NATIONAL ROAD ADMINISTRATION (ANE)
GOVERNMENT OF REPUBLIC OF MOZAMBIQUE

PREPARATORY SURVEY
FOR
NACALA CORRIDOR ROAD NETWORK
UPGRADING PROJECT
IN
THE REPUBLIC OF MOZAMBIQUE

FINAL REPORT
MAIN REPORT

MAY 2018

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
EIGHT-JAPAN ENGINEERING CONSULTANTS INC.
KOKUSAI KOGYO CO., LTD.

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TABLE OF CONTENTS

Page

CHAPTER 11 Implementation Plan

CHAPTER 12 Environmental and Social Considerations

LIST OF FIGURES

Page

LIST OF TABLES

Page

List of Abbreviations

AADT .... Annual Average Daily Traffic
AASHTO .... American Association of State Highway and Transportation Officials
ACV .... Aggregate Crushing Value
AHWL .... Annual High Water Level
ANE .... National Road Administration / Administração Nacional de Estradas
ARA .... Regional Water Administration / Administração Regional de Águas
CBD .... Central Business District
CBR .... Crude Birth Rate
CFM .... Mozambique Ports and Railways / Portos e Caminhos de Ferro de Moçambique
CFMP............. Cenario Fiscal de Medio Prazo/Medium Term Fiscal Framework
COI.................. Corridor of Impact
CSIR: .... Council for Scientific and Industrial Research
DNA:............... National Water Directorate
DNAIA: .... National Directorate of Environmental Impact Assessment
DPCA: .... Provincial Directorate for Coordination of the Environmental Affairs
DPTADER: ... Provincial Directorate of Land, Environmental and Rural Development
Direcção Provincial da Terra, Ambiente e Desenvolvimento Rural
DUAT .... Right to Use and Benefit from the Land /Direito de Uso e Aproveitamento da Terra
EIA :................ Environmental Impact Assessment
ENDE:............. National Development Strategy / Estratégia Nacional de Desenvolvimento
ESAL: .... Equivalent Standard Axle Load
FDI:................. Foreign Direct Investment
FHWA:............ Federal Highway Administration
HEC-RAS: ...... Hydrologic Engineering Centre-River Analysis System
HHWL: .... Historical High Water Level
ICOR:.............. Incremental Capital-Output Ratio
IFZ: .... Industrial Free Zone
INAM:............. National Institute of Meteorology / Instituto Nacional de Meteorologia
ITS: .... Intelligent Transport Systems
LA:.................. Loss by Abrasion
MDD:.............. Maximum Dry Density

MOPWH: .... Ministry of Public Works, Housing and Water Resources
MICE: .... Meetings, Incentives, Conferences, and Exhibitions
MICOA: .... Ministry of Coordination of Environmental Affairs
MITADER: ..... Ministry of Land, Environment and Rural Development /
Ministério da Terra, Ambiente e Desenvolvimento Rural
NDS: .... National Development Strategies
NEC: .... National Environmental Commission
NEMP: .... National Environmental Management Programme
OD.................. Origin and Destination
OE:.................. Orçamento do Estado / State Budget
OMC: .... Optimum Moisture Content
PARP : .... Action Plan for Reducing Poverty / Plano de Acção de Redução da Pobreza
PC: .... Prestressed Concrete
PCU................. Passenger Car Unit
PES: .... Economic and Social Plan / Plano Económico e Social
PESOP: .... Economic and Social Plan-Provincial Budget /
Plano Económico e Social-Orçamento de Provincial
PII: .... Programa Integrado de Investimentos
PMU:............... Project Management Unit
PQG: .... Government Five Year Programme/Plano Quinquenal do Governo
PRISE: .... Programa Integrado do Sector de Estradasl
PR: .... Resettlement Plan
PSDP:.............. Provincial Strategic Development Plan
RAP :............... Resettlement Action Plan
RSS: .... Road Sector Strategy
SATCC: .... Southern Africa Transport and Communications Commission
SER:................ Simplified Environmental Report
SEZ: .... Special Economic Zones
TAZ................. Traffic Analysis Zone
TFR:................ Total Fertility Ratio
TRMM: .... Tropical Rainfall Measuring Mission
TIA:................. Traffic Impact Assessment
UNCCF: .... United Nations Framework Convention on Climate Change
ZAE:................ National Agro-Ecological Zoning / Zonamento Agro-Ecologico National

CHAPTER 1 Introduction

1.1 Background of the Project

The Republic of Mozambique has developed her road network mainly on intercity arterial roads which connect major cities in the country. Roads are classified into national roads comprising primary roads and secondary roads, and regional roads comprising tertiary roads and vicinal roads, urban roads and unclassified roads. The National Road Administration (*Administração Nacional de Estradas*, *ANE*) is in charge of 30,464 km of roads which consist of 7,344 km (24%) paved sections, and 23,120 km (76%) unpaved sections. When it comes to the road condition by province in 2015, about 70% of the road was "good" or "reasonable" in Maputo Province, Inhambane Province, Manica Province and Niassa Province, whereas it was less than 50% in Nampula Province[1].

Development of social and economic infrastructure is prioritised in the Mozambican Government Five Year Programme (*Plano Quinquenal do Governo*, *PQG*) (2015 – 2019), and, maintenance and improvement of roads and bridges are strategic targets to achieve the goal. The Poverty Reduction Strategy Paper (2011 – 2014) (*Plano de Acção de Redução da Pobreza*, *PARP*), as an action plan of the previous PQG (2010-2014) focusing on the poverty reduction, sets increasing production and efficiency of agricultural and fishery industries as primary targets. To achieve these primary targets, maintenance of roads and bridges as well as pavement level is selected as PARP's outcome index. This means that development of the road sector is one of the key issues in Mozambique to be taken into consideration. In terms of the road development plan, the third Road Sector Strategy (RSS) defines seven international corridors including Nacala Corridor and the national arterial roads connecting the international corridors to be developed.

Among these major corridors, Mozambique Highway (N1), which penetrates the country from North to South, and Maputo Corridor and Beira Corridor, which connect the capital city of Maputo and adjacent countries, maintain a high level of service. Due to the civil war, road development of Nacala Corridor and Pemba Corridor, which connect the eastern coastal area and the western border area in the northern region, is still left behind. Especially, the ratio of paved roads in Nacala Corridor region is far below the national average. The unpaved condition restricts vehicles to very low speeds, and causes less visibility due to dust, which is unsafe for driving. Especially, there are a lot of sections of unpaved roads that are impassable during the rainy season. Pavement of regional roads is considered as a national issue.

Prior to this survey, JICA and other international development partners have assisted with a series of projects in the road sector of this region. In the post evaluation mission of "The Project for Reconstruction of Bridges on Main Roads（Phase 2）" including reconstruction of Natete Bridge (Road Number 8) (Exchange of Note in September 2000), the importance of road development of this corridor was identified. Then, a feasibility study and detail design of the "Montepuez Lichinga Road Project" (L/A in March 2007) and "Nampula Cuamba Road Upgrading Project" (L/A in March 2010) were conducted by the JICA and counterpart fund of Japan, respectively. These projects are currently under construction. The "Mandimba Lichinga Road Upgrading Project" (L/A in November 2013) is also ongoing with assistance from AfDB and JICA. The

[1] Economic and Social Plan Integrated Road Sector Program (PES/PRISE 2016)

"Project for Nacala Corridor Economic Development Strategies in the Republic of Mozambique" or PEDEC-Nacala, which was conducted by JICA and the Ministry of Economy and Finance from 2012, formulates development strategies to guide appropriate development and investment in the Nacala Corridor. The project was officially endorsed by the Cabinet in November 2016. PEDEC-Nacala also features a road sector and three proposed roads; Nacala Port Access Road, Nampula Southern Bypass Road and Cuamba Bypass Road; as high priority roads. Other related projects in this region and the road sector include the "Project for Capacity Development of Road Maintenance by JICA" (from August 2011 to July 2014), the "Project for Urgent Rehabilitation of Nacala Port Development" (Japanese grant aid agreed in December 2012) and the "Project for Improvement of Nacala Port" (Japanese ODA Loan, Phase 1 L/A in March 2013, Phase 2 L/A in June 2015).

Under these circumstances, passenger and cargo traffic volumes are drastically increasing in Nacala, Nampula and Cuamba Cities on the Nacala Corridor as population grows. Since intercity and arterial roads penetrate the cores of these cities, the surge in traffic volume results in traffic congestion in the centres of the cities. There are also issues of traffic safety of pedestrians and living environment of residents along the roads. In addition, under the expectation that the railway track rehabilitation from Tete province to Nacala Port will be completed by 2015, the cargo volumes handled by Nacala Port are predicted to be almost 10 times the current volume in the next 15 years. Therefore, the significant increase of frequency of railway operation as well as cargo vehicle volume is expected. It is evident that this could cause deterioration of the urban function and urban environment.

In order to alleviate traffic congestion and minimise the negative impact on the urban environment, the development of bypass roads to detour around urban residential areas and to reduce railway crossing points for Nampula and Cuamba as well as the road development of the new port access for Nacala Port are essential.

1.2 Objectives of the Survey

This study aims to conduct the Feasibility Study including preliminary design, preliminary cost estimation and to formulate institutional arrangements for project implementation, operation and maintenance systems and to support the social and environmental considerations by the government of Mozambique on the "Nacala Corridor Road Network Upgrading Project" which comprises three components. The result of this feasibility study on the Project will be utilised as basic information for appraisal of a Japanese Yen-Loan project, but it is not decided if it will be a Japanese Yen-Loan project yet.

The Environmental Impact Assessment (EIA) and Resettlement Action Plan (RAP) are to be prepared by the Mozambican government by subcontracting to a local consultant using the budget of the ANE. This survey supports the Mozambican side by providing technical advice to ANE throughout the process including reviewing and commenting on the reports produced by the environmental local consultant. Since ANE's procurement of the environmental consultants was continuously being delayed, JICA and ANE agreed on June 28, 2016 that JICA concentrates its technical support for environmental and social considerations on the Nacala Port Access Road Project leaving the other two components out of its scope.

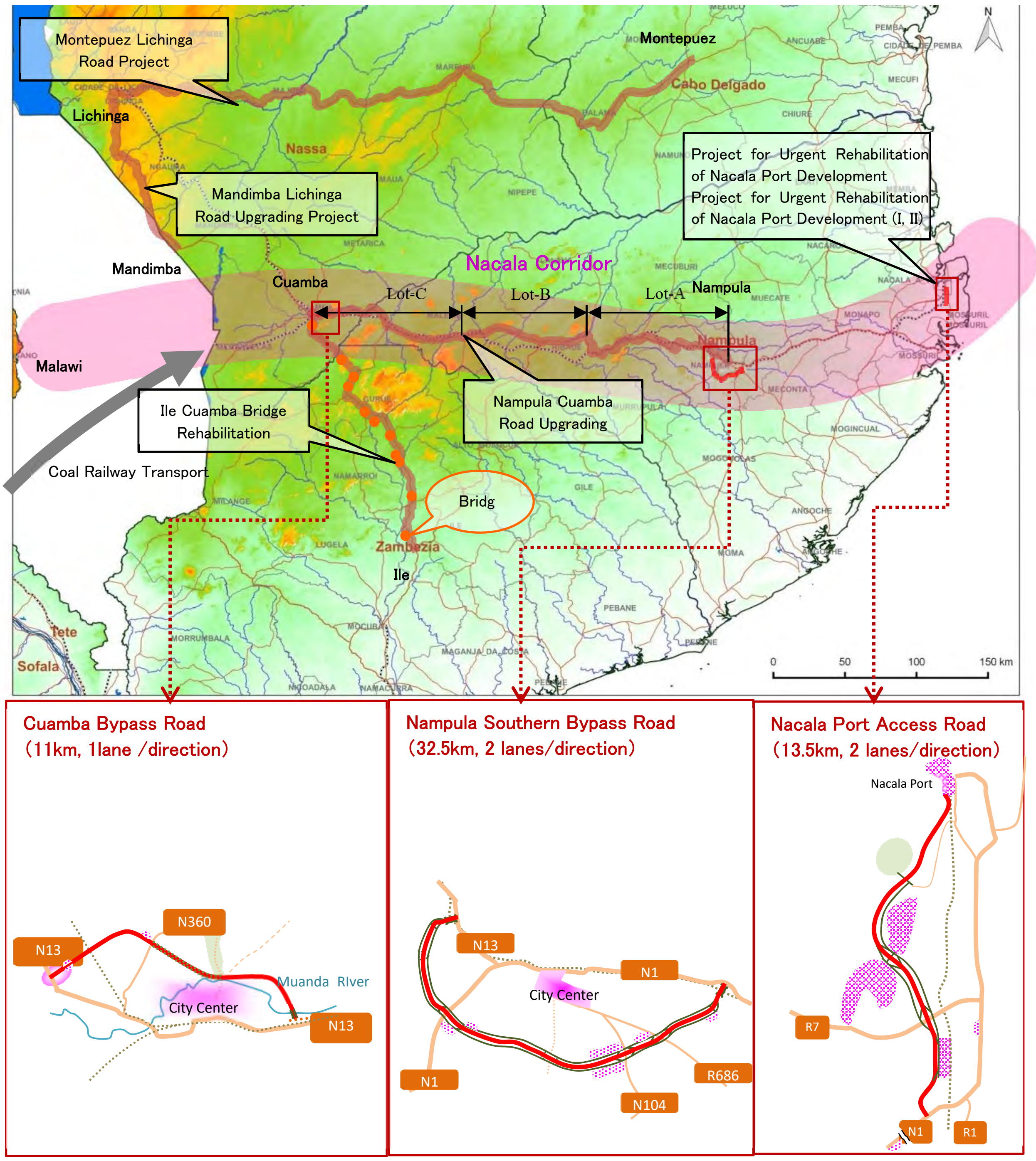
1.3 Project Scope: Study Area and Target Roads

This project, namely the "Nacala Corridor Road Network Upgrading Project", aims to develop and promote the Nacala Corridor Region by providing a new essential road network, especially providing the road to ensure the traffic diversion and to promote urban development with urban roads.

The target areas and roads of the study are located within the Nacala Corridor Region and especially those located in Nampula City and Nacala City in Nampula Province, and Cuamba City in Niassa Province. The target roads are listed as follows[2];

- Nacala Port Access Road (Nacala City)
- Nampula Southern Bypass Road (Nampula City)
- Cuamba Bypass Road (Cuamba City)

[2] As explained in '1.2 Objectives of the Survey', technical support for environmental and social considerations was provided only to Nacala Port Access Road Project leaving the other two road projects out of its scope.



Source: The Study Team

Figure 1.3.1 Locations of Target Roads

1.4 Scope of the Survey

This preparatory survey shall cover the following items;

- Review and confirmation of background and necessity of the project
- Road design and engineering for three target roads, which include a) natural condition survey, b) visual site survey, c) preliminary design, d) cost estimate, e) economic analysis and f) traffic analysis.
- Formulation of the project, which consists of implementation schedule, procurement packages and project effect indicators
- Confirmation of institutional and organisational setups for the project implementation
- Formulation of operation and maintenance plan
- Assistance for execution of EIA and RAP by ANE

1.5 Rationale of Target Roads

1.5.1 Nacala Port Access Road

(1) Situation and Issues in the Road Sector in the Area

As a gate city of the Nacala Corridor Region and adjacent landlocked countries, Nacala Bay Area, which comprises Nacala City, Nacala-a-Velha District and adjoining areas, is expecting dramatic growth in the population and economy. The status of the Special Economic Zone (SEZ) together with a deep sea port is attracting Foreign Direct Investment (FDI). With the growth of the area, a significant increase of population[3] is expected. To ensure the economic development, improvement of roads capacity to meet the future demand is essential.

In addition, freight vehicles, including large container trailers that go from/to the port, run through the city centre of Nacala City which hampers the economic activity inside the city. Thus, it is highly expected to separate inner city passenger vehicles and freight vehicles to the Port.

(2) Road Development Policy and the Role of the Nacala Port Access Road

To solve the issues, PEDEC-Nacala proposed the Nacala Port Access Road which by-passes the central urban area of Nacala City. The road will connect the Nacala Bay Area to N12 for Nampula. In between, it will cross with R702 bound for Nacala-a-Velha. The road will realize direct access to the Port area without going through the urban area of Nacala City.

At the same time, the road will serve as the major access to the large scale Industrial Free Zone (IFZ) and the industrial area for the spontaneous factory development. In addition, a multi-modal transport terminal (Shunting Yard) which connects road transport and the railway is planned along the alignment of the proposed road. Without development of the Port Access Road, these plans will not be materialised.

[3] The current urban population of 233,825 in 2007 in the Nacala Bay Area is expected to increase to 927,100 in 2035 according to PEDEC-Nacala.

Source: The Study Team

Figure 1.5.1 Passenger and Freight Vehicles in Nacala City

1.5.2 Nampula Southern Bypass Road

(1) Situation and Issues in the Road Sector in the Area

Nampula City is a dominant city in the Northern Region of Mozambique and it is estimated that the Greater Nampula, which includes Nampula City and 3 administrative posts (Anchilo, Namaita and Rapale) in Nampula District, will continue steady growth in line with the development of Nacala Corridor Region. The Nampula City will continue to play a key role as an administrative and commercial centre. Thus, it is estimated that the urban population of the Greater Nampula will be 1,328,900 in 2035 while it was 471,171 in 2007.

One of the key obstacles to development is concentration of traffic in the city centre. As the national corridor of the Mozambique Highway (N1 Road) located in the centre of the city, intercity long distance through traffic and inner city traffic share the same road space. This causes traffic congestion and hinders economic activity. Therefore, these two types of traffic should be separated.

(2) Road Development Policy and the Role of the Nampula Southern Bypass Road

The Nampula Municipal Government developed a land use plan together with a ring road plan including the Northern and Southern Bypass Roads. The Nampula Southern Bypass Road is proposed as a high priority project in the road sector for the Grater Nampula Area Programme.

The Southern Bypass Road starts from N1 Road in the east of the city and ends at the intersection with N13 Road in the west of the city, bypassing the traffic from/to the Nacala Port to/from inland. In between, it will cross with R686 and N104 radially.

The bypass road is expected to reduce the traffic congestion caused by the through traffic. In addition to that, the construction of the road will stimulate the demand for industrial area development along it, which will contribute further growth of the Greater Nampula Area..

Source: The Study Team

Figure 1.5.2 Traffic Congestion on N1 Road in Nampula City

1.5.3 Cuamba Bypass Road

(1) Situation and Issues in the Road Sector in the Area

Cuamba city is located at a strategic location in the Nacala Corridor Region where two railway lines from Malawi and Entre Lagos meet. As the road improvement of N13, road improvement of the Nampula – Cuamba segment is ongoing. As a result of road improvement, a significant population[4] and economic growth is expected, together with increase of traffic. With the expansion of the city, new development is expected for both residential areas and industrial area, such as factory for agricultural processing industry.

There are not so many highway and most of the roads in the city are not paved yet, so N13 road, which is passing the heart of the city centre, plays a major road for intra-city traffic. In addition to that, traffic including domestic intercity and international freight transport interfere with inner city traffic. To meet the future traffic demand through the city, the separation of through traffic is required.

In Cuamba, railway lines cross the city centre. As the frequency of railway operating will significantly increase due to coal transport, the intersection of road and railway can be a bottleneck for road traffic in the city. Therefore, physically separating road traffic from railway traffic is essential.

(2) Road Development Policy and the Role of the Cuamba Bypass Road

Dividing through traffic from the city centre is ranked as the high priority project in the road sector for Cuamba Logistics Centre Area Programme. In this context, the Cuamba Bypass Road is proposed by the PEDEC-Nacala. The new road by-passes the city centre of Cuamba to the north, connecting N13 to each other. In between, it will cross with N360. By using the road, through traffic can bypass both the city centre and the grade intersection with railway track.

[4] The population of Cuamba City is expected to increase from 79,013 in 2007 to 267,000 in 2035.

Source: The Study Team

Figure 1.5.3 Traffic on N13 Road in Cuamba City

1.6 Organisation of the Project and Survey Team

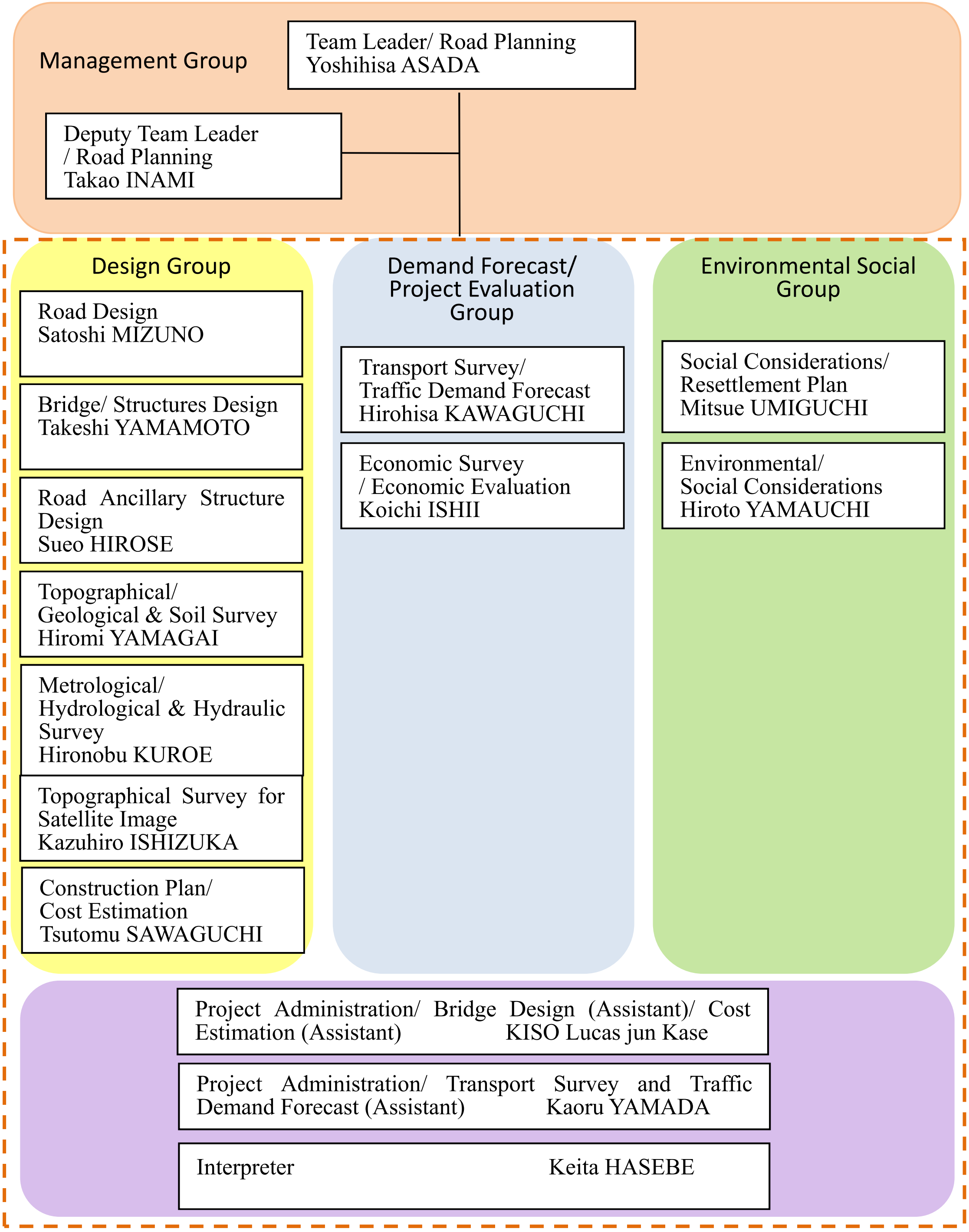
1.6.1 Project Organisation

The project implementation agency is the National Road Administration (*Administração Nacional de Estradas*, *ANE*), and, the Director of Projects (DIPRO) is the director in charge of the Project. Under the DIPRO, the Head of the Department of Studies and Projects and the Head of the Division of Roads are key counterpart officers. Other relevant directorates and departments are also involved in the project for cross-cutting issues depending on needs (Please refer to the organization chart of ANE in Chapter 11.4.1 Figure 11.4.4 for the detail structure of ANE). In addition to ANE's headquarters, focal point officers under ANE delegate offices in Nampula and Niassa Provinces are appointed.

For the smooth implementation of the survey in the field, focal point officers in Nampula District and Nampula Municipality were appointed based on the request from the Study Team.

1.6.2 Survey Team

Organisation of the Study Team is illustrated in Figure 1.6.1.



Source: The Study Team

Figure 1.6.1 Study Team Organisation

1.6.3 Steering Committee

The Steering Committee (S/C) of the Project has been established as the highest decision-making body, and is chaired by the Director General, ANE. The S/C members are mainly from the central government organisation while opinions from local authorities are collected and discussed through meetings with the Study Team and the delegates.

Table 1.6.1 Members of the Steering Committee

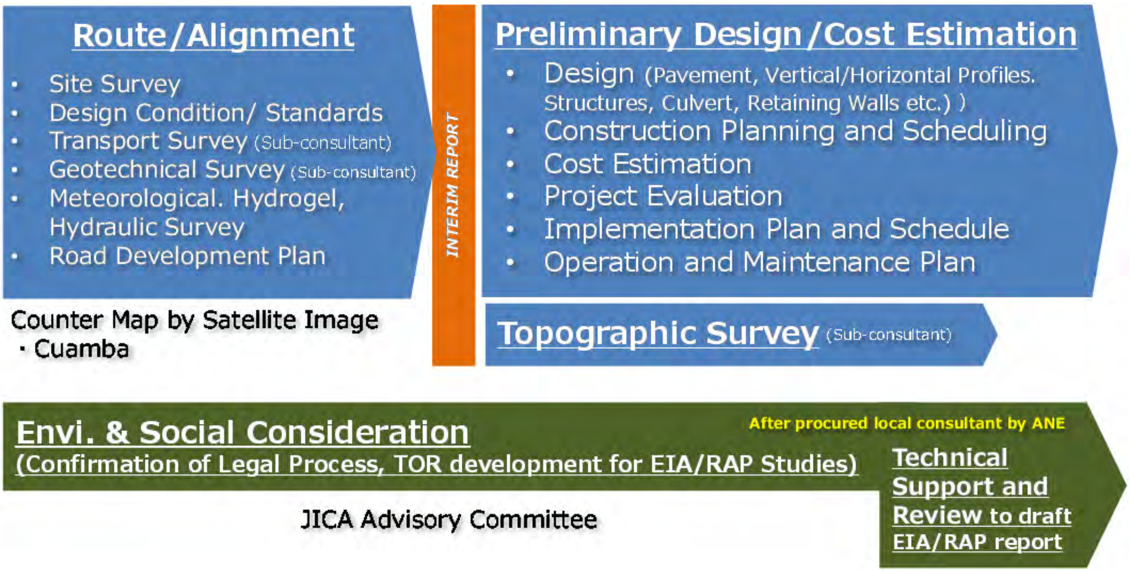
Organisation
National Road Administration (ANE)
Ministry of Public Works, Housing and Water Resources (MOPWH)
Road Fund
Ministry of Transport and Communication (MTC)
Ministry of Land, Environmental and Rural Development (MITADER)
Ministry of Industry and Commerce (MIC)
Ministry of Economy and Finance (MEF)
National Land Transport Institute (INATTER)
Special Economic Zones Office (GAZEDA)
Mozambique Ports and Railways (CFM)
Northern Development Corridor (CDN)
Porotos de Norte
The United Nations Human Settlements Programme (UN-Habitat)

Note: Chairperson is the Director General of ANE

1.7 Progress of the Survey

1.7.1 Survey Process and Schedule

The survey process is depicted in Figure 1.7.1. As the Interim Report of this project suggested, a survey on design condition and standards, transport survey, and formulation of a road development plan was established, and parts of the topographic, geotechnical, meteorological, hydrological and hydraulic surveys were implemented. Based on this, routes/ alignments of the three components of the project were proposed.



Source: The Study Team

Figure 1.7.1 Survey Process and Schedule

1.7.2 Activities during the Survey

After preparation of the inception report, direction on this study including backgrounds, objectives of the Project, the initial alignment, technical considerations, procedure of environmental and social considerations, schedule, and application of advanced technologies were discussed in the first Steering Committee Meeting held on 27th April, 2015.

Consultation with local authorities was also conducted in April and June 2015 for the purpose of discussing issues of the Project. After the consultation meeting on each municipality, comments were submitted in written format by each authority. Comments included consistency with the plans of the municipalities and ongoing projects, requests for connection to the existing road network, and if the facilities might affect the alignment plan and so forth.

From an engineering perspective, technical and design standards to be followed were collected. The typical cross section was prepared based on these standards as well as technical discussions with ANE. Together with consultation results and engineering analysis on gradient, curve, connection with existing network, required bridges and earth work, and the routes/ alignments of the proposed three components of the project were prepared. After discussions with ANE officers, the proposed routes/ alignments were submitted to the Chairperson of the Steering Committee, the Director General of ANE.

Procurement of local consultants for the traffic survey and a package of geotechnical, topographic, hydrological and hydraulic surveys were completed. The field transport survey and traffic demand forecast have been implemented on the basis of the aggregated data. The field topographic survey has been implemented after ANE submitted letters to local authorities on the routes/ alignments of the Project. Also, the geotechnical survey has been implemented on the basis of the sample data retrieved there.

The preliminary design and cost estimation have been implemented based on a design suggested in the Interim Report, which was based on the survey outcome and the data obtained by the geotechnical survey.

The project evaluation has been implemented on the basis of the cost consisting of the construction cost as above and the benefit calculated by the outcome of the traffic demand forecast with/without the implementation of this project.

With regard to environmental and social considerations, the first meeting of an advisory committee on environmental and social considerations for JICA was held on 13th July, 2015 in Tokyo to discuss legislative and regulatory frameworks regarding the environment in Mozambique, route alternatives and terms of reference of the environmental survey. Based on their advice, the environmental survey was implemented by ANE. JICA Study Team provided technical support and advice to ANE throughout this process, including reviewing and commenting on the reports produced by the environmental local consultant.

The outcome of the survey was summarised in the Draft Final Report-2, and the contents of the report were discussed in the third Steering Committee Meeting held on 13th April, 2018.

1.8 Contents of the Final Report

In Chapter 1, the background, objectives, study area and target roads, rationale of the target roads, organisation of the Project and the Study Team and the progress of the survey are discussed.

Chapter 2 summarises the development plans and policies related to this project including the National Strategic Plan (2015-2035), Integrated Investment Programme (PII) (2014-2017), Integrated Road Sector Programme (PRISE) (2012-2014), the Nacala Corridor Regional Development Strategy (PEDEC-Nacala) and the urban plans of local authorities.

Chapter 3 describes the present national and socioeconomic conditions of the target roads. The basic natural condition required to be understood for technical and environmental considerations such as meteorology, topography, hydrology, and geology are described. Population and regional economies are also summarised.

Chapter 4 is on traffic surveys and preliminary analysis on traffic demand. Basic assumptions as well as a summary of ANE annual average daily traffic, PEDEC-Nacala transport survey and traffic surveys of this project are mentioned. Preliminary analysis on time-series traffic volume is conducted.

Chapter 5 describes a demand forecast of the future traffic on the basis of Chapter 4.

Technical and design standards utilised for this study are mentioned in Chapter 6 including road design standards, geometric standards, regulations on right of way, and clearance between railways and power lines.

Chapter 7 discusses alternative routes/ alignments. Considering the proposed alternative routes/ alignments of the three components of the Project, the results of consultations with local authorities, evaluation method, criteria and results are described.

In Chapter 8, preliminary design and estimated cost are examined. The implementation of the procedure of design, methodology of national conditions survey, pavement design, drainage design, structural and road design concepts, traffic safety facilities and cost estimation are mentioned as the outcome.

Chapter 9 suggests some of the newest technologies recommended for applying to the project road in order to improve the effect of the project.

Chapter 10 describes project evaluation based on the results of economic analysis of the project.

Chapter 11 proposes an implementation plan for the project regarding the implementation and maintenance system and a draft plan for the survey team as the discussion material going forward.

Chapter 12 describes the Environmental Impact Assessment (EIA) and Resettlement Action Plan (RAP) for the implementation of this project.

Finally, Chapter 13 presents the findings of the survey and recommendations for the next stage of the project.

CHAPTER 2 Overview of Road Sector and Development Plan

2.1 Overview of Road Sector

2.1.1 Road System in Mozambique

(1) Road Classification

The classification system of roads, which carry high ratios of both goods and passenger transport, is summarised in Table 2.1.1 and a network illustration is depicted in Figure 2.1.1. The classified roads consist of national roads (primary and secondary) and regional roads (tertiary and vicinal roads). These roads are administrated by the National Road Administration (ANE). Urban roads and unclassified roads fall under the jurisdiction of the municipal councils and the district administrations respectively. Urban roads are classified into four categories (primary, secondary, tertiary and unclassified such as footpaths) as well.

Table 2.1.1 Road Classification System

Category	Designation	Functional Definition	Numbering
National Roads	Primary Roads	Form the national trunk road network and link: Provincial capitals Provincial capitals and other cities Provincial capitals and main ports Provincial capitals and important border posts	(a):N1 to N100 (b):N101 to N199
	Secondary Roads	Form the secondary network complementing the trunk road network and link: Primary roads Provincial capitals and sea or river ports Primary roads and economic poles of high importance Primary roads and (other) border posts	N200 to N399
Regional Roads	Tertiary Roads	Tertiary roads link: Secondary roads with primary roads or with other secondary roads District centres District centres and administrative posts District centres and economic poles of high importance	R400 to R799
	Vicinal Roads	Vicinal roads link: Tertiary roads Administrative posts Administrative posts and other population centres	R800 onwards
Urban Road	Jurisdiction of the municipal council (43 municipalities in the country)		
Un-classified	Jurisdiction of the district administration (130 districts in the country)		

(a): Roads that constitute major routes (b): Other primary roads

Source: Final Report on the Reclassification of the Mozambique Road Network, 2003

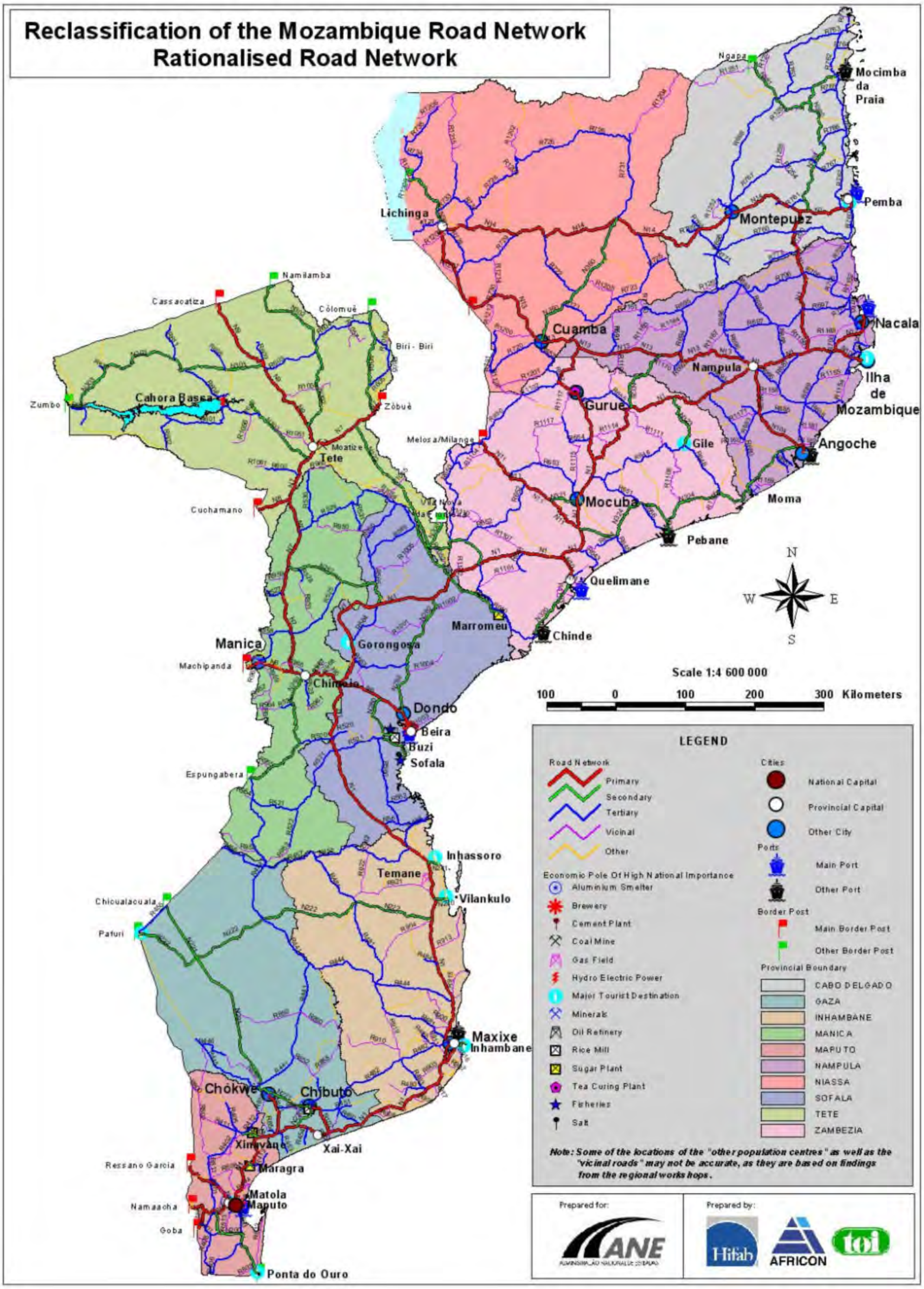
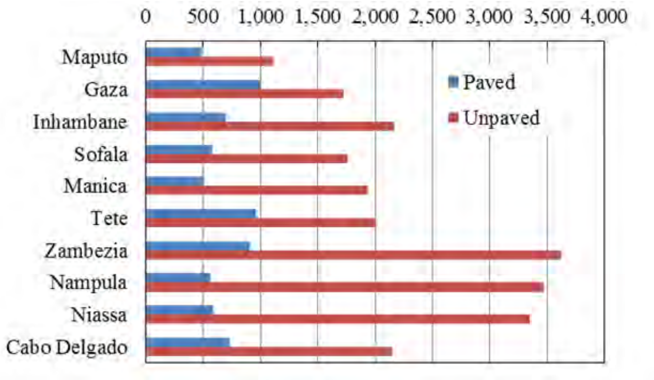


Figure 2.1.1 Classified Road Network in Mozambique

(2) Condition of Roads

According to the ministerial diploma no. 193/2005 July, the classified roads had reached a total length of 29,266 km with only 23% (6,812km) paved roads. According to PRISE in 2016, ANE managed the total length of the 30,464km of roads with 24% (7,344km) of paved roads. Figure 2.1.2 shows the data for the length of paved/unpaved roads in each province. Nampula and Niassa provinces still have a lot of unpaved roads; especially Niassa has a shorter paved road network even though it has the largest area of land in Mozambique. In the case of Nampula province, only 54% of the primary roads have been paved, Niassa has only 59%, Zambézia has 75% and Cabo Delgado has 67%, and the other 6 provinces have 100%.

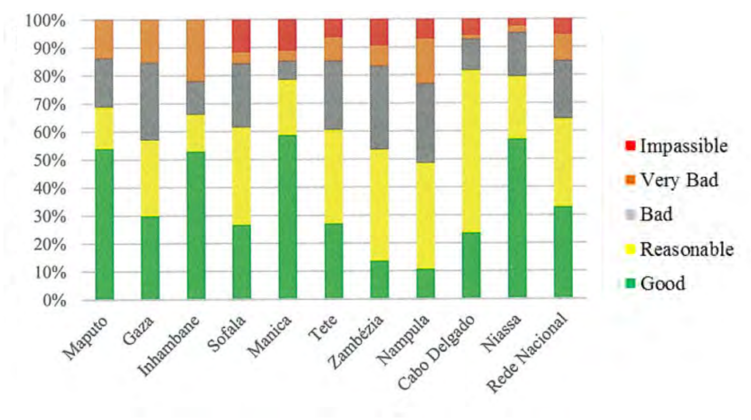


Unit: km,

Source: Condicoes de Transibilidade da Rede de Estradas Cllasificadas, ANE, 2015, 2nd Semester 2014

Figure 2.1.2 Length of Paved/Unpaved Roads in each Province

The road conditions in 2015 were reported as 64% were relatively good, 36% as bad and 6% as impassable. In the development indicator of PRISE 2012-2014, the percentage of "relatively good" condition was set as 70% in general and 87% in primary roads.



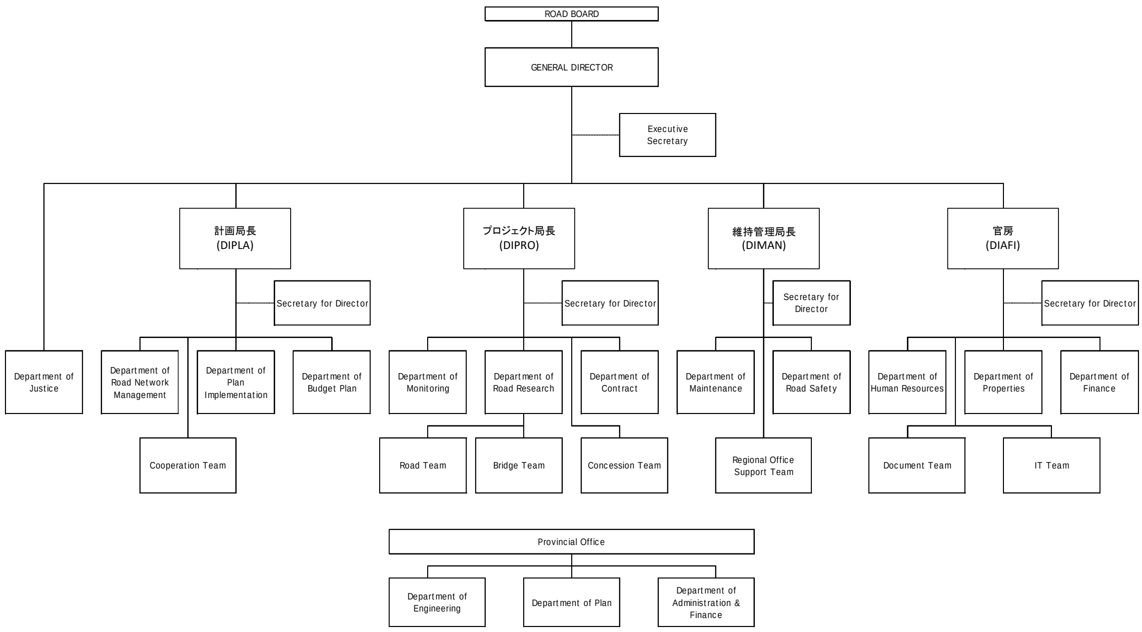
Source: PRISE 2016

Figure 2.1.3 Road Conditions in each Province (2015)

(3) Organisation Structure of ANE

Major reforms of the road sector have been implemented since 1999. In 1999, National Directorate of Roads and Bridges (DNEP) were separated from MOPH, and ANE was established (Decree 14/1999, 15/1999). In 2003, the Road Fund was separated (Decree 22/2003) under the World Bank's Road Management Initiative.

Mozambique's road network is currently managed by ANE, which reports to the Ministry of Public Works, Housing and Water Resources (MOPWH). The Road Fund is responsible for managing the funds for road maintenance to be collected by the Government in a sustainable manner



Source: ANE

Figure 2.1.4 Organisation of ANE

<u>Responsible Section for Project Implementation</u>

The Directorate of Projects (DIPRO) of ANE is responsible for road implementation such as rehabilitation and upgrading, as well as new road construction. ANE's Directorate of Projects has lengthy experience managing road implementation projects such as feasibility studies and design preparation for projects. The Provincial Delegation is responsible for supporting the DIPRO works as the liaison between the provincial and municipality governments. The social and environmental considerations including the resettlement action plan formulation is handled by the cross-cutting issue section under the director general's office.

<u>Section Responsible for Maintenance</u>

Periodic and routine maintenance of primary, secondary and tertiary roads is under the direct responsibility of the Directorate of Maintenance (DIMAN) and the Provincial Delegation

(DPANE) of ANE. DIMAN has a crucial role in ensuring that the delegations in the provinces are fully aware of and complying with the technical and operational guidelines for implementation of the annual maintenance plan; and that roads of all types (Primary, Secondary, Tertiary, vicinal, paved, unpaved) are being maintained and provided for. DIMAN also supports the provinces in the execution of the improvement, rehabilitation and construction of tertiary and vicinal roads. The directorate's role includes providing technical advice to municipal councils and districts on their road programs through the provincial delegations. Actual engineering works in DIMAN are outsourced to consultants. Routine / periodic works for road maintenance in each province are also outsourced to contractors with 2-year contracts.

The institutional responsibilities for the various classes of roads and types of road works are presented in Table 2.1.2.

Table 2.1.2 Responsible Institutions for the Road Sector

Road class	Rehabilitation /Upgrading	Periodic Maintenance	Routine Maintenance
Primary	ANE / DIPRO	ANE / DIMAN	ANE / DIMAN/DPANE
Secondary	ANE / DIPRO	ANE / DIMAN	ANE / DIMAN/DPANE
Tertiary	ANE/DPANE	ANE/DPANE	ANE/DPANE
Urban	Municipal Authorities	Municipal Authorities	Municipal Authorities
District (vicinal)	ANE/DPANE District	ANE/DPANE District	ANE/DPANE District
Un-classified	District Beneficiaries	District Beneficiaries	District Beneficiaries

(4) Other Road Implementation/ Management Institutions

In the interview with the Maputo Sul, E.P. with regard to the Maputo Circular Road, which has more than 70km length of urban bypass road, they stated that the road maintenance and management after opening shall be their own responsibility including the four toll gates. This is a different type of road management than the ANE's, and the method for road classifications and numbering of the roads within the road system in Mozambique is not clear.

2.1.2 Budget Allocation and Expenditure of ANE

(1) PRISE 2012-14

According to the PRISE 2016, the total resources provided was estimated as 25.0 billion MZM, equivalent to USD 403 million[1] in Table 2.1.3, comprising 25.8% of internal resources and 74.2% of foreign funds (external resources).

Internal revenue in PRISE 2012-14 consisted of tax revenues, earmarked revenue from the fuel tax, toll and road charges and other revenues. The structure of internal revenue comprised 36.4% of tax revenue, 47.2% of revenues consigned from fees levied on diesel, and 11.7% on gasoline, 3.8% road tax and 0.98% toll fee, and 0.01% of other revenue.

[1] 1 USD = 62.7 MZN in March 2018

Table 2.1.3 Summary of Funding Resources for the PRISE 2016

	Internal	External	Total
Cost and Administrative Support	553,740	39,254	592,994
Technical Training and Sectorial Studies	5,330	264,734	270,064
Maintenance of Roads and Bridges	4,545,426	3,260,327	7,805,753
Construction of Bridges	169,552	309,790	479,342
Rehabilitation of Bridges	193,565	0	193,565
Rehabilitation of Regional Roads	18,131	413,876	432,007
Tarring of Regional Roads	43,208	40,320	83,528
Rehabilitation of National Roads	39,223	0	39,223
Tarring of National Roads	496,007	4,170,058	4,666,065
Road Safety	21,526	62,762	84,288
Engineering Projects	0	130,085	130,085
Rural Development (IFAD)	0	140,262	140,262
Private-Public Partnerships	282,947	9,927,094	10,210,041
Urban Mobility	164,102	0	164,102
Total	**6,532,756**	**18,758,563**	**25,291,318**

Unit: 1,000 MZN

Source: PRISE 2016

(2) PRISE 2016 Expenditures

According to PRISE 2016, the total expenditure in 2016 was 10.7 billion MZN, which was 42.4% of the required budget. The expenditures with internal component amounted to 6.66 billion MZN (62.1%) and expenditures with external component amounted to 4.06 million MZN (37.9%). This implies that the support from the donors has dramatically decreased.

The allocation of the resources to different types of expenditures is summarised in Table 2.1.4. A total of 34% of its budget was allocated to Maintenance of Roads and Bridges, 19% for Tarring of National Roads, and 16% for PPP projects. About 1.7% was allocated for Technical Training and Sectorial Studies, and it was increased from 2014.

Table 2.1.4 Summary of Budget Allocations and Expenditures in 2016

	Budget	Expenditure	Execution
Cost and Administrative Support	592,994	928,700	156.6%
Technical Training and Sectorial Studies	270,064	182,255	67.5%
Maintenance of Roads and Bridges	7,805,753	3,685,281	47.2%
Construction of Bridges	479,342	993,979	207.4%
Rehabilitation of Bridges	193,565	163,624	84.5%
Rehabilitation of Regional Roads	432,008	183,357	42.4%
Tarring of Regional Roads	83,528	200,850	240.5%
Rehabilitation of National Roads	39,223	144,110	367.4%
Tarring of National Roads	4,666,065	2,233,321	47.9%
Road Safety	84,288	21,526	25.5%
Engineering Projects	130,085	5,834	4.5%
Rural Development (IFAD)	140,262	78,833	56.2%
Private-Public Partnerships	10,210,041	1,732,262	17.0%
Urban Mobility	164,102	164,102	100.0%
Total	**25,291,318**	**10,718,035**	**42.4%**

Unit: 1,000 MZN

Source: PRISE 2016

2.2 National and Regional Development Plans

The implementation plan in the road sector is developed based on the strategic objective of the national and regional development plan. In this section, the national and regional development plans in Mozambique are summarized, and the required role of road sector is described.

2.2.1 Types of Development Plans

Development plans under the National Planning System consist of the different types at the central, provincial and district levels and their target periods are as listed below;

(1) Long-term (more than 5 years)

In the central government level, there are the "Agenda 2025 *(Agenda 2025)*"[2], "National Development Strategy *(Estratégia Nacional de Desenvolvimento: ENDE)*"[3] and "Millennium Development Goals *(Objectivos de Desenvolvimento do Milénio)*"[4]. Each province prepares their own development plan as a "Provincial Strategic Plan *(Plano Estratégico da Província: PEP)*".

[2] Agenda 2025 is an action plan described within the long-term national development principals and guidelines.
[3] ENED is a strategy how to realize the principal and development guidelines set by the Agenda 2025.
[4] Millennium Development Goals (Objectivos de Desenvolvimento do Milénio) 2010 reports the progress and expectations into 2015 for the 8 indicators, such as poverty, primary education, gender, health and accessibilities to infrastructure and its services.

(2) Mid-term (Five year) development policies (for each administration)

Central government prepares the "Government Five Year Programme *(Programa Quinquenal do Governo: PQG)*", "Poverty Reduction Strategy Paper *(Plano de Acção para Redução da Pobreza: PARP)*" to describe the target of development with prioritised policies[5]. In line with the PQG and PARP, each sector ministry sets their own Strategy.

(3) Scenarios of budgetary plan (every 3 years)

The central government, provinces and districts prepare the "Mid-term Expenditure Framework *(Cenario Fiscal de Medio Prazo: CFMP)*" as three year budget plans. They are revised every year for the next 3-year term.

(4) Annual action plan (every year)

Finally, the "Economic and Social Plan *(Plano Económico e Social: PES)*" is prepared by the central government as an annual budget plan. The provinces and districts prepare similar plans called the *"Economic and Social Plan and Budget (Plano Económico e Social-Orçamento de Provincial)"* in one document. And the annual national budget plan is entered into the State Budget Plan (Orçamento do Estado: OE).

Since the year of 2012, under the situation of the starting of coal exports and looking at the potential for mineral resources, energy and agro-economy, the government recognised the needs of the integrated infrastructure developments and started formulating the "Integrated Investment Programme *(Programa Integrado de Investimentos:PII)*".

Among the above development plans, the outline of the ENDE, PII and road sector strategy, which are highly related to the target roads are summarized in the following sections.

2.2.2 National Development Strategy/ Estratégia Nacional de Desenvolvimento (ENDE) (2015-2035)

The National Development Strategy has been prepared with the need to ensure the implementation of development strategies recommended in the Agenda in 2025, as a vital tool for the achievement of the national development vision. This strategy shall be implemented through coordinated actions towards the horizon of 20 years, ensuring economic and social development is balanced and sustainable. These actions include integrated policies aimed at generation of wealth and ensure income redistribution for realisation of equity.

In order to promote the national development, the integrated industrialisation in the structural transformation of the economy is the mechanism in which the country shall invest because it is a decisive factor. On one hand, this process needs the establishment of economic and social policies.

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[5] The priority policies of POG are; a) Consolidating National Unity, Peace and Sovereignty, b) Develop the Human and Social Capital, c) Promoting Employment, Productivity and Competitiveness, d) Develop Economic and Social Infrastructure, and e) To ensure sustainable management and Transparent Natural Resources and Environment.
The three important pillars for PARP are; a) Increase output and productivity in Agricultural and Fisheries Sectors, b) Promote employment, and c) Fostering Human and social development.

This National Development Strategy aims to improve the living conditions of the population through structural transformation of the economy, and expansion and diversification of the production base. It identifies as the main challenge for the Economy increasing the competitiveness of the economy by diversifying the economy; investing in development poles; investment in human capital, infrastructure and in research and innovation, which are described as four pillars;

- **a.** Development of human capital (socialised training for marketing; institution and expansion of a vocational education and improving health standards and social protection).
- **b.** Development of production base infrastructure (investment and planning of infrastructure: industrial parks, special economic zone (ZEE), water resources, power plants, roads, ports and railways, definition of residential areas and state reserves).
- **c.** Research, innovation, and technological developments (creating specialised research and development centres (R&D) in the following areas: agriculture, livestock and fisheries; energy; mineral resources; management of water resources and ICT.
- **d.** Coordination and Institutional Coordination (improvement of public institutions, improving coordination and inter-sectoral coordination, reform of legislation and creation of institutions that serve the industrialisation strategy).

This National Development Strategy strongly emphasises an integrated approach of action by the Government, which is to create the special economic zones matching the potential of each region and industrial parks along the development corridors.

2.2.3 Integrated Investment Programme/ *Programa Integrado de Investimentos* (PII)

The original PII (2012-14) was documented in 2012, which was the year that represented a major turning point for the country because large investment projects in mining activities started and the country has started exporting coal from Tete. At the same time, the country discovered large natural gas reserves in the Rovuma basin and Mozambique was spotlighted by major international companies in the energy area. However, when starting coal exports and looking at the potential for mineral resources, energy and agro ecological, it appeared that the country lacked the infrastructure needed for transportation, energy and irrigation projects to meet the challenges of integration of the national economy.

In September 2013 the Government approved the PII (2014-17) as the revised document describing the rolling plan and prioritising public investments. This revision of PII includes additional information and detailed analysis of projects with secured financing.

Furthermore, based on the recognition of the above factors mentioned, the Government of Mozambique remains committed to economic reforms and with the implementation of the Action Plan for Poverty Reduction (PARP) and the revised PII aims to; (i) remove administrative barriers to investment, (ii) create a favourable business environment to attract more investment to the country, and (iii) promote economic and social development of the economy.

The fundamental objectives of the PII are summarised as;

- **a.** to improve the Economic Integration of the country,
- **b.** to increase Agricultural Productivity,

c. to reduce Logistics Costs and to improve Market Access,

d. to increase the added value and diversification of the national economy, and

e. to improve the Quality of Infrastructure for the Human Resource Development.

In addition, the Government recognises the potential of investments in certain parts of country, such as "Growth Poles" which can play roles in the economic growth and improvement of citizens' lives. Note that the PII describes the “Growth Poles” below, especially the Nacala Corridor is highlighted with the figure in the document;

Zambezi Valley, which consists of Tete (all Districts), Zambézia (Morrumbala, Nicoadala, Milange, Mocuba, Mopeia, Chinde, Inhassunge, Namacurra, Quelimane and Maganja da Costa), Sofala (Gorongosa, Maringue, Chemba, Caia, Marromeu, Cheringoma and Mwanza), and Manica (Barué, Macossa, and Guro Tambara),

Nacala Corridor, which due to the recent economic dynamics in the economy of the northern region of the country, extends the reference area to include all Nampula, Cabo Delgado province, Niassa Province, and the northern districts of Zambézia Province in particular Alto Molocué, Gile, Gurué, Ile, and Lugela Namarroi. The exploitation of coal in the Tete Province, and particularly the logistics associated with this activity, has contributed to further integration of Tete province with the coastal provinces, namely, Nampula and Sofala, thus increasing the expansion of investments made in each of these regions to the rest of the region and the country[6]. Figure 2.2.1 is titled the Nacala Development Corridor in the PII 2014-17.

In order to stimulate the growth poles, the following infrastructures are identified as high priority, such as **Energy** (Power line connection/ hydro power), **Transport** (rehabilitation and construction of new access links, modernisation of corridors, ports and cargo railways, air transport, and installation of toll roads), **Multimodal Corridors** (Rehabilitation and reconstruction of railway links, roads, including customs offices as one-stop border posts along the Corridors of Nacala, Beira and Maputo. Improvement of the capacity of ports including dredging, Development of natural resources including watershed coal of Moatize in the Zambezi Valley and export ports), **Water** (Building multipurpose dams, strengthening irrigation capacity and taking advantage of the irrigation capacity of the river basins in the Chire, Zambezi, Limpopo Lúrio rivers and transboundary waters), **Information and Communication Technologies** (Enhancement of the capacity of optical cable, telecommunication base and broadband services).

[6] These statements related to the Nacala corridor have just been extracted from the PII document.

Figure 2.2.1 The Nacala Development Corridor in the PII 2014-17

2.2.4 Road Sector Strategy (RSS) and Integrated Road Sector Program (PRISE)

In the Road Sector, there was the Road Sector Strategy (RSS) *(Estratégia do Sector de Estradasl ESE)*, which presented the main elements of the Government of Mozambique's (GOM's) strategy for developing and managing the classified road network. The RSS adds a level of detail to the GOM's Road Sector Policy to establish the main principles, approaches, and activities.

The RSS takes into account a medium to long term perspective, however, it includes a 5-year horizon investment plan, reviewed and revised for implementation on a 3-year basis which in turn is adjusted annually, considering needs and budget constraints.

This strategy presents the themes that should govern the planning and development of the road sector. The main themes of the earlier strategy are described as;

- **Sustainability**: the policy that what is upgraded and rehabilitated continues to be maintained,
- **Connectivity**: the policy of identifying critical road links between important points and focusing development efforts to enhance these links, and
- **Accessibility**: the policy of providing minimal or better access to all inhabitants of the country.

In addition to the above, the RSS complements these themes with several more, which are;

- **Asset Preservation**: the policy of prioritising maintenance works over improvement works to ensure that the investment made in the infrastructure is not lost through lack of maintenance,
- **Enhanced Transitability**: the policy of providing at least minimal access to communities to which existing roads have deteriorated to the point where these areas are cut off from the trunk highway system, and
- **Maintainability**: the policy of incorporating into the design of an improvement work, the features and materials that make maintaining the work easier or less expensive.

In the RSS-3 (November 2015), development of 7 corridors are proposed. Figure 2.2.2 shows the development strategy in northern region, detecting the longitudinal/transversal arterial and main connector roads. The main required interventions for the Nacala Corridor, identified in RSS-3, are:

- A high-level of routine and periodic maintenance to ensure a good level of service for paved sections,
- Timely completion of the Nampula-Cuamba sections under construction,
- Good implementation of the Cuamba-Lichinga sections including procurement and project management, (during PQG 2015-2019)
- Study and implementation of concession or tolling wherever feasible.

The target roads are located so as to connect as diversions of the trunk road at the major towns and connect with other national roads. Nacala city and Nampula city are the major urban area of the Nacala Corridor. The target road could contribute to the strong development of Nacala Corridor area by limiting the through traffic flow into the city centre and by promoting urban development.

For realization of the objective of RSS 2015-2024, PRISE 2016 has planned for connectivity pillar tarring and rehabilitation actions for national road (487 km) and mobility interventions for regional road (302 km). The investment was complemented by preservation of road (22,520 km) including routine maintenance (20,500 km) and periodic maintenance of paved and non-paved road (320 km) respectively.

Source: RSS-3 (2015 November)
Locations of three target roads are added on the map by the Study Team.

Figure 2.2.2 Relation between Northern Network strategy and the Target Roads

2.2.5 PEDEC-Nacala (Nacala Corridor Economic Development Strategies)

PEDEC-Nacala (the Project for Nacala Corridor Economic Development Strategies in the Republic of Mozambique) was a study project for formulating the “Integrated Development Strategies” for the Nacala Corridor and its surrounding areas including five provinces related to the Nacala Corridor Region.

PEDEC-Nacala seeks to promote “Dynamic and Inclusive Development” by paying attention not only to the dynamic relation between mineral resources development, transport corridor development and other economic sector development, but also to the inclusive need for environmental management, human resources development and institutional development. Furthermore, PEDEC-Nacala is also concerned about socially vulnerable people and remote area people who might not be able to participate in the development opportunities that will emerge due to such mineral resources development, transport corridor development and other economic sector development. In addition, PEDEC-Nacala provides a “Long-Term Vision and Spatial Structure” for the Nacala Corridor Region and discusses “Essential Development Strategies” that are required for triggering/initiating development and leading the initiated development to further development so that development can be continuously realised leading to region-wide development in the Nacala Corridor Region.

In order to formulate development strategies to guide appropriate development and investment in the Nacala Corridor, the development strategies of PEDEC-Nacala are integrated in the coverage of economic sectors and infrastructure sectors, especially the road sector is included, and social service sectors.

The goals to be attained by utilising the development strategies are described as follows, and its formulation process of the strategy is illustrated in the following diagram:

- To enhance social capacity and economic growth in the Nacala Corridor Region
- To effectively guide appropriate development in the Nacala Corridor Region
- To promote private investment in the Nacala Corridor Region
- To appropriately manage the resources of the Nacala Corridor Region

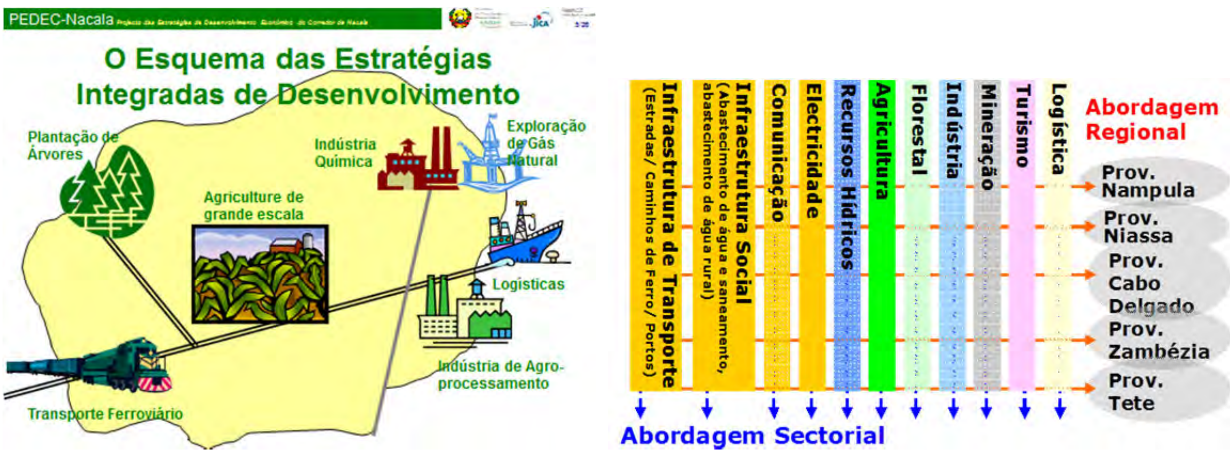


Figure 2.2.3 Image of Integrated Development Strategy and Sector/Regional Approach

Under the PEDEC-Nacala, the spatial structure of Nacala Corridor Region in 2035 was recommended as shown in Figure 2.2.4. The blue arrows indicate the proposed corridor routes, while the brown arrows are the existing transportation routes. The corridor structure is designed in such a way that Nacala Port will run through Lilongwe of Malawi and Lusaka (or Serenje) of Zambia for approximately 2,000km as an international corridor and the effect of improved access will extend to as many areas in the Mozambican part as possible to enhance people's mobility and promote development along the routes.

In addition, PEDEC-Nacala recommended many infrastructure developments/ soft measures and selected priority programs/projects to be implemented by 2035, which include the **"Nacala International Gateway Programme"**, **"Nampula regional Growth Centre Programme"** and **"Cuamba Logistics and Industrial Centre Programme"**. As the result of the evaluation of the projects/programs, 46 projects were selected as the "Short- and Medium- Term High Priority Projects". Following are the high priority projects which are contained within the Nacala, Nampula and Cuamba area programmes with the diagrams illustrated for the projects for the presentation at the economic council.

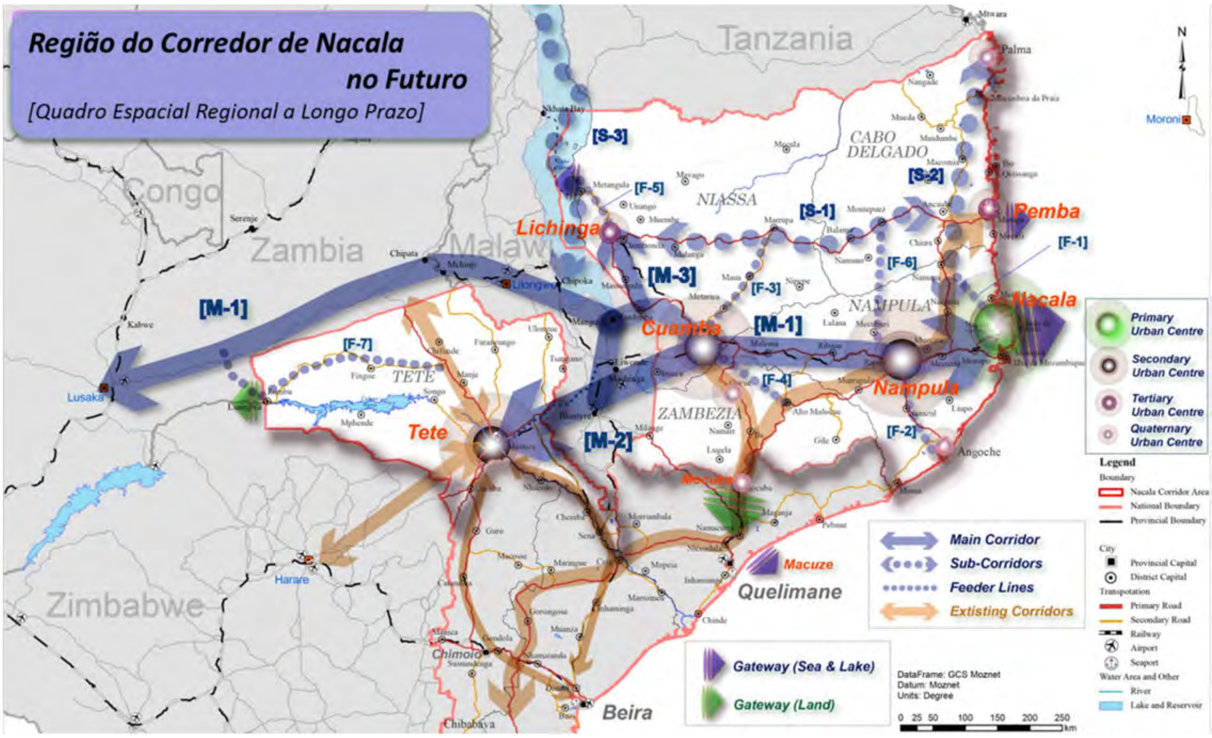


Figure 2.2.4 Image of Integrated Development Strategy and Sector/Regional Approach

<u>**Nacala International Gateway Programme**</u>

- Nacala Industrial Park Project
- Nacala Industrial Belt Area Development Project
- <u>Nacala Port Access Road Project</u>
- Nacala Multi-Modal Terminal and Railway Shunting Yard Project
- Nacala Thermal Power Plant Project

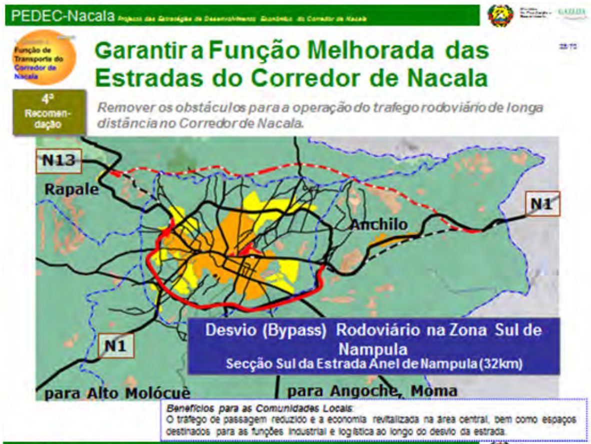
- Nacala Urban Water Supply Expansion Project
- SEZ/IFZ Management Improvement Project

Nampula Regional Growth Centre Programme

- Nampula Southern Road Bypass Project
- Nampula Railway Bypass Project
- Nampula Multi-Modal Terminal and Railway Shunting Yard Relocation Project
- Railway Crossings Improvement Project

Cuamba Logistics and Industrial Centre Programme

- Cuamba Bypass Road Project
- Cuamba Industrial Park Project
- Cuamba-Marrupa Road Upgrade projects



Upper (Left):	Nacala Port Access Road Project
Upper (Right):	Nampula Southern Road Bypass Project
Lower:	Cuamba Bypass Road Project

Figure 2.2.5 Area Programmes with High Priority Projects including the Target Roads

2.3 Provincial and Municipal Plans

As mentioned in Chapter 1, the target area of the study is located in the Nampula and Niassa provinces. In this section, the basic information and outline of Provincial Strategic Development Plans (PSDP) of the provinces are introduced. In addition, the current situation, urban structure and transport system in each city are described to identify the position of the target roads.

