Chapter 7 Preliminary Design

Chapter 7 Preliminary Design

7.1 Introduction

7.1.1 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.

7.1.2 Procedure of Alternative Route and Design

The procedure of the design study and definition of alternative routes, followed by the selection of the preferred route, is a three-step process, as indicated below:

Step-1: Site Survey (Initial Route Study)
Step-2: Screening of Conceivable Alternative Routes and Design
(based on tentative cost estimates, economical analysis, environmental aspects)
Step-3: Optimum Route and Design Selection for the preliminary design

7.2 Screening of Conceivable Alternative Routes and Design

7.2.1 Concept of the Project

This study aims to upgrade the Study Road, the Nampula – Cuamba Road which has a length of 350km. Although the road is part of the Nacala Corridor and is one of the most important major roads in Mozambique, adequate maintenance and upgrading works have not been carried out due to lack of funds. As a result, this road has serious problems leading to interruption of traffic during the rainy season.

In order to maximize the benefits from the available funds, two alternative approaches for the project were considered:

- alternative 1: construct the entire road section or
- alternative 2: construct only certain sections selected on the basis of the condition of the existing road

It is proposed that each approach be evaluated on the following items

- ✓ Economical efficiency within the expected lifecycle
- ✓ Necessity for improvement of the project road sections
- ✓ Function of the road within the primary road network and within the northern region
- ✓ Construction features for community situation
- ✓ Consistency with the regional environment

The two alternatives for approaching the project are evaluated below in Table 7.2.1 below.

Table 7.2.1 Evaluation of Alternative Approaches

Item	Detail	Alternative 1	Alternative 2
Economical Efficiency within expected lifecycle	• Project cost • Maintenance cost • Cost/benefit analysis which also considered social benefits	0 + +	+ - -
Necessity for improvement of the project road sections	• Future traffic volume • Role/function of the project road (use of transport vehicles) • Reduction of traffic accidents	+ + +	- - -
Functionality within primary road network and within the northern region	• Connection between main capital cities • Formation of National Road network (Connection to other main road) • Improvement to high-speed operation • Supporting regional development projects	+ + + +	0 - - 0
Construction feature for community situation???	• Availability of materials and equipment • Consistency with construction plan (Damage level after completion)	0 +	* -
Consistency with regional environment	• Impact to social environment such as resettlement • Impact to natural environment such as fauna/flora	- -	+ +-
Evaluation		+	-

Effectiveness + = High **0** = Normal **-** = Low

Alternative 1 seems considerably more effective than alternative 2. It is therefore recommended that the project should comprise of the upgrading / reconstruction of the entire Cuamba- Nampula road.

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

7.2.2 Road Alignment Design and Alternatives

1) Introduction

The upgrading concept for the road design and alignment will be discussed in this sub-chapter, based on the findings of the analysis of the road inventory survey (see Chapter 2.2.5). The road upgrading concept, which is dictated by the road function, will influence the final construction cost of the Project. This concept should be clearly defined . Alternatives for the road alignment and design should also be determined and compared in accordance with the upgrading concept.

2) Upgrading Concepts for Road Alignment

Upgrading concepts for the choice of alignment are based on following concepts:

Alternative-1: Minimum Upgrading Alternative (Design Speed of 80km/h)
Alternative-A is based on the existing alignment with minimal changes to accommodate a design speed of 80km/h, except for the town sections of Nampula, Rapale, Namina, Namigonha, Ribaue, Malema, Mutuali, Lurio and Cuamba. Pavement upgrading in the town sections is included.

Alternative-2: Maximum Upgrading Alternative (Design Speed of 100km/h)
Alternative-B is based on a re-alignment of the existing road to accommodate a design speed of 100km/h, except for the town sections and intersections of Nampula, Rapale, Namina, Namigonha, Ribaue, Malema, Mutuali, Lurio and Cuamba. Pavement upgrading in the town sections is included.

3) Prior Condition for the Alternative Alignment Plan

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

- The existing centerline shall be followed in the town and major villages.
- Other sections outside the towns and major villages shall satisfy the SATCC Standards taking into account the existing centerline wherever feasible.
- Bridges as evaluated in good condition by the bridge inventory survey shall be maintained in the project design to minimize initial capital costs.

The considerable sections for keeping the existing alignment are shown in Table 7.2.2.

Table 7.2.2 Considerable Sections for the Existing Alignment

No.	Ref. Name	Bridge Name	Station	Remarks
1	Nampula_BP		0+000	
2	Nampula_EP		1+020	
3	Rapale_BP		15+550	
4	Rapale_EP		18+790	
5	B-1	Intephe	34+608	
6	B-2	Namuca	36+590	
7	B-3	Mutivaze1	40+016	Japan's Grant Aid
8	Namina_BP		73+510	
9	Namina_EP		74+130	
10	B-4	Mecuburi	86+367	Japan's Grant Aid
11	Namigonha_BP		119+065	
12	Namigonha_EP		121+305	
13	Ribaue_BP		131+860	
14	Ribaue_EP		133+365	
15	B-6	Muco	134+005	
16	B-7	Namicuti	138+318	
17	B-8	Nepuipui	147+993	
18	B-9	Napala	149+320	
19	B-11	Natete	156+147	Japan's Grant Aid
20	B-12	Monapo	159+640	
21	N326 Int.		161+525	
22	B-13	ThiThi	165+348	Japan's Grant Aid
23	B-21	Niose	210+022	Japan's Grant Aid
24	Malema_BP		235+175	
25	B-27	Mutivaze2	235+260	
26	Malema_EP		236+995	
27	B-28	Malema	241+018	
28	B-30	Namuela	263+365	
29	B-31	Malume	280+836	
30	Mutuali_BP		281+055	
31	N103 Int.		281+405	
32	B-32	Nuail	282+188	
33	Mutuali_EP		282+700	
34	Lurio_BP		310+435	
35	Lurio_EP		310+780	
36	B-35	Murusso	329+230	Japan's Grant Aid
37	B-36	Namutimbua	343+920	Japan's Grant Aid
38	Cuamba_BP		344+250	
39	Cuamba_EP		EP	

4) Comparison of the Alignment alternatives

The results of the comparison of the alignment alternatives are as follows. The item of geometry shows upgrading level after completion. Information on detailed cost estimates are attached in appendix-C.

Table 7.2.3 (1) Result of the Alignment (Nampula-Ribaue)

			Existing	80km/h ALT1	100km/h ALT2
Length (km)			133.0	131.85	132.03
Geometry	Horizontal Curvature	deg/km	50.9 (1.00)	37.2 (0.73)	36.3 (0.71)
	Rise + Fall	m/km	14.2 (1.00)	13.7 (0.97)	13.3 (0.94)
	No. of Rise + Fall	no./km	10.0	1.9	1.9
No. of the Existing Rail Crossings			5	-	-
No. of Eliminated Existing Rail Crossings			-	0	0
No. of New Rail Crossings			-	0	2*
Additional Bridges			-	0	1**
US$/km			-	505,629 (1.00)	525,152 (1.04)
Traffic Volume (veh/day) in 2026			767 (0.56)	1,379 (1.00)	1,446 (1.05)

Note: AC and Granular Base-course base on the SATCC Standard are tentatively applied to the pavement type for the cost estimate.

*: Sta.86+540, 88+660 (attributable to control the Mecuburi bridge)

**: Sta.40+016 (Mutivaze1 bridge is located in a curve.)

Table 7.2.3 (2) Result of the Alignment (Ribaue-Malema)

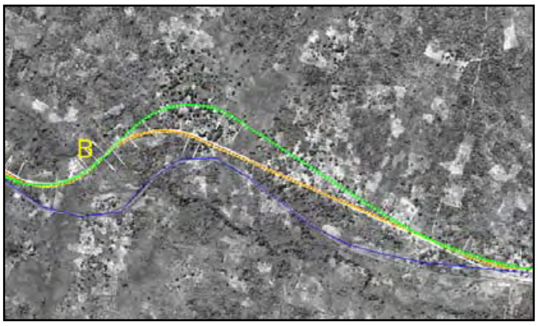
			Existing	80km/h ALT1	100km/h ALT2
Length (km)			103.0	102.87	102.82
Geometry	Horizontal Curvature	deg/km	31.3 (1.00)	15.3 (0.49)	14.4 (0.46)
	Rise + Fall	m/km	20.4 (1.00)	19.8 (0.97)	18.0 (0.88)
	No. of Rise + Fall	no./km	10.0	1.9	1.9
No. of the Existing Rail Crossings			1	-	-
No. of Eliminated Existing Rail Crossings			-	0	0
No. of New Rail Crossings			-	0	0
Additional Bridges			-	0	0
US$/km				576,828 (1.00)	615,103 (1.07)
Traffic Volume (veh/day) in 2026			447 (0.38)	1,164 (1.00)	1,262 (1.08)

Note: AC and Granular Base-course base on the SATCC Standard are tentatively applied to the pavement type for the cost estimate.

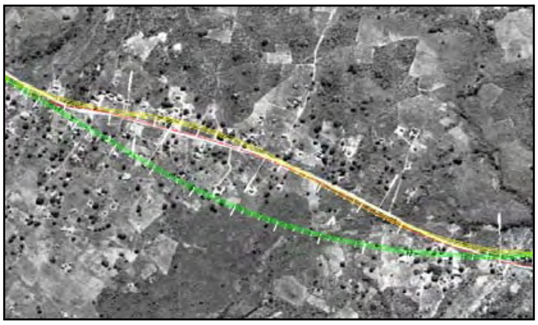
Table 7.2.3 (3) Result of the Alignment (Malema-Cuamba)

			Existing	80km/h ALT1	100km/h ALT2
Length (km)			112.0	112.91	112.66
Geometry	Horizontal Curvature	deg/km	41.7 (1.00)	29.5 (0.71)	24.7 (0.59)
	Rise + Fall	m/km	13.8 (1.00)	13.5 (0.98)	13.0 (0.94)
	No. of Rise + Fall	no./km	10.0	2.5	2.4
No. of the Existing Rail Crossings			10	-	-
No. of Eliminated Existing Rail Crossings			-	4	4
No. of New Rail Crossings			-	0	0
Additional Bridge Construction Work			-	0	0
US$/km				636,371 (1.00)	650,872 (1.02)
Traffic Volume (veh/day) in 2026			408 (0.33)	1,223 (1.00)	1,263 (1.03)

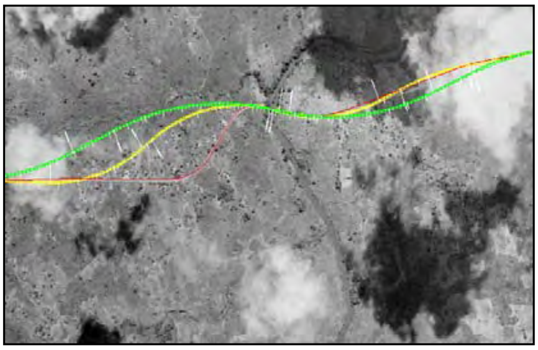
Note: AC and Granular Base-course base on the SATCC Standard are tentatively applied to the pavement type for the cost estimate.



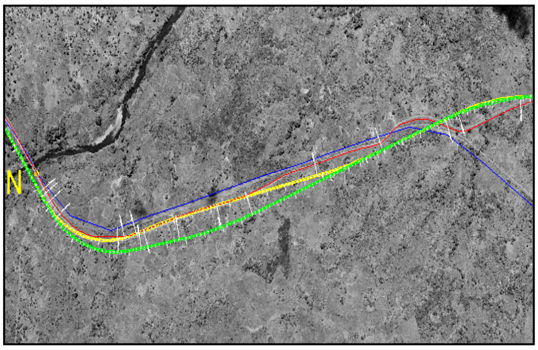
(1) Chainage: 40km from Nampula



(2) Chainage: 169km from Nampula



(3) Chainage: 240km from Nampula



(4) Chainage: 308km from Nampula

: Ex. Road **: 100km/h** **: 80km/h** **: Railway**

Figure 7.2.1 Examples of typical Alignments for 100km/h and 80km/h

5) Recommended Design Speed

Based on considerations for traffic safety, construction cost, social impacts, traffic management and operation, a design speed of 80km/h is recommended as the most appropriate. The main reasons for the application of a 80km/h design speed are as follows:

- ANE's Standards (currently in draft form) suggest a design speed of 80km/h when the road is located in Rolling Terrain.
- Alignments for a design speed of 100km/h require substantial relocation and subsequent compensation schemes (the compatibility of the existing road alignment with this design speed is low).
- The geometric requirement for alignments accommodating a design speed of 100km/h require substantial higher construction cost.
- In the case of a design speed more than 100km/h, the access control should be applied from viewpoint of a traffic safety for the pedestrians, bicycles and low-speed traffic.

Table 7.2.4 ANE's Standard (currently in a draft form)

	ROAD CLASS					
	Primary (A)		Secondary (B)		Tertiary (C)	
	Min.	Desir.	Min.	Desir.	Min.	Desir.
TRAFIC						
1.1 Daily Traffic (vpd)	> 100		40 - 100		< 40	
GENERAL						
1.1 Minimum Design Speed (km/hr)						
1.1.1 Flat Terrain	80	100	70	80	50	60
1.1.2 Rolling Terrain	60	80	50	70	40	50
1.1.3 Mountainous Terrain	40	60	35	50	30	40

7.2.3 Necessity of Bypasses for the Major Towns

1) Change of the Usage Traffic on the Study Road

The predicted traffic volume will drastically increase if the Study road is to be improved. According to the results of the traffic demand study (chapter 4), over the 20-year period (from the base year 2006 to the end of the design life 2026), daily traffic will exceed a 1,000veh/day, of which at least 40% is through traffic . Most of this traffic consists of trucks.

Table 7.2.5 Through Traffic Ratio in 2026

Section	Diverted Traffic From Beira	Passenger Car	Mini-Bus	Bus	Cargo	Total
Nampula-Cuamba	With (a)	134	203	144	781	1262
	Without (b)	134	203	144	271	752
Difference		0	0	0	510	510
% (a/b)		100%	100%	100%	35%	60%

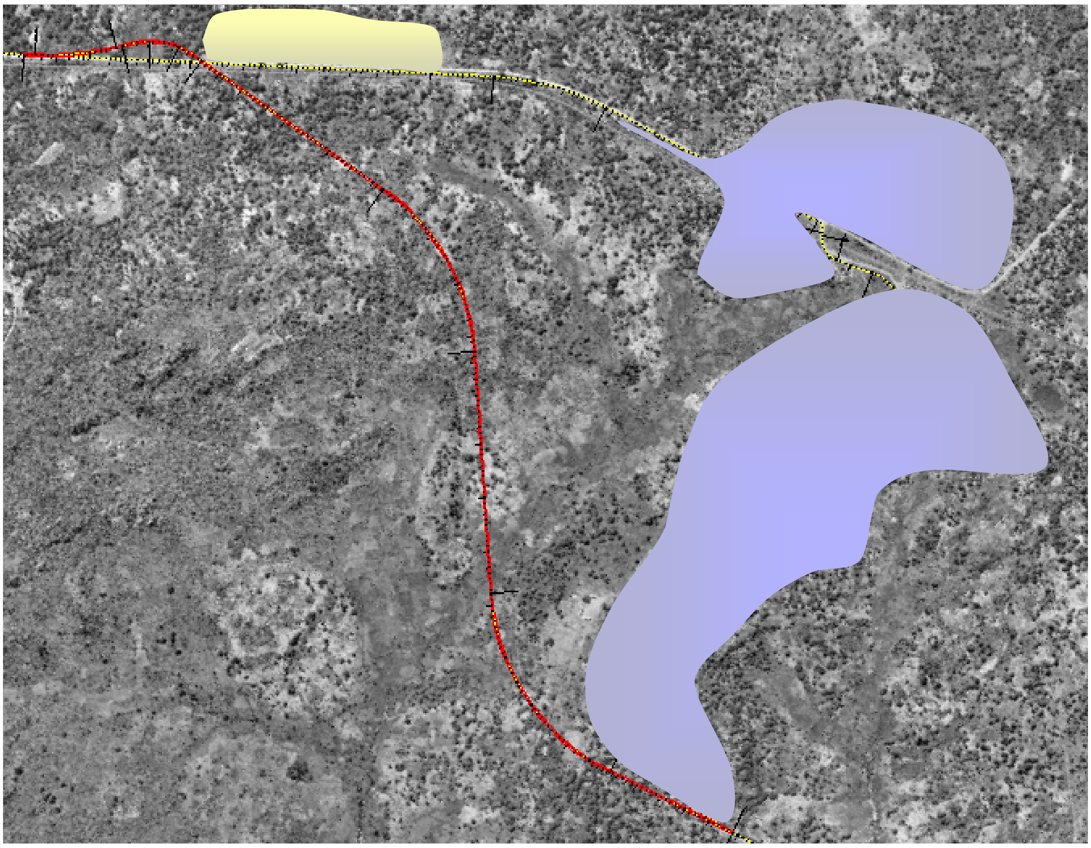
The Study Road currently passes through the centre of district towns with a large number of pedestrians. Increase in traffic, as described above, will also increase the risk of traffic accident especially at the cost of the most vulnerable road users, and negatively impact on the living conditions in the towns

In this subchapter, the effectiveness of the construction of bypasses is discussed.

2) Potential Routes of the Bypasses around the District Towns

Possible bypass routes were identified as follows:

Rapale Bypass



: HD Area **: LD Area** **: Airport**

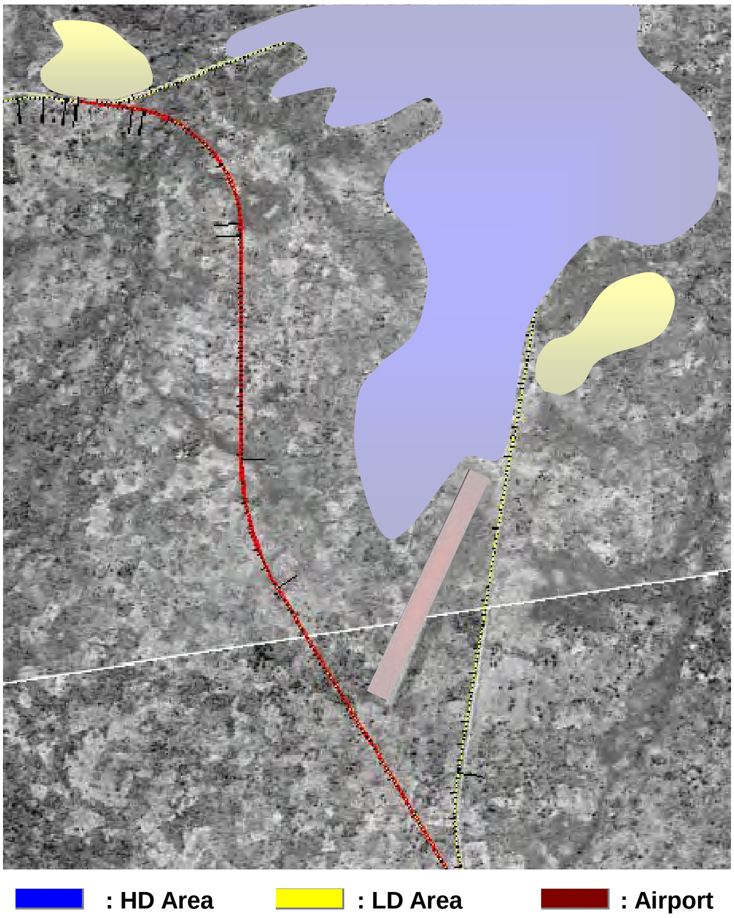
- Length: 4.47km
- Construction Cost: 2.5 Milion US$
- Points checked:
  Residential Compound (High and Low Density), Public Utilities
- Route Overview

In Rapale, residential compounds are spread along he Study Road. The railway line is running parallel to the Study Road on the northern side. Possible bypass routes should be planed to the west in order to avoid the relocation of residences. The crossing with the railway line at the end of the bypass remains an issue to be discussed.

***HD: High-density residential area , LD: Low-density residential area**

Figure 7.2.2 Potential Bypass Routes for Rapale

Ribaue Bypass

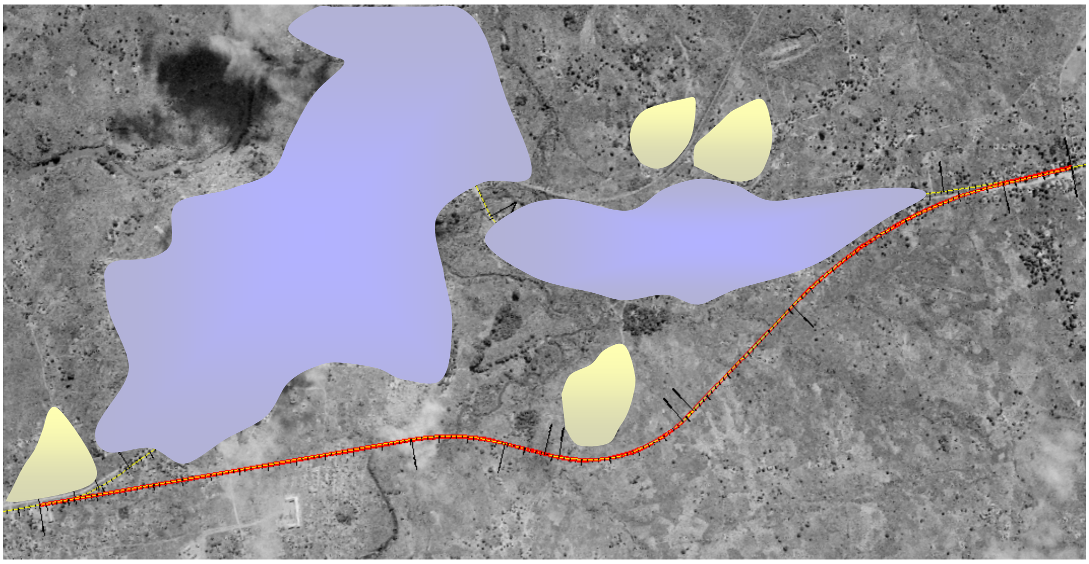


- Length: 4.20km
- Construction Cost: 2.4 Million US$
- Points checked:
  Residential Compound
  (High and Low Density)
  Public Utilities
- Route Overview

In Ribaue, residential compounds are spread along the Study Road, towards the east side. The airport (not operational) is located towards the south side the town. Therefore possible bypass routes should be planned on the west side of town to avoid relocation of residences and to avoid the airport.

Figure 7.2.3 Potential Bypass Routes for Ribaue

Malema Bypass



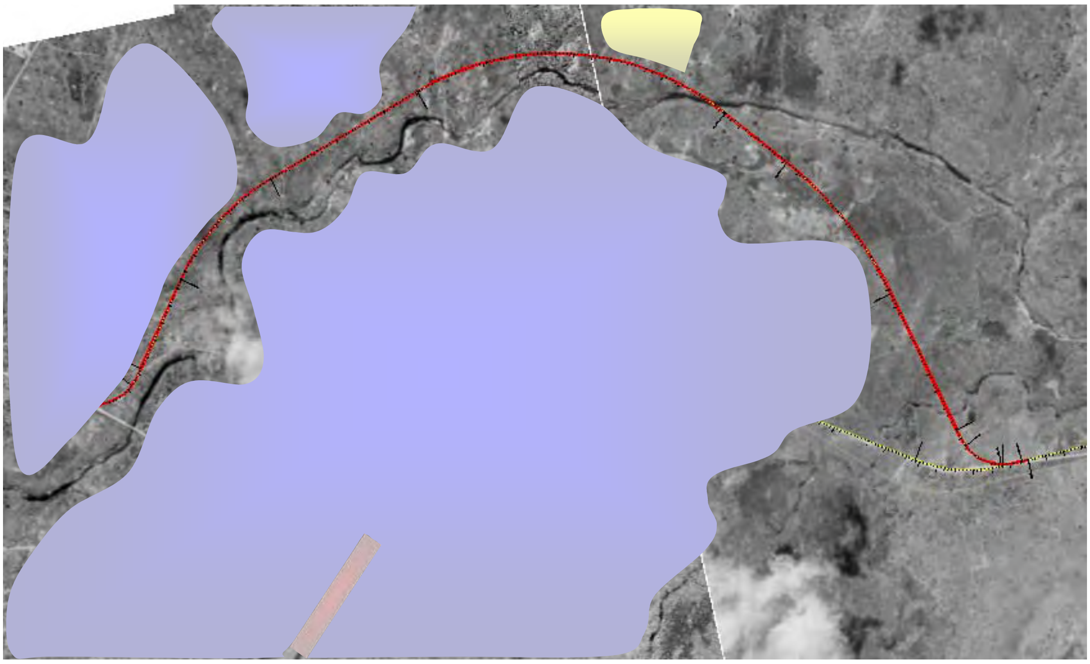
: HD Area : LD Area : Airport

- Length: 3.90km
- Construction Cost: 2.2 Million US$
- Points checked:
  Residential Compound (High and Low Density), Public Utilities
- Route Overview

In Malema, residential compounds are spread along the Study Road. The railway line is located to the north side of the town. Therefore possible bypass routes should be planned on the south side to avoid relocation of residences and avoid crossing the railway.

Figure 7.2.4 Potential Bypass Routes for Malema

Cuamba Bypass



: HD Area **: LD Area** **: Airport**

- Length: 7.25km
- Construction Cost: 4.1 Million US$
- Points checked
  Residential Compound (High and Low Density), Public Utilities
- Route Overview
  In Cuamba, residential compounds are widely spread with the Study Road being located in the centre of town and currently spread to the north side with crossing the northern river. The Cuamba Airport is located to the south. Therefore possible bypass routes are situated along the northern riverside.

Figure 7.2.5 Potential Bypass Routes for Cuamba

3) Applicable Criteria for the selection of Bypasses

The necessity of constructing bypasses is considered in the following cases:

- Important activities in town (such as emergency evacuation to the hospital) are disturbed by traffic congestion.
- Significant economic losses due to traffic congestion.
- Increase of traffic volume causes a significant increase of traffic accidents, especially between motorized through traffic and localized non motorized traffic.
- Increase of traffic volume causes a deterioration of the local environment in the residential areas.

After improvement of the Study Road, the traffic situation in the major towns is expected to change as follows:

Issues	Change of Traffic Situation
Traffic Congestion	Traffic congestion is not expected with the predicted traffic volume.
Lowering Speed	Economic losses due to traffic delays are not expected.
Traffic Accidents	The risk of traffic accidents will increased with higher traffic volumes
Local Environment	The expected levels of air pollution and noise are not likely to change significantly and cause adverse impacts to residents' health. (see chapter 5)

4) Conclusion

Based on these considerations, the Study Team proposes not to construct bypass routes in the district towns. Bypasses would not bring any economic advantage, on the contrary, it is likely to detaches new consumers from the local markets located in the town centres. Having concluded that bypasses are not desirable, the road safety aspect should be addressed by separation of pedestrians from vehicles in the town centres. Therefore the Study Team proposes to construct separate sidewalks in the the major towns. Pedestrian sidewalks already exists in Ribaue, Malema and Cuamba towns. The Study Team proposes to adopt the following cross section in the district towns.

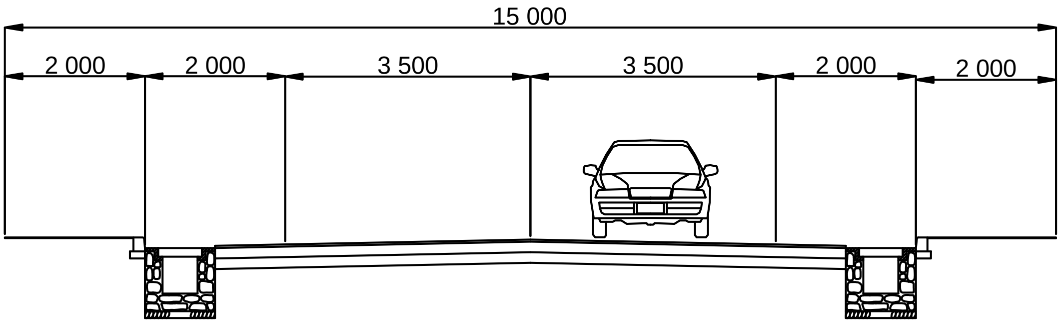


Figure 7.2.6 Typical Cross Section with Side Walk

7.2.4 Pavement Design and Alternatives

1) Upgrading Concepts for Pavement Design

Upgrading concepts for pavement design are based on the following concepts:

- To establish a structurally sound primary road securing a smooth traffic flow and corresponding to the future traffic demand
- To reduce the life cycle costs (maintenance cost and operational cost) taking into

consideration the maximum use of local materials and future maintenance by labor based methods

The Project area can be classified as a wet region. The following pavement alternatives will be considered:

Pavement (Sub)Base Layer

Important factors for the selection of the type of pavement base layer were:

- Maximize the use of suitable local materials to minimize haulage costs
- In case such materials are not available, the use of other economical materials will be considered.

The materials along the Study Road consist of quartzite sands, sandy (quartzite) gravels and laterite. Various base layer options will be investigated to ascertain which would give the most economical pavement.

The material types locally available indicated the use of the following options:

Alternative-A: Granular Base and Sub-base Course

Alternative-B: Stabilized Base and Sub-base Course

Alternative-C: Granular Base and Stabilized Sub-base Course

Pavement Seal

In selecting the bituminous surface the following important considerations should be taken into account:

- The seal must be suitable for repairs by labor based methods without the use of heavy plant
- The seal should make maximum use of locally available materials;

The following pavement seal options will be investigated:

Alternative-A: Asphalt Concrete as per SATCC Standard

Alternative-B: Bituminous surface treatment (similar as the Nampula – Nacala Road)

2) Conversion of DCP Results to CBR results

The underlying principle of the Dynamic Cone Penetration (DCP) testing 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. The DCP will also identify the boundaries between soil layers by the sudden change in the rate of the penetration.

Numerous authors have described the relationship between a DCP values and the situ California Bearing Ratio (CBR). In this Project, the following formula, commonly used in

Mozambique, will be 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: 66.66xDN^{2}-(330xDN)+563.33 = in-situ CBR

Source: CICTRAN

The graph below illustrates the in situ CBR values, derived from DCP testing, along the road.

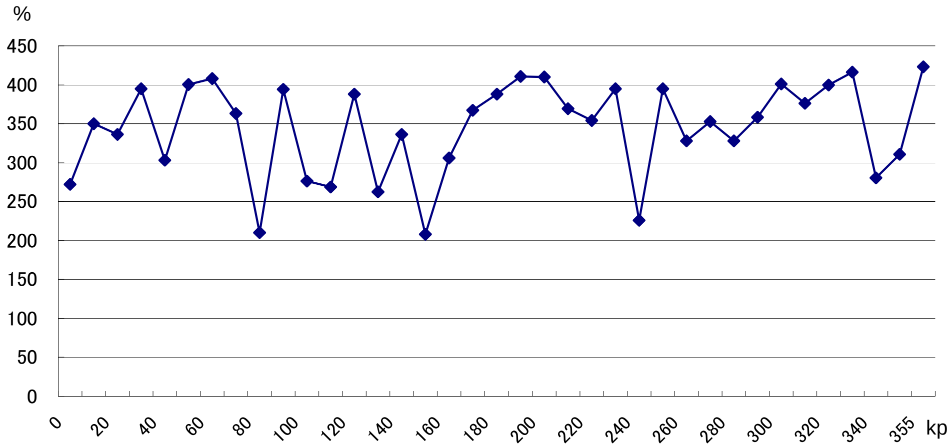


Figure 7.2.7 In-Situ CBR Values along the road

The sub-grade CBR’s are 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’s , it is common practice to evaluate the strength of the sub-grades by means of in-situ CBR’s (also called DCP CBR’s). In order to establish a relationship between the in-situ CBR’s (obtained through the DCP tests) and soaked CBR’s,, soaked CBR tests were carried out on 5 samples of existing sub-grade materials. The results of these tests indicate a soaked CBR value of 5% of the in-situ CBR.value.

