shortage of finance for repair and maintenance. Therefore, the contractor shall use vehicle transport instead of uncertain railway service.

6.3.2 Road Construction Plan

(1) Introduction

This construction plan includes a brief description on the construction method of road works including earthwork, sub-grade, base-course and pavement surface works as well as temporary works such as the installation of diversion roads

(2) Construction Method in Rural Section

Road construction work shall be executed in so-called construction units with traffic being closed from the existing road. Therefore, traffic diversions should be prepared for. Furthermore, a temporary construction road shall also be constructed to avoid mixing between construction plant / equipment and ordinary traffic. The continuous length of diversions shall not exceed 5km and each unit shall be at least 5km apart from the next unit according to the ANE's regulation. Traffic controllers shall be assigned at the junctions between the existing road and the work units. A sample layout of the rural section is shown in Figure 6.3.1. And Figure 6.3.2 shows the work process in each of the work units. Note desirable timing of traffic open shall be completion of principal works (up to lane-marking) with continuous length of 30 to 50km according to previous experience in Mozambique.

(3) Town Section

Unlike rural sections, construction work in towns is facing the difficulty of securing sufficient area for diversions and the construction road. Therefore, the work shall be executed on one side of the road in order to secure one-lane traffic on the other side at all times. Construction vehicles shall share this one lane with public vehicles. Well-trained traffic controllers shall be assigned to these sections. A sample layout in town sections is shown in Figure 6.3.3.

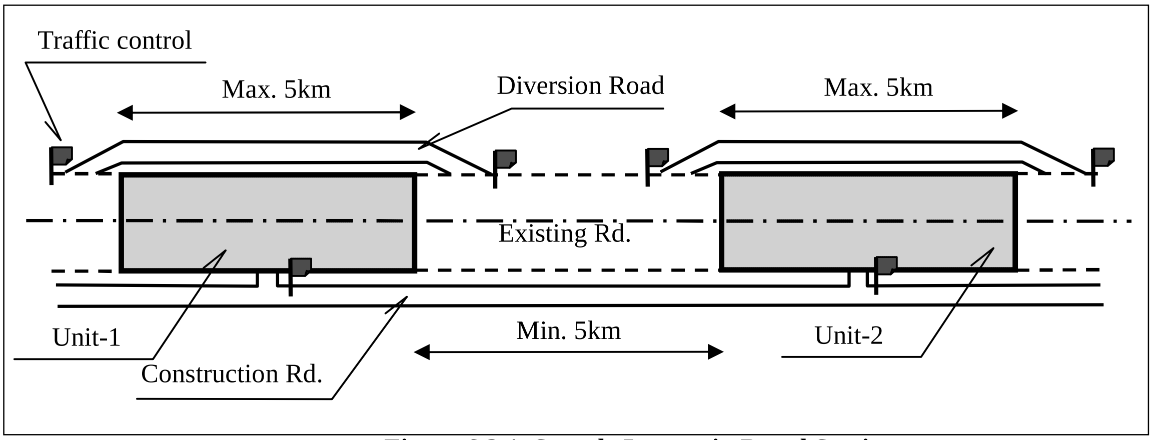


Figure 6.3.1 Sample Layout in Rural Section

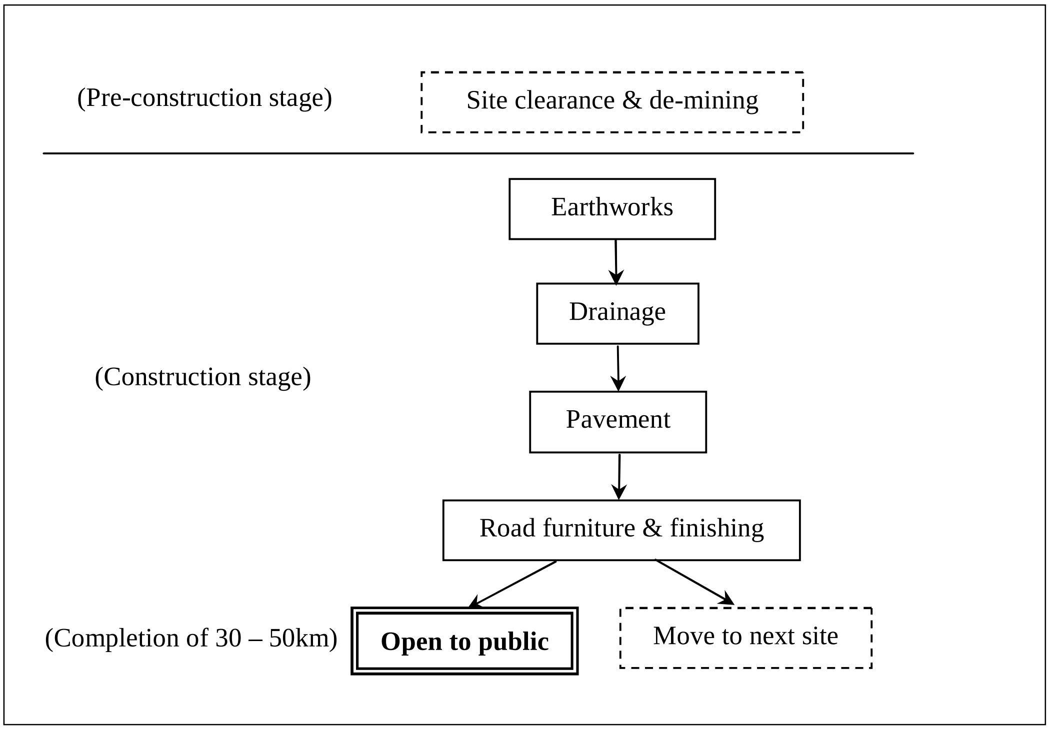


Figure 6.3.2 Construction Process in the Construction Unit

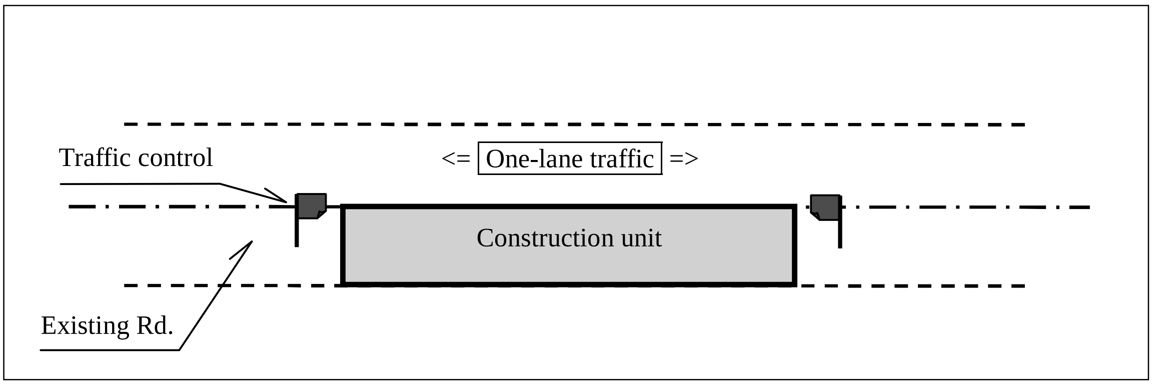


Figure 6.3.3 Sample Layout in Town Section

6.3.3 Bridge Construction Plan

(1) Introduction

This construction plan includes a brief description on the construction method of superstructure, substructure and foundation, construction procedures and the construction schedule for bridge construction works.

(2) Construction Plan for Superstructure

1) Construction Method

RC-I girder (L=17m & 15m) shall be utilized for the Project. For the girder fabrication, there are two methods; fabrication on site or transport of the girders from a factory. Although the latter has advantages in terms of improved quality control of the fabrication process and timely completion of the girders, the former method shall be recommended for the Project site because:

The site is remote from possible girder factory (e.g. Nacala, Nampula). And,

Access roads from the factory to the site are in poor condition which would damage the girders during transportation.

Consequently, it is recommended that the RC-I girder shall be fabricated at the construction yard near the bridge sites. Applying mobile crane (over 50 ton) for girder erection is also recommended.

2) Construction Procedure

The standard construction procedure for superstructure is shown in Figure 6.3.4.