2.3.1 Overview and Plans of Nampula and Niassa Provinces

(1) Nampula Province

Nampula Province, with cities such as Nampula city and Nacala city is the most populated (4.1 million) and urbanised province of the five provinces[7] (28.6% of population live in an urban area). Nacala has a natural deep-sea port, which acts as the gateway to Nacala corridor. Nacala and Nacala-a-Velha have been designated as special economic zones (SEZ), which has attracted direct investment in manufacturing and other industries. Thus, Nampula Province has the largest GRDP (29,321 Million MZN) of the five provinces and high annual growth of GRDP (9.2%).

The length of primary roads per land area is the highest (12.63 km per 1,000 km^2). The airport in Nampula plays the role of a hub in the northern region of Mozambique. The coal of Tete Province is planned to be transported by the railway passing through Nampula to Nacala. An airport was newly built in Nacala. The urban structures of these cities would be changed and their clear urban plans are yet to be developed. In addition, the literacy rate of Nampula is the highest (40.0%), thus people in Nampula Province are comparatively more educated. It has tourism development potential in beach tourism (Nacala, and Angoche) and history and culture tourism (Mozambique Island).

(2) Niassa Province

Niassa Province is located next to Tanzania (Niassa lake forms its border) and Malawi (there are three border posts). It currently has the smallest population (1.2 million) and the smallest economic activities (5,930.7 Million MZN in GRDP) among the five provinces. On the other hand, it has the largest land area (129,600 km^2), which is mainly covered by forest (76% of the total land area in Niassa, which is 39% of the forest area in the Nacala Corridor Region). Niassa Province is situated at a comparatively high altitude and has the lowest temperature. Its urban population is relatively low.

Furthermore, it has a relatively low poverty ratio (31.9%) despite its having the highest unemployment rate (31.7%). Lichinga and Cuamba are major cities in Niassa Province with populations of 147,475 and 81,982 respectively. The length of primary roads per land area is relatively low at 6.07 km per 1,000 km^2. As its unemployment rate was the highest (31.7 %) in the five provinces, it is necessary to develop work opportunities for the people. As development potentials, it has coal resources in the northern area, tourism around Niassa Lake and Niassa Reserve, tree plantations around Lichinga City, and so on.

[7] PEDEC-Nacala defined the Nacala Corridor Region as the four provinces of Nampula, Cabo Delgado, Niassa, Tete and the seven northern districts of Zambezia Province, which are the districts of Alto Molocue, Gile, Gurue, Ile, Lugela, Milange and Namarroi.

Table 2.3.1 Overview of Major Indicators for Nampula and Niassa Province

	Nampula	Niassa
Population		
Population (2007, INE)*1	4,084,656	1,213,398
Population Density (people/km^2 , 2007, INE) *1	52.3	9.91
Annual Growth Rate (1997-2007, %, INE)*1	2.92	4.14
Urban Population (2007, INE)*1	1,167,813	277,838
Ratio of Urban Population (%, 2007, INE)*1	28.6	22.9
Land Cover (AIFM, 2007*2)		
Dense and Open Forest (km^2)	23,846	98,160
Prairies (km^2)	2,345	9,343
Aquatic or Regularly Flooded Woodlands & Bushes (incl. Mangrove) (km^2)	784	180
Forest with Shifting Cultivation (km^2)	28,019	2,256
Agriculture (km^2)	19,622	11,104
Built-up Area & Bare Area (km^2)	2,839	915
Water (km^2)	462	7,647
Total (km^2)	77,917	129,605
Socio-Economy		
Literacy Rate (%, 2008, MICS)*3	40	35.6
Poverty Ratio (%, 2009, DNEAP)*4	54.7	31.9
Unemployment Ratio (%, 2004/5, INE)*5	15.7	31.7
Infant Mortality Rate (per 1,000 live birth, MICS)*3	104.9	97.4
GRDP Constant Price: Base year 2003 (MZN Million, 2011, INE)*6	29,321.30	5,930.70
Share of Economic Sector (2011, INE)		
Agriculture, Fishery, & Forestry (%)	39.9	49.5
Manufacturing (%)	10.2	4.1
Others (%)	49.9	46.4
Annual Growth of GRDP (%, 2005-2011)	9.2	8.6
Total Investment (USD Million)	19.3	50.3
Natural Conditions*7		
Temperature (Capital City, 2011 for Tete)	22-28	15-23
Maximum Altitude (MINAG)	1,801	1,848
Infrastructure		
Primary Road (km) (2011, ANE)*9	987	743
Primary Road per Land Area (km/1,000 km^2)	12.63	6.07
Classroom Student Ratio (2010, %, MINED)*9	56.7	51

	Nampula	**Niassa**
Total Number of Health Facilities (2003, MISAU)*10	187	123
Agriculture		
Major crops (√√√: >1 million ton,√√:> 100 thousand ton ,√: > 10 thousand ton: 2007, MINAG)*11		
Maize	√	√√
Cassava	√√√	√
Rice	-	-
Haricot Beans	-	√
Cowpea	√	-
Sweet Potato	-	√
Cashew Nuts	√	-
Tobacco	-	√
Tourism		
International Guest Arrivals (2012, INE)*12	4,259	2,992
Domestic Guest Arrivals (2012, INE)*12	10,604	11,060
Major Tourism Resources (√: Numbers of Potential Areas, JICA Study Team)		
Beach*13	√√√	√
Safari*13	-	√
Others*13	√	√
Urban Development		
Population of Major Cities (2007, INE*1)	Nampula: 483,572 Nacala: 211,915 Nacala-a-Velha: 90,991	Lichinga: 147,475 Cuamba: 81,982

Note: The figures in the blocks are the highest and those in italics are the lowest.
Source:
*1: PEDEC-Nacala based on INE, 2007, General Population and Housing Census
*2: PEDEC-Nacala calculation based on AIFM land cover GIS data in 2007
*3: Final Report of the Multiple Indicator Cluster Survey 2008, 2009, INE
*4: Poverty and Wellbeing in Mozambique: Third National Poverty Assessment, 2010, DNEAP, MPD
*5: Integrated Survey on the Labour Force (IFTRAB), 2005-2006, INE
*6: INE's Statistics, 2011
*7: National Meteorology Institute of Mozambique (INAM), http://www.inam.gov.mz/, 2011.
*8: PEDEC-Nacala based on Road Sector Strategy (RSS) Final Report, 2007-2011, ANE
*9: PEDEC-Nacala based on MINED's (Ministry of Education) Statistics, http://www.mec.gov.mz/STATS/Pages/default.aspx
*10: MISAU (Ministry of Health), 2003, National Plan for Health Human Resource Development
*11: National Agriculture Survey (TIA), 2007, MINAG
*12: Statistical Yearbook 2012, 2013, INE
*13: PEDEC-Nacala

Table 2.3.2 Outline of Provincial Strategic Development Plans for Nampula and Niassa Provinces

Province	Target Years	Vision, Mission, Objectives
Nampula	2010-2020	**Vision:** Nampula Province as a National example in the production and distribution of wealth and job creation. **Mission:** Place the Province of Nampula in the higher standards of wealth creation, with its epicentre in the district by maximising public-private-community partnership **Development Pillars:** Economic Growth, Participatory Governance, Infrastructure and Promotion of the Environment, Social and Human Capital Development
Niassa	2008-2017	**Vision:** Niassa will have consolidated bases for fighting poverty and promoting accelerated and sustainable development. **Mission:** Accelerate social and economic development on a sustainable basis, integrating the province competitively within the national and regional economy **General Objective:** Accelerate and consolidate the economic, social and cultural development of the province and reduce poverty by 15% by 2017. **Development Pillars:** Social Development, Economic Development, Institutional Development

Source: Provincial Strategic Development Plan for each Province

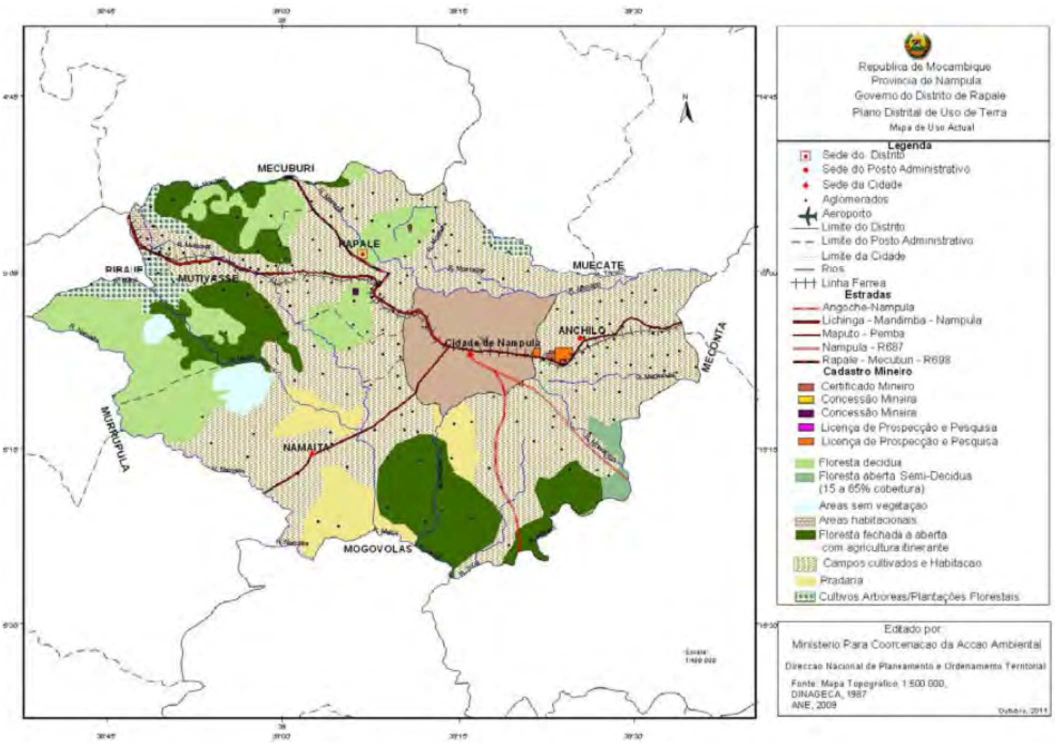
2.3.2 Nampula City and Surroundings

(1) Present Situation in Nampula City and its Surroundings

Nampula is the capital city of Nampula Province, and is considered to be a centre of the northern region. The Nampula urban area is the third largest in the country in terms of population and extension of infrastructure. The territory of Nampula City is completely surrounded by the district of Nampula/Rapale, which has its headquarters in Rapale. The city is located along the railway line from Nacala to Malawi and the road link to the Provinces of Zambézia and Cabo Delgado.

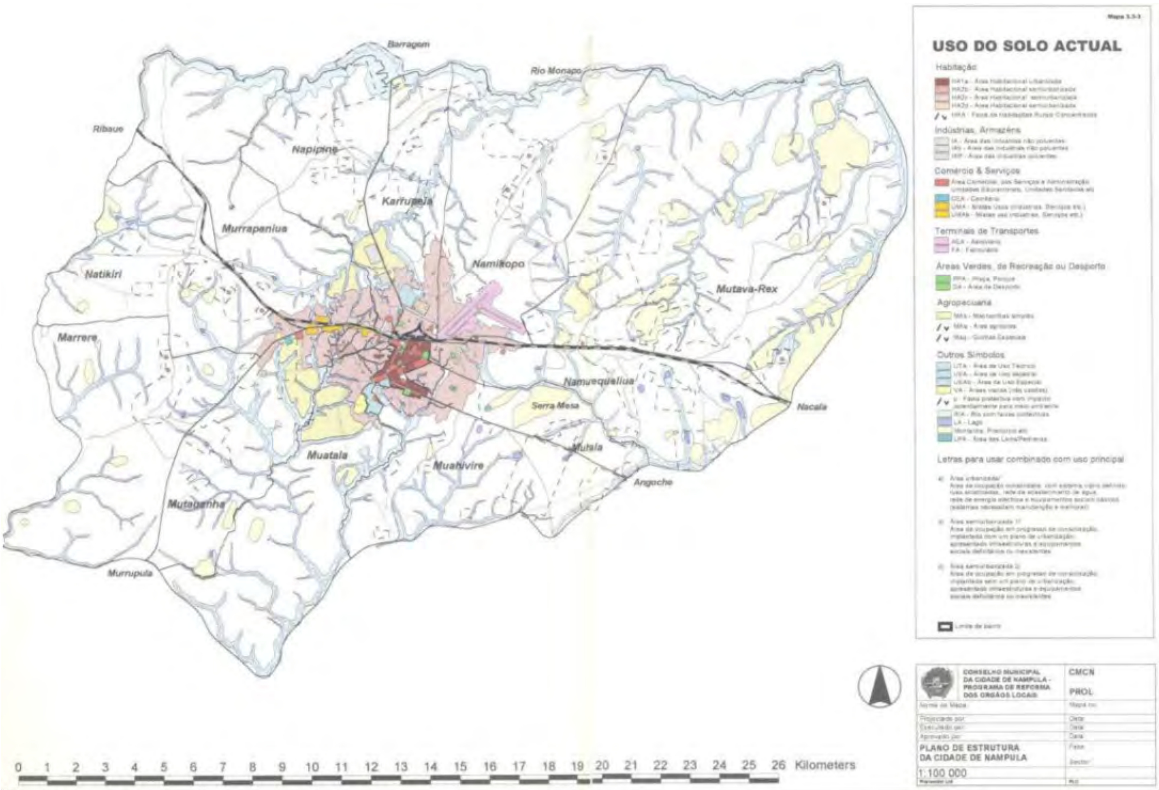
The City area is divided into six administrative posts, which are further divided into 18 neighbourhoods (bairros). The Central Administrative Post covers the cement city with six small neighbourhoods for the other posts, the administrative division is made radially and each neighbourhood extends from the boundary of the Central Administrative Post. According to the second census taken in 1997, the city of Nampula had about 303,000 inhabitants. The population increased by 4.6% per year and the third census taken in 2007 indicated a population of 477,771.

The District of Nampula/Rapale comprises four administrative posts including: Rapale, Mutivaze, Namaita and Anchilo. According to the 2007 population census, Nampula/Rapale was one of the most populous districts of Nampula Province with 203,733 inhabitants. The district population represents 8.3% of the provincial population, which is a considerable population increase. The territorial distribution of the population in the district is rather irregular as the Anchilo Administrative Post had 75,543 inhabitants, corresponding to 59% of the population of the district.



Source: DINAPOT, MICOA, 2011

Figure 2.3.1 Current Land Use of Nampula - Rapale District



Source: MCA, CENACARTA

Figure 2.3.2 Current Land Use of Nampula City

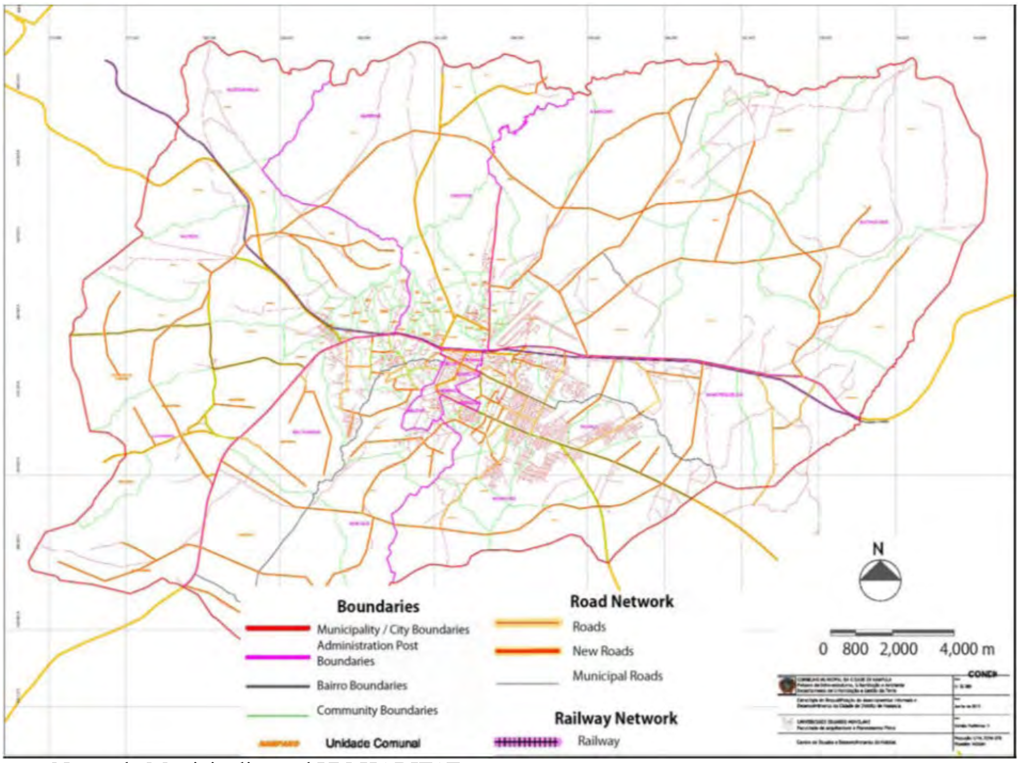
(2) Urban Structure and Transport System for Nampula City and its Surroundings

The present city centre of Nampula City area is located in a planned area developed during the Portuguese era. This central built-up area is situated on a large high land prominence and is surrounded by valleys which consist of rather gentle slopes. The fringe of the unplanned residential area is formed of hilly parts once again, and thus several housing developments have been planned by the municipal government. The area of unplanned settlements is significantly large and suffers from the risk of erosion and lack of infrastructures.

The railway runs on the ridge of the hill forming the city of Nampula. There is a railway station in the middle of the built-up area serving passengers as well as cargo. A shunting yard is located on the west side of the station, while the international airport of Nampula is situated north east and covers a large area. The planned built-up area is on the south side of the railway. Since the urbanisation has taken place on the north side of the railway, these transport facilities are coming to be the major factor dividing the city area into two areas.

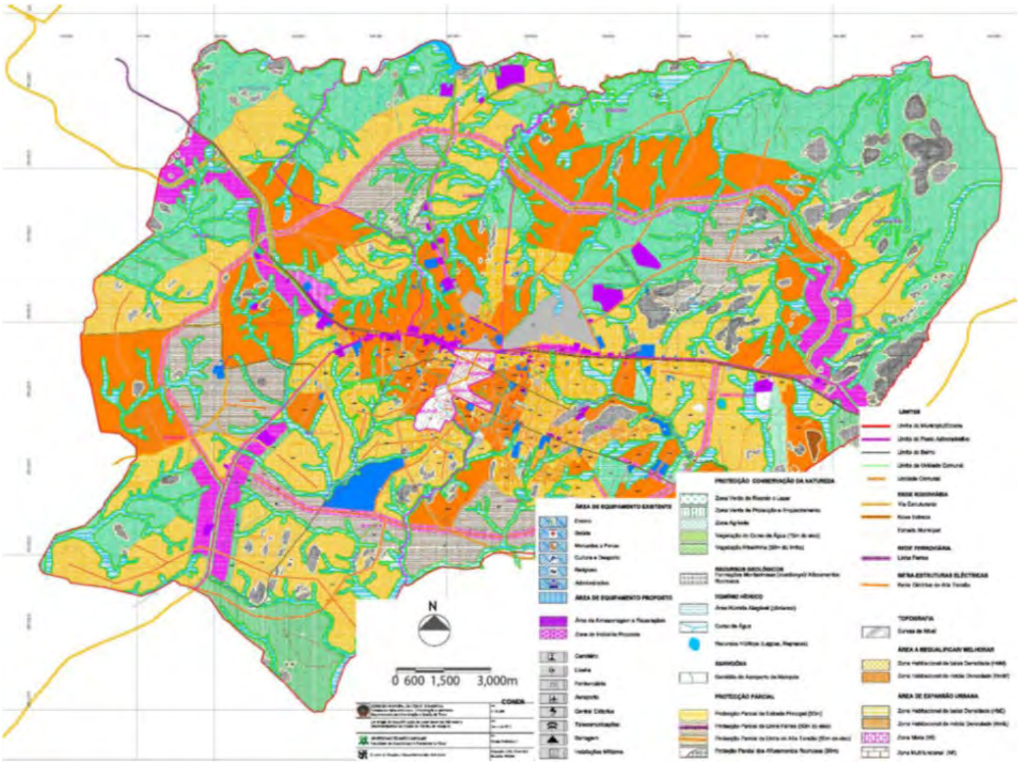
The national road (N-13) also runs in an east-west direction along the railway, and currently functions as a trunk urban route for both city dwellers and bypassing traffic. The road is facilitating the formation of the ribbon style sprawl, especially to the east to the area of Anchilo Administrative Post. Regarding the area to the west, the road separates into two directions: EN-13 to link with Cuamba, Lichinga, and Malawi, and EN-1 to the Central and Southern regions.

There is a land use inventory map that was prepared as a part of the MCA programme for the territory of Nampula City. This is followed by the formulation of the Partial Urbanisation Plans with technical and financial assistance by various donors coordinated by the UN-HABITAT. The Partial Urbanisations are prepared for five areas covering almost all the territory of the City except for the central city part. The programme also covered the neighbouring Bairros belonging to Nampula District along the three national roads stretching to the outside. The major outputs of the Partial Urbanisation Plan are presented in Figure 2.3.3 and Figure 2.3.4.



Source: Nampula Municipality and UN-HABITAT

Figure 2.3.3 Transport Network Proposed in Partial Urbanisation Plan



Source: Nampula Municipality and UN-HABITAT

Figure 2.3.4 Land Use Zoning Proposed in the Partial Urbanisation Plan

(3) Direction of Urban Development proposed in the PEDEC-Nacala

Following are the documents extracted from the PEDEC-Nacala Draft Final Report which present the direction of urban development in Grater Nampula Area in line with the regional economic development strategies in Nacala Corridor Region, which are the basis of the Nampula Southern Bypass Road.

<u>Future Prospects for Greater Nampula</u>

Being a dominant city in the Northern Region of the country, development of Nampula will maintain a steady pace, even after significant development takes place in Nacala Bay Area. The city will continue to be the administration centre, as well as a centre of production and consumption on a significant scale. However, there are various risks for healthy development of Nampula City brought as side effects of being a major node of the Nacala transport corridor. The most explicit example is the increase of railway traffic caused by mass-scale coal transport. Significant efforts will be required by all relevant organisations to help avoid the risks of traffic accidents and degradation of the urban environment for ordinary people. These efforts also need to consider effective contributions to create/enhance conditions for industry, services and other economic activities.

<u>Vision for Greater Nampula</u>

The target image of the development of Greater Nampula is to create a growth pole of the Northern Region and contribute to the national development, through not only preventing the deterioration of the urban environment by the increased transport and other economic activities, but also enhancing the quality of lives. To this end, it is critically important to concentrate efforts on diversion of major transport infrastructure. The function of production and service centre may be strengthened by creation of a highly efficient city with a rather compact built-up area. The ongoing rapid urbanisation should be contained within a certain area, and prevent involvement of neighbouring rural areas.

<u>Development Framework for Greater Nampula</u>

The population of Greater Nampula in 2035 will reach almost 1,800,000 persons combining Nampula City and three neighbouring administrative posts of Nampula Rapale District as summarised in Table 2.3.3. The total urban population in the same area in 2035 is forecast to be 1,322,000 persons as shown in Table 2.3.4. The pace of population increase will be moderate compared with the case of Nacala Bay Area, but still in a rapid state.

Table 2.3.3 Population Forecast for Greater Nampula

City/District/ Administrative Post	Population				Annual Population Growth Rate (% per annum)		
	2007	2017	2025	2035	2007-17	2017-25	2025-35
Nampula City	483,572	729,000	941,000	1,180,000	4.2%	3.2%	2.3%
Anchilo AP (Nampula Rapale District)	75,543	118,000	157,000	207,000	4.5%	3.7%	2.8%
Namaita AP (Nampula Rapale District)	52,464	86,000	117,000	156,000	5.1%	3.9%	2.9%
Rapale AP (Nampula Rapale District)	57,491	80,000	103,000	133,000	3.4%	3.1%	2.6%
Total of Greater Nampula	669,069	1,014,000	1,318,000	1,676,000	4.2%	3.7%	2.4%

Source: PEDEC-Nacala

Table 2.3.4 Forecast of Urban Population for Greater Nampula

City/District/ Administrative Post	Population				Annual Population Growth Rate (% per annum)		
	2007	2017	2025	2035	2007-17	2017-25	2025-35
Nampula City	483,572	729,100	941,000	1,180,000	4.2%	3.5%	2.6%
Anchilo AP (Nampula Rapale District)	0	12,600	30,300	62,100	-	11.6%	7.5%
Namaita AP (Nampula Rapale District)	0	9,300	22,600	46,900	-	11.8%	7.6%
Rapale AP (Nampula Rapale District)	0	8,600	19,900	39,900	-	11.0%	7.2%
Total of Greater Nampula	471,171	759,600	1,013,800	1,328,900	4.6%	3.7%	2.7%

Source: PEDEC-Nacala

Conceptual Spatial Structure for Greater Nampula

As shown in Figure 2.3.5, the Conceptual Spatial Structure for Greater Nampula is proposed in PEDEC-Nacala. The components of the Conceptual Spatial Structure are listed as follows. The underlined two components, which are related to this study, are summarised below.

- **Diversion of Concentrated Traffic**
  - ***Rerouting of Railway for Coal Transport***
  - ***Ring Road Development***
  - Relocation of Airport
  - Relocation of Railway Shunting Yard

- **Urban Cores for Greater Nampula**
  - New CBD at Shunting Yard and Airport Sites
  - Industrial Zones in Outskirts along Ring Road
  - New Housing Area and Urbanisation
- **Supporting Water Resources**

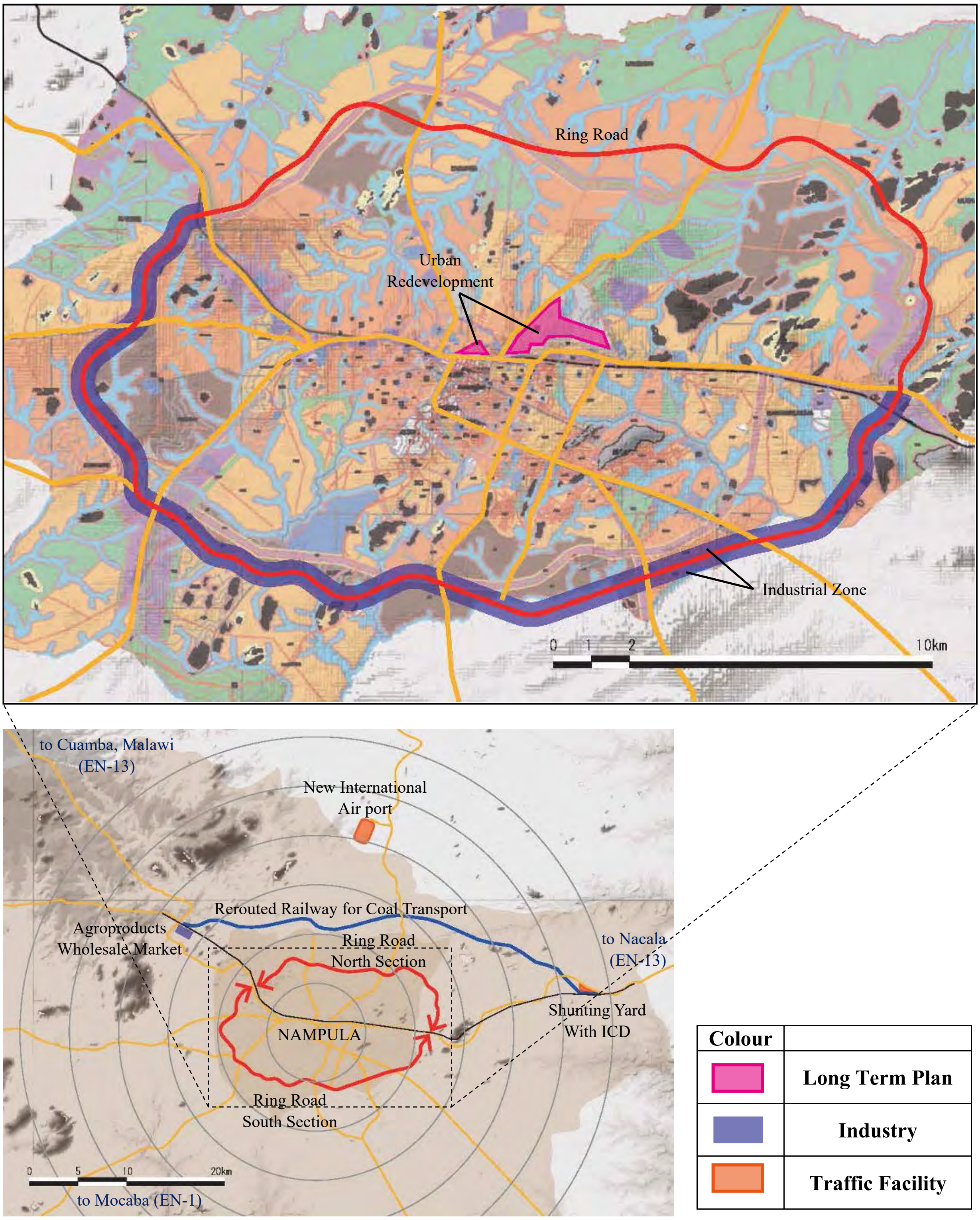
The most critical factor for the development of the area is to divert the existing concentrated traffic to prevent creating risks for both human lives and the city's efficiency. The effort to match the changed nature of the transport is required even though it is costly.

Rerouting of Railway for Coal Transport

The highest risk potential to the urban lives will be brought by the change in the nature of railway operation. By the significant increase of the number of trains (28/day in 2035), the city will be totally divided as crossing of the railway will become a very time consuming factor. Plus the current ground level separation of the space from the ROW of the railway will cause the risk of accidents and may create social instability. After analyses for several options, it is proposed to divert the coal transport portion of the railway traffic to a new line in the north of the City territory, while trains for general cargos and passengers will continue to use the present alignment. The new segment of the diverted route will be less undulating and far enough from the city centre.

Ring Road Development

A ring road has been proposed as a result of the joint effort by the municipality and UN-HABITAT. The general alignment is set to serve as the trunk road of the city as well as encouraging the through traffic to avoid reaching the city centre. This concept is effective and needs to be shared by the relevant authorities.



Colour	
	Long Term Plan
	Industry
	Traffic Facility

Source: PEDEC-Nacala

Figure 2.3.5 Conceptual Spatial Structure of Greater Nampula Development

2.3.3 Nacala City and Nacala-a-Velha District

(1) Present Situation in Nacala City and Nacala-a-Velha District

The seaport of Nacala, the starting point of the Nacala Corridor, is situated on the eastern coast of Nacala Bay, belonging to Nacala City. On the western coast of Nacala Bay, a largescale bulk port is under construction for the export of coal, to be operated by the mining company. The western coast of Nacala Bay mostly belongs to Nacala-a-Velha District. The combined area of Nacala and Nacala-a-Velha is designated as the Nacala SEZ.

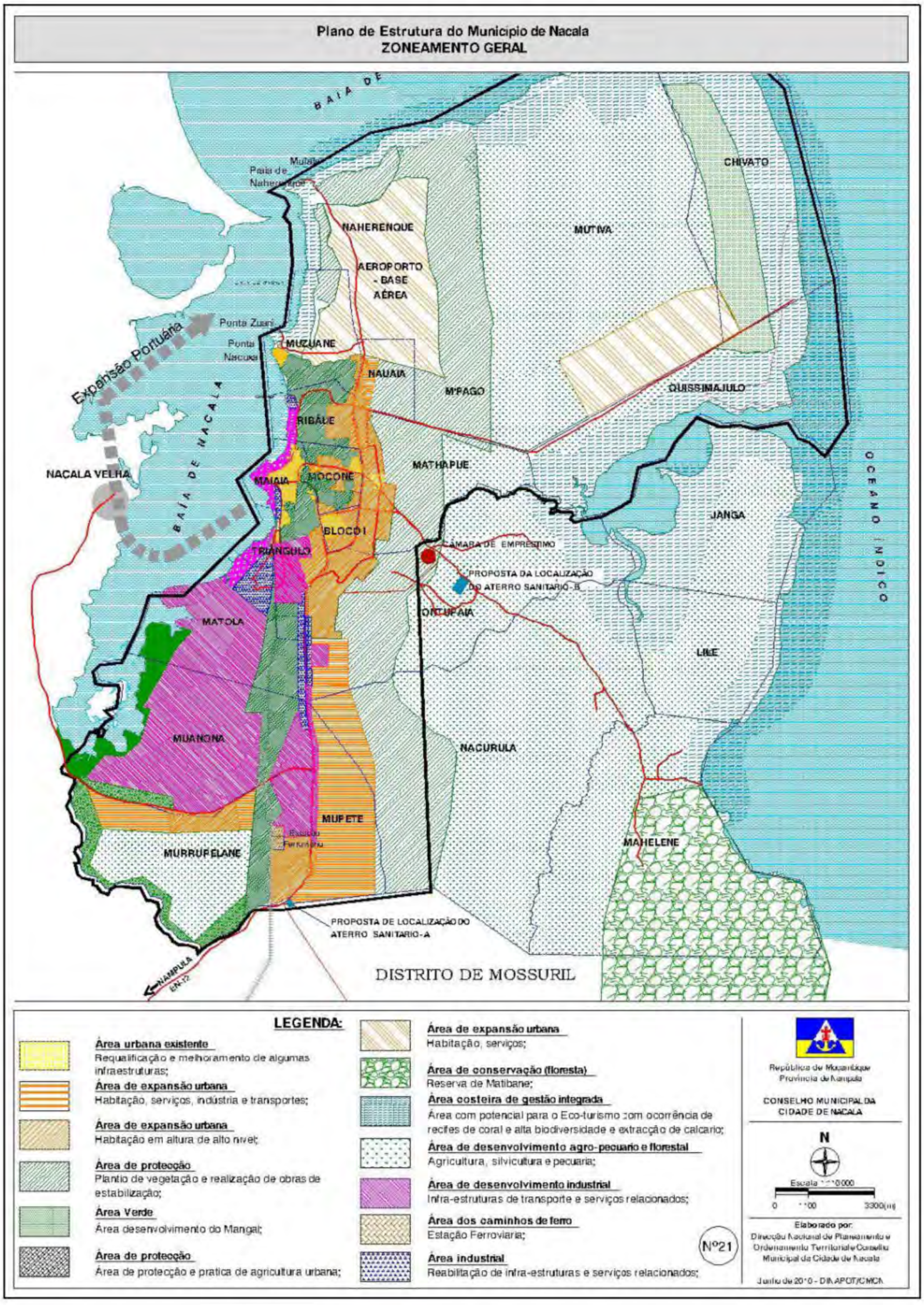
According to the census, Nacala had about 206,449 inhabitants in 2007, distributed over an area of around 370 km^2, with a density of 558 persons per km^2. The City area is managed by two administrative posts and 22 neighbourhoods (bairros). Among the 22 bairros, nine have rather rural characteristics. Nacala-a-Velha consists of two administrative posts. The total population of the district was 88,807, of which 66,666 inhabitants, or 75.1%, were in Nacala-a-Velha Administrative Post and the remaining 22,141, or 24.9%, lived in Covo Administrative Post.

(2) Urban Structure and Transport System for Nacala City and Nacala-a-Velha District

In the entire area of the SEZ, the built-up area with a road network of secondary roads is limited to two locations, namely the city centres of Nacala and Nacala-a-Velha. The corridor line, or EN-12, approaches the SEZ from the south-west and turns to the north heading to the sea port of Nacala. Along this main access route to the port city, many factories have located recently to enjoy the privileges of the SEZ. From the centre of Nacala, a paved road extends to the north up to the end of the peninsula where several resort facilities have been located. Near the middle of this road, the international airport has been in service from December 2014. Several administrative buildings have been constructed in the area from the entrance point of the road to the gate of the airport.

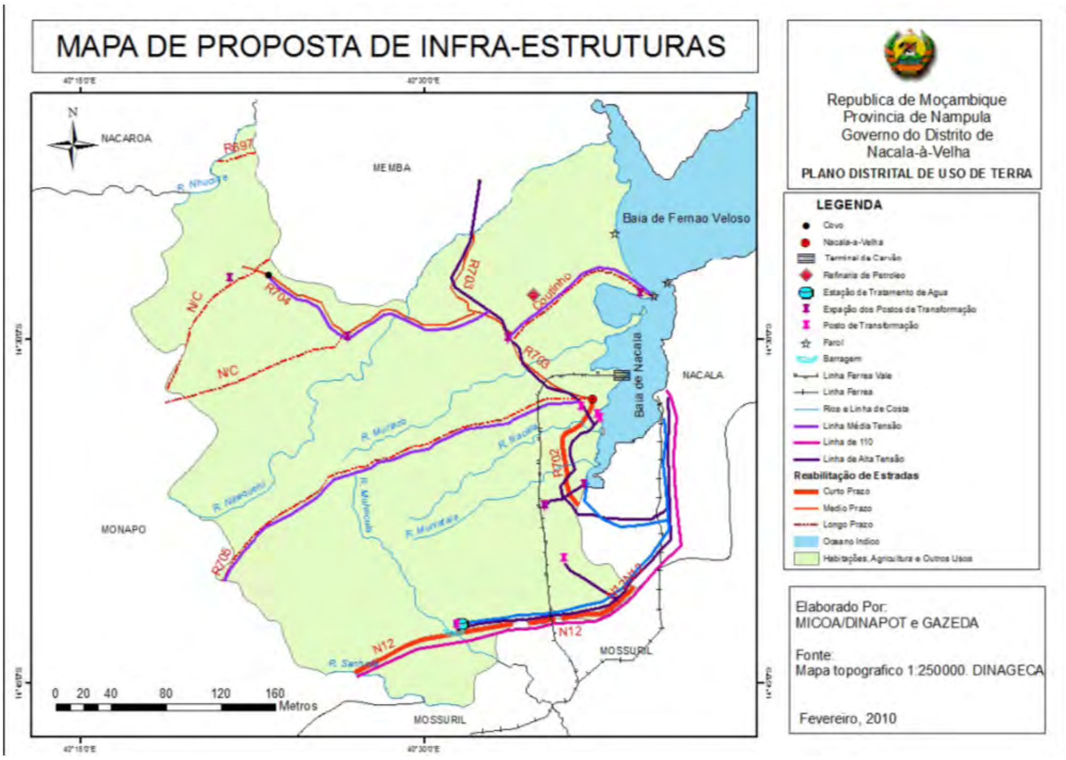
EN-12 has a junction at the south end of the bay, and the branch road extends to the city centre of Nacala-a-Velha, running along the west side of the coast. From the centre of Nacala-a-Velha, several roads head north and west, forming radials. The one heading to the north is linked to the centre of Memba district, while the others head to rural areas and end without connecting to major roads. All of these roads are unpaved.

The city centre of Nacala is situated on the planned built-up area in the middle of the eastern coast of Nacala Bay. The planned built-up area is formed from the top of the hill to the port area. There are older manufacturing industries located in the flat areas near the port. The valleys surrounding the planned area are mostly occupied by unplanned settlements, which suffer from occasional land slide and erosion on top of the lack of necessary infrastructure. Nacala-a-Velha is not yet affected by urbanisation pressure, but will inevitably face a massive influx of population triggered by the start of operation of both the new port dedicated to the coal export and the railway connecting the port with the Nacala Corridor. Once the urbanisation starts, it will be hard to accommodate the immigrants in the existing built-up area. The district is already experiencing a shortage of accommodation facilities for the newly arrived workers, as the construction of the bulk port brought many engineers and workers to the area. Within the SEZ, GAZEDA plans to promote development of IFZs.



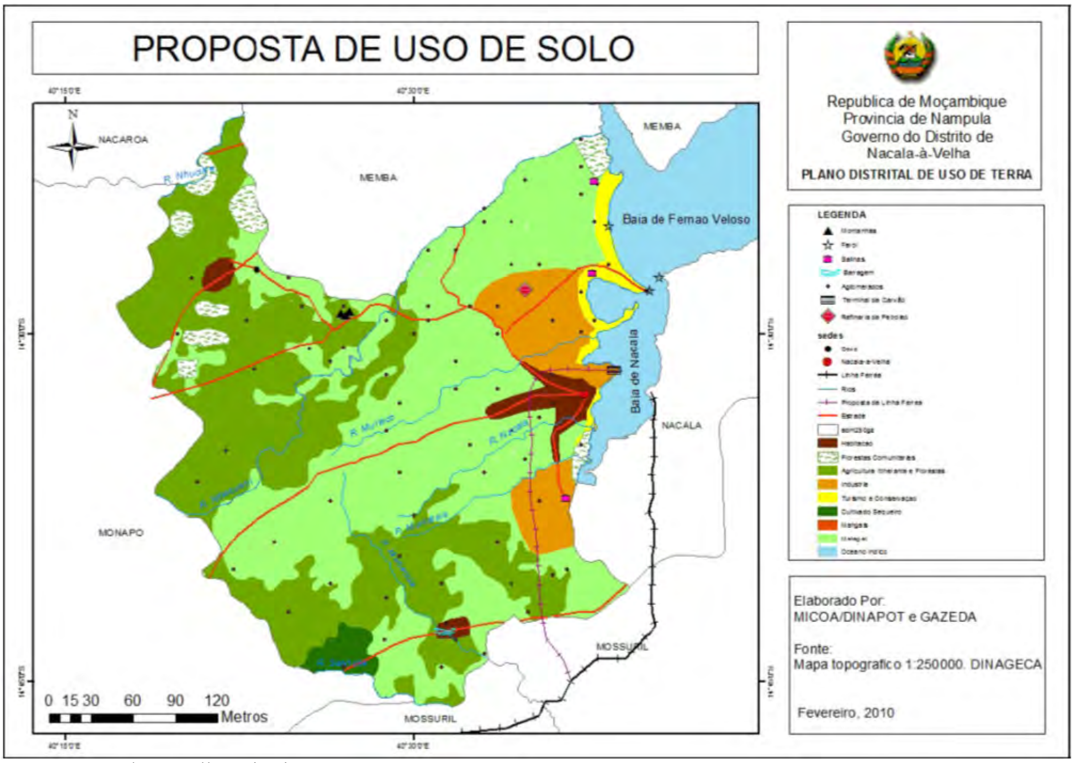
Source: Nacala Municipality, 2010

Figure 2.3.6 General Zoning Plan of the New Structure Plan for Nacala City



Source: Nacala-a-Velha District Government, 2010

Figure 2.3.7 Future Infrastructures in the New Land Use Plan for Nacala-a-Velha District



Source: Nacala-a-Velha District Government, 2010

Figure 2.3.8 Future Land Use Zoning in the New Land Use Plan for Nacala-a-Velha District

(3) Direction of Urban Development proposed in the PEDEC-Nacala

Following are the documents extracted from the PEDEC-Nacala Draft Final Report which presents the direction of urban development in Nacala Bay Area in line with the regional economic development strategies in Nacala Corridor Region, which are the basis of the Nacala Port Access Road.

Future Prospects for Nacala Bay Area

The existing deep seaport, together with the status of SEZ, will continue to attract FDIs heading into the area of the Nacala SEZ. The start of coal handling at the new port in Nacala-a-Velha will change the shape of the spatial structure. Employment opportunities will extend to the western side of Nacala Bay and dynamic movements of goods will take place along the coast.

Locating FDIs is critically important to the development of the Northern Region of the country beyond the Nacala SEZ alone. Preparation for an efficient and reliable base for operation of factories is the key to success in attracting FDIs as envisaged. The industrial base for FDI promotion will include accommodation and housing, office and convention facilities, and resort and recreational spaces to support foreign expatriates, on top of the reliable infrastructure for manufacturing.

Vision for Nacala Bay Area

The target image for the development of Nacala Bay Area is to create a new international gateway to Africa, equipped with a first class urban environment, facilities and infrastructure to attract the FDIs. To this end, a longer vision needs to be established with possible involvement of the surrounding areas. For instance, the possibility of a third deep seaport development may need to be taken into consideration, and thus the planning area should include Memba-sede Administrative Post in Memba District located to the north of Nacala-a-Velha. Like-wise, inclusion of Matibane Administrative Post in Mossuril District is also necessary as available land for urban use is limited in the territory of Nacala City. The future residential area will inevitably extend to the territory of Mossuril District.

Population Framework for Nacala Bay Area

The population of the Nacala Bay Area in 2035 will reach 1,309,000 persons combining a City and four administrative posts as summarised in Table 2.3.5. The total population will be doubled from the present level of around 600 thousand. The future urban population in the area may reach 927,000 persons in 2035 by faster growth rates compared with the growth rate of the total population. Table 2.3.6 presents forecasts of the urban population for Nacala Bay Area.

Table 2.3.5 Population Forecast for Nacala Bay Area

City/District/ Administrative Post	Population				Annual Population Growth Rate (% per annum)		
	2007	**2017**	**2025**	**2035**	**2007-17**	**2017-25**	**2025-35**
Nacala City	211,915	319,000	440,000	635,000	4.2%	4.1%	3.7%
Nacala-a-Velha District	90,991	131,000	189,000	300,000	3.7%	4.7%	4.7%
Memba-sede AP (Memba District)	109,899	144,000	187,000	269,000	2.8%	3.3%	3.7%
Matibane AP (Mossuril District)	24,075	53,000	73,000	105,000	4.3%	4.0%	3.8%
Total of Nacala Bay Area	379,733	648,000	889,000	1,309,000	3.8%	4.0%	4.0%

Source: PEDEC-Nacala

Table 2.3.6 Forecast of Urban Population for Nacala Bay Area

City/District/ Administrative Post	Population				Annual Population Growth Rate (% per annum)		
	2007	**2017**	**2025**	**2035**	**2007-17**	**2017-25**	**2025-35**
Nacala City	211,915	319,300	440,000	634,900	4.2%	4.1%	3.7%
Nacala-a-Velha District	15,691	42,600	84,500	179,800	10.5%	9.0%	7.8%
Memba-sede AP (Memba District)	0	13,900	35,800	80,700	-	12.5%	8.5%
Matibane AP (Mossuril District)	62,219	11,800	18,700	31,700	6.6%	5.9%	5.4%
Total of Nacala Bay Area	233,825	387,600	579,000	927,100	5.2%	5.1%	4.8%

Source: PEDEC-Nacala

Conceptual Spatial Structure for Nacala Bay Area

The Conceptual Spatial Structure for Greater Nacala Bay Area is proposed in PEDEC-Nacala as shown in Figure 2.3.9. The components of the Conceptual Spatial Structure are listed as follows. One of the components, the transport system is extracted in the following part.

- **Urban Cores**
  - New CBD (Airport City)
  - MICE and Tourism Complex
  - Industrial Zone
  - New Housing Area and Guided Urbanisation
  - Existing Built-up Area
  - Suburban Agriculture Promotion Zone
  - ***Transport System***
- **Supporting Water Resources**

Transport System

The international airport, existing deep seaport for general cargos as well as the new bulk port under construction, and the location of a possible new deep seaport need to be well connected with each other. These key transport facilities also need to be connected with wider regions both by railway and road systems. The major components of the future transport system include the following:

a. Seaports

Nacala Port has been rehabilitated as emergency works as grant scheme and been started its expansion project by Japanese yen loan for bulk and container ports based on the planning supported by JICA. The Port for Coal terminal is under construction by private initiatives. The third port located at the southern end of Memba-sede Administrative Post with the possible function of an additional bulk and general cargo port.

b. Railways

The main structure of the railroad system will be formed by the following:

- The existing railway connecting to the Nacala Seaport from the entire catchment of the Nacala Corridor
- A new line to branch out from the existing railway to connect the bulk port under construction in Nacala-a-Velha
- A possible extension of the bulk port line to the north to connect to the third port

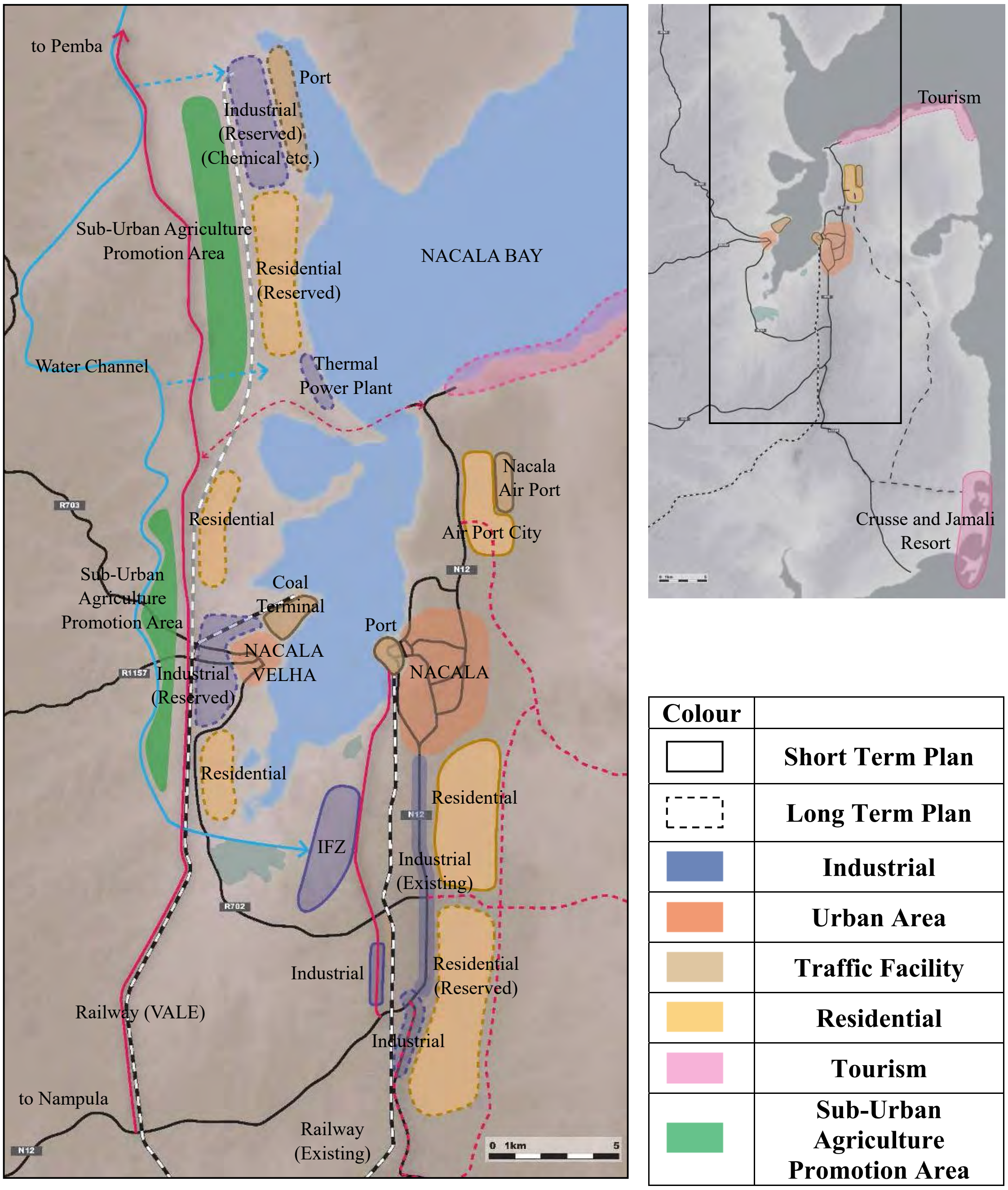
The last one is likely to be a different gauge size from the others if the envisaged alternative railway link from Tete to Nacala becomes a reality.

c. Road Network

The main structure of the road system will be formed by the following:

- Two wider access roads will connect the Nacala Bay Area with Nampula and Pemba.
- A circular road will be introduced to accept the traffic from the wider access roads as well as regional and urban trunk roads. This circular road may be completed by introduction of a great bridge over the mouth of the bay to link the two currently separated areas for promotion of urbanisation, and establish the location of the Airport City at the central part between the urban areas of the east coast and west coast.
- The port-expressway, proposed by the Port Study funded by JICA, needs to be realised for the entire success of the efforts of Nacala Corridor development. The route is proposed to bypass the NE-12 which is heading to the Nacala seaport across the central area of the city of Nacala. The alignment of the port-express way is proposed to by-pass the central urban area of Nacala City. At the same time the road will serve as the major access to the above mentioned large scale IFZ and the industrial area for the spontaneous factory development.

- Urban trunk roads need to be introduced in accordance with the pace of urbanisation. Among the many possible routes, two segments are critically important, namely: a) a north-south line from the airport that runs parallel to the segment of EN-12 in the City area of Nacala to promote the housing estate development in the flat area of Matibane Administrative Post area, and b) a link to the Crusse and Jamali resort development area from the circular road mentioned above.



Source: PEDEC-Nacala

Figure 2.3.9 Conceptual Spatial Structure of Nacala Bay Area Development

2.3.4 Cuamba City

(1) Present Situation in Cuamba City

Cuamba is located at the junction of the railways from Nampula Nacala to the east with the one to Lichinga to the north-west and the other to Malawi to the south-west. The national roads also follow the railway, thus making the city strategically important.

The urbanisation of Cuamba has been generally calm until now but it is expected to experience a drastic change soon after the completion of the road Upgrading project between Cuamba and Nampula. The start of operation of the coal industry will also affect the shape of urbanisation as the traffic movements will dramatically increase.

There is a Structure Plan that was prepared to serve until 2008, which is still in effect as the revision work has not been initiated. There is a Land Inventory Map available that was prepared as a part of the programme of the MCA. The review of the Structure Plan is scheduled to start in the near future with agreement of MICOA to provide technical support. Figure 2.3.10 shows the current land use in Cuamba City as prepared by PEU.

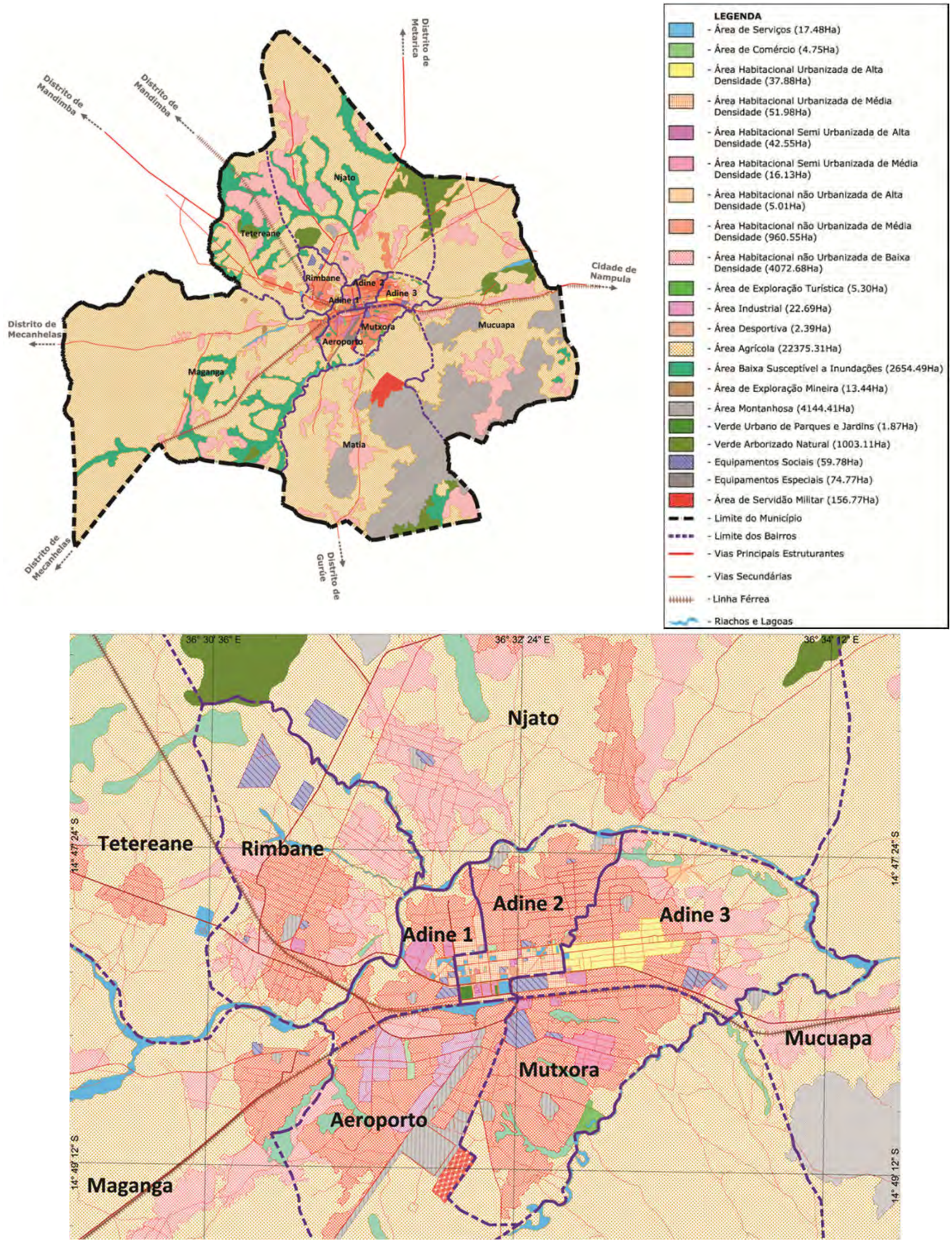
(2) Urban Structure and Transport System for Cuamba City

The city area is divided into the north side and the south side by the national road together with the railway. The city centre is located in the planned area on the north side. There is an airport located on the south side where density is lower than the north side built-up area. Despite the low density, the south side is mostly covered by private land occupation. The overall conditions of the south area are not ideal for housing use as it is located close to a swamp area. The expansion of the north side has been blocked by the river running in the north. The area beyond the river is mostly vacant with scarce private land occupation.

There is a road connecting to Marrupa branched from the one to Lichinga shortly after passing the built-up area to the north-west. This road will form a part of the Lichinga-Marrupa-Cuamba triangle, which has a large potential for agricultural development.

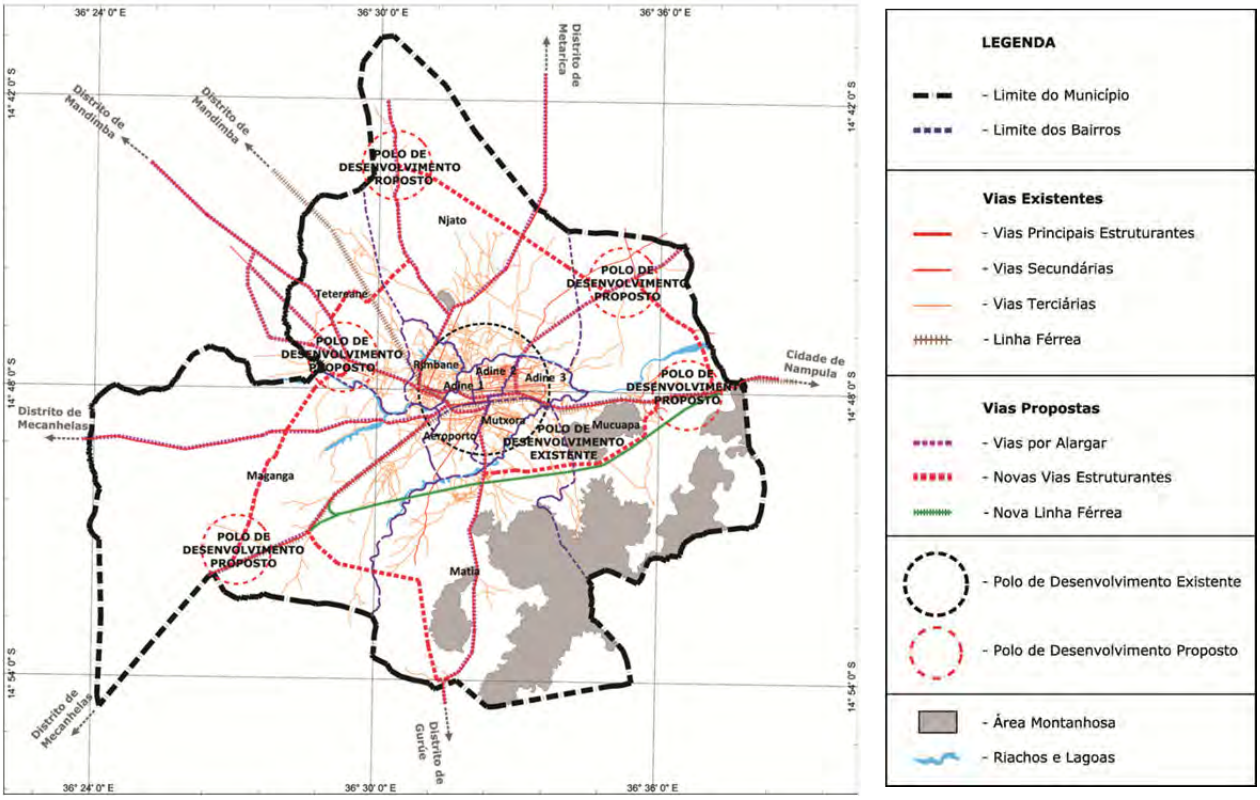
There are several unplanned settlements along these main roads, but they are not yet contiguous with the main urban area of Cuamba.

There is the Urban Structure Plan (PEU) prepared by MICOA/ DINAPOT-DPU and the Municipal Council of Cuamba City in 2013. It presents the road development plan with the diagram to show the new road links within the City as shown in Figure 2.3.11. The new road links are considered to be the only connection between the planned “Growth Poles”. The radial roads from the city centre towards each growth pole are to be enhanced in the future. Although the land use plan written in PEU in section 6.4.4 proposed the creation of alternative routes for through traffic to ease traffic congestion in the city centre, there are no concrete routes on the diagrams.



Source: PLANO DE ESTRUTURA URBANA, Cuamba Municipality, June, 2013

Figure 2.3.10 Current Land Use in Cuamba



Source: PLANO DE ESTRUTURA URBANA, Cuamba Municipality, June, 2013

Figure 2.3.11 Road Network Plan in Cuamba

(3) Direction of Urban Development proposed in the PEDEC-Nacala

Following are the documents extracted from the PEDEC-Nacala Draft Final Report which presents the direction of urban development in Cuamba area in line with the regional economic development strategies in Nacala Corridor Region, which are the basis of the Cuamba Bypass Road.

Future Prospects for Cuamba City

The strategic location of the city has not been utilised effectively due largely to the poor condition of national roads connecting Cuamba to other regions of the country. The urbanisation, however, will be dramatically accelerated after completion of the improvement of the N-13 Nampula-Cuamba segment. Despite the fact that the past urbanisation was at a moderate pace, the city is already facing the shortage of land for housing use of the migrants. It is necessary to expand the area for urbanisation by connecting the flat area located north-east of the city centre across the river running roughly from west to east.

Vision for Cuamba City

The target image of the development of Cuamba City is to create an Inland Regional Logistics and Industrial Centre, which will help bring the benefit of the transport corridor development to the areas distant from the corridor route. In other words, the development of Cuamba is a touch stone to assess the effectiveness of the Nacala Corridor development as a development corridor beyond being a mere transport corridor. Expanding the dynamism of economic development along the corridor to the remote areas can be achieved by strengthening the urban functions of the central towns located along the corridor. In this light, the development of Cuamba needs to focus on accumulation of higher urban functions, such as efficient cargo transit, availability of higher education and health services, and creation of value added on the products of its remote catchment area.

Population Framework for Cuamba City

The population of the Cuamba City area in 2035 is expected to be 267,000 persons, while that of the Cuamba District area is 446,000, as presented in Table 2.3.7. The total population will triple from the record of 2007 census population (79,013).

Table 2.3.7 Population Forecast for Cuamba

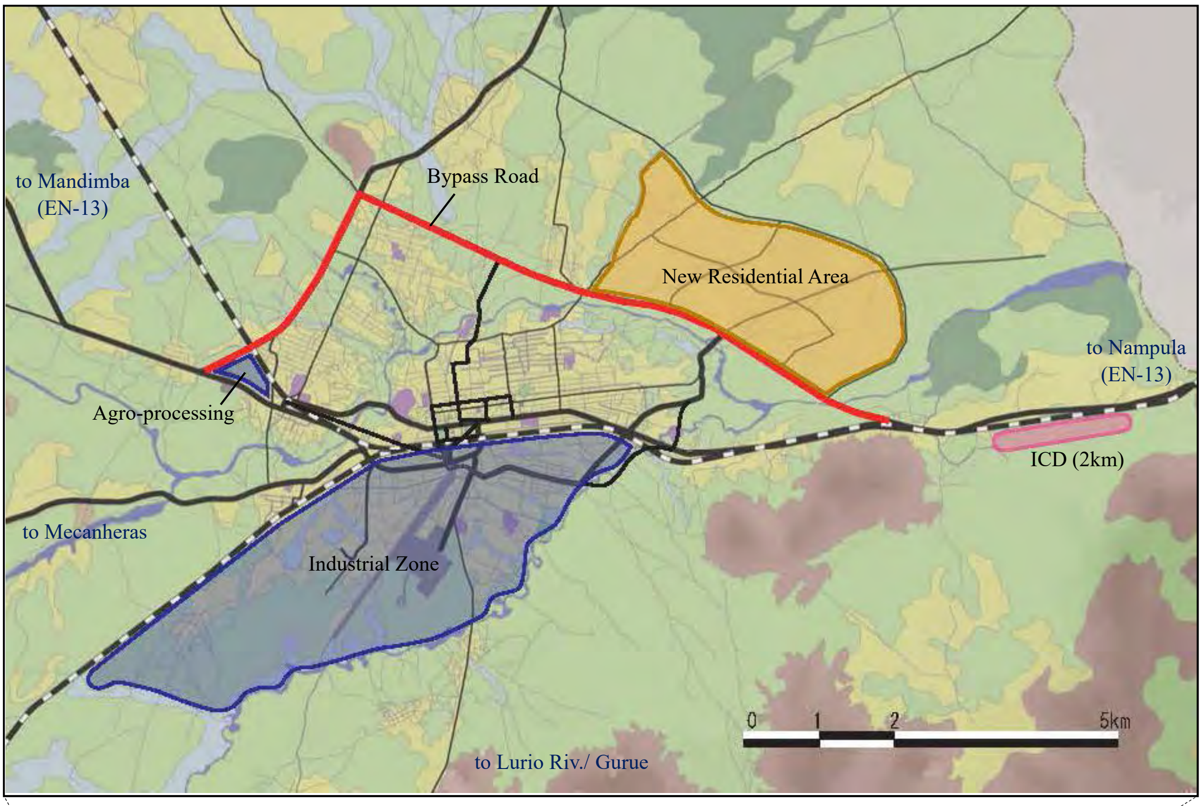
City/District/ Administrative Post	Population				Annual Population Growth Rate (% per annum)		
	2007	2017	2025	2035	2007-17	2017-25	2025-35
Cuamba District (incl. City)	191,642	241,000	336,000	446,000	3.8%	3.1%	2.3%
Cuamba City	79,013	133,000	1,789,000	267,000	5.3%	4.4%	3.5%

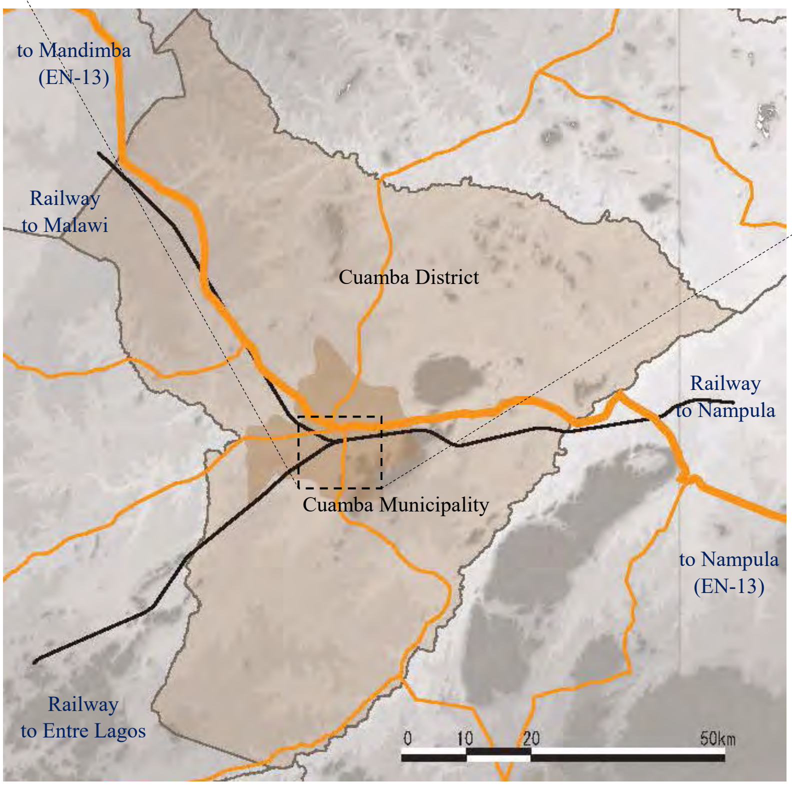
Source: PEDEC-Nacala

Conceptual Spatial Structure for Cuamba City

Similar to the case of Nampula City, the railway crosses the geographical centre of the urban area of the City. Therefore, it is necessary to deal with the expected division of the city brought by the operation of the coal forwarding by the railway. At the same time, it is necessary to expand the urban area to the north-east by crossing the river course. Taking these issues into account, three alternatives can be generated as follows:

- A bypass road will be introduced to the north side of the river to ease the influx of traffic to the city centre as well as to facilitate the development of new urbanisation areas on the north-eastern side of the river. The railway will be kept as it is to support locating of distribution and logistics industries by transforming the south side of the city into an industrial zone.
- A bypass road will be introduced in the same manner as in the above alternative, but the railway will be relocated to the south end of the city. By doing this, the south part can be used as a residential area, as the division of the city will be avoided.
- A bypass road will be introduced in the same manner. The junction of the railway will be relocated to the east of the city and the line toward Lichinga will be realigned along the proposed bypass. By doing this, the introduction of an agro-processing complex may be better located on the north side of the river, while the distribution industry will be located in the south part of the city.