Figure 7.2.8 below shows the soaked CBR values after conversion of the in situ CBR values using the 5% conversion factor.

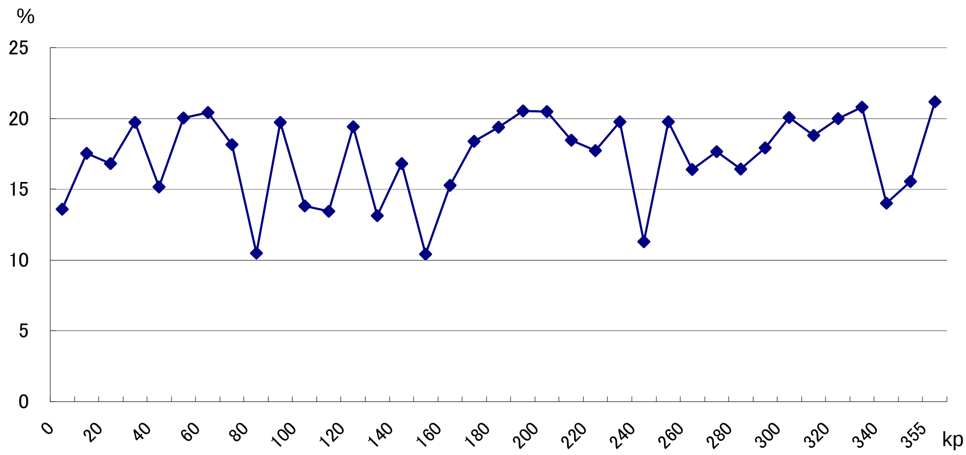


Figure 7.2.8 Soaked CBR Value

3) Design CBR

The Design CBR for a section is usually decided by the 90 percentile value of the CBR test results for a section with homogenous strength. The method illustrated in figure 7.2.9 will be used for determination of the design CBR of each homogenous section.

CBR values plotted in
ascending order

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

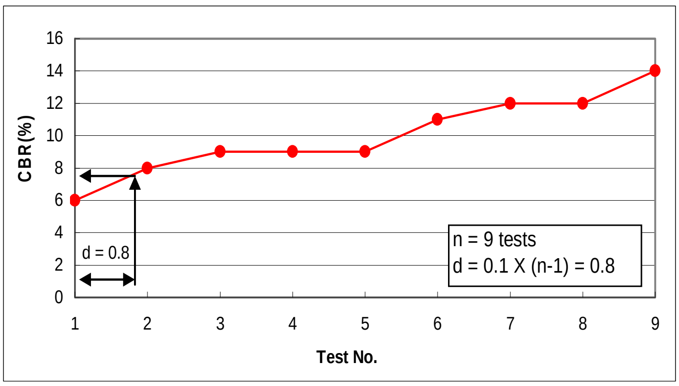


Figure 7.2.9 Design CBR as the 90%-ile Value

Table 7.2.6 Determination of the Design CBR

No	Section 1 (Nampula-Ribaue)	Section 2 (Ribaue-Malema)	Section 3 (Malema-Cuamba)
1	20	21	21
2	20	20	21
3	20	20	20
4	20	19	20
5	19	18	20
6	18	18	19
7	18	18	18
8	17	17	18
9	15	15	16
10	14	10	16
11	14		16
12	13		14
13	13		11
14	10		
d	1.30	0.90	1.20
Design CBR (%)	13	15	15
Sub-grade Class	S4	S5	S5

4) Design Traffic Load

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 on the pavement structure.

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 y_0 (includes large buses, medium goods vehicles, and large goods vehicles) for both directions.

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

y = Design life of Project road.

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

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

Table 7.2.7(1) Design ESA Value/ [10^6] for Nampula - Ribaue

	Type of Vehicle	ESAL	1	2	3	4	5	6	7	8
			2012	2013	2014	2015	2016	2017	2018	2019
Traffic Volume	Buses		178	183	190	195	200	206	212	218
	Tracks		421	439	457	476	496	518	540	563
Axle Load	Buses	1.20	38982	40077	41610	42705	43800	45114	46428	47742
	Tracks	4.06	311940	325277	338614	352692	367511	383812	400113	417155
	Total		350922	365354	380224	395397	411311	428926	446541	464897

	Type of Vehicle	9	10	11	12	13	14	15	15-year D-Life
		2020	2021	2022	2023	2024	2025	2026	
Traffic Volume	Buses	223	230	236	243	249	256	264	
	Tracks	588	614	642	671	701	733	767	
Axle Load	Buses	48837	50370	51684	53217	54531	56064	57816	
	Tracks	435679	454943	475690	497177	519406	543116	568309	
	Total	484516	505313	527374	550394	573937	599180	626125	7.1E+06

Table 7.2.7(2) Design ESA Value/ [10^6] for Ribaue - Malema

	Type of Vehicle	ESAL	1	2	3	4	5	6	7	8
			2012	2013	2014	2015	2016	2017	2018	2019
Traffic Volume	Buses		146	149	154	158	162	166	170	174
	Tracks		409	425	443	461	481	502	523	546
Axle Load	Buses	1.20	31974	32631	33726	34602	35478	36354	37230	38106
	Tracks	4.06	303049	314904	328241	341578	356397	371957	387517	404559
	Total		335023	347535	361967	376180	391875	408311	424747	442665

	Type of Vehicle	9	10	11	12	13	14	15	15-year D-Life
		2020	2021	2022	2023	2024	2025	2026	
Traffic Volume	Buses	177	182	185	190	194	198	203	
	Tracks	569	595	622	650	680	710	743	
Axle Load	Buses	38763	39858	40515	41610	42486	43362	44457	
	Tracks	421601	440865	460871	481618	503846	526075	550526	
	Total	460364	480723	501386	523228	546332	569437	594983	6.8E+06

Table 7.2.7(3) Design ESA Value/ [10^6] for Malema - Cuamba

	Type of Vehicle	ESAL	1	2	3	4	5	6	7	8
			2012	2013	2014	2015	2016	2017	2018	2019
Traffic Volume	Buses		141	144	149	152	156	160	164	167
	Tracks		457	476	495	516	538	561	586	611
Axle Load	Buses	1.20	30879	31536	32631	33288	34164	35040	35916	36573
	Tracks	4.06	338614	352692	366770	382330	398631	415673	434197	452720
	Total		369493	384228	399401	415618	432795	450713	470113	489293

	Type of Vehicle	9	10	11	12	13	14	15	15-year D-Life
		2020	2021	2022	2023	2024	2025	2026	
Traffic Volume	Buses	170	175	178	182	186	189	194	
	Tracks	637	666	697	728	762	796	833	
Axle Load	Buses	37230	38325	38982	39858	40734	41391	42486	
	Tracks	471985	493473	516442	539412	564604	589796	617211	
	Total	509215	531798	555424	579270	605338	631187	659697	7.5E+06

4) Pavement layer Design

Design Basis: SATCC *Code of Practice for Design of Road Pavements*

Climatic Zone: Wet Region

Design Traffic: T6 (Design Life 15-year)

Design Sub-grade: S4 (Nampula-Ribaue), S5 (Ribaue-Cuamba)

On this basis, the following surface designs are proposed by the Study Team: Asphalt Concrete (AC) and a Double Surface Dressing (DBST)

Possible alternative pavement structures are calculated using the following equation:

$SN = \Sigma L_i T_i$

Where,

L_i = Layer coefficient for layer i

Ti = Thickness (in.) of layer i

Table 7.2.8 Calculation for Each Layer Thickness

Section	Material CBR			Layer coefficient			Thickness (cm)			Total
	SG	SB	BS	SB	BS	AS	SB	BS	AS	
Granulare Base and Sub-base										
Nampula - Ribaue										
SATCC	8 - 14	30	80	0.250	0.350	1.000	17.5	20.0	10.0	21.38
Alternative	8 - 14	30	80	0.250	0.350	1.000	40.0	25.0	3.0	21.75
Ribaue - Cuamba										
SATCC	15 - 29	30	80	0.250	0.350	1.000	15.0	15.0	10.0	19.00
Alternative	15 - 29	30	80	0.250	0.350	1.000	37.5	20.0	3.0	19.38
Cemented Base and Sub-base										
Nampula - Ribaue										
SATCC	8 - 14	0.75-1.5Mp	1.5-3.0Mp	0.250	0.550	1.000	20.0	15.0	5.0	18.25
Alternative	8 - 14	0.75-1.5Mp	1.5-3.0Mp	0.250	0.550	1.000	30.0	15.0	3.0	18.75
Ribaue - Cuamba										
SATCC	15 - 29	0.75-1.5Mp	1.5-3.0Mp	0.250	0.550	1.000	20.0	15.0	5.0	18.25
Alternative	15 - 29	0.75-1.5Mp	1.5-3.0Mp	0.250	0.550	1.000	30.0	15.0	3.0	18.75
Granular + Cemented										
Nampula-Ribaue										
SATCC	8 - 14	0.75-1.5Mp	80	0.250	0.350	1.000	17.5	15.0	10.0	19.63
Alternative	8 - 14	0.75-1.5Mp	80	0.250	0.350	1.000	32.5	25.0	3.0	19.88
Ribaue-Cuamba										
SATCC	15 - 29	0.75-1.5Mp	80	0.250	0.350	1.000	15.0	15.0	10.0	19.00
Alternative	15 - 29	0.75-1.5Mp	80	0.250	0.350	1.000	32.5	22.5	3.0	19.00

Note: Layer coefficients quote from “Asphalt Pavement Guideline from Japan”.

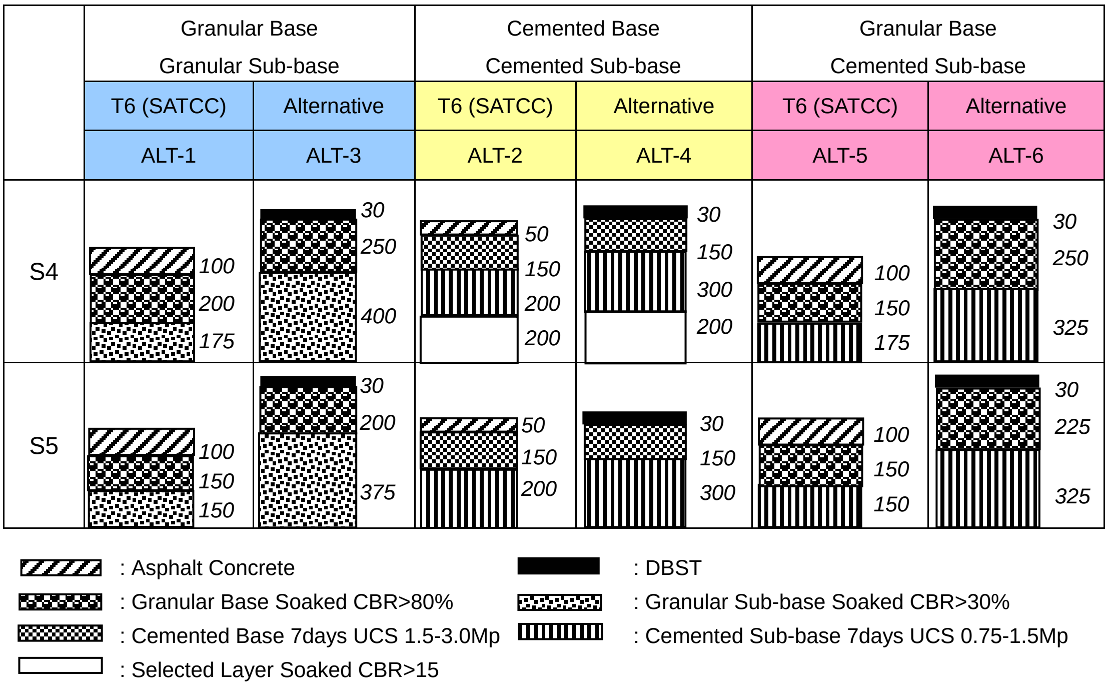


Figure 7.2.10 Possible Pavement Structures

Alternative1, 2, 5 are applied from the SATCC Standard, and alternative3, 4, 6 are proposed by the Study Team based on the above calculation.

5) Suitable Pavement Composition

The pavement composition has a significant impact on the initial investment cost and future maintenance cost of the Study Road. It is therefore important to decide using a concept of a life cycle costing. The Study Team calculated the construction quantities for each pavement composition and evaluated their economic viability with the RED/HDM-4 model. Details of RED/HDM-4 model are explained in chapter 10.

The Study Team used the following maintenance interventions, its frequency and related cost based on examples from RSS and other projects.

Table 7.2.9 Maintenance Cost and Frequency

With/Without Project	Intervention		Without Project
Surface Condition	Solid Pavement (Asphalt Concrete)	Low-cost Pavement (DBST)	Earth Road (poor condition)
Routine Maintenance in US$/km/year	1,100	1,100	1,789
Periodic Maintenance in US$/km/4years			6,000
Periodic Maintenance in US$/km/5years	-	5,600	-
Periodic Maintenance in US$/km/10years	5,600	-	-

Table 7.2.10 Economic Analysis for the Selection of the Pavement Composition

Section	Length (km)	Design Pavement Type	Construction Cost US$	Construction Cost US$/km	EIRR
ALT-1					
Nampula-Ribaue	131.6	AC on Granular	66,667,173	505,629	12.7%
Ribaue-Malema	102.9	AC on Granular	59,338,341	576,828	11.0%
Malema-Cuamba	112.9	AC on Granular	71,852,594	636,371	9.6%
ALT-2					
Nampula-Ribaue	131.6	AC on Cemented	62,422,412	473,435	13.6%
Ribaue-Malema	102.9	AC on Cemented	46,412,493	451,176	14.4%
Malema-Cuamba	112.9	AC on Cemented	55,160,401	488,534	13.0%
ALT-3					
Nampula-Ribaue	131.6	DBST on Granular	42,492,526	322,279	19.5%
Ribaue-Malema	102.9	DBST on Granular	36,171,403	351,622	18.2%
Malema-Cuamba	112.9	DBST on Granular	43,906,546	388,863	16.4%
ALT-4					
Nampula-Ribaue	131.6	DBST on Cemented	59,261,962	449,465	14.4%
Ribaue-Malema	102.9	DBST on Cemented	40,921,706	397,800	14.4%
Malema-Cuamba	112.9	DBST on Cemented	48,940,488	433,447	14.2%
ALT-5					
Nampula-Ribaue	131.6	AC on Granular + Cemented	71,692,453	543,743	11.7%
Ribaue-Malema	102.9	AC on Granular + Cemented	61,471,715	597,567	11.8%
Malema-Cuamba	112.9	AC on Granular + Cemented	74,316,072	658,189	11.6%
ALT-6					
Nampula-Ribaue	131.6	DBST on Granular + Cemented	52,957,575	401,650	16.0%
Ribaue-Malema	102.9	DBST on Granular + Cemented	40,719,839	395,838	16.1%
Malema-Cuamba	112.9	DBST on Granular + Cemented	49,204,877	435,788	15.9%

The selection of the suitable pavement composition is evaluated based on the initial cost and its financial viability using the EIRR indicator. The results of the cost estimates (see Appendix-C) and the economic analysis, the ALT-3 which constitutes of a DBST surface on a Granular type (sub) base layer is selected as the most economically viable pavement composition. Its composition shows the lowest initial cost and the highest EIRR (see table

7.2.10).

7.2.5 Bridge and Crossing Structures

1) Introduction

The upgrading concept for bridges and other river crossings will be discussed in this sub-chapter, based on the findings of the analysis of the bridge inventory survey (see Chapter 2.3.5), Since the bridge improvement cost forms a large portion of the total construction costs for any Project, considering alternatives for the upgrading of bridges is important in the initial design stage of the Study Road.

2) Upgrading Concepts for Bridge and River Crossing Structures

Concept-1: Retaining the Existing Bridges that have Sufficient Width for 2-lane Traffic Operation as well as Sufficient Discharge Capacity for design Floods

The issue here is whether or not these bridges have sufficient capacity and durability against the expected level of live loads, equivalent to a 25ton vehicle load. This increased live load was adopted in the early 1990s according to trends and demands for larger freight transport. The bridges on the Study road were constructed in the 1960s-70s, and these bridges are therefore assumed to have been designed for a lower live load. However, it is recommended that the existing bridges be retained for the following reasons.

- One bridge of this type was retained in the bridge rehabilitation project funded by the Japanese Grant Aid Scheme. Their study report justified that these bridges are in sound condition through both visual observations on site as well as by results of the Schmidt-hammer tests on the concrete slab.
- The comparison between the previous specification and the present one with respect to the bending moments derived from the live load reveals that there is a low volume of heavy vehicles at present and a rapid increase of heavy trucks is expected from the traffic demand forecast. Consequently, these bridges can be expected to function adequately for another 10-15 years, if proper maintenance is undertaken.

A total of 8 bridges, namely Muco, Mamicuti, Nepuipui, Napala, Niose, Malema, Malume, and Nuam Bridges, will fall into this category.

Concept-2: Replacement of Existing Narrow, Short and Old Bridges by Box Culverts

The narrow, short and old bridges can be defined as existing bridges that were constructed in the 1930-40s with insufficient width to accommodate 2-lane traffic operation (in this project less than 6.5m width is considered insufficient).

It is recommended that the existing narrow, short and old bridges be replaced by new multi-cell box culverts for the following reasons.

- Due to the small sizes of the structures, there is little difference in cost between adding an additional one-lane width to an existing bridge or the replacement with a 2-lane new;
- The life of this category of existing bridges is expected to have come to an end based on the commonly accepted standards used for concrete structures. Should these structures be retained, they will possibly require replacement in the near future due to damage caused by an increase in heavy vehicles.
- A multi-cell box culvert rather than a single span bridge will be the most appropriate structure for the Study Road for river crossings of less than 10m in width. Firstly, because, a single span crossing of the river is not required as no large debris is expected (lowly vegetated catchment areas), and secondly, it will be more economical than a single span bridge.

A total of 16 bridges fall under this upgrading category.

Concept-3: Improvement of the Existing Bridges that have Insufficient Discharge Capacity for the design Flood

As mentioned in Chapter 2.3.5, actual flood damage or the potential for flood damage has been reported at the six bridge sites. It is judged that those existing bridges have insufficient discharge capacity against design floods at the appropriate return period level for primary roads, i.e. return periods of approximately 25-50 years. Accordingly, a flood discharge analysis will be executed on the basis of the rainfall data or high water level data obtained in Chapter 3.3 and an appropriate flow discharge area will be proposed for each of the bridge sites. Three existing bridges will only fall under this category (the other three bridges were discussed under concept 1 as they were considered too straight for 2-lane traffic).

Having said that, it must be pointed out that a structural upgrading plan for these bridges must be given a serious consideration due to the high cost of their replacement with new bridges. The possible alternatives are described below for each bridge site.

Table 7.2.11 Upgrading Alternatives for Monapo Bridge

1.Bridge Name: No.12 Monapo Bridge (159+560)	
2.Existing Bridge Description: L=11.5m, Win= 7.3m, RC-Slab type	
3.Alternatives to be considered	
Alternative-A	Replacement with a new bridge with sufficient discharge capacity
Alternative-B	Extension of the existing bridge to ensure sufficient discharge capacity
Alternative- C	Installation of a box culvert under the approach roads in order to increase the discharge capacity

Table 7.2.12 Upgrading Alternatives for Nataleia Bridge

1.Bridge Name: No.24 Nataleia Bridge (225+600)	
2.Existing Bridge Description: L=22.6m(7.5m x 3), W=7.3m, RC-Slab type	
3.Alternatives to be considered	
Alternative-A	Replacement with a new bridge with sufficient discharge capacity
Alternative-B	Extension of the existing bridge to ensure sufficient discharge capacity
Alternative- C	Protection of the approach roads by concrete paving and revetment on the embankment slopes

Table 7.2.13 Upgrading Alternatives for Mutivaze-2 Bridge

1.Bridge Name: No.27 Mutivaze-2 Bridge (234+810)	
2.Existing Bridge Description: L=24.3m(6.3x4), W=3.4m, RC-slab type	
3.Althernatives to be considered	
Alternative-A	Replacement with a new bridge with sufficient discharge capacity
Alternative-B	Extension of the existing bridge to ensure sufficient discharge capacity

The appropriateness of these alternatives are discussed in 7.4.5. on the basis of the design HWL analysis.

Concept-4: Improvement of Existing Medium Size Bridges with Narrow Bridge Width

There are three bridges which fall into this category; namely the bridges over Lalaua, Namuela, and Lurio rivers, their lengths ranging from 28m to 94m. These bridges are still in good condition and seem to have had sufficient clearance against past floods. These bridges are “narrow” in width and can only accommodate one-lane traffic. This is an issue in the evaluation of alternatives for their improvement, as their replacement cost (to 2-lane standard) will be high. Various improvement alternatives to should ensure traffic safety and a smooth passage of traffic .The possible alternatives are described below and the appropriateness of the alternatives will be discussed in 7.4.5 on the basis of the design HWL analysis.

Table 7.2.14 Upgrading Alternatives for Lalaua Bridge

1.Bridge Name: No.19 Lalaua Bridge (186+740)	
2.Existing Bridge Description: L=28.0m (8.6+9.9+10.4), W=3.6m, RC-slab	
3.Alternatives to be considered	
Alternative-A	Replacement with a new bridge accommodating 2-lane traffic operation
Alternative-B	Addition of a new bridge with one-lane width, beside the existing one

Table 7.2.15 Upgrading Alternatives for Namuela Bridge

1.Bridge Name: No.30 Namuela Bridge (262+870)	
2.Existing Bridge Description: L=30.6m , W=4.2m, Bailey type	
3.Alternatives to be considered	
Alternative-A	Replacement with a new bridge accommodating 2-lane traffic operation

Note: There is no other alternative for this bridge because the current bridge is temporary and need to be replaced .

Table 7.2.16 Upgrading Alternatives for Lurio Bridge

1.Bridge Name: No.34 Lurio Bridge (309+400)	
2.Existing Bridge Description: L=94.2m (15.7 x 6), W=1.1+3.6+0.7, RC T-shaped Girder	
3.Alternatives to be considered	
Alternative-A	Construction of a new bridge accommodating 2-lane traffic operation
Alternative-B	Construction of a new bridge accommodating one-lane traffic operation
Alternative-C	Construction of a new bridge with a staged construction, First stage: construct substructure for 2-lane superstructure, and superstructure for only one-lane. Second stage: Erect another one-lane superstructure in the future

7.3 Preliminary Design of the Study Road

7.3.1 Detail Study for the Re-Alignment Plan

1) Concept for the Re-Alignment Plan

As previously explained in 7.2.2, the road alignment should benefit as much as possible from the existing alignment keeping in mind the geometric design criteria for 80 km /h. This will result in some sections of the existing road be realigned. The Study Team carried out an aerial photography survey to better understand the environmental and social impact of road realignment. Based on this survey, the Study Team has made efforts to reassess the realignment issue to further minimize impact to the natural and social environment. This was based on previous concepts as explained in 7.2.2 and the following additional issues.

- To reserve big trees along the road wherever possible
- To reduce social impacts to not only major towns but also the (small) villages

2) Result of the Re-Alignment Plan

The result of reassesing the alignment issue based on the aerial photos has resulted in an alignment which has less deviation to the existing alignment as with the previous selected alignment. Negative social impact to the smaller villages was also minimized.

Table 7.3.1 Result of the Re-alignment Plan

Nampula - Ribaue			Existing	Previous Plan	Re-Alignment Plan
Length (km)			133.0	131.85	131.80
Geometry	Horizontal Curvature	deg/km	50.9 (1.00)	37.2 (0.73)	41.5 (0.82)
	Rise + Fall	m/km	14.2 (1.00)	13.7 (0.97)	15.7 (1.11)
	No. of Rise + Fall	no./km	10.0	1.9	1.4
Ribaue - Malema			Existing	Previous Plan	Re-Alignment Plan
Length (km)			103.0	102.87	102.90
Geometry	Horizontal Curvature	deg/km	31.3 (1.00)	15.3 (0.49)	13.8 (0.44)
	Rise + Fall	m/km	20.4 (1.00)	19.8 (0.97)	22.4 (1.10)
	No. of Rise + Fall	no./km	10.0	1.9	1.8
Malema - Cuamba			Existing	Previous Plan	Re-Alignment Plan
Length (km)			112.0	112.91	112.88
Geometry	Horizontal Curvature	deg/km	41.7 (1.00)	29.5 (0.71)	26.7 (0.64)
	Rise + Fall	m/km	13.8 (1.00)	13.5 (0.98)	15.3 (1.11)
	No. of Rise + Fall	no./km	10.0	2.5	2.0

7.3.2 Drainage System

1) Side Drainage

The existing road is lower than the surrounding ground and this has resulted in eroded side drains in some of the sections. The erosion problem results from various causes such as the materials used for the drains (earth drains) and the accepted flow velocities. The SATCC Standard regulates the maximum flow velocity for the prevention of scouring (erosion) as follows.

Table 7.3.2 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)

In this project, the laterites found along the route will be used as the principal material for road construction. This soil falls within the "Fine Sand" category for which a maximum velocity of 0.6m/s is recommended.

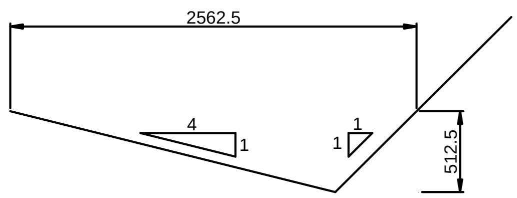


Figure 7.3.1 Proposed Earth Lined Ditch

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

Where,

n = Roughness coefficient = 0.027 (for earthen drain)

R =Hydraulic radius = 0.231

I = Grade

The table below shows the recommended maximum gradients for earth drains with various flow velocities

Table 7.3.3 Permissible Maximum Grade for an earthen side drain

i	v (m/s)
0.1%	0.44
0.2%	0.62
0.3%	0.76
0.4%	0.88
0.5%	0.99
0.6%	1.08
0.7%	1.17

In order to ensure good drainage of the road and side drains, the minimum longitudinal gradient is recommended to be 0.3%. Thus concrete lined drains as mentioned below are recommended for drains where the velocity of flow exceeds 0.6m/s.

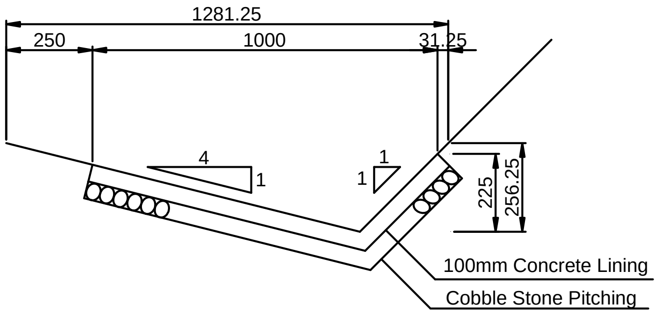


Figure 7.3.2 Proposed Concrete Lined Ditch

In the town sections, a new U-type drain with concrete cover is proposed to ensure smooth traffic flows during heavy rain and to prevent damage to the road structure.

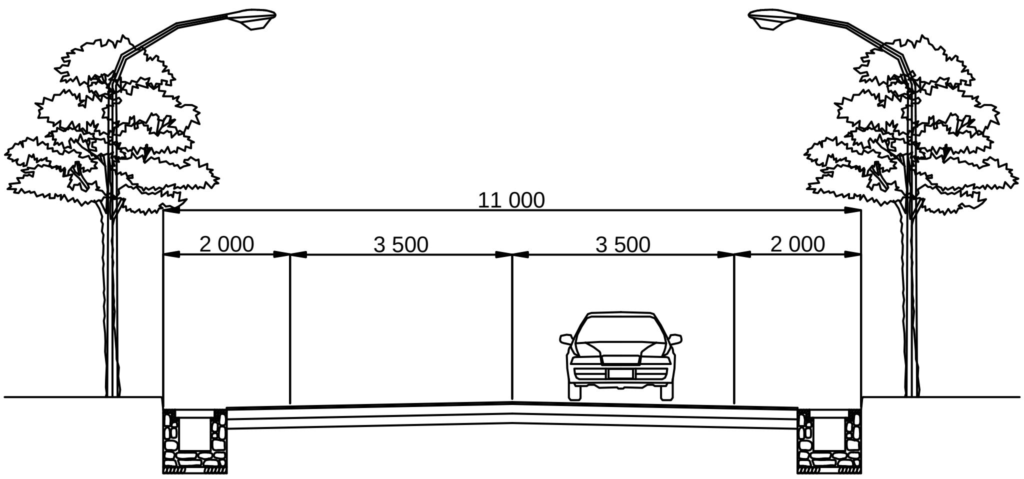


Figure 7.3.3 Proposed U-Type Ditch on Town Section

2) Cross Drainage

As already mentioned in chapter 2, 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. (they were constructed as un reinforced brick structures) .Therefore, it is proposed that all existing culverts be replaced by new “Concrete Box Culverts” with sufficient capacity and strength. Design policies for the provision of new box culverts are given blow.