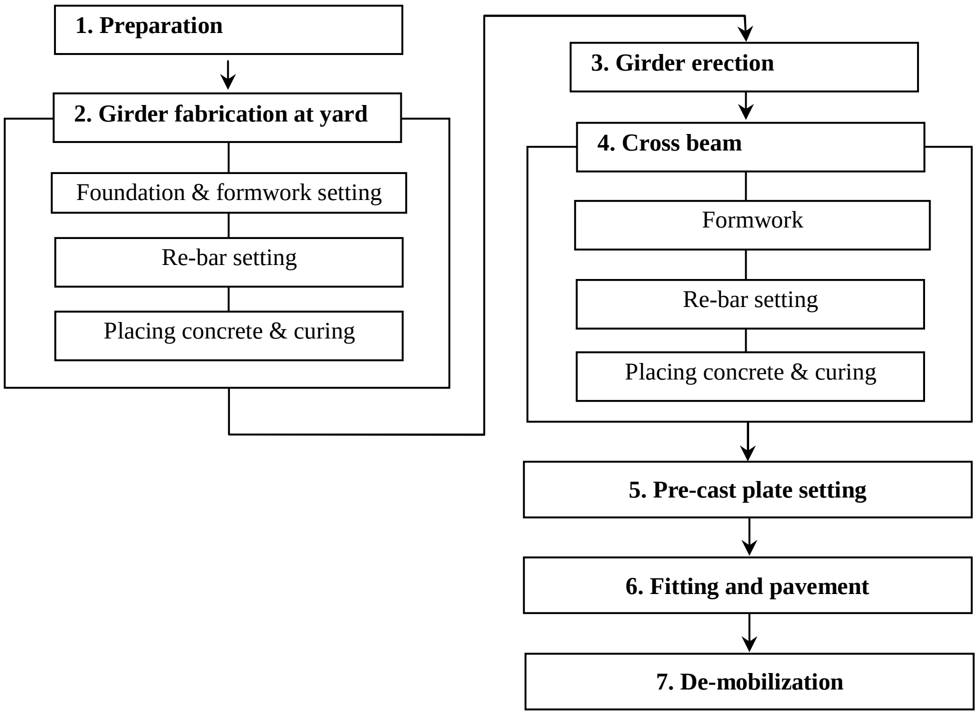


Figure 6.3.4 Construction Procedure for Superstructure (RC-I Girder)

(3) Construction Plan for Substructure and Foundation

1) General

There are four bridges in Section 1 that are supported by pile foundations on the Project Road. According to the preliminary design, steel tube pile (D=400mm) shall be applied for. Brief information regarding pile foundations is shown in Table 6.3.1.

Table 6.3.1 Brief Information on Pile Foundations

No.	River name	No. of pile	Length (m)
1	Muambessi	56	7.85 – 9.35
2	Lussangassi	28	6.78
3	Ngolua	28	8.47
4	Ngame II	69	13.18 – 16.17

2) Construction Procedure for Substructure and Foundation

Construction work of the foundation and substructure should be undertaken with the following procedure as shown in Figure 6.3.5.

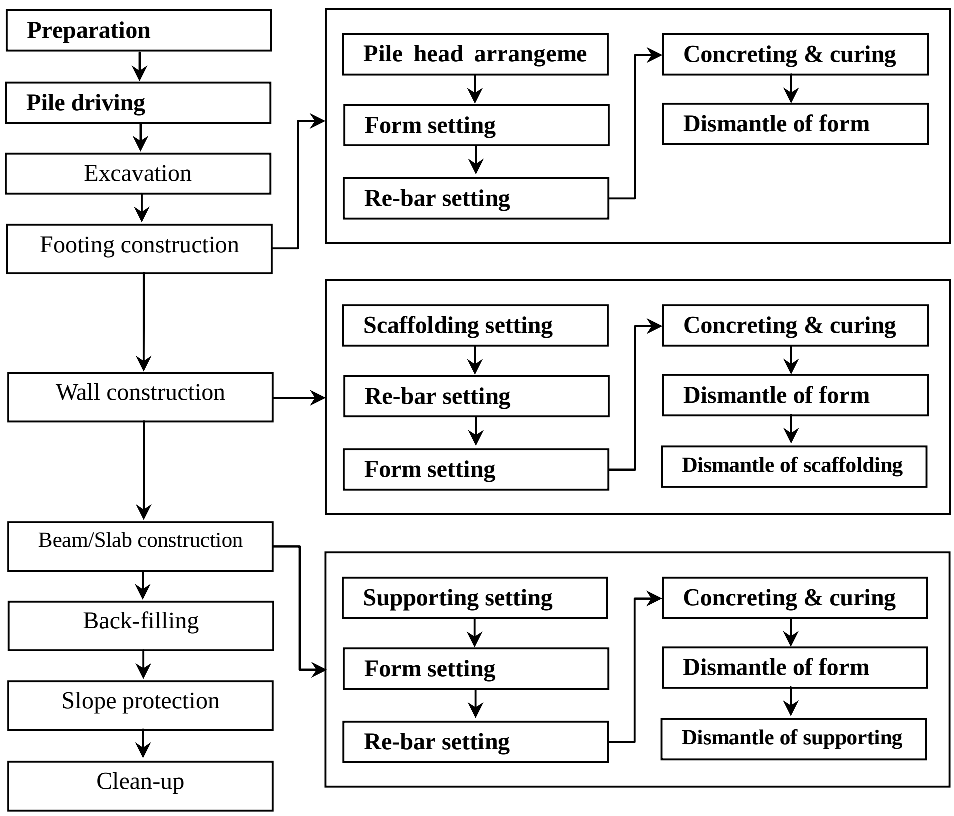


Figure 6.3.5 Construction Procedure for Substructure & Foundation

6.4 Contents of Construction Works

Construction work items and their quantities are shown in Table 6.4.1. Note breakdown of the work items and their quantities for the bridges are attached in Appendix.

Table 6.4.1 Work Items & Quantities

Item	Description			Unit	Quantity	Remarks
Bill A: Road works						
1000	General			Ls.	1.00	
2000	Drainage	(1)	Prefabricated pipe culvert (RC)	m	2,906.00	
		(2)	Concrete lined ditch	m	12,920.00	
		(3)	Concrete kerb	m		
		(4)	Stone pitching	sq.m	5,100.00	
		(5)	Gabion	cu.m	1,610.00	
3000	Earthworks & pavement layers of gravel or crushed stone	(1)	Cut & fill	cu.m	170,436.00	
		(2)	Haulage of embankment material from borrow pit (1.0km)	cu.m	5,895,030.00	Distance btw. site & pit = 10km
		(3)	Disposal of surplus material (1.0km)	cu.m	42,609.00	
		(4.1)	Upper subgrade	cu.m	350,157.00	
		(4.2)	Lower subgrade	cu.m		
		(5.1)	Cement stabilized gravel sub base course (C2)	cu.m		
		(5.2)	Cement stabilized gravel sub base course (C3)	cu.m		
		(5.3)	Cement stabilized gravel sub base course (C4)	cu.m	313,512.00	
		(5.4)	Gravel wearing course	cu.m		Equivalent with gravel sub base course (CBR>30%)
		(6)	Crushed stone base course	cu.m	270,191.00	Transport distance of aggregate = 40km
4000	Asphalt pavements & seals	(1)	Prime coat	sq.m	1,376,110.00	
		(2)	Single seal	sq.m	229,349.00	
		(3)	Double seal	sq.m	1,146,761.00	
		(4)	Asphalt concrete (t=10cm)	sq.m		
		(5)	Interlocking block pavement	sq.m		
5000	Ancillary roadworks	(1)	Km post	No.	306.00	
		(2)	Guardrail	m	905.00	
		(3)	Road sign	sq.m	171.90	
		(4)	Road marking (W=10cm)	km	458.70	
		(5)	Grassing (embankment slope)	sq.m	553,363.00	
6000	Structures	(1)	Box culvert	cu.m	3,349.00	
		(2)	Bridge	Ls.	1.00	
7000	Testing & quality control			Ls.	1.00	
8000	Other works	(1)	Railway level crossing	No.	2.00	
		(2)	One stop border post	Ls.	1.00	
		(3)	Demolishing existing concrete	cu.m	3,836.00	
		(4)	Removal of corrugated pipe	m	1,243.00	
		(5)	Finishing of road & road reserve (single carriageway)	km	152.90	
		(6)	Treatment of old road & temp. diversion	km	153.80	
		(7)	Transportation of construction material	Ls.	1.00	75km from Cuamba by trailer truck (50t)

6.5 Construction Schedule

Construction schedule for the Project shall be estimated on the basis of quantities of construction works, daily performance rate of working unit, local conditions, etc. Further, net working rate in unit period of time, considering non-working days (i.e. rainy days, Sundays and holidays) highly affects the construction schedule. Estimated working rate is shown in Table 6.5.1.