Colour	
	Industry
	Traffic Facility
	Residential

Source: PEDEC-Nacala

Figure 2.3.12 Conceptual Spatial Structure of Cuamba City Development

Considering the relatively small size of the city as well as the need for momentum to create a new urban area north-east of the river, it is proposed that the following options may be the most efficient way of achieving the above two requirements:

- A road to bypass National Road No.13 will be introduced along the north-eastern side of the river
- No rerouting of the railway will be planned, but the area on the southern side of the railway will be designated as an industrial promotion zone where construction of factories and other non-residential facilities are encouraged, but new construction and/or major renovation of residential facilities is discouraged or prohibited
- The road to Marrupa will be improved to provide better access from the high potential agriculture area, and help form the agricultural product triangle together with Lichinga
- An agro-processing zone will be established to support the increase of the value-added portion of the agricultural products from the remote catchment area of the city. The best location may be the junction point of the roads to/from Nampula, Lichinga, and Marrupa
- A shunting yard will be constructed at the eastern end of the city along the railway to enhance the capacity for handling goods to and from Nacala

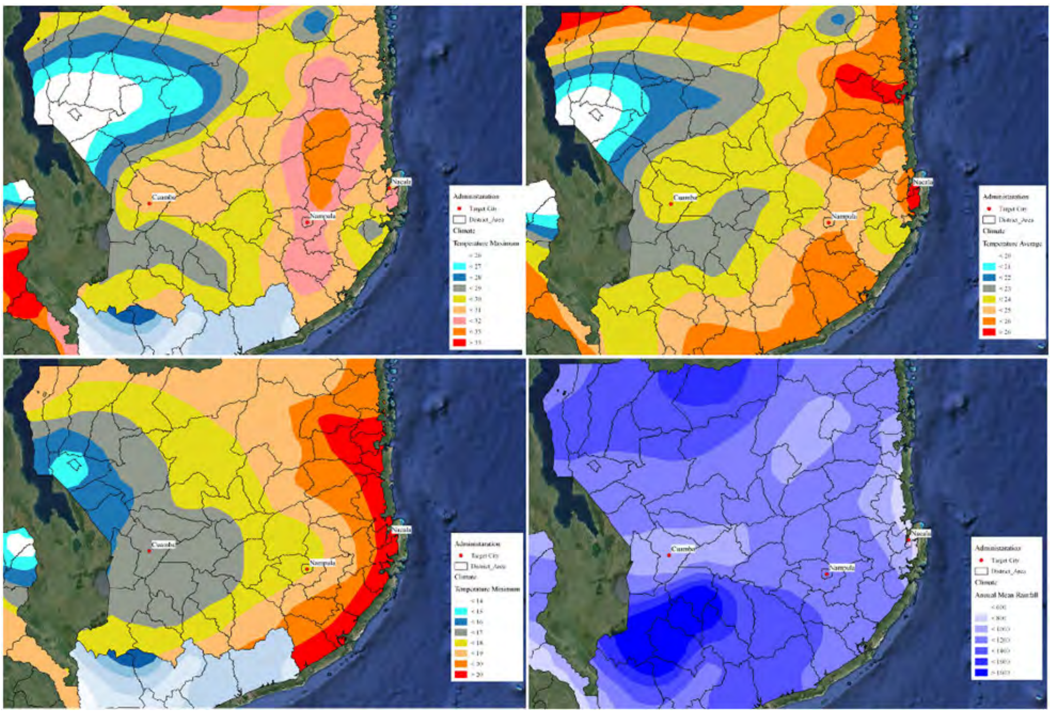
CHAPTER 3 Present Condition of the Target Road

3.1 Natural Conditions

3.1.1 Meteorology

According to the Köppen climate classification system, the study areas are classified as a tropical rain savannah climate ("Aw", a part of Nacala is "As".)

In the north of Mozambique, represented by the study area, temperatures are in general higher, with an annual mean of 24 to 26°C in the low-lying coastal areas. In the higher areas, the temperature is slightly lower: this is the case with the city of Cuamba in the Northwest, located at 600m above sea level. The average relative humidity is 71% in the coastal areas, and 64% on the border with Zimbabwe. There is a great variation in rainfall between the north and the south of the country, and between coastal and inland areas. Along the coastal strip, mean annual rainfall is in the order of 800-1,200mm. South of Pemba there is a reduction to below 800mm, and between Beira and Quelimane, the figure is higher than 1,200mm. Because of the influence of the northwest monsoon, which affects the north and centre of the country, and the influence of the high altitude, this area has mean annual rainfall of 1,000-1,600mm. The rainy season, which is a hot and wet period, runs from November to March, and is followed by a dry and relatively cooler season between April and October. (Figure 3.1.1)



Source: INAM, the Study Team

Figure 3.1.1 Annual Maximum/Mean/Average Temperatures and Annual Rainfall around the Study Area

3.1.2 Topography and Geology around the Target Roads

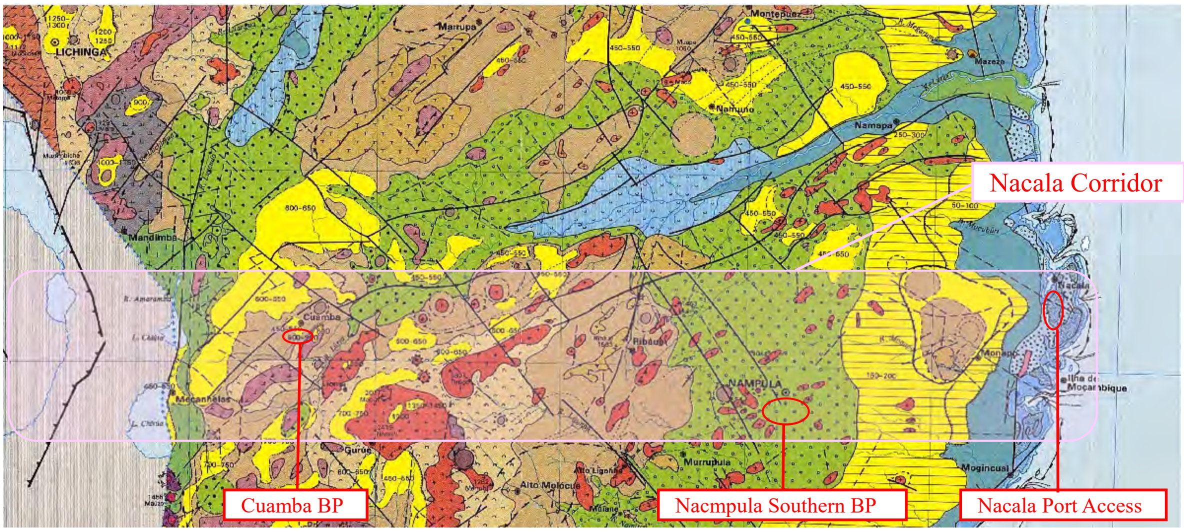
(1) Topographic Characteristics along Nacala Corridor

The morphology of Mozambique can be characterised by distinct units: coastal lowlands, middle plateaus, upland plateaus and mountainous areas. This division generally coincides with certain altitudinal intervals: 0 to 200 m (44 % of the surface area), 200 to 500 m (29%), 500 to 1,000 m (21 %) and over 1,000 m (6%). The units are bounded by more or less pronounced escarpments, giving rise to a step-like cross section, rising from the coast toward inland. The coastal lowlands mainly coincide with the sedimentary terrains, whereas the other units are underlain by the crystalline rocks of the Basement Complex.

The topography of the terrain of Nacala Corridor, which lies across the northern part of Mozambique from east to west, is divided into the following characteristics as shown in Figure 3.1.2.

- **a.** Coastal lowlands (blueish coloured in the map) in the vicinity of Nacala,
- **b.** Middle plateau (yellow and olive) occupying most of the eastern part, including Nampula, and
- **c.** Upland plateau (light brownish coloured) in the western part including Cuamba.

The many prominent mountains (reddish or purplish coloured) that mainly consist of intrusive igneous rocks are distributed in the Middle Plateau and Upland Plateau.

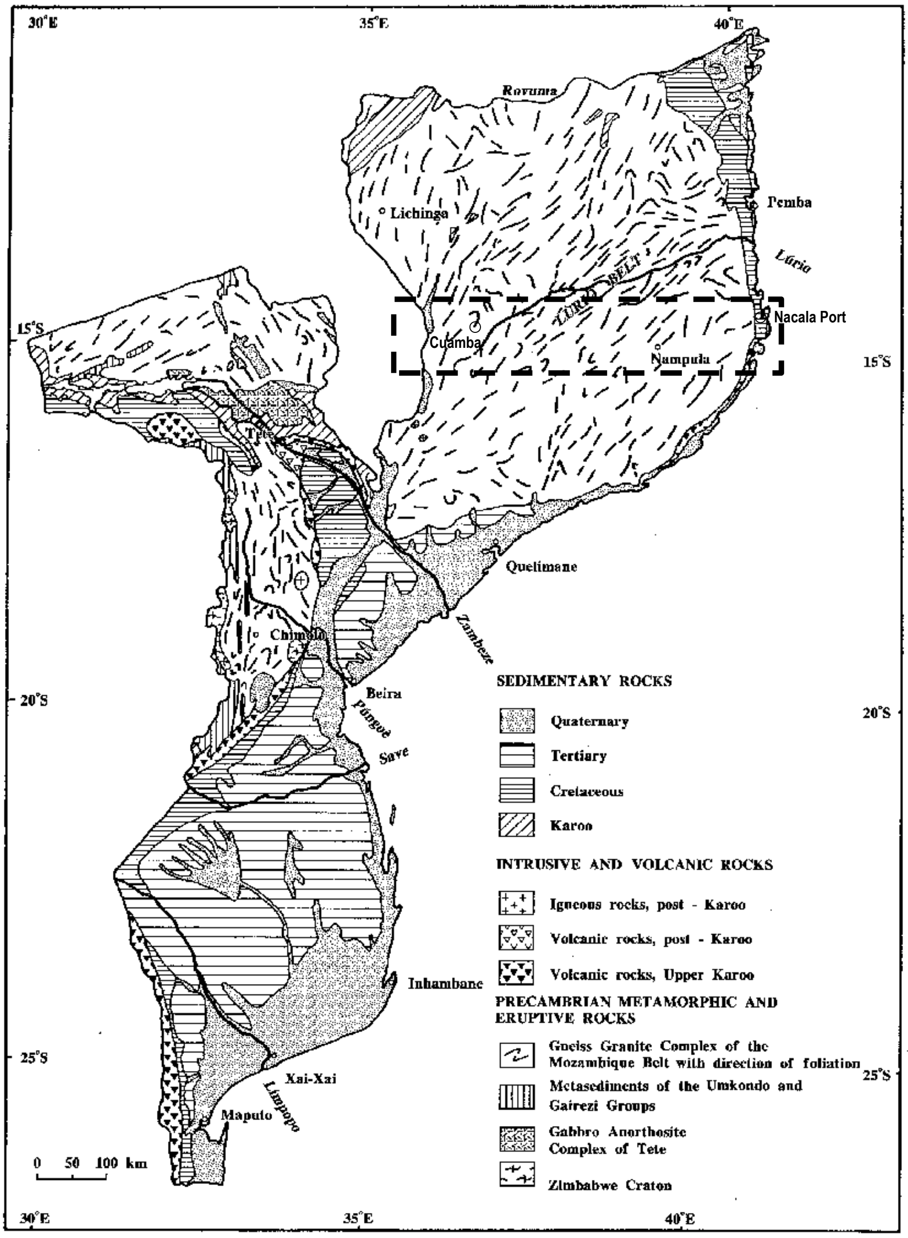


Strand and River Valleys; Lower Quaternary beds cut by alluvial deposits; Coastal platforms covered with Cretaceous conglomerates and sandstone
Depressions; Depressions with sedimentary and erosive terraces
Sedimentary Plateau: Levelled surfaces intercepting base complex, peneplains and pediments;
River terraces carved into rock; Foot of plains with clearly defined alluvial and deluvial cover
Erosive - stripped Plateau: Compartmentalised gentle reliefs; Hills of foot zone
Tectonic Intrusive Rocks; Reliefs on plateau in the area of rift; Reliefs of granitic rocks
(Extracted from "CARTA GEOMORFOLÓGICA, 1982, DIRECÇÃO NACIONAL DE GEOLOGIA, MINISTERIO DOS RECURSOS MINERAIS, REPÚBLICA POPULAR DE MOÇAMBIQUE)

Figure 3.1.2 Geomorphic Classification Map for Northern Mozambique

(2) Geological Formations in Nacala Corridor

The rocks in Mozambique belong to four main lithological/stratigraphic groups: Precambrian crystalline rocks of the Basement Complex (57%), Karoo sedimentary rocks (5%), Post Cambrian volcanic and igneous rocks (3%) and Meso-Kenozoic sedimentary rocks (35%) as shown in Figure 3.1.3.



Source: Explanatory Notes to the Hydrogeological Map of Mozambique; National Directorate for Water Affairs, Ministry of Construction and Water, GRM, 1987

Figure 3.1.3 Geological Outline for Mozambique

Northern Mozambique, which consists of 5 provinces, is a bedrock zone except for the coastal areas. The geology of the bed rocks is a metamorphic complex rock body called “Mozambique Zone” consisting of granite-gneiss and migmatite formed in late Precambrian (about a billion years ago). The Mozambique zone is divided into north and south by the shear zone called the “Lurio Belt”, which was formed in the southwest direction by the crustal movement in early Paleozoic. In the southern side of Lurio Belt called the “Nampula block”, several kinds of igneous rocks (granite, mottled gabbro, etc.) intruded and formed many mountains standing erectly. The north side is called the “Unango block”, which spreads west from Cuamba City and has relatively less intrusive rocks and is a formed peneplain with gentle undulations.

The sedimentary rocks which were formed after the above tectonic movement are classified into two types; the Karoo series formed in Paleozoic times are widely distributed in the southern part of Mozambique. The other sedimentary rocks were deposited in the basin which formed related to the crustal deformation associated with the East African Rift Valley after the Mesozoic period.

In the northern coastal areas from Tanzania to Mozambique Island, mudstones, sandstones and limestone which were deposited intermittently during late Mesozoic (Cretaceous) to Cenozoic (Tertiary) periods are distributed. In the area of these sedimentary rocks, folds are rare, while many faults developed. The surfaces of the sedimentary rocks have weathered zones with a thickness of around 10 m, and these are covered with loose soil and sand. As unconsolidated sediments, the alluvium deposit is in the lowland along rivers, eolian soil is in the coastal area, and Colluvium deposit covers the lower part of the slopes.

(3) Topography of Nacala Port Access Road

On the east side of Nacala Bay, which has an open mouth on the north side, a ridge which has elevations of 100 to 160 m runs continuously in a north-south direction about 35 km from the northern tip of the peninsula.

Nacala Port is located on the middle of the Nacala Bay’s east coast, about 10 km south from the northern tip of the peninsula. Nacala Port Access Road is planned from the Port to the south, through the coastal line and the western slopes of the ridge, connected to National Road N-12 which runs about 15km south of the Port.

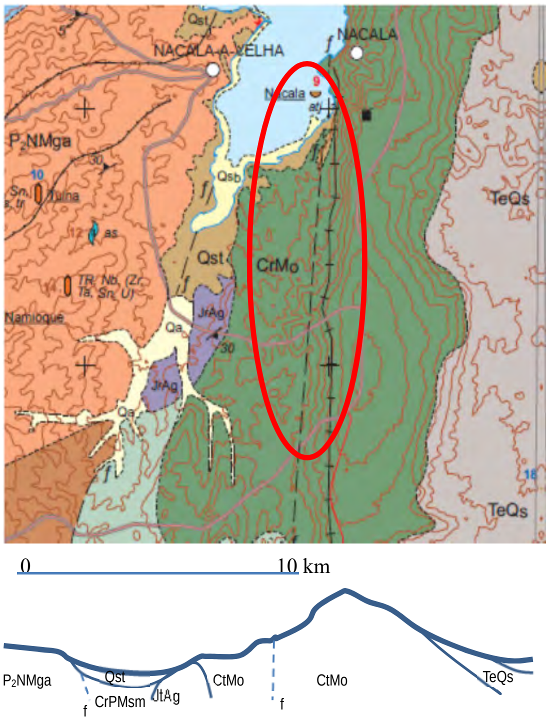
The planned route traverses many small valleys formed on the western slope of the ridge, and its elevation gradually rises, reaching about 120 m at the junction with the National Road.

Item	Description
Starting point	Southern Warf of Nacala Port (Under Development)
End point	Junction with N12 Road
Length	About 15 km
Direction	to South
Altitude	Highest point: 140 m, Lowest point: 0 m,
Geomorphic Classification	- Lower Quaternary beds cut by alluvial deposit - Coastal platforms covered with Cretaceous sandstone - The route passes mainly on the slope of the platform, partly on the Quaternary bed.

As the soft sedimentary rocks are vulnerable to erosion, the surface of the slope is likely to be washed out by heavy rainfall. Evidence is observed that in recent years erosion is progressing frequently, especially on the downstream side of the drainage in the developing land such as reclamation sites for factory construction and road construction.

(4) Geology along Nacala Port Access Road

The geological map and schematic West-East section of Nacala Bay area is shown in Figure 3.1.4.



Geological Age (Ma: million years)		Symbol	Description
Quaternary Holocene	0.01Ma	Qsb	Sub-tidal Sandbars
Pleistocene	2.6 Ma	Qst	Organic-rich and saline mud, mangrove swamps and salt marsh flat
Neogene Pliocene			
Miocene			
Paleogene Oligocene	66 Ma	TeQs	Coral bearing limestone, coquina
Mesozoic Cretaceous		CrPMsm CrMo	Grey sandstone and Interbedded coquina horizon Fine to medium gained cross-bedded Sandstone
Jurassic	200 Ma	JrAg	Dark grey to dark red amygdaloidal andesite and basaltic andesite subordinate mud rock and tuff
Palaeozoic Cambrian	542 Ma		
Proterozoic Neoproterozoic	1,000 Ma		
Mesoproterozoic		P_2NMga	Streaky augen and augen granitic gneiss

f — — - : fault, inferred

Source: Geological Map “NACALA”, 1/250,000, DIRECÇÃO NACIONAL DE GEOLOGICA (December 2006)
Schematic Section: interpretation by JICA Study Team

Figure 3.1.4 Geological Map and Schematic Section

The geology of the west side of Nacala peninsula on which the Nacala Port Access Road will pass is as follows;

- Fine to medium grained cross-bedded sandstone (CtMo), which was deposited in the Cretaceous period, is predominant in Nacala Peninsula as base rock. This bedding plane is horizontal or slightly inclined toward the east.
- The fault is inferred on the west side of Peninsula in North-South direction. In the west side of the fault, an upper Cretaceous layer (CrPMsm) overlays the sandstone (CtMo). In the east side of the fault, a steep slope is formed between the fault and the ridge. The dip of this fault is unclear, but the eastern (ridge) side is supposed to have risen against the western (bay) side. The exact location and features of the fault are not indicated clearly on the geological map.

Sedimentary rocks of the Cretaceous period (CtMo) that made up the ridge of the peninsula, which has been accompanied by the weathering zone having a thickness of about 10m, are susceptible to erosion by rainwater or surface run-off water. This erosion is easily progressed anywhere on the steep slopes formed along the east side of the fault. Furthermore, penetrated rainwater in the sandstone layer is hindered to penetrate downward at the surface of the sandwiched mudstone layer, and springs out on the slopes. These springs lead to the collapse of the slope, and it also promotes erosion.

ER-1: Many informal houses are constructed on the erosive steep slope near Nacala Port

ER-3: Eroded valley, drainage from the developed area and its sediment affected the embankment of railway (foreground).

ER-2: Mudstone layer sandwiched in sandstone makes spring water

ER-4: Eroded valley, downstream from the spring on the slope

Figure 3.1.5 Example of eroded slope on the Cretaceous sandstone (CtMo) layer

During earthworks associated with road construction on the slope, it is recommended to note the historical spring portions and to provide appropriate drainage for the groundwater.

The fault is not an active fault. Although the route can be planned crossing the fault, bridges and other heavy structures are not recommended on the inferred fault line because of insufficient bearing capacity for the foundation.

Quarry sites are generally difficult to find in this area except for small scale intrusive volcanic/igneous rocks (JrAg).

In the surrounding area, the Tertiary sedimentary rock (TeQs), which consists of coal-bearing limestone, overlays the Sandstone (CtMo) and is gently inclined toward the east. Furthermore, unconsolidated sub-tidal sand dunes were deposited in the Quaternary period to cover these sedimentary rocks where the lowland faces Nacala Bay.

(5) Topography of Nampula Southern Bypass Road

The route passes along the outskirts of the southern end of urban area of Nampula city. The existing National Road runs on the watershed between Monapo River basin in the north and the basin of Meluli River and Mogincual River which run down to the south-east. So the Nampula South Bypass will cross many of the small branches of Meluli and Mongincual Rivers. But, the west end of the route runs on the ridge in the Meluli River basin and connects with the above mentioned main watershed.

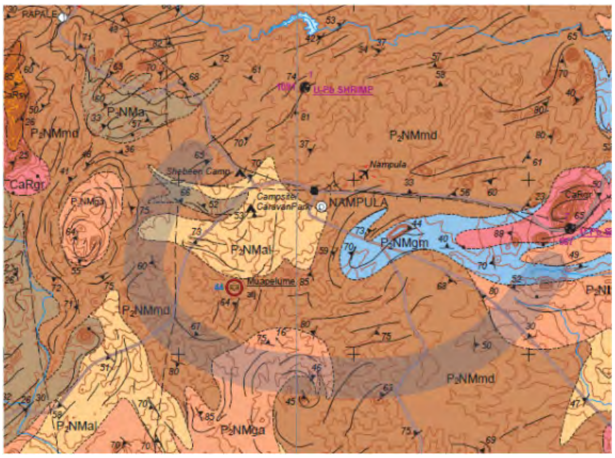
There is a gently undulating plateau except for some prominent mountains located near the starting point. The route crosses two main ridges directed along the two National Roads N-104 and N-1.

Item	Description
Starting point	Junction with N-1 Road, 12 km East of the Centre of Nampula City
End point	Junction with N-13 Road, 7.5 km North West of the Centre of Nampula City
Length	About 30 km
Direction	to SSW and rotating clock-wise for 225 degrees to ENE
Altitude	Highest: 430 m near the End point. Lowest: 330 m at the river crossing on the SW side of the route
Geomorphic Classification	Sedimentary (Middle) Plateau (Foot of plains with clearly defined alluvial and deluvial cover)

Figure 3.1.6 Morphological Features for Nampula Southern Bypass

(6) Geology along Nampula Southern Bypass

The geology of the bedrock in the vicinity of Nampula is called the Nampula Complex, and consists of granite, gneiss and migmatite, and igneous rocks (mainly granites) intruded into the cracks of the bedrock body.



Geological Age (Ma: million years)			Symbol	Description
Palaeozoic	Cambrian	542 Ma	CaRgr	(Marrupula Group) CaRgr: Granite Equi-granular, medium-grained, locally leucocratic
Proterozoic	Neoproterozoic	1,000 Ma		
	Mesoproterozoic	1,200 Ma	P_2NMga P_2NMa P_2NMmd P_2NMgn*	<NAMPULA COMPLEX: P_2NM> (Culicui Group) P_2NMga P_2NMal: Leucocratic (whitish) gneiss P2NMga: Streaky augen granitic gneiss (Mamala Gneiss Formation) P_2NMa Undifferentiated metamorphic rocks – Metapelite, etc. (Rapale Gneiss) P_2NMmd Hornblend-bearing tonalitic-granodiolitic gneiss (Undifferentiated NAMPULA COMPLEX) P_2NMa

0 10 km : Nampula Southern Bypass Road

Source: Geological Map "NAMPULA", 1/250,000, DIRECÇÃO NACIONAL DE GEOLOGICA (December 2006)

Figure 3.1.7 Geological Map for Nampula Southern Bypass Road

The thickness of sediments on the bedrock seems relatively thin because outcrops of bedrock are observed on the riverbed of the dendritic valley system, though the geomorphology is classified as a peneplain called "sedimentary plateau". However, the thickness of the weathered zone and the sediments on the bedrock are presumed to be largely changed by the influence of such faults and cracks. Also, some of the intrusive rock bodies are possibly hidden in addition to those exposed on the surface.

(7) Topography along Cuamba Bypass Road

The route cuts the tip of a ridge after passing over Muanda River, a branch of Lurio River, near the starting point. After crossing over the tip of the ridge, the route runs on the peneplain with an altitude of 560 -570 m for 4 km, then rises up to a higher hill zone of altitude 580 -600 m for 6 km up to the end point on N-13 Road.

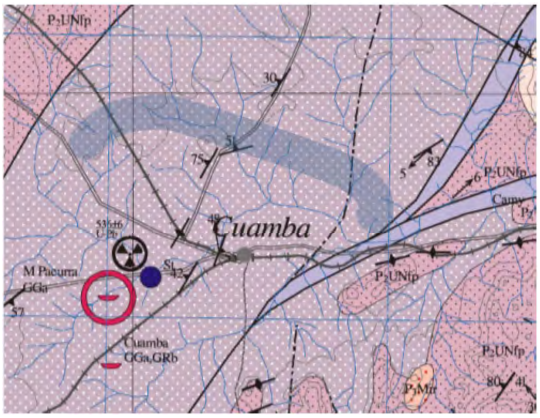
Muanda River had more than 300 m width during a flood in early 2015 while it is only 20 to 30 m width in a normal dry season.

Item	Description
Starting point	Junction with N-13 Road, 4 km East of the Centre of Cuamba City
End point	Junction with N-13 Road, 3 - 6 km North West of the Centre of Cuamba City
Length	About 12 km
Direction	to NNW for 1.9 km, to W for 2.6 km, to NW 3.7 km and to SW for 3.6 km
Altitude	Highest: 602 m near Marrupa Road Crossing. Lowest: 562 m at river crossing near Starting point
Geomorphic Classification	Sedimentary (Upland) Plateau: Levelled surfaces, peneplains and pediments Erosive - stripped (Upland) Plateau: Hills of foot zone

Figure 3.1.8 Morphological Features for Cuamba Bypass

(8) Geology along Cuamba Bypass

The geology in the vicinity of Cuamba, called Unango Block, is a basement complex composed mainly of granite and gneiss. Intrusive rock bodies are scarcely found in the area on the west side of the mountains which is located 10 km east of Cuamba City. This terrain is classified as erosive-stripped plateau, and its weathered zone seems to be relatively thin. Since the bedrock of this region is homogeneous and is not so affected by weathering, many quarry sites have been extensively developed north of Cuamba. The quarry stones are being supplied for the construction of railways and roads in a wide area that extends to Nacala Port.



Geological Age (Ma: million years)		Symbol	Description
Palaeozoic Cambrian	542 Ma	Camy CaMgr	Camy: Mylonite CaMga: Granite (517±12 Ma, intrusion)
Proterozoic Neoproterozoic	1,000 Ma	P3Mr	P3Mr: Granitic gneiss (749±20 Ma, intrusion)
Mesoproterozoic	1,600 Ma	P2UNfp P2UNcm	<UNANGO COMPLEX: P_2UN> P_2UNfp: Charnockitic granofels and Gneiss, partly porphyric (1,001±33 Ma, intrusion) P2UNcm: Chanockitic gneiss, partly migmatitic, (536±6 Ma, metamorphic, U-Pb)

Radiometric age & method, Commodity (GGa: Garnet, GAq: Aquamarine, Quarry)

0 10 km : Cuamba Bypass Road

Source: Geological Map "MANDIMBA-CUAMBA", 1/250,000, DIRECÇÃO NACIONAL DE GEOLOGICA (February 2007)

Figure 3.1.9 Geological Map for Cuamba Bypass Road

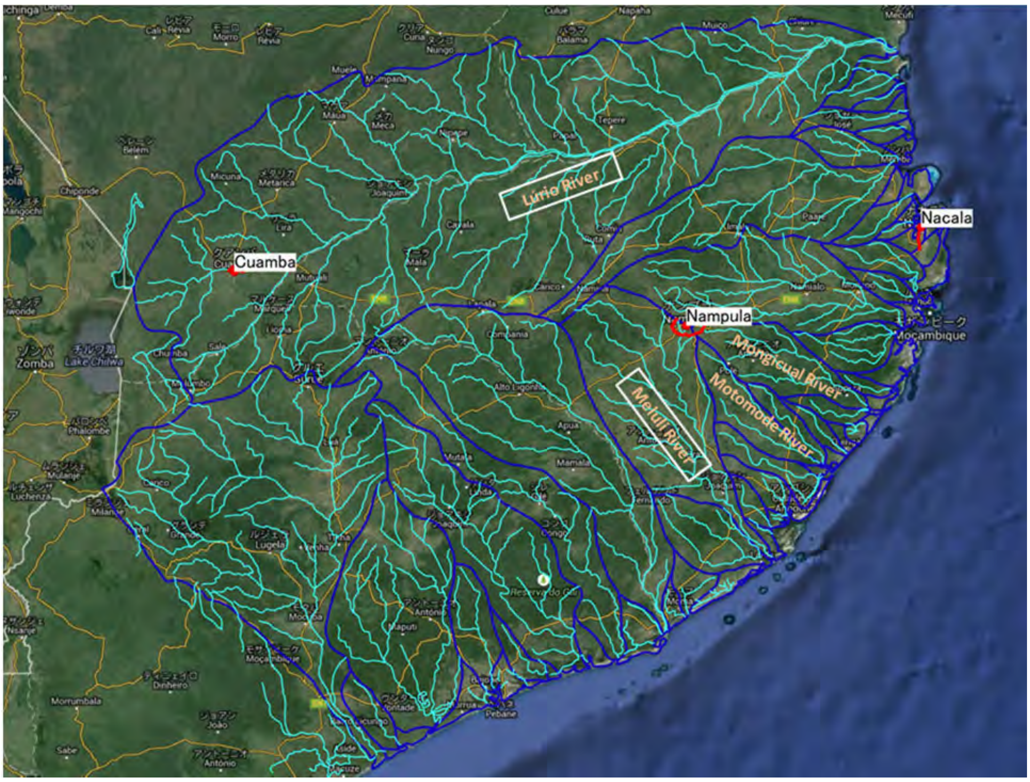
Alluvium is developed in a narrow area along the rivers in most places, except along Muanda River. In the flood area having a width of about 300 to 400 m along Muanda River, unconsolidated sediments are widely distributed, but there is no detailed record about the thickness.

The organic black soil can be found on a part of flat ground surface near the North-West end of the planned route, and some other areas as well. The area of distribution of this soil is several ha or more (Figure 3.1.10). Many cracks develop in a mesh pattern on the surface in dry season, the depth has reached at least 20cm or more. This feature indicates that the soil is possibly expansive and shrinkable, and may affect the stability of road and related structure. The distribution and soil characteristics will be examined through the geo-technical investigation.

Figure 3.1.10 Expansive organic soil

3.1.3 Hydrology around the Target Roads

Rivers related to the Study Area are contained within the Lúrio River basin for the Cuamba study area, and the Meluli River, Motomode River and Mongicual River basins for the Nampula. The Lúrio River basin area is about 61,000 km^2, the Meluli River is 9,700 km^2, the Motomode River is 2,000 km^2 and the Mongicual River is 3,200 km^2. The study areas of Nampula and Cuamba are located around upstream regions of the rivers. In addition to these major river basins, there are many other smaller rivers, in the Nacala area of the coastal zone (Figure 3.1.11)



Source: ARA centro norte, DPA, INAM, the Study Team

Figure 3.1.11 River Basins in the ARA Centro-Norte Region

Among of above-mentioned rivers, 2 major river basins of the Lúrio and Meluli Rivers are presented in the following.

(1) Lúrio River Basin (WMO 8907)

The Lúrio river basin is the largest entirely Mozambican river basin with an area of about 61,000 km^2, including parts of the Provinces of Niassa, Cabo Delgado, Nampula and Zambézia.

The basin has the shape of an ellipse with a main axis of approximately 600 km. The shape factor is 0.23, indicating a low flood prone basin. It raises in Mount Malema in the administrative post of Molumbo at an altitude of 1300 m, the source is close to the administrative post of Lúrio. The main tributaries are the rivers Muanda, Nihuregè, Luleio, Muataza, Rurruma, on the left bank and on the right bank the rivers Lalaua, Malema, Nalume.

The topography of the basin is characterised by the existence of dispersed mountains with altitudes between 1500m and 2400m, a meso-plain with altitudes between 1000m and 1500m and a low plain with altitudes lower than 200 m.

The sub-basin with the higher runoff coefficient is the Malema. While in this sub-basin an annual precipitation of 1000 mm can generate 300 to 500 mm depth of surface runoff, across the total basin the same rainfall can only generate 120 mm of runoff.

In the past, a total of 37 hydrometric stations and 80 rainfall stations were installed, of which only 2 and 5 are in operation now. Flow measurements were made in only 7 hydrometric stations. Because of the low coverage of hydrometric stations after the time the Lurio study was made, it is not possible to update the information and findings of that study.

There are many dams in the basin and total hydropower generation had been estimated at 6,000 GWh.

(2) Meluli River Basin (WMO 8913)

The Meluli river basin has an area of about 9700 km^2, being limited by the river basins of the Mecuburi, Motomode and Monapo to the north and the Larde to the south. It has its source in a mountainous area, at some 1100 m of altitude, 10 km from the administrative post of Namina. The river has a total length of 250 km and its main tributaries are the Namaita, Naha, Mecucu and Murrioze on the right bank; the tributaries on the left bank are quite small.

Like most of the other basins of the region, the Meluli basin has an elongated shape, narrowing in the terminal part. The shape factor is 0.25, indicating a low flood prone basin. However, the basin has recorded floods of considerable magnitude in its most downstream section.

The upstream part of the basin has altitudes between 400 and 600 m, with some mountain peaks reaching 800 m. The most downstream section stands below 200 m altitude.

According to DNA, 8 hydrometric stations were installed, of which one is working presently and 20 rainfall stations of which 4 are functional, but none of the rainfall stations are presently in operation.

3.2 Socioeconomic Conditions

3.2.1 Population

(1) Historical Growth by Province

According to the preliminary result of the General Census of Population and Housing in 2017, the national population was 28,861,863 in 2017. (Table 3.2.1) According to the World Bank database, the national population has reached 29,669,000 in 2017. Basically, the Average Annual Growth Rate (AAGR) in Mozambique has hovered around 2.5% since 1970. However, between 1980 and 1997, it dropped almost one percent due to the civil war between 1977 and 1992.

The share of population in the Nacala Corridor Region[1] accounted for more than half of the national population in 2007. (Table 3.2.2) Among the five provinces related to the region, the population of Nampula is largest at 4 million, followed by Zambézia, Tete Cabo Delgado and Niassa. In terms of AAGR, Niassa Province and Tete Province shows comparatively high value, 4.14% and 3.96% respectively.

Table 3.2.1 Population and Average Annual Growth Rate in Mozambique (1950-2015)

	1950	1960	1970	1980	1997	2007	2017
Population (mil.)	6.47	7.60	9.41	12.13	16.08	20.63	28.86
		50-'60	60-'70	70-'80	80-'97	97-'07	07-'17
Average Annual Growth Rate		1.62%	2.16%	2.57%	1.67%	2.52%	3.41%

Source:
Population and Housing Census 1997, 2007 and 2017, INE
PEDEC-Nacala

Table 3.2.2 Population and Average Annual Growth Rate by Province (1997-2007)

Provinces	Population		Average Annual Growth Rate
	1997	2007	1997-2007
Nampula	3,063,456	4,084,656	2.92%
Niassa	808,572	1,213,398	4.14%
Cabo Delgado	1,380,202	1,634,162	1.70%
Zambézia	3,096,400	3,890,453	2.31%
7 districts in Zambézia	1,360,831	1,808,220	2.88%
Tete	1,226,008	1,807,485	3.96%
Sub Total (Nacala Corridor Region)	7,839,069	10,547,921	3.01%
Mozambique	16,075,708	20,632,434	2.53%

Source: Population and Housing Census 1997 and 2007, INE

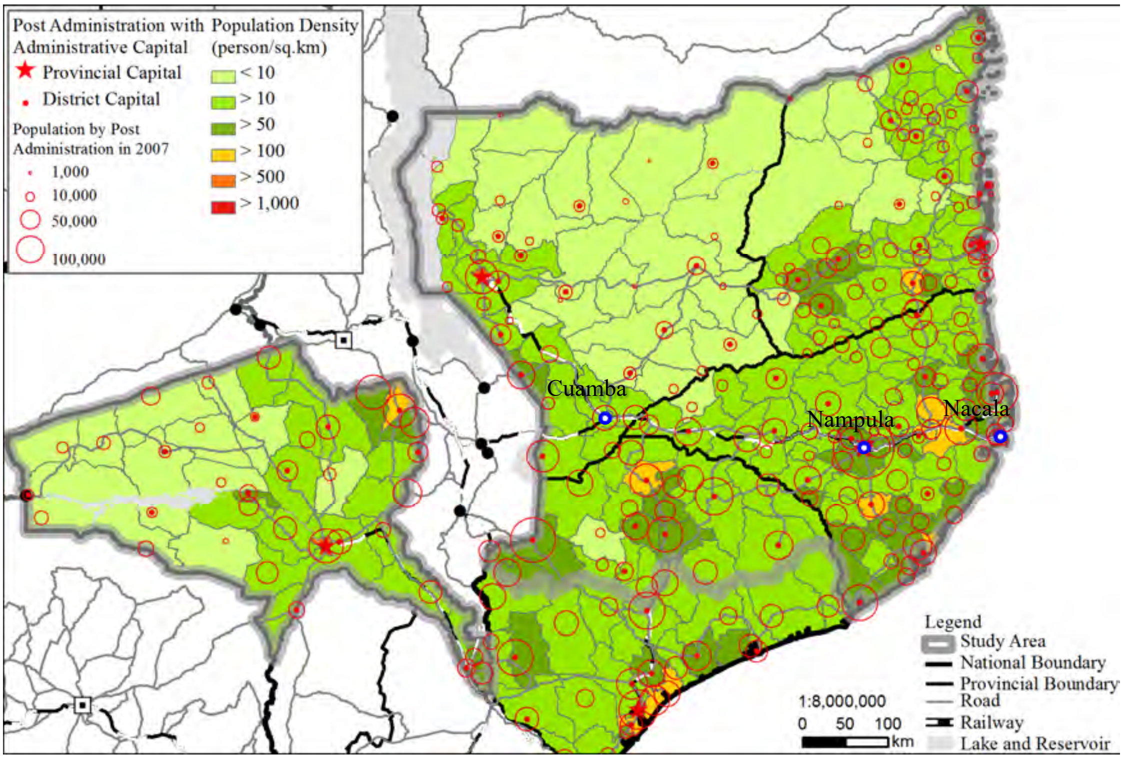
(2) Spatial Distribution of the Population

Figure 3.2.1 shows the population density in the Nacala Corridor Region. In the Nampula province, almost all areas have population densities of more than 10 person/sq. km. Especially, in the maritime area and the area around Nampula city it is higher than other areas. On the other hand, population in Niassa province is concentrated in the south-west side of the province, along the railway line. Because the large part of the north-east side of the province is the Niassa Natural Reserve, population density is low in the area.

Location of villages is shown in the Figure 3.2.2 along with information about the scale of the village. In general, villages are concentrated along the primary and secondary roads. Especially near the cross points of these roads, many villages are concentrated in small areas.

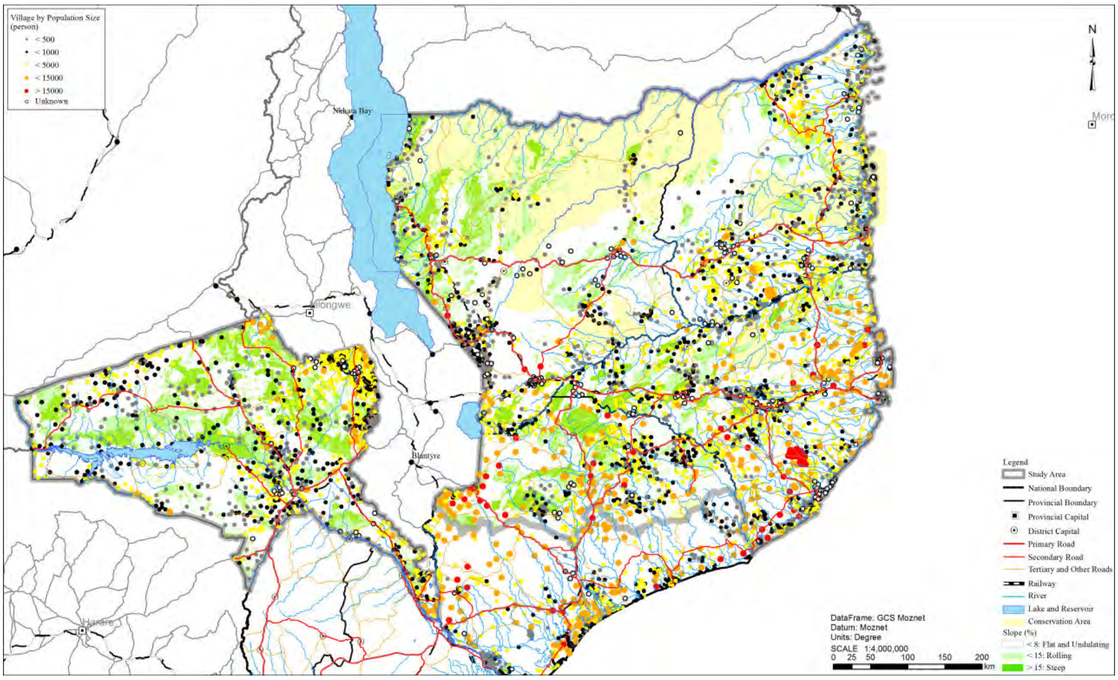
[1] PEDEC-Nacala defined the Nacala Corridor Region as the four provinces of Nampula, Cabo Delgado, Niassa, Tete and the seven northern districts of Zambezia Province, which are the districts of Alto Molocue, Gile, Gurue, Ile, Lugela, Milange and Namarroi.

Population growth rate by post administration between 1997 and 2007 is shown in Figure 3.2.3. In Nampula province, has been localised in the area around Nampula city. On the other hand, the area with the highest population growth rate in Niassa province has spread widely. However, the increase in the population in the suburb of Niassa area was not so large. That suggests that the high population growth rate in these areas does not indicate that there will be a drastic change of population distribution.



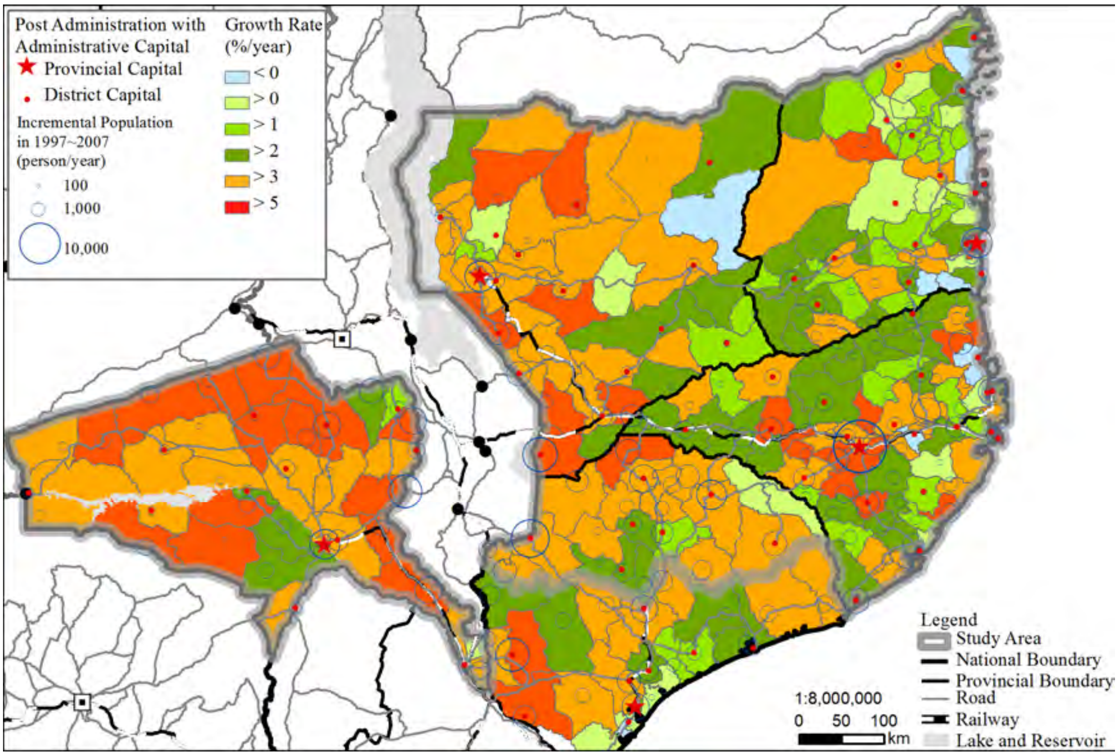
Source:
Population and Housing Census 2007, INE
Mapped by PEDEC-Nacala

Figure 3.2.1 Population Density by Post Administration (2007)



Source: Population and Housing Census 2007, INE
Mapped by PEDEC-Nacala

Figure 3.2.2 Village point data with population is extracted from the Census data in 2007



Source: Population and Housing Census 1997 and 2007, INE
Mapped by PEDEC-Nacala

Figure 3.2.3 Population Growth Rate by Post Administration (1997-2007)

Table 3.2.3 shows the urban population in Mozambique by province. The urban population in the five provinces has increased from 1.8 million to 3.2 million (80%) between 1997 and 2001. Among the five provinces, Nampula has the largest urban population at 1.37 million. In Nampula, the urban population ratio has raised from 25 percent to 30 percent between 1997 and 2001. This means that the urbanisation is remarkable in Nampula province. In Niassa province, the urban population ratio has been at the same level between 1997 and 2011.

Table 3.2.3 Urban Population by Province (1997-2011)

	Total Population			Urban Population			Urban Population Ratio		
Province	1997	2007	2011	1997	2007	2011	1997	2007	2011
Nampula	3,063,456	4,084,656	4,529,803	765,864	1,168,212	1,368,001	25.0%	28.6%	30.2%
Niassa	808,572	1,213,398	1,415,157	186,780	277,868	328,316	23.1%	22.9%	23.2%
C. Delgado	1,380,202	1,634,162	1,764,194	231,874	339,906	395,179	16.8%	20.8%	22.4%
Zambézia	3,096,400	3,890,453	4,327,163	418,014	676,939	822,161	13.5%	17.4%	19.0%
Tete	1,226,008	1,807,485	2,137,700	180,223	247,625	290,727	14.7%	13.7%	13.6%
Maputo	830,908	1,225,489	1,444,624		832,107	996,791		67.9%	69.0%

Source: Population and Housing Census 1997 and 2007, INE

(3) Future Population by Province

1) Population Projection by PEDEC-Nacala

PEDEC-Nacala has predicted future population in the Nacala Corridor Region 2007-2035. The prediction is based on the INE's population projection 2007-2040 and the following perspectives for each province in the Nacala Corridor Region. The population projection developed by the United Nations was also referred to in the prediction.

- Nampula Province has a lower Total Fertility Ratio (TFR) compared to other provinces due to its urban population, but it is expected that in-migration will occur with the development of the Nacala Corridor in Greater Nampula and Nacala Bay Area.
- Niassa Province will continue to have higher crude birth rates than the other provinces, but considering the development of other provinces, out-migration will occur.
- It is assumed that the Cabo Delgado Province has been experiencing out-migration in the past, but with the development expected to occur in Pemba and Palma, the out-migration population is expected to decrease.
- The expected phenomenon in the northern seven districts of the Zambézia Province will be similar to that of the Niassa Province.
- Tete Province will continue its current trend with high TFR and in-migration, but Tete Province will have lower TFR than projected by INE.

The national population growth rate is the same in the projections of INE and PEDEC-Nacala, but the population growth rate of each province is adjusted based on the above mentioned perspectives (Table 3.2.4).

Table 3.2.4 Adjusted Population Growth Rates by Province in the Nacala Corridor Region

Province	97-07	07-10	10-15	15-17	17-20	20-25	25-30	30-35
Nampula	2.92	3.08	2.99	2.69	2.69	2.48	2.22	1.97
Niassa	4.14	3.53	3.34	3.07	2.87	2.56	2.18	1.79
Cabo Delgado	1.70	2.21	2.3	2.28	2.26	2.24	2.20	2.17
Zambézia*	3.59	3.11	2.98	2.62	2.62	2.37	2.06	1.76
Tete	3.96	4.11	4.00	3.66	3.66	3.44	3.15	2.87
Nacala Corridor Region	3.13	3.18	3.11	2.82	2.82	2.62	2.38	2.13
Other Area	1.93	2.41	2.48	2.41	2.41	2.36	2.31	2.25
Whole Country	2.53	2.80	2.81	2.63	2.63	2.50	2.34	2.19

Unit: %
Source: PEDEC-Nacala based on INE's Statistics 2007 Population and Housing Census
Note: * Population from northern 7 districts in Zambézia

Table 3.2.5 Population Projection by Province in the Nacala Corridor Region

	Population (1,000) AAGR (%)				AAGR (%)	
Province	2007	2017	2025	2035	2007-2025	2007-2035
Nampula	4,085	5,480	6,707	8,252		
	-	3.0%	2.6%	2.1%	2.8%	2.5%
Niassa	1,213	1,686	2,083	2,535		
	-	3.3%	2.7%	2.0%	3.0%	2.7%
Cabo Delgado	1,634	2,046	2,444	3,034		
	-	2.3%	2.2%	2.2%	2.3%	2.2%
Zambézia *	1,808	2,425	2,946	3,561		
	-	3.0%	2.5%	1.9%	2.7%	2.4%
Tete	1,807	2,675	3,528	4,747		
	-	4.0%	3.5%	3.0%	3.8%	3.5%
Nacala Corridor Region	10,548	14,312	17,707	22,129		
	-	3.1%	2.7%	230.0%	2.9%	2.7%
Other Area	10,084	12,846	15,508	19,425		
	-	2.4%	2.4%	2.3%	2.4%	2.4%
Mozambique	20,633	27,158	33,215	41,554		
	-	2.8%	2.5%	2.3%	2.7%	2.5%

Source: PEDEC-Nacala based on INE's Statistics 2007 Population and Housing Census
Note: * Population from northern 7 districts in Zambézia

(4) Future Population of Selected Cities/Districts

The population in the major cities and districts in the Nacala Corridor Region is projected in the PEDEC-Nacala. These cities or districts have a key role for the growth in the area. The projected population growth rates of these cities and districts are based on the INE's projection adjusted by the growth rate of the whole province. The population in these areas will sustain high rates of growth in the next 20 years. The population in Nampula City is predicted to reach 1 million in 2035.

Table 3.2.6 Population Projection of Selected Cities in the Nacala Corridor Region

City /District	Province	Population (1,000) AAGR (%)					AAGR (%)	
		1997	2007	2017	2025	2035	'07-'25	'07-'35
Lichinga City	Niassa	86	142	241	336	467		
		-	5.6%	5.1%	4.2%	3.4%	4.4%	4.0%
Cuamba City*	Niassa	57	79	133	189	267		
		-	3.3%	5.4%	4.4%	3.5%	5.0%	4.4%
Pemba City	Cabo Delgado	85	168	219	312	474		
		-	5.0%	4.6%	4.6%	4.3%	4.6%	4.5%
Nacala City	Nampula	158	212	319	440	635		
		-	3.0%	4.2%	4.1%	3.7%	4.1%	4.0%
Nampula City	Nampula	303	484	729	941	1180		
		-	4.8%	4.2%	3.2%	2.3%	3.8%	3.2%
Nacala-a-Velha	Nampula	78	91	131	189	300		
District		-	1.6%	3.7%	4.7%	4.7%	4.1%	4.4%
Tete City	Tete	102	156	230	303	409		
		-	4.3%	4.0%	3.5%	3.0%	3.8%	3.5%
Moatize City*	Tete	27	39	68	104	158		
		-	3.9%	5.7%	5.5%	4.3%	5.6%	5.1%

Source: PEDEC-Nacala based on INE's Statistics 2007 Population and Housing Census
Note: * Based on urban population in 2007

3.2.2 Regional Economy

(1) Past Trend of Economic Growth

1) GRDP (Gross Regional Domestic Product)

Table 3.2.7 shows the historical GDP and GRDP by province in Mozambique. As shown in the table GDP in constant prices in 2003 in Mozambique reached 197 billion MZN in 2011. According to the latest information of INE statics, it has reached 226 billion MZN in 2013[2]. The

[2] GDP constant price in 2009 was 338,281 million MZN in 2011 and 388,696 million MZN in 2013.

AAGR has hovered around 7-8 percent between 1997 and 2011. Among the 5 provinces in the Nacala Corridor Region, Nampula province has the largest proportion in Mozambique (14.8%), followed by Zambézia (9.4%), Tete (5.7%), Cabo Delgado (4.7%) and Niassa (3.0%).

Table 3.2.7 GRDP and Growth Rate by Province in Mozambique

	GRDP (Million MZN, 2003 Constant Prices)				AAGR (%)		
Province	**1997**	**2000**	**2007**	**2011**	**97-'00**	**00-'07**	**07-'11**
Nampula	10,635	13,118	22,192	29,321	7.2	7.8	7.2
Niassa	2,368	2,652	4,587	5,931	3.8	8.1	6.6
Cabo Delgado	3,518	4,038	6,904	9,199	4.7	8.0	7.4
Zambézia	7,250	8,102	13,977	18,506	3.8	8.1	7.3
Tete	3,553	5,731	9,218	11,291	17.3	7.0	5.2
Sub Total (5 Provinces)	27,324	33,641	56,879	74,248	7.2	7.8	6.9
Others	41,750	51,348	94,421	123,277	7.1	9.1	6.9
Mozambique	69,074	84,989	151,300	197,524	7.2	8.6	6.9

Source: PEDEC-Nacala based on INE, 1997, 2000, 2007 and 2011

2) GRDP per Capita

GDP per capita in Mozambique doubled between 1997 and 2011. GRDP per capita in the five provinces was 61 percent of that in the whole of Mozambique in 2007 and 2011. Especially, in Niassa Province, the GRDP per capita was half of that in all of Mozambique in 2011, and the growth rate was less than 3 percent. This indicates that the economic activity per person in the northern part of Mozambique is smaller than in the southern provinces. And the tendency has grown between 1997 and 2011.

Table 3.2.8 GRDP and Growth Rate by Province in Mozambique（1997-2011）

	GRDP per Capita (MZN at 2003 Constant Prices)			Proportion of GRDP to the Whole Country			AAGR (%)
Province	**1997**	**2007**	**2011**	**1997**	**2007**	**2011**	**1997-2011**
Nampula	3,471	5,433	6,473	0.81	0.74	0.76	4.6%
Niassa	2,929	3,780	4,191	0.68	0.52	0.49	2.6%
Cabo Delgado	2,549	4,225	5,214	0.59	0.58	0.61	5.2%
Zambézia	2,341	3,593	4,277	0.54	0.49	0.50	4.4%
Tete	2,898	5,100	5,282	0.67	0.70	0.62	4.4%
Sub Total (5 Provinces)	2,854	4,503	5,238	0.66	0.61	0.61	4.4%
Others	6,422	11,799	13,889	1.49	1.61	1.62	5.7%
Mozambique	4,297	7,333	8,570	1.00	1.00	1.00	5.1%

Source: PEDEC-Nacala based on INE, 1997, 2000, 2007 and 2011

3) Share of Economic Sector

In Mozambique, GDP in the service sector accounted for roughly half of GDP (48.6%), followed by Agriculture (27.7%) and the Industry sector (23.7%) in 2011. On the other hand, in Nacala Corridor Region, more than 40 percent of the GRDP is in Agriculture. In Niassa, almost half the GDP was produced in the Agriculture sector, and the amount in the Industry sector was comparatively low. In Nampula province, the Service sector has the highest ratio at 43.1%, followed by Agriculture (39.9%) and the Industry sector (17%).

The ratio of GRDP in each sector has not drastically changed in the 5 provinces between 2000 and 2011. For further regional development of the northern area, industrialisation of this area is highly expected. To realise it, the improvement of the transport infrastructures is necessary.

Table 3.2.9 Sectoral GRDP by Province in Mozambique（2000-2011）

	2000				2011			
	Agriculture	Industry	Service	Total	Agriculture	Industry	Service	Total
Nampula	38.7%	15.4%	45.9%	100.0%	39.9%	17.0%	43.1%	100.0%
Niassa	47.6%	10.2%	42.2%	100.0%	49.5%	7.2%	43.4%	100.0%
Cabo Delgado	49.5%	12.2%	38.3%	100.0%	51.2%	12.5%	36.3%	100.0%
Zambézia	49.8%	11.4%	38.8%	100.0%	50.8%	12.3%	36.9%	100.0%
Tete	25.9%	40.2%	33.9%	100.0%	20.0%	43.3%	36.7%	100.0%
Sub Total (5 Provinces)	41.1%	18.0%	40.9%	100.0%	41.7%	18.5%	39.8%	100.0%
Other Provinces	19.1%	23.8%	57.1%	100.0%	19.3%	26.9%	53.8%	100.0%
Mozambique	27.9%	21.5%	50.7%	100.0%	27.7%	23.7%	48.6%	100.0%

Source: INE, 2000 and 2011

(2) Economic Framework for the Nacala Corridor Region

The PEDEC-Nacala developed GRDP projections for the Nacala Corridor Region in 2025 and 2035 based on the following plans or projections.

- Action Plan for Reducing Poverty (PARP): 2011–2014
- National Development Strategies (NDS): 2015-35
- The growth rates of GRDP as projected in the provincial plans
- The information regarding the development volume and timing of the large-scale projects[3]

[3] The large-scale projects include coal extraction and hydro power plant development in Tete and natural gas development and construction of derived plant facilities in Cabo Delgado.

- The past study on the impact of large-scale projects on GDP[4]
- Trend analysis on the incremental capital-output ratio (ICOR) in the recent years

In the GRDP projection, the following two patterns for economic growth are taken into account.

a. **Unmanaged Economic Growth Pattern:** reflects economic growth which is affected by an over-heated or bubble economy. It is characterised by extremely large-scale and high speed development based on huge investments and exploitation of natural resources. This type of development tends to result in a large number of resettlements and large environmental impact in mining areas and transport corridors. Large scale projects in mining (coal and natural gas) are expected in the Nacala Corridor Region. However, without appropriate management of the economy, the development of the area may not be sustainable. In that case, the poverty reduction and the balanced distribution of income may not be accomplished in the long term, even though the growth of the area will be very rapid in the initial stage.

b. **Managed Economic Growth Pattern:** means economically, environmentally and institutionally managed growth that leads to a sustainable economy. In the managed economic growth pattern, large scale projects/corporations are encouraged to link with small scale local companies and personnel. As a result of these efforts, the economic growth rates would be lower in the beginning, but would be more sustainable than the unmanaged growth pattern. The sustainable and balanced economic growth in the Nacala Corridor Region will increase production and productivity of the agricultural sector, and expand the number of manufacturers in the growth poles. The investment by large-scale projects will be distributed to the whole economy in the Nacala Corridor Region.

The managed economic growth pattern is adopted in PEDEC-Nacala because it is consistent with the concept of the draft NDS. The pattern is aiming at inclusive and sustainable growth through balanced vitalisation of the agriculture, mining, and processing industries, and the logistics and tourism sectors.

Table 3.2.10 shows the GRDP projection which was developed in PEDEC-Nacala. The projection includes the economic growth due to large-scale mining projects, assuming that large-scale projects will contribute to an increase of 1% of GRDP during 2016-20, 2% during 2021-25 and 2% during 2026-35. Even in the latter part of the targeted period, the contribution to GRDP by the large-scale mining projects is not changed through the combination of coal and gas field development activities with downstream processing, transportation and other services including support for Small and Medium-Sized Enterprises.

[4] According to a study titled "Contribution of Large-Scale Projects to GDP in Mozambique" by Christoffer Sonne-Schmidt, et al, April 2009, the direct contribution by three large-scale projects, namely (i) the aluminium smelter (Mozal in Maputo Province), (ii) the gas extraction and pipeline project (Sasol Gas Project in Inhambale) and (iii) the titanium ore or heavy sand project (Moma in Nampula), to growth in GDP at factor cost was estimated to be between 0.8 and 1.1 percentage points in 2006. The study concluded that rapid economic growth in Mozambique holds with or without the direct contribution of these large-scale projects or in other words that the contribution of large-scale projects to economic growth in the country is rather small. However, scale and impact by the large-scale projects defined in the study of PEDEC-Nacala seems to be much larger than the above-mentioned ones. In PEDEC-Nacala, contribution of the large-scale projects to the economy of the Nacala Corridor Region is assumed to be a 1 - 2 percent point growth in GRDP for both growth patterns, considering the analysis of the Incremental Capital-Output Ratio (ICOR) in the recent years.

Table 3.2.10 Economic Framework for the Nacala Corridor Region* (2011-2035)

	2011	2017	2025	2035
GRDP of the Five Provinces in Nacala Corridor Region (million MZN in 2003 prices)	64,254	101,000	203,000	503,000
Annual Growth Rate (%)	-	7.8%	9.1%	9.5%
GRDP per Capita (thousand MZN in 2003 prices)	4,597	6,080	9,900	19,449
Annual Growth Rate (%)	-	4.8%	6.3%	7.0%

Sources: PEDEC-Nacala based on INE's Statistics
Note*: The figures in this table include districts in Zambézia Province which are not part of the Nacala Corridor Region

Based on the above mentioned existing projections and plans, the shares of the economic sectors in 2025 and 2035 are set as shown in Table 3.2.11 within the framework of the managed economic growth pattern. The percentage shares of the agriculture and the service sector will slightly decrease from 40.3% to 23.9% and from 40.2% to 28.8% between 2011 and 2035, respectively. On the other hand, the share of mining/large scale projects will be increased from 0.2% in 2011 to 27.7% in 2035.

Table 3.2.11 Change of Economic Structure in the Nacala Corridor Region

	GRDP at Factor Cost (million MZN, 2003 prices)	Agriculture	Mining/Large-scale Projects	Manufacturing, Construction & Utilities	Services
2011	64,254	40.3%	0.2%	19.3%	40.2%
2025	181,700	33.1%	12.8%	19.2%	34.8%
2035	450,300	23.9%	27.7%	19.6%	28.8%

Sources: PEDEC-Nacala based on INE's Statistics

(3) Provincial GRDP in the Nacala Corridor Region: 2017, 2015 and 2035

Based on the INE's data of the provincial GRDP by economic sector in 2011, the provincial GRDP at factor cost in the Nacala Corridor Region by economic sector for each province is estimated in PEDEC-Nacala as shown in Table 3.2.12. The growth rates by economic sector which were discussed in the preceding section are applied in the estimation. The initial figures by economic sector and by province that were calculated using those growth rates are adjusted to coincide with the GRDP at factor cost by sector in the Nacala Corridor Region as a whole. The GRDP contributions of large-scale projects are separately calculated and distributed to Cabo Delgado and Tete Provinces. The value-added amount of the mining sector in Niassa, Nampula, and Zambézia Provinces is simply distributed to 10 million MZN and 30 million MZN each in 2025 and 2035, respectively, since its production could not be projected. The shares of the manufacturing, construction and utility sector in GRDP in Nampula and Tete have increased, while the provinces of Niassa, Zambézia and Nampula will maintain their higher share of agriculture. Nampula holds the largest share of GRDP in the Nacala Corridor Region.

Table 3.2.12 Provincial GRDP at Factor Cost by Economic Sector: 2017, 2025 & 2035

	Agriculture, Fishery & Forestry		Mining/Large-scale Projects		Manufacturing, Construction and Utilities		Services		GRDP at factor cost
	million MZN	Share (%)	million MZN	Share (%)	million MZN	Share (%)	million MZN	Share (%)	million MZN
Provincial GRDP in 2017									
Nampula	15,900	39.1%	10	0.0%	7,300	17.9%	17,500	43.0%	40,700
Niassa	3,900	48.8%	0	0.0%	600	7.5%	3,500	43.8%	8,000
Cabo Delgado	6,200	49.2%	200	1.6%	1,700	13.5%	4,500	35.7%	12,600
Zambézia*	5,800	50.0%	0	0.0%	1,500	12.9%	4,300	37.1%	40,700
Tete	3,000	17.2%	1,800	10.3%	6,900	39.7%	5,700	32.8%	17,400
Study Area	34,800	38.5%	2,000	2.2%	18,000	19.9%	35,500	39.3%	90,400
Other Area	39,100	21.1%	24,300	13.1%	34,400	18.6%	87,200	47.1%	184,500
Mozambique	73,900	26.8%	26,300	9.6%	52,400	19.0%	122,700	44.6%	274,900
Provincial GRDP in 2025									
Nampula	27,400	37.7%	10	0.0%	14,100	19.4%	31,100	42.8%	72,700
Niassa	6,800	47.9%	10	0.1%	1,200	8.4%	6,200	43.6%	14,200
Cabo Delgado	10,800	34.5%	9,300	29.7%	3,200	10.2%	8,000	25.6%	31,400
Zambézia*	10,000	48.8%	10	0.0%	2,900	14.1%	7,600	37.1%	20,600
Tete	5,200	12.1%	14,000	32.6%	13,400	31.2%	10,400	24.2%	43,000
Study Area	60,200	33.1%	23,300	12.8%	34,900	19.2%	63,300	34.8%	181,700
Other Area	66,700	20.5%	53,800	16.6%	72,000	22.2%	132,300	40.7%	324,800
Mozambique	126,900	25.1%	77,100	15.2%	106,900	21.1%	195,600	38.6%	506,500
Provincial GRDP in 2035									
Nampula	49,100	33.1%	30	0.0%	35,800	24.1%	63,600	42.8%	148,500
Niassa	12,100	43.5%	30	0.1%	3,000	10.8%	12,700	45.6%	27,800
Cabo Delgado	19,400	13.5%	99,700	69.4%	8,100	5.6%	16,400	11.4%	143,600
Zambézia*	18,000	43.9%	30	0.1%	7,400	18.0%	15,600	38.0%	41,000
Tete	9,300	10.4%	24,900	27.9%	33,900	37.9%	21,300	23.8%	89,400
Study Area	107,800	23.9%	124,700	27.7%	88,200	19.6%	129,600	28.8%	450,300
Other Area	141,900	20.3%	169,200	24.2%	167,200	23.9%	220,600	31.6%	698,900
Mozambique	249,700	21.7%	293,900	25.6%	255,400	22.2%	350,200	30.5%	1,149,200

Sources: PEDEC-Nacala based on INE, MPD Data from NDS
Note: *Only GRDP from the northern 7 districts in Zambézia
GRDP is in 2003 constant prices

3.3 Transport Characteristics of the Target Roads

3.3.1 Vehicle Registrations

Table 3.3.1 shows the number of registered vehicles by province. In Nampula Province, the number of motorbikes amounts to 20 % of all motorbikes in the whole country, and it has increased 40 percent between 2011 and 2013. This number indicates the urban traffic in Nampula is growing rapidly. The number of trailers has jumped up from 606 to 809 (33%) in Nampula, even though the rehabilitation of Nampula-Cuamba road was still in progress in 2013. In Niassa province, the number of light vehicles has increased 17%.

Table 3.3.1 Number of Registered Vehicles by Province (2011-2013)

	Vehicle Type	Nampula	Niassa	C. Delgado	Zambézia	Tete	Mozambique
2011	Motorbike	9,439	669	858	1,506	1,914	**54,061**
	Light Vehicles	12,361	1,650	3,230	253	3,968	**268,494**
	Heavy Vehicles	5,212	1,141	825	954	1,855	**92,828**
	Trailer	606	62	120	66	548	**8,562**
	Tractor	796	33	156	177	91	**3,882**
	Total	**28,414**	**3,555**	**5,189**	**2,956**	**8,376**	**427,827**
2013	Motorbike	13,180	688	1,005	1,506	2,432	**64,987**
	Light Vehicles	14,140	1,923	3,350	289	4,229	**343,653**
	Heavy Vehicles	6,254	1,306	1,047	974	2,110	**115,951**
	Trailer	809	69	170	66	634	**12,944**
	Tractor	945	33	187	187	104	**4,801**
	Total	**35,328**	**4,019**	**5,759**	**3,022**	**9,509**	**542,336**
Growth Rate	Motorbike	140%	103%	117%	100%	127%	**120%**
	Light Vehicles	114%	117%	104%	114%	107%	**128%**
	Heavy Vehicles	120%	114%	127%	102%	114%	**125%**
	Trailer	133%	111%	142%	100%	116%	**151%**
	Tractor	119%	100%	120%	106%	114%	**124%**
	Total	**124%**	**113%**	**111%**	**102%**	**114%**	**127%**

Source: Ministry of Transport and Communication, National Institute of Transport, 2013

CHAPTER 4 Traffic Survey and Traffic Demand Forecast

4.1 Introduction

For the purpose of forecasting the future travel demand of the Nacala Port Access Road, Nampula Southern Bypass Road and Cuamba Bypass Road, several transport data were collected and analysed.