- replace all existing box culverts with new concrete box culverts
- install new concrete box culverts in all areas considered to have inadequate cross drainage

Table 7.3.4 Schedule of New Concrete Box Culverts

Ribaue - Malema

No.	Ref. No.	Bridge Name	Station	Existing Structure Type	Ex. Q (m3/s)	1.0 x 1.0 Q	2.0 x 2.0 Q	No. of New Culvert 1.0 x 1.0	2.0 x 2.0	Q (m3/s)	>Ex. Q	Remarks
1	C-152		133132	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
2	B-6	Muco	134005	RC Slab								Continuous girder
3	C-153		134615	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
4	C-154		134869	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
5	C-155		135438	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
6	C-156		135670	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
7	C-157		136159	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
8	C-158		136808	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
9	C-159		137296	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
10	B-7	Namicuti	138318	RC Slab								Continuous girder
			138420			3.20	20.35	1				New
11	C-160		139388	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
12	C-161		139645	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
13	C-162		140037	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
14	C-163		140539	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
15	C-164		141320	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
16	C-165		141492	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
17	C-166		141575	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
18	C-167		141780	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
19	C-168		142084	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
20	C-169		144000	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
21	C-170		145185	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
22	C-171		145873	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
23	C-172		146200	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
24	C-173		146550	Box Culvert	1.77	3.20	20.35	1		3.20	OK	
25	C-174		146657	Box Culvert	2.31	3.20	20.35	1		3.20	OK	
26	B-8	Nepuipui	147993	RC Slab								
27	C-175		148567	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
28	C-176		148747	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
29	C-177		148980	Box Culvert	1.16	3.20	20.35	1		3.20	OK	
30	B-9	Napala	149320	RC Slab								
31	C-178		149930	Corgate Pipe	0.96	3.20	20.35	1		3.20	OK	
32	C-179		151560	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
33	C-180		151635	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
34	C-181		152002	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
35	C-182		152718	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
36	C-183		153253	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
37	C-184		153339	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
38	C-185		153539	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
39	B-10	Mutololoua	153717	RC Slab		3.20	20.35		4	81.40		Equivalent Q
40	C-186		154400	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
41	C-187		154531	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
			156080			3.20	20.35	1				New
42	B-11	Natete	156147	RC Hollow Slab								Japan's Grant Aid
43	C-188		157811	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
44	C-189		158370	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
45	C-190		158672	Corgate Pipe	0.33	3.20	20.35	1		3.20	OK	
46	C-191		158855	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
47	B-12	Monapo	159640	RC Slab								See Bridge Design
48	C-192		160392	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
49	C-193		160612	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
50	C-194		160779	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
51	C-195		161527	Box Culvert	1.16	3.20	20.35	1		3.20	OK	
52	C-196		162256	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
53	C-197		162862	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	Damp Ground
54	C-198		163641	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	Damp Ground
55	C-199		163988	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	Damp Ground
56	C-200		164590	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	Damp Ground
57	C-201		164750	Corgate Pipe	0.33	3.20	20.35	1		3.20	OK	Damp Ground
58	C-202		165128	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	Damp Ground
59	B-13	ThiThi	165348	RC Hollow Slab								Japan's Grant Aid
60	C-203		165958	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
61	C-204		167710	Box Culvert	6.82	3.20	20.35		1	20.35	OK	
62	C-205		168020	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
63	C-206		168178	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
64	C-207		168338	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
65	C-208		168470	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
66	C-209		168670	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
67	C-210		169635	Box Culvert	6.82	3.20	20.35		1	20.35	OK	
68	C-211		171745	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
69	C-212		173352	Corgate Pipe	0.33	3.20	20.35	1		3.20	OK	
70	C-213		173591	Box Culvert	3.20	3.20	20.35	1		3.20	OK	
71	C-214		173809	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
72	C-215		173842	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
73	C-216		174675	Box Culvert	40.29	3.20	20.35		2	40.70	OK	
			174780			3.20	20.35	1				New
74	B-14	Naiua	175700	RC T-shaped		3.20	20.35		4	81.40		Equivalent Q
75	B-15	Nampaua	177420	RC T-shaped		3.20	20.35		5	101.75		Equivalent Q
76	C-217		179890	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
77	C-218		180181	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
78	B-16	Iuhapua	181013	RC T-shaped		3.20	20.35		5	101.75		Equivalent Q
			181060			3.20	20.35	1				New
79	C-219		181372	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
80	C-220		181698	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
81	C-221		183381	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
82	C-222		183480	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
83	B-17		183785	RC T-shaped		3.20	20.35		4	81.40		Equivalent Q
84	C-223		185036	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
85	B-18		185603	RC Slab		3.20	20.35		2	40.70		Equivalent Q
86	C-224		186340	Box Culvert	40.29	3.20	20.35		2	40.70	OK	Equivalent Q
87	B-19	Lalaua	187090	RC Slab								See Bridge Design
88	C-225		188270	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
89	C-226		188787	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
90	C-227		190155	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
91	C-228		190600	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
92	C-229		191100	Corgate Pipe	0.11	3.20	20.35	1		3.20	OK	
93	C-230		191341	Corgate Pipe	0.11	3.20	20.35	1		3.20	OK	
94	C-231		191587	Box Culvert	1.77	3.20	20.35	1		3.20	OK	
			192380			3.20	20.35	1				New
95	C-232		192428	Corgate Pipe	1.27	3.20	20.35	1		3.20	OK	
			192880			3.20	20.35	1				New

109	C-387		315695	4-Corgate Pipe Culvert	32.24	3.20	20.35		2	40.70	OK	
110	C-388		317140	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
111	C-389		317590	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
112	C-390		318072	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
			318660			3.20	20.35	1				New
113	C-391		318719	Corgate Pipe	8.06	3.20	20.35		1	20.35	OK	
114	C-392		320000	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
115	C-393		320730	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
116	C-394		321154	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
117	C-395		321199	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
118	C-396		321438	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
119	C-397		322020	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
120	C-398		322182	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
121	C-399		324362	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
122	C-400		324422	Corgate Pipe	8.06	3.20	20.35		1	20.35	OK	
123	C-401		326019	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
			326860			3.20	20.35	1				New
124	C-402		326910	2-Corgate Pipe Culvert	16.12	3.20	20.35		1	20.35	OK	
125	C-403		327586	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
126	C-404		327962	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
127	C-405		328539	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
128	C-406		328970	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
129	B-35	Murusso	329230	RC Hollow Slab								Japan's Grant Aid
			329740			3.20	20.35	1				New
130	C-407		329990	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
131	C-408		330122	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
			330220			3.20	20.35	1				New
132	C-409		330321	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
133	C-410		330595	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
134	C-411		330665	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
135	C-412		331053	Corgate Pipe	8.06	3.20	20.35		1	20.35	OK	
136	C-413		331275	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
137	C-414		331425	Corgate Pipe	8.06	3.20	20.35		1	20.35	OK	
			332020			3.20	20.35	1				New
138	C-415		332134	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
139	C-416		332268	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
140	C-417		332630	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
141	C-418		332972	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
142	C-419		333459	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
143	C-420		333718	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
144	C-421		334100	2-Corgate Pipe Culvert	16.12	3.20	20.35		1	20.35	OK	
145	C-422		334640	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
146	C-423		334822	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
147	C-424		334885	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
			335260			3.20	20.35	1				New
148	C-425		335348	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
149	C-426		335620	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
150	C-427		335820	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
151	C-428		336072	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
152	C-429		336285	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
153	C-430		336360	Corgate Pipe	0.33	3.20	20.35	1		3.20	OK	
154	C-431		336845	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
155	C-432		336890	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
156	C-433		337130	Corgate Pipe	8.06	3.20	20.35		1	20.35	OK	
157	C-434		337330	2-Corgate Pipe Culvert	4.13	3.20	20.35	2		6.41	OK	
158	C-435		337399	Corgate Pipe	8.06	3.20	20.35		1	20.35	OK	
159	C-436		338070	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
160	C-437		338568	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
161	C-438		338704	4-Corgate Pipe Culvert	32.24	3.20	20.35		2	40.70	OK	
162	C-439		338708	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
163	C-440		340160	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
164	C-441		340490	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
165	C-442		341039	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
166	C-443		341448	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
167	C-444		341617	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
			341800			3.20	20.35	1				New
168	C-445		341921	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
			342100			3.20	20.35	1				New
169	C-446		342250	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
170	C-447		342567	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
171	C-448		342729	3-Corgate Pipe Culvert	6.19	3.20	20.35	2		6.41	OK	
172	C-449		342895	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
			343000			3.20	20.35	1				
173	B-36	Namutimbua	343920	RC Hollow Slab								Japan's Grant Aid
174	C-450		344155	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
			344250			3.20	20.35	1				New
175	C-451		344411	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
176	C-452		345122	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
177	C-453		346580	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
178	C-454		346636	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
179	C-455		346683	Corgate Pipe	2.06	3.20	20.35	1		3.20	OK	
180	C-456		347800	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	
181	C-457		347990	2-Corgate Pipe Culvert	4.13	3.20	20.35	2		6.41	OK	
182	C-458		348240	Corgate Pipe	0.70	3.20	20.35	1		3.20	OK	

7.3.3 Road Traffic Safety

1) Pedestrian Way

As discussed in section 7.2.3, the risk of traffic accidents is likely to increase with increase volume of traffic and higher driving speeds. The survey indicated that the following towns located along the N13 have a large number of pedestrians:.

Nampula	:	Medium scale markets and bus terminals are located on the Study Road.
Namina	:	A railway station and some shops are located along the Study Road, and farmers sell farm produce to the railway passengers.
Namigonha	:	A railway station is located along the Study Road. Local shops area located along both sides of the Study Road

Cross sections that accommodate the safe movement of pedestrians along side the road such as presented in figure 7.2.6 should be applied to the town sections.

2) Traffic Sign

The SATCC Road Traffic Sign Manuals of November 1997 will be used for preparing the specifications for road signs and road markings in this report.
Road signs and markings are used to provide the road users with important information alerting them on potential dangerous situations thereby, to accommodating an efficient and safe traffic flow
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

These markings and signs will be positioned in accordance with the relevant SATCC manual.

7.4 Preliminary Design of Bridges

7.4.1 Introduction

This sub-chapter describes the methodology for the selection of bridges and the procedures for the preliminary bridge design of the new bridges on the Study Road. There are six bridges to be replaced due to various reasons, most of those being narrow or having insufficient clearance against flood levels. The appropriate type of bridge design is based on a number of factors such as the required span length,, the availability of heavy equipment for erecting superstructure, the available materials, and the cost.

7.4.2 Selection of Bridge Type

(1) Superstructure

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

1) Structural Requirements

The general relationship between span length and bridge type is shown in Table 7.4.1. The minimum span 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 bridge Once the span length is fixed then the choice of bridges is limited.

A superstructure using beams or 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.

Table 7.4.1 Standard Applicable Span

TYPE		SPAN										Girder Height/ Span ratio
			10m		20m		30m		40m		50m	
RC Bridge	R.C Simple I Girder	—	—									1/10
RC Bridge	R.C Slab	—	—									1/12
RC Bridge	R.C Hollow Slab		—	—								1/15
PC Bridge	Pretensio Girder	—	—	—	—							1/15
PC Bridge	Hollow slab			—	—	—						1/22
PC Bridge	Simple Post-tension I girder				—	—	—	—				1/17
PC Bridge	Simple composite girder				—	—	—	—				1/15
PC Bridge	Connected Continuous Composite girder				—	—	—	—	—			1/15
PC Bridge	Continuous Composite girder					—	—	—	—	—		1/16
PC Bridge	Simple box girder						—	—	—	—		1/20

3) Construction Requirement

If the construction period is limited, 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 a 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 .

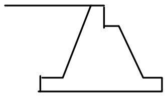
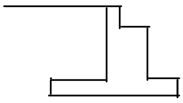
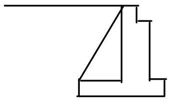
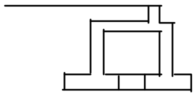
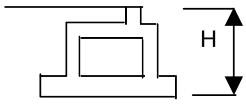
(4) Substructure

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

1) Abutment

Reinforced concrete is used for the abutment. The type of abutment is selected based on the relationship between the height of the bridge structure and the suitability of the respective abutment as shown in Table 7.4.2.

Table 7.4.2 Range of Heights for 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 with round edges is recommended for rivers in order to allow for a smooth flow of water.

3) Type of Foundation

The foundation type is mainly determined by the subsoil conditions, which need to support the total the load of the bridge, and economic criteria. A spread foundation is generally utilized where the depth of the supporting strata is obtained at less than 5m, whereas a piled foundation is employed for depths of more than 5m.

7.4.3 Design of Bridge Structure

(1) Determination of Total Bridge Length and Span Arrangement

The following policy is adopted to determine the bridge length and span arrangements.

- The river crossings on the Study Road have been frequently flooded affecting the surrounding areas, The length of the bridges will take into account the river width on the upstream or downstream side during such floods.

- The span length of the bridges is determined to limit flow obstruction by piers during flooding. The number of piers should be such that no more than 5% of the sectional area of the river is obstructed.
- From an aesthetic point of view, all span lengths should be uniform as much as possible.

(2) Superstructure Design

1) Basic Bridge Type

The Project bridges selected will be of a concrete type because of the following reasons:

- Most of materials except for PC cables are locally available, which makes a concrete bridge cost effectiveness in comparison with a steel type bridge.
- Concrete bridges have been commonly used on major bridge construction projects in Mozambique, and local contractors have also some experience to built it.
- The maintenance burden on the road agency is less for a concrete bridge than for a steel type bridge, which is periodically required to be re-painted.

2) Bridge Type by Span Length

Since there is no requirement for marine transport on r any of the rivers on the Study Road, a pre-cast concrete span of less than 30m in length is considered appropriate with a view to the cost effectiveness, workability of the construction and minimizing the construction time.

However, there are some characteristics of the Project bridges listed below;

- Each Project bridge site disperses on the entire route of the Study Road
- Except for the Lulio River Bridge, it will not be difficult to set up supporting formwork on the river bottom. The height from the river bottom to the proposed elevation of the road is less than 10m, with no substantial water flow in the dry season, Many existing bridges on the Study Road have previously used the in-situ casted concrete construction method.

Based on the previous mentioned relationship (table 7.4.1) between span length and standard type of bridge and based on the current practice in Mozambique and neighboring countries, the Study Team selected the following superstructure type differentiated by span lengths. (See Table 7.4.3)

Table 7.4.3 Superstructure Types by Span Length

Span Length (m)	Superstructure Types	Remark
L<=10	RC Slab	Supporting required
10< L<18	RC I – Girder	Supporting not required
	RC Hollow Slab	Supporting required
18=<L<=33	PC I - Girder	Supporting not required

In order to facilitate maintenance of the expansion joints, a continuous connected girder will be designed.

(3) Substructure Design

1) Abutments

The height of the abutments ranges from 5m to 15m. Based on this, and considering the current construction practices in Mozambique, the adoption of the following types of abutment is proposed (See Table 7.4.4).

Table 7.4.4 Abutment Type by Its Height

Abutment Height (m)	Abutment Type
H <= 5	Concrete Gravity Type
6 <= H <=12	RC Reversed T - Type
13<H	RC Boxed Type

Wing walls and approach slabs are required in most of the locations. The wing wall length is limited to about 8m, and approach slabs are required when the height of the embankment on the backfill side is more than 5m.

2) Piers

There are many case studies of pier failures (‘pile-bent type’) due to scouring of the foundation, particularly in rapid flow rivers in developing countries. Accordingly, the Study Team recommends the wall type pier with rounded edges to provide for a smooth flow of water.

3) Minimum Cover Depth of Footings

Pier and abutment footings are provided with a sufficient soil cover. Thickness of the coverdepends on the local conditions of the site. In the case of piers built in the river bed, a minimum cover depth of two (2) meters is designed to take account of possible scouring. However, these requirements can be eased if the bearing strata consist of rocks directly under the pier or at a shallow depth.

(4) Foundation Design

1) Foundation Type

The geological survey identified the location of the bearing strata suitable for bridge foundations. At most of the rivers on the Study Road, alluvial soil covers the underlying resistant layers. The cover depth is generally between 3 and –11 m at the river banks and between 0 and 3 m in the river bed. Accordingly, some abutments and piers are required to be supported by piles rather than spread foundations. Foundations are to be a spread footing type when a bearing strata consisting of gravel, boulder or rock is situated at a shallow depth.

2) Types of Pile

Pre-cast RC square piles (40cm x 40cm) are appropriate for pile foundations both for economic reasons and in light of the existing construction practices in Mozambique,

7.4.4 Bridge Protection Works

River and approach protection work is required to protect the substructures and embankment from scouring and erosion, particularly where a rapid flow is expected at flooding. For the bridge sites on the Study Road, velocity of the river flow is assumed to be less than 3m/s at the maximum. Therefore, a gabion protection around the abutments is considered appropriate.

7.4.5 Determination of Alternatives for Concept-3 & 4 Bridges

(1) Introduction

This sub-chapter will discuss the appropriate alternatives for Concept 3 & 4 Bridges as described in 7.2.3 and determine the most suitable alternative for those bridges. Each of the bridges which fall into these categories will be discussed below.

(2) Monapo Bridge

A 25m bridge length will be required to accommodate the estimated design flood discharge, This implicates more than doubling the existing bridge length. Alternative-B, which extends new spans at both ends of the existing bridge , will not be an appropriate method for the following reasons.

The construction costs of adding new spans will not be much different from Alt-A because Existing abutments would need to be replaced because they don't have sufficient supporting capacity for the added superstructures.

- Necessity for temporary support facility for the existing superstructure during replacement of the abutments
- A detour route is required during construction.

For the same reasons, Alt-C is not considered appropriate.

Table 7.4.5 Determination of Improvement Alternative for Monapo Bridge

1.Bridge Name: No.12 Monapo Bridge (159+560)		
2.Existing Bridge Description: L=11.5m, Win= 7.3m, RC-Slab type		
3.Alternatives		
	Outline of Alternative	Results
Alt-A	Replacement with a new bridge with sufficient discharge capacity Br. L=25m (12.5m x 2) W=8m, RC-Hollow slab type	Applicable
Alt-B	Extension of the existing bridge to ensure sufficient discharge capacity Br.L=25m(7.25(new)+11.5(existing)+7.5(new))	Not applicable
Alt-C	Installation of a box culvert on the approach road in order to increase the discharge capacity	Not applicable

(3) Natalia Bridge

A 48m bridge length will be necessary to accommodate the estimated design flood discharge, which would require more than doubling the existing bridge length. Alt-A, replacement with a new bridge, will be the most appropriate option for this river crossing. Alt-B is not considered for the following reasons;

Although, the construction costs will be slightly lower than Alt-A it would be: Necessary to replace the existing abutments because they do not have enough bearing capacity if new elements of the superstructure are added. Necessary to create a temporary support facility for the existing superstructure whilst replacement the old abutments

Necessary to construct a detour route during construction.

- The flood discharge capacity is lower than Alt-A because of the high disturbance of the water flow due to much number of piers.
- Since the existing bridge is assumed to have been designed with a lower live load, the existing structure would deteriorate quickly according to the expected increase in heavy traffic volume after upgrading of the study road.

Alt-C is not considered suitable for this crossing point because the flood sometimes overflows the approach roads of the bridge and it would cause temporary closure of the road. This situation is not acceptable for a primary road.

Table 7.4.6 Determination of Improvement Alternative for Nataleia Bridge

1.Bridge Name: No.24 Nataleia Bridge (225+600)		
2.Existing Bridge Description: L=22.6m(7.5m x 3), W=7.3m, RC-Slab type		
3.Alternatives		
	Outline of Alternative	Results
Alt-A	Replacement with a new bridge with sufficient discharge capacity -Br.L=48m(9+15x2+9), W=8m, RC-Hollow slab type	Applicable
Alt-B	Extension of the existing bridge to ensure sufficient discharge capacity - Br.L=48m (13.2(new)+7.5x3(existing)+13.2(new))	Not applicable
Alt-C	Protection of the approach roads by covering with concrete paving and revetment on the embankment slopes	Not applicable

(4) Mutivasse Bridge

There will be no other alternative than building a new bridge which would allow two-lane traffic operation and which has a sufficient discharge capacity against the design flood. The existing bridge can only accommodate one-lane traffic and has insufficient flood discharge capacity. In addition, footpaths will be required at both sides of the bridge because the bridge is located in the populated area close to the town center of Malema.

Table 7.4.7 Determination of Improvement Alternative for Mutivasse Bridge

1.Bridge Name: No.27 Mutivasse Bridge (234+810)		
2.Existing Bridge Description: L=24.3m(6.3x4), W=3.4m, RC-slab type		
3.Althernatives		
	Outline of Alternative	Results
Alt-A	Replacement with a new bridge with sufficient discharge capacity - Br.L=30m(15mx2), W=10m including foot path	Applicable

(5) Lalaue Bridge

The existing bridge width (W=3.6m) is too narrow to accommodate vehicles with a design speed of 80km/h, which is used as the basic design criteria for the Study road. Accordingly, Alt-A is recommended for this crossing point.

Table 7.4.8 Determination of Improvement Alternative for Lalaue Bridge

1.Bridge Name: No.19 Lalaua Bridge (186+740)		
2.Existing Bridge Description: L=28.0m (8.6+9.9+10.4), W=3.6m, RC-slab		
3.Alternatives		
	Outline of Alternative	Results
Alt-A	Replacement with a new bridge accommodating 2-lane traffic operation -Br. L=30m(15mx2), W=8.0m, RC-Hollow slab type	Applicable
Alt-B	Addition of a new bridge with one-lane width, beside the existing one	Not applicable
	-Br. L=30m(15mx2), W=4.5m, RC-Hollow slab type	

(6) Namuela Bridge

There is no other alternative than building a new bridge with two-lanes because the existing bridge is a temporary ‘Bailey bridge’, with only one lane traffic operation. The superstructure of the ‘Bailey bridge’ can be dismantled and used for other crossing point on the regional road network.

Table 7.4.9 Determination of Improvement Alternative for Namuela Bridge

1.Bridge Name: No.30 Namuela Bridge (262+870)		
2.Existing Bridge Description: L=30.6m , W=4.2m, Bailey type		
3.Alternatives		
	Outline of Alternative	Result
Alt-A	Replacement with a new bridge accommodating 2-lane traffic operation - Br.L=30m(6.5+13.0+6.5), W=8.0m, RC-Hollow slab type	Applicable

(7) Lurio Bridge

The improvement, rehabilitation or replacement of the Lurio bridge will be a key issue for discussion in the economical feasibility of the project. The bridge length is approximately 100m and its rehabilitation or replacement will require a huge investment. The existing bridge is in structural good condition and has a sufficient flood discharge capacity. The problem remains the narrow width that can only accommodate one-lane traffic. The structural capacity of the bridge might also not be sufficient for future traffic (using the latest live load design criteria). The narrow width and long bridge length would become a bottleneck, especially if the traffic volume increases in the future. Given this situation, Alt-A or Alt-C are recommend. Final selection of the most suitable alternative will depend on the feasibility of the project.

Table 7.4.10 Determination of Improvement Alternative for Lurio Bridge

<table>
<tr><td colspan="3">1.Bridge Name: No.34 Rurio Bridge (309+400)</td></tr>
<tr><td colspan="3">2.Existing Bridge Description: L=94.2m (15.7 x 6), W=1.1+3.6+0.7, RC T-shaped Girder</td></tr>
<tr><td colspan="3">3.Alternatives</td></tr>
<tr><td></td><td>Outline of Alternative</td><td>Result</td></tr>
<tr><td>Alt-A</td><td>Construction of a new bridge accommodating 2-lane traffic operation</td><td>Applicable</td></tr>
<tr><td>Alt-B</td><td>Construction of a new bridge accommodating one-lane traffic operation</td><td>Not applicable</td></tr>
<tr><td>Alt-C</td><td>Construction of a new bridge with stage construction, First stage: construct a substructure for a future 2-lane superstructure, and construct a superstructure for only one-lane initially. Second stage: Erect another one-lane superstructure in the future</td><td>Considerable depending on the project feasibility</td></tr>
</table>

7.4.6 Results of Preliminary Design of Bridges

Table 7.4.11 shows the preliminary design results for new bridges on the Study road on the basis of the discussion in the previous sections.

Table 7.4.11 Preliminary Design Results

<table>
<tr><th rowspan="3">No</th><th rowspan="3">River Name</th><th rowspan="3">Km post</th><th colspan="9">Superstructure</th><th colspan="9">Substructure</th></tr>
<tr><th rowspan="2">Br. L (m)</th><th rowspan="2">Nos. Span</th><th rowspan="2">Span (m)</th><th rowspan="2">Br. Type</th><th rowspan="2">Inner W(m)</th><th rowspan="2">Flood Discharge (m^3/s)</th><th rowspan="2">HWL</th><th rowspan="2">Return Period (yr)</th><th rowspan="2">Clear-ance</th><th colspan="3">A1Abutment</th><th colspan="3">P1 (P2)Pier</th><th colspan="3">A2Abutment</th></tr>
<tr><th>Type</th><th>Hight (m)</th><th>Founda. Type</th><th>Type</th><th>Hight (m)</th><th>Founda. Type</th><th>Type</th><th>Hight (m)</th><th>Founda. Type</th></tr>
<tr><td>12</td><td>Monapo</td><td>159+560</td><td>25</td><td>2</td><td>12.5</td><td>RC-Hollow</td><td>8.0</td><td>89</td><td>561.5</td><td>50</td><td>0.5</td><td>Rev.-T</td><td>3.0</td><td>Pile</td><td>Wall</td><td>6.0</td><td>Pile</td><td>Rev.-T</td><td>3.0</td><td>Pile</td></tr>
<tr><td>19</td><td>Lalaua</td><td>186+740</td><td>30</td><td>2</td><td>15.0</td><td>RC-Hollow</td><td>8.0</td><td>72</td><td>545.7</td><td>50</td><td>0.5</td><td>Rev.-T</td><td>6.0</td><td>Spread</td><td>Wall</td><td>6.5</td><td>Spread</td><td>Rev.-T</td><td>9.5</td><td>Spread</td></tr>
<tr><td>24</td><td>Nataleia</td><td>225+600</td><td>48</td><td>4</td><td>15.0,9.0</td><td>RC-Hollow</td><td>8.0</td><td>197</td><td>592.1</td><td>50</td><td>0.5</td><td>Rev.-T</td><td>5.0</td><td>Spread</td><td>Wall</td><td>5.5</td><td>Spread</td><td>Rev.-T</td><td>5.0</td><td>Spread</td></tr>
<tr><td>27</td><td>Mutivasse</td><td>234+810</td><td>30</td><td>2</td><td>15.0</td><td>RC-Hollow</td><td>10.0</td><td>154</td><td>595.5</td><td>50</td><td>0.5</td><td>Rev.-T</td><td>9.0</td><td>Spread</td><td>Wall</td><td>7.5</td><td>Spread</td><td>Rev.-T</td><td>9.0</td><td>Spread</td></tr>
<tr><td>30</td><td>Namuela</td><td>262+870</td><td>30</td><td>3</td><td>14.0,8.0</td><td>RC-Hollow</td><td>8.0</td><td>42</td><td>625.2</td><td>50</td><td>0.5</td><td>Rev.-T</td><td>4.0</td><td>Pile</td><td>Wall</td><td>4.5</td><td>Pile</td><td>Rev.-T</td><td>4.0</td><td>Pile</td></tr>
<tr><td>34</td><td>Lurio</td><td>309+400</td><td>94</td><td>3</td><td>31.3</td><td>PC-I</td><td>10.0</td><td>360</td><td>506.0</td><td>100</td><td>1.0</td><td>Rev.-T</td><td>6.0</td><td>Spread</td><td>Wall</td><td>10.5</td><td>Spread</td><td>Box</td><td>14.0</td><td>Spread</td></tr>
</table>

Chapter 8 Construction Planning & Cost Estimate

Chapter 8 Construction Planning & Cost Estimate

8.1 Construction Planning

8.1.1 Introduction

This chapter shall describe the proposed construction plan for upgrading of the Nampula – Cuamba Road (hereafter referred to as "the Project") including construction methods, resources for material and equipment, construction procedures and work schedule, according to site conditions, the work quantities. The upgrading work shall be divided into 2 major components namely road and bridge works.

The Study Road has a length of approximately 350 km between Nampula and Cuamba. The road will be divided into 3 construction sections for the purpose of discussing design, construction plans and cost estimates as follows.

Section 1:	Nampula – Ribaue	(Length = 131.85 km)
Section 2:	Ribaue – Malema	(Length = 102.87 km)
Section 3:	Malema – Cuamba	(Length = 112.91 km)
	Total:	(347.63 km)

8.1.2 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 conclusions of works and the opening of the road

1) Land Acquisition and Resettlement

The land acquisition and resettlement shall be implemented by the GoM. Estimated area and structures to be relocated are summarized in Table 8.1.1. These estimates indicate land acquisition and resettlement areas depending on the clearance width for the project (for which 3 alternative were presented). For the purpose of estimating the Project cost, the 'Corridor of Impact (COI; see Part 2 chapter 5) shall be utilized.

Table 8.1.1 Estimated Quantity of Displaced Area and Structures

Case	Concept	Width of carriageway	Clearance width	Structure				Cultivable land
				Total	Concrete (10%)	Non-concrete (50%)	Movable kiosk (40%)	
		(m)	(m)	No.	No.	No.	No.	sq.km
0	Law based	10	60	2,427	243	1,213	971	20.88
1	Lichinga-Montepuez Rd.	10	20	809	81	404	324	6.96
2	COI + construction Rd. + diversion	10	10	405	41	202	162	3.48

2) Survey and Clearance of Land Mines

The existence of land mines along the Study Road has not been confirmed in the FS stage, this after interviews with National De-mining Institute (IND). Other road projects have considered costs for verifying whether a land mine exists as part of the general items. These costs shall be included in the Project cost.

At present, de-mining is an obligation of the contractor who has been awarded the job. 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.

8.1.3 Construction Plan for the Project

1) Construction Conditions

(1) Procurement of Crushed Stone

The Study Team conducted sampling and testing at 4 potential quarry sites along the Study Road and one existing quarry in Namialo. According to the test results, all sites can be used for obtaining aggregate for concrete works, and 3 sites (i.e. Malema, Cuamba and Namialo) are suitable for aggregate that can be used in pavement layers. The source for obtaining crushed stones shall be selected based on the distance between the construction site and the quarry. Further studies should be carried out during the detailed design stage to find additional quarries with detailed information about size of the deposits. This will help to minimize the Project cost.

(2) Procurement of other Major Materials and Construction Equipment

(i) Material

Cement and re-bars are available on the domestic market. Bitumen, PC cables and other special materials for bridge construction (e.g. expansion joint, bearing shoe) shall be imported. Such materials can be imported through the Nacala port and transported inland by railway and / or by road.

(ii) Equipment

Major construction equipment for road and bridge works is locally available. However, erection girder for PC-I girder should be imported.

(3) Procurement Source for the Project

Sources of materials, equipment and plant and other important places (e.g. major city, border point of the construction section) for the Project and their functions are described in Figure 8.1.1. Construction planning and cost estimate shall be done according to this figure.

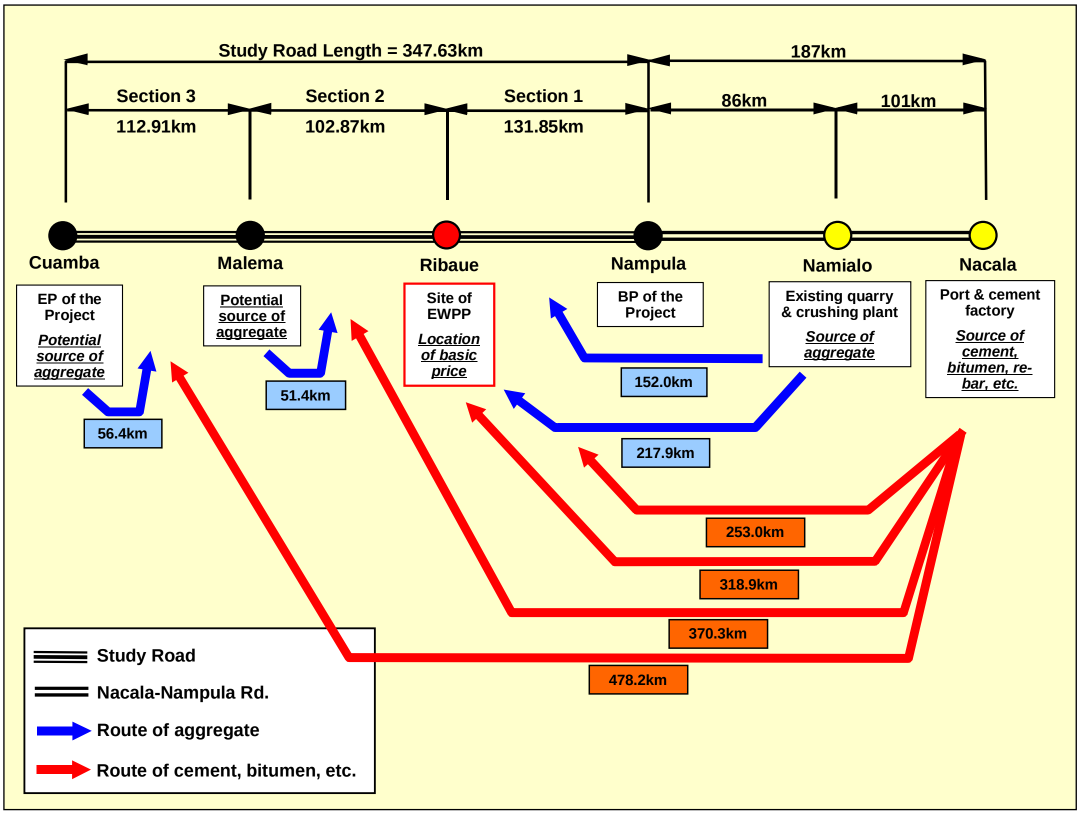


Figure 8.1.1 Locations & Functions of Important Places

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 regulation. Traffic control persons 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 8.1.2. And Figure 8.1.3 shows the work process in the each of the work units.