Table 6.5.1 Net Working Rate

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
No. of day	31	28	31	30	31	30	31	31	30	31	30	31	365
Rainy day (over 10mm)	10.30	6.10	4.50	2.70	0.30	-	0.10	0.10	-	0.30	2.00	5.00	31.40
Sunday	4	4	5	4	5	4	4	5	4	4	5	4	52
Holiday	1	1	-	1	1	1	-	-	2	1	1	1	10
(*1)	1.66	1.09	0.73	0.45	0.06	-	0.01	0.02	-	0.05	0.40	0.81	5.27
Non-working day	13.64	10.01	8.77	7.25	6.24	5.00	4.09	5.08	6.00	5.25	7.60	9.19	88.13
Working day	17.36	17.99	22.23	22.75	24.76	25.00	26.91	25.92	24.00	25.75	22.40	21.81	276.87
Working Rate (Average)	0.56	0.64	0.72	0.76	0.80	0.83	0.87	0.84	0.80	0.83	0.75	0.70	0.76
Working Rate (dry season)					Dry season								0.82
Working Rate (rainy season)	Rainy season											Rainy season	0.68

(*1) Rainy days fall on Sunday or holiday.

As a result of above discussion, the provisional construction schedule is shown in Table 6.5.2.

Table 6.5.2 Construction Schedule

Task	Duration
Commencement of construction	Mid.Dec.2011
Construction for 3 years (152.9km)	36 months
Bill 1300 & 1400, Contractor's establishment, housing & offices	6 months
Bill 1700, Clearing & grubbing	12 months
Bill 2000, Drainage	24 months
Bill 3000, Earthworks & gravel pavement	30 months
Bill 4000, Surface seal	30 months
Bill 5000, Ancillary road works	24 months
Bill 6000, Bridge & box culvert	30 months
Bill 7000, Testing & quality control	33 months
Item 8000, Others	24 months
Completion of construction	Mid.Dec.2014

: Rainy season

6.6 Applicability of Construction Method for Cost Reduction

6.6.1 General

Key factors affecting construction cost are (i) accessibility to materials, (ii) construction period and (iii) complexity of construction work, etc. This section shall discuss applicability of construction methods to contribute to cost reduction for road and bridge as follows.

6.6.2 In-place Base Course Recycling Method for Road Construction

Road construction is composed of comparatively simple and common work items. Further the Project site is located in quite a remote region. Therefore, applying latest construction method is unpractical and difficult to confirm the effect of cost reduction.

According to previous projects, the cost of pavement work covers 40 to 80% of total construction cost, therefore, focusing on this work item is quite effective for minimizing construction cost. Now applicability of captioned method shall be described as follows.

This method is to recycle from existing aged pavement structures (i.e. surface, base & sub-base course) to new granular base and sub-base course on site. This method shall reduce transportation process of the materials and material cost itself by recycling existing ones. This method is composed of the following processes:

(i) Crush existing pavement structures

(Required equipment: Road stabilizer)

(ii) Mix fragments of pavement and stabilizing agent (e.g. cement, bitumen, & crushed stone)

(Required equipment: Road stabilizer)

(iii) Grading and compaction

(Required equipment: Motor grader, pneumatic tire roller, road roller & vibration compactor)

Mechanisms of this method by material type of existing structure are shown in Figure 6.6.1 and 6.6.2.

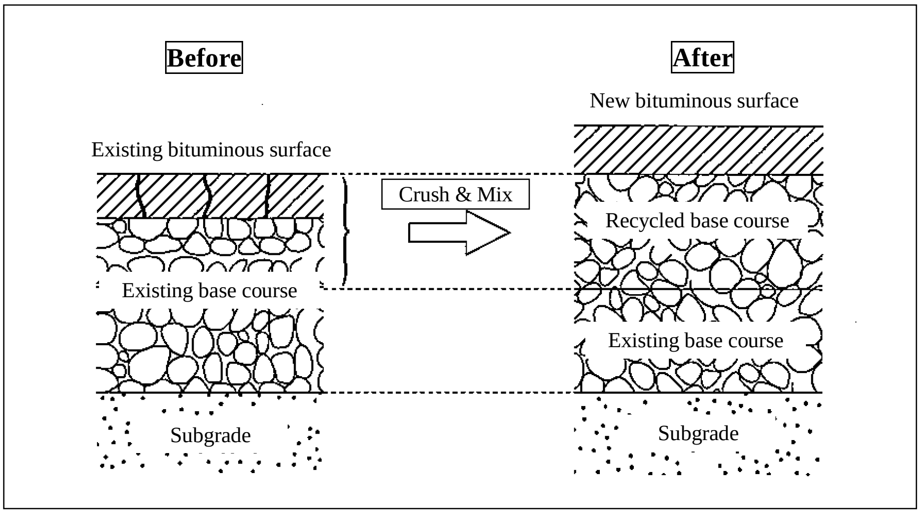


Figure 6.6.1 Sample Drawing of In-place Base Course Recycling Method from Existing Surface Course & Base Course

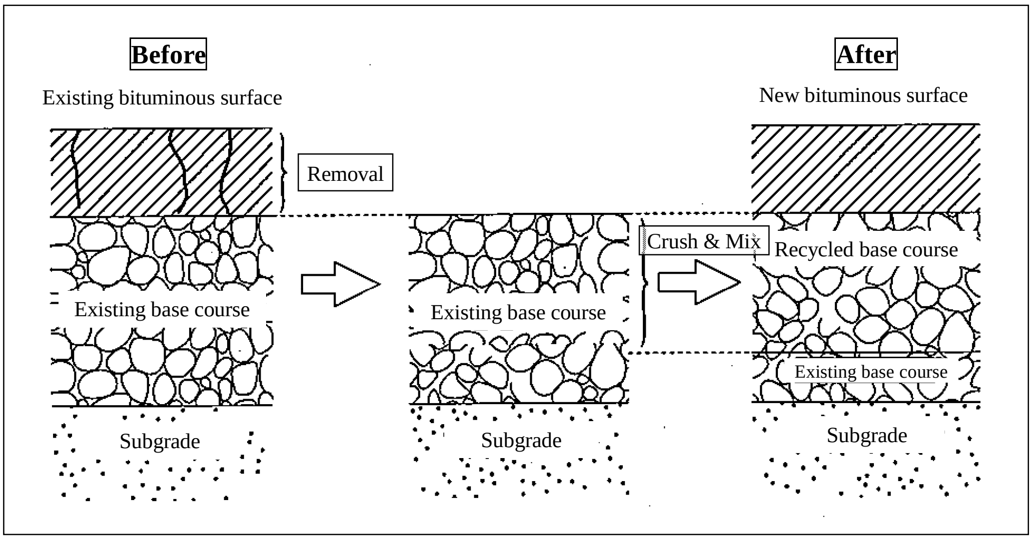


Figure 6.6.2 Sample Drawing of In-place Base Course Recycling Method from Existing Base Course

Applicability of the Project

The point of this method is to utilize existing pavement structure to re-build a part of new base and/or sub-base course in place. Therefore, generally proposed alignments (i.e. horizontal and vertical) should be onto the existing road's ones, for example, re-construction work of pavement structures. On the other hand, this method would not be applicable in following cases:

The alignments shall be re-designed because of upgrading of the road structure. It means that construction work will be newly commenced from building subgrade.

Speed and effectiveness of construction work shall decline in cases where existing road section and new construction section frequently alternate with each other.

And now turning to the Project, the result of preliminarily design indicates that applicability of this method is improper because of the following reasons.

(i) Elevation of Existing Road Surface

Elevation of existing road surface is lower than roadside area in most of the Project section. It brings severe damages such as erosion and scouring on the surface due to inflow of flood water during rainy season. Therefore, designed surface elevation will be raised with filling material to protect the road structure from the above damages. Consequently, utilizing of existing pavement is not expected.

(ii) Quality of Existing Pavement Material

Quality of existing pavement material is insufficient to utilize for base and sub-base course according to sampling and laboratory testing described in Chapter 2 "Natural Condition Survey".