The National Roads Administration (*Administração Nacional de Estradas*, *ANE*) of the Republic of Mozambique developed a systematic traffic data collection system beginning in 2010. ANE estimates annual average daily traffic (AADT) for over 250 nation-wide survey locations. The ANE AADT database was utilised to understand the historical trend of traffic in the region as it is reliable time-series data.

During the "Project for Nacala Corridor Economic Development Strategies in the Republic of Mozambique" (PEDEC-Nacala) conducted by the Japan International Cooperation Agency (JICA) and the Ministry of Economy and Finance, the Republic of Mozambique, intensive transport surveys were conducted mainly to understand freight movements. These data were utilised to understand the flow of cargo vehicles in the three cities.

In addition, traffic surveys were conducted for this study to understand the latest travel demand and origin-destination flow in the three cities. The traffic surveys consisted of the traffic count surveys, directional traffic count surveys at intersections and roadside origin-destination (OD) interview surveys. The survey results are utilised to understand current traffic volume at major sections and traffic flow including origin-destination.

4.2 Traffic Survey Data

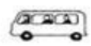
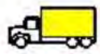
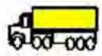
4.2.1 Basic Assumptions

Basic assumptions made for the analyses of transport and traffic surveys are summarised below. Vehicle classification, method of estimating annual average daily traffic (AADT), and parameters of daily, weekly and seasonal conversion factors are described.

(1) Vehicle Classification

For the analysis of AADT as well as road planning in Mozambique, 8 vehicle types are defined by ANE as shown in Table 4.2.1. In addition, motorcycle is added as an additional vehicle type for the survey implemented by the Study Team. However, motorcycles are not counted for the estimation of AADT to compare with previous survey results which do not include the number of motorcycles.

Table 4.2.1 Vehicle Classifications for the Study

ID	Category	Image	Description
A	Passenger car		Normal passenger cars
B	Pickup truck		Light truck called "Pick-up"
C	Minibus		Passenger cars with a capacity below 20 people
D	Bus		Large passenger vehicle
E	2-axle truck		Heavy goods truck with 2 axles and dual wheels on the rear axle
F	3 and 4 axle truck		Heavy goods truck with 3 and 4 axles and dual wheels on the rear axles
G	5 and more axle truck		Heavy goods truck with more than 4 axles
H	Tractor		Tractors (mainly for agriculture and construction use)
I*	Motorcycle		Motorcycles

Source: ANE edited by the Study Team
Note: *As motorcycle is not included in the ANE vehicle classification, it is added by the Study Team.

(2) Estimation of Annual Average Daily Traffic (AADT)

Traffic volume fluctuated by hour, by week and by seasons due to various factors. To compare several traffic survey results, the traffic count survey results are converted to the AADT. The ANE estimated the parameters of daily traffic conversion factors, weekly factors and seasonal factors. These parameters are utilised in this study and several traffic count survey results were converted to AADT to understand the time-series trend. The parameters utilised in this study are summarised below.

1) Daily Traffic Conversion Factors

Based on the survey results of 24-hour counts, ANE estimated the daily traffic conversion factors for both Nampula and Niassa Provinces as below.

- 24-hour survey (5: 00 AM to 5: 00 PM) – 1.00
- 17-hour survey (5: 00 AM to 10: 00 PM) – 1.10
- 12-hour survey (6: 00 AM to 06: 00 PM) – 1.34

2) Weekly Factors

For the analysis of variation of traffic volume over the days of the week, ANE estimated weekly factors by province by utilising information from gas stations as shown in Table 4.2.2.

Table 4.2.2 Weekly Factors for Estimation of AADT by Province

Day of the Week	Nampula Province	Niassa Province
Sunday	1.12	1.13
Monday	1.03	0.99
Tuesday	1.00	0.99
Wednesday	1.00	0.98
Thursday	0.99	1.03
Friday	0.93	0.93
Saturday	0.95	0.98

Source: ANE

3) Seasonal Factors

The monthly extrapolation was estimated by province based on counts made over the years by ANE such as key survey locations as shown in Table 4.2.3.

Table 4.2.3 Seasonal Factors for Estimation of AADT by Province

Month	Nampula Province	Niassa Province
January	1.17	1.42
February	1.27	1.75
March	1.08	1.23
April	1.06	0.94
May	1.18	0.95
June	0.98	0.75
July	0.92	0.90
August	0.75	0.86
September	1.05	0.86
October	0.90	0.85
November	0.91	1.20
December	0.98	0.99

Source: ANE

4.2.2 Annual Average Daily Traffic (AADT) of National Roads Administration (ANE)

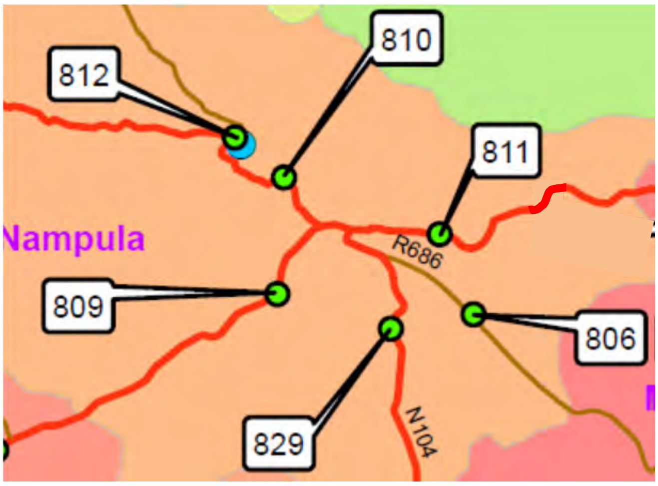
For the purpose of road planning, efficient management of maintenance, preparation of cost-benefit analyses of investment, capacity analysis and road accident rates; the National Roads Administration (ANE), collects data on road traffic on the national road network systematically. In 2010, the traffic count data collection system was improved in order to provide better and more reliable results. At present, traffic counts are performed on 10 key survey locations and 256 non-key survey locations spread over all provinces. There are one key survey location and 37 non-key survey locations in Nampula province. There are one key survey location and 26 coverage survey locations in Niassa province.

For the key survey locations, 17-hour traffic surveys from 5AM to 10PM are conducted for 1 week every month. A 24-hour survey is also conducted on Thursday. Every year, 84 days are surveyed taking seasonal variation into consideration.

For the coverage survey locations, 12-hour surveys from 6AM to 6PM are conducted in weekdays. and 3 days from different seasons are selected for the surveys. Holidays, weekends and periods with road closure or any events are avoided for the survey implementation.

ANE provided the AADT data for Nampula and Niassa provinces from 2010 to 2014. It is considered that this is a reliable data source as it is time-series data collected with the same methodology. These data were utilised to analyse historical trends since 2010 as well as to analyse the elasticity of traffic volume and economic activities.

Survey locations around Nampula, Nacala and Cuamba are shown in Figure 4.2.1, Figure 4.2.2 and Figure 4.2.3 respectively. All survey locations are coverage survey locations.

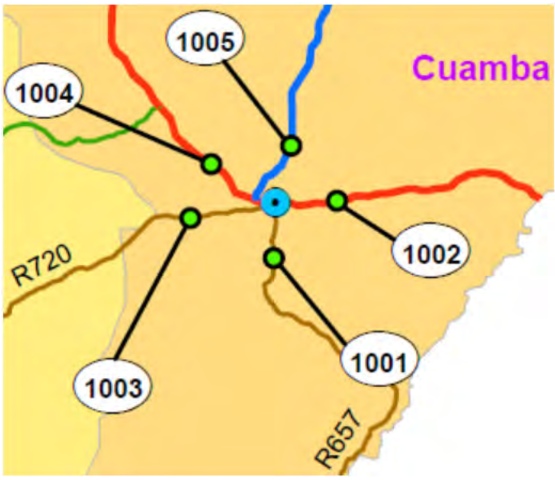


Source: ANE

Figure 4.2.1 AADT Survey Locations around Nampula City

Source: ANE

Figure 4.2.2 AADT Survey Locations around Nacala



Source: ANE

Figure 4.2.3 AADT Survey Locations around Cuamba

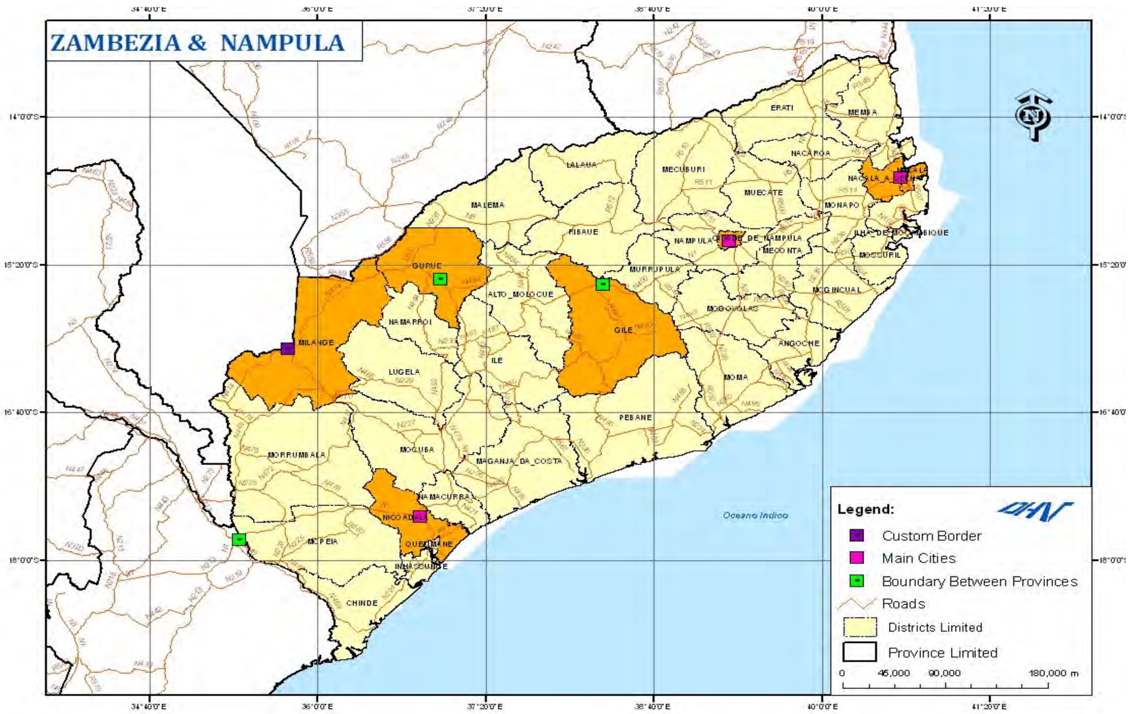
4.2.3 PEDEC-Nacala Transport Survey

The "Project for Nacala Corridor Economic Development Strategies in the Republic of Mozambique" (PEDEC-Nacala) is implemented in order to formulate development strategies to guide appropriate development and investment in the Nacala Corridor. The development strategies of PEDEC-Nacala are selective and integrated in the coverage of economic sectors, infrastructure sectors and social service sectors.

As a part of the PEDEC-Nacala Study, intensive transport surveys mainly focusing on cargo vehicles were conducted covering the whole Nacala Corridor region to understand the logistics flow and their bottlenecks. The surveys were implemented in two phases, namely, dry season (August 2012) and rainy season (December 2012).

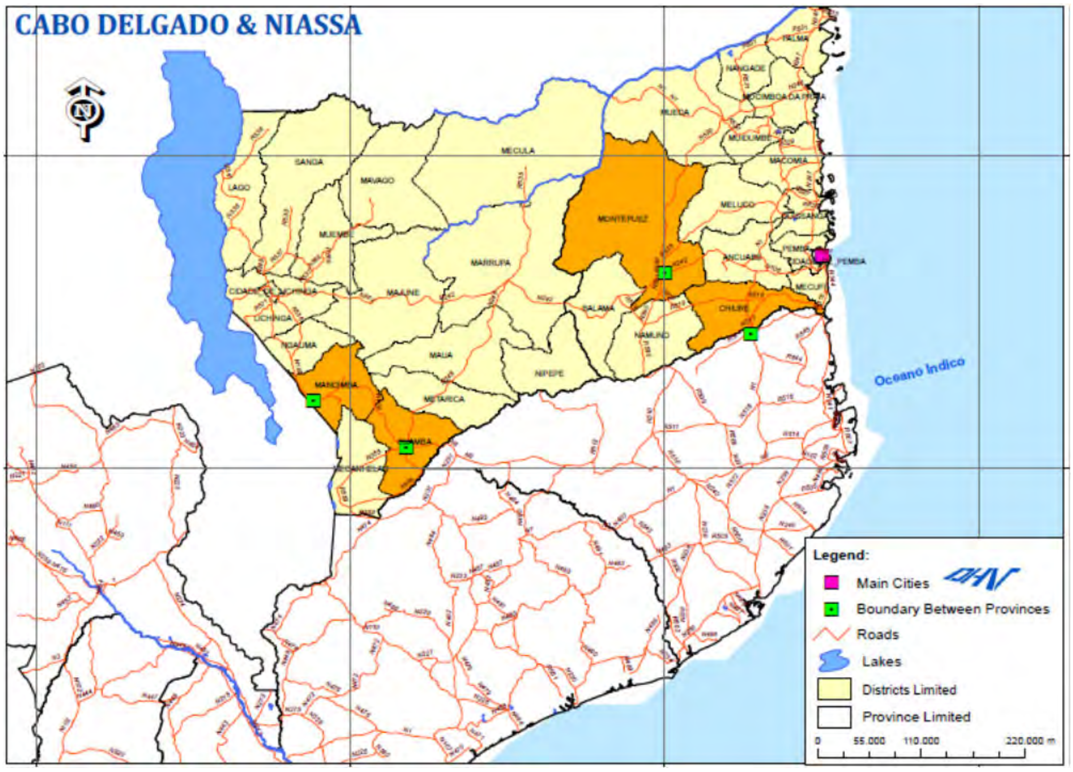
The surveys include traffic count surveys and roadside OD interview surveys at 6 survey locations around main cities, 8 survey locations at the boundaries of provinces and 6 survey locations at custom borders as shown in Figure 4.2.4 and Figure 4.2.5. The traffic count surveys were executed during 18 hours from 5:00 AM to 11:00 PM in 5 consecutive days including Saturdays and Sundays.

In addition, goods transport for railway and the ports were surveyed. Goods transport survey for railway was conducted for Nacala and Sena railway lines of the Northern Corridor Mozambique Railway. Goods transport record surveys for main ports were conducted in Pemba, Nacala, Quelimane, Beira and Metangula Ports.



Source: PEDEC-Nacala

Figure 4.2.4 Traffic Count and Roadside OD Interview Survey Locations of PEDEC-Nacala in Zambezi and Nampula Provinces



Source: PEDEC-Nacala

Figure 4.2.5 Cabo Delgado and Niassa Provinces

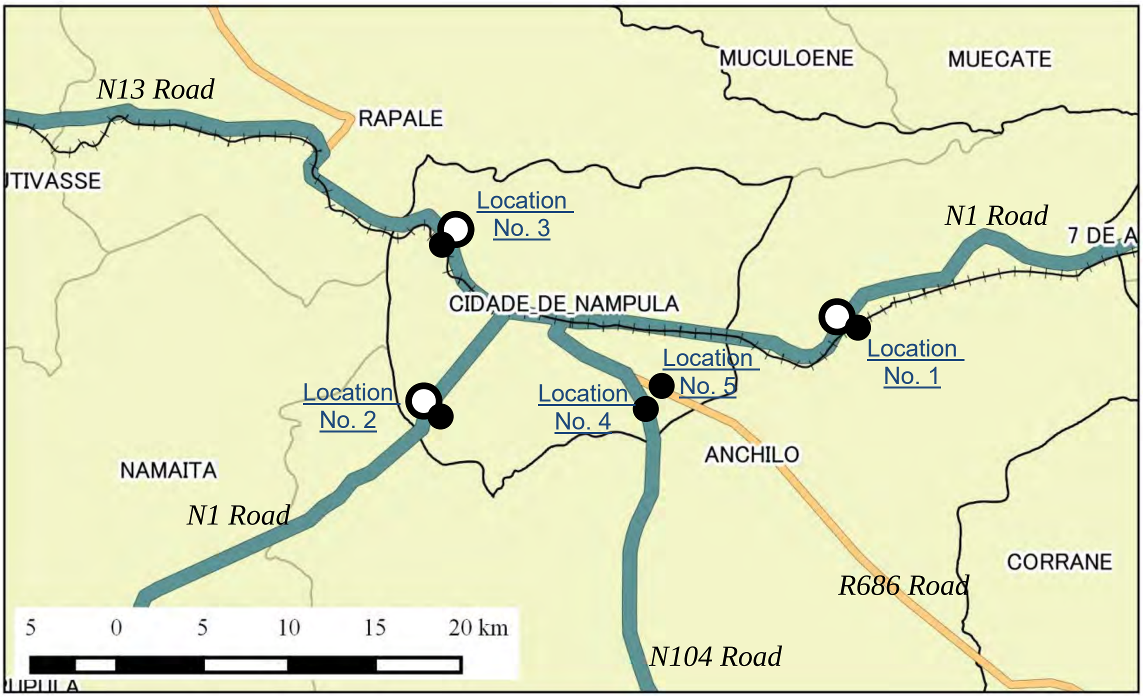
4.2.4 Traffic Survey of This Study

In addition to the ANE AADT data and PEDEC-Nacala survey, traffic count and roadside OD interview surveys were conducted to understand the latest travel demand in the three cities. The scope of the surveys is described in this sub-section.

(1) Survey Location and Date for Nacala

1) Nampula Traffic Volume Survey and Roadside OD Interview Survey

Traffic count surveys were conducted at 5 locations around the boundary of the Nampula City to capture vehicles entering/exiting the city. Roadside OD interview surveys were conducted at 3 locations around the boundary of Nampula City. The survey locations are depicted in Figure 4.2.6. The survey was conducted on the 21st, 23rd and 24th June, 2015 for 17 hours from 5AM to 10PM.



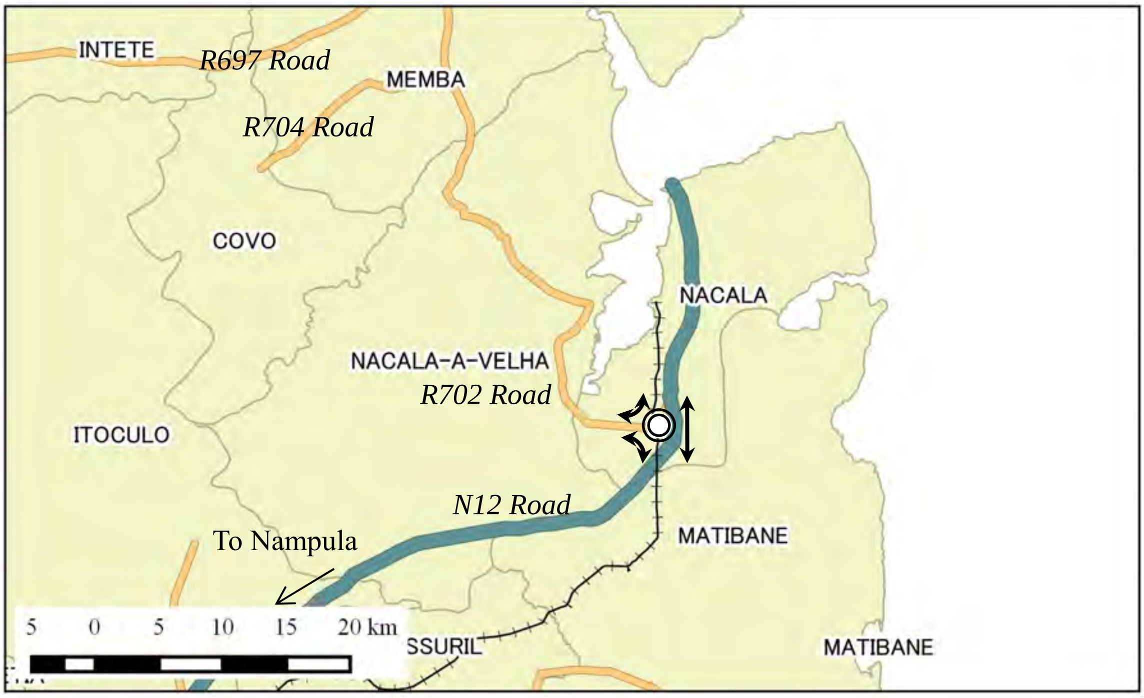
Note: ○ Survey locations for roadside OD interview survey
● Survey locations for traffic count survey

Source: the Study Team

Figure 4.2.6 Traffic Survey Locations at Nampula

2) Nacala Traffic Volume Survey

Directional Traffic Count at the T-Intersection with N12 and R702 were conducted for 7 days from the 19th (Sunday) to 25th (Saturday) July, 2015 for 24 hours a day. Taking the current road network into consideration, traffic between the Nacala Port and 2 directions; to Nacala-a-Velha and to Nampula were captured at the directional traffic count survey at the survey intersection. The survey duration was 7 days considering the daily fluctuation of traffic volume is significant at the seaport due to arrival/departure of large ships. Figure 4.2.7 shows the location of the traffic survey at Nacala.



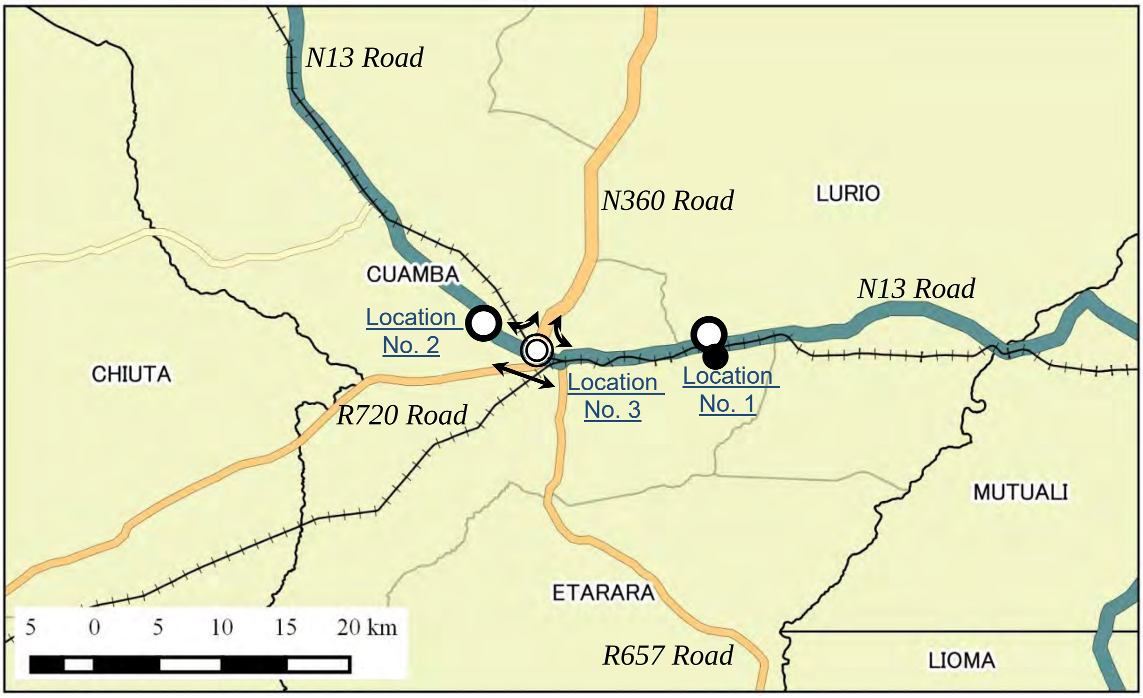
Note: ◎ Survey locations for directional traffic count survey Arrows show directions surveyed.

Source: the Study Team

Figure 4.2.7 Traffic Survey Location at Nacala

3) Cuamba Traffic Volume Survey and Roadside OD Interview Survey

A directional traffic count survey was conducted at the junction of N13 road and N360 at the west side of the city to capture traffic in the Marrupa and Mandimba directions. Roadside OD interview surveys were conducted at the east side and west side of the city on N13 road. At the east side of the city, a traffic count survey was also conducted. The survey was on the 19th, 21st and 23rd July, 2015 for 17 hours from 5AM to 10PM.



Note: Survey locations for roadside OD interview survey
Survey locations for traffic count survey
Survey locations for directional traffic count survey Arrows show directions surveyed.

Source: the Study Team

Figure 4.2.8 Traffic Survey Locations at Cuamba

4.3 Traffic Survey Analysis Results

4.3.1 Nampula

(1) Traffic Survey Results of This Study

The survey results by location by survey date of this study are shown in Table 4.3.1.

Table 4.3.1 Survey Results in Nampula (Raw Data)

Unit: Number of Vehicles per 16 Hours

Loca-tion No.**	Date (2015)	Day of the Week	Motor cycle	Car & Pick-up	Mini-bus	Bus	2 Axles	3&4 Axles	5+ Axles	Tractor	Total (no MC*)	Total (with MC*)
1	21 Jun	Sun	408	1,282	526	39	170	70	139	0	2,226	2,634
1	23 Jun	Tue	386	1,101	472	88	317	122	316	0	2,416	2,802
1	24 Jun	Wed	339	1,030	485	49	264	117	305	1	2,251	2,590
2	21 Jun	Sun	768	1,013	367	157	152	141	240	1	2,071	2,839
2	23 Jun	Tue	502	682	282	159	226	152	324	4	1,829	2,331
2	24 Jun	Wed	514	577	233	60	93	38	112	1	1,114	1,628
3	21 Jun	Sun	950	1,103	344	243	382	212	245	2	2,531	3,481
3	23 Jun	Tue	950	1,133	357	236	391	265	218	21	2,621	3,571
3	24 Jun	Wed	709	963	324	270	412	270	234	7	2,480	3,189
4	21 Jun	Sun	532	416	77	0	3	14	3	0	513	1,045
4	23 Jun	Tue	505	457	132	3	28	15	13	0	648	1,153
4	24 Jun	Wed	503	349	52	5	24	13	4	0	447	950
5	21 Jun	Sun	618	307	48	190	63	3	4	1	616	1,234
5	23 Jun	Tue	568	359	29	404	75	28	0	4	899	1,467
5	24 Jun	Wed	695	357	52	324	79	8	5	2	827	1,522

Note: *MC stands for motorcycle. ** The survey location is indicated in Figure 4.2.6.

Source: the Study Team

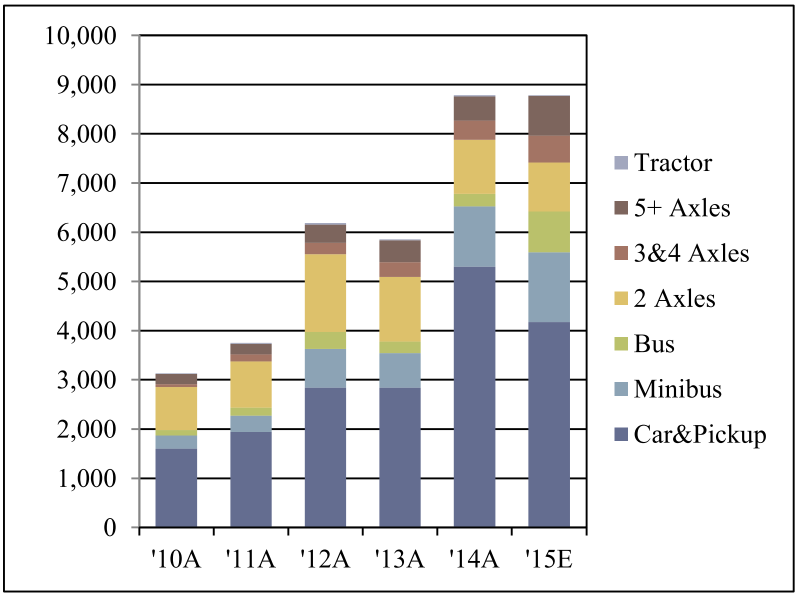
(2) Historical Trend of Traffic Count Survey

The historical trend of total traffic volume entering/exiting Nampula city is summarised in Table 4.3.2 and Figure 4.3.1. As of 2015, a total of approximately 4,000 vehicles are entering the city every day. The graph shows the number in two directions. Surge increase in the number of motorised vehicles is obvious since 2010 while annual fluctuation is observed. It is also noteworthy that the number of large trucks such as more than 3 axles is rapidly increasing. As the current N1 road penetrates the city centre of Nampula, a number of large trucks are running in the centre of the city.

Table 4.3.2 Total Traffic Volume Entering/Exiting Nampula City (AADT)

Year / Source*	Motor-cycle***	Passenger car & pickup	Mini-bus	Bus	2 Axles	3&4 Axles	5+ Axles	Tractor	AADT
'10A	-	1,602	266	113	869	62	206	17	3,136
'11A	-	1,939	336	160	938	145	216	15	3,749
'12A	-	2,841	787	342	1,584	229	369	37	6,189
'13A	-	2,838	707	235	1,309	305	440	23	5,857
'14A**	-	5,299	1,228	251	1,101	390	490	26	8,784
'15E	3,356	4,177	1,417	827	996	546	804	16	8,783

Source: *'10A – '14A; ANE AADT data from 2010 to 2014 '15E; traffic count survey results of this study
Note: **Survey results of location code "811" in 2014 were interpolated from 2013 and 2015 results as a discrepancy was observed. *** Motorcycles are not included in AADT. ****The sum of all vehicle types and the AADT in the table are not always the same, because some of them have a number of decimals.

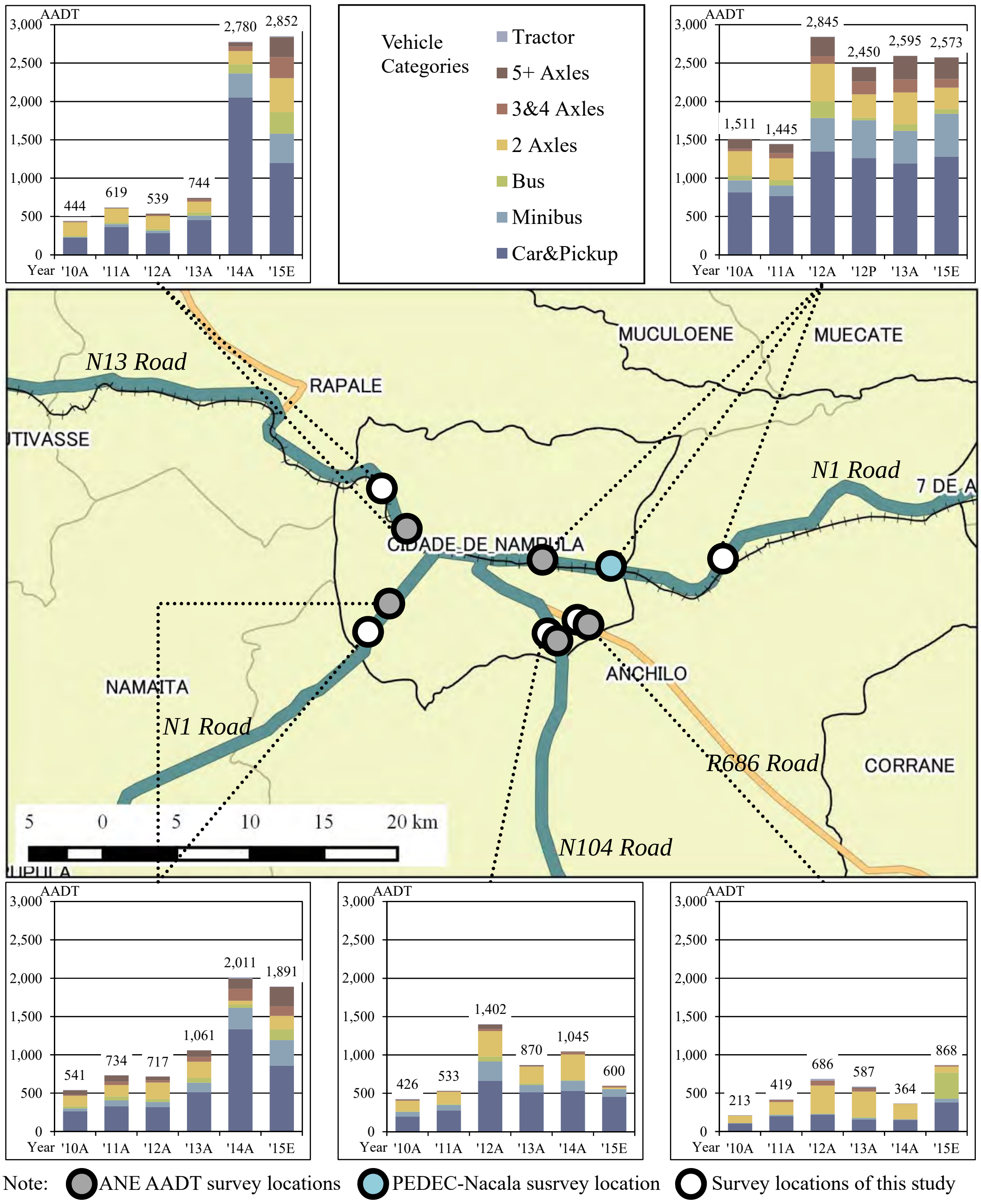


Source: *'10A – '14A; ANE AADT data from 2010 to 2014 '15E; traffic count survey results of this study

**Survey results of location code "811" in 2014 were interpolated from 2013 and 2015 results as a discrepancy was observed.

Figure 4.3.1 Total Traffic Volume Entering/Exiting Nampula City (AADT)

The traffic volumes by survey locations are depicted in Figure 4.3.2. Increase of traffic volume of survey points located in the western side of the city is significant. This increase of freight vehicles might be affected by the construction works of Nampula – Cuamba road and railway renovation as a number of the trucks were carrying construction materials.

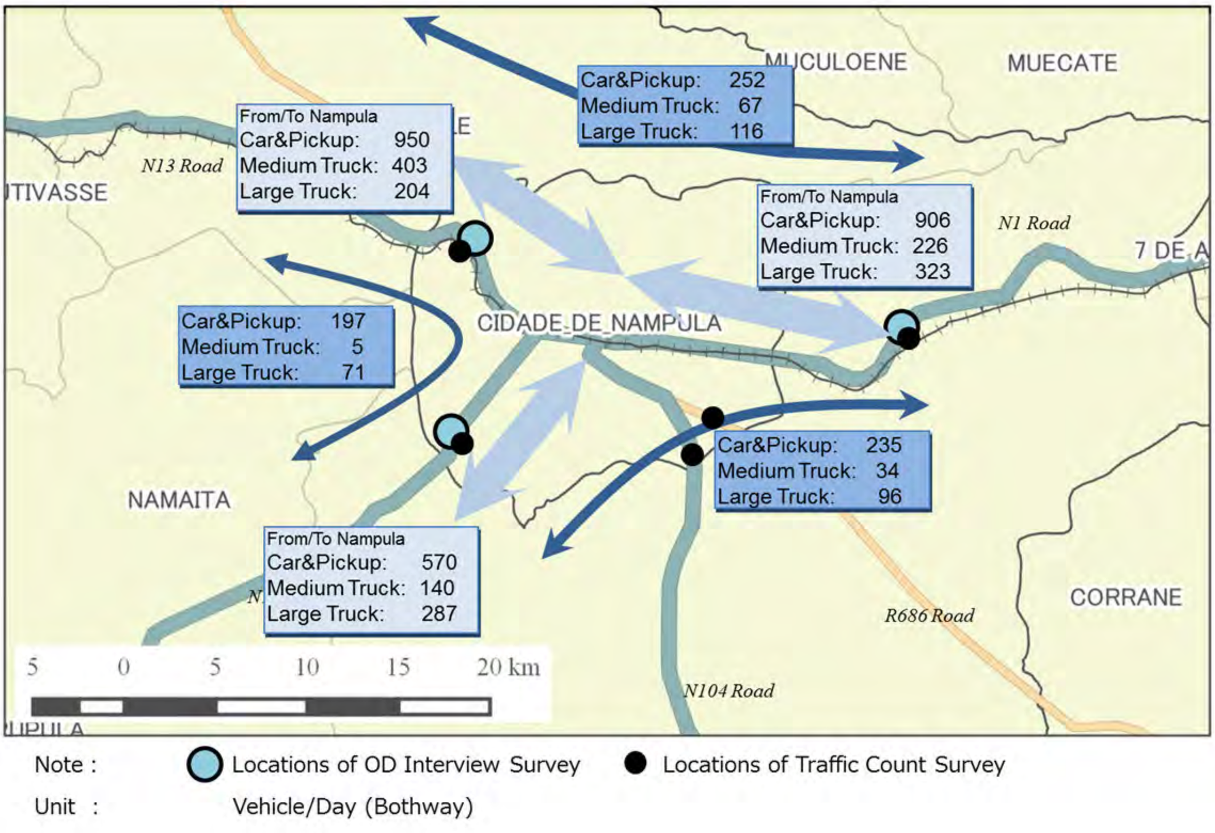


Source: *'10A – '14A; ANE AADT data from 2010 to 2014
'12P; traffic count survey results of PEDEC-Nacala '15E; traffic count survey results of this study

Figure 4.3.2 Traffic Volumes by Survey Locations in/around Nampula City

(3) Analysis on Through Traffic of Goods Vehicles

Utilising the results of the roadside OD interview survey in this study, traffic volume which pass through Nampula city was estimated. Based on the origin-destination information, daily traffic volumes of cargo and passenger vehicles by directions are shown in Figure 4.3.3. It is estimated that approximately 25% (283 vehicles in 1,097 vehicles) of the vehicles with 3 or more axles pass through Nampula city. This means that roughly 300 large trucks affect the traffic of the city centre just to pass the city while their final destinations are not Nampula. These total numbers are smaller than for trucks with 3 and more axles, but in addition, approximately 100 light trucks with 2 axles pass through the city every day. N1 road and N13 road are dominant directions of through traffic as those are national key transport corridors.



Source: the Study Team

Figure 4.3.3 Volume of Through Traffic at Nampula

4.3.2 Nacala

(1) Traffic Survey Results of This Study

The survey results by location by survey date of this study are shown in Table 4.3.3.

Table 4.3.3 Survey Results at Nacala (Raw Data)

Unit: Number of Vehicles per 24 Hours

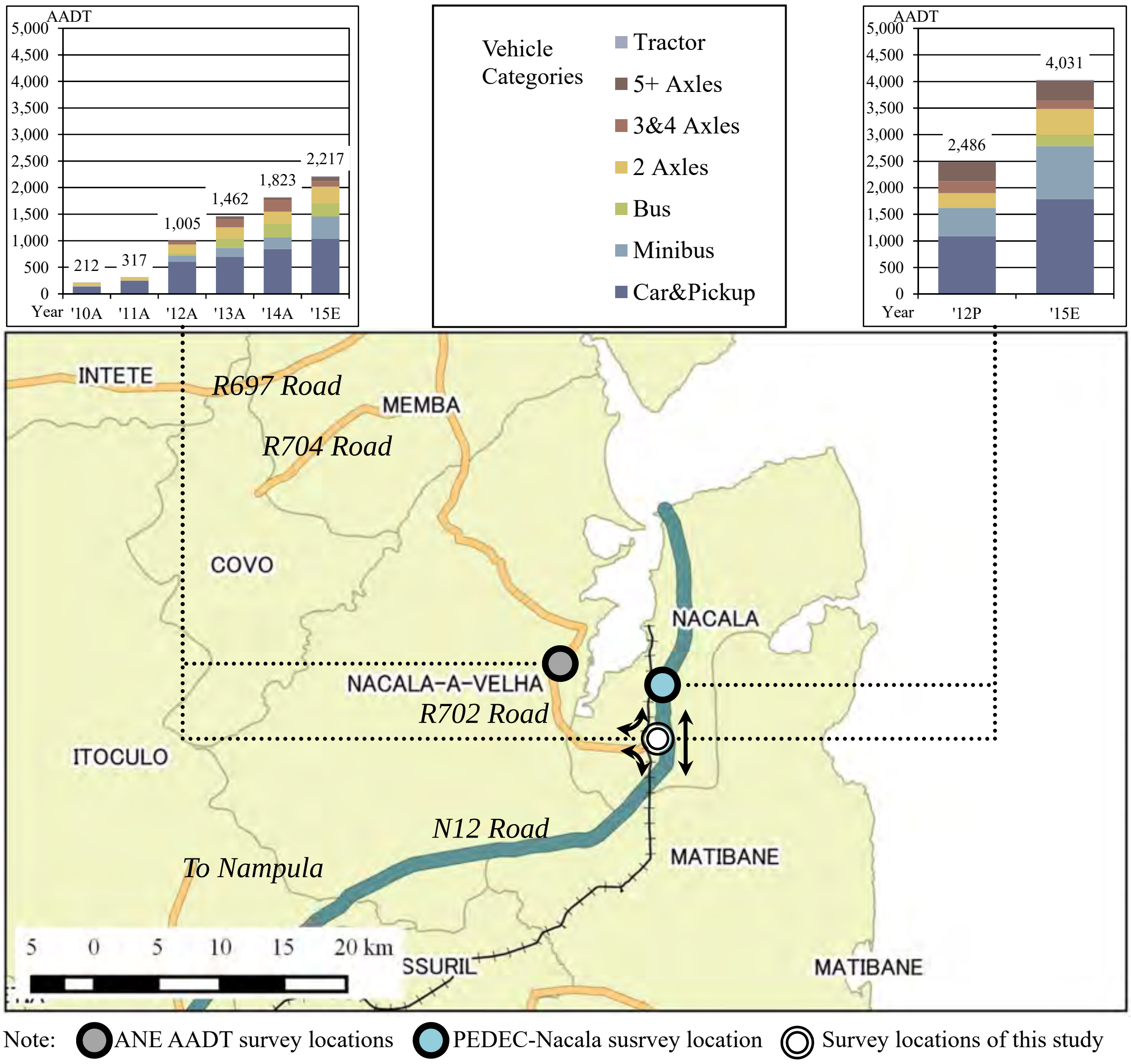
Leg (Direction)	Date (2015)	Day of the Week	Motor cycle	Car & Pickup	Mini-bus	Bus	2 Axles	3&4 Axles	5+ Axles	Tractor	Total (no MC*)	Total (with MC*)
West	19 Jul	Sun	1,444	918	366	132	179	17	19	8	1,639	3,083
West	20 Jul	Mon	909	1,145	421	240	365	77	66	11	2,325	3,234
West	21 Jul	Tue	991	1,145	490	320	354	216	105	2	2,632	3,623
West	22 Jul	Wed	1,134	928	372	182	305	111	106	6	2,010	3,144
West	23 Jul	Thu	1,454	1,548	665	492	498	249	207	9	3,668	5,122
West	24 Jul	Fri	1,387	1,313	477	390	357	70	85	38	2,730	4,117
West	25 Jul	Sat	1,342	921	364	179	286	51	46	17	1,864	3,206
South	19 Jul	Sun	1,567	1,310	779	72	167	23	89	7	2,447	4,014
South	20 Jul	Mon	1,378	1,498	848	119	455	120	374	6	3,420	4,798
South	21 Jul	Tue	1,445	1,573	972	198	654	241	479	10	4,127	5,572
South	22 Jul	Wed	1,305	1,299	810	85	342	125	387	3	3,051	4,356
South	23 Jul	Thu	1,759	1,806	1,139	247	410	312	488	7	4,409	6,168
South	24 Jul	Fri	1,434	1,711	954	189	548	222	535	28	4,187	5,621
South	25 Jul	Sat	1,379	1,434	704	67	283	69	278	5	2,840	4,219
North	19 Jul	Sun	1,977	1,646	965	114	246	24	98	7	3,100	5,077
North	20 Jul	Mon	1,601	1,931	1,039	199	590	129	392	7	4,287	5,888
North	21 Jul	Tue	1,672	1,960	1,136	284	770	263	514	10	4,937	6,609
North	22 Jul	Wed	1,599	1,643	968	139	447	144	433	3	3,777	5,376
North	23 Jul	Thu	2,027	2,384	1,340	319	548	289	567	16	5,463	7,490
North	24 Jul	Fri	1,825	2,178	1,189	337	709	240	580	24	5,257	7,082
North	25 Jul	Sat	1,805	1,851	956	166	441	104	314	16	3,848	5,653

Note: *MC stands for motorcycle. **The survey location is indicated in Figure 4.2.7.

Source: the Study Team

(2) Historical Trend of Traffic Count Survey

Traffic count results of ANE AADT, PEDEC-Nacala and this study were summarised in Figure 4.3.4, but the number of survey locations is limited. However, results of 2 survey locations presented a similar trend of drastic increase in AADT during the last half decade. The AADT almost doubled in only 3 years. This might be caused by an increase of cargo handling volume at Nacala port and development around Nacala city supported by rapid economic growth of the Nacala Corridor region. As the increase is rapid, it is inferred that current transport infrastructures will not meet the increasing demand in the near future.

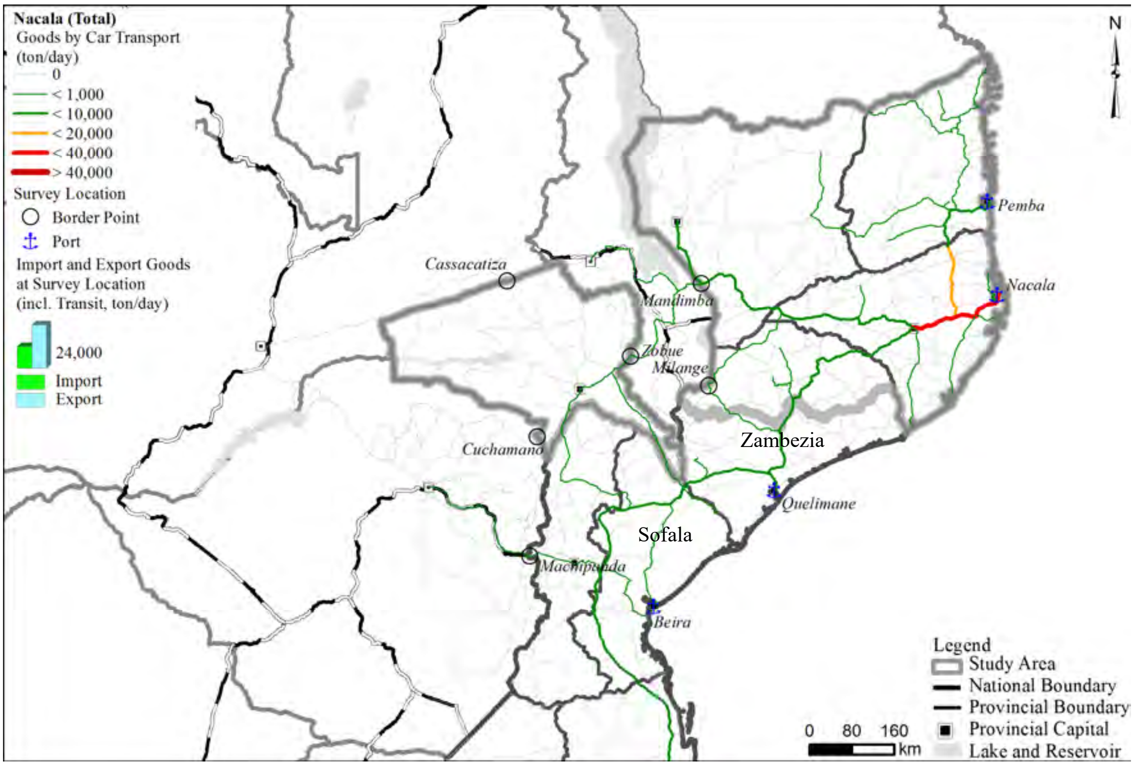


Source: *'10A – '14A; ANE AADT data from 2010 to 2014
'12P; traffic count survey results of PEDEC-Nacala '15E; traffic count survey results of this study
For '15E; directional traffic count survey at intersection of this study, traffic volume of corresponding directions are compared with the previous survey results.

Figure 4.3.4 Traffic Volume by Survey Location around Nacala City

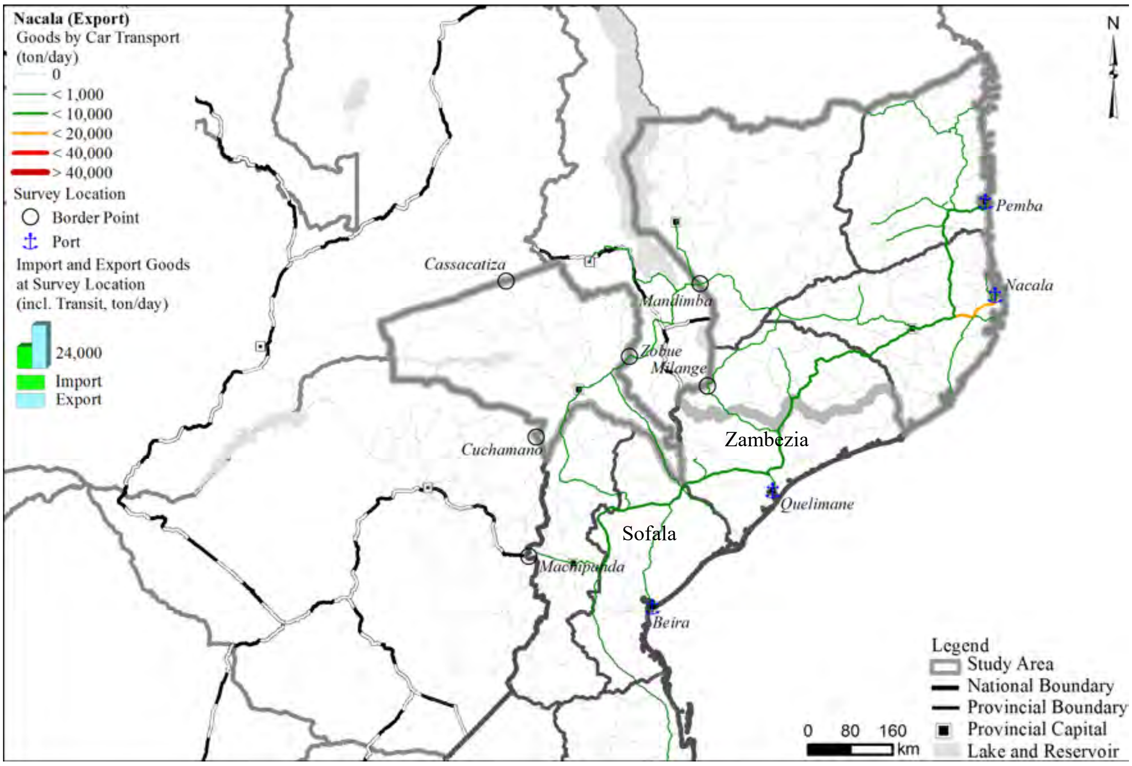
(3) Analysis on Origin-Destination of Goods Vehicles from Nacala Port

Flow of goods handled at Nacala Port is shown in Figure 4.3.5, Figure 4.3.6 and Figure 4.3.7. It is noteworthy that cargo handled at Nacala Port is transported all the way from / to Zambézia and Sofala via N1, N13 and other national roads. However, this flow is affecting traffic in the city due to the configuration of the current road network which does not have direct access from the Port to intercity arterial roads.



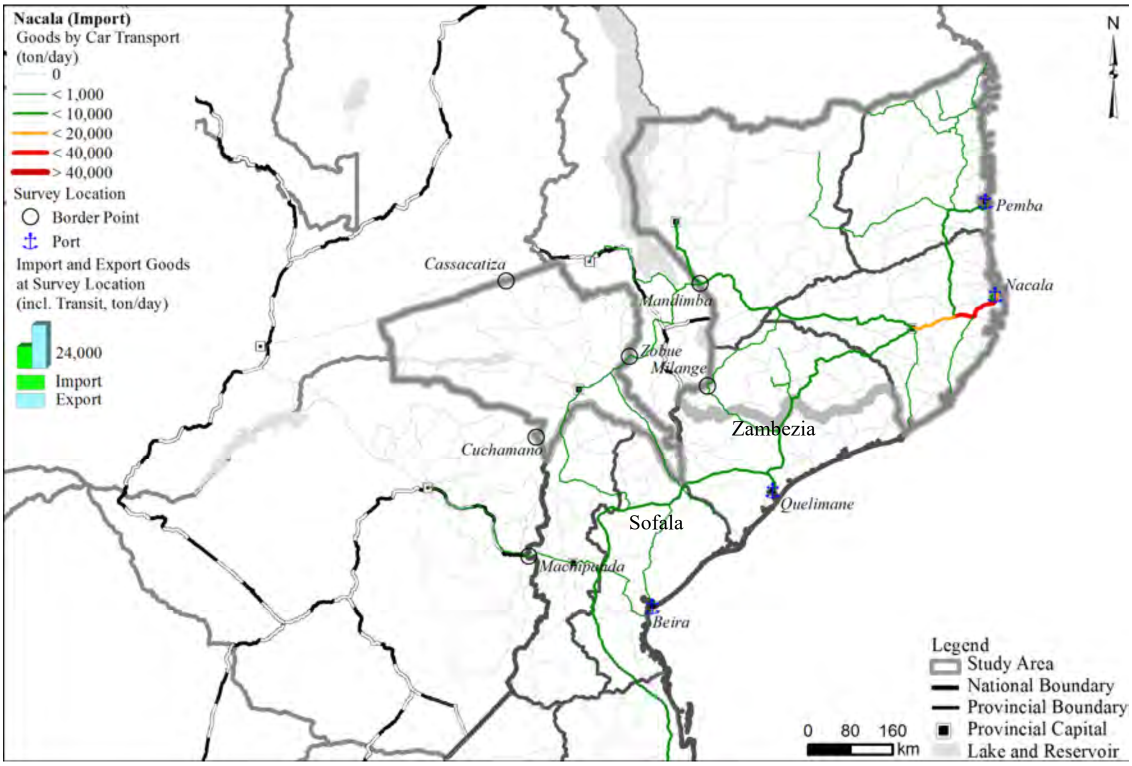
Source: PEDEC-Nacala

Figure 4.3.5 Flow of Imported and Exported Goods at Nacala Port



Source: PEDEC-Nacala

Figure 4.3.6 Flow of Exported Goods at Nacala Port



Source: PEDEC-Nacala

Figure 4.3.7 Flow of Imported Goods at Nacala Port

4.3.3 Cuamba

(1) Traffic Survey Results of This Study

The survey results by location by survey date of this study are shown in Table 4.3.4.

Table 4.3.4 Survey Results in Cuamba (Raw Data)

Unit: Number of Vehicles per 16 Hours

Loca-tion No.**	Leg (Direction)	Date (2015)	Day of the Week	Motor cycle	Car & Pickup	Mini-bus	Bus	2 Axles	3&4 Axles	5+ Axles	Tractor	Total (no MC*)	Total (with MC*)
1	-	26 Jul	Sun	356	211	28	9	118	12	27	2	407	763
1	-	28 Jul	Tue	350	180	35	13	111	55	34	0	428	778
1	-	30 Jul	Thu	351	151	28	17	83	65	75	5	424	775
3	North	19 Jul	Sun	314	158	38	1	113	5	8	0	323	637
3	North	21 Jul	Tue	300	253	38	4	175	13	11	0	494	794
3	North	23 Jul	Thu	289	270	43	0	152	24	6	4	499	788
3	West	19 Jul	Sun	77	54	3	1	52	1	3	0	114	191
3	West	21 Jul	Tue	80	40	1	0	61	4	0	0	106	186
3	West	23 Jul	Thu	61	50	4	0	52	4	2	0	112	173
3	East	19 Jul	Sun	706	310	67	0	144	9	40	3	573	1,279
3	East	21 Jul	Tue	730	431	96	7	239	53	37	2	865	1,595
3	East	23 Jul	Thu	769	477	103	3	209	140	33	6	971	1,740

Note: *MC stands for motorcycle. **The survey location is indicated in Figure 4.2.8.

Source: the Study Team

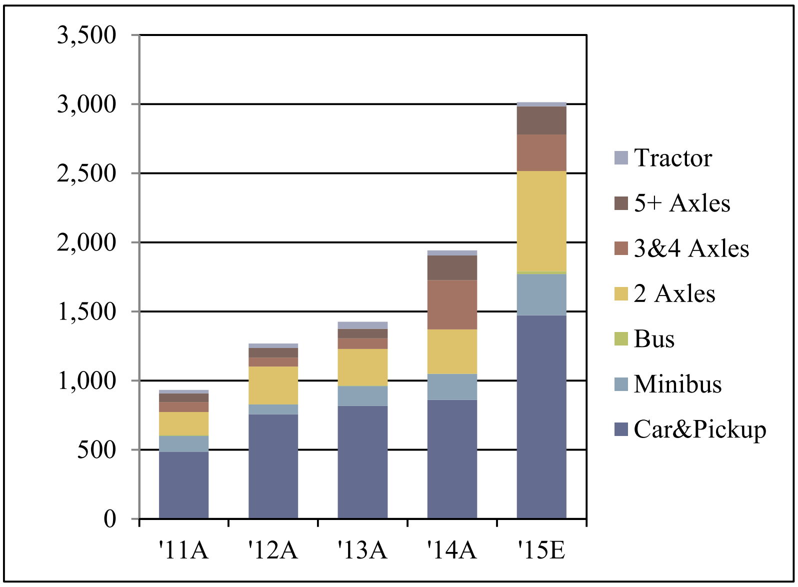
(2) Historical Trend of Traffic Count Survey

Historical trend of total traffic volume entering/exiting Cuamba city is summarised in Table 4.3.5 and Figure 4.3.8. As of 2015, a total of approximately 1,500 vehicles are entering the city every day as the graph shows the number in two directions. Surge increase since 2010 in the number of motorised vehicles is obvious. In addition to passenger cars and pickups, the number of trucks is rapidly increasing. This might be affected by the completion of Lot A and Lot B of Nampula – Cuamba section of N13 as well as construction works on Lot C.

Table 4.3.5 Total Traffic Volume Entering/Exiting Cuamba City (AADT)

Year / Source*	Motor-cycle***	Passenger car & pickup	Mini-bus	Bus	2 Axles	3&4 Axles	5+ Axles	Tractor	AADT
'11A	-	485	115	6	167	72	63	26	933
'12A	-	756	72	1	273	65	69	33	1,269
'13A	-	816	144	4	264	77	69	51	1,425
'14A	-	862	186	2	319	357	179	36	1,941
'15E**	2,044	1,471	299	22	723	265	203	30	3,013

Source: *'11A – '14A; ANE AADT data from 2010 to 2014 '15E; traffic count survey results of this study
Note: **2015 traffic volume is assumed to be same as 2014 for the survey locations which were not covered by this study. *** Motorcycles are not included in AADT. Motorcycle values are sum of traffic survey points of this study. ****The sum of all vehicle types and the AADT in the table are not always the same, because some of them have a number of decimals.

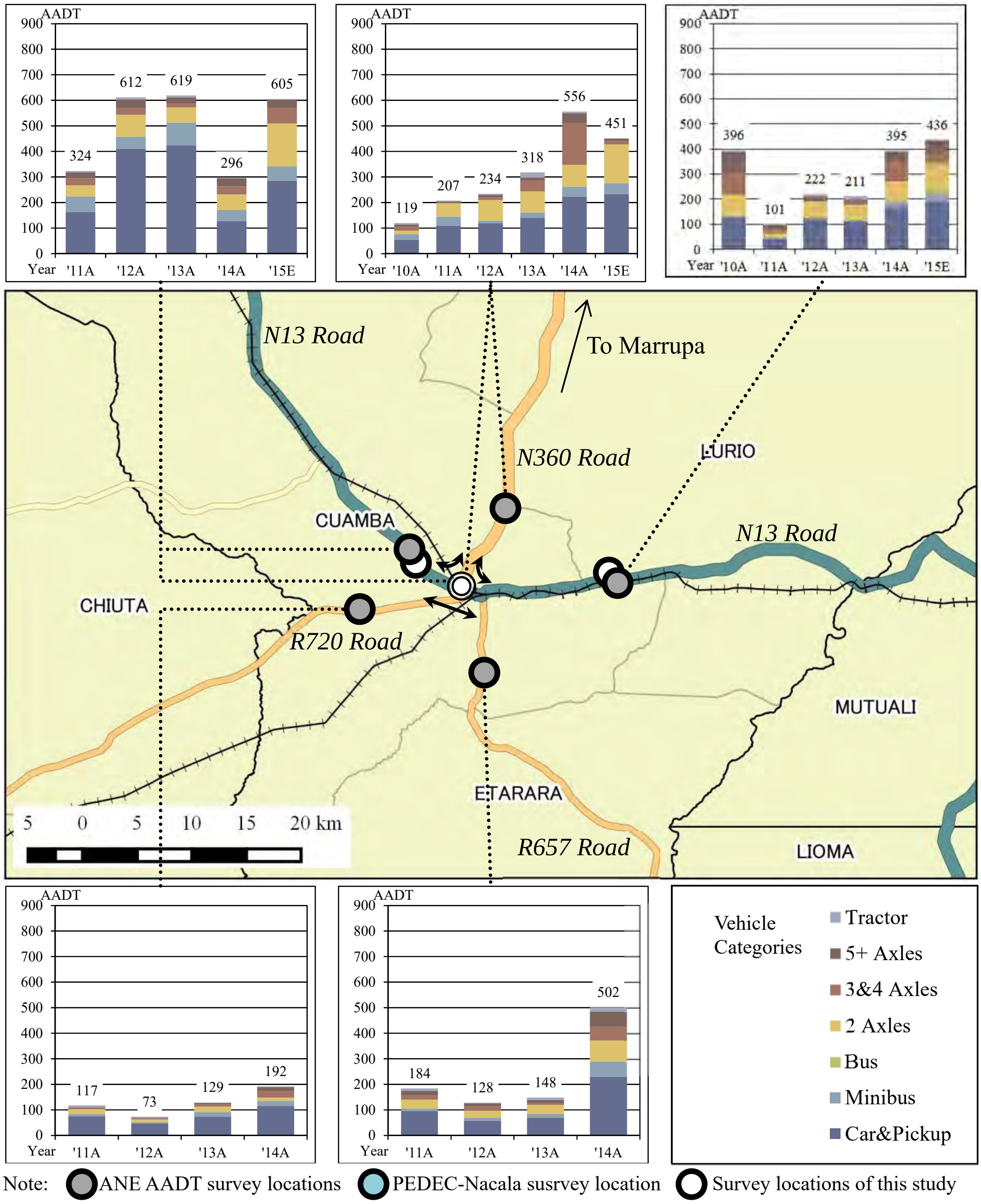


Source: *'11A – '14A; ANE AADT data from 2010 to 2014
'15E; traffic count survey results of this study

Note: **2015 traffic volume is assumed to be same as 2014 for the survey locations which were not covered by this study.

Figure 4.3.8 Total Traffic Volume Entering/Exiting Cuamba City (AADT)

The traffic volumes by survey locations are depicted in Figure 4.3.9. It is observed that N13 road to Lichinga and Nampula and N360 road to Marrupa carry the dominant flow though there are yearly fluctuations. For the N360 road to Marrupa, the trend of increase in traffic is remarkable for the last 6 years, even though the number of vehicles decreased between 2014 and 2015.



Source: the Study Team

Figure 4.3.9 Traffic Volumes by Survey Locations in/around Cuamba City

CHAPTER 5 Traffic Demand Forecast

5.1 Introduction

The traffic situation in the target year is analysed in this chapter by comparing the results of the "With Project" with the "Without Project" cases. Those outcomes are then utilised for the economic analysis and for road design (thickness of pavement).

The user equilibrium traffic assignment is conducted by using JICA STRADA 3.5 software. The results of the traffic survey are used for developing an "origin-destination (OD)" table. The OD table summarises the main modelling input data.

Different methods for developing OD tables are applied in Nacala and Nampula/Cuamba, while the Nacala Port Access Road is analysed under special conditions. The basic parameters for the traffic demand forecast are introduced and discussed below.

(1) Major Input Data

The major input data for the traffic demand forecast originate from the study's road side OD interview survey and the classified traffic count survey. Other input parameters are the projected future population, "gross-regional-domestic product (GRDP)", the cargo volume at Nacala Port and the land use plan in PEDEC-Nacala.

(2) Passenger Car Unit (PCU)

The conversion factors into PCU for various vehicle types are based on the "Comprehensive Urban Transport Master Plan for the Greater Maputo", which was provided by ANE, the variables that are applied are: Passenger Car=1, Pickup=1, Minibus=2, Bus=2, 2 Axle Truck=2.5, 3 or 4 Axle Truck=2.5 and 5+ Axle Truck=2.5.

(3) QV function

Following BPR function is applied as the QV function.

$$T'_a = T_{a0}\left(1 + \alpha\left(\frac{Q_a}{C_a}\right)^{\beta}\right)$$

$where\ T'_a$: Travel Time of Link a

T_{a0} : Free Flow Travel Time of Link a

Q_a : Number of Daily PCUs on Link a (PCU/day)

C_a : Daily Capacity of Link a (PCU /day)

$\alpha = 0.15 \quad \beta = 4.0$

(4) Capacity and Maximum Speed of the proposed Bypass Roads

The road network has been developed using GIS software, which is then translated to the form of a JICA STRADA network file. "SATCC Code of Practice for the Geometric Design of Trunk Roads" is referenced in order to define the capacity/speed of each road link. According to the standard, road capacity can be defined by "Terrain", "K factor" and "Number of Lanes". "Terrain = Flat" and "K factor = 0.15", which is normally assumed, are applied for the Nampula and Cuamba roads. In accordance with these parameters, the capacity is defined as 15,200 PCU/day for 2 lane roads and 40,200 PCU/day for 4 lane roads. In the case of the Nacala Port Access Road, "Terrain = Flat" and "K factor = 0.11" are applied. The capacity in accordance with these criteria is defined as 20,800 PCU/day for 2 lane roads and 54,800 PCU/day for 4 lane roads.

The entry regulations to the city centres for large trucks (more than 3 axles) are applied in the "With Project" case, in order to reduce the number of large trucks inside the city centre. The regulation is not applied for cases in which the trip-end is in the city centre.

(5) Cases for Traffic Demand Forecast

The traffic Demand Forecast comprises the following 8 cases, broken down by year and by "With/Without Project".

- 2017 Without Project
- 2017 With Project(2 Lanes)
- 2025 Without Project
- 2025 With Project(2 Lanes)
- 2025 With Project(4 Lanes) *Only for Nacala and Nampula roads
- 2035 Without Project
- 2035 With Project(2 Lanes)
- 2035 With Project(4 Lanes) *Only for Nacala and Nampula roads

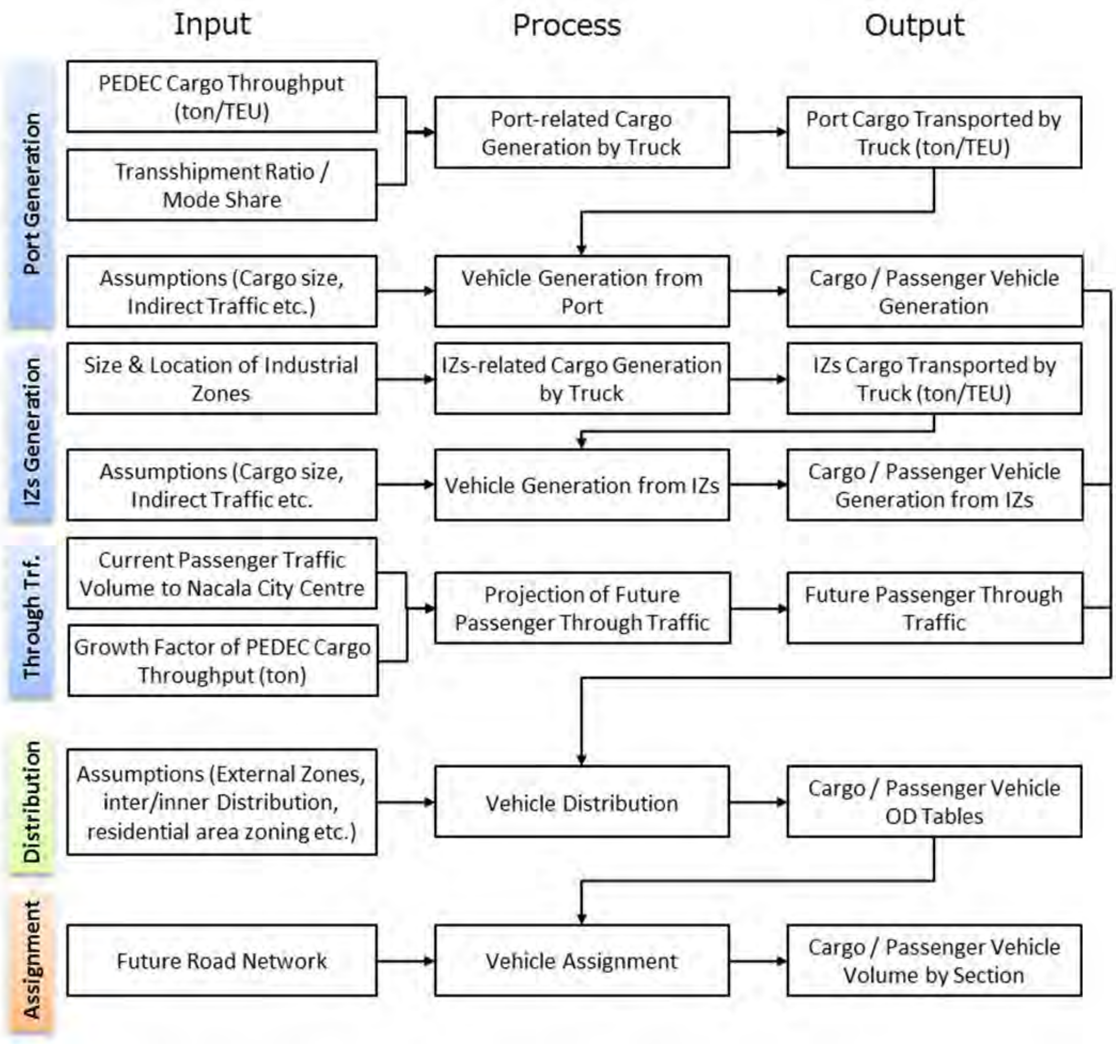
5.2 Nacala Port Access Road

5.2.1 Flow of Traffic Demand Forecast

Figure 5.2.1 shows the flow of traffic demand forecast for the Nacala Port Access Road.