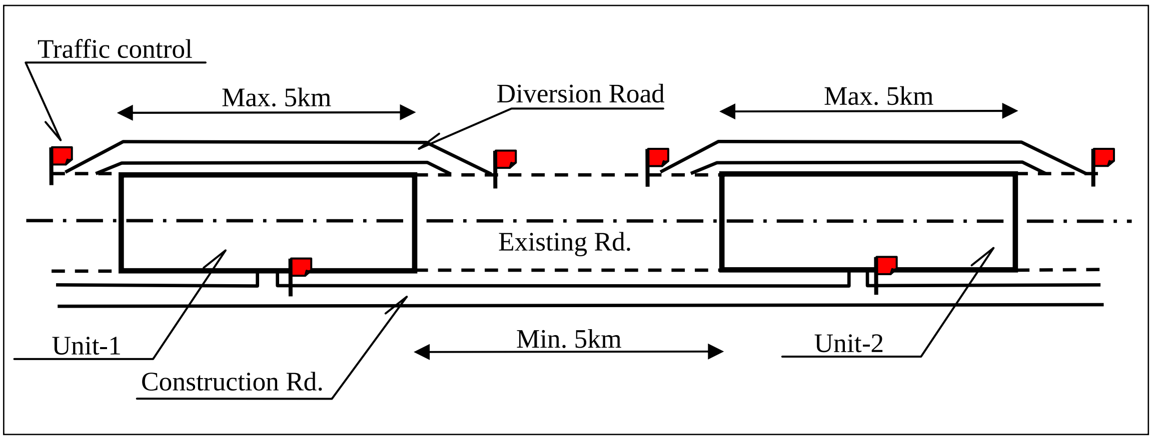


Figure 8.1.2 Sample Layout in Rural Section

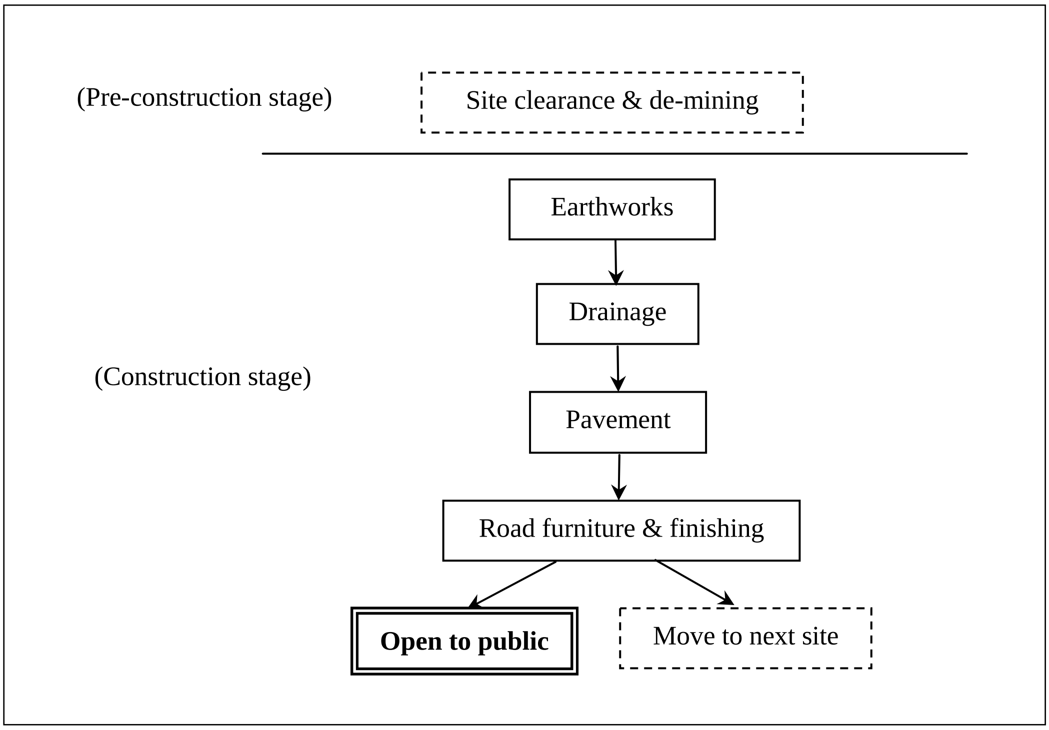


Figure 8.1.3 Construction Process in the Construction Unit

(i) 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 all times. Construction vehicles shall share this one lane with public vehicles. Well-trained traffic control persons shall be assigned to these sections. A sample layout in town sections is shown in Figure 8.1.4.

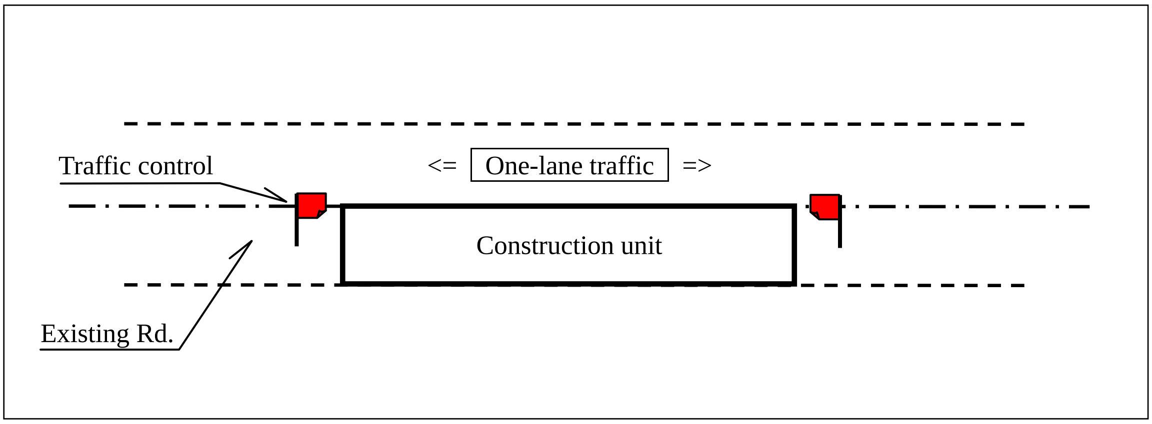


Figure 8.1.4 Sample Layout in Rural Section

3) Bridge Construction Plan

(1) Introduction

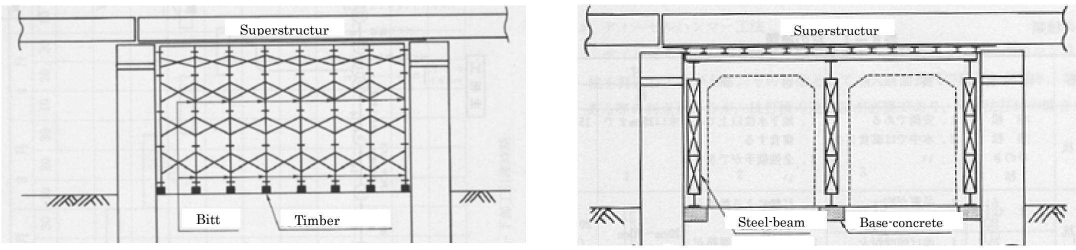
This construction plan includes a brief description on the construction method for superstructure, substructure and foundation, construction procedures and the construction schedule for each bridge type.

(2) Construction Plan for Superstructure

a) Construction Method

<u>Girder Fabrication Method</u>

Two types of superstructure shall be utilized for this project; namely, 'RC-hollow slab type', and 'PC-I girder'. The former shall be constructed with in-situ cast concrete using formwork that is erected from the river bed ('staging method'). This is the only method for this type of superstructure construction on bridges with short spans. It has also been utilized for the other bridge rehabilitation projects on the Study Road. Figure 8.1.5 shows a sketch of the 'staging method' for the RC hollow slab type. Depending on the flow of the waterway under the bridge, 'bitty' or 'beam type' supporting shall be utilized.



(In case of no water flow) (In case of securing waterway)

Figure 8.1.5 Staging Method with Support for RC Hollow Slab Construction

A PC-I girder type superstructure is planned to be utilized for the Rulio Bridge, which requires a longer span (approximately 31m) than other bridges to be rehabilitated for this project. For the girder fabrication, there are two methods; fabrication at site or transport of the girders from a factory. Although the latter has advantages in an improved quality control of the fabrication process and a timely completion of the girders, the former meothod shall be recommended for this site because:

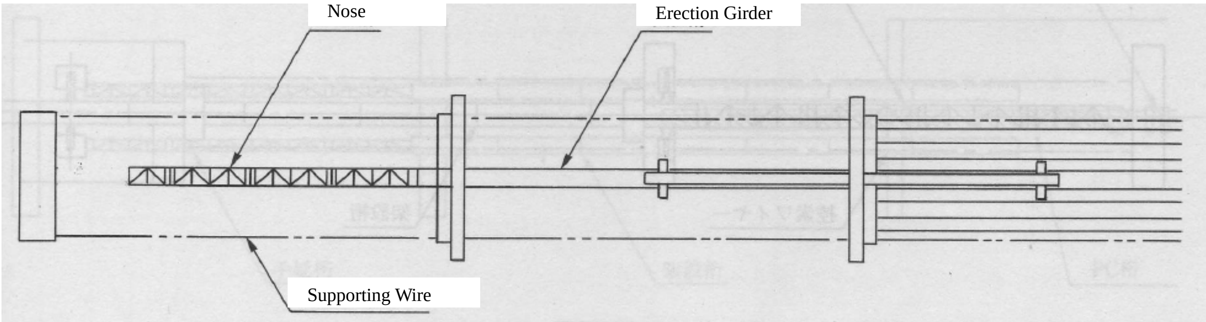
- A PC girder factories are only located in South Africa and transport would be too far away from the bridge location;
- Access roads from the factory to the bridge site are in poor condition which would damage the girders during the transportation.

Consequently, it is recommended that the PC-I girder be fabricated at the construction yard near the bridge sites. It was confirmed that space is available at the left bank of the river for the fabrication of girders.

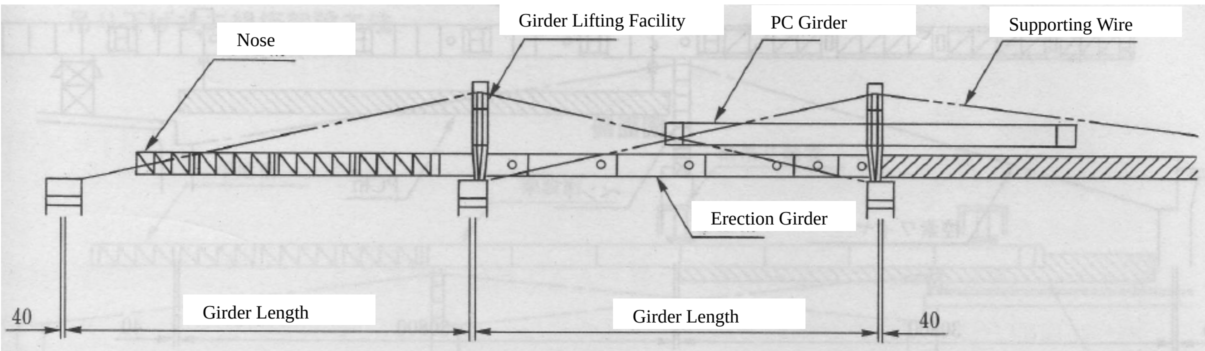
Girder Erection Method

As mentioned earlier, the RC hollow slab superstructure shall be constructed with in-situ cast concrete on formwork that is supported by the river bed

For the PC-I girder erection, the erection girder method shall be appropriate to the prevailing site conditions (see Figure 8.1.6) because the Lurio River has a permanent water flow, and it is difficult to mobilize a crane in the northern area of Mozambique that is capable of lifting a large weight. To place a 31m-girder, two cranes with 160 tons lifting capacity will be required It is too far and expensive to mobilize such cranes from South Africa to the bridge site.



Plan



Side View

Figure 8.1.6 Girder Erection using Erection Girder

b) Construction Procedure

The standard construction procedure for the superstructure is shown in Figure 8.1.7 and 8.1.8.

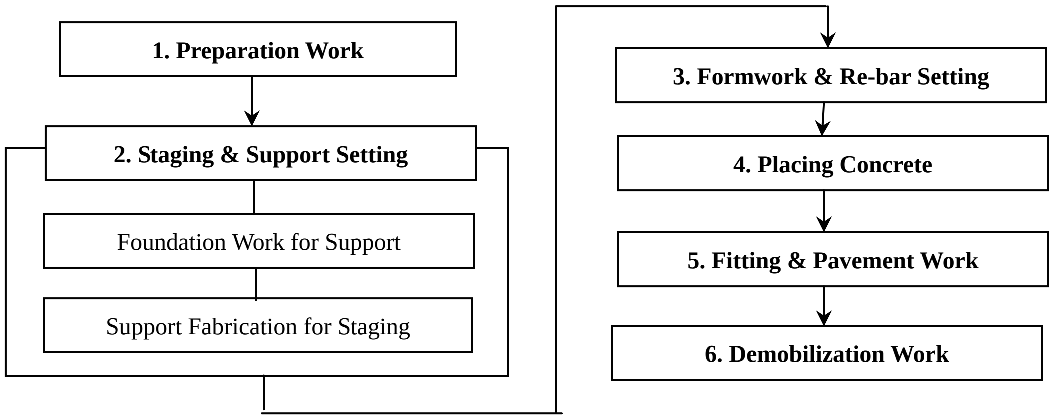


Figure 8.1.7 Construction Procedure of Superstructure (RC-Hollow Slab)

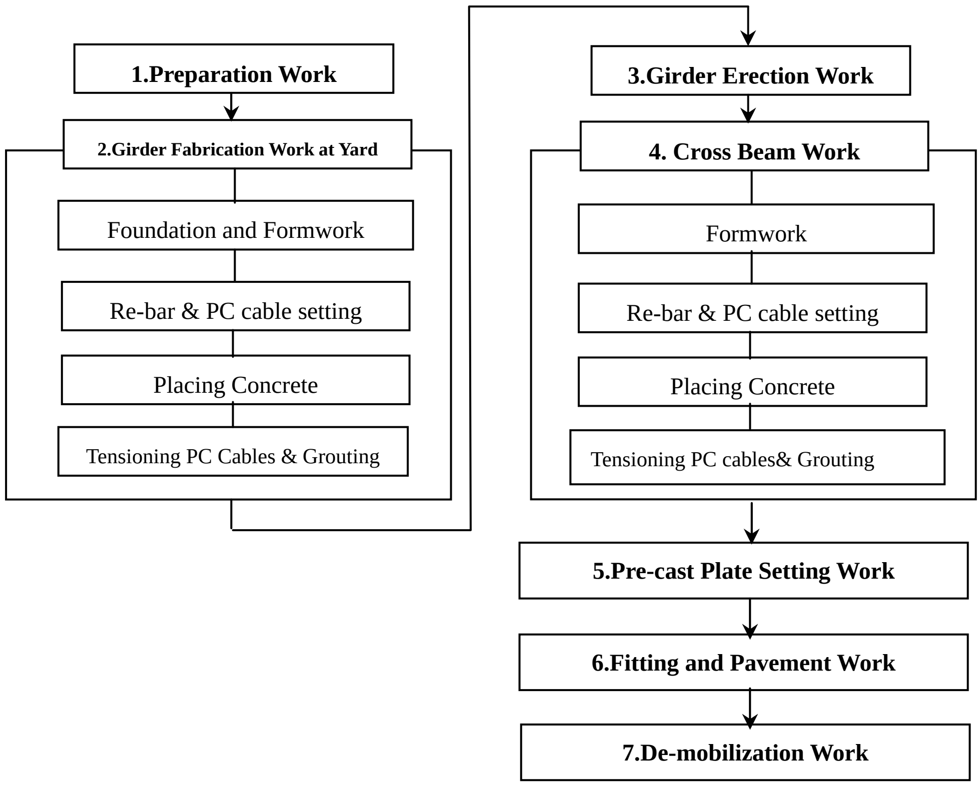


Figure 8.1.8 Construction Procedure of Superstructure (PC-I Girder)

(3) Construction Plan for Substructure and Foundation

a) Construction Method for Pile Foundation

There are two bridges that are supported by pile foundations on the Study Road. According to the preliminary design, the scale of a typical pile foundation can be assumed to be as follows:

Pile length: 5-9 m
Feature of subsoil: Clayey sand to Sand with N values ranging from 3 to 20
Surrounding condition: almost no houses near the site
Pile type: RC pile (40cm x 40cm)

In consideration of these conditions, pile driving by a hammer is the most appropriate method. Vibration and noise induced by pile driving will not cause any serious impact on the houses nearby, because these are located at quite a distance from the construction site.

For the Monapo Bridge, the lower part of the layer just above the bearing stratum (granite rock) is very stiff with clayey sand, and it may be difficult for some piles to reach the bearing strata. In this case, it is necessary to stop hammering the pile in order to avoid any structural damage of the pile (according to the refusal criteria)

2) Construction Procedure for Substructure and Foundation

The construction of the foundation and substructure should be undertaken with the following procedure, shown in Figure 8.1.9.

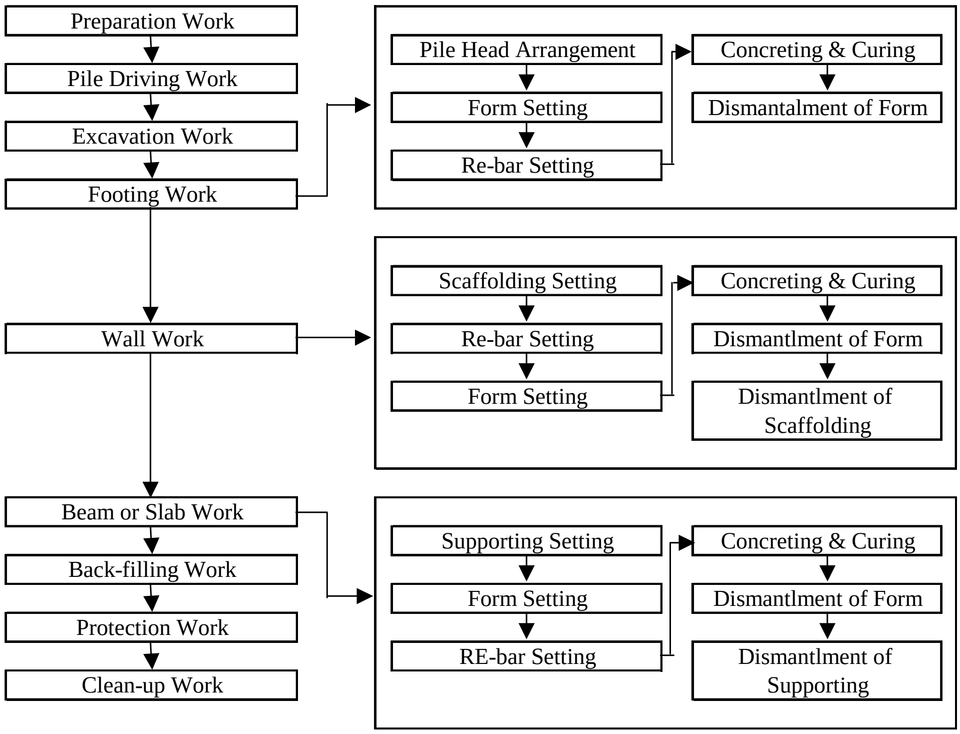


Figure 8.1.9 Construction Procedure of Substructure & Foundation

8.1.4 Contents of Construction Works for the Project

Construction work items and their quantities are shown in Table 8.1.2 and 8.1.3.

Table 8.1.2 Bill items for the Road Works

Item	Description		Unit	Section 1 Nampula - Ribaue (131.85km)	Section 2 Ribaue - Malema (102.87km)	Section 3 Malema - Cuamba (112.91km)	Total (347.63km)
1	Preliminary & general works		L.S.	1	1	1	1
2	Earthworks						
	2.1	Excavation	cu.m	875,431	595,259	460,346	1,931,036
	2.2	Fill (use excavated soil)	cu.m	875,431	405,156	261,433	1,542,020
	2.3	Fill (borrow material)	cu.m	89,144			89,144
	2.4	Disposal of surplus soil	cu.m		190,103	198,913	389,016
3	Pavement						
	3.5.2	Granular sub base course (t = 375mm) (Soaked CBR > 30%)	sq.m		928,970	1,034,780	1,963,750
	3.5.3	Granular sub base course (t = 400mm) (Soaked CBR > 30%)	sq.m	1,202,390			1,202,390
	3.11.1	Granular base course (t = 200mm) (Soaked CBR > 80%)	sq.m		928,970	1,034,780	1,963,750
	3.11.3	Granular base course (t = 250mm) (Soaked CBR > 80%)	sq.m	1,202,390			1,202,390
	3.15	Prime coat	sq.m	1,202,390	928,970	1,034,780	3,166,140
	3.16	Tack coat	sq.m	1,202,390	928,970	1,034,780	3,166,140
	3.18	Double bituminous surface treatment (DBST)	sq.m	1,202,390	928,970	1,034,780	3,166,140
	3.19	Otta seal for sidewalk	sq.m	29,680	3,760	15,880	49,320
	3.20	Granular sub base course for sidewalk (t = 100mm; Soaked CBR > 30%)	sq.m	29,680	3,760	15,880	49,320
4	Drainage						
	4.1	Unlined side ditch	m				0
	4.2	Concrete lined side ditch	m	76,040	72,920	61,400	210,360
	4.3	U-shaped side ditch (open)	m	1,170	240	1,350	2,760
	4.4	U-shaped side ditch (covered)	m	14,840	2,960	17,240	35,040
	4.5	Cross culvert	m	252	72	420	744
	4.6	Box culvert (1.0*1.0)	No	179	139	179	497
	4.7	Box culvert (2.0*2.0)	No	12	60	38	110
5	Road furniture						
	5.1	Road sign (Warning) A=0.62m2/no	m2	54	16	64	134
	5.2	Road sign (Regulatory) A=1.13m3/no	m2	54	14	44	112
	5.3	Road marking (continuous) W=100mm	m	283,242	217,356	244,095	744,693
	5.4	Road marking (continuous) W=400m	m	1,430	330	1,210	2,970
6	Miscellaneous work						
	6.1	Concrete kerb	m	14,840	1,880	12,200	551,437.00
	6.2	Demolishing existing concrete (plain)	m3	754	826	1,183	34,497.15
	6.3	Demolishing existing concrete (reinforced)	m3	114	535	28	15,358.93
	6.4	Removal of bailey bridge (W=4m)	m			31	2,813.16
7	Bridge						
	No. 12 Monapo bridge	L = 25m	No		1		1
	No. 19 Lalaua bridge	L = 30m	No		1		1
	No. 24 Nataleia bridge	L = 48m	No		1		1
	No. 27 Mutivasse bridge	L = 30m	No		1		1
	No. 30 Namuela bridge	L = 30m	No			1	1
	No. 34 Lurio bridge	L = 94m	No			1	1
8	Temporary construction road		km	124.00	101.00	104.00	329.00
9	Dayworks		L.S.	1	1	1	1

Table 8.1.3 Bill items for the Bridge Construction Works

No.	Description			Unit	Section 2 No. 12 Monapo	Section 2 No. 19 Lalaua	Section 2 No. 24 Nataleia	Section 2 No. 27 Mutivasse	Section 3 No. 30 Namuleia	Section 3 No. 34 Lurio	Total
7.1	Foundation for structures										
	7.1.1	Excavation (soil)		cu.m	396.1	2,285.5	737.5	2,089.3	787.2	1,311.9	7,607.5
	7.1.2	Excavation (hard rock)		cu.m	0.0	112.1	635.8	134.6	0.0	123.7	1,006.2
	7.1.3	Excavation (soft rock)		cu.m	0.0	0.0	0.0	0.0	0.0		0.0
	7.1.4	Pile	RC-400*400	m	301.5	0.0	0.0	0.0	212.0		513.5
7.2	Substructure										
	7.2.1	Concrete	σck=240kgf/cm2	cu.m	129.1	300.4	312.9	445.4	179.6	654.3	2,021.7
	7.2.2	Formwork		sq.m	204.3	424.9	487.0	595.1	295.2	1,248.1	3,254.6
	7.2.3	Reinforcement bar	SD295	t	7.89	16.62	20.40	24.81	11.10	40.76	121.6
7.3	Superstructure										
	7.3.1(1)	Concrete for girder	σck=240kgf/cm2	cu.m	144.4	186.8	298.8	225.8	186.8	0.0	1,042.6
	7.3.1(2)	Concrete for girder	σck=350kgf/cm2	cu.m	0.0	0.0	0.0	0.0	0.0	304.6	304.6
	7.3.2	Concrete for deck	σck=240kgf/cm2	cu.m	0.0	0.0	0.0	0.0	0.0	406.6	406.6
	7.3.3	Concrete for Precast panel	σck=240kgf/cm2	cu.m	0.0	0.0	0.0	0.0	0.0	48.8	48.8
	7.3.4	Formwork		sq.m	356.3	427.5	684.0	502.5	427.5	3,090.0	5,487.8
	7.3.5	Reinforcement bar		t	29.70	38.61	61.78	47.19	38.61	145.30	361.2
	7.3.6	PC cable for girder		t	0.0	0.0	0.0	0.0	0.0	17.04	17.0
	7.3.7	Erection of girders	PC-I girder	t	0.0	0.0	0.0	0.0	0.0	1,035.0	1,035.0
7.4	Miscellaneous										
	7.4.1	Expansion joint		m	16.0	16.0	16.0	20.0	16.0	40.0	124.0
	7.4.2	Bearing		No	15.0	15.0	25.0	15.0	20.0	30.0	120.0
	7.4.3	Drainage pipes		m	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7.4.4	Demolishing existing concrete	Plain	cu.m	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7.4.5	Demolishing existing concrete	Reinforced	cu.m	65.3	51.5	81.0	45.0	16.9	0.0	259.7
	7.4.6	Slope protection	Riprap	sq.m	210.0	210.0	210.0	210.0	210.0	210.0	1,260.0

8.1.5 Construction Schedule

A provisional construction schedule for the Project is estimated on the basis of quantities of construction works, expected daily performance of the working units, local conditions, etc. Furthermore, the effective working rate, considering non-working days (i.e. rainy days, Sundays and holidays) will have a significant impact on the construction schedule. The expected working rates for the 3 road sections are shown in Table 8.1.4 – 8.1.6.

Table 8.1.4 Effective Working Rate of Section 1: Nampula - Ribaue

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)	10.50	7.10	6.10	2.70	0.40	0.30	0.30	0.30	0.10	0.60	2.00	4.80	35.20
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)	1.69	1.27	0.98	0.45	0.08	0.05	0.04	0.05	0.02	0.10	0.40	0.77	5.90
Non-working day	13.81	10.83	10.12	7.25	6.32	5.25	4.26	5.25	6.08	5.50	7.60	9.03	91.30
Working day	17.19	17.17	20.88	22.75	24.68	24.75	26.74	25.75	23.92	25.50	22.40	21.97	273.70
Working Rate (Average)	0.55	0.61	0.67	0.76	0.80	0.83	0.86	0.83	0.80	0.82	0.75	0.71	**0.75**
Working Rate (dry season)					Dry season								**0.81**
Working Rate (rainy season)	Rainy season											Rainy season	**0.66**

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

Table 8.1.5 Effective Working Rate of Section 2: Ribaue - Malema

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)	9.90	6.20	6.40	1.50	0.20	0.20	0.20	0.10	0.10	0.50	2.50	4.70	32.50
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)	1.60	1.11	1.03	0.25	0.04	0.03	0.03	0.02	0.02	0.08	0.50	0.76	5.46
Non-working day	13.30	10.09	10.37	6.25	6.16	5.17	4.17	5.08	6.08	5.42	8.00	8.94	89.04
Working day	17.70	17.91	20.63	23.75	24.84	24.83	26.83	25.92	23.92	25.58	22.00	22.06	275.96
Working Rate (Average)	0.57	0.64	0.67	0.79	0.80	0.83	0.87	0.84	0.80	0.83	0.73	0.71	**0.76**
Working Rate (dry season)					Dry season								**0.81**
Working Rate (rainy season)	Rainy season											Rainy season	**0.68**

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

Table 8.1.6 Effective Working Rate of Section 3: Malema - Cuamba

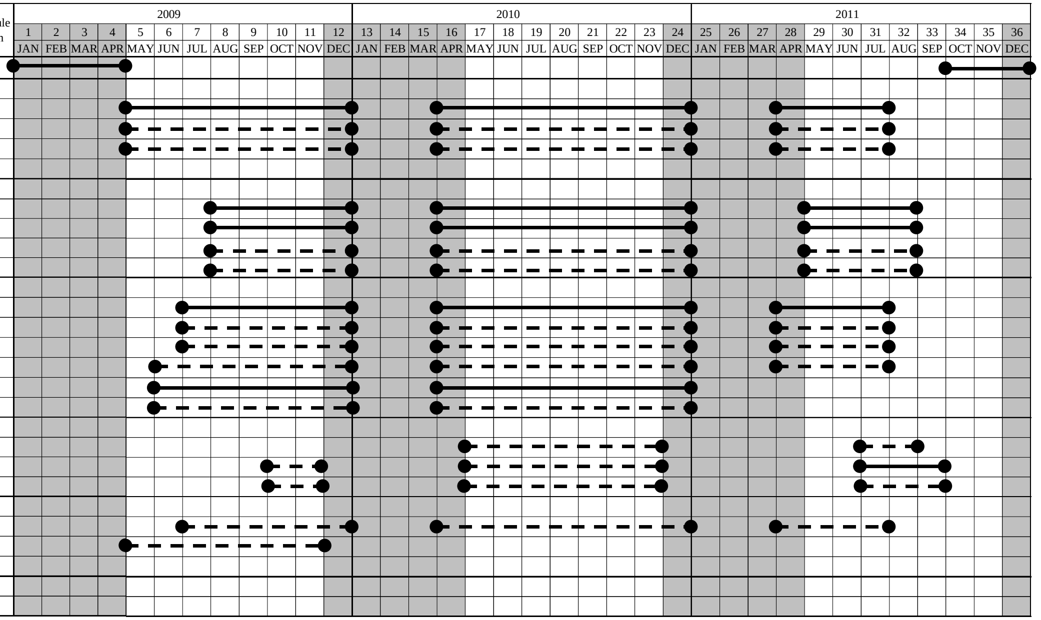
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
No. of day	31	28	31	30	31	30	31	31	30	31	30	31	365
Rainy day (over 10mm)	9.20	6.10	4.70	1.10	0.20	0.10	-	-	0.10	0.10	1.50	6.30	29.40
Sunday	4	4	5	4	5	4	4	5	4	4	5	4	52
Holiday	1	1	-	1	1	1	-	-	2	1	1	1	10
(*1)	1.48	1.09	0.76	0.18	0.04	0.02	-	-	0.02	0.02	0.30	1.02	4.92
Non-working day	12.72	10.01	8.94	5.92	6.16	5.08	4.00	5.00	6.08	5.08	7.20	10.28	86.48
Working day	18.28	17.99	22.06	24.08	24.84	24.92	27.00	26.00	23.92	25.92	22.80	20.72	278.52
Working Rate (Average)	0.59	0.64	0.71	0.80	0.80	0.83	0.87	0.84	0.80	0.84	0.76	0.67	**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 this, the provisional construction schedules for the 3 road sections are estimated as shown in Table 8.1.7 – 8.1.9.