6.6.3 Uniformity of Precast Girder for Bridge Construction

This method aims to simplify construction work for cost reduction applying a few types of precast RC girder. This method shall minimize and speed up manufacturing work at fabrication yard and erection work at the construction site.

According to preliminarily design result of the bridge, two types of precast RC girders namely 17m and 15m shall cover all bridge construction works (four bridges in Section 1). It might boost achievement of the above aims.

Chapter 7 Project Implementation Plan

7.1 Introduction

This chapter describes the Project implementation plan and disbursement schedule based on the capital investment and maintenance costs, which form the basis for the cost estimate and economic analysis.

7.2 Prerequisites for the Implementation Plan

7.2.1 Project Implementation Strategy for the Nacala Corridor by AfDB

The size of the Project, comprising 510km of road upgrading, 9.2km of bypass road, 442km of road rehabilitation and two one-stop border posts all at different stages of preparation, dictates that the Nacala Road Corridor be implemented in three phases as follows:

Phase I

- ✓ Civil works for upgrading of Nampla-Cuamba Road (350km) in Mozambique.
- ✓ Civil works for construction of Lilongwe Bypass (9.2km) in Malawi.
- ✓ Supervision of the civil works above.
- ✓ Compensation and resettlement.
- ✓ Feasibility and detailed engineering design studies for Zero-Vila Nova da Fronteira-Nsanje road.
- ✓ Audit services

Phase II

- ✓ Civil works for rehabilitation of Luangwa-Chipata-Mwami Border (360km) in Zambia.
- ✓ Civil works for rehabilitation of Mangochi-Liwonde Road (90km).
- ✓ Supervision of the civil works above.
- ✓ Compensation and resettlement.
- ✓ Audit services.

Phase III

- ✓ Civil works for upgrading the Cuamba-Mandimba Road (160km) in Mozambique.
- ✓ Civil works for rehabilitation of the Liwonde-Nsipe Road (82km) in Malawi.
- ✓ Construction of two one-stop border posts/axle load control facilities, one between Zambia and Malawi and the other between Malawi and Mozambique.

- ✓ Compensation and resettlement
- ✓ Audit services

As mentioned above, implementation of section between Cuamba and Mandimba including the one-stop border is scheduled in Phase III.

According to the Programme of Road Integrated Sector Strategy (PRISE) 2009 to 2011 established by the Road Fund in 2009 and Project Appraisal Report for MULTINATIONAL-NACALA ROAD CORRIDOR-PHASE I prepared by AfDB, the section between Nampula and Cuamba will be upgraded from 2010 to 2013 as indicated below.

Activities	2009				2010				2011				2012				2013				2014			
Quarter																								
I. Civil Works																								
1. Compensation and Resettlement		■	■	■																				
2. PQ of Contractors			■	■																				
3. Bidding/Contract Award					■	■																		
4.Mobilization							■																	
5. Civil Works Execution								■	■	■	■	■	■	■	■	■	■	■	■					
6. Defect Liability																				■	■	■	■	
II. Contract Supervision																								
1. EOI, Request for Proposals/Award		■	■																					
2. Pre-contract Services				■	■	■																		
3. Civil Works Supervision							■	■	■	■	■	■	■	■	■	■	■	■	■					
4. Defects Liability Period																				■	■	■	■	

Source: Project Appraisal Report for MULTINATIONAL-NACALA ROAD CORRIDOR-PHASE I

Figure 7.2.1 Nampula-Cuamba Road Project Program

For now, the African Development Bank and Japan are going to finance the civil works and supervision for the Cuamba-Mandimba Road similar to the Nampula-Cuamba Road.

7.2.2 Procurement System

(1) Typical Procurement System

The African Development Bank revised the procurement method and released the procedures for procurement goods and works and the rules and procedures for recruitment of consultants in May 2008. One of the major changes in the new rules is a requirement for borrowers to prepare and submit a procurement plan to the Bank for approval before the start of loan negotiations.

Based on the rules and the procedures of the Bank, the International Competitive Bidding (ICB) method is the most typical procedure for the procurement of goods and works for the project implementation. The common types of the contracts provide for payments on the basis of the lump sum, unit prices, reimbursable cost plus fees, or combinations thereof. Reimbursable cost contracts are acceptable to the Bank only in exceptional circumstances such as conditions of high risk or where costs cannot be determined in advance with sufficient accuracy.

In order to implement the ICB procedure the following documents shall be prepared during the detailed design of the project after the confirmation of the viability of the Project by the feasibility study.

- ✓ Invitation to bid
- ✓ Instructions to bidders
- ✓ Form of bid
- ✓ Form of contract
- ✓ Conditions of contract
- ✓ General and special specifications and drawings
- ✓ Relevant technical data
- ✓ List of goods or bill of quantities
- ✓ Delivery time or schedule of completion
- ✓ Necessary appendices, such as formats for various securities

(2) Other Methods of Procurement

In cases where the methods of procurement that can be used are not the most economical and efficient method of procurement, the following methods of procurement are also applicable and authorized by the Bank.

Limited International Bidding: This method is essentially ICB by direct invitation without open advertisement and is an appropriate method of procurement where (a) there are only a limited number of suppliers, or (b) other exceptional reasons may justify departure from full ICB procedure.

National Competitive Bidding (NCB): NCB is the competitive bidding procedure normally used for public procurement in the country of the borrower. NCB may be the most appropriate method of procurement where foreign bidders are not expected to be interested because (a) the contract values are small, (b) works are scattered geographically or spread over time, (c) works are labor intensive, or (d) the goods or works are available locally at prices below the international market rate.

Shopping and Direct Contracting: Shopping is a method based on comparing price quotations obtained from several suppliers. Direct contracting is contracting without competition and may be appropriate in cases where an existing contract for goods or works is accepted and may be extended for additional goods or works of a similar nature.

Force Account: Force account construction by use of the borrower's own personnel and equipment may be the only practical method for some kinds of works.

Procurement from Specialized Agencies

Procurement under BOO/BOT/BOOT, Concessions and Similar Private Sector

Arrangements: Where the Bank is participating in financing the cost of a project procured under a BOO/BOT/BOOT, concessions or similar type of private sector arrangement, the concessionaire or entrepreneur under the BOO/BOT/BOOT or similar type of contract shall be selected under ICB procedures acceptable to the Bank.

Performance-Based Procurement: Performance-based procurement, also called Output-based procurement, refers to competitive procurement process (ICB or NCB) resulting in a contractual relationship where payments are made for measured outputs instead of the traditional way where inputs are measured. Performance-based procurement can involve: design, supply, construction (or rehabilitation) and commissioning of a facility to be operated. For the cases of procurement of a facility and services where design, supply and/or construction of a road and operation and maintenance are required, toll road/bridge and tunnels are the typical projects and the contractor is free to propose the most appropriate solution, based on mature and well proven experience and shall demonstrate that the level of quality specified in the bidding documents will be achieved. The bidding documents do not normally prescribe the inputs, nor a work method for the contractor. For the cases where design, supply and/or construction are required, prequalification is normally required and the use of two-stage bidding for the turn key project will be applied.

Community Participation in Procurement: Community participation in procurement is desirable to (a) call for the participation of local communities and/or nongovernmental organizations (NGO), or (b) increase the utilization of local know-how and materials, or (c) employ labor-intensive and other appropriate technologies that may be suitable.

Procurement under Disaster and Emergency Assistance

(3) Proposed Procurement Method

Based on the description of the above mentioned procurement methods, each method of procurement has applicable conditions. In case of this Project, the following items can be considered as the features of the Project.

- ✓ This road project will result in the improved road being maintained by ANE as one of the national trunk roads through the established procedure of either periodic or routine maintenance program.

- ✓ In order to minimize an insecure investment both for initial and routine/periodic maintenance, a detailed design shall be necessary and shall be conducted by the Project owner.

- ✓ In case of the design, construction and maintenance method, the contracted amount and duration seems to be lower and shorter than the traditional step by step method. But the detailed design including detailed topographical survey shall be conducted by the contractor, then the contractor shall frequently request the design change which usually incurs higher cost than the original contracted design due to fitting it to the existing terrain conditions. But if the owner could not answer correctly and quickly, then the owner will spend much time for the evaluation of the proposed design change and finally accept the higher cost of the design change. As a result, the original duration of the contract will become longer with long idle time of construction equipments and manpower requiring higher project cost.