The generation and Attraction volume are estimated for Port-related, Industrial Zone-related and Through Traffic. The future Generation and Attraction volumes are estimated by referring to the cargo volume estimation and the area development plan in PEDEC-Nacala.

It is assumed that the trip distribution for freight traffic is proportional to the scale of the industrial zones and the trip distribution for passenger traffic is proportional to the scale of the residential areas.



Source: the Study Team

Figure 5.2.1 Flow of Traffic Demand Forecast for Nacala Port Access Road

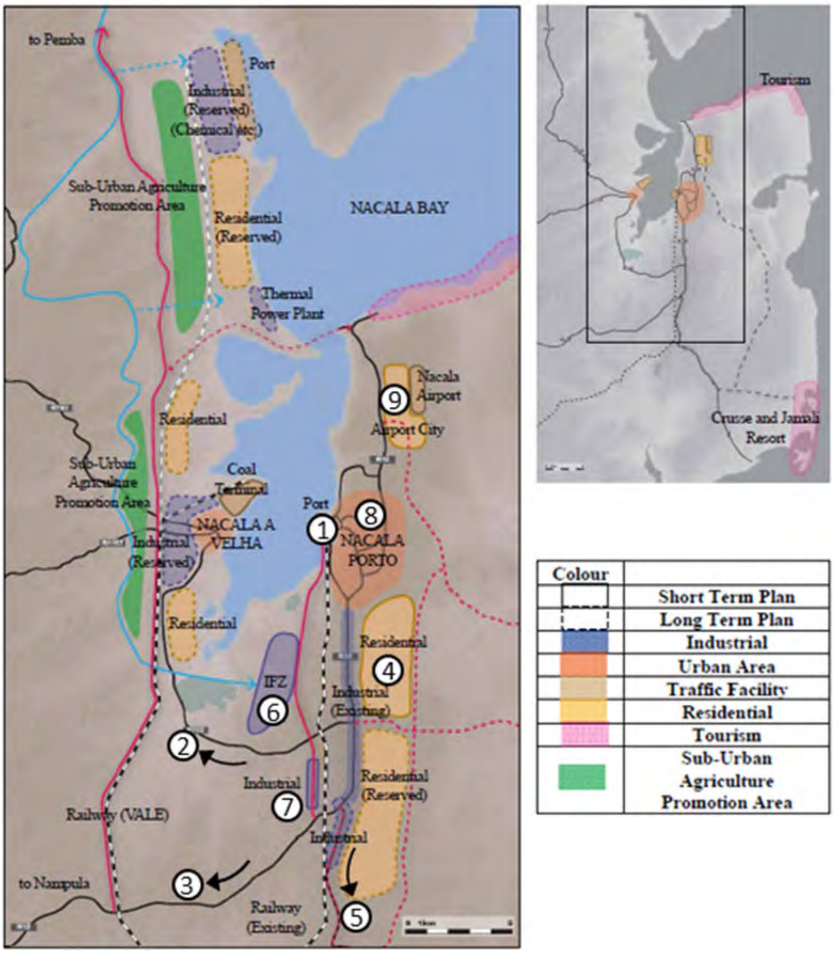
5.2.2 Future OD table

(1) Traffic Analysis Zone (TAZ) and Land Use Plan

The Traffic Analysis Zone (TAZ) is defined based on the future land use plan in PEDEC-Nacala (Figure 5.2.2). The target area is sub-divided into 9 TAZ, considering the structure of arterial roads and land use.

- Zone 1: Nacala Port
- Zone 2: R702 (Cordon Zone, the direction of Nacala Velha)
- Zone 3: N12 (Cordon Zone, the direction of Nampula City)
- Zone 4: Existing Industrial Zone and future residential area

- Zone 5: South Industrial Zone (South IZ) and future residential area
- Zone 6: IFZ (Industrial Free Zone) (North IZ)
- Zone 7: Central Industrial Zone (Central IZ)
- Zone 8: Nacala City Centre, and
- Zone 9: North-East area of Nacala City and the Airport City.



Source: the Study Team based on PEDEC-Nacala

Figure 5.2.2 Traffic Analysis Zones (TAZ) and Land Use Plan

(2) Traffic Generation and Attraction

1) Port-Related traffic volume

The generation and attraction traffic volume at the Nacala port is estimated based on freight handling volume in Nacala Port in PEDEC-Nacala in combination with a freight trip generation rate. "The Preparatory Survey on Nacala Port Development Project (2011)" and international examples are referenced in order to define the freight trip generation rate. The estimated generation and attraction traffic volume includes not only large trucks, but also the medium trucks, passenger vehicles and empty container trucks.

Some part of the freight handling volume of Nacala port will be in the future transported by railway. Therefore, the railway transfer volume which is estimated in PEDEC-Nacala is deducted from the freight handling volume for calculation of the generation and attraction traffic volume. According to PEDEC-Nacala, 100% of the minerals (including Coal), 50% of wheat and 5~10% of other freight is assumed to be transported by railway.

Table 5.2.1 Freight Handling Volume in Nacala Port in PEDEC-Nacala

Import and Transit to Neighboring Countries					
	Internal / Regional		2017	2025	2035
		Containers	275	511	1,274
		Bulk (Fuel)	252	480	1,125
		Bulk (Clinker)	390	210	24
		Bulk (Wheat)	225	277	420
		Bulk (Rice)	333	333	708
		Vehicles	49	49	283
		Bulk (Others)	0	168	850
		Sub-total	1,524	2,028	4,684
	Transit Cargo to Neighbouring Countries				
		Containers	564	1,193	2,822
		Bulk (Fuel)	358	587	1,104
		Bulk (Wheat)	125	311	323
		Vehicles	77	161	321
		Bulk (Others)	338	679	1,385
		Sub-total	1,462	2,931	5,955
	Total		2,986	4,959	10,639
Export and Transit from Neighboring Countries					
	Internal / Regional		2017	2025	2035
		Containers	412	1,027	2,631
		Mineral (Others)	0	5,000	7,500
		Bulk (Wood chip)	0	192	576
		Bulk (Others)	76	189	485
		Sub-total	488	6,408	11,192
	Transit Cargo from Neighbouring Countries				
		Containers	259	446	901
		Bulk (Others)	100	175	351
		Bulk (Food)	0	175	194
		Sub-total	359	796	1,446
	Total		847	7,204	12,638
Grand Total			3,833	12,163	23,277

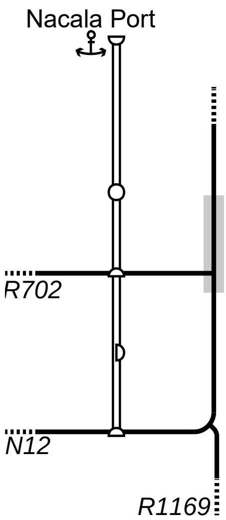
Unit: 1,000 ton/year
Source: PEDEC-Nacala

2) Industrial Zone-Related Traffic Volume

The Generation and Attraction traffic volumes from/to Industrial Zones (IZs) is estimated based on the area of the Industrial Zones by industry type in combination with a trip generation rate. The location, area and industry type of the Industrial Zones are based on the development plan of IZs and land use plan in PEDEC-Nacala.

"The Preparatory Survey on Nacala Port Development Project (2011)" and international examples are referenced, in order to define the trip generation rate from IZs.

Year 2015

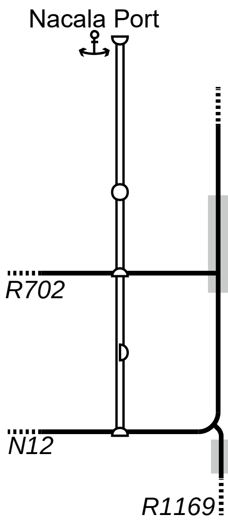


Industrial Zones (IZ)

Existing IZ	150
North IZ	0
Central IZ	0
South IZ	0

(Unit: ha)

Year 2017

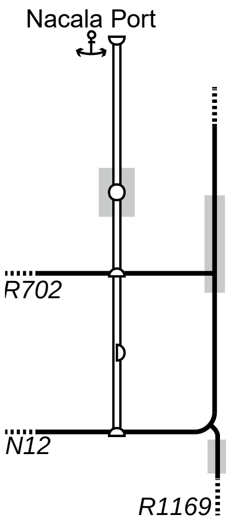


Industrial Zones (IZ)

Existing IZ	150
North IZ	0
Central IZ	0
South IZ	40

(Unit: ha)

Year 2025

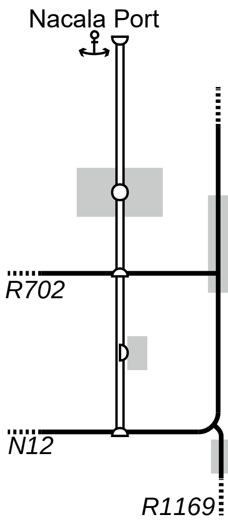


Industrial Zones (IZ)

Existing IZ	150	ha
North IZ	140	ha
Central IZ	0	ha
South IZ	80	ha

(Unit: ha)

Year 2035



Industrial Zones (IZ)

Existing IZ	150
North IZ	350
Central IZ	70
South IZ	80

(Unit: ha)

Source: the Study Team

Figure 5.2.3 Locations of Industrial Zones around Nacala Port Access Road

3) Through Traffic volume (passengers)

In addition to the traffic from/to the Nacala Port and the Industrial Zones, passenger traffic between the future residential areas (zone 4, 5, 8, 9) and the areas outside the region (zone 2, 3) is included into the considered traffic volume of the demand forecast.

The volume of through traffic is based on the results of the traffic count survey (Table 5.2.2), and the future volume is assumed to be proportional to the freight handling volume of the Nacala Port. The volume distribution of the generation/attraction from each residential area is based on the estimated population in each zone.

Table 5.2.2 Results of Traffic Count Survey (between city centre and outside)

(passenger vehicle/day)

From		To		Volume
R702	Nacala A Velha	Port	Nacala Porto	363
N12	Namialo	Port	Nacala Porto	518
Port	Nacala Porto	R702	Nacala A Velha	352
Port	Nacala Porto	N12	Namialo	554

Source：Traffic Survey in this Project

(3) Traffic Distribution

Regarding the port-related traffic, taking into consideration the volume of empty containers and empty chassis, half of all freight traffic from the port is assumed to go to the IZs.

Traffic distribution from/to the IZs is assumed to be proportional to the scale of the IZs.

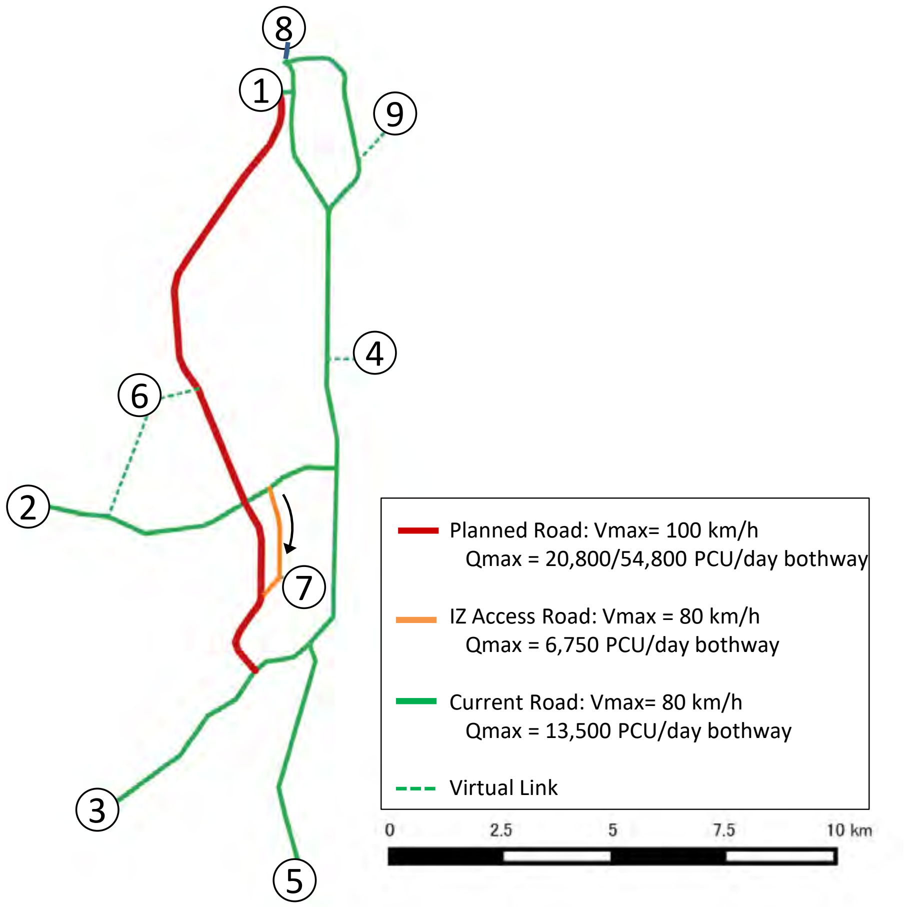
Traffic distribution from/to the areas outside the region (zones 2, 3) and to/from the port and IZs is calculated considering the location of the IZs.

The OD tables for 2017, 2025 and 2035 are presented in Appendix 1.

5.2.3 Road Network for Traffic Assignment

The road network for traffic assignment is set as shown in Figure 5.2.4. The maximum speed for the planned road is defined as 100 km/h and the capacity for it is set as described in 5.1(4). The road section to the IZ including the Multi-modal Terminal (zone 7) is a one-way section from north to south. Therefore, the capacity of this section is reduced to 50%.

The capacity of the current road sections complies with ”SATCC Code of Practice for the Geometric Design of Trunk Roads” and set as 13,500 PCU/day (“Terrain = Flat”, “K factor = 0.11” and ”No. of Lanes = 2”). The maximum speed of the current roads is set as 80 km/h.



Source: the Study Team

Figure 5.2.4 Road Network for Traffic Assignment (Nacala)

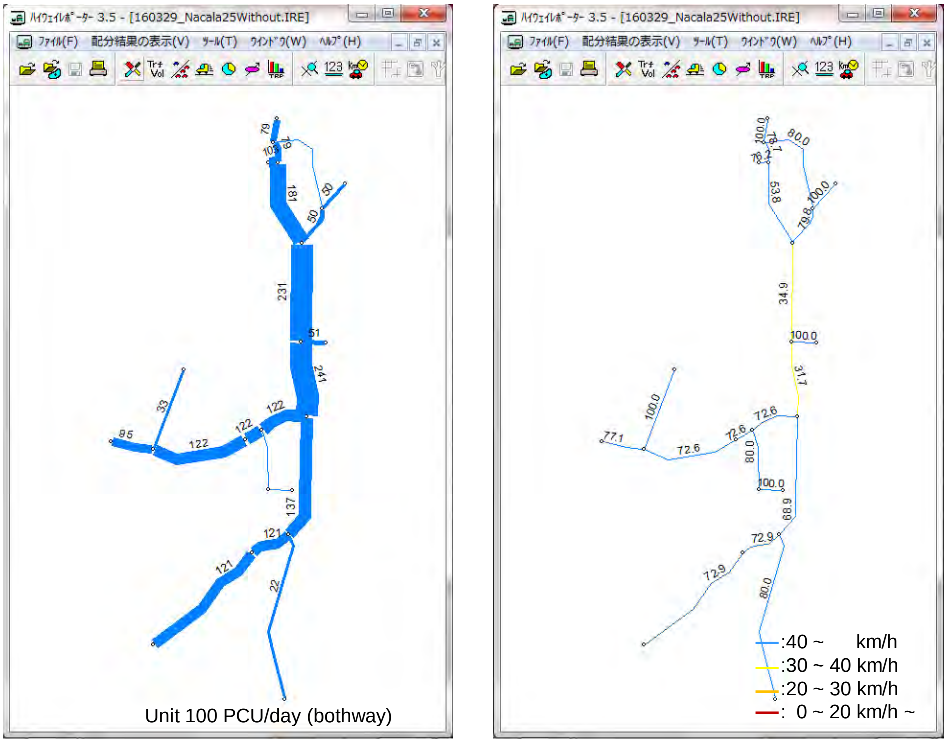
5.2.4 Traffic Demand Forecast

(1) Results of Traffic Demand Forecast

The network traffic assignment is conducted for 8 cases, as already mentioned in item 5.1(5). The results are shown in Figure 5.2.5 and Figure 5.2.8, both of which are important when discussing the demand of the Nacala Port Access Road.

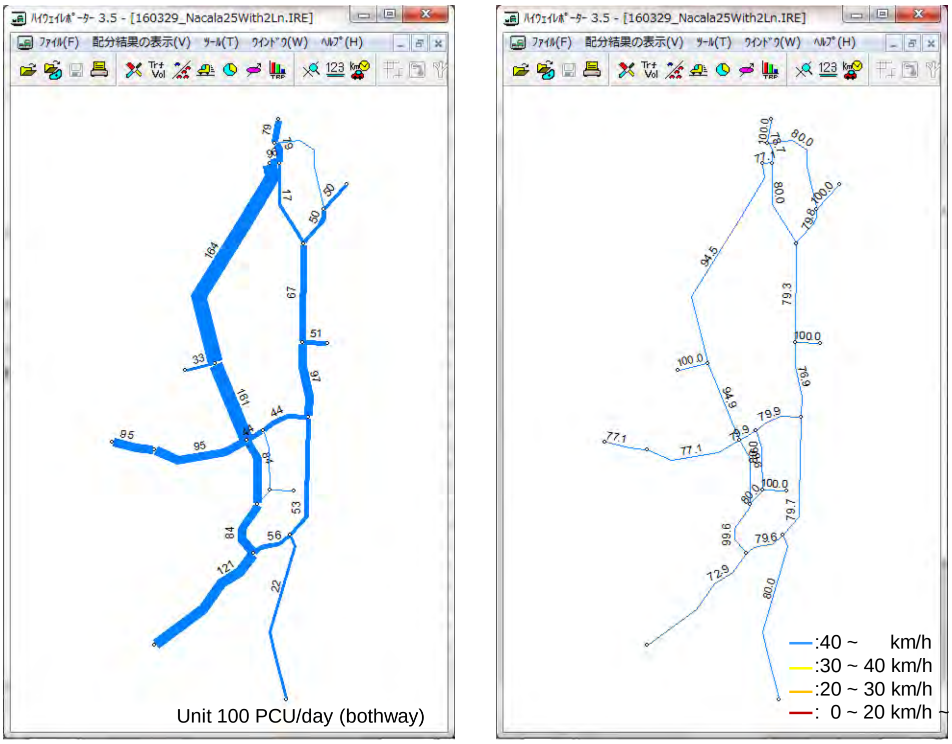
In the 2025 Without Case, the traffic volume exceeds the capacity and causes congestions on the main road section (Figure 5.2.5). On the other hand, in the 2025 With 2 Lanes case, the congestion is mitigated and roughly 16,400 PCU/day (both way total) use the Nacala Port Access Road (Figure 5.2.6).

In the 2035 With 2 Lanes Case, the traffic volume of the current road section reaches 19,000 PCU/day and that of the planned road section reaches 28,000 PCU/day. That traffic volume causes congestion in both sections and diminishes the velocity of the traffic (Figure 5.2.7). In the 2035 With 4 Lanes Case, the capacity of the planned road is sufficient, and traveling speed is improved (Figure 5.2.8).



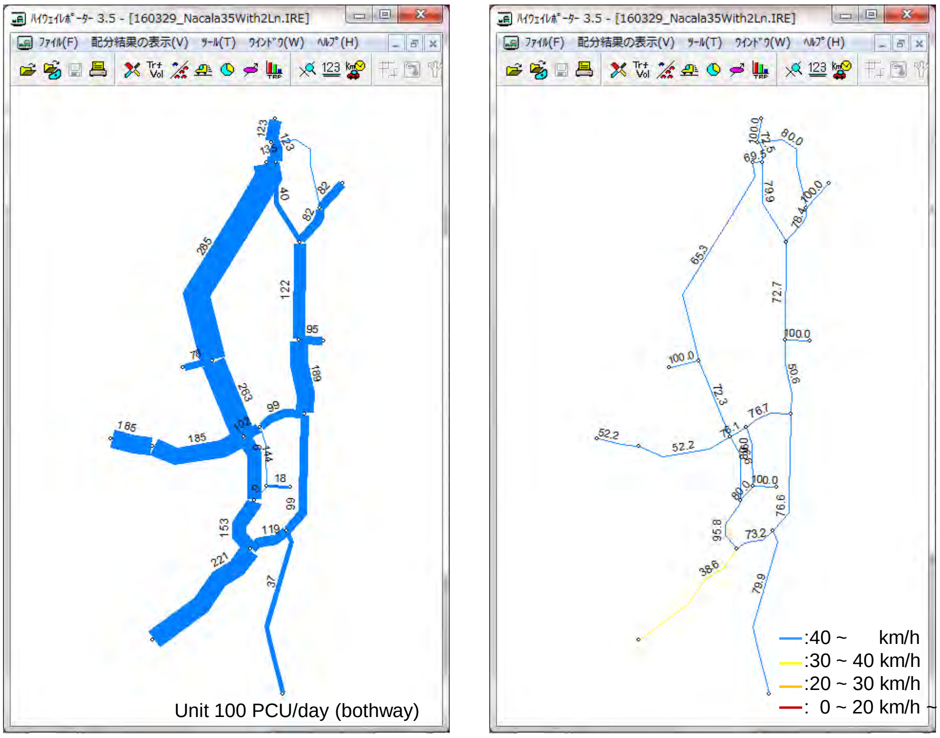
Source: the Study Team

Figure 5.2.5 Nacala 2025 Without Case (left: Volume, right Velocity)



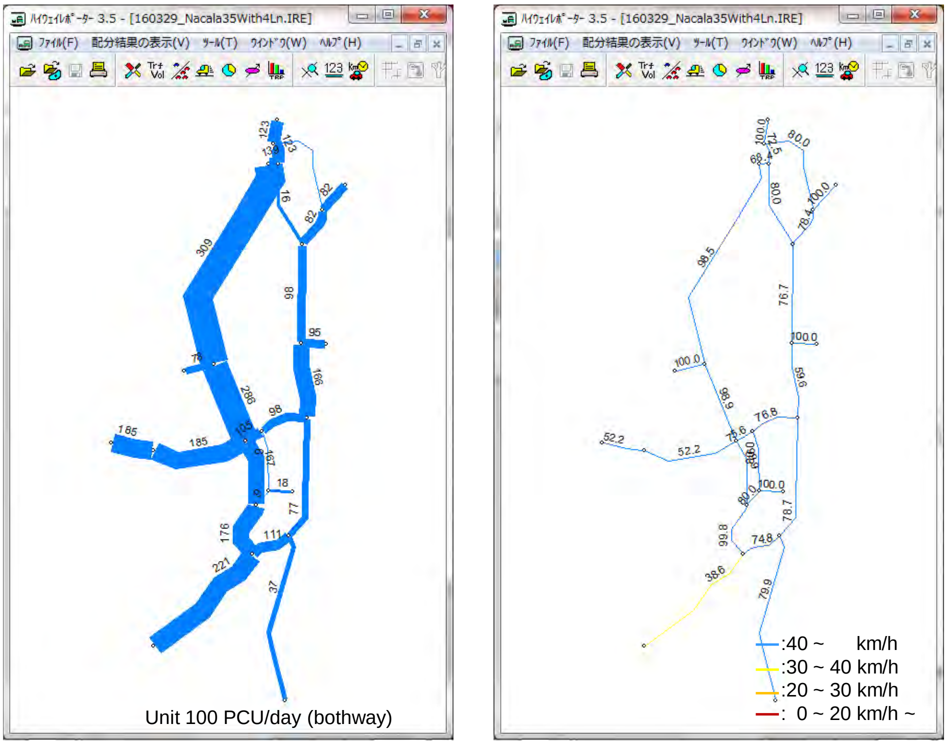
Source: the Study Team

Figure 5.2.6 Nacala 2025 With 2 Lanes Case (left: Volume, right Velocity)



Source: the Study Team

Figure 5.2.7　Nacala 2035 With 2 Lanes Case (left: Volume, right Velocity)



Source: the Study Team

Figure 5.2.8　Nacala 2035 With 4 Lanes Case (left: Volume, right Velocity)

(2) Traffic Demand by Case by Vehicle Type and by Section

Table 5.2.3 shows the results of the traffic demand forecast of the Nacala Port Access Road broken down by case, by vehicle type and by section. All the variables in the table are total vehicle/day, both ways.

Table 5.2.3 Traffic Demand by Vehicle Type and by Section (Nacala)

Year 2017 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	654	654	345	345	91	91	332	332	542	542	1,964	1,964
Section 2	654	654	345	345	91	91	332	332	542	542	1,964	1,964
Section 3	403	403	213	213	56	56	180	180	204	204	1,056	1,056
Section 4	403	403	213	213	56	56	180	180	204	204	1,056	1,056

Year 2025 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	1,781	1,781	939	939	248	248	642	642	976	976	4,586	4,586
Section 2	1,828	1,828	964	964	254	254	617	617	903	903	4,566	4,566
Section 3	1,098	1,098	579	579	152	152	266	266	391	391	2,486	2,486
Section 4	1,098	1,098	579	579	152	152	266	266	391	391	2,486	2,486

Year 2035 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	2,516	2,576	1,327	1,359	351	359	1,461	1,453	1,872	1,872	7,526	7,619
Section 2	2,616	2,676	1,380	1,412	365	373	1,222	1,214	1,567	1,567	7,150	7,242
Section 3	2,072	1,824	1,093	962	287	253	520	486	574	556	4,546	4,080
Section 4	2,072	1,843	1,093	973	287	256	520	662	574	712	4,546	4,446

Year 2035 4 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	2,891	2,891	1,524	1,524	403	403	1,557	1,658	1,872	1,872	8,247	8,348
Section 2	2,991	2,991	1,577	1,577	417	417	1,318	1,419	1,567	1,567	7,870	7,971
Section 3	2,398	2,235	1,265	1,178	333	311	621	594	578	558	5,195	4,875
Section 4	2,398	2,254	1,265	1,189	333	314	621	770	578	715	5,195	5,241

I to J = South to North
Passenger Vehicle = Passenger Vehicle, Pickup
Minibus = less than 32 seats
Bus = 32 seats and more
Medium Truck = 2 Axle Truck
Large Truck = 3,4 Axle Truck, 5+Axle Truck
Source: the Study Team

(3) Travel Time on Major Road Sections

Table 5.2.4 summarises the travel time on the major road sections of the current road and the planned road, broken down by case and by section.

In the 2025 without case, the travel time increases because of the congestion in section 1 and 2. On the other hand, in the with 2 lanes case, the travel time from sections1 to 4 decreases by half.

In the 2035 without case, the travel time in sections 3 and 4 increases significantly. Even in the with 2 lanes case, the travel time slightly increases.

Table 5.2.4 Travel Time by Section (Nacala)

Section	Without	With 2 Lanes		With 4 Lanes	
1~4	Current Rd.	Bypass Rd.	Current Rd.	Bypass Rd.	Current Rd.
2015	10.98	8.78	10.94		
2017	11.22	8.79	10.94		
2025	18.64	9.14	11.06	8.78	11.03
2035	84.46	11.96	12.54	8.87	11.84

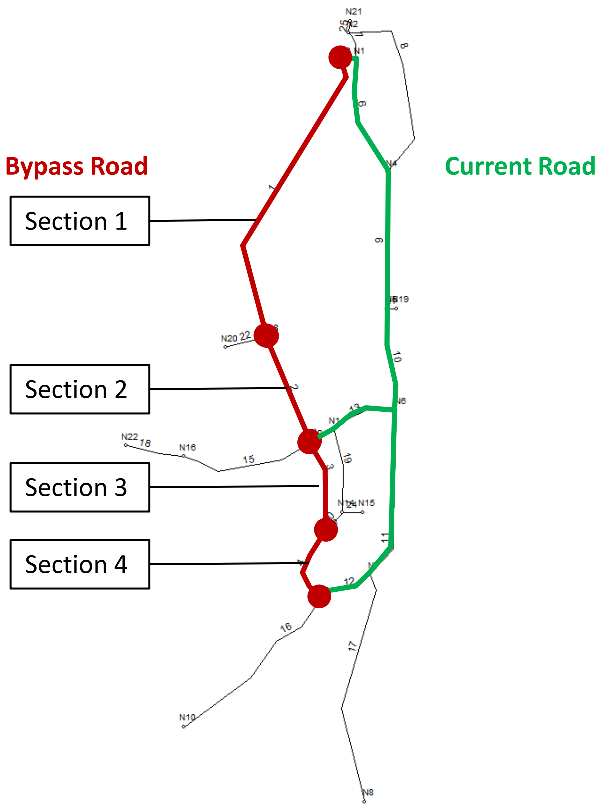
(unit: min)

Section	Without	With 2 Lanes		With 4 Lanes	
1~2	Current Rd.	Bypass Rd.	Current Rd.	Bypass Rd.	Current Rd.
2015	8.53	6.27	8.49		
2017	8.75	6.28	8.49		
2025	15.77	6.63	8.59	6.27	8.57
2035	79.86	9.35	9.93	6.35	9.35

(unit: min)

Section	Without	With 2 Lanes		With 4 Lanes	
3~4	Current Rd.	Bypass Rd.	Current Rd.	Bypass Rd.	Current Rd.
2015	5.88	2.51	5.87		
2017	5.90	2.51	5.87		
2025	6.65	2.52	5.89	2.51	5.89
2035	14.88	2.61	6.18	2.51	6.07

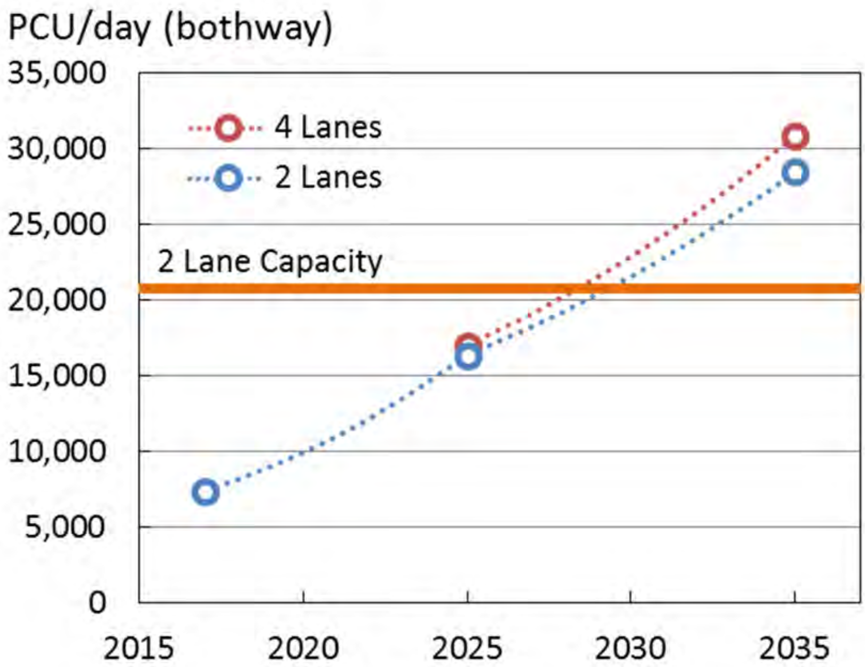
(unit: min)



Source: the Study Team

(4) Time for Upgrading to 4 Lanes

Figure 5.2.9 reflects the estimation results of the traffic volume in the most-used road section of the planned road in each year, for both 2 and 4 lane cases. The estimation indicates that it is required to upgrade the planned road to 4 lanes, because the traffic volume reaches the capacity of 2 lane roads around 2030.



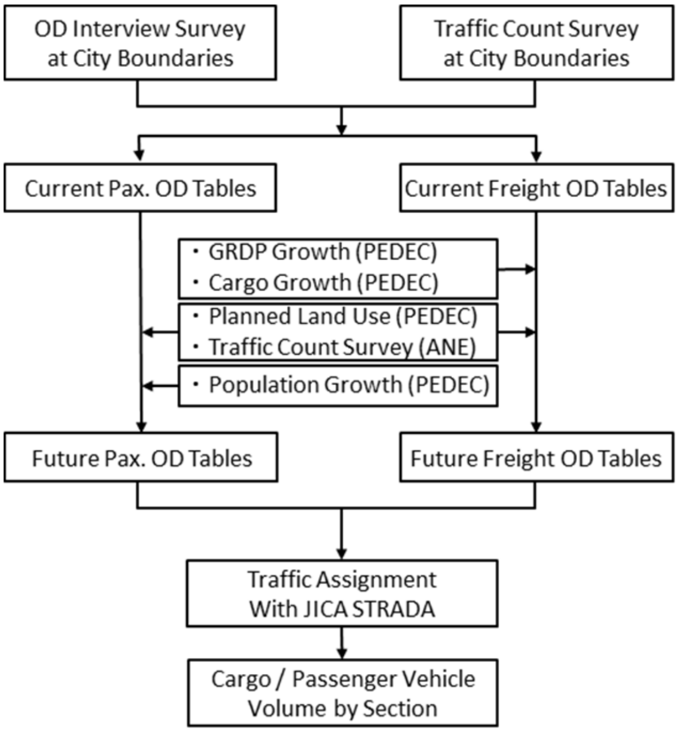
Source: the Study Team

Figure 5.2.9 Relation between Number of Lanes and Traffic Volume (Nacala)

5.3 Nampula Southern Bypass Road

5.3.1 Flow of Traffic Demand Forecast

The flow of the traffic demand forecast for the Nampula Southern Bypass Road is shown in Figure 5.3.1. The current OD tables are developed based on the results of the road side OD interview survey and the classified traffic count survey at the city boundaries, which were both conducted in this study. The future OD tables are developed based on population and GRDP estimation, land use plan and cargo handling volume in PEDEC-Nacala, the results of the traffic count survey by ANE and the current OD tables.



Source: the Study Team

Figure 5.3.1 Flow of Traffic Demand Forecast for Nampula Southern Bypass Road

The methodology of the traffic demand forecast in Cuamba is basically the same as that in Nampula.

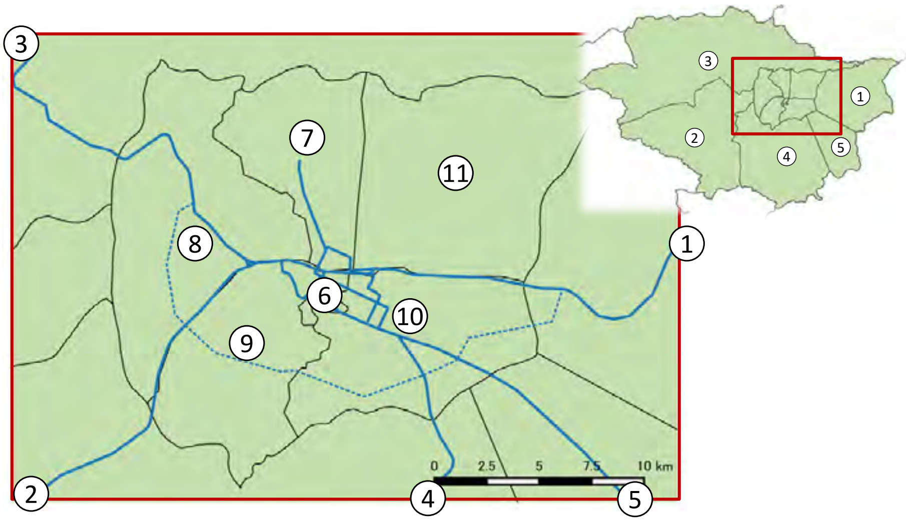
5.3.2 Current OD Tables

(1) Methodology

The survey was conducted near the city boundary of Nampula, in order to capture the number and the origin/destinations of the vehicles entering into the city. The survey consists of the classified traffic count survey at 5 locations (both ways) and the road side OD interview survey at 5 locations (only for the entering direction). For the details of the survey, please refer to Chapter 4. The current OD tables were developed by expanding the results of the road side OD interview survey using the results of the classified traffic count survey.

(2) Setting of Traffic Analysis Zone (TAZ)

As shown in Figure 5.3.2, the Nampula district in this study is divided into 5 zones outside of the city (Zones 1~5) and 6 zones inside the city (Zones 6~11). The 5 zones outside of the city combine the roles of cordon zone and normal TAZ. The zones inside of the city are defined by referring to the web page[1] of the Nampula Municipal Council.



Source: the Study Team

Figure 5.3.2 Traffic Analysis Zone (Nampula)

(3) Assumptions

The assumptions for developing the current OD tables are as follows.

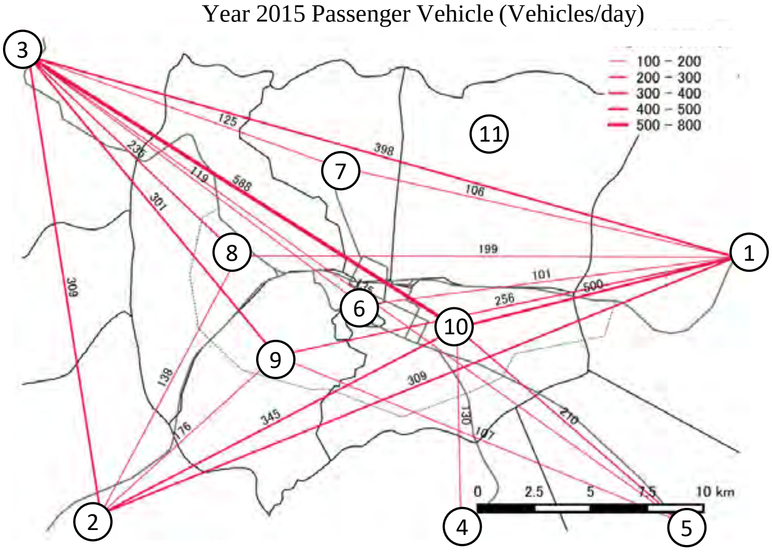
- The objective of the survey was to capture vehicles entering/exiting the city boundary (In-Out, Out-In). Therefore, the vehicles traveling within the city (In-In) are not included in the current OD tables. This means that traffic volume and the level of congestion inside the city are underestimated.
- In the OD interview survey, the detailed location information in the city was not available in many samples. The trip ends of these samples are assumed to be proportional to the current residential area which is available from the satellite image.
- The number of trips between zones 1, 2 and 3 is expanded by direction, because the results of the OD interview survey for both directions are available.
- It is assumed that there is no through traffic between zones 4 and 5. This means that the vehicles crossing the city boundary near zone 4 are assumed to go to zone 1, 2, 3 or a zone inside the city (zones 6~11).
- The number of trips between zones 1~3 and 4~11 are calculated based on the inflow volume at the city boundary near 1~3, because the OD interview survey is only for the inflow direction at the 3 locations near zones 1~3.

[1] http://www.commonwealthofnations.org/partner/nampula-municipal-council-mozambique/

(4) Development of Current OD Table

The OD table is developed for 7 vehicle types, using the same classification as in the traffic survey. Figure 5.3.3 shows the desire lines of passenger vehicles (passenger vehicle, pickup, minibus and bus) and Figure 5.3.4 shows the desire lines of freight vehicles (2 axle, 3 or 4 axle and 5 or more axle truck).

Year 2015 Passenger Vehicle (Vehicles/day)

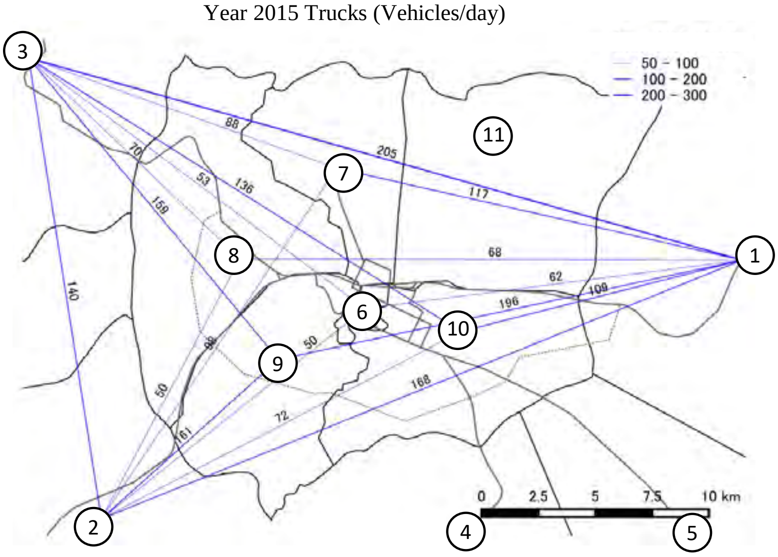


Note: Less than 100 Vehicles are omitted

Source: the Study Team

Figure 5.3.3 Desire Line of Passenger Traffic (Nampula 2015)

Year 2015 Trucks (Vehicles/day)



Note: Less than 50 Vehicles are omitted

Source: the Study Team

Figure 5.3.4 Desire Line of Cargo Traffic (Nampula 2015)

5.3.3 Future OD Table

The future OD table is developed by (1) estimating the regression expression of the total traffic volume crossing the city boundary, using the population of Nampula city, GRDP of Nampula province and the freight handling volume of Nacala Port and (2) adjusting the growth rate the of generation/attraction volume from/to each zone based on the land use plan. The results of the classified traffic count survey undertaken by ANE, which was conducted at almost the same locations as the survey in this study, is also used to estimate the regression expression model.

(1) Growth Rate of Traffic Volume

The growth rate of traffic volume is estimated by using the regression model for 1) Passenger Traffic, 2) Large Trucks and 3) Medium Trucks separately.

1) Passenger Traffic (passenger car, minibus, bus)

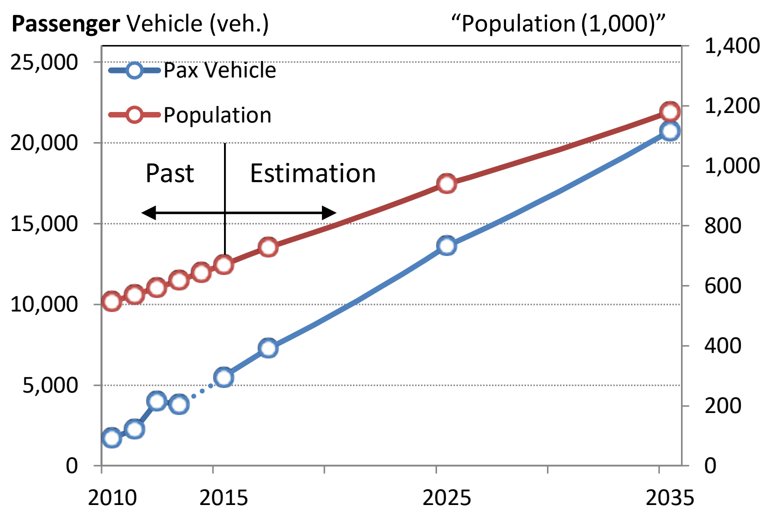
The traffic volume of the three vehicle types is assumed to grow across the board. This is so, because policy for the promotion of public transport utilization is assumed in this study, even though it could be argued that the number of passenger cars will grow more rapidly than the other 2 types caused by the effect of motorization. Besides, the results of the traffic count survey in 2014 undertaken by ANE are not used for the estimation of the regression model, because the results have a major difference from that in other years.

Y=29.8495 X - 14,477.7 (adjusted R^2: 0.89)

Where Y: Generation/Attraction Volume (vehicle) (ANE, the Study Team)

X: Population of Nampula city (1000 people) (PEDEC-Nacala)

The passenger traffic volume compared to that in 2015 is estimated to be 1.31 times in 2017, 2.44 times in 2025 and 3.72 times in 2035.



Source: the Study Team

Figure 5.3.5 Growth Rate of Passenger Traffic (Nampula)

2) Large Trucks (more than 2 axle)

The growth rates of large trucks are estimated based on the freight handling volume at the Nacala Port, because the volume of long distance trucks from the Nacala Port is considered to be significant for the number of large trucks. The freight handling volume at Nacala Port in the past year is based on “The Project for Improvement of Nacala Port” and that in the future is based on the PEDEC-Nacala estimation. The freight handling volume excludes liquid bulk cargo and the volume earmarked for railway transfer.

The survey location in this study is little bit far from the city compared to the survey by ANE, and the effect is considerable for large trucks. Therefore, the dummy variable for suburbs is adopted in the regression model.

$Y=0.6479 X_1 + 345.8099 X_2 - 457.5746$ (adjusted R^2: 0.90)

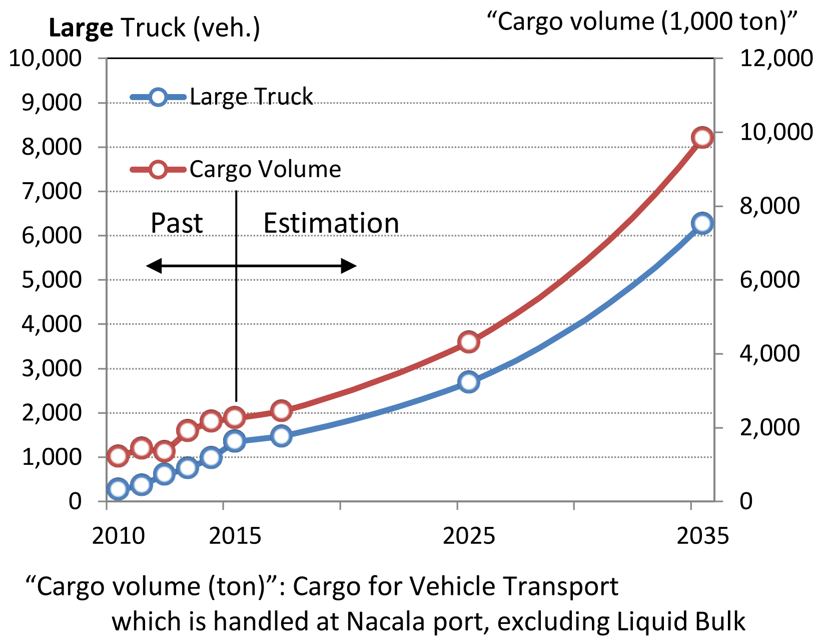
Where Y: Generation/Attraction Volume (vehicle) (ANE, the Study Team)

X_1: freight handling volume at Nacala Port (1,000 ton)

(PEDEC-Nacala, the Project for Improvement of Nacala Port)

X_2: Dummy Variable for Suburbs (1 if 2015)

The volume of large trucks is compared to that in 2015which is estimated to be 1.09 times in 2017, 1.98 times in 2025 and 4.64 times in 2035.



Source: the Study Team

Figure 5.3.6 Growth Rates of Large Trucks (Nampula)

3) Medium Trucks (2 axle and pickup)

The growth rate of medium trucks is estimated based on the GRDP of Nampula province. This is because the volume of short distance trucks is considered to be a significant percentage of the total volume of medium trucks, other than the long distance trucks from the Nacala Port.

The volume of medium trucks has increased after 2014, the year of completion of the pavement improvement project between Nampula-Cuamba. Therefore, the dummy variable for pavement improvement is adopted in the regression model.

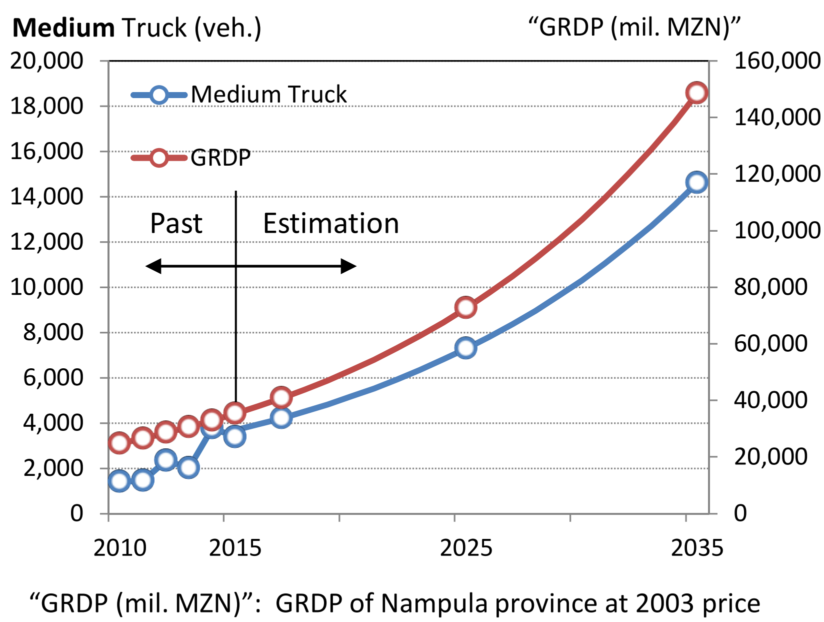
$Y=0.0965 X_1 + 1143.984 X_2 – 860.1491$ (adjusted R^2: 0.83)

Where Y: Generation/Attraction Volume (vehicle) (ANE, the Study Team)

X_1: GRDP of Nampula Province (mil. Mt 2003 Constant Price) (PEDEC-Nacala)

X_2: Dummy Variable for Pavement Improvement (1 after 2014)

The volume of large trucks compared to that in 2015 is estimated to be 1.14 times in 2017, 1.98 times in 2025 and 3.96 times in 2035.

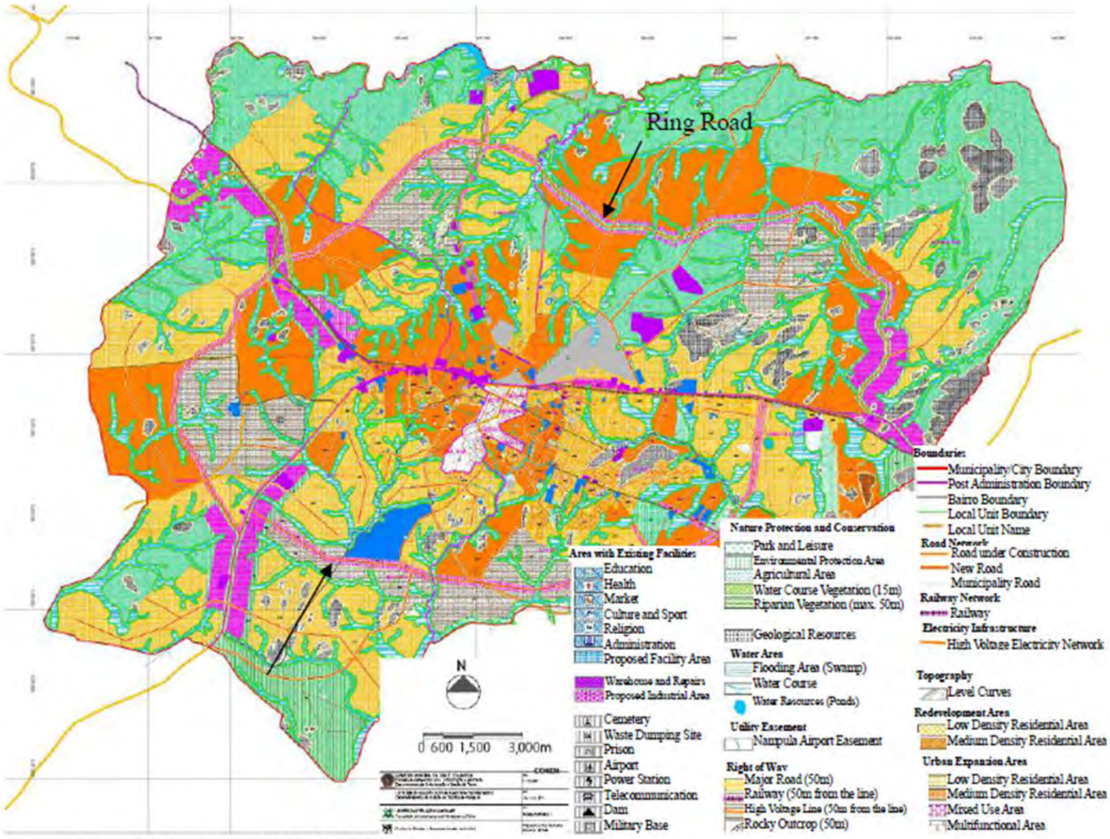


Source: the Study Team

Figure 5.3.7 Growth Rate of Medium Trucks (Nampula)

(2) Assumed Land Use Plan

The trips which have a trip-end at zones inside the city are assigned to each zone in proportion to the area by land use type. The area by land use type in 2017 is assumed to be the same as the current land use. The area by land use type in 2025 and 2035 is assumed based on Figure 5.3.8 which is referenced in PEDEC-Nacala.



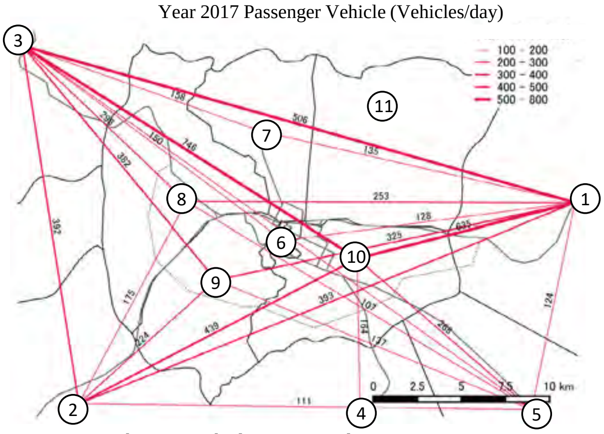
Source: Nampula Municipality and UN-HABITAT

Figure 5.3.8 Future Land Use Plan (Nampula)

(3) Future OD Table

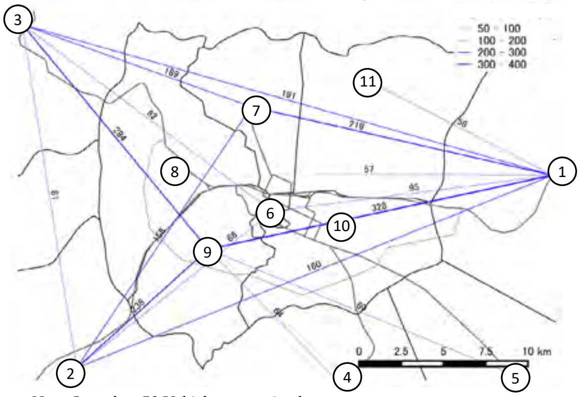
Figure 5.3.9 to Figure 5.3.11 are the desire lines which were drawn based on the OD tables for 2017, 2025 and 2035. The future OD tables are attached in Appendix 1.

Year 2017 Passenger Vehicle (Vehicles/day)



Note: Less than 100 Vehicles are omitted

Year 2017 Trucks (Vehicles/day)

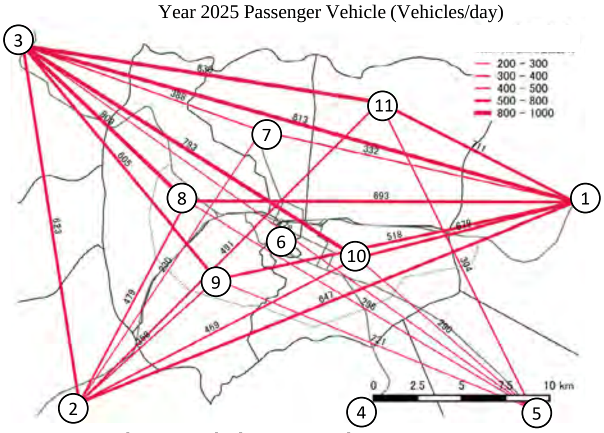


Note: Less than 50 Vehicles are omitted

Source: the Study Team

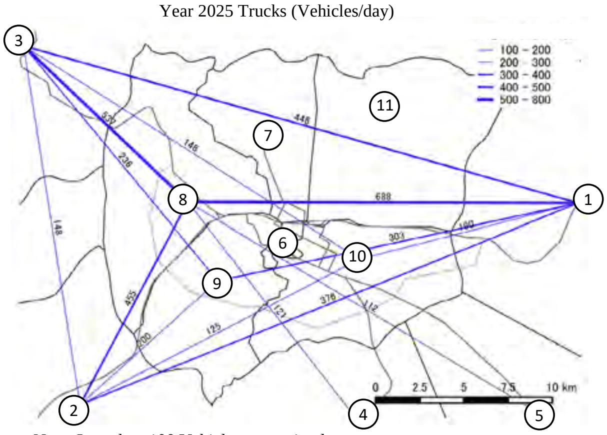
Figure 5.3.9 Desire Line in 2017 (Left: Passenger, Right: Freight) (Nampula)

Year 2025 Passenger Vehicle (Vehicles/day)



Note: Less than 200 Vehicles are omitted

Year 2025 Trucks (Vehicles/day)

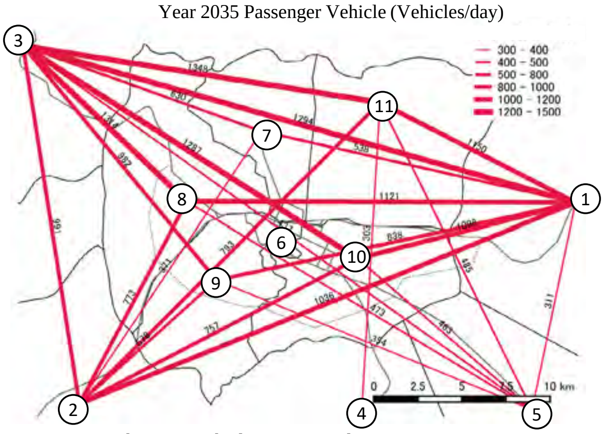


Note: Less than 100 Vehicles are omitted

Source: the Study Team

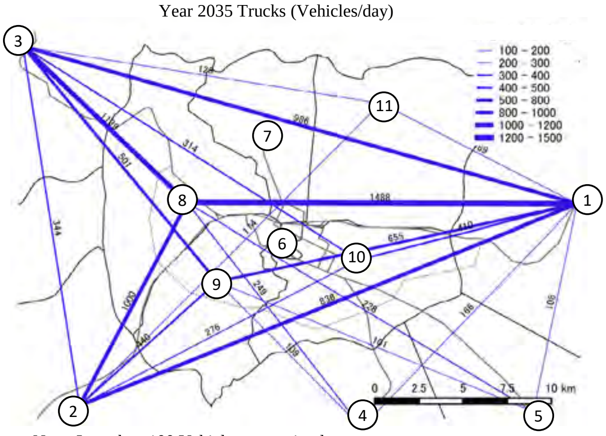
Figure 5.3.10 Desire Line in 2025 (Left: Passenger, Right: Freight) (Nampula)

Year 2035 Passenger Vehicle (Vehicles/day)



Note: Less than 300 Vehicles are omitted

Year 2035 Trucks (Vehicles/day)



Note: Less than 100 Vehicles are omitted

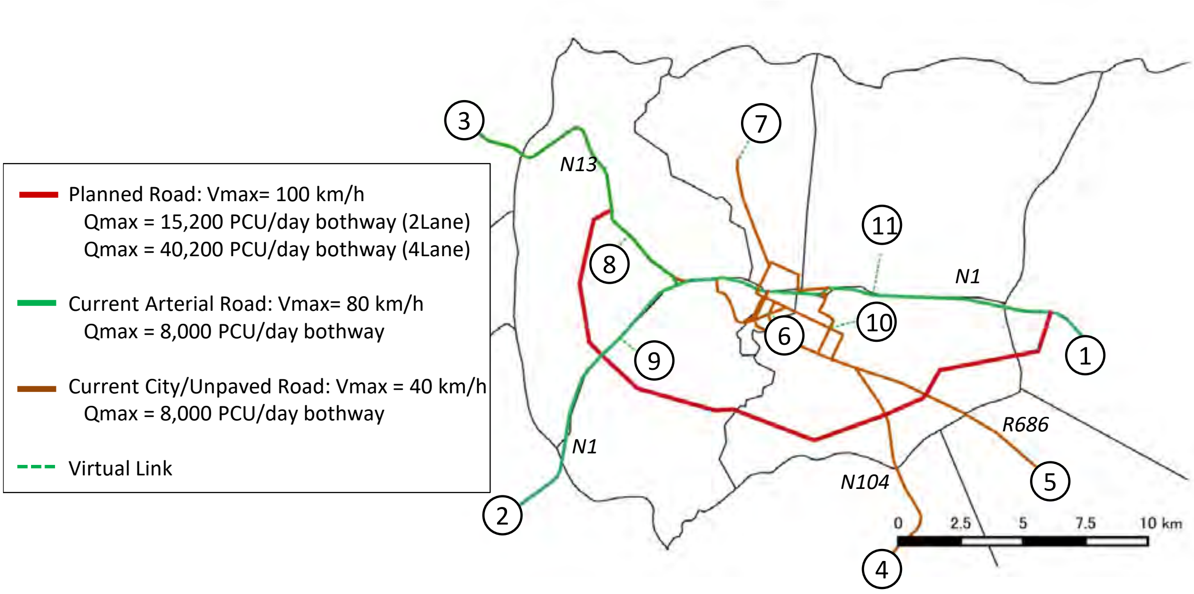
Source: the Study Team

Figure 5.3.11 Desire Line in 2035 (Left: Passenger, Right: Freight) (Nampula)

5.3.4 Road Network for Traffic Assignment

The road network for the traffic assignment is set as shown in Figure 5.3.12. The maximum speed for the planned road is defined as 100 km/h and the capacity for it is set as described in item 5.1(4).

The capacity of the current road sections complies with "the Study on Upgrading of Nampula-Cuamba Road" and set as 8,000 PCU/day. The maximum speed of the current roads is set as 80 km/h on inter-urban arterial road (N1 and N13) and 40 km/h on the other roads in the city centre and unpaved arterial roads.



Source: the Study Team

Figure 5.3.12 Road Network for Traffic Assignment (Nampula)

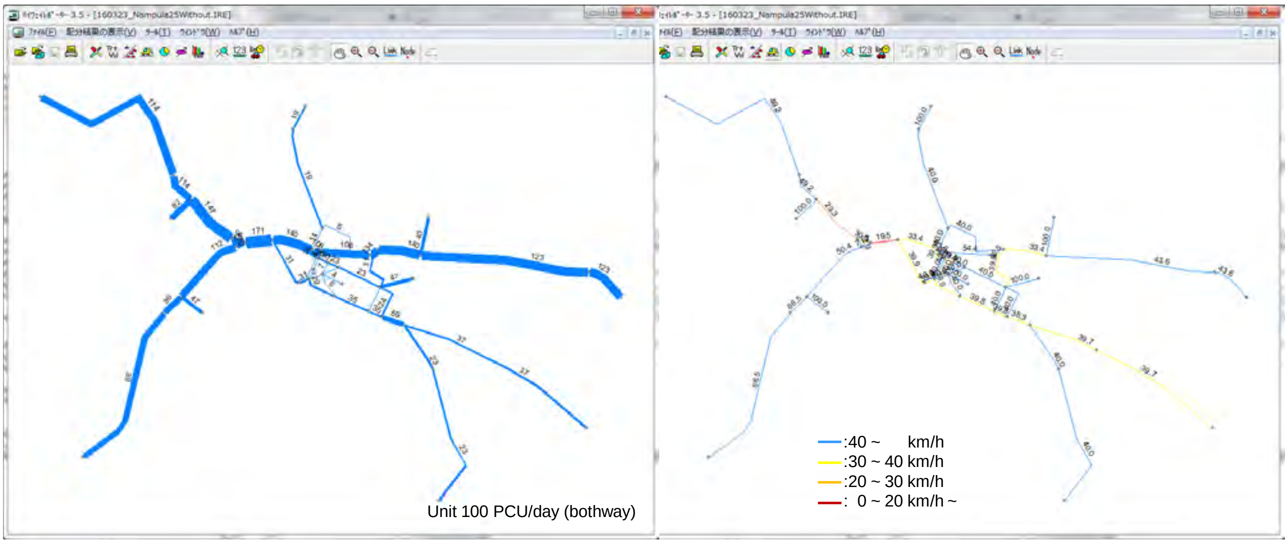
5.3.5 Traffic Demand Forecast

(1) Results of Traffic Demand Forecast

The network traffic assignment is conducted for 8 cases as mentioned in item 5.1(5). The results are shown in Figure 5.3.13 to Figure 5.3.16, which are important when discussing the demand on the Nampula Southern Bypass Road.

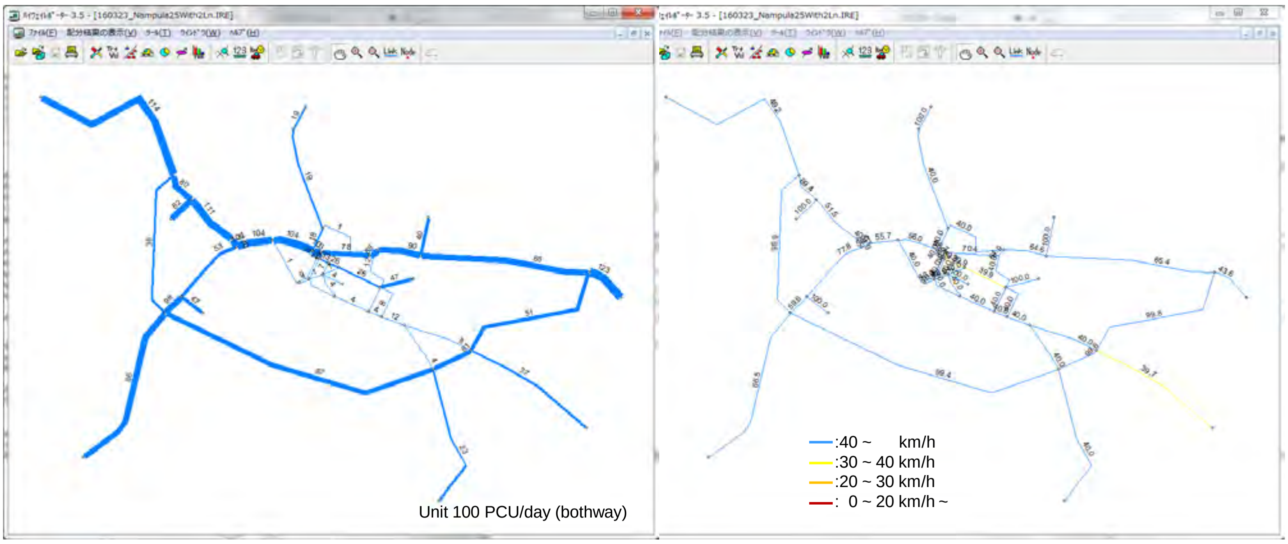
In the 2025 Without Case, the traffic volume exceeds the capacity and causes congestion on the main road section near the city centre (Figure 5.3.13). On the other hand, in the 2025 With 2 Lane case, the congestion is mitigated and roughly 6,700 PCU/day (both ways total) uses the Nampula Southern Bypass Road (Figure 5.3.14)

In the 2035 With 2 Lane case, traffic volume of both the current road and the planned road reaches capacity, and it begins to cause traffic congestion (Figure 5.3.15). In the 2035 With 4 Lane case, the traveling speed is improved and roughly 21,000 PCU/day (both ways total) uses the planned road (Figure 5.3.16).