Table 8.1.7 Construction Schedule of Section 1: Nampula - Ribaue

Item		Description	Unit	Qty	Daily unit performance	No. of working unit	Working rate (dry season)	Total daily Qty (dry season)	Calculated month	Schedule month
1		Preliminary & general works	L.S.	1						7.0
2		Earthworks								
	E1	Excavation	cu.m	875,431	350	5	0.81	1,418	20.6	21.0
	E2	Fill (use excavated soil)	cu.m	875,431	420	5	0.81	1,701	17.2	21.0
	E3	Fill (borrow material)	cu.m	89,144						21.0
	E4	Disposal of surplus soil	cu.m							
3		Pavement								
	P1	Granular sub base course (t = 400mm)	sq.m	1,202,390	555	5	0.81	2,248	17.8	18.0
	P2	Granular base course (t = 250mm)	sq.m	1,202,390	666	5	0.81	2,697	14.9	18.0
	P3	Surface course (DBST)	sq.m	1,202,390	1,800	2	0.81	2,916	13.7	18.0
	P4	Otta seal for sidewalk	sq.m	29,680	700	1	0.81	567	1.7	18.0
4		Drainage								
	D1	Concrete lined side ditch	m	76,040	15.0	11	0.81	134	19.0	19.0
	D2	U-shaped side ditch (open)	m	1,170	10.0	3	0.81	24	1.6	19.0
	D3	U-shaped side ditch (covered)	m	14,840	5.0	10	0.81	41	12.2	19.0
	D4	Cross culvert	m	252	5.0	3	0.81	12	0.7	16.0
	D5	Box culvert (1.0*1.0)	No	179	0.16	3	0.81	0	15.3	16.0
	D6	Box culvert (2.0*2.0)	No	12	0.10	1	0.81	0	4.9	16.0
5		Road furniture								
	F1	Road sign (Warning & Regulation)	m2	108						9.0
	F2	Road marking (continuous) W=100mm	m	283,242						12.0
	F3	Road marking (continuous) W=400m	m	1,430						12.0
6		Miscellaneous work								
	M1	Concrete kerb	m	14,840	15.0	3	0.81	36	13.6	19.0
	M2	Demolishing existing concrete	m3	868						7.0
	M3	Removal of bailey bridge (W=4m)	m							
7		Bridge								
	B1	Bridge construction	No.	0						



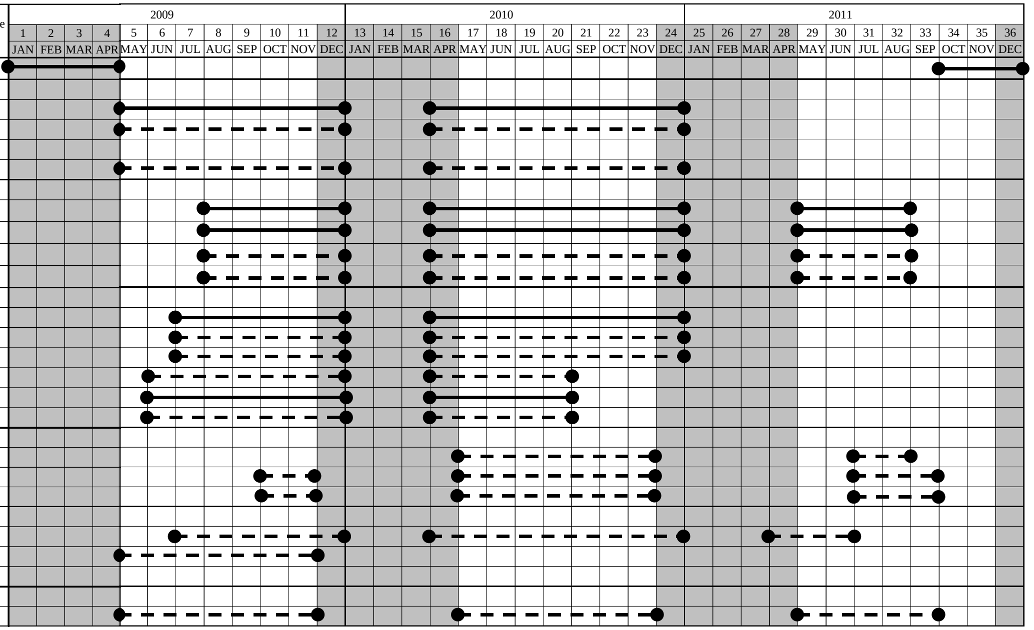
: Critical work

: Non-critical work

: Rainy season

Table 8.1.8 Construction Schedule of Section 2: Ribaue - Malema

Item		Description	Unit	Qty	Daily unit performance	No. of working unit	Working rate (dry season)	Total daily Qty (dry season)	Calculated month	Schedule month
1	Preliminary & general works		L.S.	1						7.0
2	Earthworks									
	E1	Excavation	cu.m	595,259	298	5	0.81	1,205	16.5	17.0
	E2	Fill (use excavated soil)	cu.m	405,156	357	4	0.81	1,157	11.7	17.0
	E3	Fill (borrow material)	cu.m							
	E4	Disposal of surplus soil	cu.m	190,103						17.0
3	Pavement									
	P1	Granular sub base course (t = 375mm)	sq.m	928,970	444	5	0.81	1,798	17.2	18.0
	P2	Granular base course (t = 200mm)	sq.m	928,970	533	5	0.81	2,158	14.4	18.0
	P3	Surface course (DBST)	sq.m	928,970	1,440	2	0.81	2,333	13.3	18.0
	P4	Otta seal for sidewalk	sq.m	3,760	560	1	0.81	454	0.3	18.0
4	Drainage									
	D1	Concrete lined side ditch	m	72,920	15.0	14	0.81	170	14.3	15.0
	D2	U-shaped side ditch (open)	m	240	10.0	2	0.81	16	0.5	15.0
	D3	U-shaped side ditch (covered)	m	2,960	5.0	2	0.81	8	12.2	15.0
	D4	Cross culvert	m	72	5.0	2	0.81	8	0.3	12.0
	D5	Box culvert (1.0*1.0)	No	139	0.16	3	0.81	0	11.9	12.0
	D6	Box culvert (2.0*2.0)	No	60	0.10	3	0.81	0	8.2	12.0
5	Road furniture									
	F1	Road sign (Warning & Regulation)	m2	30						9.0
	F2	Road marking (continuous) W=100mm	m	217,356						12.0
	F3	Road marking (continuous) W=400m	m	330						12.0
6	Miscellaneous work									
	M1	Concrete kerb	m	1,880	15.0	2	0.81	24	2.6	15.0
	M2	Demolishing existing concrete	m3	1,361						7.0
	M3	Removal of bailey bridge (W=4m)	m							
7	Bridge									
	B1	Bridge construction	No.	4						19.0



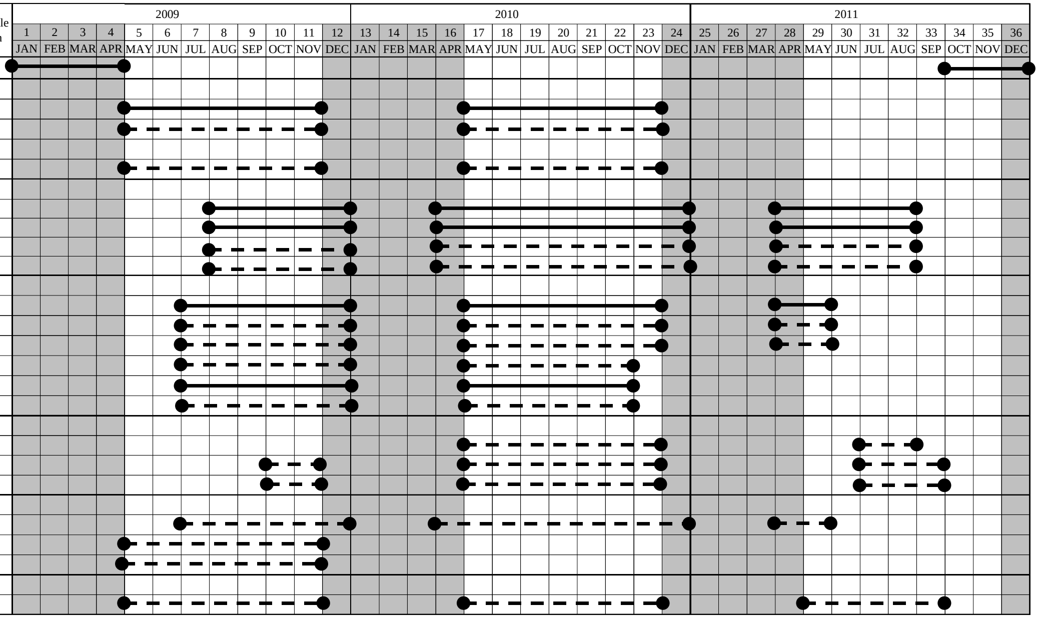
: Critical work

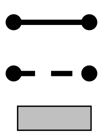
: Non-critical work

: Rainy season

Table 8.1.9 Construction Schedule of Section 3: Malema - Cuamba

Item		Description	Unit	Qty	Daily unit performance	No. of working unit	Working rate (dry season)	Total daily Qty (dry season)	Calculated month	Schedule month
1		Preliminary & general works	L.S.	1						7.0
2		Earthworks								
	E1	Excavation	cu.m	460,346	280	5	0.82	1,148	13.4	14.0
	E2	Fill (use excavated soil)	cu.m	261,433	336	4	0.82	1,102	7.9	14.0
	E3	Fill (borrow material)	cu.m							
	E4	Disposal of surplus soil	cu.m	198,913						14.0
3		Pavement								
	P1	Granular sub base course (t = 375mm)	sq.m	1,034,780	444	5	0.82	1,820	18.9	19.0
	P2	Granular base course (t = 200mm)	sq.m	1,034,780	533	5	0.82	2,184	15.8	19.0
	P3	Surface course (DBST)	sq.m	1,034,780	1,440	2	0.82	2,362	14.6	19.0
	P4	Otta seal for sidewalk	sq.m	15,880	560	1	0.82	459	1.2	19.0
4		Drainage								
	D1	Concrete lined side ditch	m	61,400	15.0	13	0.82	160	12.8	13.0
	D2	U-shaped side ditch (open)	m	1,350	10.0	2	0.82	16	2.7	13.0
	D3	U-shaped side ditch (covered)	m	17,240	5.0	10	0.82	41	14.0	13.0
	D4	Cross culvert	m	420	5.0	2	0.82	8	1.7	12.0
	D5	Box culvert (1.0*1.0)	No	179	0.16	4	0.82	1	11.4	12.0
	D6	Box culvert (2.0*2.0)	No	38	0.10	3	0.82	0	5.1	12.0
5		Road furniture								
	F1	Road sign (Warning & Regulation)	m2	108						9.0
	F2	Road marking (continuous) W=100mm	m	244,095						12.0
	F3	Road marking (continuous) W=400m	m	1,210						12.0
6		Miscellaneous work								
	M1	Concrete kerb	m	12,200	15.0	3	0.81	36	11.2	13.0
	M2	Demolishing existing concrete	m3	1,211						7.0
	M3	Removal of bailey bridge (W=4m)	m	31						7.0
7		Bridge								
	B1	Bridge construction	No.	2						19.0




: Critical work

: Non-critical work

: Rainy season

8.2 Cost Estimate

8.2.1 Introduction

The Project cost estimate (hereafter referred to as "the Estimate") shall be made on the basis of result of the preliminary design, the quantity of each work item, and the construction planning of the Project. The result of this Estimate will be utilized for the economic analysis (see Part 3 chapter 10).

8.2.2 Methodology of Cost Estimate

Unit cost of construction work for the Project shall be calculated on the basis of comparison and analysis of real market prices of similar projects (hereafter referred as "Group A" projects) previously implemented in Mozambique. These groups 'A' projects are:

- Rehabilitation of the EN 8 Road between Nampula and Nacala (2001)
- Rehabilitation of the Namacurra – Rio Ligonha Road, Lot 3: Alto Molocue – Rio Ligonha (2004)
- Lichinga – Montepuez Road Project (2004)
- Rural Road Rehabilitation of N104 (EN239) between Nametil and Angoche in Nampula Province (2005)
- The Project for Reconstruction of Bridges on the Main Roads II (2001)

The Bill of Quantities of Emergency Works under the Pilot Project (EWPP) in Ribaue (hereafter referred as "Group B") as submitted by the bidders including the unit rates will also be utilized to calculate the unit cost of construction.

(1) Modification of Unit Cost of Construction Work

Unit costs abstracted from Group A and B works are modified by applying the following methods to satisfy the specific project conditions of the Study road.

1) Group A

Unit prices of this group shall be averaged out for the Estimate. However, their prices should be updated to the year 2007. Regarding the Estimate, an annual price inflation factor of 109.81% per year (average of 1996 – 2005 by INE) is applied. Therefore, the original prices shall be updated with the following percentages as presented in Table 8.2.1.

Table 8.2.1 Percentage of Price Escalation

Project	Year	%
Nampula – Nacala Rd.	2001	$(109.81\%)^6$ = **175.33%**
Alto Molocue – Rio Ligonha Rd.	2004	$(109.81\%)^3$ = **132.41%**
Lichinga – Montepuez Rd.	2004	$(109.81\%)^3$ = **132.41%**
Nametil – Angoche Rd.	2005	$(109.81\%)^2$ = **120.58%**
Reconstruction of Bridges	2001	$(109.81\%)^6$ = **175.33%**

2) Group B

The estimate is based on the average price among the 3 BOQs. However, in case that the price of one company is much higher than the other 2 companies, the higher one is omitted from the average. Examples of calculation are shown in Table 8.2.2.

Table 8.2.2 Sample Calculation of Unit Price

Work Item	Unit	Company			Applied Price (USD)
		A	B	C	
Excavation	m3	~~15.00~~	2.38	4.56	**3.12** (90% of B & C)
DBST	m2	6.10	4.03	6.60	**5.02** (90% of A – B)
U-shaped side ditch (with cover)	m	~~116.50~~	64.19	54.00	**53.19** (90% of B & C)

3) Common

The following modification coefficients are applied for Group A and B projects.

(i) Transport Coefficient

The Project road has a length of approximately 350 km between Nampula and Cuamba. The road shall be divided into 3 construction sections:

Section 1:	Nampula – Ribaue	(Length = 131.85 km)
Section 2:	Ribaue – Malema	(Length = 102.87 km)
Section 3:	Malema – Cuamba	(Length = 112.91 km)
	Total:	(347.63 km)

The sources of major construction materials assumed for the calculation of the Estimates are as presented in the Study. There are substantial differences in haulage distances depending on the locations between the construction sections and the material sources as shown in Figure 8.1.1. Therefore, unit prices shall be modified according to the haulage distance. Modification coefficients of transport are listed in Table 8.2.3. Note that Ribaue is defined as the reference point to calculate the coefficient. This is done because the unit prices of Group B projects originate from tender documents of the emergency works (EWPP) in the Ribaue area.

Table 8.2.3 Transport Coefficient of Major Material sources

Section	**Source & Distance**								
	Aggregate (Surface course)			Aggregate (Base course)			Cement, bitumen		
	Source	Distance (km) (*)	%	Source	Distance (km) (*)	%	Source	Distance (km) (*)	%
Ribaue	Namialo	217.9	100.0	Namialo	217.9	100.0	Nacala	318.9	100.0
1	Namialo	152.0	69.7	Namialo	152.0	69.7	Nacala	253.0	79.3
2	Malema	51.4	23.6	Malema	51.4	23.7	Nacala	370.3	116.2
3	Cuamba	56.4	26.0	Cuamba	56.4	26.0	Nacala	478.2	150.1

(*) Distance is between material source and middle point of each section.

(ii) Material Coefficient

Basically, the unit price of construction work is composed of 3 elements namely labor, equipment and material. The portion of material cost in the total unit price shall be abstracted from the analysis of similar projects previously implemented. The result of this analysis is shown in Table 8.2.4.

Table 8.2.4 Percentage of Material Cost in Unit Price of Major Construction Work

Material	Work Item	Sites of Sample Projects					Average (Material Coefficient)
		Ethiopia	Kenya	Laos	Vietnam	Sri Lanka	
Cement	Concrete work per 1m3 (21N/mm2)	56.1%	47.3%	54.3%	38.4%	N/A	**49.0%**
Aggregate (base course)	Base course per 1m2	88.6%	75.4%	N/A	78.8%	N/A	**80.9%**
Bitumen (surface course)	Pavement per 1m2	N/A	36.1%	N/A	54.1%	18.9%	**36.4%**

(iii) Application to Modify Unit Price

Modification coefficients calculated in (i) Transport and (ii) Materials shall then be applied to calculate the unit prices for the Estimate (as per the following sample calculations)

Sample Calculations: DBST each Section

(Section 1)

Unit Price = (Basic Price – Basic Price × Material Coefficient) + (Basic Price × Material Coefficient × Transport Coefficient)

= ($5.02 – $5.02 × 36.4%) + ($5.02 × 36.4% × 79.3%)

= **$4.64/m2**

(Section 2)

Unit Price = ($5.02 – $5.02 × 36.4%) + ($5.02 × 36.4% × 116.2%)

= **$5.31/m2**

(Section 3)

Unit Price = ($5.02 – $5.02 × 36.4%) + ($5.02 × 36.4% × 150.1%)

= **$5.93/m2**

Reference

Basic Price : Table 8.2.2
Transport Coefficient : Table 8.2.3
Material Coefficient : Table 8.2.4

(2) Determination of Unit Construction Cost

Unit construction costs are determined on the basis of previous discussions. The costs of road and bridge work items are shown in Table 8.2.5 and 8.2.6 respectively.

Table 8.2.5 Unit Construction Costs of Road Section (1 of 3)

(Currency: US $)

	Description		Unit	Unit Cost		
				Sec. 1	Sec. 2	Sec. 3
2	Earthworks					
	2.1	Excavation	cu.m	3.12	3.12	3.12
	2.2	Fill (use excavated soil)	cu.m	3.16	3.16	3.16
	2.3	Fill (borrow material)	cu.m	4.87	4.87	4.87
	2.4	Disposal of surplus soil	cu.m	3.50	3.50	3.50
3	Pavement					
	3.1.1	Replacement of subgrade (t = 150mm)	sq.m	2.47	2.47	2.47
	3.1.2	Replacement of subgrade (t = 200mm)	sq.m	2.87	2.87	2.87
	3.2	Granular sub base course (t = 150mm)	sq.m	0.89	0.45	0.47
	3.3	Granular sub base course (t = 175mm)	sq.m	1.04	0.53	0.55
	3.4	Granular sub base course (t = 225mm)	sq.m	1.34	0.68	0.71

Table 8.2.5 Unit Construction Costs of Road Section (2 of 3)

(Currency: US $)

	Description		Unit	Unit Cost		
				Sec. 1	Sec. 2	Sec. 3
	3.5.1	Granular sub base course (t = 325mm)	sq.m	1.93	0.98	1.03
	3.5.2	Granular sub base course (t = 375mm)	sq.m	2.23	1.13	1.19
	3.5.3	Granular sub base course (t = 400mm)	sq.m	2.38	1.21	1.27
	3.6	Cemented sub base course (t = 150mm)	sq.m	3.68	1.87	1.96
	3.7	Cemented sub base course (t = 175mm)	sq.m	4.30	2.18	2.28
	3.8	Cemented sub base course (t = 200mm)	sq.m	4.91	2.49	2.61
	3.9.1	Cemented sub base course (t = 225mm)	sq.m	5.52	2.80	2.94
	3.9.2	Cemented sub base course (t = 250mm)	sq.m	6.14	3.11	3.26
	3.9.3	Cemented sub base course (t = 300mm)	sq.m	7.36	3.73	3.92
	3.9.4	Cemented sub base course (t = 325mm)	sq.m	7.98	4.04	4.24
	3.10	Granular base course (t = 150mm)	sq.m	2.59	1.31	1.38
	3.11.1	Granular base course (t = 200mm)	sq.m	3.46	1.75	1.84
	3.11.2	Granular base course (t = 225mm)	sq.m	3.89	1.97	2.07
	3.11.3	Granular base course (t = 250mm)	sq.m	4.32	2.19	2.30
	3.12	Cemented base course (t = 150mm)	sq.m	5.07	2.57	2.69
	3.13	Cemented base course (t = 180mm)	sq.m	6.08	3.08	3.23
	3.14	Cemented base course (t = 200mm)	sq.m	6.76	3.43	3.59
	3.15	Prime coat	sq.m	1.59	2.33	3.01
	3.16	Tack coat	sq.m	0.88	1.29	1.66
	3.17.1	Asphalt concrete (t = 50mm)	sq.m	10.22	11.71	13.07
	3.17.2	Asphalt concrete (t = 100mm)	sq.m	20.45	23.42	26.15
	3.18	Double bituminous surface treatment (DBST)	sq.m	4.64	5.31	5.93
	3.19	Otta seal for sidewalk?????	sq.m	2.78	3.19	3.56
	3.20	Granular sub base course for sidewalk (t= 100m)	sq.m	0.59	0.30	0.32

Table 8.2.5 Unit Construction Costs of Road Section (3 of 3)

(Currency: US $)

	Description		Unit	Unit Cost		
				Sec. 1	Sec. 2	Sec. 3
4	Drainage					
	4.1	Unlined side ditch	m	3.35	3.35	3.35
	4.2	Concrete lined side ditch	m	21.36	25.65	29.60
	4.3	U-shaped side ditch (open)	m	38.43	46.16	53.26
	4.4	U-shaped side ditch (covered)	m	47.79	57.41	66.24
	4.5	Cross culvert	m	292.41	351.25	405.31
	4.6	Box culvert (1.0*1.0)	No.	7,226.46	8,680.57	10,016.46
	4.7	Box culvert (2.0*2.0)	No.	22,795.51	27,382.42	31,596.40
5	Road furniture					
	5.1	Road sign (Warning) A=0.62m2/no	sq.m	232.05	340.03	439.23
	5.2	Road sign (Regulatory) A=1.13m3/no	sq.m	232.05	340.03	439.23
	5.3	Road marking (continuous) W=100mm	m	0.52	0.76	0.98
	5.4	Road marking (continuous) W=400m	m	2.08	3.05	3.93
6	Miscellaneous work					
	6.1	Concrete kerb	m	16.21	19.48	22.47
	6.2	Demolishing existing concrete (plain)	cu.m	12.49	12.49	12.49
	6.3	Demolishing existing concrete (reinforced)	cu.m	22.69	22.69	22.69
	6.4	Removal of bailey bridge (W=4m)	m	90.75	90.75	90.75

Table 8.2.6 Unit Construction Costs of Bridge Section (1 of 2)

(Currency: US $)

	Description		Unit	Unit Cost		
				Sec. 1	Sec. 2	Sec. 3
7	7.1 Foundation for structures					
	7.1.1	Excavation (soil)	cu.m		36.71	36.71
	7.1.2	Excavation (hard rock)	cu.m		161.54	161.54
	7.1.3	Excavation (soft rock)	cu.m		73.43	73.43
	7.1.4	Pile (RC-400*400)	m		542.75	626.28
	7.2 Substructure					
	7.2.1	Concrete (σck=240kgf/cm2)	cu.m		364.42	420.50
	7.2.2	Formwork	sq.m		18.40	23.77
	7.2.3	Reinforcement bar (SD295)	ton		3,222.68	4,162.86

Table 8.2.6 Unit Construction Costs of Bridge Section (2 of 2)

(Currency: US $)

	Description		Unit	Unit Cost		
				Sec. 1	Sec. 2	Sec. 3
	7.3 Superstructure					
	7.3.1 (1)	Concrete for girder (σck=240kgf/cm2)	cu.m		444.68	513.12
	7.3.1 (2)	Concrete for girder (σck=350kgf/cm2)	cu.m		505.95	583.81
	7.3.2	Concrete for deck (σck=240kgf/cm2)	cu.m		397.71	458.91
	7.3.3	Concrete for Precast panel (σck=240kgf/cm2)	cu.m		413.24	476.84
	7.3.4	Formwork	sq.m		18.40	23.77
	7.3.5	Reinforcement bar	ton		3,591.46	4,639.23
	7.3.6	PC cable for girder	ton			5,362.53
	7.3.7	Erection of girders PC-I girder	No.		279.57	279.57
	7.4 Miscellaneous					
	7.4.1	Expansion joint	m		363.75	469.87
	7.4.2	Bearing	No.		419.98	542.50
	7.4.3	Drainage pipes	m		22.76	29.40
	7.4.4	Demolishing existing concrete (Plain)	cu.m		12.49	12.49
	7.4.5	Demolishing existing concrete (Reinforced)	cu.m		22.69	22.69
	7.4.6	Slope protection (Riprap)	sq.m		31.79	36.68

(3) Cost of Non-Construction Works

Costs of non-construction works namely Preliminaries & General Works, Dayworks and Social issues shall be applied as an average percentage of the total cost of construction works in Group A. Applied percentages are shown in Table 8.2.7.

Table 8.2.7 Percentages of Non-Construction Works

Project	% according to construction work		
	Preliminary	Dayworks	Social Issues
Nampula – Nacala Rd.	50.0%	3.5%	N/A
Alto Molocue – Rio Ligonha Rd.	36.7%	1.4%	2.7%
Lichinga – Montepuez Rd.	39.1%	2.5%	0.9%
Average	**41.9%**	**2.5%**	**1.8%**

(4) Contingency and Engineering Cost

Contingency and Engineering costs are estimated to the following percentages.

- Contingency Cost: 10% of Total Construction & Non- Construction Costs
- Engineering Cost: 8% of Construction, Non-Construction & Contingency Costs

8.2.3 Result of The Project Cost Estimate

The result of the Estimate are summarized in Table 8.2.8 – 8.2.10. A further breakdown is attached in Appendix-I.

Table 8.2.8 Total Project Cost (Design Speed = 80km/h; ALT-3)

(Currency: US $)

No.	Description		Section 1 Nampula to Ribaue 131.85 km	Section 2 Ribaue to Malema 102.87 km	Section 3 Malema to Cuamba 112.91 km	Total 347.63 km	% of (1-10)
0	Compensation		443,675	346,158	379,942	1,169,775	
1	Preliminary & general		11,882,980	9,776,507	11,598,963	33,258,450	28.7%
2	Earthworks		5,930,179	3,802,568	2,958,588	12,691,336	10.9%
3	Pavement		16,707,209	10,991,198	14,168,338	41,866,745	36.1%
4	Drainage		4,018,899	4,926,522	6,195,310	15,140,730	13.1%
5	Road furniture		175,198	176,688	292,253	644,139	0.6%
6	Miscellaneous		252,626	59,068	292,412	604,106	0.5%
7	Bridge		0	2,337,294	2,703,350	5,040,644	4.3%
8	Temporary construction road		1,262,692	1,028,483	1,059,032	3,350,207	2.9%
9	Dayworks		697,331	573,717	680,664	1,951,712	1.7%
10	Social issues		507,408	417,461	495,280	1,420,149	1.2%
Total (1-10)			41,434,523	34,089,506	40,444,189	115,968,218	100%
11	Contingency	10%	4,143,452	3,408,951	4,044,419	11,596,822	
Total construction cost (1-11)			45,577,975	37,498,457	44,488,608	127,565,039	
12	Engineering cost	8%	3,646,238	2,999,877	3,559,089	10,205,203	
Total project cost (1-12)			49,224,213	40,498,333	48,047,697	137,770,243	
13	VAT	17%	8,368,116	6,884,717	8,168,108	23,420,941	
Total project cost with VAT (1-13)			57,592,329	47,383,050	56,215,805	161,191,184	
14	Total(13) + (0)Compensation		58,036,004	47,729,207	56,595,747	162,360,959	

Table 8.2.9 Bridge Construction Cost

(Currency: US $)

Section	Bridge No.	Name	Span & Length	Type	Cost
2	12	Monapo	2@12.5=25.0m	RC hollow	452,123.97
	19	Lalaua	2@15.0=30.0m	RC hollow	522,422.84
	24	Nataleia	9.0+2@15.0+9.0=48.0m	RC hollow	710,680.92
	27	Mutivasse	2@15.0=30.0m	RC hollow	652,066.08
3	30	Namuleia	8.0+14.0+8.0=30.0m	RC hollow	602,003.26
	34	Lurio	31.3+31.4+31.3=94.0m	PC-I girder	2,101,346.61
				Total	**5,040,643.69**

Table 8.2.10 Unit Cost of the Project per kilometer

(Currency: US $)

Type of unit cost	Section 1	Section 2	Section 3	Total
Unit construction cost (1-10)	$314,255 /km	$331,384 /km	$358,198 /km	$333,597 /km
Unit construction cost (1-11)	$345,681 /km	$364,523 /km	$394,018 /km	$366,956 /km
Unit project cost (1-12)	$373,335 /km	$393,685 /km	$425,540 /km	$396,313 /km
Unit project cost with VAT (1-13)	$436,802 /km	$460,611 /km	$497,882 /km	$463,686 /km
Unit project cost +VAT + Compensation. (1-14)	$440,167 /km	$463,976 /km	$501,247 /km	$467,051 /km
Unit construction cost (0-10)	$317,620 /km	$334,749 /km	$361,563 /km	$336,962 /km

Chapter 9 Project Implementation Plan

Chapter 9 Project Implementation Plan

9.1 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 economic analysis.

9.2 Project Implementation Schedule

The funds for the Project implementation are expected the sources from the Road Fund of Mozambique and from various bilateral and multilateral organizations. At present, AfDB and JBIC are considering to finance the Project. The Project implementation schedule should be consistent with the technical requirements and the availability of financial resources for the Project. The proposed Project implementation schedule is shown in the bar chart of Figure 9.2.1 below.

As mentioned in the previous chapter, the entire Project Road shall be divided into three sections (packages). Each package will be scheduled for completion in a period of 36 months. Commencement of earthworks and foundation works for bridges and box culverts should be programmed to start at the end of the rainy season (end of March). It is expected that the construction commences in the beginning of 2009 and be completed by the end of 2011.

There are some constraints to affect the schedule as bellow:

Appraisal by donor agencies

AfDB and JBIC have both expressed their concerns on financing the Project. The appraisal by those agencies will be done after the Detailed Design stage. Detailed design will start after the F/S, and will be expected to be finalized in June 2008.

Engineering Services: Detailed Design and Tender Documents Preparation

A preliminary road alignment was established at the Draft Final Report stage of the F/S on August 2007, the results of the aerial photographic survey are also available. The final road alignment will be decided during the detailed design stage. Bidding documents for construction contracts will be prepared at the same time around June 2008.

Land Acquisition and Resettlement

The land acquisition and resettlement plans should be completed early in the detailed design stage. And the legal process and actions required for acquisition/resettlement should be undertaken in parallel with the detailed design. Furthermore, the area and number of households affected and assets involved should be determined and measured during the detailed survey. All the required land should be acquired prior to the award of construction contracts and be cleared by the commencement of construction work. From previous experiences, it is estimated that these legal process is assumed to take approximately six months

Contractor Selection

The procurement process for the construction will commence at the beginning of July 2008 and the contractors will be selected by the end of October 2008 through the Pre Qualification stage.

Construction

Construction will commence in the beginning of 2009 and be completed by the end of 2011. The program suggest that the earthworks and foundation works for structures can commence at the end of the rainy season (the end of March).