- ✓ In such case, both contractor and owner cannot easily settle those issues by themselves, making it necessary to adopt an arbitration process and the project will be stuck or fall through. Accordingly, the traditional ICB method will be recommendable for the selection of construction contractor of this Project, and both BOT and the design, construction and maintenance method will not be adequate for the implementation of the Project. On the other hand, the procurement method of engineering consultant for the detailed design will be recommendable to introduce quality-based procurement in order to keep the quality of the design accuracy of this Project.

7.3 Project Implementation Plan

7.3.1 Executing Agency

The ANE has been delegated by the Ministry of Public Works and Housing to manage the national road network. The project implementation responsibility will be located under the DEPRO of ANE. There is also GAT dealing with environmental and social issues that also serves this directorate though reporting directly to the Director General of ANE.

7.3.2 Typical Implementation Conditions

Project implementation plan usually has some constraints affecting the schedule as below:

- ✓ The Feasibility Study Report on this Project shall be submitted by February 2010.
- ✓ GOM/ANE will try to find an expected source of funding for the detailed design (D/D) of this Project as early as possible.
- ✓ After finding of the fund, selection of consultant for D/D will require four to five months procedure and preparation of D/D with tender documents will require minimum five months.
- ✓ Preparation of environmental impact assessment and RAP will require about eight to nine months and will be submitted to AfDB and JICA 120 days prior to the submission of the appraisal report and loan agreement of the Project, respectively.
- ✓ Negotiation with the lending agencies (AfDB and/or other donors) for approval and finalization of loan agreement will require minimum four months
- ✓ Tendering for construction contractor will require minimum nine to ten months procedure including pre-qualification, tender announcement, tender preparation of 90 days limitation and tender evaluation and approval by ANE and lending agencies
- ✓ Selection of supervision consultant and tender assistance will require about five to six months.
- ✓ Physical commencement of contractors' work (usually 30 days from notice to proceed)

- ✓ Construction work and supervision service will require about three years (33 months)

7.3.3 Project Implementation Plan

Based on the abovementioned conditions, proposed implementation plan for this Project can be summarized as shown below and in Fig. 7.3.2.

Construction duration: year 2011 to 2014 with three years construction and opening to the public will be in 2014 as planned in the PRISE 2009.

Construction packaging: as the total length of the road is the level of 154km length, one packaging of the contractor procurement will be recommendable based on the evaluation of much construction cost required for the establishment of construction camps and temporary works in case of multi packaging of the contractor procurement.

Detailed design: The source of funding for the detail design is not yet determined. Therefore, GOM/ANE have applied for the fund of the detail design to AfDB as the NEPAD project and have already started discussion with AfDB and Development Bank of Southern Africa (DBSA). At the moment GOM/ANE is expecting the financing for the detailed design from AfDB or DBSA at an early stage. Hence a minimum duration of the finding of the funding will be introduced for the scheduling of the detailed design of this Project.

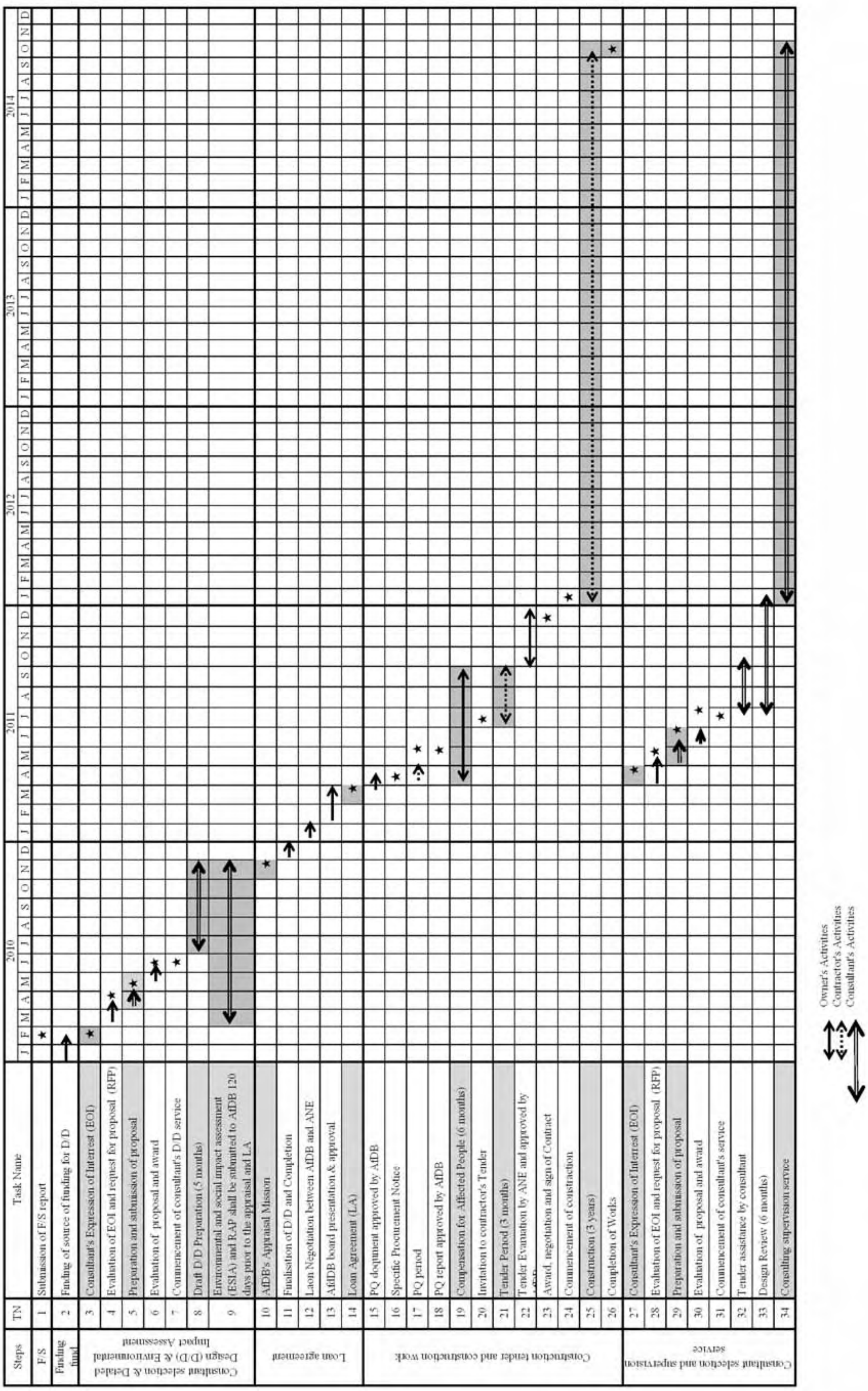
Additionally the Study Team proposes the following activities and additional surveys for the detailed design based on the results of the Study.

Month	1	2	3	4	5	Remarks
I. Key Engineer						
1. Highway Engineer						
2. Hydrologist						
3. Structural Engineer						Bridge Design (N=4)
4. Material Engineer						
5. Cost Estimator						
6. Document Specialist						
7. Architect						One Stop Border Post
8. Economist						
II. Topographical & Geological Survey						
1. Topographic Survey						DMS* survey (L=154km)
2. Geological Survey						Boring Survey (N=2, L=25m)

*DMS: Detailed Measurement Survey

Figure 7.3.1 Proposed Detail Design Activities and Additional Surveys (L=154km)

Figure 7.3.2 Proposed Implementation Program for Cuamba-Mandimba Road



Chapter 8 Project Cost Estimate

8.1 Introduction

Preliminary cost estimate of the Project (hereinafter referred as “the Estimate”) shall be made based on the results of the preliminarily design, the quantity of each work item, and the construction planning of the Project. Results of the Estimate will be utilized for the economic analysis.

8.2 Methodology of the Estimate

(1) Analysis and Modification of Similar Project

Basically unit construction cost of “Upgrading of Nampula – Cuamba Road” (hereinafter referred as “NCR”) is utilized for the Estimate due to high similarities between the two projects as follows.

Site location: The Project road is the extension of NCR beyond Cuamba in northern region.

Time of estimate: Engineering estimate of NCR was finalized at its detailed design stage in April 2009.

However, the following matters are considered and modified to customize for the Estimate.

1) Updating of Material Price

Material price highly affects construction cost. Therefore, prices of some essential materials are updated according to market research in Nampula province (see below). Researched price is applied for the Estimate instead of NCR’s.