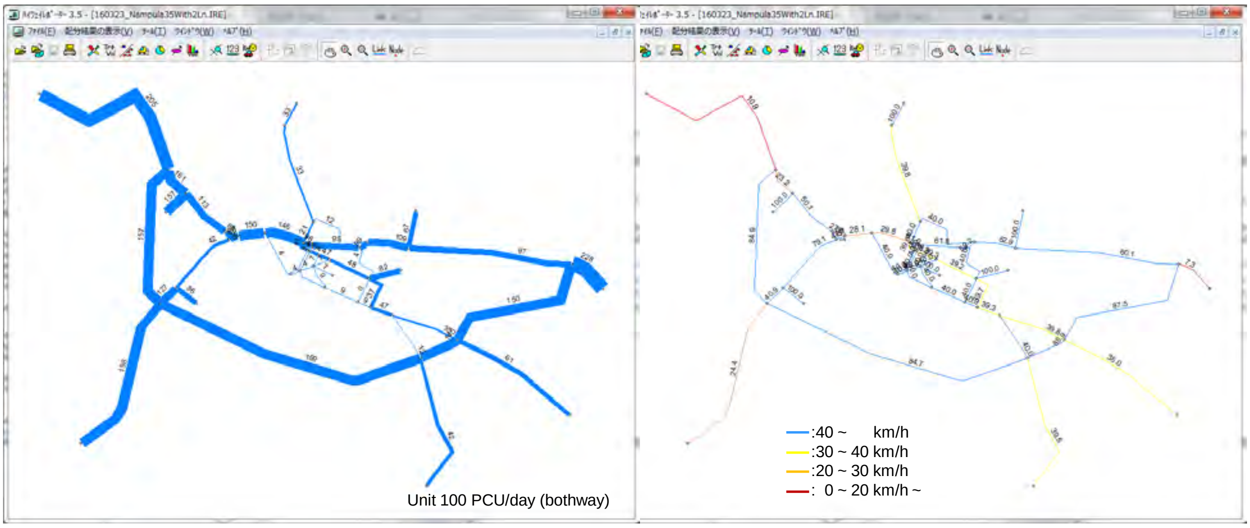
Source: the Study Team

Figure 5.3.13 Nampula 2025 Without Case (left: Volume, right Velocity)



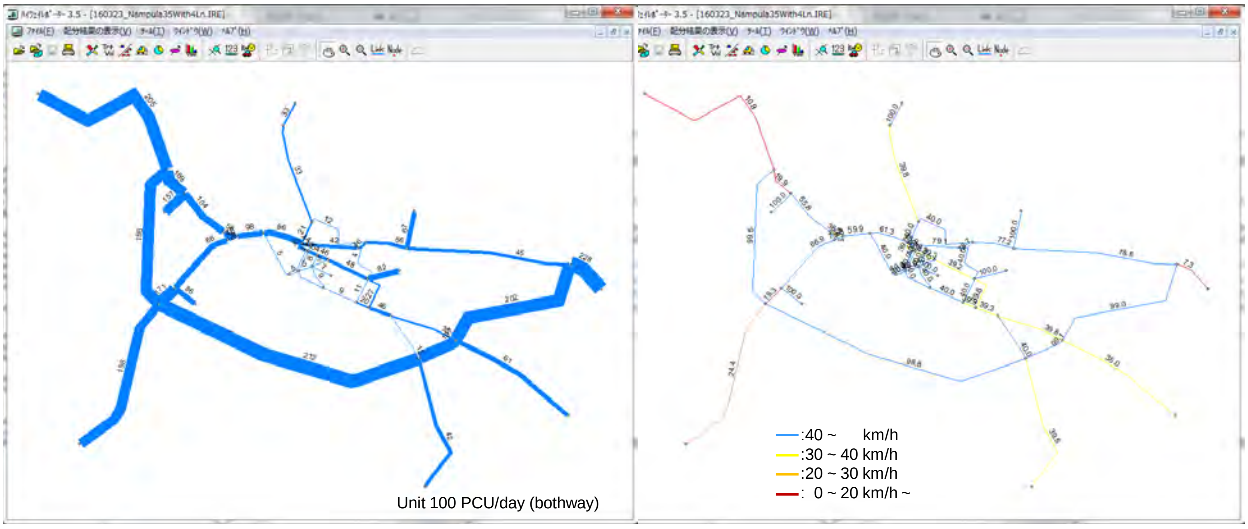
Source: the Study Team

Figure 5.3.14 Nampula 2025 With 2 Lane Case (left: Volume, right Velocity)



Source: the Study Team

Figure 5.3.15 Nampula 2035 With 2 Lane Case (left: Volume, right Velocity)



Source: the Study Team

Figure 5.3.16 Nampula 2035 With 4 Lane Case (left: Volume, right Velocity)

(2) Traffic Demand by Case by Vehicle Type and by Section

Table 5.3.1 shows the results of the traffic demand forecast for the Nampula Southern Bypass Road by case, by vehicle type and by section. All the variables in the table are expressed in vehicle/day, both ways total.

Table 5.3.1 Traffic Demand by Vehicle Type and by Section (Nampula)

Year 2017 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	230	204	77	79	59	54	76	65	88	103	530	505
Section 2	300	294	90	96	126	131	72	71	65	104	653	696
Section 3	376	366	112	112	126	130	91	90	67	139	772	837
Section 4	206	196	66	65	62	62	4	0	77	14	415	337

Year 2025 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	660	594	250	244	155	139	229	206	246	225	1,539	1,407
Section 2	760	734	267	271	255	260	265	257	248	230	1,794	1,751
Section 3	854	818	294	286	258	260	312	300	262	244	1,979	1,906
Section 4	568	527	187	171	158	154	108	93	220	62	1,241	1,007

Year 2035 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	1,679	1,699	674	697	314	295	693	702	928	735	4,287	4,128
Section 2	1,464	1,548	511	550	438	448	660	696	938	747	4,011	3,988
Section 3	1,739	1,811	583	607	442	452	766	794	956	760	4,485	4,424
Section 4	1,686	1,752	558	567	434	436	717	738	1,188	662	4,582	4,155

Year 2035 4 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	2,034	2,054	850	873	342	323	1,052	1,061	1,305	1,114	5,583	5,426
Section 2	1,818	1,903	687	726	466	476	1,019	1,055	1,317	1,127	5,307	5,287
Section 3	2,091	2,164	759	783	469	479	1,124	1,153	1,342	1,148	5,785	5,727
Section 4	1,715	1,789	602	616	390	394	777	805	1,276	759	4,760	4,362

I to J = West to East
Passenger Vehicle = Passenger Vehicle, Pickup
Minibus = less than 32 seats
Bus = 32 seats and more
Medium Truck = 2 Axle Truck
Large Truck = 3,4 Axle Truck, 5+Axle Truck
Source: the Study Team

(3) Travel Time in Major Road Sections

Table 5.3.2 summarises the travel time on the major road sections of the current road and the planned road, by case and by section.

In the "2025 Without" case, the travel time increases because of the congestion in the current road. On the other hand, in the with 2 lane case, the travel time decreases by almost half.

In the "2035 Without" case, the travel time in the sections increases significantly. Even in the "With 2 lane" case, the travel time slightly increases.

Table 5.3.2 Travel Time by Section (Nampula)

Section	Without	With 2 Lanes		With 4 Lanes	
1~4	Current Rd.	Bypass Rd.	Current Rd.	Bypass Rd.	Current Rd.
2015	15.36	18.24	14.88		
2017	16.17	18.24	15.23		
2025	30.64	18.30	18.93	18.24	17.95
2035	172.36	21.27	25.26	18.40	19.26

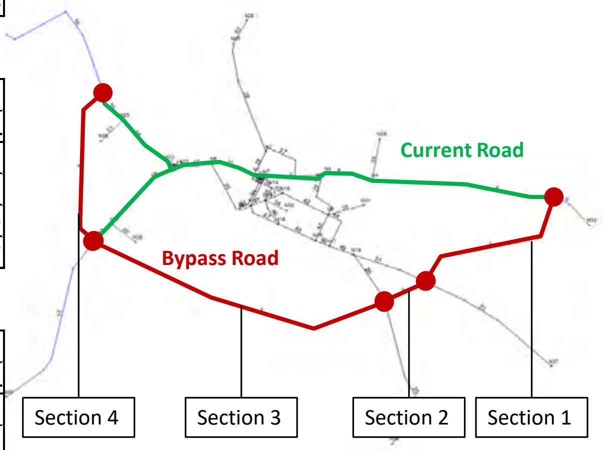
(unit: min)

Section	Without	With 2 Lanes		With 4 Lanes	
1~3	Current Rd.	Bypass Rd.	Current Rd.	Bypass Rd.	Current Rd.
2015	15.34	13.20	14.86		
2017	16.17	13.20	15.18		
2025	28.44	13.26	17.96	13.20	17.30
2035	148.33	15.35	22.45	13.34	18.27

(unit: min)

Section	Without	With 2 Lanes		With 4 Lanes	
4	Current Rd.	Bypass Rd.	Current Rd.	Bypass Rd.	Current Rd.
2015	6.48	5.04	6.31		
2017	6.72	5.04	6.41		
2025	11.56	5.04	7.88	5.04	7.38
2035	64.80	5.92	10.57	5.06	12.88

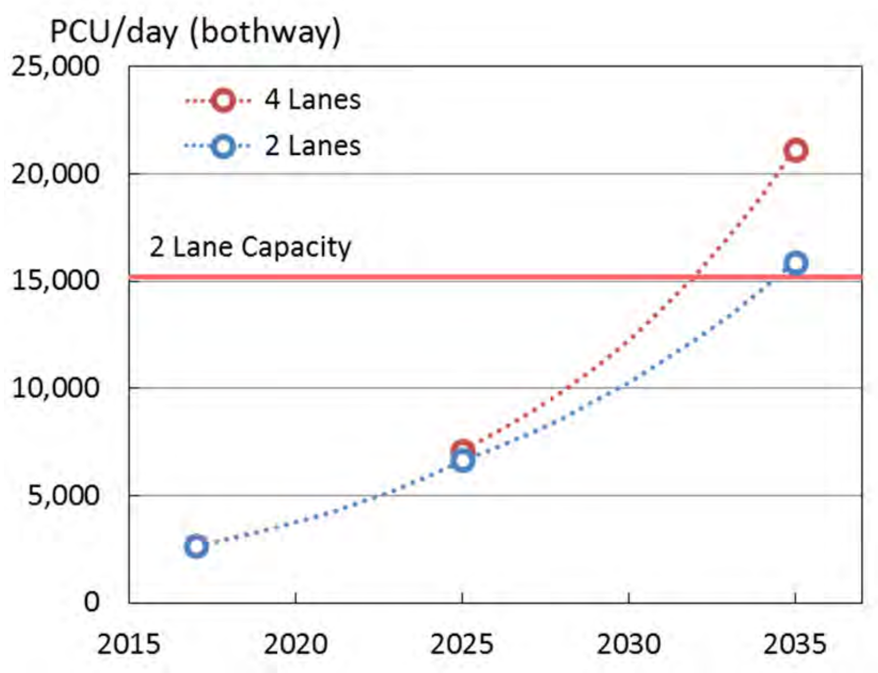
(unit: min)



Source: the Study Team

(4) Time for Upgrading to 4 Lane

Figure 5.3.17 shows the estimation results of the traffic volume in the most-used road section of the planned road in each year, for both 2 and 4 lane cases. It indicates that the traffic volume on the planned road reaches the capacity of 2 lane roads around 2035.



Source: the Study Team

Figure 5.3.17 Relation between Number of Lanes and Traffic Volume (Nampula)

5.4 Cuamba Bypass Road

5.4.1 Flow of Traffic Demand Forecast

The flow of the traffic demand forecast for the Cuamba Bypass Road is the same flow as that for the Nampula Southern Bypass Road.

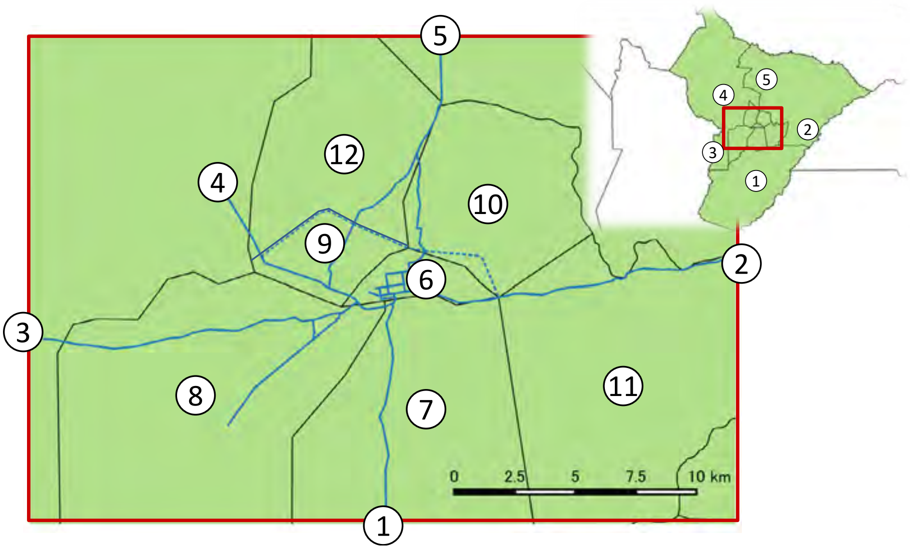
5.4.2 Current OD Tables

(1) Methodology

The survey was conducted near the city boundary of Cuamba, to capture the number and the origin/destination of the vehicles crossing the city boundary. The survey consists of the classified traffic count survey at 2 locations (both ways) and the road side OD interview survey at 2 locations (by direction). For the details of the survey, please refer to Chapter 4. The current OD tables were developed by expanding the results of the road side OD interview survey using the results of the classified traffic count survey.

(2) Setting of Traffic Analysis Zones (TAZ)

As shown in Figure 5.4.1, the traffic analysis zones are defined in this study as 5 cordon zones (zones 1~5) and 6 zones inside the city (zones 6~11).



Source: the Study Team

Figure 5.4.1 Traffic Analysis Zones (Cuamba)

(3) Assumptions

The assumptions for developing the current OD table are the same as that for Nampula (5.3.2(3)).

5.4.3 Future OD Table

The future OD table is developed by (1) estimating the regression expression of the total traffic volume crossing the city boundary, using the population of Cuamba city and GRDP of Niassa province and (2) adjusting the growth rate of the generation/attraction volume from/to each zone based on the land use plan. The results of the classified traffic count survey undertaken by ANE, which was conducted at almost the same locations as the survey in this study, is also used to estimate the regression expression model.

(1) Growth Rate of Traffic Volume

The growth rate of the traffic volume is estimated by using the regression model for 1) Passenger Traffic, and 2) Freight Traffic separately.

1) Passenger Traffic (passenger car, Pickup, minibus, bus)

The traffic volume of the four vehicle types is assumed to grow across the board. This is so because a policy for promotion of public transport utilization is assumed in this study, even though it could be argued that the number of passenger cars will grow more rapidly than the other 2 types caused by the effect of motorization.

The locations of the survey conducted by ANE were compared to the survey locations in this study which were a little bit farther from the city. Therefore, the dummy variable for suburbs is adopted in the regression model.

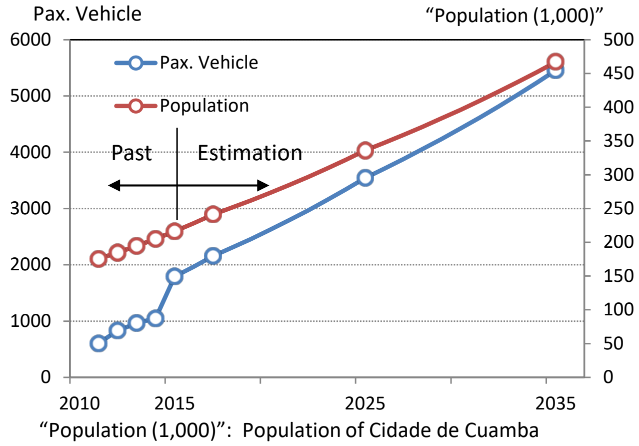
$Y = 14.6198\ X_1 - 544.765\ X_2 \quad -1370.2$ (adjusted R^2: 0.99)

Where Y: Generation/Attraction Volume (vehicle) (ANE, the Study Team)

X_1: Population of Cuamba city (1000 people) (PEDEC-Nacala)

X_2: Dummy Variable for Suburbs (1 if 2011~2014)

The passenger traffic volume was compared to that in 2015 and was estimated to be 1.20 times in 2017, 1.98 times in 2025 and 3.05 times in 2035.



Source: the Study Team

Figure 5.4.2 Growth Rate of Passenger Traffic (Cuamba)

2) Freight Traffic (2 axle, 3 or 4 axle and 5 or more axle truck)

The growth rate of freight traffic is estimated based on the GRDP of Niassa province.

The volume of freight traffic has increased after 2014, the year of the completion of the pavement improvement project between Nampula-Cuamba. Therefore, the dummy variable for pavement improvement is adopted in the regression model.

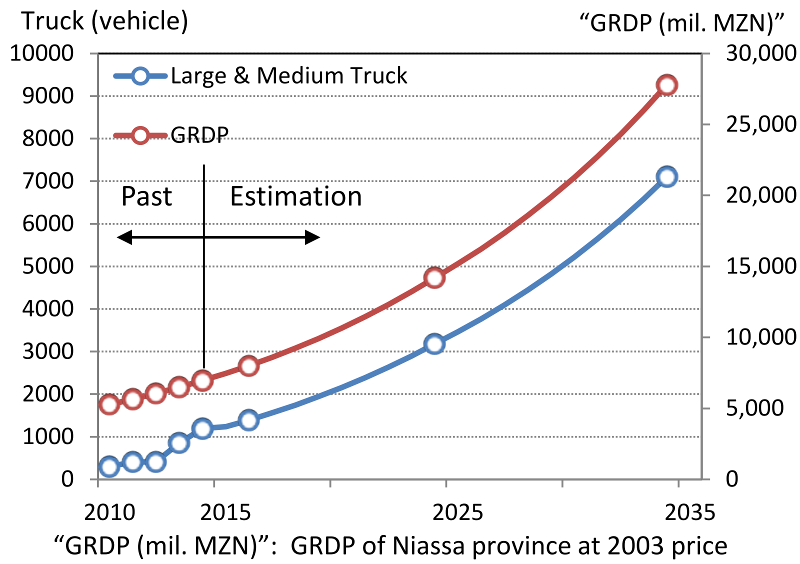
$Y=0.2887\ X_1 + 341.9905\ X_2 - 1261.45$ (adjusted R^2: 0.90)

Where Y: Generation/Attraction Volume (vehicle) (ANE, the Study Team)

X_1: GRDP of Niassa Province (mil. Mt 2003 Constant Price) (PEDEC-Nacala)

X_2: Dummy Variable for Pavement Improvement (1 after 2014)

The volume of large trucks was compared to that in 2015 and was estimated to be 1.27 times in 2017, 2.92 times in 2025 and 6.52 times in 2035.

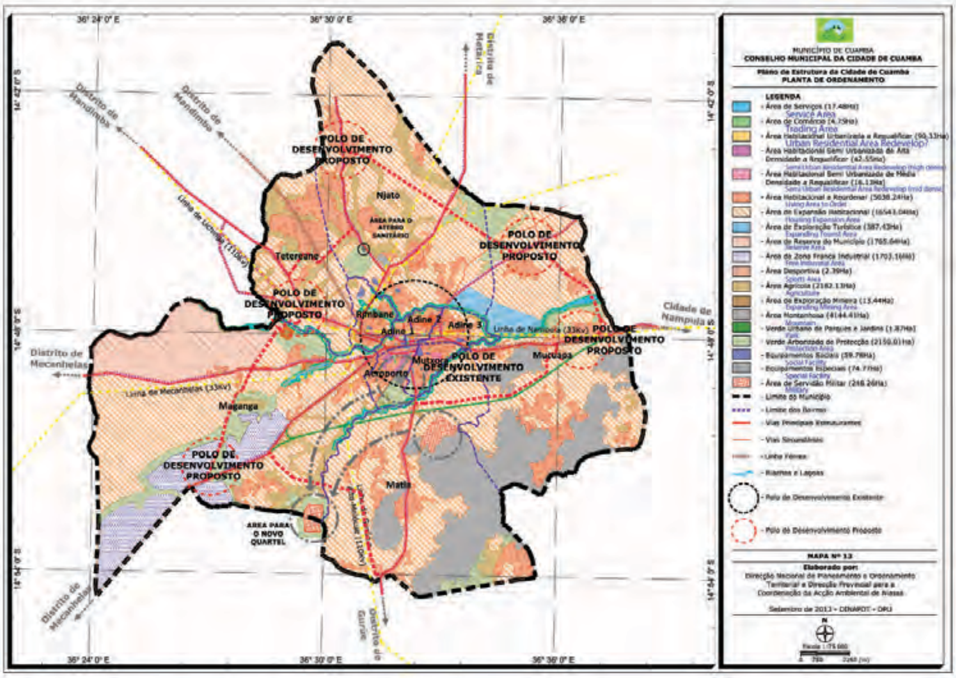


Source: the Study Team

Figure 5.4.3 Growth Rate of Freight Traffic (Cuamba)

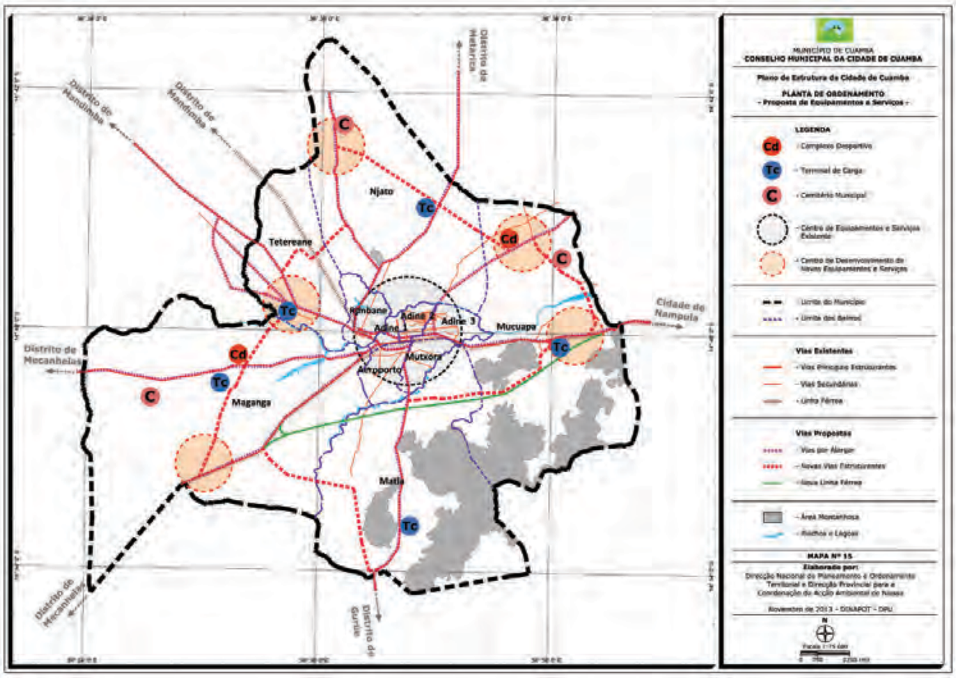
(2) Assumed Land Use Plan

The trips which have a trip-end in zones inside the city are assigned to each zone in proportion to the area by land use type. The area by land use type in 2017 is assumed to be the same as the current land use. The area by land use type in 2025 and 2035 is assumed based on the land use plan of Cuamba city (Figure 5.4.4 and Figure 5.4.5). However, the development pressure is assumed to be weaker in the southern part of the city. This is because the bypass road is planned in the north part of the city, and large scale development in the south area is considered to be difficult, especially in the area where there is no connection to the current road.



Source：Plano de Estrutura de Cidade de Cuamba

Figure 5.4.4　Future Land Use Plan (Cuamba)



Source：Plano de Estrutura de Cidade de Cuamba

Figure 5.4.5　the Plan for Freight Transport Complex (Cuamba)

(3) Future OD Table

The OD tables of 2017, 2025 and 2035 are presented in Appendix 1.

5.4.4 Road Network for Traffic Assignment

The road network for traffic assignment is set as shown in Figure 5.4.6. The maximum speed for the planned road is defined as 100 km/h and the capacity for the road is set as described in item 5.1(4).

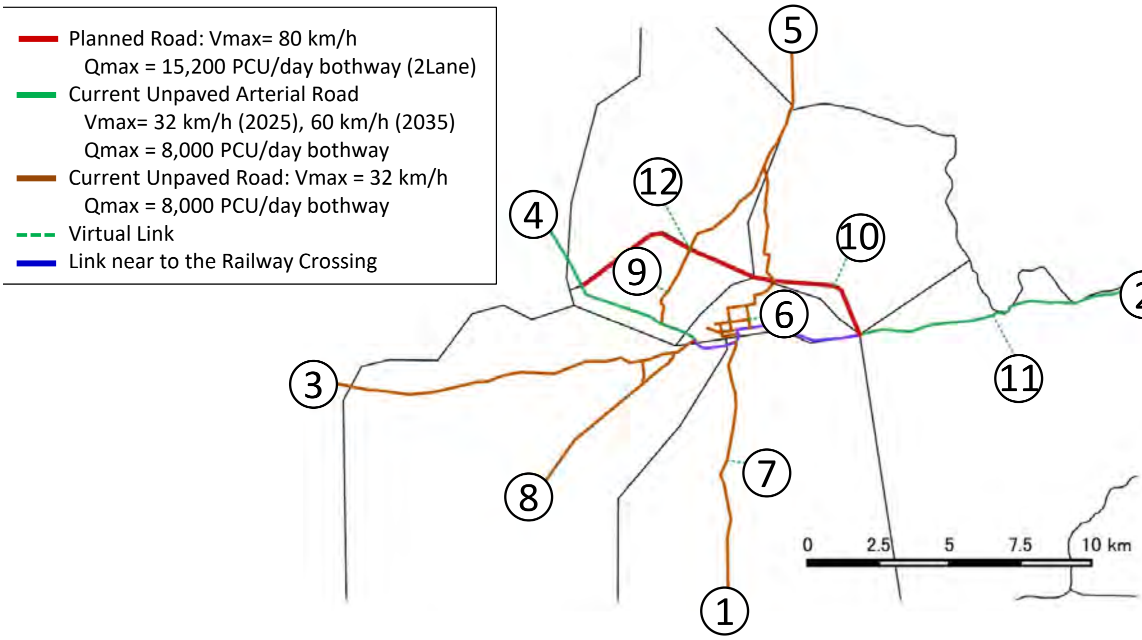
The capacity of the current road sections complies with "the Study on Upgrading of Nampula-Cuamba Road" and set as 8,000 PCU/day. The maximum speed of the current roads is set as 32 km/h because the current roads around Cuamba city are unpaved. It is assumed that the pavement of N13 road will be completed by 2035 and the maximum speed in that year is set as 60 km/h.

There are some level crossings of roads and railways near the city centre, and the traffic flow is restricted during the time that the trains are passing through. In PEDEC-Nacala, the number of trains passing through is estimated as 14 pairs/day in 2017, 19 pairs/day in 2025 and 28 pairs/day in 2035. In this study, the capacities of the road sections which are close to the crossing places are reduced as shown in Table 5.4.1. The ratio is calculated based on the number of trains passing, considering the average breaking time per train is 9 minutes.

Table 5.4.1 Capacity Reduction Ratio at Level Crossing Places (Cuamba)

Year	**2017**	**2025**	**2035**
Number of Trains (pairs/day)	14	19	28
Number of Trains (per day)	28	38	56
Number of Trains (per hour)	1.17	1.58	2.33
Train Crossing Time（minutes/hour）	10.5	14.25	21
Capacity Reduction Ratio	0.83	0.76	0.65

Assumption: train length is 2 km, velocity of train at the cross is 15 km/h
Source: the Study Team



Source: the Study Team

Figure 5.4.6 Road Network for Traffic Assignment (Cuamba)

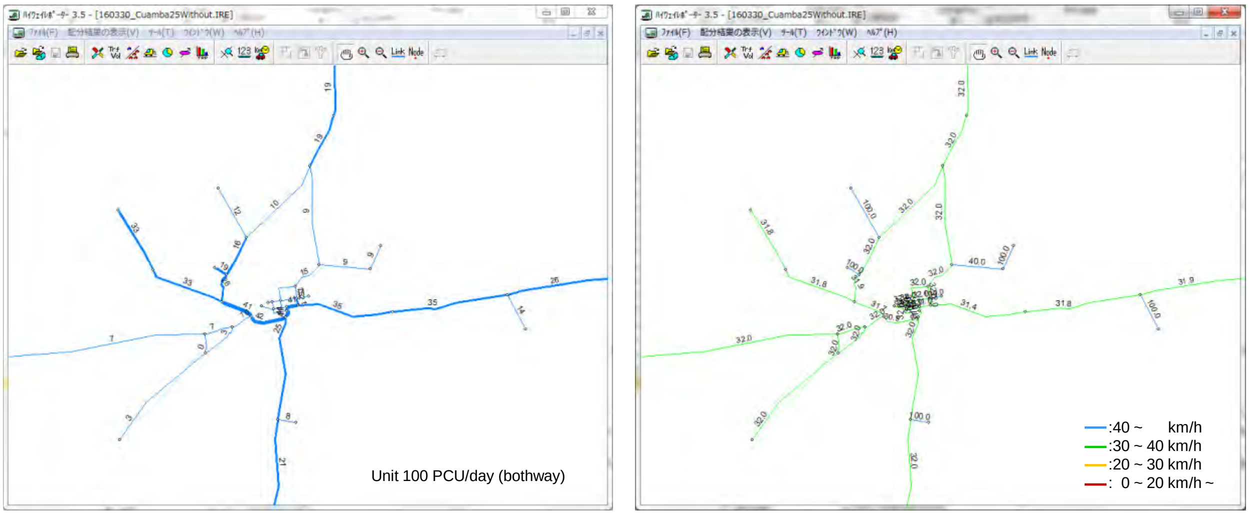
5.4.5 Traffic Demand Forecast

(1) Results of Traffic Demand Forecast

The network traffic assignment is conducted for 8 cases as mentioned in item 5.1(5). The results are shown in Figure 5.4.7 to Figure 5.4.10, which are important when discussing the demand on the Cuamba Bypass Road.

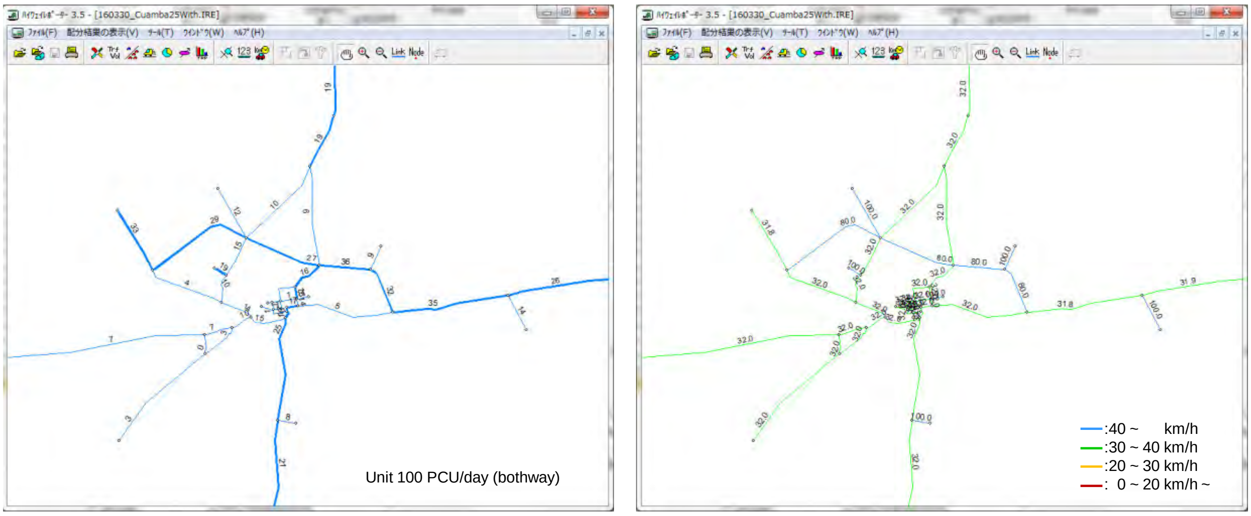
In the “2025 Without” case, the traffic volume is still small and there is no congestion (Figure 5.4.7).

In the “2035 Without” case, with the increase of the traffic volume and the train crossing time, the traveling speed decreases on N13 at the city centre (Figure 5.4.9). In the “2035 With 2 Lane” case, the traveling speed is improved and the number of vehicles entering the city centre is decreased. Roughly 6,000 PCU/day (both ways total) uses the planned road (Figure 5.4.10).



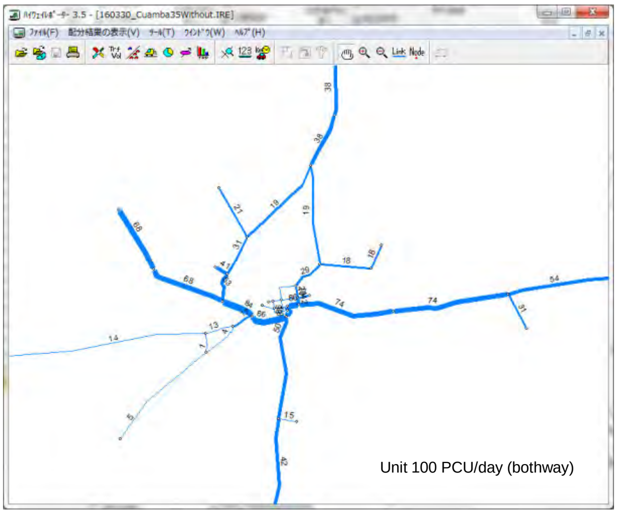
Source: the Study Team

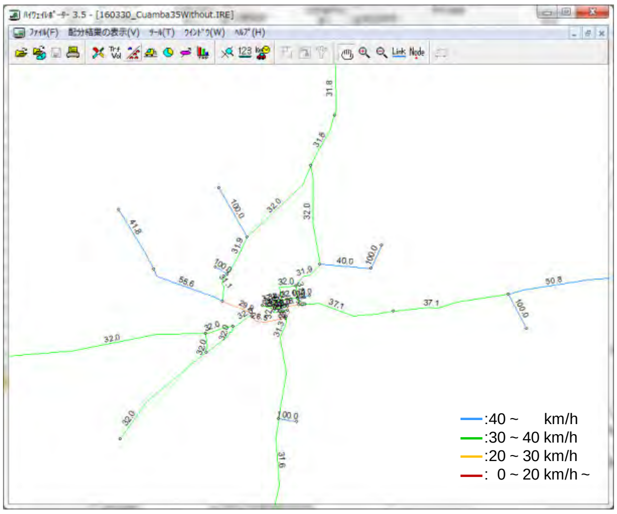
Figure 5.4.7 Cuamba 2025 Without Case (left: Volume, right Velocity)



Source: the Study Team

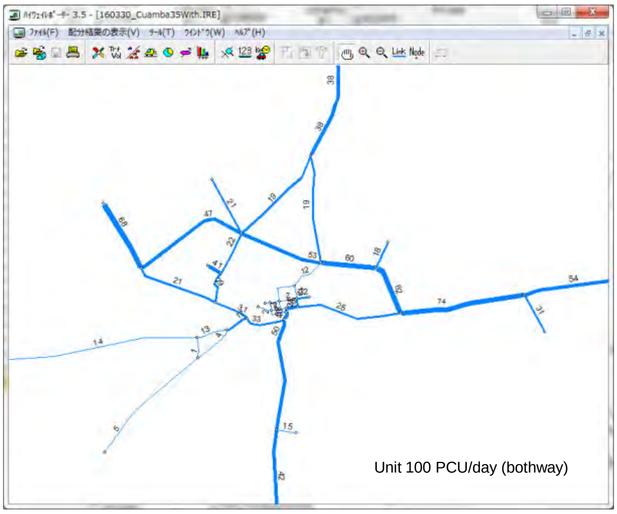
Figure 5.4.8 Cuamba 2025 With 2 Lane Case (left: Volume, right Velocity)

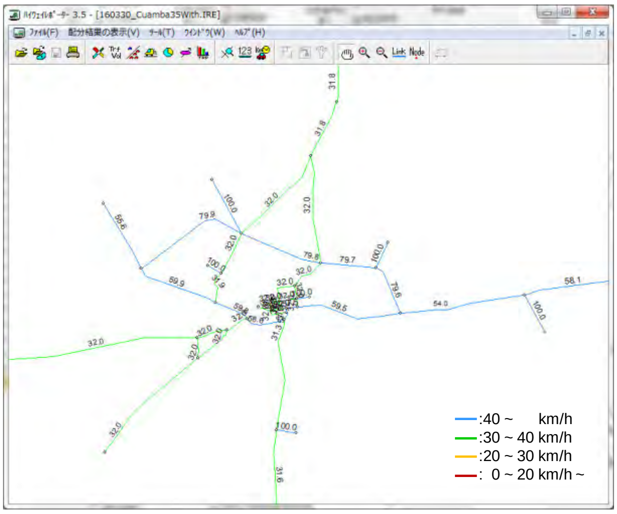




Source: the Study Team

Figure 5.4.9 Cuamba 2035 Without Case (left: Volume, right Velocity)





Source: the Study Team

Figure 5.4.10 Cuamba 2035 With 2 Lane Case (left: Volume, right Velocity)

(2) Traffic Demand by Case by Vehicle Type and by Section

Table 5.4.3 shows the results of the traffic demand forecast of the Cuamba Bypass Road by case, by vehicle type and by section. All the variables in the table are measured in vehicle/day, both ways total.

Table 5.4.2 Traffic Demand by Vehicle Type and by Section (Cuamba)

Year 2017 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	75	104	28	28	3	1	105	86	60	78	271	297
Section 2	72	75	19	16	3	2	94	82	55	73	243	248
Section 3	120	120	26	27	8	7	106	94	61	54	321	302
Section 4	106	105	23	23	8	7	106	94	61	54	304	283

Year 2025 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	146	198	48	49	5	2	287	259	173	210	659	719
Section 2	173	178	43	41	8	5	267	247	171	195	662	666
Section 3	281	292	56	59	12	10	385	355	187	187	921	903
Section 4	197	197	40	43	14	12	346	315	197	192	794	759

Year 2035 2 Lane (vehicles/day)

Section	Passenger Vehicle		Minibus		Bus		Medium Truck		Large Truck		Total	
	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I	I to J	J to I
Section 1	160	233	66	70	8	3	490	378	344	391	1,068	1,075
Section 2	233	236	63	61	11	7	549	487	364	423	1,220	1,214
Section 3	233	248	46	45	11	8	696	620	402	408	1,388	1,329
Section 4	243	241	60	60	14	11	671	594	447	444	1,435	1,350

I to J = West to East

Passenger Vehicle = Passenger Vehicle, Pickup

Minibus = less than 32 seats

Bus = 32 seats and more

Medium Truck = 2 Axle Truck

Large Truck = 3,4 Axle Truck, 5+Axle Truck

Source: the Study Team

(3) Travel Time in Major Road Sections

Figure 5.4.10 summarises the travel time in the major road sections of the current road and the planned road, by case and by section. The travel time for passing through the city is dramatically decreased by the implementation of the project, even though there is no delay caused by traffic congestion in 2025 or 2035.

Table 5.4.3 Travel Time by Section (Nampula)

Section	Without	With 2 Lanes	
1~4	Current Rd.	Bypass Rd.	Current Rd.
2015	20.75	8.90	20.75
2017	20.75	8.90	20.75
2025	21.09	8.90	20.75
2035	17.94	8.92	11.19

(unit: min)

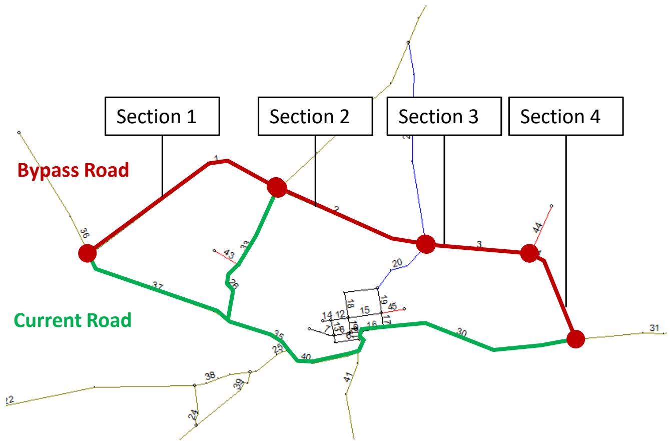
Section	Without	With 2 Lanes	
1	Current Rd.	Bypass Rd.	Current Rd.
2015	11.55	3.42	11.55
2017	11.55	3.42	11.55
2025	11.58	3.42	11.55
2035	9.08	3.42	8.77

(unit: min)

Section	Without	With 2 Lanes	
2~4	Current Rd.	Bypass Rd.	Current Rd.
2015	20.34	5.48	20.34
2017	20.34	5.48	20.34
2025	20.66	5.48	20.34
2035	20.14	5.49	13.57

(unit: min)

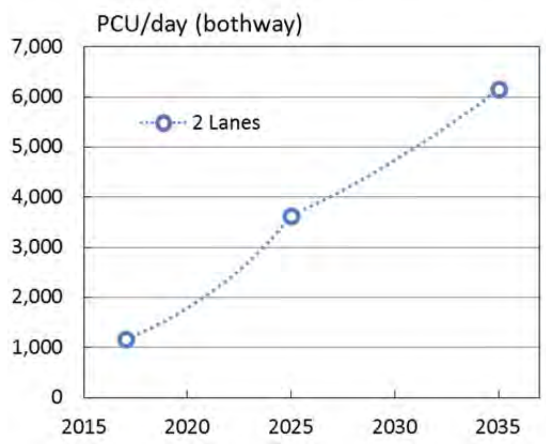
* assumed that pavement of N13 is completed by 2035



Source: the Study Team

(4) Time for Upgrading to 4 Lane

Figure 5.4.11 displays the estimation results of the traffic volume in the most-used road section of the planned road in each year. The data indicate that the traffic volume on the planned road reaches the 6,000 PCU/day level around 2035.



Source: the Study Team

Figure 5.4.11 Traffic Volume of the Planned Road Section (Cuamba)

CHAPTER 6 Road Design Conditions

6.1 Road Design Criteria/Standard

6.1.1 Road Classification

The ANE Design Standard (Draft) (hereinafter referred to as “ANE Standard”) provides guidance regarding acceptable geometric standards to be employed for the design of roads in Mozambique. In the ANE Standard, there are three Design Classes, Primary Roads, Secondary Roads and Tertiary Roads. The different road design classes are governed by the road function.

With the consideration of the functions of the Study roads, such as Nacala Port Access Road, Nampula Southern Bypass Road and Cuamba Bypass Road, these roads shall form part of the national road network and let the heavy vehicles pass through the Nampula and Cuamba city on the study road, and on the direct port access road in Nacala.

In this therefore, the classification of the Study Roads are to be categorised as the “Primary Road” with paved roads in the ANE Standard.

Table 6.1.1 Comparison of Basic Parameters

Standard Parameter	SATCC Geometric Standard	ANE Design Standard	South Africa Geometric Standard	The Road Design Manual, Japan	Recommen-dations
Design Class					
	Primary	Primary	Arterial Street with extensive development	Class 3-1 or 4-1	Primary
Design Speed [km/h]					
Absolute Desirable	120	100	70	80	100
Absolute Minimum	80	60	50	50	80
Right-of-Way Width [m]					
	-	30m and 50m from road shoulders on both sides (depending on lane number)	Road Prism + Verge	Road Prism + Verge	30m and 50m from road shoulders on both sides (depending on lane number)

6.1.2 Geometric Standards

(1) Design Speed

As mentioned above, the design speed for "Primary" roads defined in ANE standard is 100 km/hour.

It should be noted that the ANE Standard was developed only for the trunk road for inter-urban connections mainly in rural areas with high speed free-flow running conditions, and there were no standards within the urban area for the bypass/ring road. Because the Nampula Southern Bypass Road and Cuamba Bypass Road would run within what is expected to be an urban area in the future as part of the circular road for the residents, some minor modification, such as 80km/h design speed, would be applied within some sections under special conditions which require ensuring traffic safety and reduce the compensation costs. The possible sections are listed below;

- Residential areas
- Areas around public facilities such as schools, temples and hospitals
- Industrial areas
- Topographic conditions such as hilly and mountainous areas
- River areas
- Soft soil area, etc.

With regards to the operational speed, the Study Team proposes to apply 80km/h in all the sections of the three roads in order to ensure traffic safety.

(2) Design Criteria

The Study Team reviewed the geometric standards of the ANE Standard, SATCC (September 1998), along with those of South Africa and Japan. The comparison tables are shown in Table 6.1.2 and Table 6.1.3.

After a series of discussions with ANE DPPRO, it will be recommended to apply the ANE Standard, Primary Road Class. Table 6.1.4 shows the applied design standard for the Study Roads.

As for the items are not covered by the above standard, the Study Team will refer to the comparison table and propose a suitable one for each road in the preliminary design stage.

Table 6.1.2 Comparison of Design Criteria (Design Speed = 100 km/hour)

Primary Road			**SATCC**	**ANE Standard**	**South Africa**	**Japan**
		Design Speed (km/h)	**100**	**100**	**100**	**100**
Sight Distance	Visibility Obstruction Parameters for sight lines (m)	Object Height	0.15	-	0-1.3	0.1
		Driver Height	1.05	-	1.05	1.2
		Min. Stop Sight Distance	155	205	140	160
	Min. Passing Sight Distance (m)	Desirable	670	680	900	-
		Absolute	395	-	680	500
Horizontal Alignment	Min. Radius of Curves (m)	Desirable Minimum Max. super-elevation of 6%	420	-	440	460
		Minimum Max. super-elevation of 8%	380	350	390	410
		Absolute Minimum Max. super-elevation of 10%	350	-	360	380
	Min. length of curve (m)	Desirable	300	-	-	170
		Absolute	150	-	-	170
	Max. length of curve (m)	Desirable	800	-	-	-
		Absolute	1000	-	-	-
		Min. Radius of Curve with adverse cross-fall (m)	-	-	-	5000
		Desirable Length of Transition Curve (m)	-	-	-	85
		Max. Radius for use of a spiral curve (m)	1350	-	590	1500
Cross-fall	Min. Cross-fall of Surfaced road (%)	For vertical grade>0.5%	-	2.0	-	-
		For vertical grade<=0.5%	-	3.0	-	-
		Max. Super-elevation (%)	10	8	6/8	10
Vertical Alignment	Min. K Value (min. K)	Crest curve	60	60	100	* 6500
		Sag curve	36	36	25	* 3000
		Crest Vertical Curve Stopping	-	-	200	-
		Crest Vertical Curve Passing	-	-	-	-
		Sag Vertical Curve Stopping	-	-	-	-
		Min. length of vertical curves	180	180	200	85
Vertical Alignment	Max. Grade (%)	Flat/Rolling	4	4	4	6/3
		Rolling/Hilly	5	5	5	6/3
		Mountainous	6	6	6	6/3
	Critical lengths of grade (%)	3%	500	500	380	-
		4%	300	300	300	700
		5%	240	240	240	500
		6%	200	200	180	400
		7%	170	-	140	-
		8%	150	-	100	-
		Min. Grade (%)	-	-	-	0.3
		Max. Combined Gradient (%)	-	-	-	10.0

Note: (*) Minimum vertical curve (m)

Table 6.1.3 Comparison of Design Criteria (Design Speed = 80 km/hour)

Primary Road			SATCC	ANE Standard	South Africa	Japan
		Design Speed (km/h)	**80**	**80**	**80**	**80**
Sight Distance	Visibility Obstruction Parameters for sight lines (m)	Object Height	0.15	-	0-1.3	0.1
		Driver Height	1.05	-	1.05	1.2
		Min. Stop Sight Distance	115	140	140	110
	Min. Passing Sight Distance (m)	Desirable	540	560	650	-
		Absolute	312	-	550	350
Horizontal Alignment	Min. Radius of Curves (m)	Desirable Minimum Max. super-elevation of 6%	250	-	250	280
		Minimum Max. super-elevation of 8%	230	210	230	250
		Absolute Minimum Max. super-elevation of 10%	210	-	210	230
	Min. length of curve (m)	Desirable	300	-	-	140
		Absolute	150	-	-	140
Horizontal Alignment	Max. length of curve (m)	Desirable	800	-	-	-
		Absolute	1000	-	-	-
		Min. Radius of Curve with adverse cross-fall (m)	-	-	-	3500
		Desirable Length of Transition Curve (m)	-	-	-	70
		Max. Radius for use of a spiral curve (m)	850	-	380	900
		Acceptable angles of skew at intersections (degree)	75-120	-	-	75-
Cross-fall	Min. Cross-fall of surfaced (%)	For vertical grade>0.5%	-	2.0	-	-
		For vertical grade<=0.5%	-	3.0	-	-
		Max. Super-elevation (%)	10	8	6/8	6/10
Vertical Alignment	Min. K Value (min. K)	Crest curve	33	33	50	3000
		Sag curve	25	25	16	2000
		Crest Vertical Curve Stopping	-	-	140	-
		Crest Vertical Curve Passing	-	-	-	-
		Sag Vertical Curve Stopping	-	-	-	-
		Min. length of vertical curves	140	140	160	70
	Max. Grade (%)	Flat/Rolling	5	5	5	4/7
		Rolling/Hilly	6	6	6	4/7
		Mountainous	7	7	7	4/7
	Critical lengths of. Grade (%)	3%	500	500	380	-
		4%	300	300	300	-
		5%	240	240	240	600
		6%	200	200	180	500
		7%	170	170	140	400
		8%	150	-	100	-
		Min. Grade (%)	-	-	-	0.3
		Max. Combined Gradient (%)	-	-	-	10.5

Note: (*) Minimum vertical curve (m)

Table 6.1.4 Applied Design Criteria for the Study Roads

No	DESCRIPTION	Criteria	
		General Section	**Special Section**
1	GENERAL		
	1.1 Design Speed	100 km/h	80 km/h
	1.2 Minimum Spacing between Intersections	600 m	300 m
2	HORIZONTAL ALIGNMENT		
	2.1 Minimum radius	350 m	
	2.2 Minimum Cross fall of surfaced cross section		
	• For vertical grade > 0,5%	2 %	2 %
	• For vertical grade <=0,5%	3 %	3 %
	2.3 Minimum Cross fall of unpaved shoulders	4.0 %	4.0 %
	• Maximum Super elevation	8 %	8 %
3	VERTICAL ALIGNMENT		
	3.1 Maximum longitudinal grade	5 %	6 %
	3.2 Minimum longitudinal grade	0.2 %	0.2 %
	3.3 Minimum K value		
	• For crest curve	60	33
	• For sag curve	36	25
	3.4 Minimum Sight Distances		
	• Stopping Sight Distance on level roads	205 m	140 m
	• Stopping Sight Distance on downgrades		
	i. - 3%	220 m	150 m
	ii. - 4%	225 m	180 m
	iii. - 5%	230 m	210m
	iv. - 6%	-	240 m
	• Meeting (Barrier) Sight Distance	320 m	240 m
	• Passing Sight Distance	680 m	560 m
	3.5 Shoulder Sight Distance for Yield Condition	180 m	
	• Minimum length of vertical curves	180 m	
	• Maximum gradients		
	• Flat topography	4 %	5 %
	3.6 Rolling topography	5 %	6 %
	3.7 Mountainous topography	6 %	7 %
	3.8 Critical length of grade (truck speed is reduced to 20km/h)		
	i. - 3%	500 m	500 m
	ii. - 4%	300 m	300 m
	iii. - 5%	240 m	240 m
	iv. - 6%	-	200 m
	3.8 Minimum run-off length	60 m	50 m
4	LANE WIDTH		
	4.1 Minimum lane width	3.5 m	3.0 m
	4.2 Minimum surfaced shoulder width	1.5 m	1.0 m
	4.3 Minimum unpaved shoulder width		
	• with a paved shoulder	1.0 m	0.5 m
	• without a paved shoulder	3.0 m	1.0 m

6.1.3 Right of Way (ROW)

The Right of way (ROW) is a reserve of land acquired for the purposes of maintenance or construction of new lanes. According to the Land Law (Law 19/97) of Mozambique of July 1997 in Chapter II: Ownership of the land and public domain, Article-8: Partial protection zone (g), as well as The Land Law Regulations (Decree 66/98) in 1998 in Chapter-II Pubic domain, Article-6 Installation of public infrastructure (b) (c), the “Partial Protected Zone” is regulated as the ROW, which are described below;

a. Four lane road and motorways: 50 m from outside edge of shoulder of road.

b. Two lane road and road: 30 m from outside edge of shoulder of road.

According to the plan of the Nacala Port Access Road and Nampula Southern Bypass Road, at future completion of their roads it is expected that they will have four lanes. Therefore, the ROW shall be set at 50m from the edge of the shoulder of the road. As for the Cuamba Bypass Road, because it is two lanes, the ROW shall be set at 30m.

Note that in other countries, such as South Africa and Japan, the ROW is limited to only the width of the Road Prism plus Verge, which is the COI (Corridor of Impact).

For reference, regarding similar urban bypass and circular roads in Mozambique, the ROW of Maputo Ring Road is only 5m within urban areas and 30 to 50m in the rural areas.

6.1.4 Typical Cross Section

(1) Standard Width

A typical carriageway width of 3.5m based on ANE Standard and paved shoulder width of 1.5 – 2.0m are recommended. A shoulder width of 2.0m will double as a parking space for roads with 2-lanes. Median width of 1.5m is also recommended as reasonable width for road safety.

Table 6.1.5 Standard Widths for Each Road Element

Standard Parameter	SATCC Geometric Standard	ANE Design Standard	SA Geometric Standard	The Road Design Manual, Japan	Recommen-dations
Carriageway Lane [m]	3.10 – 3.70	3.50	3.70	3.25 - 3.50	3.50
Paved Shoulder [m]	1.00 – 3.00	0.00 - 1.50	1.00 – 3.00	0.50 – 1.25	1.50 – 2.00
Median Width [m]	1.50 – 9.20	-	1.60	1.00 – 1.75	1.50
Footway Widths [m]	-	-	1.50 (absolute minimum)	2.50 - 3.50	1.50 - 3.00
Cycle Lane [m]	1.20 – 1.50	-	2.00 – 3.00 One-way path shared with pedestrians	3.00 – 4.00 One-way path shared with pedestrians	3.00 One-way path shared with pedestrians
Service Road [m]	-	-	-	4.00	4.00
Parking Space [m]	-	-	2.70	1.50 – 2.50	2.00

In road sections with cyclists and pedestrians, a shared path of 3.0m for both cyclists and pedestrians is applied. Use of the paved shoulder by cyclists and pedestrians will be allowed from a road safety aspect.

(2) Basic Concept for Determination of Typical Cross Sections

Based on the standards applied, such as minimum width of lane and shoulders, the Study Team proposes the following typical cross sections for each study road which has different requirements to fulfil its function to carry the expected traffic flow and to coordinate with future urban land use plans. The Study Team considers the following aspects;

- Ensure **full controlled access** to the main road to secure smooth traffic flow capacity as a bypass road,
- Secure appropriate **width of carriageway and shoulder** to accommodate traffic safely,
- Prepare appropriate **lane composition/arrangements** to accommodate urban land use plans for each city, and
- Secure **other necessary spaces** to ensure road safety.
- Required lane number and timing from provisional opening with 2-lanes to final shape with required lane number will be determined by both capacity analysis based on future traffic volume and analysis of passing opportunity which is influenced by the number of heavy vehicles traveling at low speed.

(3) Nacala Port Access Road

This road runs through a prohibited area for built environments and connects to the Nacala Port directly to form convenient direct access to the port as well as future planed industrial parks and cargo terminals for heavy vehicles. Therefore, the cross section of the road shall be focused on how to maintain the traffic flow function in the main lanes. Also, it is necessary to provide proper service roads to connect the planned industrial park and other local communities. The proposed cross sections are described below;

- A four lane (two lanes for each direction) road is proposed to meet the estimated future traffic volume. However, considering the initial stage after completion which will still be low traffic volume, the Study Team proposes a staged construction method to reduce initial investment/construction cost,
- Considering the future industrial park development along the road alignment, a service road is proposed along the edge of the ROW to secure an unbuilt area within the ROW and provide good connectivity to the industrial park. The service road should provide a sidewalk in the sections where the local people might walk, and
- The proposed typical cross section is shown in Figure 6.1.3, which has the total road reserve and the ROW width of 120.50 m.

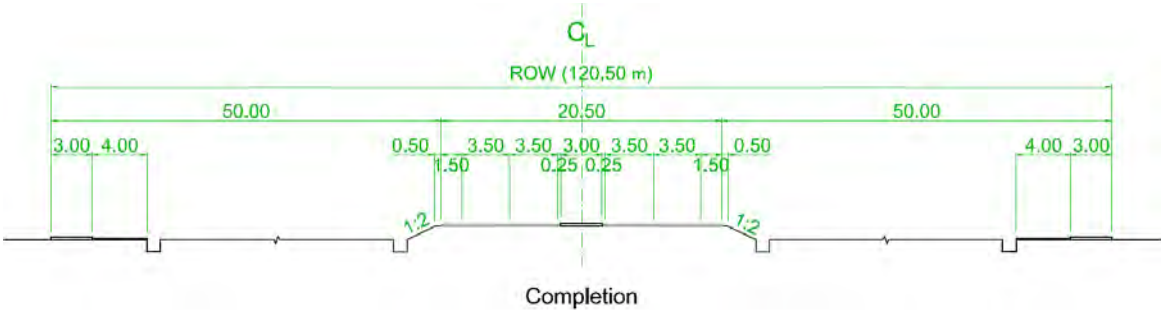


Figure 6.1.1 Typical Cross Section for Nacala Port Access Road (At Completion)

Image of this road is illustrated in Figure 6.1.2.

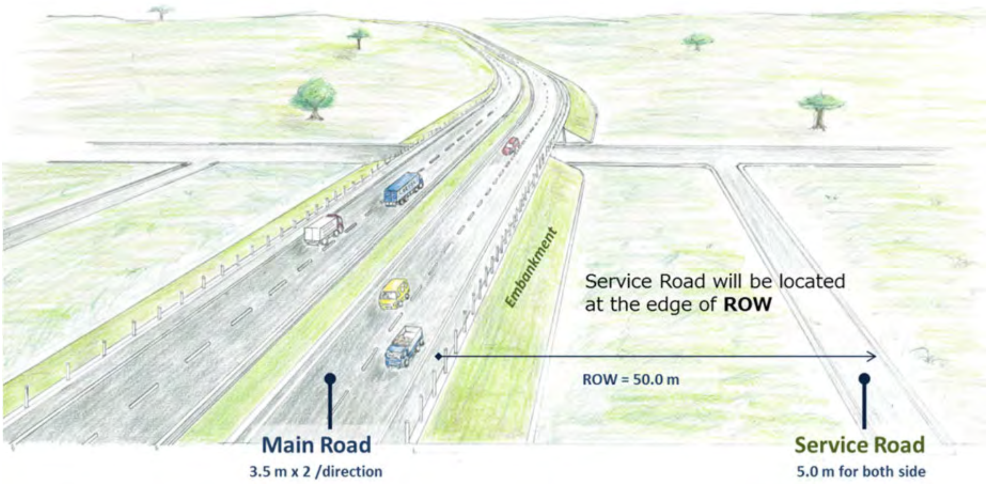


Figure 6.1.2 Image of Nacala Port Access Road (At Completion)

As we discussed above, in the initial stage the current limited traffic volume can be adequately served with a two lane road (one lane for each direction). Securing the future completion cross sections described above, there are two alternatives for the cross section in first stage construction to save the initial construction cost. In these cases, the road shoulder shall be wider to secure the space for stopped/troubled vehicles and installation space for median barriers to avoid head-on collisions. The following figures depict the ideas for the initial stage cross section. During the preliminary design period, these alternatives were examined based on the result of the topographic survey and limitation of vertical alignments.

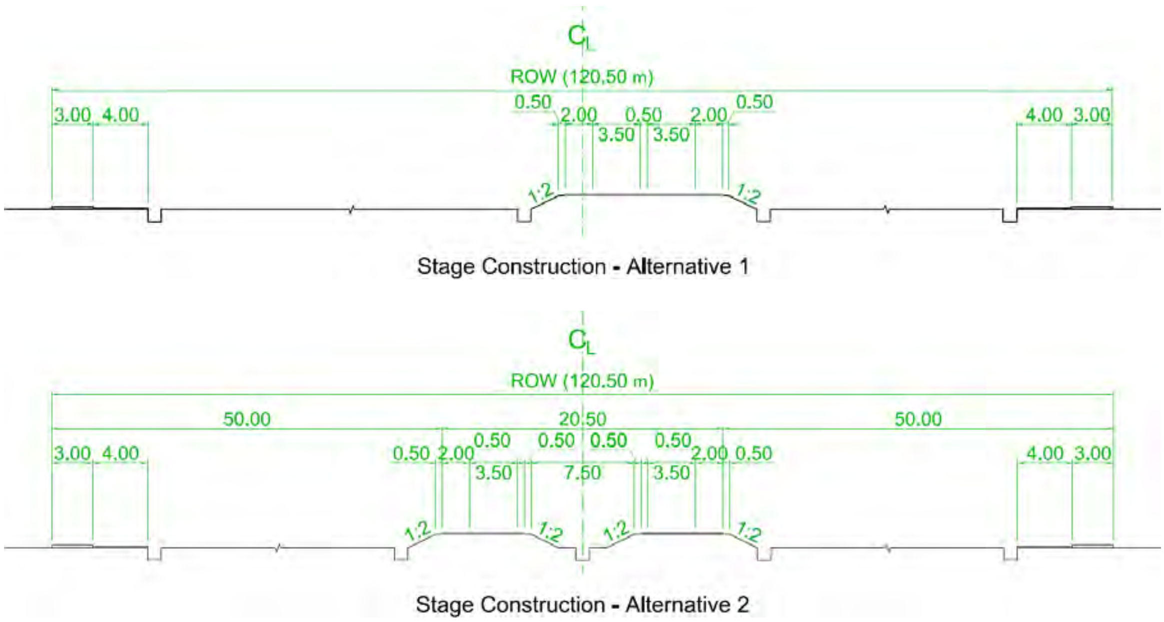


Figure 6.1.3 Typical Cross Sections for Nacala Port Access Road (Initial Stage)

(4) Nampula Southern Bypass Road

This road runs around the edge of the city, and has been designed to allow for the envisioned future urbanisation along the road once the Study road is opened. As we presented in chapter-3, the UN-Habitat supported preparation of the partial land use plan that indicated a circular road where the Study road is located. In this sense, the requirements of the Study road itself are not limited to providing the capacity for diverted traffic but to provide a useful service road for residents of the city and future urban development along the road. Therefore, the cross section of the road shall focus on different points of view than the Nacala Port Access Road, and the function of a service road for residents shall be added. The proposed cross sections are described below;

- A four lane road (two lanes for each direction) is proposed in the main section to meet the traffic capacity for future estimated “through traffic” demand, especially cargo vehicles. However, considering reducing the initial investment cost, a two lane road (One lane for each direction) will be adequate within the period of low traffic volume.
- Based on the current Land Law, the ROW will be set at 50m from each edge of the shoulder of the road, and if the allowed urban land uses are limited beyond the ROW, a service road shall be installed within the ROW but at the edge of the ROW as presented in Alternative-1. If the area within the ROW is developed with pubic purpose facilities and controlled urban land use such as commercial and logistics purposes, which are proposed in the partial land use plan by UN-Habitat, there is another alternative for the cross section which is more accommodating in urban circular and bypass roads such as Alternative-2. Both service roads have sidewalks for the residents and provide enough space for bus stops.
- The typical cross sections proposed are shown in Figure 6.1.7 , which has the total road reserve, the ROW, with a width of 120.50 m.

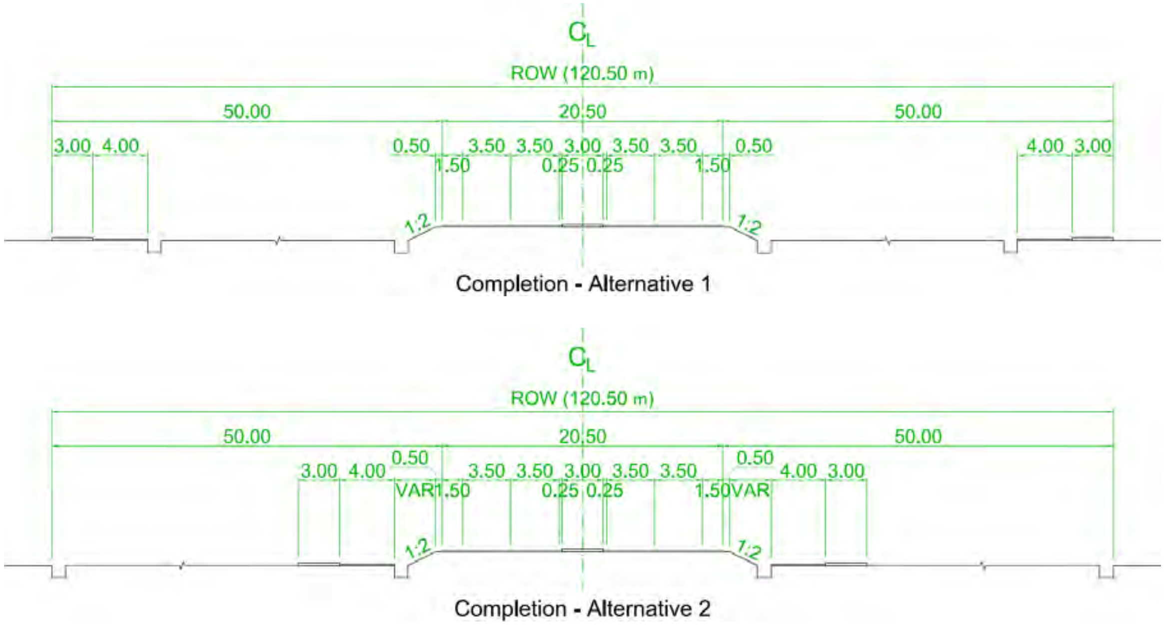


Figure 6.1.4 Typical Cross Sections for Nampula Southern Bypass Road (At Completion)

The image of the above cross sections of the Nampula Southern Bypass Road with ROW (Alternative-2) is illustrated in the Figure below.

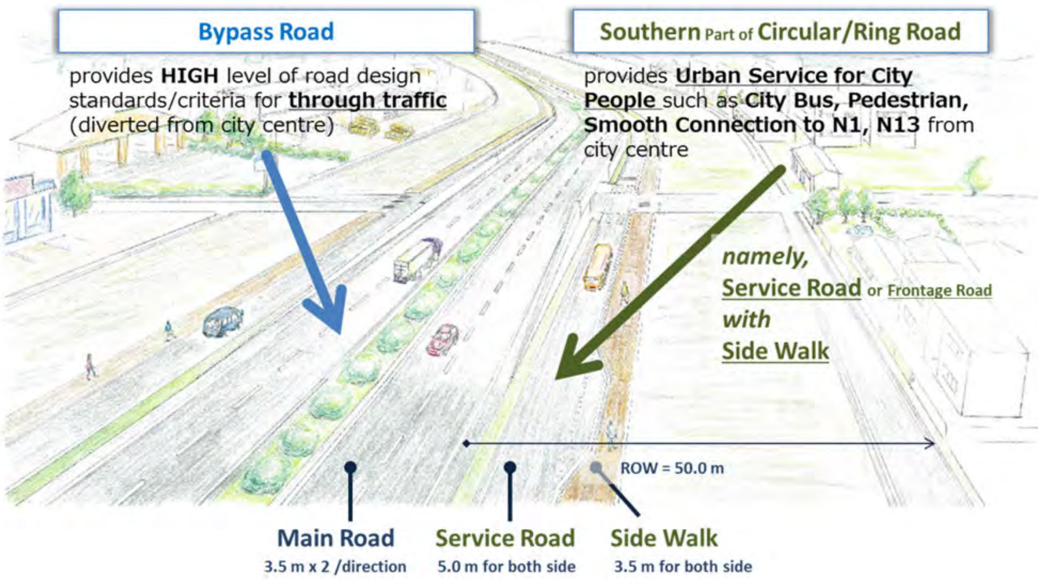


Figure 6.1.5 Image of Nampula Southern Bypass Road (Completion, Alt-2)

If there are no service roads along the main road, it is likely that the public buses will stop on the main road for the residents along the road. The following photo shows that event occurring in the Northern Bypass Road in Kampala, Uganda.