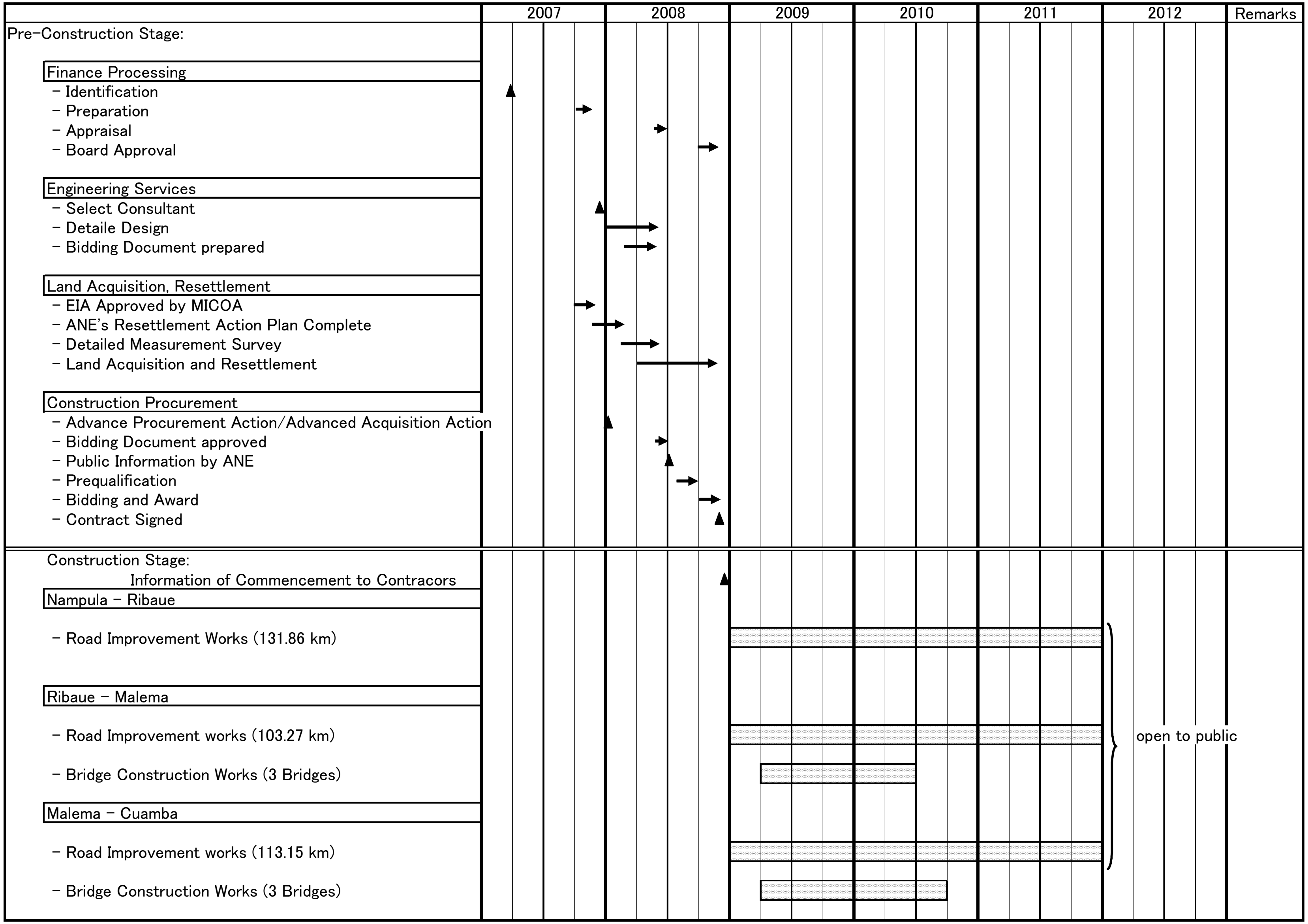


Figure 9.2.1 Project Implementation Schedule

9.3 Disbursement Schedule

Based on the above implementation schedule, the disbursement schedule (cash flow estimate) indicating both construction and maintenance requirements for a period of 20 years is presented in Table 9.3.1. Table 9.3.1 presents a summary of the initial project management costs, construction costs and the future maintenance costs.

Table 9.3.1 Summary of Disbursement Schedule

Year	Pre-Construction Stage		Construction Stage							Operation	Total		
			E/S (SV)		Civil Works		Others	Physical Contingency		Maintenance & Monitoring			
	A	B	A	B	A	B	B	A	B	B	A	B	Total (US$)
2007											0	0	0
2008	1,667,000										1,667,000	0	1,667,000
2009			1,706,200		41,914,000			4,191,400			47,811,600	0	47,811,600
2010			1,706,200		41,914,000			4,191,400			47,811,600	0	47,811,600
2011			1,706,200		20,957,000			2,095,700			24,758,900	0	24,758,900
2012										9,953,000	0	9,953,000	382,808
2013										9,953,000	0	9,953,000	382,808
2014										9,953,000	0	9,953,000	382,808
2015										9,953,000	0	9,953,000	382,808
2016										60,622,000	0	60,622,000	2,331,615
2017										9,953,000	0	9,953,000	382,808
2018										9,953,000	0	9,953,000	382,808
2019										9,953,000	0	9,953,000	382,808
2020										9,953,000	0	9,953,000	382,808
2021										60,622,000	0	60,622,000	2,331,615
2022										9,953,000	0	9,953,000	382,808
2023										9,953,000	0	9,953,000	382,808
2024										9,953,000	0	9,953,000	382,808
2025										9,953,000	0	9,953,000	382,808
2026										60,622,000	0	60,622,000	2,331,615
2027										9,953,000	0	9,953,000	382,808
2028										9,953,000	0	9,953,000	382,808
2029										9,953,000	0	9,953,000	382,808
2030										9,953,000	0	9,953,000	382,808
2031										60,622,000	0	60,622,000	2,331,615
Total	1,667,000		5,118,600		104,785,000			10,478,500		401,736,000	122,049,100	401,736,000	137,500,485

<u>Note</u>:

- All costs are ‘financial costs’.
- “Others” contains ‘borrow pit restoration cost’ & ‘project management costs’.
- A: Component A defines imported items excluding items purchased on the local market.
- B: Component B defines domestic items including imported items purchased on the local market.
- E/S: Engineering Services
- SV: Construction Supervision

Chapter 10 Economic & Financial Analysis

Chapter 10 Economic and Financial Analysis

10.1 Economic Analysis for the Project

10.1.1 Introduction

Economic Analysis for the Project consists of comparing the case without the project to those with the different project alternatives. The case without the project is maintaining the existing road and applying periodic maintenance where necessary. The case with the project is the implementation of the road improvement interventions discussed in the previous chapters. The analysis determines their impact, and whether or not they are economically feasible, i.e. yielding a positive Net Present Value (NPV) at a 12% discount rate. Sensitivity tests are then applied on costs and traffic increases.

In this chapter, the quantitative measure used to determine the feasibility of the Study Road to evaluate the project from an economic perspective is the economic internal rate of return (EIRR). The EIRR is the discount rate at which the net present value of an investment is zero. The study team estimated the economic indicator using both the Highway Design and Maintenance Standards Model (HDM-4 model) and the Roads Economic Decision Model (RED model) for the road evaluated.

According to the surveys related to the road improvement between Nampula and Cuamba under the RBMMP by the World Bank and the other major road construction projects, EIRR and the multi-criteria analysis (MCA) are mainly applied by HDM-4 or RED. In this Study, both HDM-4 and RED models are used for a feasibility calculation, using traffic demand forecast data obtained from the survey conducted by the study team. Further, the MCA approach which incorporates assessments of each project’s contribution in four areas of economic feasibility, connectivity, accessibility and social weight is applied for supplemental analysis.

10.1.2 Highway Design and Maintenance Standards Model (HDM-4)

HDM-4 was developed by the World Bank's Transportation Department to meet the needs of highway authorities, particularly in developing countries, for evaluating policies, standards, and programs of road construction and maintenance.

The key decision variables used in the models to determine the economic benefits are savings in Vehicle Operating Costs (VOCs) and savings in Travel Time. On the cost side, the key variables are development or road investment costs and maintenance and operations costs. The net benefits derived from these variables are discounted over the life of the road project to determine the EIRR.

- Estimate of Vehicle Operating Costs: Estimates for VOCs have been developed for each vehicle class in Mozambique. VOCs are typically defined as fixed costs and variable costs. Fixed costs are the cost of owning the vehicle and include the cost of a license, permit and fees, insurance, and depreciation, etc. Variable costs are those costs which are derived from operating the vehicle, and include the cost of maintenance and repairs, spare parts, tires, petroleum, oil and lubricants, as well as crew and idling costs for trucks. Changes in VOCs are directly related to the running surface and condition of the road being used. Road surface condition is defined using an International Roughness Index (IRI).

- Estimate of Travel Times: Travel time is a function of vehicle speeds on a given surface condition. Vehicle speeds that will form the basis of the travel time estimates are derived from the HDM-4 model. These are pre-determined vehicle speeds for varying road surface conditions or road roughness for different terrains.

10.1.3 Roads Economic Decision Model (RED)

Another alternative model currently reviewed in the ANE Planning division is the Roads Economic Decision Model (RED) which is a consumer surplus model designed to help evaluate investments in lower volume roads. RED is a simplified model developed by the World Bank for use in the economic appraisal of lower traffic volume road projects. The vehicle operating cost model within the RED is the same model as used in the HDM-4 Road User Effects model, except that those aspects relating to road capacity and traffic congestion effects are largely excluded as they are not relevant for lower volume roads.

The model is implemented to: a) collect all user inputs; b) present the results in a user-friendly manner; c) estimate vehicle operating costs and speeds; d) perform an economic comparison of investments and maintenance alternatives; and e) perform sensitivity, switch-off values and stochastic risk analyses. The model computes benefits accruing to normal, generated, and diverted traffic, as a function of a reduction in vehicle operating and time costs. It also computes safety benefits, and model users can add other benefits or costs to the analysis, such as those related to non-motorized traffic, social service delivery and environmental impacts.

10.1.4 Basic Assumptions for Analysis

An economic evaluation period for the project is assumed to be 20 years from the year 2009 at which the construction work is due to be commenced for 3 years.

Careful attention should be paid when selecting the discount rate for cost-benefit analysis and investment decision making. The estimated economic benefits that are expected to accrue from improving the roads should be assessed against the expected benefits from making alternative investments. From an economic perspective, the opportunity cost of capital is the most appropriate discount rate to rationalize road investment decisions and inform investment choices. For purposes of the economic analysis conducted in this feasibility study, the discount rate applied to the cash flows is 12 percent, as is suggested by ANE.

10.1.5 Conversion Factors to Economic Price

For the purpose of the economic analysis, all project construction, maintenance and vehicle operating costs are expressed as economic costs. Economic costs represent the opportunity cost of using a factor of production in the project, or of a benefit resulting from the project, such as savings in vehicle operating expenses. This entails removing transfer payments such as taxes, import and export duties and subsidies from the financial, or accounting costs, thus changing them to their values "on the border", such as CIF or FOB. The economic cost of transporting them to the job site is also included.

In practice, this means that the direct unit costs of every construction and maintenance activity such as borrow, fill, sub-base, etc., to be used as input to the RED/HDM-4 model must be broken down by percentages into their basic components, such as labor, materials and equipment. Each percentage is weighted by its economic pricing factor, then added together and multiplied times the quantities to obtain the direct economic cost of the activity. Total economic cost is obtained by adding indirect costs such as contractor's overhead. It is important to calculate economic prices for the construction and maintenance activities because the vehicle operating costs, which are project benefits, will be expressed in economic terms. As economic costs are usually lower than financial ones, failure to do so will negatively impact the economic feasibility of the project. The economic pricing factors are determined as follows for labor, materials and others.

Table 10.1.1 Assumptions for conversion factor to economic cost

Conversion Factor	CF	Remarks
Fuel/ Oil	0.85	15% of the price is assumed as fuel tax.
Unskilled labor	0.48	Extracted from the VOC model of ANE and calculated from a production loss of agricultural goods by unskilled labor.
Imported materials	0.95	According to the rate of average import tax of asphalt and steel bars
Machine and skilled labor	1.00	Due to the scarcity of these items in Mozambique.
Tax and license	0.00	They are just financially transferred to the government.
House compensation (or land acquisition cost)	1.00	It is assumed that a land within the right-of -way has a potential to be productive so that resettlement accrues the cost of losing such potentials and the price of house compensation reflects such loss.
Facility reallocation	0.85	Considered as construction

Source: JICA Study Team

a. Construction Material

The economic pricing for materials was based on the removal of taxes and import duties from the financial prices. The principal material items in civil works on roads are asphalt, gravel, structural steel, culverts and cement. Asphalt is imported, likely from the Republic of South Africa, and cement and gravel are produced locally. Cement, structural steel and culverts also include the same taxes. As materials are fairly common in the project area, haulage is considered as included in the costs of the equipment portion. The economic prices for surfacing, which include asphalt seal, cement stabilized base and maintenance activities, such as patching and resealing were a weighted average of the economic factors for bitumen and gravel.

The financial and economic prices and factors for material are tabulated in Table 10.1.2.

b. Maintenance Costs

To calculate the maintenance costs used in the RED/HDM-4 analysis, economic costs are used for the comparison of alternatives. As explained in the last section, this means that the direct unit costs of every maintenance activity such as pothole filling, seals etc. to be used as input to the RED/HDM-4 model must be broken down by percentages into their basic components, such as labor, materials and equipment. Each percentage is weighted by its economic pricing factor, then added together and multiplied times the quantities to obtain the direct economic cost of the activity. The factor for material is a weighted average of the material types used in each intervention.

The results are shown in Table 10.1.2 below. The financial unit costs for each intervention were taken from the previous chapter results. The percent direct cost represents an estimate of the participation of labor, equipment and material in the direct costs of each intervention. The factor for materials is the weighted average of the economic prices of material – cement, bitumen, culvert pipe and reinforcing steel or rebar. The economic factors are calculated by weighting the economic prices by the participation of each. A mutilation by the financial unit costs gives the economic unit costs. These values are entered into the RED/HDM-4 program for each of the interventions.

c. Construction Costs

The construction costs are treated in the same manner as maintenance costs. The financial total costs are broken down into labor, materials and plant, weighted by the economic pricing factors to create the corresponding economic costs. The different cost components are road works, day works and social issues. To the total of these direct costs are added contingencies, supervision and IVA, and a reserve for compensation. IVA does not enter into the economic costs, since IVA, being a tax, is a transfer payment, and compensation is a wash in economic terms, as it compensates people for the economic value of the returns to the land or other properties that are appropriated for use on the project. But, as it is a cost to the project, it is included in the economic cost.

The calculation of economic and financial costs for the different project alternatives are presented in Table 10.1.2. These include upgrading of three sections from gravel to seal and construction of bridges between Nampula and Cuamba. The inclusion of these costs in the project alternatives is presented in the previous chapter.

Table 10.1.2 Conversion Factors for Each Cost Item

Component	Construction Materials			Construction Works			Maintenance Works		
	% (A)	CF (B)	A x B	% (A)	CF (B)	A x B	% (A)	CF (B)	A x B
Materials				20%	0.86	0.17	15%	0.86	0.13
Land	20%	1.00	0.20						
Machine (Rent)	35%	1.00	0.35	30%	1.00	0.30	20%	1.00	0.20
Fuel/Oil	5%	0.85	0.04	10%	0.85	0.09	5%	0.85	0.04
Skilled Labor	5%	1.00	0.05	10%	1.00	0.10	10%	1.00	0.10
Unskilled Labor	15%	0.48	0.07	10%	0.48	0.05	40%	0.48	0.19
License/Tax	5%	0.00	0.00	5%	0.00	0.00	5%	0.00	0.00
Imported Material				10%	0.95	0.10			
Others	15%	1.00	0.15	5%	1.00	0.05	5%	1.00	0.05
Total	100%	**0.86**		100%	**0.85**		100%	**0.71**	

Source: JICA Study Team

10.1.6 Intervention Alternatives

The intervention alternatives are presented in the previous chapters of this Report. The study team used the RED/HDM-4 model to represent the intervention alternatives to be proposed. First, the components of the work in each alternative are defined, then the effect of executing it determined, and finally its cost is developed.

The pavement composition has a large impact on the initial cost and maintenance cost of the Study Road and it is therefore important to decide using a concept of a life cycle cost. The study team calculated construction quantities for each pavement composition and evaluated by use of RED/HDM-4 model. The selection of the suitable pavement composition is checked in term of the initial cost and financial efficiency.

As a result of cost estimate (see Chapter 8) and economic analysis, ALT-3 (DBST on Granular) type is selected as the most suitable pavement composition. Its composition shows the lowest initial cost and the highest financial efficiency.

10.1.7 Traffic Demand Forecast

Based on the results of the traffic surveys, a traffic demand forecast is carried out in the previous chapters. The result is incorporated into the computation by the RED/HDM-4.

10.1.8 Estimation of Benefits

As indicated in Table 10.1.3, the economic analysis includes two major types of savings as result of improving the road in the Northern Province: (1) savings in Vehicle Operating Costs and (2) travel times savings:

· Savings in Vehicle Operating Costs
Vehicle Operating Cost Savings (VOCs) come about when the surface condition or the road pavement is improved. For example, when an unpaved road is improved to paved road standards. Because such an improvement result in changes in the surface conditions of the road, the costs for operating a vehicle over the road are reduced. Quantification of these benefits is performed in the RED/HDM-4 model.

· Travel Time Savings
Travel time is a function of vehicle speeds on a given surface condition. Vehicle speeds which form the basis of travel time will be derived from the RED/HDM-4's model and survey result. These are pre-determined vehicle speeds for varying road surface conditions or road roughness for different terrains. It is defined that: (1) the road roughness based on the International Roughness Index (IRI) for different classes of roads, and (2) the traffic composition based on data provided by road condition surveys conducted in this Study for the Project road proposed for development.

Table 10.1.3 List of Costs related to Operation of a Vehicle

Vehicle Operation	Travel Time	Overhead Cost
Fuel cost Tire cost Oil / Lubricant cost Maintenance cost Depreciation cost	Values of Passenger's time Driver's time Crew's time	Insurance cost Administration cost

Source: Study Team

It should be noted that the benefits for the diverted traffic from Nacala corridor and the railway mode possibly caused by travel time saving are assumed a half of those gained from VOC savings mainly for the normal traffic. In the RED/HDM-4 analysis output attached hereto as Appendix 10, those benefits from diverted traffic are indicated separately in the column "Other Benefits."

Input Data required for RED/HDM-4 computation of the economic analysis concerning Nampula-Cuamba Project is obtained in the report "Road User Costs in 2006" prepared by ANE as shown below.

Basic Input Data

Country/Region	North Region
Year	2007

Currency Name	US$
Exchange Rate Divider to US$	1.00

Terrain Types

Code	Description	Rise & Fall (m/km)	Horizontal Curvature (deg/km)	*Number of Rises & Falls (#)*	*Super_ elevation (%)*
A	Flat	13	37	1	2
B	Rolling	14	51	1	2
C	Mountainous	40	300	1	2

Road Characteristics

Altitude (m)	500.0
Percent Time Driven on Water	20.0
Percent Time Driven on Snow	0.0
Paved Roads Texture Depth (mm)	30

Road Types

Code	Description	Surface Type 1-Bituminous 2-Concrete 3-Unsealed	Carriageway Width (m)	Speed Limit (km/hour)	*Speed Limit Enforcement (#)*	*Roadside Friction (#)*	*NMT Friction (#)*
X	Paved	1	7.0	80.0	1.1	1.0	1.0
Y	Gravel	3	6.0	30.0	1.1	1.0	1.0
Z	Earth	3	5.0	30.0	1.1	1.0	1.0

Vehicle Types

Code	Description	Number of Wheels	Number of Axles
1	Car Medium	4	2
2	Four-Wheel Drive	4	2
3	Bus Light	4	2
4	Bus Medium	6	2
5	Delivery Vehicle	4	2
6	NOT USED	#N/A	#N/A
7	Truck Medium	6	2
8	Truck Heavy	10	3
9	Truck Articulated	18	5

Vehicle Fleet Characteristics

	Car Medium	Four-Wheel Drive	Bus Light	Bus Medium	Delivery Vehicle	NOT USED	Truck Medium	Truck Heavy	Truck Articulated
Economic Unit Costs									
New Vehicle Cost ($/vehicle)	23682	54102	29524	66382	20087	26000	61208	105995	126449
Fuel Cost ($/liter for MT, $/MJ for NMT)	0.61	0.61	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Lubricant Cost ($/liter)	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71
New Tire Cost ($/tire)	46.00	63.00	63.00	120.00	63.00	170.00	123.00	233.00	233.00
Maintenance Labor Cost ($/hour)	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
Crew Cost ($/hour)	0.66	0.66	2.42	2.77	1.55	0.50	2.79	3.38	3.38
Interest Rate (%)	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Utilization and Loading									
Kilometers Driven per Year (km)	20000	25000	40000	45000	25000	50000	40000	50000	60000
Hours Driven per Year (hr)	400	1000	1100	1250	600	1300	1000	1500	1500
Service Life (years)	8	12	10	12	10	9	12	12	12
Percent of Time for Private Use (%)	100.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gross Vehicle Weight (tons)	1.20	1.80	2.30	6.00	1.50	6.00	8.00	15.00	35.00

Reference Vehicle Adopted to Estimate Roughness as a Function of Speed of Reference Vehicle

Car Medium

10.1.9 Investment Cost and Maintenance Cost

Cost is calculated from the cost estimation made in the separate chapter. The conversion of financial cost to economic cost is carried out by applying the different conversion factors to respective cost items. It is briefly explained by that financial or market price contains several price disturbances such as tax or subsidies which disturb the function of the price qualifying the real value of items. In order to measure the real loss of the value, i.e. economic cost, such disturbances should be subtracted from the financial price of costs. Conversion factors calculated as above are applied in the RED/HDM-4 computation.

The cost to improve, maintain and operate each road was developed on a U.S. dollar per kilometer basis. Investment and maintenance costs data were obtained for alternative road improvements for both paved and unpaved. The road improvements are multiyear investments that were allocated over a time period of three years, and the road maintenance costs include routine and periodic maintenance costs over the year life of the project for each type of road works performed. Source data for determining road improvement, maintenance and operating costs were obtained from ANE.

Table 10.1.4 Maintenance Cost and Frequency (Financial)

With/Without Project	Intervention		Without Project
Surface Condition	Good Pavement (Asphalt Concrete)	Low-cost Pavement (DBST)	Bad Earth
Routine Maintenance in US$/km/year	1,100	1,100	1,789
Periodic Maintenance in US$/km/4years			6,000
Periodic Maintenance in US$/km/5years	-	5,600	-
Periodic Maintenance in US$/km/10years	5,600	-	-

Source: "RSS" and Study Team

Table 10.1.5 Investment Cost (Financial)

Section	Length (km)	Design	Construction Cost	
		Pavement Type	US$	US$/km
ALT-3				
Nampula-Ribaue	131.6	DBST on Granular	41,878,198	317,620
Ribaue-Malema	102.9	DBST on Granular	34,435,664	334,749
Malema-Cuamba	112.9	DBST on Granular	40,824,131	361,563
Total	347.4	DBST on Granular	117,137,993	336,962

Source: Study Team

10.1.10 Result of Analysis

Output Data worked out as a result of RED/HDM-4 analysis for the Project is tabulated in Table 10.1.6.

Table 10.1.6 Result of Economic Analysis

Section	Length	Design	Construction Cost	Economic Ratio		
	(km)	Pavement Type	US$/km	NPV	B/C	EIRR
Nampula-Ribaue	131.6	DBST on Granular	317,620	21,094	1.59	19.8%
Ribaue-Malema	102.9	DBST on Granular	334,749	15,389	1.53	19.0%
Malema-Cuamba	112.9	DBST on Granular	361,563	13,951	1.40	17.5%
Total	347.4	DBST on Granular	336,962	50,433	1.51	18.8%

Source: Study Team

The EIRR hurdle rate used to determine if a road project is economically feasible is 12 percent in general, over the estimated twenty-year period. The decision rule applied in conducting the economic analysis was to recommend to ANE this road project alternative that equaled or exceeded the 12 percent hurdle rate. The study team considered other factors that influence their investment decision, based on local conditions and information developed during this study, as an alternative to strict adherence to the EIRR in the subsequent chapter.

The project scores an average level as an upgrade-to-paved intervention and its economic viability is acceptable, with an EIRR of over 12% in the selected alternative. Based on this result, the N13 (Nampula - Cuamba) project is evaluated as one of the prioritized projects. The particular importance of this primary road and of bringing it to all-weather transit-able condition is well established.

10.1.11 Sensitivity Analysis of Economic Analysis Result

In order to confirm to the above favorite result, sensitivity analysis is conducted for the best alternative case ALT-3 that scores the highest EIRR. This is firstly done by changing the value of benefit and cost by +20% and –20%. When the EIRR is less than the discount rate of 12%, the project is thought less feasible. The following cases for those projects were analyzed:

- Increase in normal traffic of +20%,
- Decrease in normal traffic of -20%,
- Decrease in investment costs of -20% and
- Increase in investment costs of +20%

The results of sensitivity analyses are presented in Table 10.1.7.

Table 10.1.7 Result of Sensitivity Analysis (EIRR)

Case	Assumptions	Section			
		N-R	R-M	M-C	Total
Base	Upgrade to paved road with DBST on Granular	19.8%	19.0%	17.5%	18.8%
1	Increase in traffic volume of +20%	23.0%	22.1%	20.5%	21.9%
2	Decrease in traffic volume of -20%	16.2%	15.5%	14.2%	15.3%
3	Decrease in investment costs of -20%	23.8%	22.8%	21.2%	22.6%
4	Increase in investment costs of +20%	16.8%	16.1%	14.8%	15.9%

Source: Study Team

10.1.12 Multi Criteria Analysis (MCA)

Multi-criteria analysis (MCA) approach incorporates assessments of each project's contribution in four areas:

1. Economic Feasibility as measured by its internal rate of return;
2. Connectivity as defined by the major function of the road in the national grid;
3. Accessibility: external economic benefits accruing from increased accessibility, in particular, existing or potential for promoting small-holder agricultural, agro-industry, other industries, natural resource exploitation, tourism, inter-modal transportation, and additional Government priorities;
4. Social Weight: a factor measuring the incidence of poverty in the area of influence of the road

Alternative weighting scheme are then applied to the results to evaluate the sensitivity of the prioritization to emphasis on different attributes. Each of these factors is grouped into categories which contribute to the justification of an investment in a road. The majority of them is difficult to define quantitatively, and represented in the tables below.

The method is based on the allocation of points for the various functions that the road fulfils. After assigning a value for each function, the program automatically sums the respective values for each function and produces an overall total. By comparison of this total score for each road in the country, an order of priority or 'rank' is defined finally as in the following tables.

Table 10.1.8 Criteria Weights for MCA

Main Area of Interest in the Prioritization 'Ranking'	Economic Feasibility	Network Connectivity	Accessibility	Social
Base	40%	20%	20%	20%
No EIRR	0%	35%	35%	30%
Low EIRR	20%	30%	30%	20%
High Weighting for Social Benefits	20%	20%	20%	40%

Source: ANE

<table>
<tr><th rowspan="2">Score</th><th>Economic Feasibility</th><th>Connectivity</th><th colspan="2">Accessibility</th><th colspan="2">Social Weight</th></tr>
<tr><th>EIRR</th><th>Function</th><th>Services that need the Road for their Access and Operation</th><th>Access Road to Agricultural Areas with the Following Characteristics</th><th>Poverty Incidence</th><th>Population Density</th></tr>
<tr><td>5</td><td rowspan="5">The resulting EIRRs are used for the MCA, with maximum values being given to projects with EIRR of 50. EIRRs were converted to a five-point scale by dividing the EIRR by 10 and limiting minimum and maximum values.</td><td>Part of EN1
Connects to a major port (Beira, Maputo, Nacala)</td><td>Institution of higher education
Hospital</td><td>Surpluses of high value crops such as cotton, tobacco, sunflower, prawns, livestock or fish</td><td>Maximum value of poverty incidence amongst the Districts considered</td><td>Maximum value of population density amongst the Districts considered, but not greater than 75 people per km2</td></tr>
<tr><td>4</td><td>Connects the provincial capital to EN1
Connects to a main Border Post</td><td>Secondary school</td><td>Surpluses of staple crops such as maize, cassava or fruit</td><td></td><td></td></tr>
<tr><td>3</td><td>Connects between two provincial capitals
Connects to a secondary Border Post
Connects to a secondary port</td><td>Market or commercial centre</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Connects to a major town
Connects to a district capital</td><td>More than one health centre or primary school</td><td>Crop production or fishing sufficient to support the local population</td><td></td><td></td></tr>
<tr><td>1</td><td>Connects to Administrative Post</td><td>A health centre or primary school</td><td>Insignificant levels of production</td><td>Minimum value of poverty incidence amongst the Districts considered</td><td>Minimum value of population density amongst the Districts considered</td></tr>
</table>

Source: ANE

The results of the multi-criteria analysis exercise conducted in RSS are shown in the following Table 10.1.9. Among the 59 projects evaluated, the ranking and the project's MCA scores are calculated, after converted to a 100-point scale. Although any particular project's score has only meaning in relation to the scores of other projects, it is interesting to note that the process yielded a wide dispersion, indicating that according to the methodology and specific scoring used, there is much to differentiate among the projects. For each project, scores are shown for the four alternative weighting schemes.

Table shows the rank of the four alternative weighting schemes. For reference, and to indicate "gaps" in the ranking list, the Base Weight Score is also shown. This result is very consistent for the first twenty or so projects, with relatively little sensitivity to the weighting scheme used.

Since the computed EIRR in this F/S demonstrates a sound level similarly in RSS, it is assumed that such conclusion of the multi-criteria analysis exercise conducted in RSS remains unchanged, even after the F/S is carried out.

Table 10.1.9 Result of Multi Criteria Analysis for the Project

Evaluation Criteria	Rank/Score
MCA rank for Nampula – Cuamba project among National Roads Candidates	2nd
Base Weight	86
No EIRR	77
Low EIRR	76
High Weighting for Social Benefits	81

Source: ANE

10.1.13 Assessment of Beneficiaries

a. Assessment of Population Benefit

The population of the four Northern provinces, at around 10 million persons, is about 50% of Mozambique's total population of 20 million. The majority (74%) of the population in the four Northern provinces lives in Nampula and Zambezi, which account for nearly 40% of Mozambique's total population (Table 10.1.10).

Table 10.1.10 Population Statistics (2006)

Area	Population ('000)
Zambezia	3,800
Nampula	3,800
Cabo Delgado	1,650
Niassa	1,030
Total North	10,280
Total Mozambique	20,000

Source: www.ine.gov.mz

To make an accurate assessment of the number of project beneficiaries which in any case is virtually difficult at this level of assessment except to say that all of the 10 million persons in the north would benefit in some way or other, through reduced food prices for instance. Whilst it is possible that the global prices of food and other commodities in the north might fall as a results of reduced transport costs on the N13 corridor alone, it is likely that the persons who experience a tangible and meaningful benefit from the improvements will be much less than this.

When considering the corridor improvement the most direct beneficiaries will be the road users and population living along the N13 corridor in Nampula and Niassa who will be able to benefit directly from increased mobility as a result of better public transport, though car ownership is very limited, and are likely to experience secondary effects of cost reduction in terms of increased income due to the stimulation of agricultural production and employment in agricultural, mineral and tourism industries.

As shown in Table 10.1.11, the total population living in the districts and major towns on the corridor is around 1 million persons, of which approximately 0.5 million live in Nampula. About half of this population will be in the economically active 15-65 age group, which will potentially gain from increased incomes and employment opportunities. A proportion of this population will benefit directly as road users.

It is likely that the actual number of persons benefiting from the project in a significant way, such as being raised out of absolute poverty, will be much less, as this depends on other factors, such as the general development of the economy and commodity prices.

Alternatively, road development surely improves the accessibility of the population embedded with road sides. The influenced population who will receive the benefits is assumed within that accessible area to a bus stop or 0.5km along the Study Road.

The following tables and figures show that the number of the beneficiaries along the Study Road is estimated at approximately 615 thousand people and 92 villages. This number may be taken as an upper bound for total potential project beneficiaries.