Currency: US $

Material	Unit	NCR	Recent Market Price (*)
(i) Cement	Ton	300.00	180.00
(ii) Diesel	Litter	1.45	0.90
(iii) Re-bar	Ton	1400.00	1,280.00

(*) Average of six large suppliers in October 2009. The prices include delivery to Cuamba.

2) Analysis of Transportation Method

Limitation of transportation method between NCR and the Project is considered. In concrete terms, railway is in service in the section of Nacala – Nampula – Cuamba for NCR. Therefore, there are two choices namely railways and vehicles for NCR. On the other hand, only vehicles such as dump trucks and trailer trucks are available beyond Cuamba for the Project. Vehicle transportation cost is estimated as follows.

- ✓ Number of trips in case of applying trailer trucks (50ton) is calculated from total weight of principal construction material and average distance between Cuamba and construction site.
- ✓ The cost is figured out by multiplying number of trips and unit vehicle cost together. Detailed figures are shown in Table 8.2.1.

Table 8.2.1 Transportation Cost

Currency: US $

Material	Unit	Qty	No. of trip	Unit V-cost (per trip)	Margin factor	Amount
(i) Cement	Ton	22,370	448	716.90	150%	603,271
(ii) Re-bar	Ton	1,585	32			
(iii) Pre-cast pipe	m	2,906	72			
(iv) Steel pile	m	1,801	9			
		Total trips	561			

Estimate conditions

- ✓ **Unit vehicle rate**: USD 716.90 per day for trailer truck (50ton). The rate includes driver, fuel and operation cost.
- ✓ **Transportation distance**: 75km (Cuamba – midpoint of the Project road)
- ✓ **Unit vehicle cost**: One round trip per day is available upon considering required trip distance (75 x 2 = 150km), existing road condition and time of loading/unloading. Therefore, the cost is estimated at USD 716.90 per trip.
- ✓ **Margin factor**: This factor is prepared for the goods and items excluding above materials.

3) Cost of Pavement Work

Generally speaking, quite high percentage (40 – 80%) of total construction cost is covered by pavement works such as base, sub-base and surface course among similar type of road projects. Further, transportation method and distance of crushed stone (i.e. principal material for pavement works) also highly affect the relevant costs. Therefore, unit construction costs of pavement works are estimated while considering the conditions as shown below.

- ✓ **Location of potential quarry**: 78km from Cuamba identified as No.2 from the material survey result
- ✓ **Transportation distance**: 40km (quarry/crushing plant to midpoint of construction section)
- ✓ **Transportation method**:Applying dump truck (10ton). Available unit transportation quantity is 5.5 days per 100 cu.m according to Japanese standard.
- ✓ **Unit construction cost**:

Currency: US $

Work	Unit	Cost
(i) Crushed stone base course	cu.m	88.55
(ii) Single surface seal	sq.m	5.52
(iii) Double surface seal	sq.m	8.86

(2) Applicability of Price Escalation Factor

Inflation rate of +10% per year (i.e. 10 years average (1999 – 2008) of consumer price index) is publicized by Institution of National Statistics (INE). However, material price is not harmonized with current trend of inflation according to recent market research stated in 8.2 (1). Fluctuation of material price is stable or declining. Therefore, applying this rate to the cost of NCR is not appropriate for updating the Estimate. Unit construction cost for the Estimate is set up based on the result of above discussion and analysis instead of unanimously applying the rate of +10%.

8.3 Determination of Unit Construction Cost

Unit construction costs are determined on the basis of above discussions. The costs of road and bridge work items (equivalent Bill-A: No. 2000 – 8000) are shown in Table 8.3.1 and 8.3.2.

Table 8.3.1 Unit Construction Cost for Road

Currency: US $

Item	Description			Unit	Unit Cost	Remarks
Bill A: Road works						
2000	Drainage	(1)	Prefabricated pipe culvert (RC)	m	1,236.63	
		(2)	Concrete lined ditch	m	158.62	
		(3)	Concrete kerb	m	33.35	
		(4)	Stone pitching	sq.m	65.55	
		(5)	Gabion	cu.m	142.00	
3000	Earthworks & pavement layers of gravel or crushed stone	(1)	Cut & fill	cu.m	6.11	
		(2)	Haulage of embankment material from borrow pit (1.0km)	cu.m	0.92	
		(3)	Disposal of surplus material (1.0km)	cu.m	5.75	
		(4.1)	Upper subgrade	cu.m	5.92	
		(4.2)	Lower subgrade	cu.m	4.74	
		(5.1)	Cement stabilized gravel sub base course (C2)	cu.m	67.78	
		(5.2)	Cement stabilized gravel sub base course (C3)	cu.m	58.10	
		(5.3)	Cement stabilized gravel sub base course (C4)	cu.m	48.42	
		(5.4)	Gravel wearing course	cu.m	36.80	Equivalent with gravel sub base course (CBR>30%)
		(6)	Crushed stone base course	cu.m	88.55	Transport distance of aggregate = 40km
4000	Asphalt pavements & seals	(1)	Prime coat	sq.m	1.53	
		(2)	Single seal	sq.m	5.52	
		(3)	Double seal	sq.m	8.86	
		(4)	Asphalt concrete (t=10cm)	sq.m	51.75	
		(5)	Interlocking block pavement	sq.m	25.30	
5000	Ancillary roadworks	(1)	Km post	No.	110.76	
		(2)	Guardrail	m	64.62	
		(3)	Road sign	sq.m	473.01	
		(4)	Road marking (W=10cm)	km	1,523.88	
		(5)	Grassing (embankment slope)	sq.m	2.94	
6000	Structures	(1)	Box culvert	cu.m	646.29	
		(2)	Bridge	Ls.	3,886,616.26	
7000	Testing & quality control			Ls.	17,250.00	
8000	Other works	(1)	Railway level crossing	No.	115,000.00	
		(2)	One stop border post	Ls.	0.00	
		(3)	Demolishing existing concrete	cu.m	42.99	
		(4)	Removal of corrugated pipe	m	6.79	
		(5)	Finishing of road & road reserve (single carriageway)	km	1,725.00	
		(6)	Treatment of old road & temp. diversion	km	1,380.00	
		(7)	Transportation of construction material	Ls.	693,761.65	75km from Cuamba by trailer truck (50t)

Table 8.3.2 Unit Construction Cost for Bridge

Currency: US $

Item	Description				Unit	Rate	Remarks
6000	(2) Bridge	1) Foundation	(i) Excavation	Soil	cu.m	2.39	
			(ii) Excavation	Rock	cu.m	17.58	
			(iii) Backfill		cu.m	5.62	
			(iv) Pile	Steel tube (D=400mm)	m	840.00	
		2) Substructure	(i) Concrete	σck=240kgf/cm2	cu.m	249.78	
			(ii) Formwork		sq.m	33.24	
			(iii) Reinforcement bar	SD295	t	2,950.25	
		3) Superstructur	(i) Precast RC girder	σck=300kgf/cm2, L=17m	No.	7,745.02	
			(ii) Concrete	σck=270kgf/cm2 (deck, cross beam, precast panel)	cu.m	225.60	
			(iii) Formwork		sq.m	30.72	
			(iv) Reinforcement bar	SD295	t	2,820.00	
			(v) Girder erection		No.	974.54	
		4) Ancillaries	(i) Expansion joint		m	1,059.73	
			(ii) Bearing		No.	336.56	
			(iii) Drainage pipe	PVC (D=75mm)	m	115.15	
			(iv) Parapet	New Jersey type	m	838.10	
			(v) Slope & river protection	Gabion (t=30cm)	sq.m	69.49	

8.4 Cost of Non-Construction Works

Costs of non-construction works are determined as follows.

(1) General Works (Bill-A: No. 1000)

Cost of this item is estimated as percentage of total amount of bill No. 2000 – 8000 on the basis of comparative analysis among similar type of road projects previously implemented in Mozambique. Analysis result is shown in Figure 8.4.1 as a graphing relation between cost (2000 – 8000) and general cost.