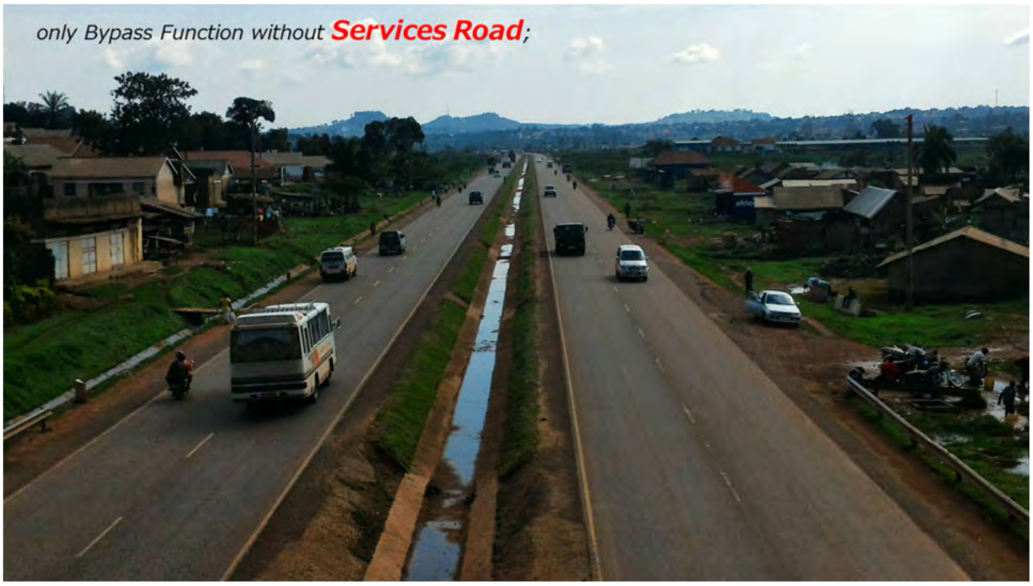
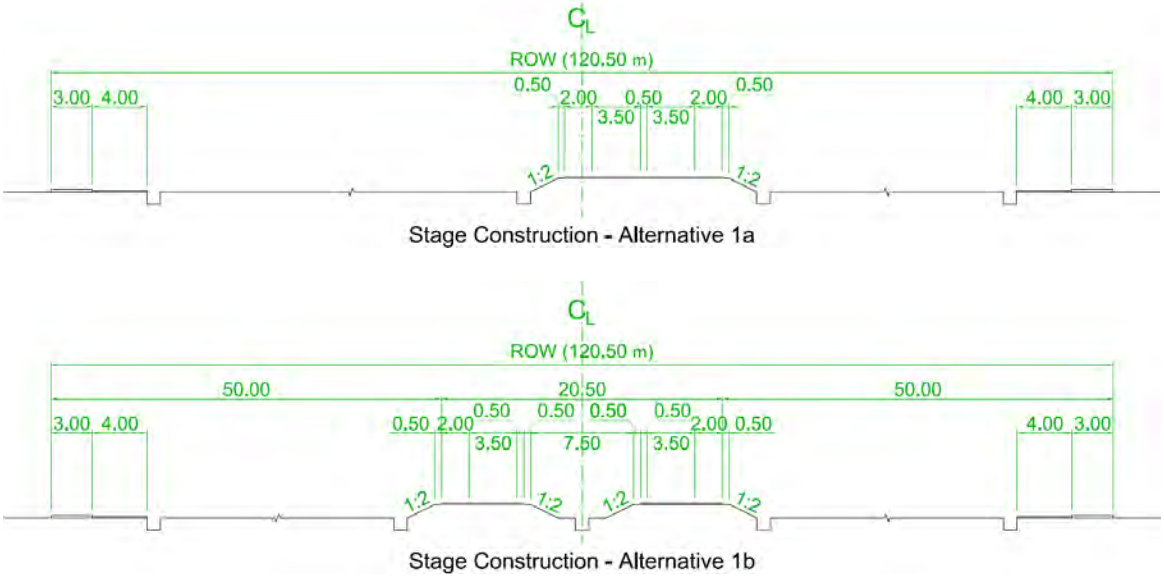


Figure 6.1.6 Northern Bypass Road in Kampala City (Uganda)

As we discussed above, the initial stage with limited traffic volume shall be adequately served by a two lane road (one lane for each direction). Securing the future completion cross sections described above, there are two alternatives for the cross section in first stage construction to reduce the initial construction cost. In these cases, the road shoulder shall be wider to secure the space for stopped/troubled vehicles and space for installation of median barriers to avoid head-on collisions. The following figures depict the ideas for the initial stage cross section (Alternative-1a and 1b, Alternative-2a and 2b). During the preliminary design period, these alternatives are to be examined based on the result of the topographic survey and limitation of vertical alignments.

Alternative 1: Service road is located at the edge of the ROW. A vacant area within the ROW (max. 50m) shall be secured as an unbuilt area with a fence or wall, but this might cause longer dissociation points for residents.



Alternative 2: Service road is located at the edge of the embankment of the future/completion cross section earthwork. The vacant area within the ROW other than the service road shall be developed under the control of RDA and the municipality in conformance with the urban plan, such as a weigh bridge area, parking, logistics, bus terminal and public facilities as well as authorised commercial area.

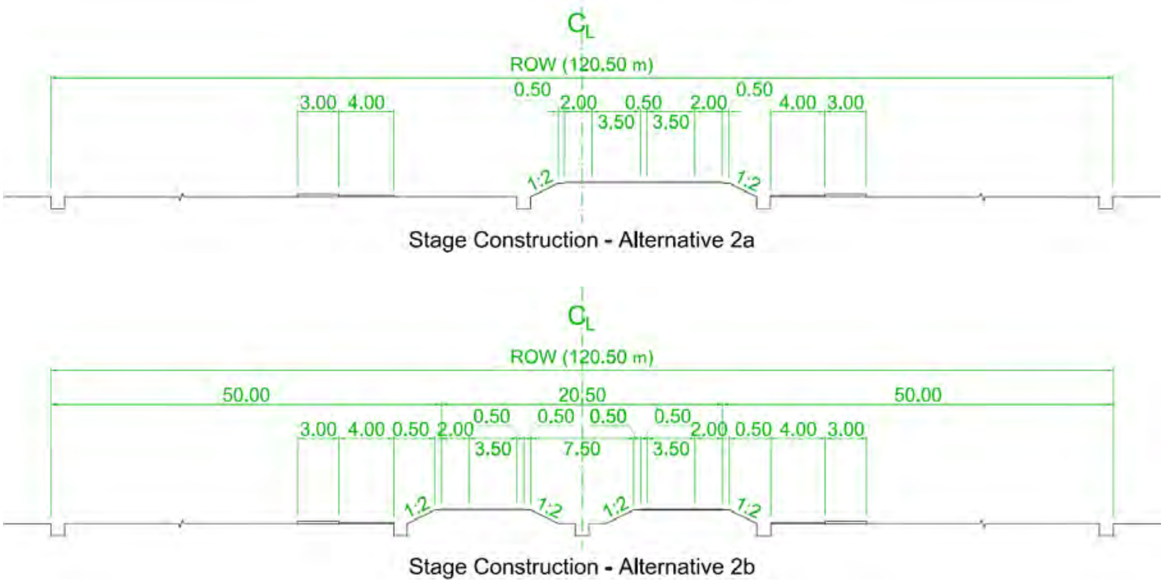


Figure 6.1.7 Typical Cross Sections for Nampula Southern Bypass Road (Initial Stage)

(5) Cuamba Bypass Road

This road runs around the Northern edge of the city because there is a natural barrier in the form of the Rio Muanda, and there are limited areas of residences at this moment. However, there will be a potential to develop along the road as new residents arrive under the urbanisation plan of the municipality. In this situation, the cross section of the road shall include a sidewalk to provide accessibility for community use. The proposed cross sections are described below;

- A two lane road (one lane for each direction) is proposed to meet the capacity for the future estimated traffic volume by both through traffic and generated traffic from/to the area along the road where the urban land uses are envisioned. There is enough space for installation of median barriers to avoid head-on collisions and wide shoulders for stopping of damaged vehicles.
- Sidewalks shall be installed at the sections that the community are supposed to use. Installation methods are proposed as in alternatives 1 and 2. In alternative 1, the service road is located at the edge of the embankment. It seems to be a more traffic safe solution than alternative-2, because it divides the level of the road between the main road and the sidewalk. Note that the main road will be regulated for an operation speed of 80km/h. It will be examined during the preliminary design stage with the consideration of pedestrian safety.
- The typical cross sections proposed are shown in Figure 6.1.8 below, which has the total road reserve, the ROW, the width of 71.50 m.

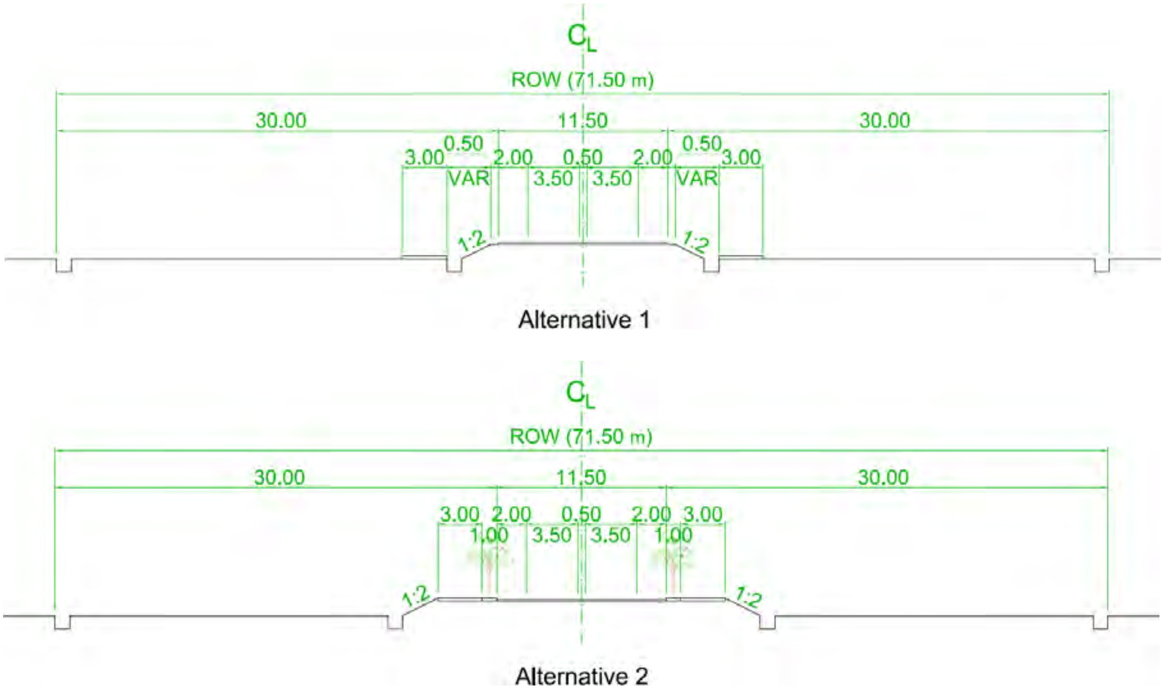


Figure 6.1.8 Typical Cross Sections for Cuamba Bypass Road

6.1.5 Control Points

Control points are defined as natural or manmade constraints imposed in the definition of the road alignment (e.g. mountain passes, bodies of water, developed areas, etc.). Avoiding control point areas/facilities also ensures lower project costs and reduction of environmental and social impacts.

The following control points are proposed for the Study roads;

(1) Topographic Constrains

Basically, the road alignment is planned in flat areas to reduce earthwork volume. Hills and mountainous terrain and the following areas shall be avoided;

- Areas affected by natural disasters (e.g. land slide): to reduce the cost for countermeasures,
- Rivers: to avoid construction of crossing structures (e.g. bridges, culverts, gabions),
- Rock formations: to avoid higher unit cost of rock excavation than soil excavation, and
- Flood zones: to avoid the need for a higher embankment level and slope protection against erosion.

(2) Public Facilities

Because public facilities play an important social role for local communities, the following facilities shall be control points to be avoided for route considerations;

- Schools (primary, secondary and others),
- Hospitals,
- Local governmental offices
- Power lines (Both transmission and distribution lines),
- Utilities (such as water distribution pipes, telephone and optic-fibre lines, Public wells), etc.

(3) Religious Sites

Considering cultural and religious aspects, it’s highly recommended to avoid the following areas;

- Churches and Mosques,
- Cemeteries and other religious sites etc.

(4) Particular Properties

In order to reduce compensation costs, the road alignment should avoid as much as possible the following particular properties;

- Residential houses and Commercial facilities such as stores,
- Railways,
- DUATs and other secured areas, etc.

6.2 Clearance from Facilities

6.2.1 Railways

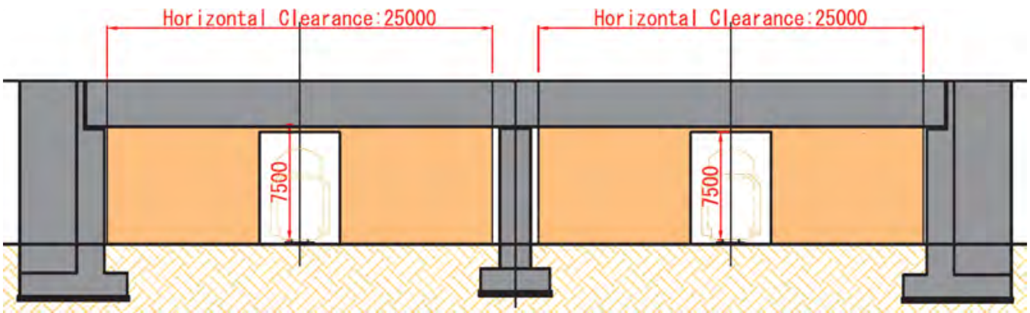
The Study Team discussed and confirmed the minimum clearance required for points where the road intercepts the railway with Mozambique Ports and Railways (CFM). A flyover crossing of the railways was requested by CFM, with the following requirements for clearance;

a. **Vertical Clearance (minimum):** 7.50m from the top of rail/track should be kept for ordinary trains as well as special cargo/trains,

b. **Horizontal Clearance (minimum):** 25.0m of inner span between overpass bridge piers should be required for one track. CFM had requested to secure the additional space (25.0m) next to current clearance of 25.0m for future development of another track, and

c. **Right of Way of Railway (ROW):** 50.0m from centre line of track should be kept at each side to secure the necessary infrastructure for railway maintenance and management. Note that further discussions will be possible if difficulties exist for special cases.

The minimum clearances for the flyover to railway are shown Figure 6.2.1.



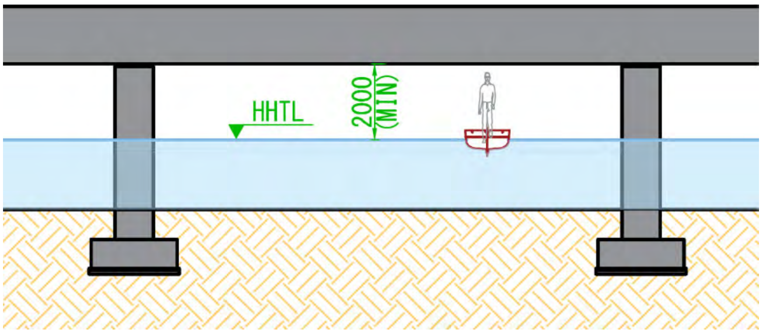
Unit: mm

Figure 6.2.1 Minimum Clearance for Railways

6.2.2 Bridges over the Sea

The clearance for the bridge over the sea must consider the necessary clearance for passage of vessels, and is controlled by the space between the higher high tide level (HHTL) and the lowest point of the bridge girder.

During the site confirmation in the area for the sea bridge installation, the Study Team observed that there were not any large vessels used, only small canoes. The Study Team understands that there are no developments in the area with larger barges, so 2.00m of clearance shall be enough, which is also referred in the guidelines of "Technical Standards and Commentaries for Port and Harbour Facilities in Japan".



Unit: mm

Figure 6.2.2 Minimum Clearance at Sea Bridge

6.2.3 Power Line (High Voltage Electric Transmission Line)

The Study Team discussed and confirmed with the organisation responsible for the Power Line Management (EDM) regarding the requirements of minimum clearance, which are as follows.

(1) Horizontal Clearance

The reserved area from the transmission line shall be at least 50.0m distance from the centre of the power line, as shown in Figure 6.2.3.

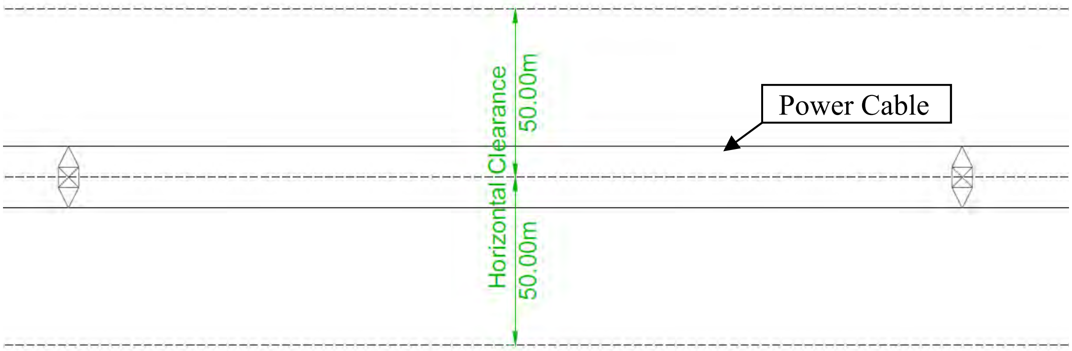


Figure 6.2.3 Horizontal Clearance from Power Line

(2) Vertical Clearance

If the road crosses the transmission line, the following minimum vertical clearance between road surface and the lowest power cable shall be required;

a. Minimum clearance: 7.50 m

b. Usual clearance: 9.00 m

c. Proposed clearance by EDM: 10.00 m

EMD considers the minimum clearance of 7.50 m insufficient due to subsequent overlay of the road surface. Usually, EDM recommends a clearance of 9.00 m. However, for this project a vertical clearance of at least 10.00 m was suggested by EDM when the Study Team interviewed them. The image of vertical clearance is shown in Figure 6.2.4.

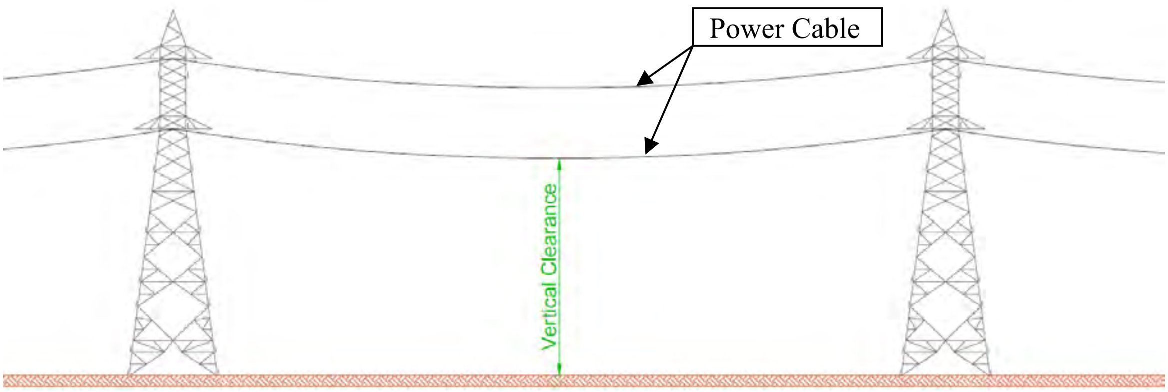


Figure 6.2.4 Vertical Clearance from Power Line

(3) Future Plan for New Transmission Line in the Nampula Area

Based on the discussion, EDM requested that the road alignment should consider horizontal and vertical clearances based on the expansion plan for the transmission line in the Nampula Area.

6.2.4 River Bridge and Embankment

In order to avoid overtopping of the road/bridge during flooding events along the river, the following clearances from the HWL shall be secured for the bridge and embankment based on the Japanese Standard, at the different categories of river volume flow level.

Table 6.2.1 River Bridge/Embankment Clearance from HWL

River Volume Flow (m^3/s)	Clearance: H (m)
< 200	0.60
200 ~ 500	0.80
500 ~ 2,000	1.00
2,000 ~ 5,000	1.20
5,000 ~ 10,000	1.50
> 10,000	2.00

Figure 6.2.5 Bridge Clearance

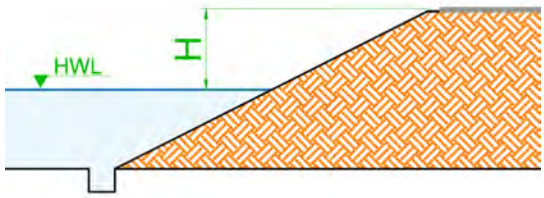


Figure 6.2.6 Embankment Clearance

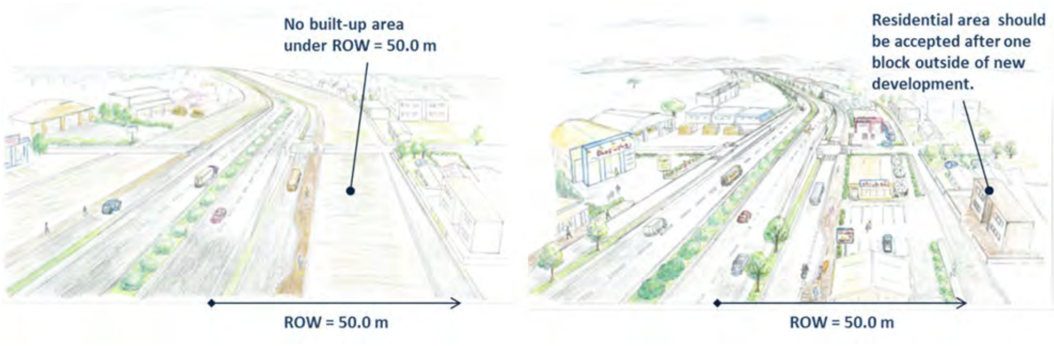
6.3 Road Development with Urban Land Use Plan (Proposal)

6.3.1 Urban Development with the Study Road (Urban Road)

As discussed in the previous section, the Nampula Southern Bypass Road plays different functions as both main road and services road. The "Bypass" function is to provide the diverted route for through traffic, especially heavy vehicles, in order to alleviate traffic congestion within the centre of the city. Therefore, it should be designed as a road in conformance with high speed standards. On the other hand, the "Service Road" is planned to be installed beside the main road in order to provide access to urban services for both the residents and drivers. The area along the Study road "Nampula Southern Bypass Road" is envisioned to start development by their own urban economic activities once the road is opened. This kind of urban development along infrastructure has occurred everywhere in the world, regardless of whether the local government has a good urban control scheme or not.

Under the current land law and regulations a partial protected zone for the road is in the form of a ROW and extends 50m from the edge of the shoulder of the road. This means that no one can build within the ROW in the future. The image of this secured ROW is illustrated in the left side of the Figure 6.3.1. The residential buildings are allowed to be built more than 50m from the road. If the urban development which can be seen in various countries shall be allowed along the road, there is some possibility to develop facilities within the ROW area for only public purposes under ANE or for commercial and logistics development authorised by the local government, which has been illustrated in the partial urbanisation plan in Nampula Municipality. The image of this urban development along the road is depicted in the right side of the same figure.

Note that this proposal requires detailed legal discussions beyond our study scopes, but it would be highly desirable to discuss this solution in order to consider the regional/urban economic development, because the Maputo Circular Road has only 5m of ROW in the urban areas.



Left: Without any buildings within ROW, Right: Urban Development within ROW only for Public purposes and controlled by the local government

Figure 6.3.1 Different Images of Road Development together with Urban Development

6.3.2 Possible Facilities within the ROW (Proposal)

The Study Team recommends that the following facilities are suitable within the ROW to promote the urban economic activities and to enrich urban services to both the residents and drivers. During the Study Tour in Japan, the Study Team introduced the results of the Japanese experience to develop the urban development along the road.

- Public purpose facilities: Local government offices, Public facilities with the additional function of evacuation areas and storage yards in case of disasters, Bus terminals for connecting city busses to long-distance busses, Road-side rest facilities (Michinoeki) with the function of farmers market and fuel station, Weigh bridge, Logistics (public warehouses and truck terminal), Public central wholesale market.
- Authorised commercial and logistics facilities: The local government will secure and control the private investment only for commercial facilities (e.g. restaurants, shopping malls) and logistics facilities (e.g. warehouses, distribution centres) after verifying its Traffic Impact Assessment (TIA). Residences are not allowed within the ROW.

The image of the urban development with the Study road is illustrated in the Figure 6.3.2.

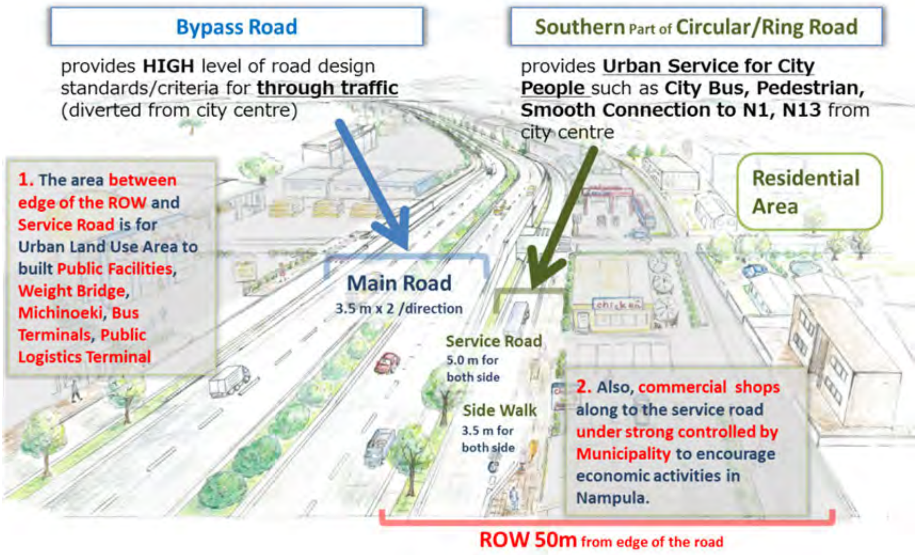


Figure 6.3.2 Image of Urban Development with the Study Road in Nampula

CHAPTER 7 Route Selection (Alternative Analysis)

7.1 Outline

7.1.1 Mapping Information

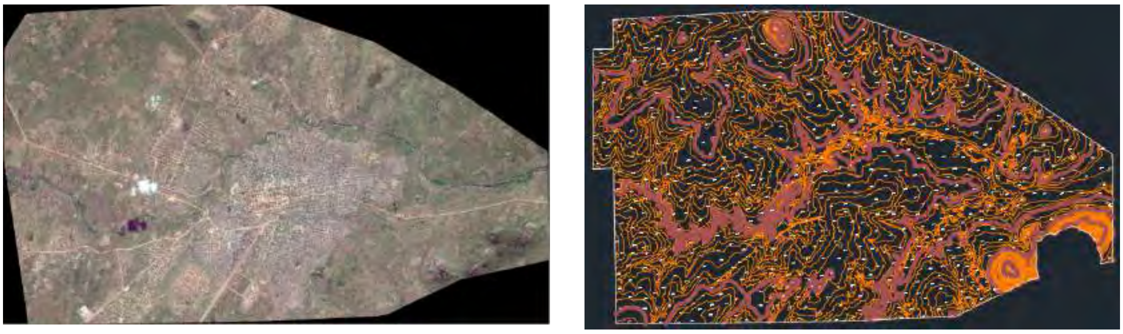
On preparing the alternative routes for the target roads, the structures/buildings and geological/topographical information become the essential and fundamental information.

In the project of PEDEC-Nacala in 2012, the objective areas of Nacala and Nampula have had topographic maps produced at a scale of 1:10,000. On the other hand, there was no topographic map available for the objective area of Cuamba for this project. The Study Team re-examined the appropriate methodology in order to reduce the project cost and work period necessary for the data acquisition by aerial photography or taking of new satellite images, as well as the validity to choose either existing aerial photographs or archived satellite images. As a result, the outlines of the methodology selected on this project are as below.

- The contour mapping to be added in Nacala and Nampula has utilized the aerial photographs and topographical data prepared in PEDEC-Nacala in 2012. The coverage areas consisting of the several outer areas to be added onto the existing contour maps have been prepared using the spatial data of existing aerial photographs with aerial triangulations based on the ground control points (hereinafter called the "GCP") that were installed in the project of PEDEC-Nacala.

- The contour mapping in Cuamba area has utilized two different archived satellite images consisting of IKONOS-2 in 2004 and WorldView-3 in 2015. In addition, the coordinates and elevations of GCP data (8 points) were measured by field survey using GPS receivers and an automatic level. The contour lines with 4m intervals have been plotted based on the aerial triangulation data of archived stereo satellite images.
  The satellite image on the ortho photo map has utilized the archived data of WorldView-2 in 2014 which was geometrically rectified by the GCP data.

The following images are the rectified satellite image of WorldView-2, and the contour line map prepared by IKONOS-2 and WorldView-3.



Upper (left): Satellite image, Upper (right): Contour Lines

Source: the Study Team

Figure 7.1.1 Sources of Ortho Map in Cuamba

The following images are the ortho photo map which was produced from the three (3) satellite images (IKONOS-2, WorldView-3 and WorldView-2).

Source: the Study Team

Figure 7.1.2 The Image the Ortho Map Created for Cuamba

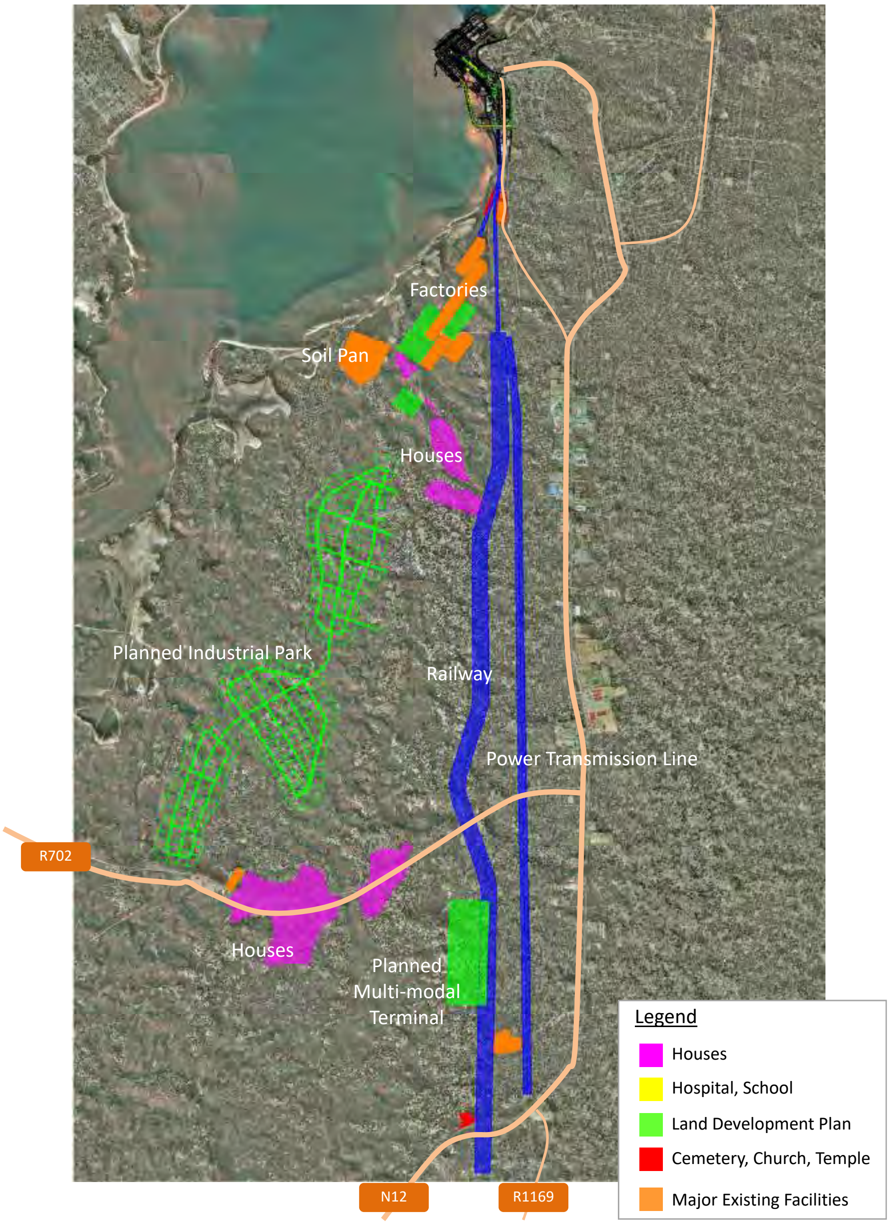
7.1.2 Procedure of Route Selection

In order to select the route/alignment for the Target Roads, the following procedure has been undertaken after discussion and consultation with the stakeholders.

After the initial route/alignment was set with reference to the high priority projects from PEDEC-Nacala, the alternative routes were proposed considering the following;

- Control points around the Target Road area;
  - Public facilities (power transmission lines, railways, schools and hospitals with the required reserved spaces),
  - Religious facilities (temples and cemeteries, etc.),
  - Private facilities (factories, houses and agricultural land etc.),
  - Topographic conditions (rivers, hill area, mountainous area, rock area, soft soil area, landslide area and soil erosion area, etc.)

The following figures show the major control points collected by the site surveys and interviews. The alternatives shall be set to avoid the above major control points and to be a reasonable route in the view of civil engineering and encouraging the traffic diversion, as well as minimising the social and environmental impacts.



Source: the Study Team

Figure 7.1.3 Major Control Points for Nacala Port Access Road

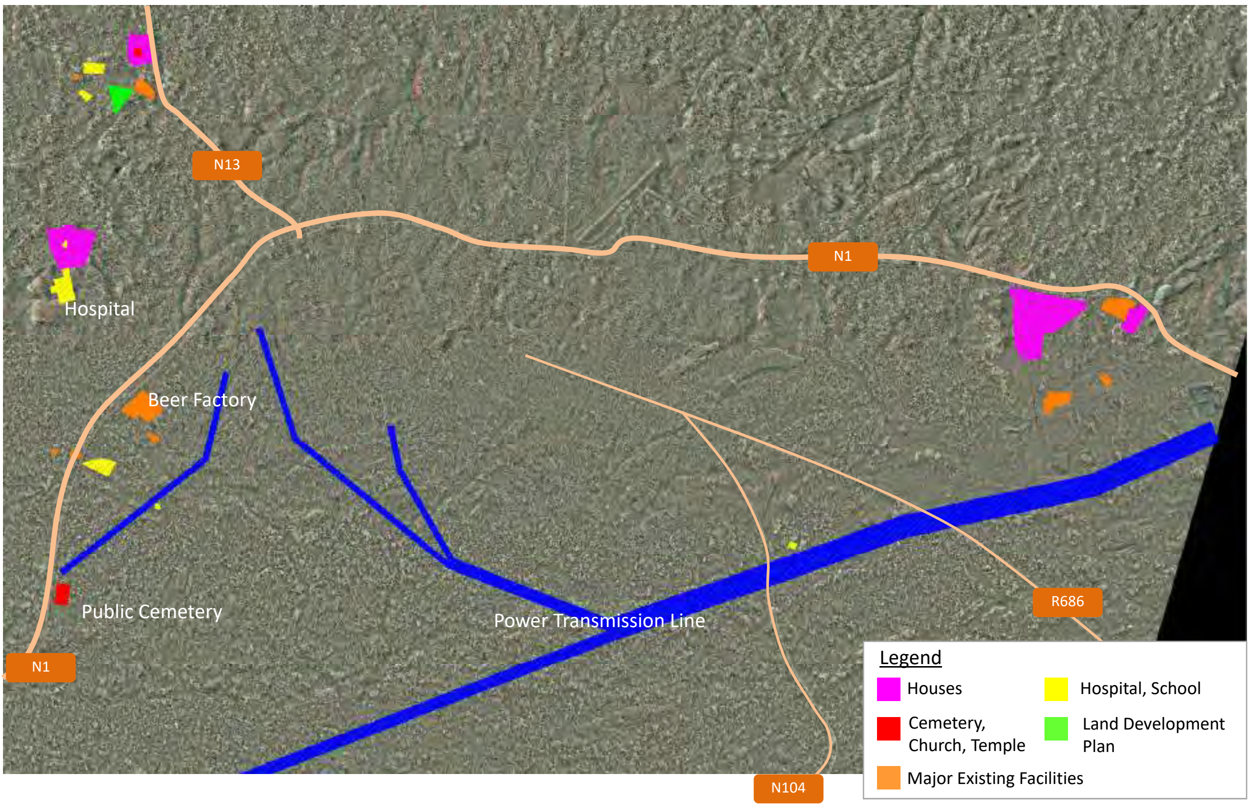


Figure 7.1.4 Major Control Points for Nampula Southern Bypass Road

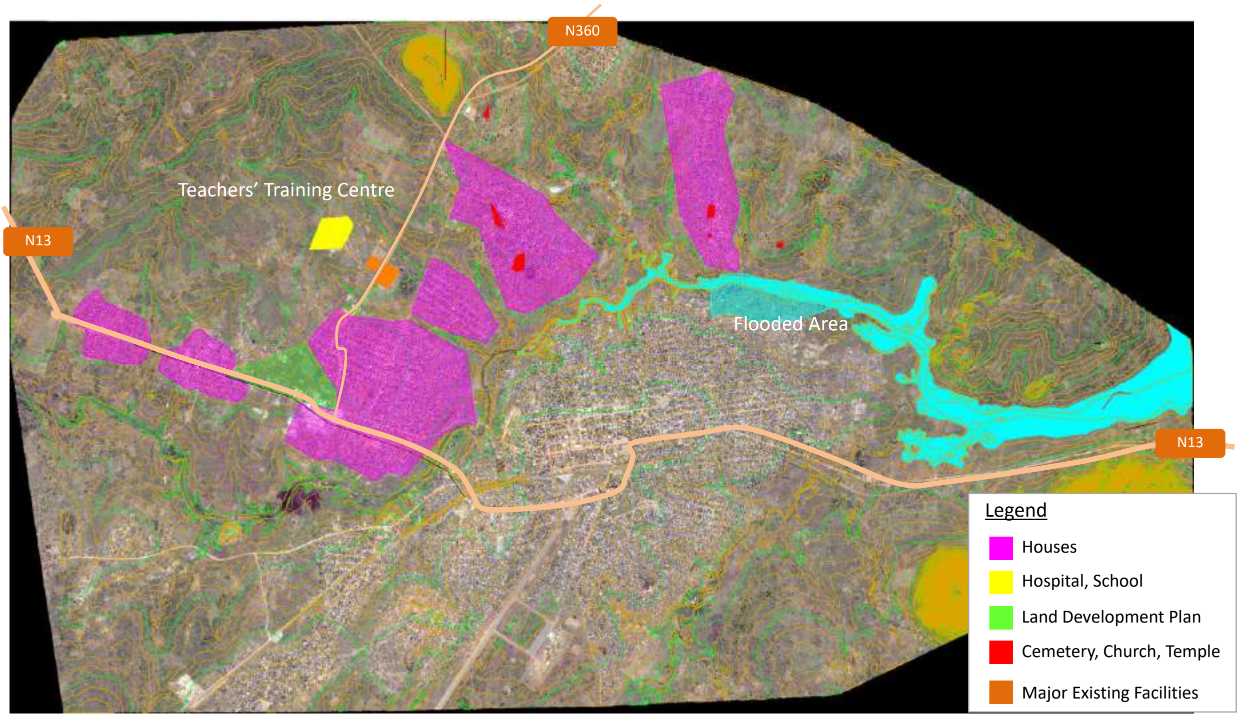


Figure 7.1.5 Major Control Points for Cuamba Bypass Road

At the same time that the alternative routes were set, the Study Team proposed the "Evaluation Criteria" for selection of the most suitable route/alignment from the alternatives. The multi-criteria analysis was applied to this process. Based on the engineering and social/environmental judgements, each evaluation score is set and the final evaluation score is calculated.

Apart from the above process, the ANE held a consultation meeting with the local government officer at each Target Road to collect the local needs and constraints for the selection of route/alignments.

The discussion on the selection of suitable route/alignment for the preliminary design was held with the ANE DIPRO officers to share the result of the multi-criteria analysis and the comments/requests from the local governments.

The details are explained in the following sections and the selected route is shown in the last section.

7.2 Outline of Proposed Alternatives

7.2.1 Nacala Port Access Road

With the considerations of the rationale, consistency to the concept of the high priority project under PEDEC-Nacala as Nacala Port Access Road and the control points identified by field survey, the alternative routes/alignments were technically set and divided into two sections as shown in Figure 7.2.1.

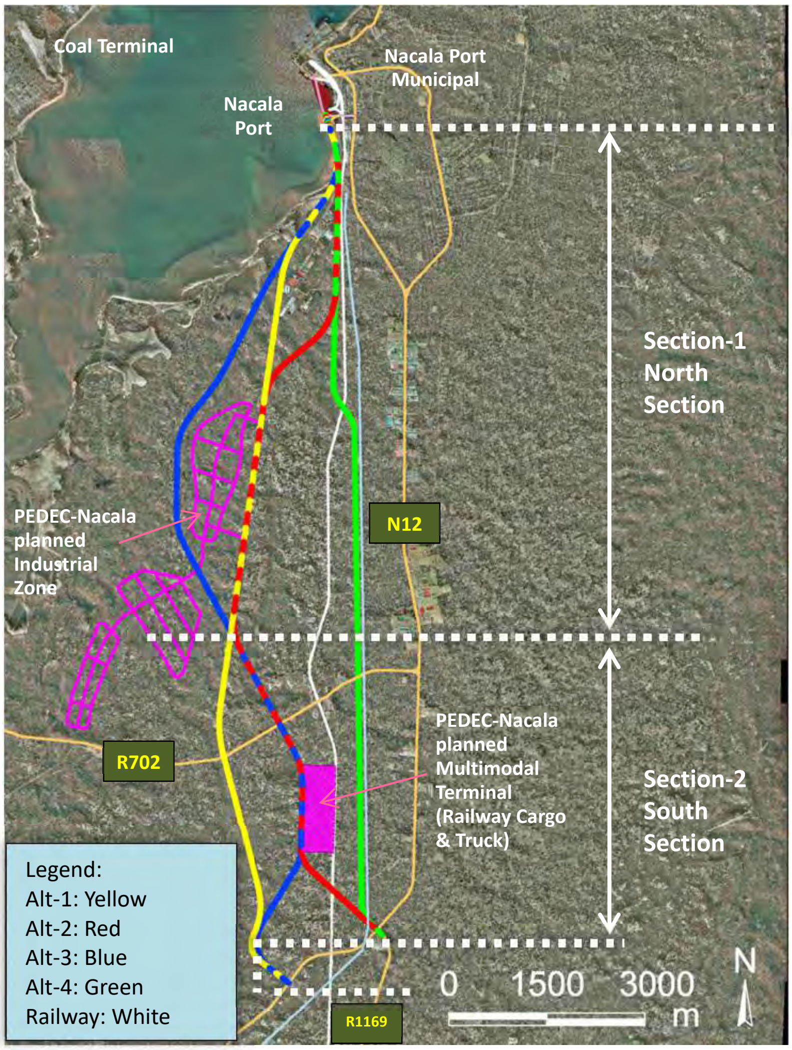


Figure 7.2.1 Alternatives for the Nacala Port Access Road

Figure 7.2.2 depicts the enlarged map for the area around the Nacala Port. Nacala Port expansion project will create an expanding area together with access road by reclamation works. The access road under the port expansion project will only connect to the existing road and not cause any change to the traffic condition which means that the heavy vehicles run through the city area.

Although the Study Team examined several alternative routes for the direct access road in this project in the hinterland area, enough spaces could not be found due to factories, railway lines and pipelines as shown in the figure. In this therefore, the alternative routes are only to connect to the port expansion area and to run through the coastal area even though it is only for a short length.

Figure 7.2.2 Alternatives for the Nacala Port Access Road (Port Connection Area)

The alternatives 1 to 3 can be joined at the same point of the divided section, which means that a different alternative can be selected in each section. The concept of the alternatives are summarised below.

Zero-Option: Nothing changed (as it is)

Alternative-1: Plan for Integration with Regional Development Strategy

- This is almost the same as the initial route proposed by the PEDEC-Nacala, as a regional development strategy for the Nacala Bay Area Development Programme with the connection of Nacala Port to R702 to ensure the connectivity with the planned industrial park, as well as avoiding the residential area.

Alternative-2: Plan for another Connection with City Road (R1169) with Shorter Route

- The idea for this route is to use the existing road around the port area and connect to the city road at the southern section with both N12 and R1169. The entire length of road is shorter than alt-1.

Alternative-3: Plan for running through the Lowland Area with Moderate Vertical Alignment

- Based on the alt-1, the slope of the road shall be moderated with use of the low land and this shall ensure the connectivity with the multi-modal terminal.

Alternative-4: Plan for Shortest Route

- The alternative is set as the shortest route to connect between N12 and the Nacala Port.

An outline with an explanation of the alternative for each section is described in Table 7.2.1

Table 7.2.1 Outline of Alternatives for Nacala Port Access Road

	Description of Section	Alt-1 (Yellow)	Alt. 2 (Red)	Alt. 3 (Blue)	Alt. 4 (Green)
Section-1: North Section	• Starting at Nacala port and ending before R702 • Running through erosion control areas • Needs to have consistency with the industrial development plan	• Along the coast • Connecting to the port by sea bridge	• Same as Alt-1, (Connecting to port by sea bridge) • Running on inland side of factory area • Crossing the pipelines.	• Same as Alt-1, (Connection to port by sea bridge) • Crossing at middle area between planned industrial zones. • Lowland area avoiding the erosion area	• Separated route after the sea bridge of alt-2. • Crossing the railway and running between railway and N12 in the upper area
Section-2: South Section	• Starting after R702 and ending at N12. • Needs to have consistency with planned shunting yard for railway cargo & truck terminal.	• Running between the populated residential areas • No connection with multi-modal terminal	• Separation from Alt-3 and crossing the railway. • Connecting at intersection of N12 and R1169 where the police station is located and is in a residential area.	• Consistency with planned shunting yard for railway cargo & truck terminal (multi-modal terminal)	• No connection with railway cargo & truck terminal due to running through the area between the railway and N12. • Connecting at the intersection of N12 and R1169 where the police station is located (same as Alt-2).

7.2.2 Nampula Southern Bypass Road

With the considerations of the rationale, consistency to the concept of the high priority project under PEDEC-Nacala as Southern Bypass Road in Nampula and the control points identified by field survey, the alternative routes/alignments were technically set and divided into three sections as shown in Figure 7.2.3 and Figure 7.2.4.

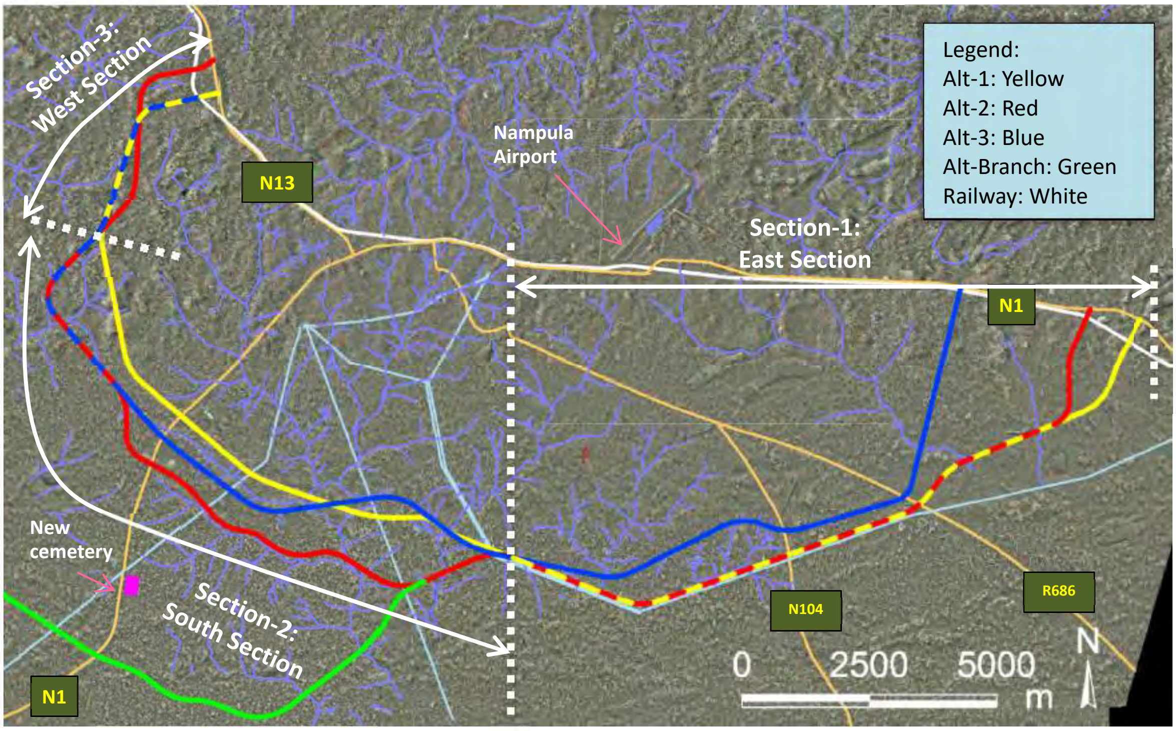


Figure 7.2.3 Alternatives for the Nampula Southern Bypass Road (1/2)

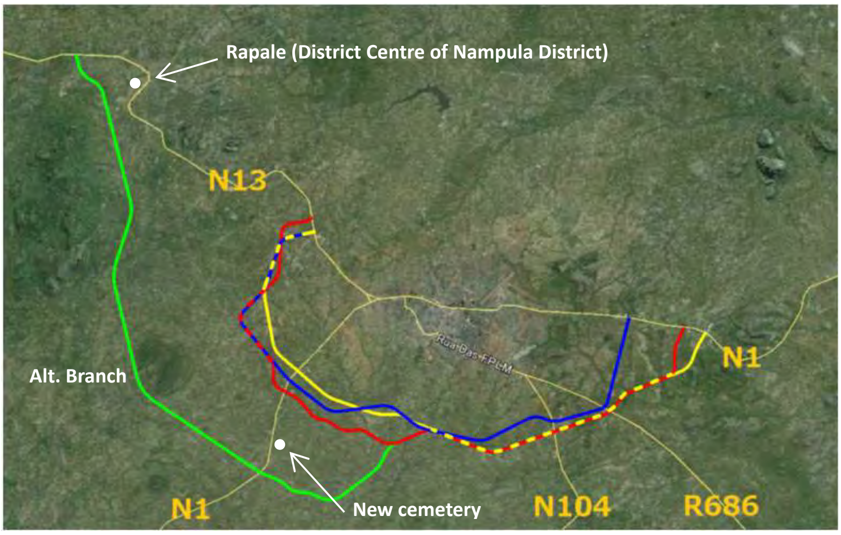


Figure 7.2.4 Alternatives for the Nampula Southern Bypass Road (2/2)

Note that Figure 7.2.4 shows one of the alternatives which were requested by the municipality and district in Nampula. Nampula district asked whether it was possible for the bypass road not to run around their district centre. Nacala Municipality requested that the bypass road be located further out, beyond the public cemetery. Those routes are combined as a branch route of the alternatives depicted in green colour.

The concept of the alternatives are summarised below.

Zero-Option: Nothing changed (as it is)

Alternative-1: Plan that gives great consideration to the Natural Conditions

- Based on alternative-2, the route was planned to be located further upstream to save the swamp area.

Alternative-2: Plan for consistency with the Regional Strategy

- This is almost the same as the initial route proposed by the PEDEC-Nacala, as the regional development strategy for the Greater Nampula Area Development Programme and is consistent with the partial land use plan in Nampula Municipality.

Alternative-3: Plan for consistency with previous Circular Road Section

- This is basically from the partial land use plan developed by UN-Habitat as the southern part of the circular road. The area along the east part of this road has been built-up and would pose difficulties for development.

Alternative-Branch: Plan requested by Local Government

- Figure 7.2.4 with the green colour line shows the basis of the requests from the district and municipality as an alternative.

An outline with the explanation of the alternatives for each section is described in Table 7.2.2.

Table 7.2.2 Outline of Alternatives for Nampula Southern Bypass Road

	Description of Section	Alt-1 (Yellow)	Alt. 2 (Red)	Alt. 3 (Blue)	Alt. Branch (Green)
Section-1: East Section	• Connecting at the east side (Nacala direction) of N1 in Nampula city • Crossing with railway • Until 7km after crossing point of R104	• Connecting with N1 and using an existing small road • Along existing high voltage transmission cable (New additional high voltage transmission line is planned next to the existing one)	• Connecting with N1 at west side of a stone quarry • Connecting point with N13 is closer to the railway than Alt-1. So, the grade separation between the alternative and the railway might be difficult • Along existing high voltage transmission line (Same as Alt-1)	• Same as the southern part of the circular road previously proposed by UN-Habitat, • uses many existing roads, therefore, many residential houses are located along the road • Connecting point with N13 is almost the same location as the railway ROW • somewhat greater distance along high voltage transmission line than alt 1 or 2	
Section-2: South Section	• From Section 1 to the midpoint between N1 and N13 • Running through N1 on the west side	• Running at some distance on the north side of the river • Connecting near the south side of the brewery on N1	• Running on the south side of the river with several streams • Few houses located (similar to alt-1)	• Has consistency with the previously planned circular road by UN-Habitat • almost on/near the river would cause difficulties in construction	• Located beyond new public cemetery
Section-3: West Section	• From Section-2 to be connected to N13	• Connecting with N13 closer to the city than the other alternatives. • Connecting point with N13 is closer to the railway. So, the grade separation between the alternative and the railway might cause some difficulty	• Connecting with N13 outside of alt-1 with some length of new construction.	• Same as Alt-1.	• Requested by Nampula District to avoid running though the Rapale district centre • Totally another function to provide an alternative route from N13 to N1

7.2.3 Cuamba Bypass Road

With the considerations of the rationale, consistency to the concept of the high priority project under PEDEC-Nacala as Cuamba Bypass Road and the control points identified by field survey, the alternative routes/alignments were technically set and divided into two sections as shown in Figure 7.2.5..

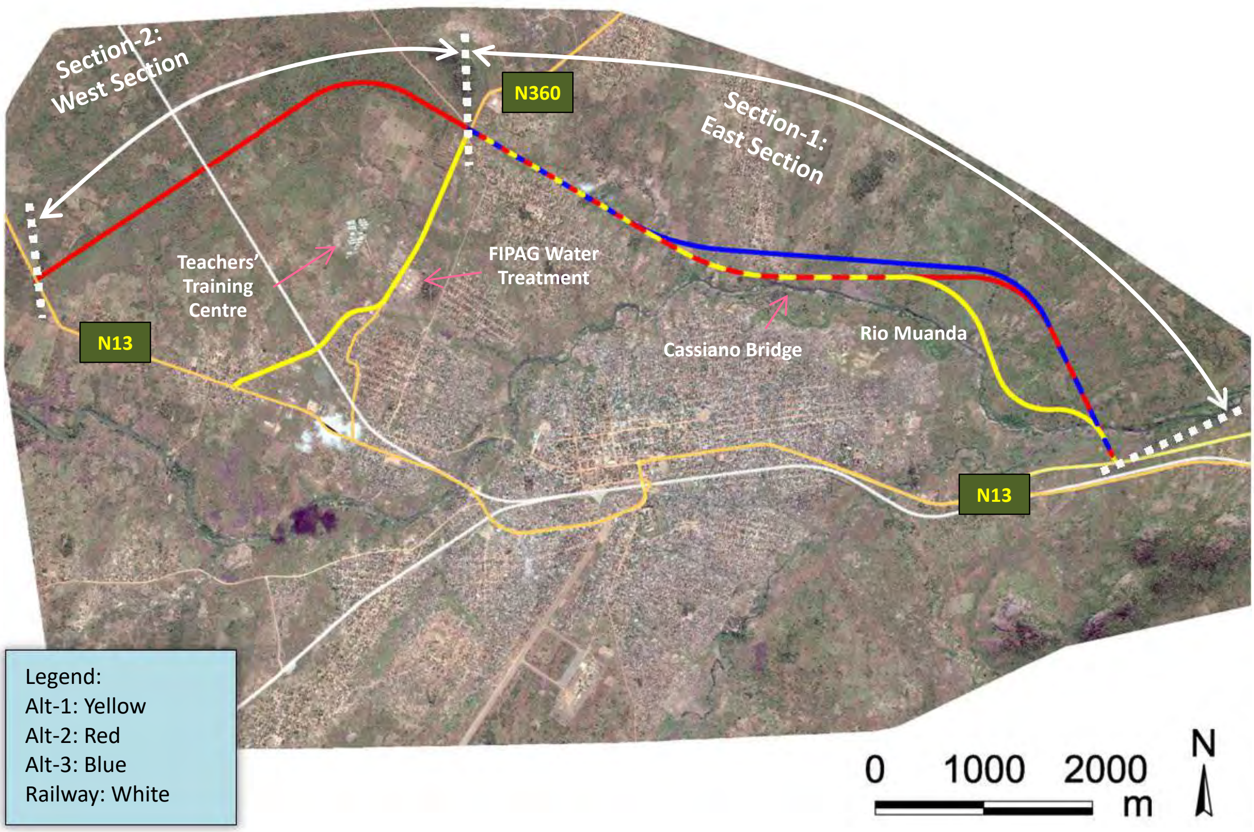


Figure 7.2.5 Alternatives of the Cuamba Bypass Road

The concept of the alternatives are summarised below.

Zero-Option: Nothing changed (as it is)

Alternative-1: Plan for consistency with Regional Strategy

- This is almost the same as the initial route proposed by the PEDEC-Nacala, as a regional development strategy for the Cuamba Logistics Centre Area Development Programme. It utilises the current roads of N360.

Alternative-2: Plan considering the Development Plans and Natural Conditions

- This is a route which can use the local stone materials that are found along this route, and this route accommodates the Growth Pole planned by the Municipality.

Alternative-3: Plan for minimising the risk of being damaged by Rio Muanda Flooding

- This route minimises the risk of damage due to the flooding of Rio Muanda, but it does not give any consideration to the current communities and houses.

An outline with the explanation of the alternatives for each section is described in Figure 7.2.5

Table 7.2.3 Outline of Alternatives for Cuamba Bypass Road

	Description of Section	Alt-1 (Yellow)	Alt. 2 (Red)	Alt. 3 (Blue)
Section-1: East Section	• Connecting with N13 at the point of the Upgraded alignment (new) • Crossing Muanda river and running on the north side along the Muanda river • Connecting with N360 (Cuamba - Marupa road) • Crossing the road from Cuamba city centre and the northern area passing over Cassiano bridge	• Running though the lowland area along the river • Avoiding the rock hill along the road	• Road length is shorter than Alt-1 due to running through the rock hill area • If the rock material has suitable strength, it can be used for base course materials for the pavement to reduce the construction cost	• Variation of Alt-2 • Shifted to the north side to avoid the risk of flooding and erosion from the river, but it runs through the current community (village)
Section-2: West Section	• From N360 to N13 bound for Lichinga with the crossing of the railway to Lichinga (currently not operating)	• Improvement on existing road (N360: Cuamba - Marupa, saving construction cost • Connection with N13 from N360 as new road development on the part of current small roads, and though/touching the edge of a village	• Requested by the Cuamba municipality • Running along the northern side and outside the developed teachers' training centre • Connecting with N13 after Tetereane village • Connecting with the planned Growth Pole for development of Cuamba City	

7.3 Consultation with Local Administrative Governments

7.3.1 Introduction

Since this Feasibility Study commenced at end of March, the Study Team and JICA H.Q. officers had several discussions with related Municipalities and Districts, with the attendance of the presidents of Nampula, Nacala and Cuamba municipal councils, as well as the administrator of Nampula District. After the conversations with the local governments, the Study Team has conducted site confirmation and discussions on technical and environmental/social considerations with ANE H.Q.

The consultation meeting with the local administrative officers aimed to exchange the opinions and receive their requests regarding the project. Following is a summary of the consultation meetings and comments/requests received from each local administrative government for ANE.

7.3.2 Nacala Port Access Road

(1) Consultation Meeting

ANE and the Study Team held a consultation meeting with Nacala Municipality on 24th June 2015 at Nacala Municipal Council Conference Room. After the project outline was explained, opinions and suggestions were exchanged among the attendees such as officers from the municipalities, ANE H.Q. officer, Nampula delegate and the Study Team. The major points discussed in the consultation are summarised as follows.

- Indication of road alignment: Road alignment study has not been completed. After the road alignment has been finalized ANE will inform all interested parties by official letter.
- Avoidance of hospitals and schools: ANE and the Study team responded that the Project road shall avoid these public facilities.
- Connection to the planned truck terminal: ANE and the Study team responded that the proposed alternative shall have connectivity to the planned multi-modal terminal.
- Consideration of truck parking area/lots in the project road: ANE and the Study team responded that provision of these facilities shall be the responsibility of the Municipality.
- Consideration of development of schools and hospitals in the project: ANE and the Study team responded that these developments are out of the scope of the project and should be secured by the municipal budgets.
- Compensation for resettlement: ANE and Study team responded that ANE will consider the social aspects very carefully and conduct a RAP.

(2) Comments/Requests from the Municipality

After the consultation, the Nacala Municipality President sent an official letter to ANE with their opinions and suggestions regarding Nacala Port Access Road on 13th July 2015.

Their comments/suggestions and responses are summarised as follows.

- Request-1: Consideration for avoidance of the three planned factory areas.

The Municipality showed the three areas for the factories near Nacala port as shown in Figure 7.3.1.

Figure 7.3.1 Area of Factories as Indicated by Nacala Municipality

Responce-1: It is confirmed that the selected route/alignment (described in section 7.4) accommodates this planned area.

- Request-2: Request for the Environmental Impact Assessment study (EIA)

  Responce-2: It is confirmed that ANE will conduct the EIA in accordance with both Mozambique and JICA guidelines.

(3) Summary of Requests and Responses

A summary of requests in the consultations and from the mayors of each city is shown in Table 7.3.1. Also, Table 7.3.1 shows a summary of answers by ANE and the Study Team.

Table 7.3.1 Summary of Requests and Answers (Nacala)

No.	Requests by Each Municipality		Answers by ANE/Study Team
	Consultation	Letter from Mayor	
1	Indication of road alignment		The road alignment study has not been completed. After the road alignment is finalized ANE will inform interested parties by official letter.
2	Avoidance of hospital and school etc.		Hospitals and schools etc. will be avoided.
3	Connection to the planned truck terminal		A truck terminal is planned to connect to the project rad.
4	Construction of truck parking area/lots in the project		Provision of these facilities shall be the responsibility of the Municipality.
5	Consideration of development of schools and hospitals in the project		These developments are out of the project scope and should be secured by Municipality budget.
6	Compensation for resettlement		ANE will consider the social aspects very carefully and conduct the RAP.
7		Consideration for avoidance of the three planned factory areas.	The selected alignment accommodates these planned areas.
8		Request for an EIA	ANE will conduct an EIA in accordance with Mozambique and JICA guidelines.

7.3.3 Nampula Southern Bypass Road

(1) Consultation Meeting

ANE and the Study Team held a consultation meeting with Nampula Municipality on the 23rd of June 2015 at the Meeting Room of the Urban Planning Department of Nampula City Municipal Council. After the project outline was explained, opinions and suggestions were exchanged among the attendees, such as the officers from the municipalities and district, the ANE H.Q. officer, Nampula delegate and the Study Team. The major points discussed in the consultation are summarised as follows.

- Indication of road alignment: The road alignment study has not been completed. After the road alignment is finalized ANE inform the interested parties by official letter.
- Road alignment near beer factory was proposed to be on the south side of the cemetery: This proposal will be considered and ANE will inform the interested parties of the best road alignment.

- Establishment of a development plan along road: ANE will consider this.
- Reduction of traffic congestion in Nampula city (CMC)
- Road alignment that is connected to N1 on the west side of Rapale city is difficult due to its being outside of the PEDEC-Nacal plan and the increase of project cost.
- Minimisation of resettlements: ANE and the Study team responded that the project road shall minimise the number of resettlements, in principal, and ANE will conduct a RAP.
- Necessity of protection against illegal occupation within the road reserved area: ANE and the Study team responded that ANE will consider the methods for its protection during the study.

(2) Comments/Requests from the Municipality

After the consultation, Nampula Municipality (Urban Planning Director) sent their opinions and suggestions regarding Nampula Southern Bypass Road via email to the Study Team on 3rd July 2015.

Their comments/suggestions and the responses are summarised as follows.

- Request-1: Minimisation of resettlements

  Responce-1: It is confirmed that the number of resettlements shall be minimised as much as possible.

- Request-2: Application for an urban development plan along the road.

  Responce-2: The Study team recommends discussing how to integrate the road and urban development along the road under the legal conditions for the ROW.

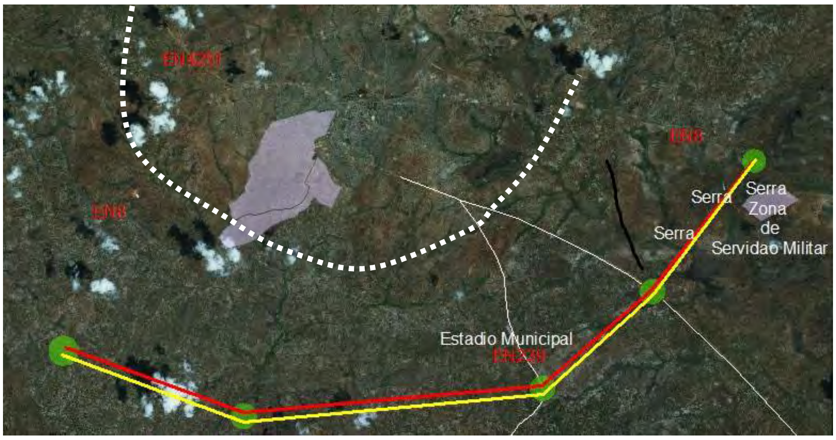
- Request-3: Necessity to protect against illegal occupation within the road reserved area

  Responce-3: Proper countermeasures regarding how to avoid illegal houses/occupation within the ROW shall be studied during the study period.

- Request-4: Proposal for an alignment.

  The Municipality requested a different road alignment as shown in Figure 7.3.2 below.

  Responce-4: After examination of the municipality's proposed route, it was found that the proposed route is longer than the Study team's alternative by more than 10km, which causes an increase in the construction costs and additional travel time. In addition, the Target Road will be formed as the Southern part of the Circular/Ring Road which has been planned by the municipal council under support of UN-Habitat and PEDEC-Nacala.



Note: White dotted line shows the proposed alignment of the Study Road

Figure 7.3.2 Another Proposed Route by Nampula Municipality (Solid Line)

Therefore, the route proposed by the municipality shall be beyond the scope of the Target Road. The Study team suggests that it will be considered as a future project after implementation of Nampula Southern Bypass Road.

(3) Summary of Requests and Responses

A summary of requests in the consultations and from mayors of each city is shown in **Table 7.3.2**. Also, **Table 7.3.2** shows a summary of answers by ANE and the Study Team.

Table 7.3.2 Summary of Requests and Answers (Nampula)

No.	Requests by Each Municipality		Answers by ANE/Study Team
	Consultation	Letter from Mayor	
1	Indication of road alignment		The road alignment study has not been completed. After the road alignment is finalized ANE will inform interested parties by official letter.
2	Proposal of new alignment near beer factory		The proposal will be considered and ANE will inform the interested parties of the best road alignment.
3	Development plan along road		ANE will consider this.
4	Reduction of traffic congestion in the city.		
5		Bypass end after Rapale City	Road alignment that is connected to N1 on the west side of Rapale city is difficult due to its being outside of the PEDEC-Nacala plan and the increase in project cost.
6	Minimization of resettlement	Minimization of resettlement	ANE will conduct a RAP and consider it. The number of resettlements shall be minimized as much as possible.
7	Necessity of protection against illegal occupation within the road reserved area	Necessity of protection against illegal occupation within the road reserved area	ANE and the study team will consider the methods for its protection during the study.
8		Application for urban development plan along the road	
9		Proposal for an alternate alignment (See Figure 7.3.2)	The alignment proposed by the Municipality would increase the road length by 10km and construction cost would be increased. Also, travel time is longer. And the target road will be formed as the Southern part of the Circular/Ring Road in Municipality's development plan under PEDEC. Therefore, ANE will execute this project road according to Study Team's proposed alignment.

7.3.4 Cuamba Bypass Road

(1) Consultation Meeting

ANE and the Study Team held a consultation meeting with Cuamba Municipality on 26th June 2015 at the Assembly of Cuamba Municipality. After the project outline was explained, opinions and suggestions were exchanged among the attendees, such as officers from the municipalities, the ANE H.Q. officer, Niassa delegate and the Study Team. The major points discussed in the consultation are summarised as follows.

- Indication of road alignment: The road alignment study has not been completed. After the road alignment is finalized ANE will inform interested parties by official letter.
- Confirmation of avoidance of cemeteries: ANE and the Study team responded that it shall be taken into consideration with their help by sending the data for the locations of these cemeteries.
- Dissemination of information regarding this project to residential people: ANE and the Study team explained that it will be done through the EIA/RAP.
- Consistency with the Urban Structure Plan (PEU): ANE and the Study team responded that the consistency of the PEU will be checked and feedback will be given if necessary.
- Minimisation of Resettlements: ANE and the Study team responded that the project road shall minimise the number of resettlements, in principal.
- Consideration of reconstruction of Cassiano bridge in the project: ANE responded that reconstruction of Cassiano bridge would be very difficult due to the limited budget, and suggested to seek other funds.
- Budget for Compensation: ANE responded that the central government will prepare the budget for compensation.

(2) Comments/Requests from the Municipality

On 13th July 2015, after the consultation, the Cuamba Municipality President sent an official letter to ANE with their opinions and suggestions regarding Cuamba Bypass Road.

Their comments/suggestions and the responses are summarised as follows

- Request-1: Proposed Alignment (run through the northern side of the teachers' training centre and connected after the Teteriane Village on N13 bound for Mandimba)

  Responce-1: It is confirmed that this alignment is already one of the alternatives.

- Request-2: Request for the Cassiano Bridge construction in the Project

  Responce-2: The Study team recognised that there are two different aspects behind their request.

  <u>1. Emergency Rehabilitation/Reconstruction of Cassiano Bridge</u>

  It is clear that the Cassiano Bridge played an essential role for the residents in Njane and Adine 3 as it connected the two areas until it collapsed last January because of the floods. The immediate needs for reconstruction of the bridge are natural for the residents. If this emergency rehabilitation/reconstruction is included in this Project scope, it might take five years or even more to be reconstructed. In order to meet the residents' needs and considering the timeline of the project, it should not be included in this project scope.