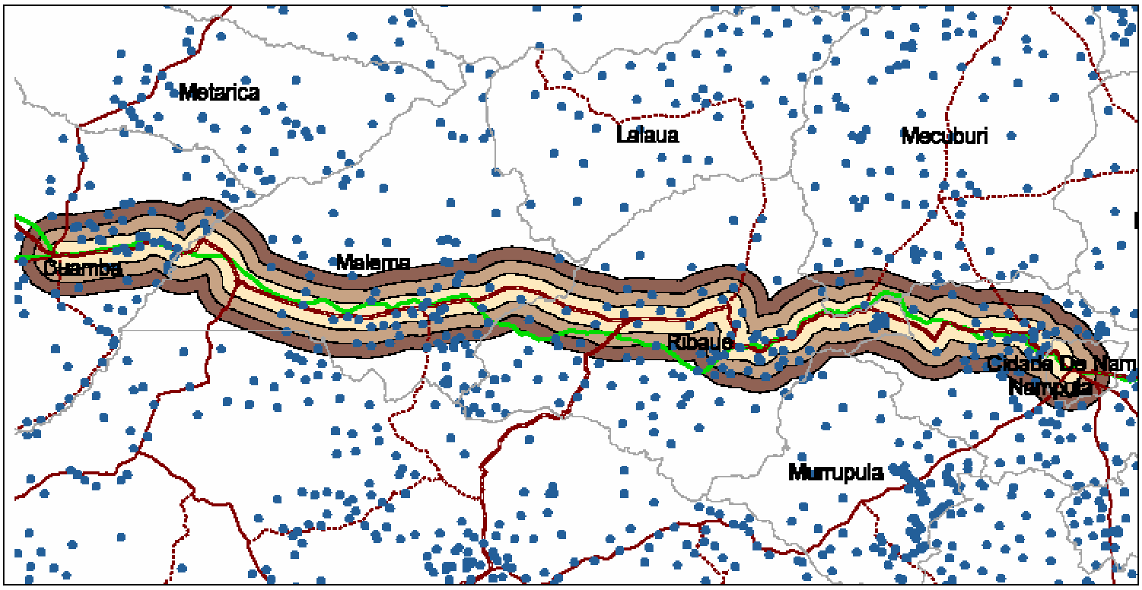


Figure 10.1.1 Villages along the Study Road

Table 10.1.11 Benefited Population

Area	Cuamba	Malema	Ribaue	Mecuburi	Nampula	Total
Urban	94,768	71,317	28,025	28,509	381,213	603,832
Within 0.5km	2,488	2,733	5,259	0	1,142	11,622
0.5-4km	5,904	17,482	24,755	2,110	20,104	70,355
4-8km	7,428	20,332	21,845	0	8,217	57,822
8-12km	12,309	17,823	15,771	4,919	20,432	71,254
12km more	44,832	25,631	56,682	106,642	79,890	313,677
Total	167,729	155,318	152,337	142,180	510,998	1,128,562

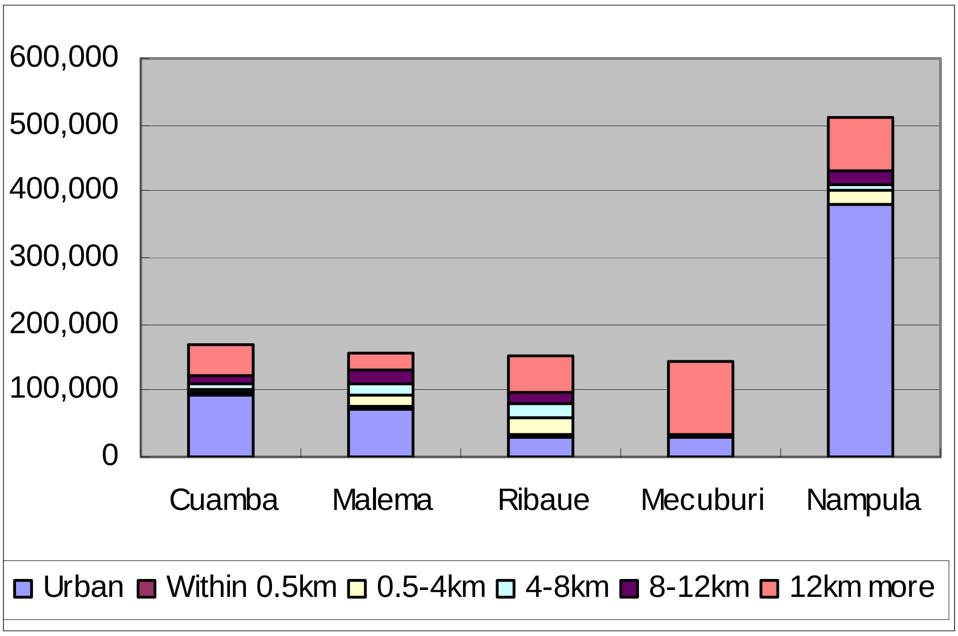
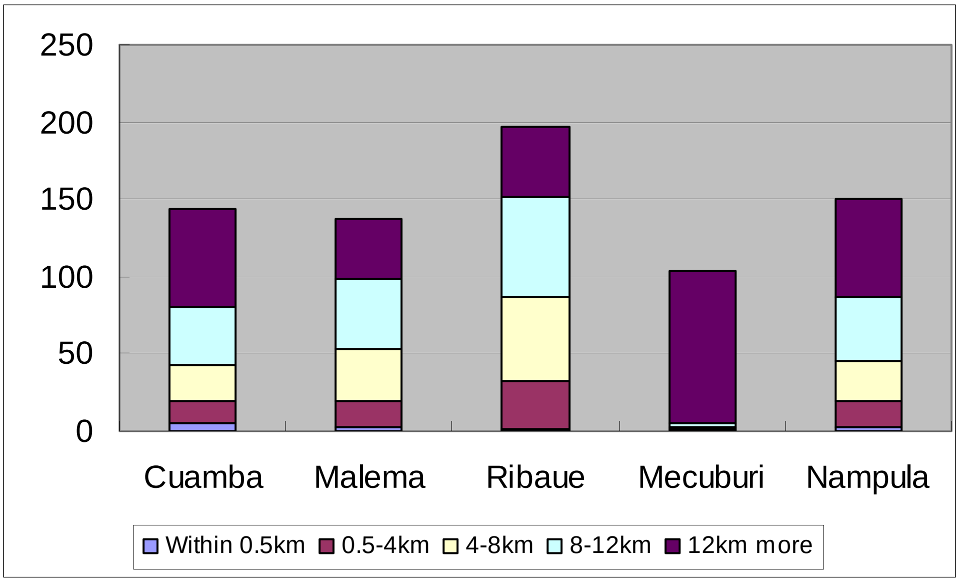


Figure 10.1.2 Benefited Population by Distance from Study Road

Table 10.1.12 Benefited Villages

Area	Cuamba	Malema	Ribaue	Mecuburi	Nampula	Total
Within 0.5km	5	2	1	0	2	10
0.5-4km	14	18	32	1	17	82
4-8km	24	33	54	1	26	138
8-12km	37	45	65	3	42	192
12km more	64	39	45	99	63	310
Total	144	137	197	104	150	732



Source: JICA Project Formulation Study Report

Figure 10.1.3 Benefited Villages by Distance from Study Road

b. Road Users

All existing and future road users will benefit from the road improvements as journey times and vehicle operating costs will reduce. As between 60 to 80% of the traffic on the national roads consists of goods vehicles, transport operators will directly benefit the most. It is expected that these savings, accruing to the several hundred trucks using the road every day, will result in reductions in prices of the goods being transported as savings in fuel and other costs are passed on to consumers.

It is also expected that bus operations will become more efficient and that public transport provision will improve for persons living on the N13 corridor. This may increase opportunities for the population living in the road corridors to access health and educational facilities more easily. Road traffic accidents may decrease on improved road sections, although this may well be counter-balanced by increased accidents due to the opportunity to travel faster.

c. Agriculture and Agricultural Industries

As Mozambique is largely an agricultural based economy the major indirect beneficiary of the road improvements will be farmers who will benefit with lower prices of inputs and better access to markets in the northern and southern part of Mozambique and neighboring countries. Niassa, which suffers from very poor access to external markets, will benefit particularly from the improvement to the N13. Niassa has extensive natural forests yielding industrial quantity of quality and exotic timber. The Government of Mozambique is encouraging the controlled export of processed timber. This industry will benefit from the reconstruction and rehabilitation of road network in the north, although care will have to be taken that illegal logging is controlled.

d. Export and Import Trade in Malawi

Due to the proximity of Cuamba to the Malawi border, and lack of better access to the interior of Mozambique, the Malawian economy currently plays an important role in the western area of influence of the road.

According to the study conducted by Millennium Challenge Corporation in 2007, agriculture is the largest sector of the Malawian economy, contributing more than a third of GDP and generating more than 90% of total export earnings. Around 85% of the population is engaged in agriculture. Tobacco is the dominant export earner, accounting for more than 60% of agricultural exports. The other main exports are sugar, tea, cotton and coffee. Commercial crops include tobacco, tea sugar etc, and cover around 1.15 million hectares of land while small hold farmers occupy a total of 4.1 millions hectares.

The total International traffic to and from Malawi averages one million tons per year. It is split between the Nacala railway corridor, the Beira road corridor and the northern route to Dar es Salam. However, the Nacala corridor offers the shortest and most economical route. The comparative advantage of this route will be improved by the fact that a private consortium has been given the concession to operate both the Malawi railway and the Nacala corridor.

The road transport to Beira, via Lilongwe is over a good paved road for a distance of about 1040 km. Assuming that Malawi uses the Study Road, the total distance from Lilongwe to Nakala would be about 870 km, eventually to save the travel time as shown in Figure 10.1.4. Thus, it is likely that Malawian traffic will use the project route for its international traffic.

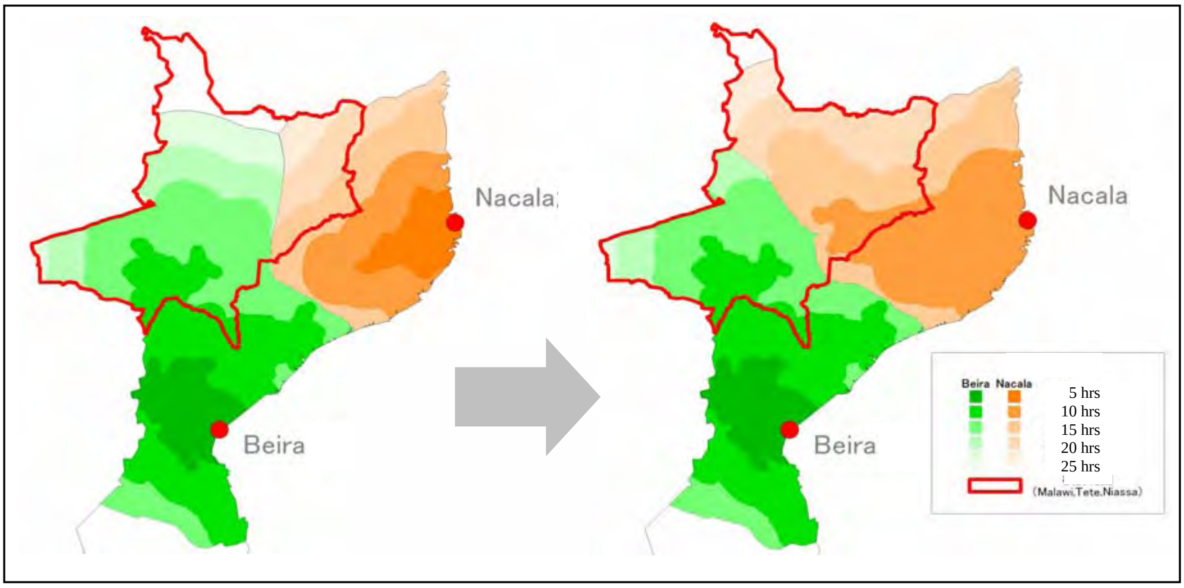


Figure 10.1.4 Change of travel time to Nakala Port

e. Mineral Extraction Industry

There is potential for mineral extraction including oil in northern Mozambique. An improved national road network will contribute to the development of this industry through facilitating the delivery of inputs and outputs.

f. Tourism Industry

There is an existing tourism industry in Cabo Delgado based on its excellent beaches and exotic islands. Accessibility is so poor to this area that most tourists fly; improved national road access should provide the opportunity for cheaper road travel for tourists to access this area and enlarge the potential market. Cheaper inputs will also benefit these industries. The improvement of the N13 to Niassa may also provide the opportunity to stimulate tourism opportunities on Lake Malawi.

10.2 Financial Analysis for the Project

10.2.1 Road Sector Strategy 2007 – 2011 (RSS)

According to the Road Sector Strategy 2007 - 2011 (RSS) that was prepared for the Government of Mozambique by ANE in August 2006, with the assistance of the Road Fund and Ministry of Public Works and Housing, main elements of the Government of Mozambique's (GOM's) strategy for developing and managing the country's classified roads are presented. The RSS is based upon the GOM's Road Sector Policy that establishes the broad goals and priorities for the sector in the context of national policy. The key financial principle of RSS is that road users pay the costs of maintaining the highways, while the government finances road investment through the state development budget and through external resources.

Financing for RSS is provided for the following elements:

- Strategic Maintenance Plan (SMP): the SMP includes funding requirements for both standard maintenance (routine and periodic maintenance) and transit ability maintenance for classified and urban road networks. The Plan also includes a provision for addressing the need for backlog maintenance (on paved roads) and funds for emergency works.
- Investment Plan: the Investment Plan for prioritized investment in rehabilitation and upgrade projects on the national network, a program of rehabilitation of the regional roads network (RRIP), and a Priority Bridge Rehabilitation and Construction Program.
- Overhead, Institutional Support and Capacity Building: this element includes the expected administrative costs of the Roads Administration System, funding for the development of road sector institutions, enhancing human resources capacities, technical assistance, studies and consultancies to assist in sector development (e.g., technical support for Integrated Road Management System (IRMS), implementation of the new road classification, network master planning, improved financial controls); assistance for improvement of private sector capacity; programs for road safety and for axle load controls; logistical and material assistance; engineering studies in support of network development, and contingencies.

Total program needs for RSS Phase 2 are shown in Table 10.2.1 projected annually for 3 year time frames. Not all expenditures will be uniformly distributed over the entire period of Phase 2, but for purposes of the Strategic Financial Plan, funding needs have not been programmed over time. Detailed programming, including procurement, implementation, and disbursement schedules are included as part of PIP[1] 2007 - 2009.

10.2.2 PRISE 2007-2009

a. Overview of Programa Integrado do Sector de Estradas (PRISE 2007-2009)

As described in the previous chapters, the objective of Programa Integrado do Sector de Estradas (PRISE 2007-2009) is to establish a sector-wide approach for the road sector that incorporates a coherent Mozambican owned and led roads program in a comprehensive and coordinated manner. Under PRISE 2007-2009, sector planning, finance, implementation, monitoring and evaluation is fully integrated.

The program was developed to be in line with the priorities and objectives of the Government of Mozambique Road Sector Policy, PARPA, Medium Term Expenditure Framework (MTEF), and RSS. PRISE will enable the GOM to guide the road sector and monitor its performance to ensure that it supports the Government's main objectives of poverty reduction and balanced economic development. It will also facilitate managing sector expenditures and inter-sectoral balance by bringing all activities on-budget. Under PRISE, all funding for the road sector supports a single sector policy and expenditure program under Government leadership while adopting common approaches across the sector, eventually progressing towards full reliance on GOM procedures to disburse and account for all funds.

b. Overview of PRISE 2007-2009 Financial Plan

The PIP generally follows the structure presented in the Strategic Financial Plan contained in the RSS 2007 – 2011 in August 2006, with the addition of several projects and activities. For clarity, the program is divided into three parts, Overhead, Maintenance and Investment. Engineering services for design and supervision are presented within the civil works component, but estimated separately.

The plan comprises $1,043.3 million of activities over three years. A substantial portion of the planned civil works is still subject to finalization of feasibility studies, detailed designs and donor commitments. The projected program for 2007 – 2009 is fully funded, subject to the caveat noted above (see Table 10.2.1.) The Road Fund component is $195 million (19% of program expenditures) and the GOM contribution is projected to be $139.1 million (13%). Both of these constitute substantial increases over the planned and realized amounts for Phase 1 of Roads-3. Donors are expected to fund $709.1 million (68%) of program activities, also a substantial increase. Not only is the program fully funded in terms of total commitments, but mismatches in funding have been eliminated, largely due to the flexibility shown by donors.

The program includes a significant level of sector budget support, constituting 16% of total donor funding and 11% of the program as currently structured. From the SBS funds 82% are allocated to paved road periodic maintenance. Most donors have also shown considerable flexibility in their allocations, especially with respect to the areas of institutional support and capacity building. This has enabled the programming of all planned activities. Implementation has been planned by year with planned execution rising

[1] Program Implementation Plan

over the three years, especially with respect to major civil works components.

Table 10.2.1 Summary Sources and Uses of Fund, PRISE 2007 -2009 (USD million)

Component	Planned Uses	Funding				Total Funding
		Road Fund	GOM	SBS[2]	Donors	
Overhead	$69.6	$29.9		$15.3	$24.4	$69.6
Maintenance	$263.9	$165.1		$98.2	$0.5	$263.9
Rehabilitation and Upgrade	$709.8		$139.1		$570.5	$709.8
Total	$1043.3	$195.0	$139.1	$113.5	$595.6	$1043.3

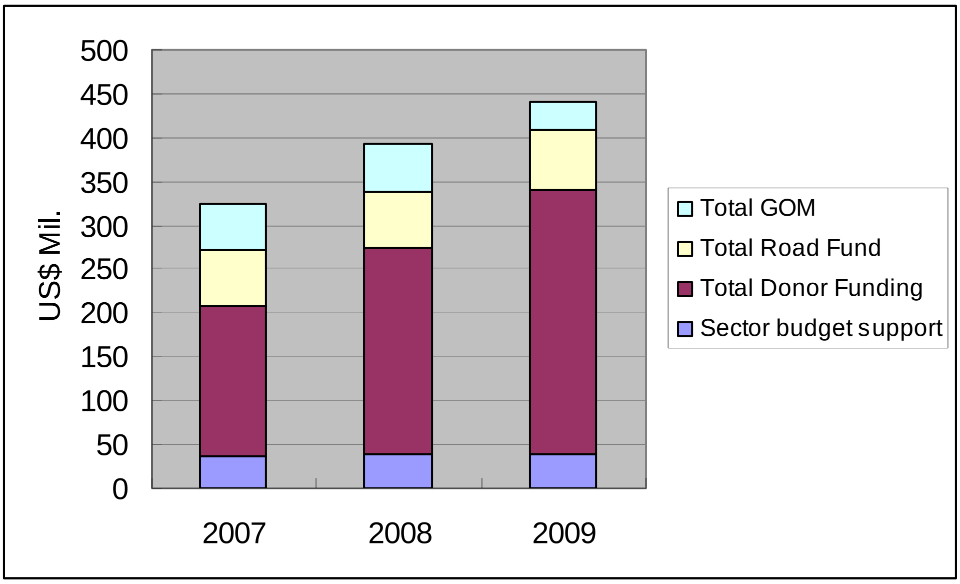
Source: PRISE

10.2.3 Sources of Funds

The three sources of funds for the road sector are:

- Road User Charges collected by the Road Fund (FE);
- Government of Mozambique contributions through the general budget;
- Donor Contributions to the road sector program.

Allocation of fund sources for PRISE 2007-2009 Financial Plan is shown in the following Figure 10.2.1.



Source: ANE

Figure 10.2.1 Allocation of Fund Resource

[2] Sector Budget Support

a. Road Fund

The Road Fund (FE) is an administrative and financial autonomous entity with responsibility for financing public roads. The role of FE is to ensure the timely collection of the funds that promoting the improvement of methods; to identify and propose new sources of revenue; to recommend funding for the road network development; to recommend foreign funding for road projects, to manage the financial resources intended for the road sector under the conditions set by the government; and to allocate resources for the maintenance of various categories of roads according to the contract plan with the government.

FE, like ANE, is undergoing important organizational changes to increase efficiency, ensure timely decision making, and implement a results-oriented management approach. Specifically, FE will have responsibility for road sector monitoring and evaluation under PAF for which it will establish a specialized unit. The linkages between ANE and FE will also be strengthened and formalized through a contract program and administrative guidelines to ensure financial accountability in planning and implementation.

The projections of road user charges collected by the Road Fund for 2007 – 2009 are for a medium scenario which forecasts moderate growth in total revenues from approximately US$ 60 million in 2007 to US$ 66 million in 2009. Projections to 2011 would indicate annual Road Fund revenues of US$ 73 million. It is noted that projections for revenues from vehicle license fees are very speculative, and as such, have not been included the comparison of sources and uses presented above Table 10.2.1.

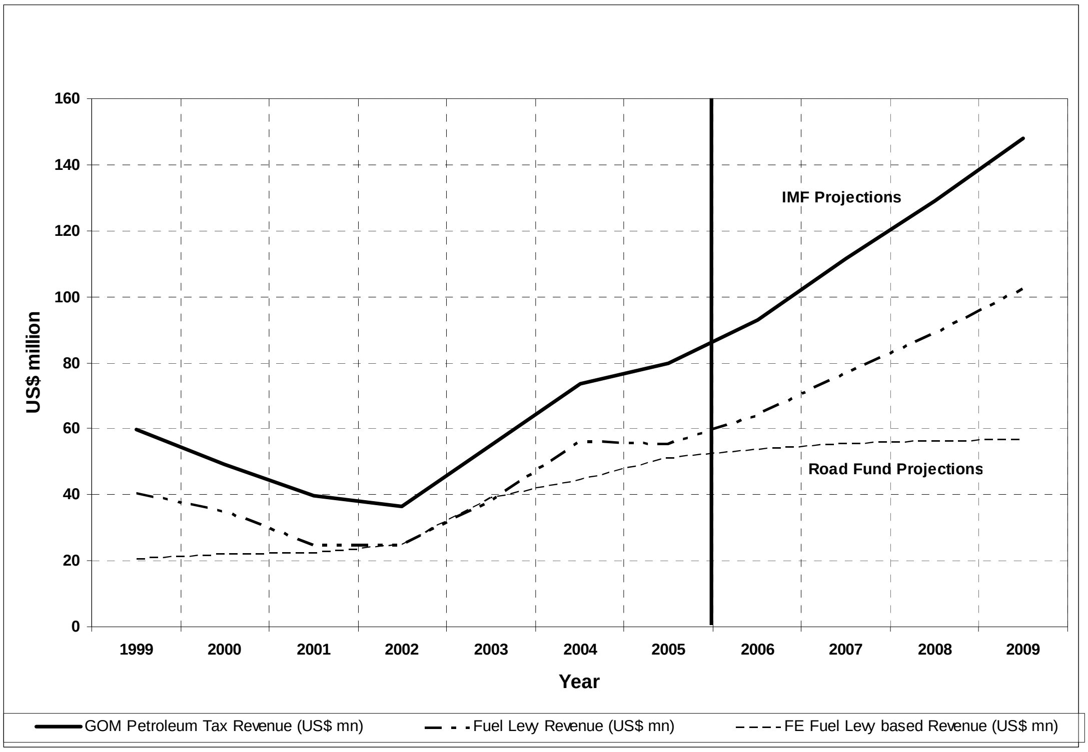
Taking all the factors into account, the possible revenues to the Road Fund from possible sources can be predicted as shown in Table 10.2.2.

Table 10.2.2: Projected Road Fund Revenues
(Values in million US$ unless otherwise noted)

Predicted Road Fund Revenues	Analysis by Year			
Sources of Funds	2007	2008	2009	Total Phase 2
User Fee (US cents per liter)	13.0	13.5	14.0	
Fuel Consumption (est., m liters)	410	415	420	
Road Fuel Levy	$53.3	$56.0	$58.8	$168.1
Road Fees	$7.0	$7.0	$7.0	$21.0
Vehicle License Fees (estimated)	$2.0	$2.1	$2.2	$6.3
Total excluding License Fee	$60.3	$63.0	$65.8	$189.1
Total including License Fee	$62.3	$65.1	$68.0	$ 195.4

Source: ANE

If the Fuel Levy continues to account for the same percentage of GOM petroleum tax revenue as in the 1999-2004 period, the Petroleum Tax (ISC) revenues will rise sharply in line with the IMF's forecast of rapidly rising petroleum based tax revenue as is shown in the figure 10.2.2. If the amount paid directly to the Road Fund is as projected by the Road Fund which is based on very conservative automotive fuel consumption forecasts, the amount of petroleum tax revenue retained by GOM will rise sharply.



Source: ANE

Figure 10.2.2 Petroleum Based Tax Revenue & Fuel Levy Revenue

b. Government of Mozambique: The GOM commitment to counterpart contributions for Phase 1 investments was approximately US$ 3.5 million annually. For Phase 2 the GOM is expected to contribute approximately US$ 100 million over 3 years. US$ 30 million will be directed to the Priority Bridge Program and an additional US$ 3.5 million annually to the Regional Roads Investment Program.

c. Donors: Donors have shown great commitment to assisting Mozambique under Roads-3 and are expected to have contributed some US$ 455 million by the end of Phase 1. The contributions of the various donors to Phase 2 are still under discussion. For purposes of the Strategic Financial Plan, only donor commitments that have been firmly established have been included.

Among international donors, it appears now that the captioned Project in particular will be included under Enhanced Private Sector Assistance (EPSA) funding, probably beginning in 2008 and extending over four years within a half period during Phase 3.

EPSA for Africa was launched by the government of Japan in 2005 as a comprehensive initiative to support African private sector development. It sets forth that Japan Bank for International Cooperation (JBIC) will provide ODA loans, in cooperation with AfDB, totaling up to USD$1 billion over the period of five years. On the ground of "the Guidelines for Implementation" to promote co-financing with the African Development Bank (AfDB) which is a regional development bank, providing financial assistance for African member countries with medium and long-term loans, equity participation, guarantee, and technical assistance, JBIC has cooperative ties which include co-financing social and economic infrastructure development projects in Africa.

10.2.4 New Financing Mechanisms

The ever-increasing demands for maintenance financing require that new and innovative sources of road user charges be explored. A comprehensive Road User Charges Study should be commissioned early in Phase 2 to explore alternative approaches for enhancing revenues. The consultancy should also include accompanying measures for implementing the proposed enhancements.

The planning for the Road Fund under the Strategy included increasing the revenue from road user charges, mainly by increasing the fuel levy, to double the resources available in the Fund within 10 years (in USD terms). It was intended that donors should assist in "bridging" the funding gap, while revenues were increased according to a practical program.

On the expenditure side the Strategy set out proposals to use these additional funds to cover routine maintenance for all roads, and to cover an increasing percentage of the periodic maintenance, up to a point at the end of the ten-year program where periodic maintenance on all roads would be funded from this source. This is in addition to covering the administration costs of both the Road Fund organization and the ANE organization.

The existing sources of revenue to the Road Fund are the fuel levy, road and bridge tolls and transit (cross border) charges. In most countries motor vehicle license fees form part of the revenue to the Road Fund. These fees enable road user charges to recover the costs related to the use of each vehicle more accurately. Including motor vehicle license fees as a user charge to be paid into the Road Fund should be explored.

A promising source of additional user charges is the imposition of road tolls and the granting of long-term concessions. A pilot project to investigate the concept recently completed was concluded that a performance-based operations and maintenance contract through concession awarded to a private-sector entity on the basis of competitive bidding and incorporating routine maintenance only is financially viable. There is a potential for covering a wider scope of maintenance (i.e., including periodic) on other road sections where traffic volumes are higher than the pilot project.

Although not all roads are candidates for tolling, more roads could be the object of maintenance concessions that bundle rehabilitation or periodic maintenance to long-term routine maintenance of the infrastructure. A number of the more heavily trafficked roads in Mozambique, e.g., those that serve tourist destinations such as coastal resorts, are potential candidates for tolling. The possibility of imposing a road-use surcharge on tourist facilities also offers an avenue to be explored.

Other sources of revenue are also used in other countries to supplement the revenue to the Road Fund, including weighbridge fees on over-loaded vehicles, permit fees for buses and heavy vehicles, weight-distance charges on heavy vehicles, and congestion charges in cities. These should be systematically considered for inclusion in the revenue to the Road Fund.

Road sector legislation empowers local authorities to raise funds to maintain roads, but, this area requires substantial investigation. The authority to raise funds must be compared to the capacity to implement. Given potential revenues can be realized, these could substantially contribute to the local maintenance and rehabilitation initiatives by District, Municipal or Provincial level. These approaches should be further studied in the Road User Charges Study .

10.3 Conclusions and Recommendations

a. Economic Viability of the Project

The project scores an average level as an upgrade-to-paved intervention and its economic viability is acceptable, with an EIRR of over 12% for the optimum intervention among alternatives. Based on this result, N13 (Nampula - Cuamba) project is evaluated as one of the prioritized projects. The particular importance of this primary road and of bringing it to all-weather transit-able condition is well established.

b. Post-Construction Management and Maintenance

ANE, through provincial delegation, ensures the management and maintenance of all classified roads including the road sections proposed under this report. FE is responsible for financing these activities. The improvement of the maintenance performance is critical for post construction sustainability. Since maintenance will largely be implemented by the provincial delegation of ANE, the establishment of functional offices will be crucial for the sustainability of the investments. Therefore, it is important to support ANE's re-organization and capacity strengthening especially at provincial level. The funding and implementation of technical assistance, on-the-job training, infrastructure and logistical support activities will be effective measures to ensure sustainability.