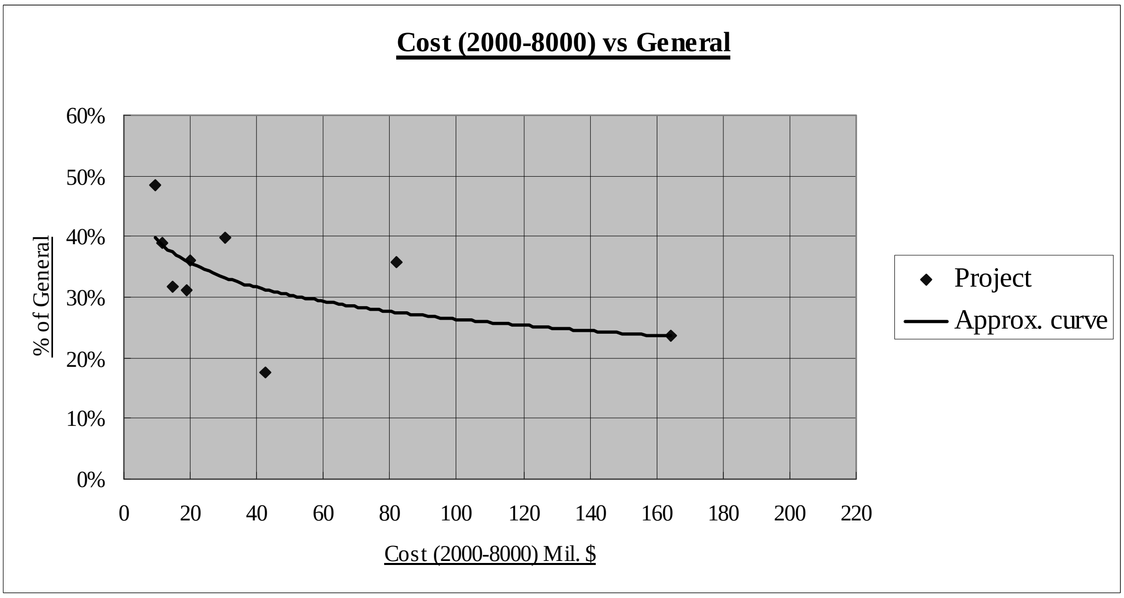


Figure 8.4.1 Relation between Cost (2000 – 8000) & General Cost

(2) Day Works, Social Issues and Environmental Mitigation

Costs of captioned items are estimated as percentage of total amount of Bill-A (Road works) based on the engineering estimate of NCR. Each percentage for application is shown below.

Bill	% of Bill-A (NCR)
Bill-B: Day works	0.86%
Bill-C: Social issues	0.94%
Bill-D: Environmental mitigation	0.25%

(3) Contingency and Engineering Cost

Contingency and engineering costs are estimated according to engineering estimate of NCR as follows.

- ✓ **Contingency cost**: 10% of total construction & non-construction costs (Bill A – D)
- ✓ **Engineering cost**: 5% of Bill A – D + contingency cost

(4) Value Added Tax (VAT)

17% of VAT is regulated in Mozambique. However, the rate will be eased to 6.8% in case of road project according to recent regulation. Therefore, the Estimate applies the eased rate.

8.5 Result of the Estimate

The results of the Estimate are summarized in Table 8.5.1 and 8.5.2. Note breakdown of the bridge construction cost is attached in Appendix.

Table 8.5.1 Total Project Cost

Currency: US $

Item	Description			Unit	Rate	Quantity	Amount	Remarks
Bill A: Road works								
1000	General			Ls.	21,773,228.78	1.00	21,773,228.78	28.00% of 2000 to 8000
2000	Drainage	(1)	Prefabricated pipe culvert (RC)	m	1,236.63	2,906.00	3,593,645.33	
		(2)	Concrete lined ditch	m	158.62	12,920.00	2,049,363.94	
		(3)	Concrete kerb	m	33.35		0.00	
		(4)	Stone pitching	sq.m	65.55	5,100.00	334,305.00	
		(5)	Gabion	cu.m	142.00	1,610.00	228,623.22	
			Total (2000)				**6,205,937.49**	
3000	Earthworks & pavement layers of gravel or crushed stone	(1)	Cut & fill	cu.m	6.11	170,436.00	1,040,767.43	
		(2)	Haulage of embankment material from borrow pit (1.0km)	cu.m	0.92	5,895,030.00	5,423,427.60	Distance btw. site & pit = 10km
		(3)	Disposal of surplus material (1.0km)	cu.m	5.75	42,609.00	245,001.75	
		(4.1)	Upper subgrade	cu.m	5.92	350,157.00	2,073,804.83	
		(4.2)	Lower subgrade	cu.m	4.74			
		(5.1)	Cement stabilized gravel sub base course (C2)	cu.m	67.78			
		(5.2)	Cement stabilized gravel sub base course (C3)	cu.m	58.10			
		(5.3)	Cement stabilized gravel sub base course (C4)	cu.m	48.42	313,512.00	15,178,683.48	
		(5.4)	Gravel wearing course	cu.m	36.80			Equivalent with gravel sub base course (CBR>30%)
		(6)	Crushed stone base course	cu.m	88.55	270,191.00	23,925,413.05	Transport distance of aggregate = 40km
			Total (3000)				**47,887,098.15**	
4000	Asphalt pavements & seals	(1)	Prime coat	sq.m	1.53	1,376,110.00	2,104,760.25	
		(2)	Single seal	sq.m	5.52	229,349.00	1,266,006.48	
		(3)	Double seal	sq.m	8.86	1,146,761.00	10,154,568.66	
		(4)	Asphalt concrete (t=10cm)	sq.m	51.75		0.00	
		(5)	Interlocking block pavement	sq.m	25.30		0.00	
			Total (4000)				**13,525,335.38**	
5000	Ancillary roadworks	(1)	Km post	No.	110.76	306.00	33,891.49	
		(2)	Guardrail	m	64.62	905.00	58,479.74	
		(3)	Road sign	sq.m	473.01	171.90	81,309.82	
		(4)	Road marking (W=10cm)	km	1,523.88	458.70	699,002.15	
		(5)	Grassing (embankment slope)	sq.m	2.94	553,363.00	1,629,100.67	
			Total (5000)				**2,501,783.87**	
6000	Structures	(1)	Box culvert	cu.m	646.29	3,349.00	2,164,420.19	
		(2)	Bridge	Ls.	3,886,616.26	1.00	3,886,616.26	
			Total (6000)				**6,051,036.44**	
7000	Testing & quality control			Ls.	17,250.00	1.00	**17,250.00**	
8000	Other works	(1)	Railway level crossing	No.	115,000.00	2.00	230,000.00	
		(2)	One stop border post	Ls.	0.00	1.00	0.00	
		(3)	Demolishing existing concrete	cu.m	42.99	3,836.00	164,898.13	
		(4)	Removal of corrugated pipe	m	6.79	1,243.00	8,433.76	
		(5)	Finishing of road & road reserve (single carriageway)	km	1,725.00	152.90	263,752.50	
		(6)	Treatment of old road & temp. diversion	km	1,380.00	153.80	212,244.00	
		(7)	Transportation of construction material	Ls.	693,761.65	1.00	693,761.65	75km from Cuamba by trailer truck (50t)
			Total (8000)				**1,573,090.04**	
			Total (Bill A: Road works)				**99,534,760.15**	
Bill B: Day works				Ls.	855,998.94	1.00	855,998.94	0.86% of Bill A
Bill C: Social issues				Ls.	935,626.75	1.00	935,626.75	0.94% of Bill A
Bill D: Environmental mitigation				Ls.	248,836.90	1.00	248,836.90	0.25% of Bill A
			Total (Bill A+B+C+D)				**101,575,222.73**	
Contingencies				Ls.	10,157,522.27	1.00	10,157,522.27	10% of A to D
IVA				Ls.	7,597,826.66	1.00	7,597,826.66	6.8% of (A to D) & Contingencies
			Total construction cost				**119,330,571.66**	
Engineering cost				Ls.	5,586,637.25	1.00	5,586,637.25	5% of (A to D) & Contingencies
IVA				Ls.	379,891.33	1.00	379,891.33	6.8% of Engineering cost
			Total project cost				**125,297,100.25**	
			Compensation for land acquisition & resettlement				156,103.00	
						(USD	820,492	per km)

Table 8.5.2 Bridge Construction Cost

Currency: US $

No.	River name	Description	Area (sq.m)	Amount	Cost per sq.m	Remarks
1	Muambessi	L=17.00m, W=10.15m, Pile foundation	172.55	868,972.00	5,036.06	
2	Lussangassi	L=2@17.00m=34.00m, W=10.15m, Pile foundation	345.10	945,484.89	2,739.74	
3	Ngolua	L=17.00m, W=10.15m, Pile foundation	172.55	680,084.17	3,941.37	
4	Ngame II	L=2@17.00m=34.00m, W=10.15m, Pile foundation	345.10	1,392,075.20	4,033.83	
		Total	**1,035.30**	**3,886,616.26**	**3,754.10**	

8.6 Result of Cost Reduction

Cost reduction is one of the essential conditions for improvement of the effectiveness of the Project. For this purpose, following items of cost reduction were proposed in consideration of minimum requirement based on several standards applied for the Project.