Economic Feasibility: DBST on Glanular

Country	Mozambique	Project	Upgrading Nampula-Cuamba Road	2007/10/1
Road	Nampula-Ribaue	Alternative	DBST on Glanular	

Alternatives	Description	Terrain Type	Road Type
Without Project	ALT 0 Without	B: Rolling	Y: Gravel
Project	DBST on Glanular	B: Rolling	X: Paved

Wet Season Duration (days/year) 150

Alternatives	Dry Season Length (km)	Dry Season Roughness (IRI)	Wet Season Length (km)	Wet Season Roughness (IRI)	Car Medium	Four-Wheel Drive	Bus Light	Bus Medium	Delivery Vehicle	NOT USED	Truck Medium	Truck Heavy	Truck Articulated
					Average Speeds (km/hr)								
Without Project	131.6	18.0	131.6	18.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Project	131.6	2.5	131.6	2.5	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
					Traffic Composition in 2009 (%)								
					17%	0%	36%	23%	0%	0%	25%	0%	0%

Alternatives	Eco. Investment (years)	Eco. Investment ('000$/km)	E. Maintenance ('000$/km/year)	Accidents (#/m veh-km)	Car Medium	Four-Wheel Drive	Bus Light	Bus Medium	Delivery Vehicle	NOT USED	Truck Medium	Truck Heavy	Truck Articulated
					Average Travel Time (hours)								
Without Project	0	0.00	1.99	0.00	4:23	4:23	4:23	4:23	4:23	4:23	4:23	4:23	4:23
Project	3	269.98	1.34	0.00	1:38	1:38	1:38	1:38	1:38	1:38	1:38	1:38	1:38

Year	Annual Normal Daily Traffic (veh/day)	Annual Generated Daily Traffic (veh/day)	Annual Induced Daily Traffic (veh/day)	Net Economic Benefits: Agency Benefits: Investment Costs (M$/year)	Agency Benefits: Maintenance Costs (M$/year)	User Benefits: Normal Traffic VOC (M$/year)	Normal Traffic Time (M$/year)	Generated Traffic VOC (M$/year)	Generated Traffic Time (M$/year)	Road Safety (M$/year)	Other Benefits (M$/year)	Total (M$/year)	Sensitivity Analysis: A Agency * 1.2 (M$/year)	B User * 0.8 (M$/year)	A & B (M$/year)
2009	256	0	0	-7.106	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-7.106	-8.527	-7.106	-8.527
2010	269	0	0	-14.212	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-14.212	-17.054	-14.212	-17.054
2011	283	0	0	-14.212	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-14.212	-17.054	-14.212	-17.054
2012	298	0	0	0.000	0.085	4.646	1.125	0.000	0.000	0.000	1.006	6.862	6.879	5.507	5.524
2013	313	0	0	0.000	0.085	4.873	1.181	0.000	0.000	0.000	1.051	7.189	7.206	5.768	5.785
2014	329	0	0	0.000	0.085	5.112	1.239	0.000	0.000	0.000	1.098	7.535	7.552	6.045	6.062
2015	346	0	0	0.000	0.085	5.363	1.301	0.000	0.000	0.000	1.148	7.897	7.914	6.335	6.352
2016	363	0	0	0.000	0.085	5.626	1.365	0.000	0.000	0.000	1.201	8.277	8.294	6.639	6.656
2017	382	0	0	0.000	0.085	5.903	1.433	0.000	0.000	0.000	1.255	8.676	8.693	6.958	6.975
2018	401	0	0	0.000	0.085	6.193	1.505	0.000	0.000	0.000	1.313	9.095	9.112	7.293	7.310
2019	422	0	0	0.000	0.085	6.509	1.582	0.000	0.000	0.000	1.376	9.552	9.569	7.659	7.676
2020	444	0	0	0.000	0.085	6.841	1.664	0.000	0.000	0.000	1.443	10.033	10.050	8.043	8.060
2021	468	0	0	0.000	0.085	7.191	1.749	0.000	0.000	0.000	1.513	10.538	10.555	8.447	8.464
2022	492	0	0	0.000	0.085	7.558	1.839	0.000	0.000	0.000	1.586	11.068	11.085	8.872	8.889
2023	518	0	0	0.000	0.085	7.944	1.934	0.000	0.000	0.000	1.663	11.626	11.643	9.318	9.335
2024	554	0	0	0.000	0.085	8.500	2.070	0.000	0.000	0.000	1.779	12.434	12.451	9.964	9.981
2025	593	0	0	0.000	0.085	9.095	2.215	0.000	0.000	0.000	1.904	13.299	13.316	10.656	10.673
2026	635	0	0	0.000	0.085	9.732	2.370	0.000	0.000	0.000	2.037	14.224	14.241	11.396	11.413
2027	679	0	0	0.000	0.085	10.413	2.535	0.000	0.000	0.000	2.180	15.213	15.230	12.188	12.205
2028	727	0	0	0.000	0.085	11.142	2.713	0.000	0.000	0.000	2.332	16.272	16.289	13.035	13.052

5.6% Growth

Evaluation Period (years): 20

	Total	A	B	A & B
Net Present Value (million $) at 12% Discount Rate	21.094	14.966	10.747	4.618
Internal Rate of Return (%)	19.8%	16.8%	16.2%	13.6%
Equivalent Annual Net Benefits ($/km) at 12% Discount Rate	19160	13593	9761	4195
Modified Rate of Return at 12% Reinvestment Rate (%)	15%	14%	14%	13%
Net Present Value per Financial Investment Costs (ratio)	0.59	0.42	0.30	0.13
First-Year Benefits per Economic Investment Cost (ratio)	0.19	0.16	0.15	0.13

Economic Feasibility: DBST on Glanular

Country	Mozambique	Project	Upgrading Nampula-Cuamba Road		2007/10/1
Road	Ribaue-Malema	Alternative	DBST on Glanular		

Alternatives	Description	Terrain Type	Road Type	Wet Season Duration (days/year)
Without Project	ALT 0 Without	B: Rolling	Y: Gravel	150
Project	DBST on Glanular	B: Rolling	X: Paved	

Alternatives	Dry Season Length (km)	Dry Season Roughness (IRI)	Wet Season Length (km)	Wet Season Roughness (IRI)	Car Medium	Four-Wheel Drive	Bus Light	Bus Medium	Delivery Vehicle	NOT USED	Truck Medium	Truck Heavy	Truck Articulated
					Average Speeds (km/hr)								
Without Project	102.9	18.0	102.9	18.0	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Project	102.9	2.5	102.9	2.5	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
					Traffic Composition in 2009 (%)								
	Eco. Investment		E. Maintenance	Accidents	35%	0%	19%	16%	0%	0%	30%	0%	0%
Alternatives	(years)	('000$/km)	('000$/km/year)	(#/m veh-km)	Average Travel Time (hours)								
Without Project	0	0.00	1.99	0.00	5:00	5:00	5:00	5:00	5:00	5:00	5:00	5:00	5:00
Project	3	284.54	1.34	0.00	1:17	1:17	1:17	1:17	1:17	1:17	1:17	1:17	1:17

Year	Annual Normal Daily Traffic (veh/day)	Annual Generated Daily Traffic (veh/day)	Annual Induced Daily Traffic (veh/day)	Net Economic Benefits: Agency Benefits Investment Costs (M$/year)	Agency Benefits Maintenance Costs (M$/year)	User Benefits Normal Traffic VOC (M$/year)	Normal Traffic Time (M$/year)	Generated Traffic VOC (M$/year)	Generated Traffic Time (M$/year)	Road Safety (M$/year)	Other Benefits (M$/year)	Total (M$/year)	Sensitivity Analysis A Agency * 1.2 (M$/year)	B User * 0.8 (M$/year)	A & B (M$/year)
2009	171	0	0	-5.856	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-5.856	-7.027	-5.856	-7.027
2010	181	0	0	-11.712	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-11.712	-14.054	-11.712	-14.054
2011	192	0	0	-11.712	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-11.712	-14.054	-11.712	-14.054
2012	204	0	0	0.000	0.066	2.432	1.306	0.000	0.000	0.000	1.529	5.334	5.347	4.280	4.293
2013	216	0	0	0.000	0.066	2.569	1.380	0.000	0.000	0.000	1.603	5.618	5.632	4.508	4.521
2014	228	0	0	0.000	0.066	2.699	1.451	0.000	0.000	0.000	1.676	5.892	5.906	4.727	4.740
2015	240	0	0	0.000	0.066	2.835	1.525	0.000	0.000	0.000	1.753	6.180	6.193	4.957	4.970
2016	253	0	0	0.000	0.066	2.979	1.604	0.000	0.000	0.000	1.833	6.482	6.495	5.199	5.212
2017	267	0	0	0.000	0.066	3.130	1.686	0.000	0.000	0.000	1.917	6.799	6.813	5.453	5.466
2018	281	0	0	0.000	0.066	3.289	1.773	0.000	0.000	0.000	2.005	7.133	7.146	5.719	5.733
2019	297	0	0	0.000	0.066	3.466	1.869	0.000	0.000	0.000	2.106	7.507	7.521	6.019	6.032
2020	313	0	0	0.000	0.066	3.653	1.970	0.000	0.000	0.000	2.212	7.902	7.915	6.335	6.348
2021	331	0	0	0.000	0.066	3.850	2.077	0.000	0.000	0.000	2.324	8.318	8.331	6.668	6.681
2022	349	0	0	0.000	0.066	4.058	2.190	0.000	0.000	0.000	2.441	8.756	8.769	7.018	7.031
2023	369	0	0	0.000	0.066	4.277	2.309	0.000	0.000	0.000	2.565	9.217	9.231	7.387	7.401
2024	394	0	0	0.000	0.066	4.576	2.471	0.000	0.000	0.000	2.744	9.858	9.871	7.900	7.913
2025	422	0	0	0.000	0.066	4.897	2.644	0.000	0.000	0.000	2.936	10.543	10.557	8.448	8.461
2026	452	0	0	0.000	0.066	5.239	2.829	0.000	0.000	0.000	3.142	11.277	11.290	9.035	9.048
2027	483	0	0	0.000	0.066	5.606	3.027	0.000	0.000	0.000	3.362	12.061	12.075	9.662	9.676
2028	517	0	0	0.000	0.066	5.999	3.239	0.000	0.000	0.000	3.597	12.901	12.914	10.334	10.347

6.0% Growth

Evaluation Period (years): 20

	Total	A	B	A & B
Net Present Value (million $) at 12% Discount Rate	15.389	10.334	7.257	2.202
Internal Rate of Return (%)	19.0%	16.1%	15.5%	12.9%
Equivalent Annual Net Benefits ($/km) at 12% Discount Rate	17876	12005	8430	2558
Modified Rate of Return at 12% Reinvestment Rate (%)	15%	14%	13%	12%
Net Present Value per Financial Investment Costs (ratio)	0.53	0.35	0.25	0.08
First-Year Benefits per Economic Investment Cost (ratio)	0.18	0.15	0.14	0.12

Economic Feasibility: DBST on Glanular

Country	Mozambique
Road	Malema-Cuamba

Project	Upgrading Nampula-Cuamba Road
Alternative	DBST on Glanular

2007/10/1

Alternatives	Description	Terrain Type	Road Type
Without Project	ALT 0 Without	B: Rolling	Y: Gravel
Project	DBST on Glanular	B: Rolling	X: Paved

Wet Season Duration	
(days/year)	150

	Dry Season		Wet Season		Car	Four-Wheel	Bus	Bus	Delivery	NOT	Truck	Truck	Truck
	Length	Roughness	Length	Roughness	Medium	Drive	Light	Medium	Vehicle	USED	Medium	Heavy	Articulated
Alternatives	(km)	(IRI)	(km)	(IRI)	Average Speeds (km/hr)								
Without Project	112.9	18.0	112.9	18.0	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Project	112.9	2.5	112.9	2.5	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
					Traffic Composition in 2009 (%)								
	Eco. Investment		E. Maintenance	Accidents	23%	0%	7%	10%	0%	0%	60%	0%	0%
Alternatives	(years)	('000$/km)	('000$/km/year)	(#/m veh-km)	Average Travel Time (hours)								
Without Project	0	0.00	1.99	0.00	5:29	5:29	5:29	5:29	5:29	5:29	5:29	5:29	5:29
Project	3	307.33	1.34	0.00	1:24	1:24	1:24	1:24	1:24	1:24	1:24	1:24	1:24

	Annual	Annual	Annual	Net Economic Benefits									Sensitivity Analysis		
	Normal	Generated	Induced	Agency Benefits		User Benefits							A	B	A & B
	Daily	Daily	Daily	Investment	Maintenance	Normal Traffic		Generated Traffic		Road	Other		Agency *	User *	
	Traffic	Traffic	Traffic	Costs	Costs	VOC	Time	VOC	Time	Safety	Benefits	Total	1.2	0.8	
Year	(veh/day)	(veh/day)	(veh/day)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)	(M$/year)
2009	200	0	0	-6.939	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-6.939	-8.327	-6.939	-8.327
2010	210	0	0	-13.879	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-13.879	-16.655	-13.879	-16.655
2011	220	0	0	-13.879	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-13.879	-16.655	-13.879	-16.655
2012	231	0	0	0.000	0.073	3.534	1.078	0.000	0.000	0.000	1.196	5.882	5.896	4.720	4.734
2013	242	0	0	0.000	0.073	3.697	1.130	0.000	0.000	0.000	1.248	6.148	6.163	4.933	4.947
2014	254	0	0	0.000	0.073	3.872	1.184	0.000	0.000	0.000	1.305	6.434	6.448	5.161	5.176
2015	266	0	0	0.000	0.073	4.054	1.242	0.000	0.000	0.000	1.364	6.733	6.747	5.401	5.415
2016	279	0	0	0.000	0.073	4.245	1.301	0.000	0.000	0.000	1.426	7.046	7.061	5.651	5.666
2017	293	0	0	0.000	0.073	4.446	1.364	0.000	0.000	0.000	1.491	7.374	7.389	5.914	5.928
2018	307	0	0	0.000	0.073	4.656	1.430	0.000	0.000	0.000	1.559	7.718	7.732	6.189	6.203
2019	323	0	0	0.000	0.073	4.887	1.502	0.000	0.000	0.000	1.635	8.096	8.111	6.492	6.506
2020	339	0	0	0.000	0.073	5.129	1.578	0.000	0.000	0.000	1.714	8.494	8.508	6.810	6.824
2021	356	0	0	0.000	0.073	5.384	1.658	0.000	0.000	0.000	1.796	8.911	8.925	7.143	7.158
2022	375	0	0	0.000	0.073	5.651	1.742	0.000	0.000	0.000	1.883	9.349	9.363	7.494	7.508
2023	394	0	0	0.000	0.073	5.932	1.830	0.000	0.000	0.000	1.974	9.809	9.823	7.861	7.876
2024	421	0	0	0.000	0.073	6.347	1.958	0.000	0.000	0.000	2.113	10.490	10.505	8.407	8.421
2025	451	0	0	0.000	0.073	6.792	2.095	0.000	0.000	0.000	2.261	11.219	11.234	8.990	9.004
2026	482	0	0	0.000	0.073	7.267	2.241	0.000	0.000	0.000	2.419	12.000	12.014	9.614	9.629
2027	516	0	0	0.000	0.073	7.776	2.398	0.000	0.000	0.000	2.588	12.835	12.849	10.282	10.297
2028	552	0	0	0.000	0.073	8.320	2.566	0.000	0.000	0.000	2.769	13.728	13.742	10.997	11.011

	Total	A	B	A & B
Net Present Value (million $) at 12% Discount Rate	13.951	7.954	5.164	-0.833
Internal Rate of Return (%)	17.5%	14.8%	14.2%	11.7%
Equivalent Annual Net Benefits ($/km) at 12% Discount Rate	14771	8421	5467	-882
Modified Rate of Return at 12% Reinvestment Rate (%)	14%	13%	13%	12%
Net Present Value per Financial Investment Costs (ratio)	0.40	0.23	0.15	-0.02
First-Year Benefits per Economic Investment Cost (ratio)	0.17	0.14	0.13	0.11

5.5% Growth

Evaluation Period (years)
20

Chapter 11 Road Maintenance & Traffic Management

Chapter 11 Road Maintenance and Traffic Management

11.1 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 over load control of vehicles, speed control and installation of traffic safety facilities.

11.2 Maintenance Activity Plan

11.2.1 Flowchart of Maintenance Activity

Upon completion of the Project, timely maintenance work, i.e., inspection, defect evaluation and maintenance work should be carried out to ensure convenient and safe driving conditions and to reduce the risk of traffic accidents. In general, road maintenance activities are categorized as routine maintenance and periodic maintenance, each with different types of interventions. Whereas the former is composed of routine inspection followed by minor repair works (i.e. patching), cleaning and crass cutting, the latter contains relatively larger scale interventions such as resurfacing or overlay according to the regular evaluation of defects and the residual strength of the road. Figure 11.2.1 shows a flowchart with the recommended procedures to be followed when planning maintenance activities

The present road maintenance system used by ANE is applicable to the upgraded Study Road, although some particular financing and technical issues on maintenance need to be addressed

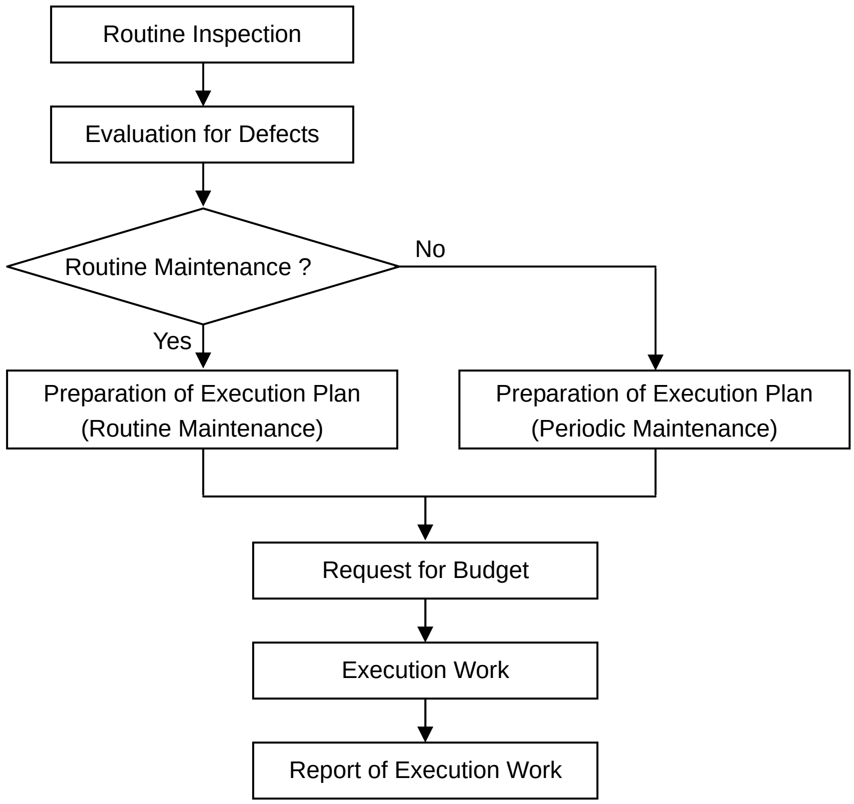


Figure 11.2.1 Flowchart of Maintenance Activity

11.2.2 Inspection Activity

(1) Inspection Items

Frequent and appropriate maintenance activities are required to keep the road in good and safe driving conditions.

Besides the pavement surface, maintenance should also include all the other road components that form an integrated part of the road structure. The various road components and their major anticipated defects are summarized in Table 11.2.1. Inspection items for bridges are shown in Table 11.2.2.

Table 11.2.1 Inspection Items for Paved Roads

Component	Sub-component	Defects
Paved Roads	Surface	Cracking, Potholes, Rutting/Deformation, Heaving/shoving, Stripping/Fretting, Bleeding, Glazing, Edge damage, Waving, Obstruction
	Base Course	Spot failure
	Sub-base	Spot failure
	Sub-grade	Spot failure
Shoulder	---	Obstruction, High vegetation, Scour, Shoulder/Carriageway step, Rutting, Depression, Potholes
Slopes	---	High vegetation, Erosion, Earth slop/Landslide, Rock avalanche, Collapse of slope protection
Embankment	---	Collapse, Settlement
Drainage	Culverts	Silting, Blockage by debris, Settlement cracks, Collapse of culvert, Erosion of stream bed at culvert outlet, Headwall/Apron/Wing-wall damage
	Ditches and Drains	Obstruction, Silting, Erosion at drainage outfall, Ponding in ditch or on shoulder, Erosion of Invert and sides of ditch, Ditch lining
Structure	Drifts and Causeway	Settlement, Erosion, Debris, Guideposts damage, Guidepost missing
	Retaining wall / Stone Masonry	Settlement, Cracking, Collapse
Road Facility	---	Dirty, Damage, Missing

Table 11.2.2 Inspection Items for Bridges

Bridge Type	Components	Defects
RC or PC Bridge	Surface	Cracks, Deformation, Potholes
	Slab and beam	Cracks, Deformation, Loss
	Railing and curb	Cracks, Deformation, Loss, Destruction
	Bearing	Cracks, Deformation, Corrosion, Loosened connection, Displacement
	Expansion joint	Loss of device, Leakage of water, Deformation, Loud Noise
	Drainage	Debris, Deformation, Loss
	Substructure	Cracks, Deformation, Loss
	Protection work	Debris, Scouring, Deformation, Displacement

(2) Frequency of Inspection Activity

Routine Maintenance

The inspection for routine maintenance should be carried out according to the inspection items indicated in Table 11.2.3 and 11.2.4, for roads and bridges respectively. Cleaning or repair work should be executed according to defects identified in the regular inspection visits.

Table 11.2.3 Frequency of Inspection for Routine Maintenance

Items	Frequency		Remarks
	Minimum	Desirable	
Carriageway shoulder	2 months	1 week	---
Slope embankment	4 months	1 month	Include after rainy season
Drainage	4 months	1 month	Include before/after rainy season
Road structure	4 months	1 month	---
Road facility	4 months	1 week	---

Table 11.2.4 Bridge Maintenance Requirements

Bridge Type	Work Activities	Interval
RC or PC Bridge	- Cleaning of carriageway surface and drainage facility - Minor repair of accessories (railing etc,) and carriageway surface - Removal of debris against piers - Removal of excess vegetation or silting deposits - Repair to scour damage around substructures and protection works	Every year

ANE contracts out the routine maintenance of the national roads to private contractors. Paved roads in good condition are maintained using a level of service contract, in which the contractor and consultant inspect the road at monthly intervals to ensure that defects are properly repaired ensuring that the level of service and quality of the road satisfies a predefined standard. The supervision of maintenance work is carried out by independent consultants working directly for ANE's provincial delegations.

Periodic Maintenance

Periodic maintenance of paved roads should be executed at least once every five years. Table 11.2.5 shows the periodic maintenance requirements for bridges.

Table 11.2.5 Periodic Maintenance Requirements for Improved Bridge

Bridge Type	Work Activities	Interval
RC or PC Bridge	- Resurfacing of carriageway - Repair of severe cracks and railing - Replacement of expansion joint - Repair of protection work	- 5 years - Responsive - 10 years - Responsive

11.2.3 Defects Evaluation (Ranking)

Routine Maintenance

A paved road management unit is being established within ANE, and procedures for the systematic collection and analysis of pavement data are being established. The evaluation ranking of defects is divided into surface defects and structural defects.

Periodic Maintenance

In order to determine an efficient periodic maintenance activity for damaged pavement surfaces, the surface roughness (IRI; International Roughness Index) will be used as an indicator A relation between the IRI value and the required periodic maintenance interventions is described below for a DBST roads.

(DBST Roads)

IRI<6.0 : No periodic maintenance required

IRI=6.0 : Resealing necessary

IRI=8.0 : Rehabilitation of DBST pavement structure, including (sub) base etc., if necessary

IRI=10.0 : Reconstruction of DBST pavement structure, including (sub)base etc., will be required and minor improvement for insufficient width of carriageway and shoulders will be required, if necessary.

Presently, ANE carries out regular road condition surveys which classifies roads in good, average, poor and very poor condition. The road condition is a function of the roughness and pavement strength. HDM4 and RED will used to determine the most economically viable maintenance strategy for paved roads. The Road Sector Strategy, which is used to orientate the preparation of maintenance plans, focuses on the importance of 'Asset Preservation '

11.2.4 Execution of Maintenance Works

The maintenance work by road component is shown in Table 11.2.6. Execution of work items will be determined on the basis of the following condition:

- Defect type
- Defect scale
- Traffic volume
- Execution cost and budget

- Defect records (frequency)

Table 11.2.6 Execution Maintenance Work Plan by Defect

Component	Sub-component	Routine maintenance	Periodic Maintenance
Paved Roads	Surface	Spot or crack sealing Patching Spot planning Sanding Moving obstruction	Resealing DBST Overlay Planning Spot reconstruction
	Base Course	Base repair	---
	Sub-base	Sub-base repair	---
	Sub-grade	Sub-grade repair	---
Shoulder	---	Bush cleaning Filling Spot reconstruction Patching	Reconstruction Add ditch Reshaping Grading Filling
Slopes	---	Bush cleaning Filling Re-cut Benching Grassing Drainage	Grassing Planning Re-cut Slope protection Benching
Embankment	---	Filling	Filling
Drainage	Culverts	Cleaning Sealing of crack Repair lining Headwall repair	Reconstruction culvert
	Ditches and Drains	Cleaning Sealing	Flatten gradient Construct cascade Reconstruct ditch
Structure	---	Cleaning Repair Sealing	Reconstruction
Road Facility	---	Cleaning Replace	Repair/replacement

11.3 Effective Road Maintenance System

The Study Team noted in Part II. Chapter 2 that would be budgetary analysis on road maintenance. This section mainly provides recommendations to enhance the road maintenance capacities of ANE.

11.3.1 Approach

To realize an effective road maintenance system, it is necessary to firstly determine the gap between the road maintenance needs and resources available. It will then be necessary to adopt appropriate strategies deal with this “maintenance needs gap”.

To accomplish this, it is necessary to analyze the factors affecting the costs of road maintenance. These factors are then incorporated into the construction of appropriate and cost effective maintenance scenarios. Assuming that resources for maintenance remain constrained for some time to go, it will be necessary to develop a core road network and to prioritize maintenance interventions. These steps need to go hand in hand with maintenance capacity building efforts and axle load control.

The proposals are comprehensive in order to develop the most effective road maintenance system. The workflow for this approach is shown in Figure 11.3.1. Before road maintenance scenarios can be proposed, the factors that impact on the costs of road maintenance must be defined.

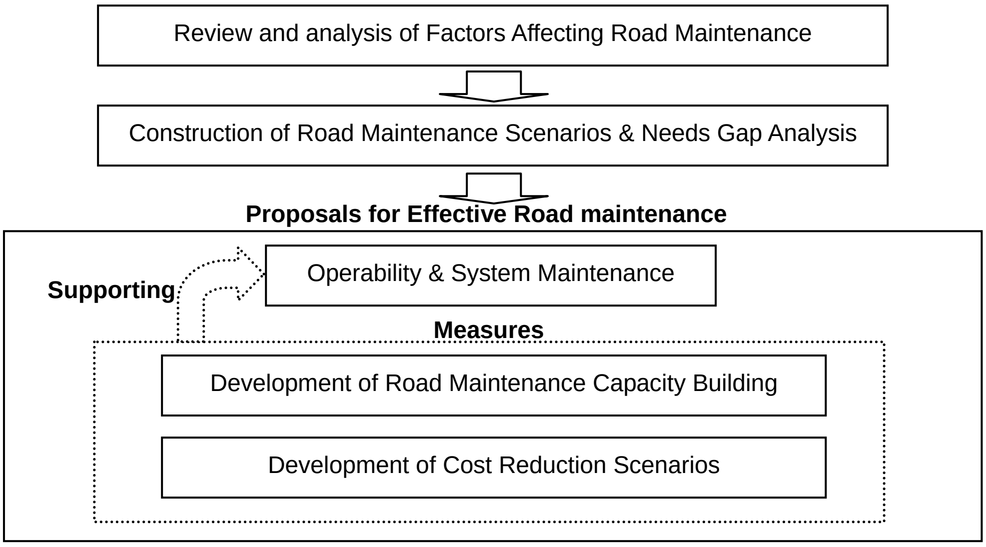


Figure 11.3.1 Developing an Effective road Maintenance

These issues were analysed in detail in the Road Sector Strategy review. It was found that a major constraint to implementing maintenance is the lack of available technical resources at provincial level to execute and supervise works. Steps are being taken to develop local contractors, which can respond to this demand.

11.3.2 Impacting Factors on Maintenance Activities

There are a number of key factors that influence road maintenance costs. These factors can be split into physical and non-physical. Key physical factors are defined as follows:

- Road surface type
- Traffic flows and composition
- Road surface condition
- Climate
- Terrain

Data on these factors can be reviewed and incorporated into the HDM-4 model, which also includes data on maintenance frequency and unit costs as well as on vehicle operating cost.

The non-physical factors that affect road maintenance cost, are of a more complex nature than the physical factors.The non-physical factors are definedas follows:

- Capacity of private contractors and the perceived business environment
- ANE's managerial capacity
- Interactions between staff and organization

11.3.3 Realizing an Effective Road Maintenance System

(1) Development of Core Road Network for Prioritizing Maintenance

It is recommended that the following data be obtained from ANE's provincial delegations to be sent to ANE headquarters for planning and analysis purposes (to be incorporate into the HDM-4 method) and be updated continuously as a basis for the justification for fund allocation.

- Road Inventory Data
- Road Condition Data
- Traffic Data

In addition, maintenance records and data should be retained on a computer database to enable ANE engineers to monitor the effectiveness of maintenance activities and standard costs for each type of road. A user-friendly database is needed to process maintenance data and allow for analysis and forecasting. Recently, ANE has been establishing systems that will allow the collection and analysis of road condition data for paved roads, to add to the procedures that exist for unpaved roads.

(2) Development of Operability and Systematic Maintenance

A standard system for the preparation of maintenance work-plans is required, including a review of unit rates for maintenance works in order to effectively and efficiently develop maintenance plans. Standard procedures for this have been defined in the RSS. ANE has a program for estimating unit costs for routine and periodic maintenance works.

(3) 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 provideds timely maintenance interventions especially in the rainy season, while enhancing income and employment generating activities for local people. Particularly, the length man 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).

The Road Training Center of MOPH , which is located in Chimoio, can play an important role in providing professional training for road technicians through the delivery of training courses to both private and public sector. However, new training topics (courses) on management, engineering, supervision, monitoring and maintenance activities are required for the various staff levels of both contractors, consultants and clients. Training should be of both a formal and informal nature (on-th-job training). Quantity control management is another crucial issue to be emphasized in the training courses .

(4) Development of Road Maintenance Manuals for Capacity Building

ANE has outsourced the supervision of road maintenance contracts to local consultancy firms. At present manuals have been developed for maintenance planning of unpaved roads, procurement and contract management and spot improvement design. There may be a need for developing a manual for the maintenance of paved roads.

11.4 Traffic Management Operation

11.4.1 Introduction

Traffic management operations comprises of mainly over-load control and a road safety component. The former is essential to ensure that the design life of the pavement structure is achieved. Pavement design does not normally consider scenarios for over-loading, which inevitably leads to premature pavement failure. The road safety component, is composed of traffic law enforcement by police, installation of road safety facilities and road safety education programs. This component is of particular importance to the rural people living along the Study Road. They are not used to high-speed driving vehicles, which will occur after the upgrading of the Study Road.

11.4.2 Axel Load Control Operation

The deterioration of paved roads caused by traffic flow is a result of both the magnitude of individual wheel loads and the number of times these loads occur. On the existing Study Road, heavy over-loaded vehicles are often observed, particularly vehicles carrying timber. The objective of controlling axle load is to maximize the road economic life and minimize the cost of maintenance. Normally, when axle-load limits are exceeded, the total cost and damage to roads increases rapidly. Therefore, axle-load controls are a crucial factor to protect roads and prevent road surface damage.

Existing methods for controlling overloading rely on the use of axle-load weighing stations located at various strategic sections on the national road network. Weighing stations will be an important measure to deal with the problem of overloaded vehicles. The following is recommended:

- Strict enforcement of axle-load regulation.
- Set up a weighing station at some locations on the road.
- Educate transporters that work in particular sectors such as timber logging heavy industry, etc….

11.4.3 Traffic Safety Operation

The current level of road fatalities, almost 20 persons per 10,000 vehicles, is the highest among Southern African countries. The strategy for traffic safety recommends to include the following elements:

- Education
- Enforcement

Coordination between drivers and pedestrians

The key issues in the strategy relate to:

- Improved driving skills
- Use of helmets and seat belts
- Combat drunk driving and excessive speeding
- Improved night-time visibility for pedestrians, bicyclist and motorcyclist
- Traffic management, signing and delineation of roads

The above-mentioned issues should be controlled by the road administrators, which are ANE, the police and other relevant organizations. These aspects lie outside the control of

ANE, and are the responsibility of INAV.

The following measures are recommended to reduce the level of road fatalities;

- Media campaigns on road safety
- Road safety awareness and education for rural children in communities and schools
- Strict enforcement of driver’s license issuance and renewal
- Enforcement of traffic violations
- Strict vehicle inspection for registration and renewal

In this Study, a road safety awareness campaign was conducted as a pilot project in cooperation with local NGOs. It included poster production by schoolchildren, performance of theater play that demonstrates importance of road safety, installation of pedestrian crossing markings, etc…. This kind of activity should be continued after commencement of the project. Further analysis and lessons learnt from the pilot project are presented in Part-4 Chapter 4 Pilot Projects.

The following measures are recommended for designs of other road improvement projects:

- Signs, guide posts and road markings
- Reserved and paved bus stop areas to allow bus to move off the road
- Speed control devices, especially at the entrance of villages and communities, as well as at a regular intervals in the towns
- Setting of appropriate speed limits suiting local conditions
- Roadside facilities (such as roadside station “Michinoeki” etc.) should be located outside the road reserve, with provisions for customer parking

Failure to maintain the signs and speed markings will significantly diminish their effectiveness as they fade away over time. Surface texture needs to be maintained with regular reseals, especially where traffic speeds are expected to be high.