The effect of the cost reduction is summarized in Table 8.5.3. As a consequence, 3.3% of total project cost and 83.0% of compensation cost were reduced by the proposed ideas.

Table 8.6.1 Effect of the Cost Reduction (USD)

Items	Original		Final		Reduced Cost
	Plan	Amount	Plan	Amount	
Shoulder Pavement	Double Seal	14,290,214	Single Seal	13,525,335	764,879
No. of Level Crossing	8 Level Crossings	920,000	2 Level Crossings	230,000	690,000
Bridge and Culvert	All target bridges are replaced to new bridge.	7,245,673	The bridges less than 12m length are replaced with a culvert.	6,051,036	1,194,636
Total Project Cost	-	129,566,263	-	125,297,100 (96.7%)	4,269,163
Compensation for land acquisition & resettlement	Right of Way (ROW): 30m from road shoulder	915,776	Corridor of Impact (COI): Construction Area	156,103 (17.0%)	759,673

Chapter 9 Road Maintenance Systems

9.1 Introduction

This chapter describes the road maintenance and traffic management plan to be implemented after commencement of operation of the upgraded Study Road in order to ensure the ultimate goal of the Project.

The purpose of maintenance is to conserve the road in a good and safe condition throughout its design life by adequate and timely repairs of damages to the road pavement and structures. It ensures that the road remains passable throughout the year accommodating a driving speed as designated in its original design. Traffic management is important to protect the road from damages caused by improper use as well as to ensure road safety. Traffic management includes overload control of vehicles, speed control and installation of traffic safety facilities.

9.2 Existing Road Maintenance System

9.2.1 Road Maintenance Situation

(1) Road Maintenance

ANE's ten provincial delegations are responsible for the implementation of all maintenance works on classified roads. The Directorate of Maintenance has a crucial role in ensuring that the delegations in provinces are fully aware of and complying with the technical and operational guidelines for implementation of the annual maintenance plan; and that roads of all types (Primary, Secondary, Tertiary, vicinal, paved, unpaved) are being maintained and provided . DIMAN also supports the provinces in the execution of the improvement, rehabilitation and construction of tertiary and vicinal roads. The directorate's role includes providing technical advice to municipal councils and districts on their road programs through the provincial delegations.

(2) Road Safety

ANE's responsibilities for road safety (thorough road design standards, physical measures to enhance safety and the placement of signs and road markings) have been entrusted to DIMAN given the important role of the provinces in the process. Activities will be coordinated with the National Road Traffic Institute, INAV. DIMAN is also responsible for overseeing vehicle overloading control measures, the use of the road reserve and the management of road concessions.

9.2.2 Donor Support for Road Maintenance

(1) SIDA: Institutional and Budget Support for the Decentralised Management of Regional Roads (2006 – 2010)

This Project is aimed at supporting this decentralisation process. Its design is based on the activities outlined in the Government's Poverty Reduction Strategy and the Road Policy. It is a key component of the Roads III Programme. Overall Goal of the Project is: ***'To improve the quality of the Regional Road network and the road maintenance carried out on National Roads'***, and three Project Purposes have been defined as:-

- Increase government agency capacity to plan and manage routine and periodic maintenance, and the rehabilitation of priority Regional Roads,

- Increase the private sector's capacity to provide road maintenance, rehabilitation, project management and supervision services at provincial level, and

- Provide employment opportunities for rural communities, in particular their most disadvantaged members.

(2) DANIDA: Agriculture Sector Programme Support (Rural Roads Component)

The Rural Roads Component supports the Government of Mozambique (GOM) efforts to achieve the ASPS II development objective of a 'sustainable and significant improvement in the living conditions of agricultural smallholders and their families'. The immediate objective of the Rural Roads Component is a 'sustainable increased road access for smallholders to agricultural inputs, markets and services'. The component initially provides support to the provinces of Manica, Tete and Cabo Delgado.

The Rural Roads Component supports the development of the tertiary and district road network supported through Spot Improvement and Periodic Maintenance of roads important to the agricultural smallholder sector.

9.3 Road Maintenance Activities

9.3.1 Road Maintenance Categories

Paved and unpaved road maintenance comprises three categories of works, routine maintenance, periodic maintenance and rehabilitation work.

Routine maintenance of the paved road network is the responsibility of the provincial delegations of ANE acting under the technical direction of the Paved Road Maintenance Section (REP) of DIMAN. Light periodic maintenance has been included in the plan for critical sections of road which have been damaged by accidents or by other adverse events.

The program for routine maintenance of unpaved roads, managed at the provincial level, covers 13,871 km. The periodic maintenance plan for 2009 for unpaved roads covered 165 km.

9.3.2 Routine Maintenance Works

Routine maintenance includes localized repairs (typically less than 150m in continuous length) of pavement and shoulder defects, and regular maintenance of road drainage, side slopes, verges and furniture. Actions include pothole patching, reshaping of side drains, repairing and cleaning of culverts and drains, vegetation control, dust control, erosion control, removal of sand from the road surface, repainting of road markings, repairing and replacing of road signs and guardrails and general roadside cleaning. Specific action for unpaved roads includes spot re-gravelling, dragging, shallow blading and dust control measures.

9.3.3 Periodic Maintenance Works

Periodic maintenance includes full-width resurfacing or treatment of the existing pavement or roadway (including minor shape correction, surface patching and restoration of skid resistance) to maintain surface characteristics and structural integrity for continued serviceability. It includes localized repairs and reconstruction (typically less than 10 percent of total project length in sections of less than 250 meters in continuous length) and limited geometric improvements related to enhancement of traffic capacity, speed and safety but not structural strengthening. Specific actions include application of slurry seals, fog sprays, enrichment treatments, surface treatments (double or single); friction courses; thin asphalt surfacing typically 30mm or less in thickness and localised base reconstruction, vegetation control, repainting road markings, repairing and replacing road signs.

Periodic maintenance of unpaved roads includes full re-graveling to restore required surfacing thickness. It will also involve deep blading with re-profiling and/or re-compaction to reshape the road profile, reduce roughness, slow deterioration, improve riding quality and better drainage.

9.3.4 Rehabilitation Works

Rehabilitation civil works involve full-width, full-length surfacing, with strengthening and shaping of existing pavements or roadways (including repair of minor drainage structures) to provide improved structural strength and integrity required for continued serviceability. Geometric improvements related to width, curvature of gradient of roadway, pavement, shoulders or structures, will be undertaken to increase traffic capacity, improve speed or increase safety. Where required this would include maintenance and/or provision of vehicle load control facilities. Specific actions include full base reconstruction, asphalt strengthening overlays, selective deep patching and overlays, granular base overlays and surfacing, surface treatment with major shape correction, and recycling of one or more pavement layers.

9.4 Realizing an Effective Road Maintenance System

9.4.1 New Road Management System

The detailed information required as ‘input data’ for the new Integrated Road Management System (IRMS) is being launched and the surveys will be implemented beginning at the end of 2009. This project is being funded by SIDA under the Support for the Decentralized Management of Regional Roads. Road condition surveys and traffic counts also includes in this project.

By appropriate operation of this system, following issues will be solved.

- Development of core road network for prioritizing maintenance
- Development of operability and systematic maintenance
- Selection of cost-effective maintenance solution
- Preparation of appropriate routine and periodic maintenance program

- Technical design of maintenance works

9.4.2 Development of Road Maintenance Capacity Building

All road maintenance works are contracted out to private contractors. The private sector participation in road maintenance works is considered effective as it provides timely maintenance interventions especially in the rainy season, while enhancing income and employment generating activities for local people. Particularly, the labor-based maintenance system as commonly used by small-scale contractors seems appropriate for use in the rural areas (such as along the Study Road) This labor-based maintenance system provides income generating opportunities to local people. However, it is important to pay attention to two important issues when promoting such system – access to resources (i.e., credit, works, equipment, materials) and an enabling environment for contracting (i.e., prompt payment, simplified contacts, contractors association and contractor registration and evaluation procedures).