2. Functional Rehabilitation of Cassiano Bridge

As mentioned above in 1., the Cassiano Bridge had an important function connecting the Njane and Adine 3 areas. It is important to maintain the connecting function the bridge used to have even after the bypass road is developed; therefore, the connection between the bypass road and the bridge is to be studied to maintain the connecting function.

- Request-3: Avoidance of Cemeteries

  response-3: The project road shall avoid the six cemeteries for which the Municipality reported the locations.

- Request-4: Proposed Alignment/ Consistency with PEU guidelines and standards

  Responce-4: During the preliminary design, the guidelines and standards presented in the PEU shall be followed. Regarding the requested new road alignment in the urban development plan (PEU), the objective of the requested road seems to be connecting between urban development centres (growth poles) but, as envisioned, it will not function as a bypass. Therefore, their proposed route will not be considered. It will be a future region-wide development project.

(3) Summary of Requests and Responses

A summary of requests in the consultations and from the mayors of each city is shown in Table 7.3.3. Also, Table 7.3.3 shows a summary of the answers by ANE and the Study Team.

Table 7.3.3 Summary of Requests and Answers (Cuamba)

No.	Requests by Each City		Answers by ANE/Study Team
	Consultation	Letter from Mayor	
1	Indication of road alignment		The road alignment study has not been completed. After the road alignment is finalized ANE will inform interested parties by official letter.
2	Avoidance of cemeteries	Avoidance of cemeteries	Cemeteries shall be avoided.
3	Dissemination of information regarding this project to residential people		ANE shall explain during the EIA/RAP.
4	Consistency with urban structure plan (PEU)		ANE and the study team responded that the consistency of the PEU will be checked.
5	Minimization of resettlement		The number of resettlements shall be minimized as much as possible.
6	Consideration of construction of Cassiano bridge	Consideration of construction of Cassiano bridge	ANE and the study team responded that reconstruction of Casiiano bridge would be very difficult due to the limited budget. Reconstruction of the bridge is an emergency project. However, this road project is not cleared construction period. Therefore, ANE suggested seeking other budget to city.
7	Budget for compensation		The central government will prepare the budget for compensation.
8		Proposal of alignment (a) Through the north side of the teacher's training centre (b) Connected after Teteriane village on N13 bound for Mandimba	The study team is considering this proposal as an alternative.
9		Proposed alignment/consistency with PEU guideline and standard	Guidelines and standards shall be followed. Since the objective of the proposed alignment seems to be connecting between urban development centres, it will not function as a bypass. Therefore, ANE shall follow the alignment proposed by the Study team.

7.4 Evaluation Criteria for Route Selection

In order to select the appropriate route/alignment, the Multi-Criteria analysis is used as a decision making tool. In applying the Multi-Criteria analysis, it is necessary to define the items and criteria for evaluation. Following are the principals to apply in this analysis.

- **Evaluation Items and Criteria**: These are set in accordance with the project objective, for this project there might be eight (8) objectives, which shall be archived by each road development.
- **Evaluation Score**: Each evaluation item shall be scored on a scale between 0 to 10 points, based on 5 levels of performance; (10) Exceeds project objective, (7) Meets project objective, (5) Partially satisfies project objective, (3) Fails to meet project objective, (0) Works against the project objective. The total score which integrates the eight evaluation items shall be calculated by the weight (%), which reflects the degree of importance of each evaluation item, then the total full score of the alternative is 10.00.
- **Weighting Ratio for each Evaluation Item**: The weight (%) of each evaluation item is set by the characteristics of each project road. Even though these roads shall play an essential role for promoting the integrated development plan, Social and environmental issues are evaluated by three items from 6) to 8) and cover around 30~36% of the importance within the total evaluation score. In the case of Nacala Port Access Road, the 2) benefit to traffic congestion relief, 4) traffic safety and 5) affordability are thought to be more important than the others. Nampula Southern Access Road has more importance with the evaluation items of 3) benefit to urban development and residents, 7) property acquisitions and 8) community including property access. Cuamba Bypass Road has characteristics similar to Nampula’s. These are set by the consulting judgement based on the result of a series of interviews and site confirmations.

The Table 7.4.1 shows the definition of evaluation items, criteria and their weight for each project road.

Table 7.4.1 Evaluation Criteria for Each Alternative

Note: NPA: Nacala Port Access Road, NSB: Nampula Southern Bypass Road, CB: Cuamba Bypass Road

	Evaluation Items	Evaluation Criteria	Weight (%)		
			NPA	NSB	CB
1)	Consistency to integrated development plan (e.g. PEDEC -Nacala, PEU)	Project Objective - To function as integrated infrastructure development plan to realise the strategy for the Nacala Corridor regional development : ✓ Consistency with PEDEC-Nacala ✓ Consistency with Urban Development Plan (PEU) ✓ Consistency with other Infrastructure Development Plans (e.g. High voltage transmission line plan, Plans by municipalities, etc.)	15%	15%	15%
2)	Benefit to Traffic Congestion Relief	Project Objective - To alleviate current and future traffic congestion: ✓ Reduction of transport cost ✓ Reduction of travel time	15%	13%	10%

	Evaluation Items	Evaluation Criteria	Weight (%)		
			NPA	NSB	CB
3)	Benefits to Urban Development and Residents	Project Objective - To promote well-organised urban developments along the road and to act as an urban road for residents of the municipality's daily use: ✓ Possibility of urban development along the road and function of generated traffic demand ✓ Function for residents in the city as an urban road	10%	13%	13%
4)	Road Safety	Project Objective - To Promote/Ensure a safe road: ✓ Safety for drivers ✓ Safety for residents	15%	13%	13%
5)	Affordability	Project Objective - To be an affordable project with sustainable maintenance costs: ✓ Construction cost ✓ Compensation costs such as houses, land and facilities ✓ Other compensation such as removal of utility lines, etc. ✓ Road maintenance cost	15%	13%	13%
6)	Environmental Impacts	Project Objective - To minimise the adverse impacts on the natural environment: ✓ Number of trees cut (soil water retention property, control soil erosion against rainfall, etc.) ✓ Reduce the volume of soil from borrow pits and crushed stone used in the construction ✓ Impacts to the coastal environment (Nacala) ✓ Other environmental impacts (Threatened species, etc.)	10%	7%	10%
7)	Property Acquisitions	Project Objective - To minimise removal of houses and land acquisition: ✓ Number of houses and facilities affected by the project ✓ Area of required land acquisition	10%	13%	13%
8)	Community including Property Access	Project Objective - To minimise the adverse social impacts in the long term, such as impact to the community along the road: ✓ Creating/ensuring access to community facilities such as schools, hospitals and cemeteries (no adverse impact such as interrupt/disconnect with existing foot paths) ✓ Impacts on Amenities, Noise, Accessibility to roads, Passing vehicles, etc.	10%	13%	13%

Note: NPA: Nacala Port Access Road, NSB: Nampula Southern Bypass Road, CB: Cuamba Bypass Road

The results of the above mentioned multi-criteria analysis for selection of the recommended route/alignment for each road along with each score and total score will be explained in 7.5. In addition to this score result, simple explanation tables as reference are also provided.

7.5 Results of Alternative Analysis / Selected Route

7.5.1 Nacala Port Access Road

As the outline of the alternatives described in Table 7.2.1 and depicted in Figure 7.2.1 and Figure 7.2.2, Table 7.5.1 and Table 7.5.2 show the result of the multi-criteria analysis for alternatives at each section of the Nacala Port Access Road. The bottom of the table shows the total numbers counted by each evaluation such as good, fair and bad for each alternative.

The evaluation result of alternatives for Section-1 is shown in Table 7.5.1.

Table 7.5.1 Characteristics of Alternatives (Section-1)

	Evaluation Items	Alternatives			
		Alt-1 (Yellow)	Alt-2 (Red)	Alt-3 (Blue)	Alt-4 (Green)
1)	Consistency to integrated development plan	Well integrated, the same as the original idea [Good]	Integrated, but passing through existing industrial area [Fair]	Well integrated with planned industrial area [Good]	No integration [Bad]
2)	Benefit to Traffic Congestion Relief	Functional [Good]	Functional [Good]	Functional [Good]	Functional, but required railway crossing [Bad]
3)	Benefits to Urban Development and Residents	No relations [Fair]	No relations [Fair]	No relations [Fair]	Adverse impact for residential area [Bad]
4)	Road Safety	Straight alignment [Good]	Many crossing points [Bad]	Gentle slope [Good]	Many crossing points with railway flyover [Bad]
5)	Affordability	Similar among alt-1 to 3 [Fair]	Same as alt-1 [Fair]	Same as alt-1 [Fair]	Additional railway bridge [Bad]
6)	Environmental Impacts	Careful embankment volume design required [Fair]	Erosion area [Bad]	Better than alt-1 [Fair]	Erosion area [Bad]
7)	Property Acquisitions	Required concession area for factories [Bad]	Required factories' property [Fair]	Minimum [Good]	Required resettlements [Bad]
8)	Community including Property Access	Required crossing point for a village [Fair]	Required many crossing points for factories, villages [Bad]	Required crossing point for a village [Fair]	Required many crossing points for factories, villages [Bad]
	[Good]	3	1	4	0
	[Fair]	4	4	4	0
	[Bad]	1	3	0	8

Note: the detail of the evaluation is attached in Appendix-2

As mentioned in the above table, the Section-1 selects the alternative-3, namely as the "Plan for passing the lowland area with moderate vertical alignment", which has the highest number of "Good" evaluations.

Because the Section-1 passes around limited space of the hinterland of Nacala port and through the planed industrial development within an erosion area, the evaluation criteria of "1) consistency to integrated development" and "6) environmental impacts" are considered as more important than the others. In addition, the study team also considers social aspects as essential; the alternative-2 and -4 are evaluated as "Bad" for "7) poverty acquisitions" and "8) community" due to relatively inappropriate social impacts.

In this therefore, the proposed alternative for the section-1 is as follows;

- Section-1: Alt-3 (Blue colour line)

Regarding the Section-2, Table 7.5.2 shows the evaluation result of the alternatives.

Table 7.5.2 Characteristics of Alternatives (Section-2)

	Evaluation Items	Alternatives			
		Alt-1 (Yellow)	**Alt-2 (Red)**	**Alt-3 (Blue)**	**Alt-4 (Green)**
1)	Consistency to integrated development plan	No integration [Bad]	Integrated, but passing through existing housing area [Fair]	Well integrated with planned multi-modal terminal [Good]	No integration [Bad]
2)	Benefit to Traffic Congestion Relief	Functional [Good]	Functional, but less diversion [Fair]	Functional [Good]	Functional, but less diversion [Fair]
3)	Benefits to Urban Development and Residents	Adverse impact for village development [Fair]	Adverse impact for residential area [Fair]	Better impact to industrial area development [Fair]	Adverse impact for residential area [Fair]
4)	Road Safety	Straight alignment and gentle slope, near village [Fair]	Pass through residential area, and railway crossing (steep road) [Bad]	Gentle slope [Fair]	Pass through residential area [Bad]
5)	Affordability	Less embankment volume [Fair]	Required railway bridge construction [Bad]	Depends on embankment volume [Fair]	Short length [Good]
6)	Environmental Impacts	Careful treatment of erosion and drainages [Fair]	Same as alt-1 [Fair]	Same as alt-1 [Fair]	Better than alt-1 to 3 [Good]
7)	Property Acquisitions	Less required acquisition [Good]	Required resettlements [Bad]	Less required acquisition [Good]	Requires resettlements [Bad]
8)	Community including Property Access	Required crossing point for a village [Fair]	Required many crossing points for residential area [Bad]	No acquisition required [Good]	Requires many crossing points for residential area [Bad]
	[Good]	2	0	4	2
	[Fair]	5	4	4	2
	[Bad]	1	4	0	4

Note: the details of the evaluation are attached in Appendix-2

As mentioned in the above table, the Section-2 would be best with alternative-3, which has the highest number of “Good” evaluations.

This section, where the future residential development is limited because it passes through the building development prohibited zone, as well as where the multi-modal terminal is planned, provides high weighting of importance to the evaluation item “1) consistency to integrated development”. Moreover, it requires the amount of traffic diversion of port related vehicles so that the “2) traffic congestion relief” are emphasized. In addition to the above, the impacts on the environment and social considerations are also to be important; less impact to the current community and residents are required.

In this therefore, the proposed alternative for the section-2 is as follows;

- Section-2: Alt-3 (Blue colour line)

The selected alignment integrated in Section-1 and Section-2 which are proposed for Nacala Port Access Road is shown in Figure 7.5.1. In Appendix-6, the alternatives and selected route/alignment with more detailed information are indicated in the maps.

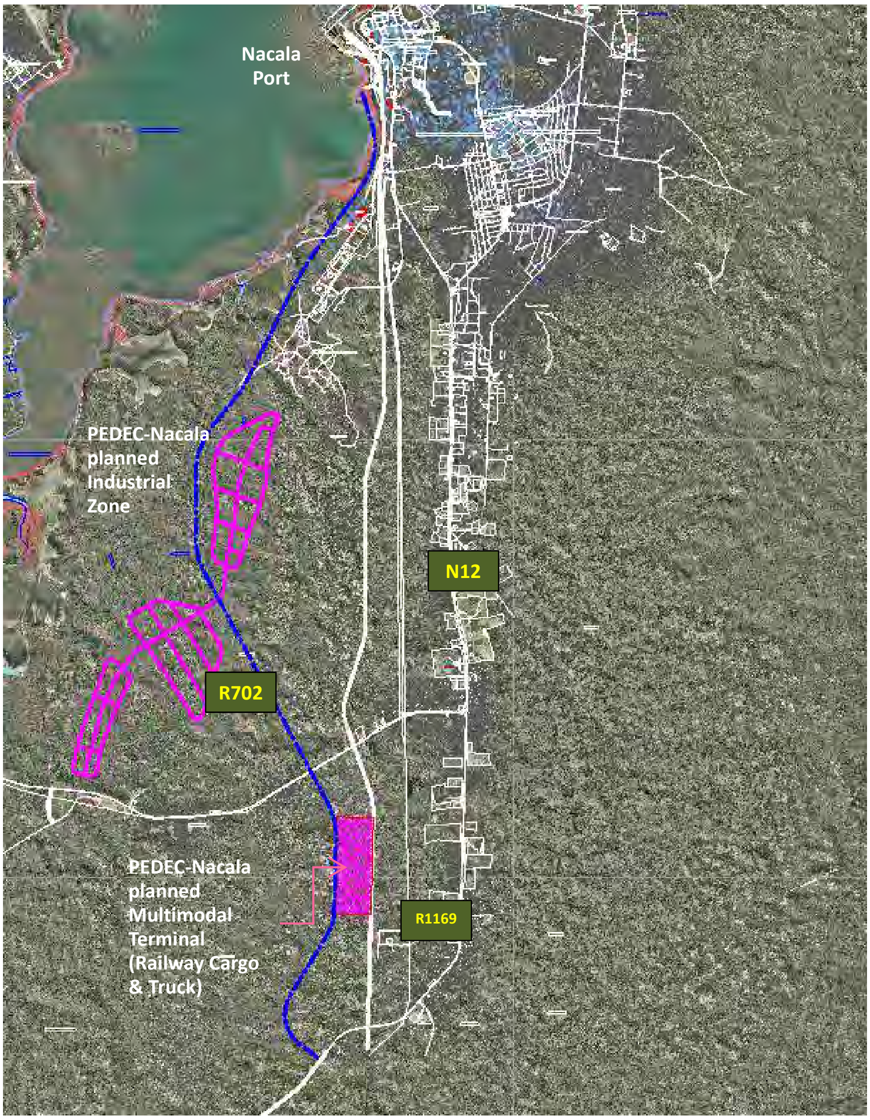


Figure 7.5.1 Selected Route/Alignment of Nacala Port Access Road

7.5.2 Nampula Southern Bypass Road

(1) Comparison of Alternatives

As the outline of the alternatives described in Figure 7.2.2 and depicted in Figure 7.2.3 and Figure 7.2.4, Table 7.5.3 to Table 7.5.5 show the result of the multi-criteria analysis for the alternatives at each section of the Nampula Southern Bypass Road. The bottom of the table shows the total numbers counted by each evaluation such as good, fair and bad for each alternative.

The evaluation result of the alternatives for Section-1 is shown in Table 7.5.3.

Table 7.5.3 Characteristics of Alternatives (Section-1)

	Evaluation Items	Alternatives			
		Alt-1 (Yellow)	Alt-2 (Red)	Alt-3 (Blue)	
1)	Consistency to integrated development plan	Well integrated same as original idea [Good]	Same as alt-1 [Good]	Same as original PEU [Good]	
2)	Benefit to Traffic Congestion Relief	Functional [Good]	Functional [Good]	Less functional due to passing urbanised area [Fair]	
3)	Benefits to Urban Development and Residents	Possibility for future urban development [Good]	Possibility for future urban development [Good]	Difficulties due to existing urbanised area [Fair]	
4)	Road Safety	Straight alignment and controllable crossing points [Good]	Straight alignment and controllable crossing points [Good]	Many crossing points required [Fair]	
5)	Affordability	Similar among alt-1 to 2 [Good]	Same as alt-1, but, Space for Railway bridge shall be examined carefully [Fair]	Same as alt-1, slightly shorter length [Good]	
6)	Environmental Impacts	No severe impacts exist [Fair]	Same as alt-1 [Fair]	Same as alt-1 [Fair]	
7)	Property Acquisitions	Minimum houses affected (17) [Good]	Minimum houses affected (3) [Good]	Houses affected / urbanised area [Bad]	
8)	Community including Property Access	Controllable for providing crossing points [Fair]	Controllable for providing crossing points [Fair]	Already urbanised and required many crossing points [Bad]	
	[Good]	6	5	2	
	[Fair]	2	3	5	
	[Bad]	0	0	2	

Note: Details of the evaluation are described in Appendix-2.

As mentioned in the above table, the Section-1 evaluates both alternative-1 and 2 as having the highest number of “Good” evaluations. In general, this section connects to N1 and flyovers above the railway and then runs within the flat area. Only the alternative-3 runs through the built-up area which creates some difficulties to secure the land and with traffic safety. Comparing with the alternative-1 and 2, engineering difficulties should be considered at the flyover structures which affect project costs, it may be more severe than the number of houses affected. A detailed examination should be conducted during the plane survey at the site. Therefore, at this moment, the proposed alternative for the section-1 is as follows;

- Section-1: Alt-1 (Yellow colour line)

However, it is not limited to alternative-1, altertive-2 will also be examined based on the result of the topographical survey.

Regarding the section-2, Table 7.5.4 shows the evaluation result of the alternatives.

Table 7.5.4 Characteristics of Alternatives (Section-2)

	Evaluation Items	Alternatives			
		Alt-1 (Yellow)	**Alt-2 (Red)**	**Alt-3 (Blue)**	**Alt-Branch (Green)**
1)	Consistency to integrated development plan	Well integrated same as original idea [Good]	Same as alt-1 [Good]	Same as original PEU [Good]	No integration [Bad]
2)	Benefit to Traffic Congestion Relief	Functional [Good]	Functional [Good]	Functional [Good]	Limited functionality only for N1-N1 bypassing [Bad]
3)	Benefits to Urban Development and Residents	Functional [Good]	Functional [Good]	Functional, but limited area along the riverside [Fair]	Far from the city area, not functional [Bad]
4)	Road Safety	Ensured with service roads [Fair]	Ensured with service roads [Fair]	Ensured if enough space for service roads provided [Fair]	Fewer pedestrian expected [Fair]
5)	Affordability	Shortest route [Good]	Same as alt-3 [Fair]	Same as alt-2 [Fair]	Additional roads/ long distance [Bad]
6)	Environmental Impacts	Further upstream location reduces the flooding risk. No severe impact for environment [Good]	No severe impact for environment [Fair]	No severe impact for environment [Fair]	No severe impact for environment [Fair]
7)	Property Acquisitions	Fewer affected houses [Good]	Some affected houses [Fair]	Some affected houses [Fair]	Some affected houses [Fair]
8)	Community including Property Access	Service roads and crossing points can provide the accessibility [Fair]	Service roads and crossing points can provide the accessibility [Fair]	Service roads and crossing points can provide the accessibility [Fair]	Only for bypass function and limited use of local people [Fair]
	[Good]	6	3	2	0
	[Fair]	2	5	6	4
	[Bad]	0	0	0	4

Note: Details of the evaluation are described in Appendix-2.

As mentioned in the above table, the Section-2 would be best with alternative-1, which has the highest number of “Good” evaluations.

This section has the potential for urban development along the planned road; therefore, the evaluation item of “3) benefits to urban development and residents” is thought to be more important than the others. In addition, the length of the alignment directly affects the construction cost and maintenance cost, so that shortest route is preferable.

In this therefore, the proposed alternative for the section-2 is as follows;

- Section-2: Alt-1 (Yellow colour line)

The Table 7.5.5 shows the evaluation result of alternatives for the Section-3.

Table 7.5.5 Characteristics of Alternatives (Section-3)

	Evaluation Items	Alternatives			
		Alt-1 (Yellow)	**Alt-2 (Red)**	**Alt-3 (Blue)**	**Alt-Branch (Green)**
1)	Consistency to integrated development plan	Well integrated same as original idea [Good]	Same as alt-1 [Good]	Same as alt-1 [Good]	No integration [Bad]
2)	Benefit to Traffic Congestion Relief	Functional [Good]	Functional [Good]	Functional [Good]	Limited functionality only for N13-N1 user (fewer users) [Bad]
3)	Benefits to Urban Development and Residents	Expected to develop along the road [Fair]	Expected to develop along the road [Fair]	Expected to develop along the road [Fair]	No possibilities [Bad]
4)	Road Safety	Ensured with service roads [Fair]	Ensured with service roads [Fair]	Ensured with service roads [Fair]	Fewer pedestrians expected [Fair]
5)	Affordability	Shortest, same as alt-3 [Good]	Slightly longer than alt-2 [Fair]	Same as alt-1 [Good]	More than twice as long as the others [Bad]
6)	Environmental Impacts	No severe impacts [Fair]	No severe impacts [Fair]	No severe impacts [Fair]	No severe impacts [Fair]
7)	Property Acquisitions	Fewer affected houses [Good]	Some affected houses [Fair]	Fewer affected houses [Good]	Some affected houses [Fair]
8)	Community including Property Access	No severe disconnection of community [Fair]	No severe disconnection of community [Fair]	No severe disconnection of community [Fair]	No severe disconnection of community [Fair]
	[Good]	4	2	4	0
	[Fair]	4	6	4	4
	[Bad]	0	0	0	4

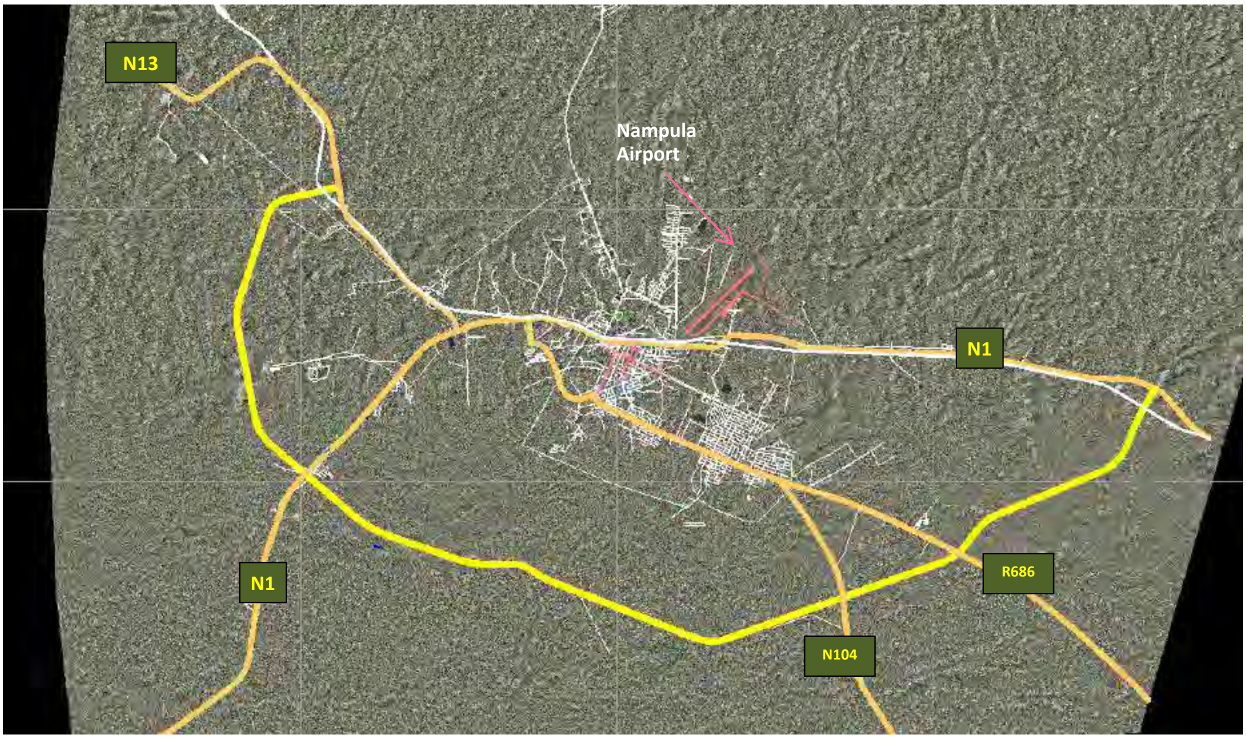
Note: Details of the evaluation are described in Appendix-2.

As mentioned in the above table, for Section-3 both alternatives-1 and 3, which are the same route, scored equally and had the same number of “Good” evaluations.

This short section gives more importance to having fewer acquisitions and project costs from the selection of alternatives. In this therefore, the proposed alternative is as follows;

- Section-3: Alt-1 or Alt-3 (Yellow or Blue colour line)

The selected alignment integrated in Section-1 and Section-3 proposed for Nampula Southern Bypass Road is shown in Figure 7.5.2. In Appendix-6, the alternatives and selected route/alignment are indicated in the maps with more detailed information.



※Alt-1 (shown by yellow line) and Alt-3 have the same linearity within Section-3.

Figure 7.5.2 Selected Route/Alignment of Nampula Southern Bypass Road

7.5.3 Cuamba Bypass Road

As the outline of the alternative described in Table 7.2.3 and depicted in Figure 7.2.5, and Table 7.5.7 show the result of the multi-criteria analysis for the alternatives at each section of the Cuamba Bypass Road. The bottom of the table shows the total number scored by each evaluation such as good, fair and bad for each alternative.

The evaluation result of the alternatives for Section-1 is shown below.

Table 7.5.6 Characteristics of Alternatives (Section-1)

	Evaluation Items	Alternatives		
		Alt-1 (Yellow)	Alt-2 (Red)	Alt-3 (Blue)
1)	Consistency to integrated development plan	Well integrated same as original idea [Good]	Same as alt-1 [Good]	Same as alt-1 [Good]
2)	Benefit to Traffic Congestion Relief	Functional [Good]	Functional [Good]	Functional [Good]
3)	Benefits to Urban Development and Residents	Limited area due to low land area along the river [Fair]	Limited area due to low land area along the river [Fair]	Limited area due to low land area along the river [Fair]
4)	Road Safety	No steep curves or slopes exist [Fair]	No steep curves or slopes exist [Fair]	No steep curves or slopes exist [Fair]
5)	Affordability	Original alignment [Fair]	Possibility of utilisation of rock material [Good]	Possibility of utilisation of rock material [Good]
6)	Environmental Impacts	No severe impacts exist [Fair]	Same as alt-1 [Fair]	Same as alt-1 [Fair]
7)	Property Acquisitions	Minimum houses affected [Good]	Minimum houses affected [Good]	Houses affected, passes through residential area [Bad]
8)	Community including Property Access	Need to avoid disconnection between community areas [Fair]	Need to avoid disconnection between community areas [Fair]	Already passes through a community area [Bad]
	[Good]	3	4	3
	[Fair]	5	4	3
	[Bad]	0	0	2

Note: Details of the evaluation are described in Appendix-2.

As mentioned in the above table, the Section-1 would be best with the alternative-2, which has the highest number of “Good” evaluations.

Almost all of the alternatives are similar except for the utilisation of rock materials and impacts on communities. Therefore, the most appropriated route shall be considered to be the one that has the least impact on communities and lowest project costs. Therefore, the proposed alternative for the section-1 is as follows;

- Section-1: Alt-2 (Red colour line)

Regarding the Section-2, Table 7.5.7 shows the evaluation result of the alternatives.

Table 7.5.7 Characteristics of Alternatives (Section-2)

	Evaluation Items	Alternatives	
		Alt-1 (Yellow)	**Alt-2 (Red)**
1)	Consistency to integrated development plan	Well integrated same as original idea [Fair]	Well integrated with original idea plus municipality's growth pole plan [Good]
2)	Benefit to Traffic Congestion Relief	Functional, mixture with current N360 users [Fair]	Functional [Good]
3)	Benefits to Urban Development and Residents	Area alongside N360 can be developed [Fair]	Growth pole is expected, other area is only undeveloped area [Fair]
4)	Road Safety	No steep curves or slopes exist, local users are mixed [Fair]	Totally undeveloped land to design a safer road [Good]
5)	Affordability	Original alignment with use of current road [Good]	Longer length than alt-1 [Fair]
6)	Environmental Impacts	No severe impacts exist [Fair]	Same as alt-1 [Fair]
7)	Property Acquisitions	Some houses affected [Fair]	Minimum houses affected [Good]
8)	Community including Property Access	Limited section passes the village area, need to avoid disconnection between community areas [Fair]	No major community area [Good]
	[Good]	1	5
	[Fair]	7	3
	[Bad]	0	0

Note: Details of the evaluation are described in Appendix-2.

The points of selection for this section consider the requests from Cuamba Municipality which is to integrate their development plan and to lessen the impact on the existing village. Therefore, the result which has highest number of "Good" scores is alternative-2.

- Section-2: Alt-2 (Red colour line)

The selected alignment integrated in the Section-1 and Section-2 which are proposed for Cuamba Bypass Road is shown in Figure 7.5.3. In Appendix-6, the alternatives and selected route/alignment are indicated in the maps with more detailed information.

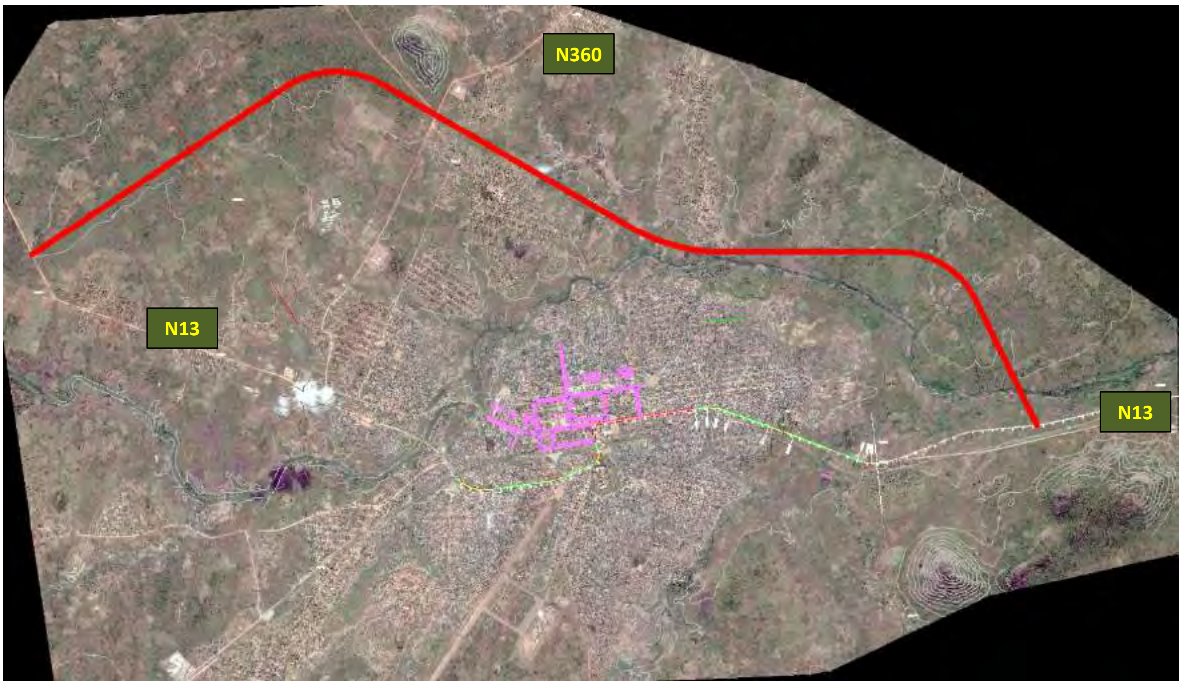


Figure 7.5.3 Cuamba Bypass Road Proposed Alternative

7.6 Road Development Plans/Image for each Target Road

These Target Roads are expected to provide not only a diversion route for through traffic, but also opportunities to enjoy urban development and accessibility to the benefits of urban services. Therefore, the future vision for the service roads and crossing/connecting types of other roads should be thought of in terms that are in accordance with the local conditions and needs.

This section describes draft ideas of the future visions around the target roads for discussion until the implementation of this project, even though they partly go beyond the scope of the preliminary design.

(1) Nacala Port Access Road

The function of this road is to provide direct access to Nacala port for the heavy vehicles diverted from passing within the Nacala city area, and to connect to the future planned industrial park and multi-modal terminal. The route is mainly in the protected area that prohibits buildings; therefore, there are not many communities along the road. In this, therefore, the services road along the main road is planned in the limited section which is indicated by the green colour line in the drawing.

The north-end point of the service road is connected to the salt pan and communities near the sea-side, where it requires crossing the main-road with a separated-grade. And the service road is provided to connect the planed industrial park and the R702.

The southern section between N12 and R702 is expected to be used by not only heavy vehicles but also the vehicles shortcutting to Nacala-a-Velha from The Nampula side, and there is a difficult area to build-up due to steep undulations. Therefore, the service road is planned in a limited section to connect the multi-modal terminal from R702.

The proposed crossing types at each road for the initial stage and completion stage are shown in Table 7.6.1, based on the expected traffic volume.

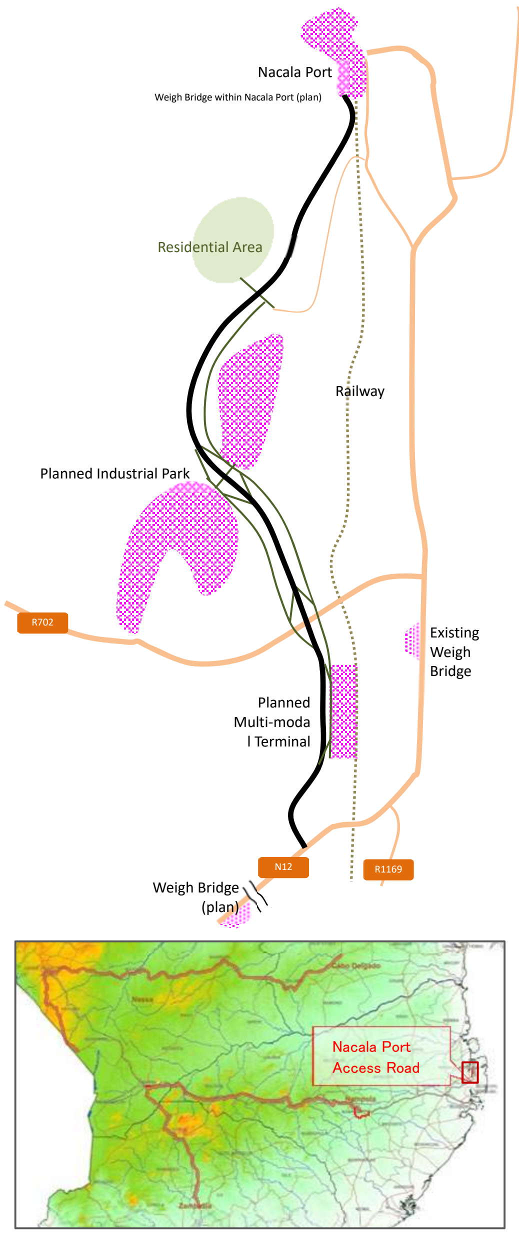


Figure 7.6.1 Road Development Plan for Nacala Port Access Road

Table 7.6.1 Crossing Types at each Road

Crossing Point	Completion Stage	Initial Stage (Desirable Vision)
R702	Separated-grade	Separated-grade
N12	Separated-grade	At-grade

(2) Nampula Southern Bypass Road

There are a lot of possibilities for development along the road; therefore, the service road shall be installed through all of the sections. In order to prevent overloaded vehicles, a weigh bridge station might be located at the beginning of the roads for both N1 sides. For the benefit of drivers and encouraging economic activities, the road side stations (Michinoeki) are proposed in the middle section of the road. Based on the interviews with the municipality, the Study Team understands that the government offices are planned to relocate near the cross-section of N104.

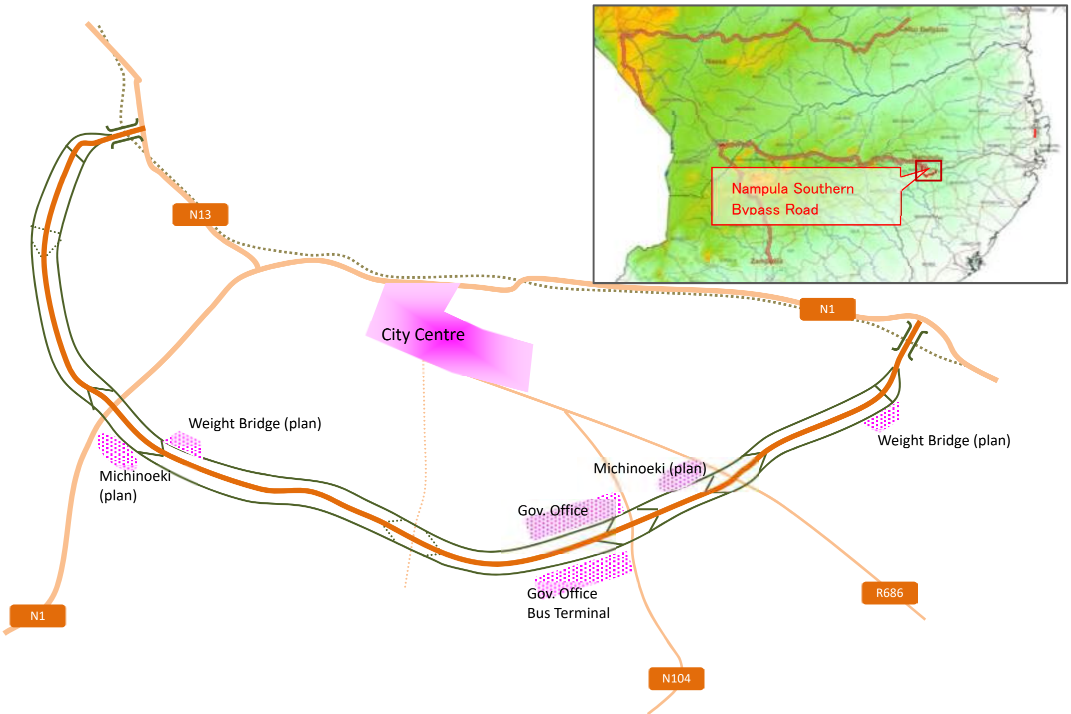


Figure 7.6.2 Road Development Plan for Nampula Southern Bypass Road

The types of connections with the roads and the railways are considered as follows.

Table 7.6.2 Crossing Types at each Road and Railway

Crossing Point	Completion Stage	Initial Stage (Desirable Vision)
N1 (East)	Separated-grade	At-grade
Railway (N1)	Flyover	Flyover
R686	Separated-grade	Separated-grade
N104	Separated-grade	Separated-grade
N1 (South)	Separated-grade	Separated-grade
Railway (N13)	Flyover	Flyover
N13	Separated-grade	At-grade

(3) Cuamba Bypass Road

Alignment of this road runs on the north side of the Muanda bridge, and passes through a residential area; therefore, sidewalks will be installed at the section where the residential area exists. A weighbridge station is proposed near the growth pole at the N13. A roadside station is proposed near the connection with N360.

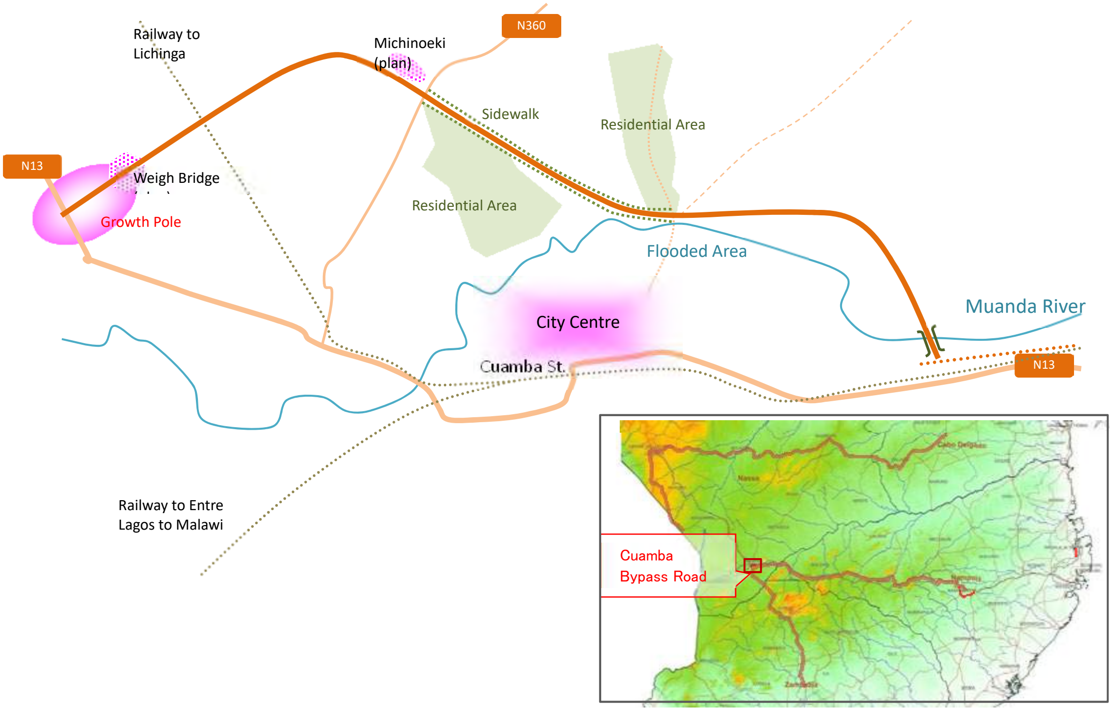


Figure 7.6.3 Road Development Plan for Cuamba Bypass Road

There are several crossing points with the Target Road, Table 7.6.3 shows the types of crossings at each point.

Table 7.6.3 Crossing Types of each Road, River and Railway

Crossing Point	Completion Stage	Initial Stage (Desirable vision)
N13 (East)	At-grade	At-grade
Muanda River	Bridge	Bridge
Road to connect between Najato to city centre (near Cassiano Bridge)	Separated-grade or At-grade	Separated-grade
N360	Separated-grade	Separated-grade
Railway to Lichinga	At-grade	At-grade
N13	Separated-grade	At-grade

In order to consider the connectivity with the future road plans, the Study Team needs to grasp the i) Road development plan between the city centre and the northern growth pole, ii) Future development plan for each growth pole and iii) Future development plan around Najane and Adine 3 area from the Cuamba Municipality.

CHAPTER 8 Preliminary Design and Cost Estimation

8.1 Design Procedure

8.1.1 Design Policy

The objectives of Chapter 8 are to propose the most technically feasible, economically viable, and environmentally acceptable road alignments, cross sections, including provisional use, and structures such as bridges in some conceivable options based on examination of the advantages/disadvantages of the respective options in terms of traffic safety aspects, environmental aspects, construction costs and other technical aspects. The Survey will also assess the impact of the selected option on vulnerable road users such as pedestrians.

The purpose of the bypass and the port access road is to alleviate serious traffic accident risk through a process of exclusion of heavy goods vehicles and through traffic in urban areas, in addition to this mobility purpose, promotion of roadside development and accessibility from the roadside should be considered as well.

8.1.2 Proposal Process for the Optimum Route and Design

(1) **Design Procedure**

The proposed road, including provisional operation, will be selected in accordance with the following procedure.

Selection of the Applicable Design Conditions	Chapter 6
↓	
Route Selection	Chapter 7
↓	
Natural Condition Survey (Topographic, Geological and Material Survey)	
↓	
Review and adjustment of selected route (from the engineering aspect and social impact)	
↓	
Necessary Analysis and Design (Hydrology, Structures, Pavement, Drainage, Safety Facilities, etc.) Specific Considerations (Groundwater, Soil Erosion, Sediment Runoff, Problem Soil)	
↓	
Examination of provisional opening with 2-lanes	
↓	
Quantities and Cost Estimation	

Figure 8.1.1 Preliminary Design Procedure

The road alignment and design should be determined and compared in accordance with the following concepts. In particular, minimisation of the social impact such as resettlements should be well-considered. In other words, the proposed road alignment and design should be determined not only from the economic and engineering viewpoints but also taking into account environmental and social impacts.

(2) **Specific Consideration**

In the first visual survey at the site and information from existing maps, some eroded areas, swamp areas and roads collapsed by concentrated heavy rain were identified as shown in the following photos.

Sediment Runoff

Spring Water

High Water Table

Figure 8.1.2 Specific Problems identified at the Site

From these situations, the following matters should be considered:

- Problem soil (soft soil at swamp area)
- Problem soil (expansive soil such as black cotton soil)
- High water table at swamp area
- Spring water at Nacala area
- Sediment runoff at Nacala area
- Soil erosion at Nacala area

Countermeasures against these considerable problems will be designed and proposed based on the natural condition survey (Topographic survey and Geotechnical survey) results in the Preliminary Design.

Additionally, in January 2015, Mozambique was ravaged by torrential rain in the central and northern regions, and this heavy rain caused washout of some bridges and roads as shown in the following photos. Hence, final road level and bridge length will be determined through careful hydrological analysis and flood records.

Figure 8.1.3 Bridges and Roads Washed out in January 2015

8.2 Natural Condition Survey

8.2.1 Geological and Soil Survey

A Geotechnical Survey was carried out for the road structural design and foundation design for the main structures planned on the target roads with the following survey works entrusted to the local sub-consultant.

(1) Nacala Port Access Road

1) Outline of Survey

Items and quantities for the Geological and Soil Survey are shown in Table 8.2.1.

Table 8.2.1 Items and Quantity for Geological and Soil Survey (Nacala Port Access Road)

Items		Unit	Quantity	Remarks
Site Survey				
Mechanical Boring includes SPT	BH NCL 1	m	12	
	BH NCL 2	m	20	
Undisturbed Soil Sampling (UDS)		No.	4	One from BH 1, 3 from BH 2
Test Pit & sub-grade Sampling		No.	14	One site per 1 km in average along the target road
Material Sampling (1)		No.	3	From candidates for borrow pit for fill material
Material Sampling (2)		No.	2	From candidates for quarry sites for aggregate material
Laboratory Tests				
Physical Soil Test (SPT , UDS samples)		No.	24	Gs, WC, Grain, LL/PL*1, etc.
Mechanical Soil Test (UDS samples)		No.	4	Tri-axial compression test CD
CBR Test for sub-grade material		No.	13	From Sub-grade sampling
CBR Test for fill material		No.	3	From Material Sampling (1)
Test for aggregate material		No.	2	From Material Sampling (2)

2) CBR of Existing Surface Soil for Subgrade

The CBR tests for subgrade were carried out for 14 samples collected from 14 trial pits dug 1.0 to 1.5 m deep targeting the existing surface soil along the targeted road. Excepting one sand sample from TP12, Compaction Tests and CBR Tests showed good results for 13 samples. The samples for the CBR Tests were prepared for three densities, 90%, 95% and 100% of Maximum Dry Density (MDD) compacted under the Modified AASHTO compaction method after a 4 day soaking. The results are shown in Table 8.2.2.

Table 8.2.2 Result of CBR Test for Subgrade and Evaluation (Nacala Port Access Road)

No. NCL	Coordinates X	Coordinates Y	MDD (g/cm³)	OMC (%)	Swell (%)	CBR (%)	Class of CBR (Section)
TP1	679861	8389325	1.950	8.1	0.50	4.2	S2 (CBR 3 – 4%) 0+00 - 39+00
TP2	679535	8388932	1.788	15.8	0.09	3.4	
TP3	679054	8388127	1.600	20.4	0.12	3.0	
TP4	678707	8387458	1.948	10.3	0.00	3.7	
TP5	678441	8386919	1.878	12.0	0.00	0.7	Unsuitable for Sub grade (CBR < 2%) 39+00 - 70+00
TP6	677662	8385561	1.800	15.5	0.11	0.9	
TP7	677666	8385484	1.922	12.4	0.10	1.0	
TP8	677675	8384503	1.652	18.5	0.09	1.5	
TP9	678127	8383547	1.970	9.7	0.00	3.4	S2 (CBR 3 – 4%) 70+00 - 102+00
TP10	679014	8381877	1.700	19.0	0.13	4.9	
TP11	679325	8381263	1.950	8.1	0.00	39.3	S4 (CBR 8 -14%) 102+00 –154+40
TP12	679575	8380300	-	-	-	-	
TP13	679477	8379258	1.972	4.0	0.07	10.8	
TP14	678900	8377975	2.087	8.0	0.09	10.3	

MDD: Maximum Dry Density, OMC: Optimum Moisture Content
(Method : 4.536kg rammer, 5 layer, 55 blows)
CBR, Swell: 4 day soak , Proctor (MDD90%) density
Class : Refer to Table 8.2.3

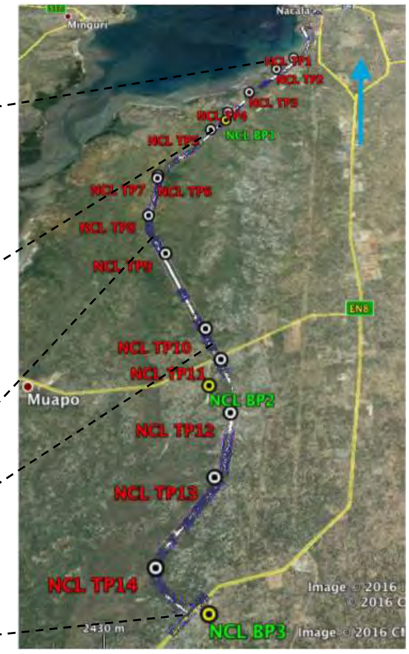


Figure 8.2.1 Location of Soil Survey (Nacala Port Access Road)

The above CBR tests were carried out on the specimens which were taken from 1 m depth of the test pits and adjusted to 90% of the maximum dry density (MDD). The results of the CBR tests are evaluated as the density of existing ground for subgrade. Therefore, these CBR values shall be applied to the subgrade of road sections where the ground will be cut or banked with thickness less than around 2 m.

SATCC set the subgrade class based on this CBR for the pavement design as shown in Table 8.2.3.

Table 8.2.3 Subgrade Class Designation Based on CBR

	Subgrade class designation					
Subgrade CBR Ranges (%)	S1	S2	S3	S4	S5	S6
	2	3 - 4	5 - 7	8 - 14	15 - 29	30+

Source: Code of Practice for the Design of Road Pavement (Draft), SATCC, 1998 (reprinted 2001)

In consideration of the economic efficiency and workability, it is desirable for the subgrade class to be set as enough long sections in accordance with cutting-filling division and the change of CBR values in perspective, and it shall not be set for excessively short divisions.

The CBR values were less than 2 % for the samples from TP5 to TP8. These sampling points were located in the deposition areas of sediment that flowed out from valleys or in the valley between the hills. There are several sections where the design elevation is close to the existing ground level where the road crosses these valleys in the section between 39+00 and 70+00. For these sections of particularly low CBR, replacement of the subgrade layer with well compacted material is recommended rather than setting a low subgrade class for each small section.

3) Material Test on Candidate Sites for Borrow Pits

The three sites for sampling were selected from the vicinity of the planned route, in consideration of the possibility to be candidate sites for borrow pits for fill material. These three samples were subjected to compaction tests and CBR tests.

For subgrade constructed with filling, SATCC[1] has recommended soaked CBR > 15% as the nominal strength. The density of this filled subgrade is 93% of MDD compacted under the modified ASSHTO.

For subbase without cementation, soaked CBR > 30% has been recommended as the nominal strength, under the condition of density with 95% of MDD compacted under the modified ASSHTO.

Test results shown in Table 8.2.4 indicate that these fill materials are able to obtain soaked CBR between 15 % and 30 % by performing the compaction degree as 95% of MDD under quality management.

Table 8.2.4 Result of Compaction and CBR Tests for Materials from Candidate Borrow Pits (Nacala Port Access Road)

No. NCL	Coordinates		MDD (g/cm^3)	OMC (%)	Swell (%)	CBR (%)		
	X	Y				MDD 90%	MDD 95%	MDD 100%
BP1	678695	8387209	2.052	8.7	0.00	6.2	29.6	43.4
BP2	679207	8380789	2.051	7.5	0.00	8.6	14.7	25.0
BP3	679650	8377362	1.977	9.0	0.09	7.5	21.1	41.7

In order to ensure a soaked CBR of 15%, these test results indicate that the subgrade shall be compacted to achieve 95 % of MDD which is equivalent to the condition for subbase, and higher than the SATCC's recommendation for subgrade.

It should be noted that the surface of the borrow pits and bank have the characteristic of being susceptible to erosion during construction and after development. This is because of the soil characteristics which are sand of fine to medium grain, including the fine fraction of about 25% in the vicinity of the planned route. In particular, on the slopes of cut and fill, there is a need to consider the preventive measures to erosion by appropriate rainwater drainage and vegetation.

[1] Code of Practice for the Design of Road Pavement (Draft), SATCC, 1998 (reprinted 2001), Table 5.1: Nominal strength classification of materials in the design catalogue

On the other hand, these soils can be improved to raise their resistance to erosion, and also to raise the efficiency of compaction by means of mixing with more fine cohesive soil. Several hundred meters west of the route, in the vicinity of 14 + 200, better quality soil that consists of a greater fine fraction has been observed, though it was not tested in the laboratory.

4) Quarry Site and Test for Aggregate

Road construction aggregate for Nacala City is often carried from Namialo quarry site about 100 km away, but there was no record of a quarry for the road construction in the vicinity of Nacala. However, two quarries (Bolder Inc. and Geocrush Co., Ltd.) are running for the rehabilitation works of the railway and construction of Nacala-a-Velha coal harbour. In the vicinity of Nacala there is a possibility to use these limestone and granitic rocks as aggregate. , Samples were taken from these quarries and subjected to aggregate test for confirmation of its acceptability. The test results are shown in Table 8.2.5, and the locations of the quarries are shown in Figure 8.2.2.

Figure 8.2.2 Location of Quarries (Nacala)

Geocrush quarry (granite) and Bolder quarry (limestone) are not suitable quarry sites that can provide quality aggregate for the surface layer and the seal of s pavement, because of high Aggregate Crushing Values (ACV) and insufficient Ten % Fineness Value (TFV) found in half of the samples (TFV).

If using these quarry stones as part of the aggregate for sub-base or surface, it is necessary to check that the quality satisfies the standard for each use for each batch to buy. In particular, the Flakiness Index (55%) indicated on the limestone of Bolder, is a value that cannot be recommended as an aggregate for the road, the Flakiness Index is an essential quality to be checked against the limestone.

Table 8.2.5 Result of Aggregate Test (Quarry Sites near Nacala Port Access Road)

Quarry Site	Characteristics and Result of Test					
	Rock Type	Density(g/cm^3)	TFV (kN)	ACV (%)	Flakiness Index (%)	LA (%)
Geocrush X= 678843 Y=8371517	Granite	2.609	N/A	32	29	47.8
		2.649	N/A		-	22.3
	Granite*	2.702	167	24.8	—	39.5
Bolder X= 699999 Y=8384379	Limestone	-	220	21.4		
	Limestone	-	100	27.5		
	Limestone	-	51.28	34.0		
	Limestone	-	51.28	34.0		
	Limestone	2.63	-	26.9	55	25.0
Standards			Subbase: 110 Surface: 180 Seal：210	□21～29 Granite, Limestone: □ 29	Subgrade:□30 Subbase □35 Surface□25-35 depend on size and class	

*: Data provided from Quarry Company
ACV: Aggregate Crushing Value, TFV: Ten percent Fines Value (= 10% FACT)
Flakiness index: Flat index by peeling resistance test for aggregate
LA (Loss by Abrasion): Weight loss ratio by Los Angeles test (abrasion loss test)
Standards： STACC Section 3700s, 4200s, 4300s、SANS 1200 M:1996 (SABS)

Based on the result of the aggregate test, it was impossible to find a quarry that can supply a suitable road aggregate stably in the vicinity of the planed route, though there were also some samples that can be used as part of the aggregate for the road. Currently, Namialo quarry, which is across the road about 80km to the west of the route, is considered the most reliable quarry site as a running site, because of experience in supplying aggregate to construction sites in Nacala City and Nacala Dam (end point because of the position to the west about 15km). The test results of Namialo quarry are shown in the section of Nampula Southern Bypass

5) Geological Condition for Foundation of Structure

Mechanical borings were carried out at two typical points where the heavy structures are planned.

The findings are summarized in the Boring Logs shown in Figure 8.2.3. It shows also the soil test results of samples taken from the boreholes.

Findings in BH NCL 01

Location: Near the planed crossing with Nacala-a-Velha Road
Elevation: 99.73m,
Groundwater Level: GL – 3.0 m.
Formation:

- Top soil (0 – 3.4m) is non cohesive sand with N-value = 8 to 9.
- Unconsolidated Layer (3.4 – 4.0m) is a mixture of loose sand and silt with low plasticity, and with an organic soil band.
- Weathered mudstone (pelitic stone/ 4.0 – 6.7m) is like very stiff silty clay having N-value more than 50
- Sand stone (6.7 – 12.0m/ bottom） is consolidated soft rock collected as cylindrical core, though crack-rich between 9.0 – 9.3 m depth.

Coordinates of Boring Points

Name	X	Y	Z
BH NCL1	679251	8381461	99.73
BH NCL2	680077	8390051	2.77

Figure 8.2.3 Location of Boring Site

The weathered mudstone layer and sandstone layer, which were found deeper than 4.0m (95.7m in Elevation, are suitable for a supporting layer for planed heavy structures here.

Findings in BH NCL 02

Location: Near the planed southern Abutment of Port Bridge

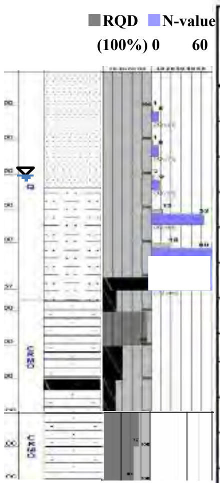
Elevation: 2.77m,
Groundwater Level: 0.8 m below ground level.
Formation: Top soil (0 - 3.5m) is non cohesive Silt and loose Sand with N-value 7 to 11

- Highly weathered mudstone (3.5 – 18m) is like moderate to stiff clayey silt with sand bands. Stiffness gradually increased with depth. (3.5 to 7.5 m: N = 19 to 22. 7.5 to 18 m : N = 31 to 44 except between 11.5 and 14.5m(N-values >50)
- Mudstone (18 to 20m) is a consolidated soft rock, collected as long cylindrical core except crack-rich zone in 18 to 19m

Further investigation is required to confirm the horizontal change of characteristics in order to evaluate the supporting layer for the heavy structures, though a very stiff layer was found in 11.5 to 14.5m with N-value more than 50.

NCL BH 1
EL = 99.73m
(No.104 + 20.0)

EL(m)
100.0 m



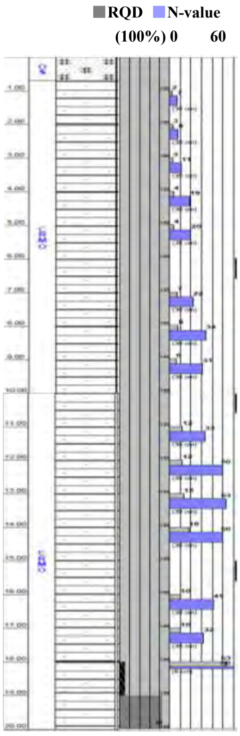
90.0 m

NACALA PORT ACCESS ROAD		SITE
Tecnica	SYNTHETIC TABLE OF RESULTS	NACALA BH1

Depth (m)	LOG Symbol	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS LL	PL	PI	LSH	MC	SIEVE ANALISYS GM	MATERIAL (%) 0.075	0.075-0.15	0.425	2.00	SG gr/cm3	Triaxial φ (°)	C' (kpa)
1				NP	NP	NP	0.00	16.93	1.75	5.90	6.00	67.10	20.70	2.585		
2		SW	8	NP	NP	NP	0.00	5.29	1.74	9.20	7.90	58.50	24.00	2.664		
3			8	NP	NP	NP	0.00	14.71	1.80	8.40	6.20	60.90	21.40	2.613		
4		SM	9	28.80	16.90	11.90	5.00	12.24	1.46	21.50	7.60	49.80	21.00	2.431		
5		CL	52					7.58	0.21	66.10	22.10	8.40	2.80	2.445		
6		CL	60 (22)					28.75						2.471	31.8	6.0
7																
8																
9		SAND STONE														
10																
11																
12																
BH1 . NACALA				ELEVATION (m)			99.73		Ground Water			3.0				

NCL BH 2
EL = 2.77m
(No.7 + 0.0)

EL (m)



0.0 m

- 10.0 m

NACALA PORT ACCESS ROAD		SITE
Tecnica	SYNTHETIC TABLE OF RESULTS	NACALA BH2

Depth (m)	LOG Symbol	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS LL	PL	PI	LSH	MC	SIEVE ANALISYS GM	MATERIAL (%) 0.075	0.075-0.15	0.425	2.00	SG gr/cm3	Triaxial φ (°)	C' (kpa)
1		SM		NP	NP	NP	0	0.20	1.07	30.80	9.80	53.60	5.90	2.619		
2		SM	7	NP	NP	NP	0	9.88	1.49	11.70	9.80	67.70	10.90	2.575		
3		SM	8	15.00	12.10	2.80	1.00	12.12	1.14	30.50	8.00	53.20	8.20	2.600		
4			11	51.50	29.50	22.00	10.00	5.85	1.15	32.40	7.20	50.70	9.50	2.589		
5			18	35.10	21.50	13.60	7.30	24.69	1.05	38.00	8.80	42.60	9.90	2.533	30.1	31.3
6			20	53.50	34.50	19.00	9.00	8.95	0.05	89.10	8.10	2.30	0.50	2.290		
7				47.70	30.80	16.50	9.00	25.30	0.26	62.40	15.80	20.50	1.30	2.291		
8			22	56.00	39.90	16.10	8.00	9.59	0.07	75.00	10.60	3.30	0.80	2.632		
9			34	42.60	31.90	10.70	5.30	31.23	0.08	87.50	6.10	6.00	0.40	2.306		
10			31					28.86						2.450	35.7	32.6
11		ML		41.20	25.80	15.40	7.70	8.18	0.04	81.80	16.20	1.50	0.50	2.220		
12			33	52.20	28.60	23.60	11.90	27.18	0.02	89.30	9.80	0.70	0.30	2.249		
13			50	49.50	34.10	15.40	7.70	8.44	0.19	75.60	16.00	4.60	2.70	2.307		
14			53	47.30	29.80	17.50	8.80	20.71	0.15	65.30	22.10	11.80	0.60	2.348		
15			50					17.62						2.516	34.8	7.7
16				51.10	28.30	22.80	11.30	5.36	0.03	92.20	6.40	1.00	0.30	2.421		
17			41	46.80	35.50	11.30	5.30	20.79	0.96	53.50	7.90	23.60	8.80	2.345		
18			32	42.00	18.90	23.10	8.30	4.60	0.04	82.00	14.30	2.50	0.30	2.548		
19		FRACT SAND STONE	60 (6)											2.208		
20														2.407		
BH2 . NACALA				ELEVATION (m)			2.77		Ground Water			0.8				

Figure 8.2.4 Bore Log and Summary of Soil Tests (Nacala Port Access Road)

(2) **Nampula Southern Bypass Road**

1) Outline of Survey

Items and quantities for Geological and Soil Survey are shown in Table 8.2.6.

Table 8.2.6 Items and Quantity for Geological and Soil Survey (Nampula Southern Bypass Road)

Items		Unit	Quantity	Remarks
Site Survey				
Mechanical Boring includes SPT	BH NPL 1	m	10.3	
	BH NPL 2	m	10	
	BH NPL 3	m	10	
	BH NPL 4	m	13.7	
Test Pit & sub-grade Sampling		No.	33	TP01 - TP33, One site per 1 km in average along the target road
Material Sampling (1)		No.	4	From candidates for borrow pit for fill material
Material Sampling (2)		No.	2	From candidates for quarry sites for aggregate material
Laboratory Tests				
Physical Soil Test (SPT , UDS samples)		No.	58	Gs, WC, Grain, LL/PL*1, etc.
CBR Test for sub-grade material		No.	33	From Sub-grade sampling
CBR Test for fill material		No.	4	From Material Sampling (1)
Test for aggregate material		No.	2	From Material Sampling (2)

2) CBR of Existing Surface Soil for Subgrade

The CBR tests for subgrade were carried out for 33 samples collected from 33 trial pits dug 1.0 to 1.5 m deep targeting the existing surface soil along the targeted road. The results of the Compaction Tests and CBR Tests were acceptable for 33 samples. The samples for the CBR Tests were prepared for three densities, 90%, 95% and 100% of Maximum Dry Density (MDD) compacted under the Modified AASHTO compaction method after soaking for 4 days. The results are shown in Table 8.2.6 together with the subgrade class evaluated based on the CBR test result.

The CBR tests were carried out on the specimens which were taken from 1 m depth of the test pits and adjusted to 90% of the maximum dry density (MDD). The results of the CBR tests are evaluated as the density of existing ground for subgrade. Therefore, these CBR values shall be applied to the subgrade of road sections where the ground will be cut or banked with thickness less than around 2 m.

The CBR values were less than 2 % for some samples taken from the section KM 22+00 to 23+50 such as TP21 and TP24. There are several sections where the design elevation is close to the existing ground level in this section. Further detailed survey is recommended to identify these sections of particularly low CBR, and replacement of the subgrade layer with well compacted material is recommended rather than setting a low subgrade class for each identified low CBR section.

Table 8.2.7 Results of CBR Tests for Subgrade and Evaluation (Nampula Southern Bypass Road)

No.	Coordinates		MDD	OMC	Swell	CBR	Subgrade Class*
NPL	X	Y	(g/cm³)	(%)	(%)	(%)	(Target section)
TP1	539974.00	8328009.00	1.994	10.7	0.00	4.3	S2 (CBR 3 - 4%) 0+00 - 5+00
TP2	539413.00	8326902.00	2.064	8.6	0.00	26.4	S4 (CBR 8 - 14%) 5+00 - 45+00
TP3	538506.00	8326112.00	2.204	11.1	0.00	7.0	
TP4	538030.00	8325988.00	2.373	7.9	0.00	15.6	
TP5	537318.00	8325568.00	2.019	8.9	0.00	13.6	
TP6	536414.11	8325242.02	1.920	10.0	0.00	2.8	S2 (CBR 3 - 4%) 45+00 - 65+00
TP7	535293.18	8324263.20	1.904	9.2	0.00	7.3	
TP8	533956.75	8323773.26	2.084	8.0	0.00	13.6	S4 (CBR 8 - 14%) 65+00 - 90+00
TP9	532983.38	8323423.24	1.986	8.9	0.00	39.1	
TP10	532241.00	8323105.00	1.915	9.1	0.00	3.1	S2 (CBR 3 - 4%) 90+00 - 150+00
TP11	530969.00	8322682.00	2.002	10.1	0.00	3.5	
TP12	530113.02	8322493.75	2.081	8.0	0.00	8.5	
TP13	528874.29	8322897.97	1.900	8.7	0.00	5.0	
TP14	527734.00	8323341.00	2.071	8.0	0.00	7.1	
TP15	526424.00	8323872.00	1.987	9.3	0.00	33.7	S4 (CBR 8 - 14%) 150+00 - 215+00
TP16	525246.96	8324134.80	1.988	6.4	0.00	33.4	
TP17	524059.92	8324186.84	2.002	8.4	0.00	13.9	
TP18	523012.03	8324236.24	1.972	10.1	0.00	17.4	
TP19	522017.53	8324669.06	2.168	7.4	0.00	26.8	
TP20	521467.07	8325242.54	1.947	8.2	0.00	37.5	
TP21	520969.55	8325925.00	1.923	10.1	0.00	1.9	S2 (CBR 3 - 4%) 215+00 - 245+00 Counter measure shall be taken for some localized low CBR portions, such as replacement.
TP22	520745.16	8326253.86	2.052	8.4	0.04	3.7	
TP23	520506.07	8326580.79	1.980	12.0	0.02	10.5	
TP24	520162.77	8327082.15	1.836	12.4	0.04	1.2	
TP25	519977.70	8327777.18	1.993	10.3	0.03	6.5	
TP26	519839.14	8328764.53	1.899	9.2	0.00	23.8	S5(CBR 15 - 29%) 245+00 - 304+00
TP27	519707.82	8329690.11	1.897	8.4	0.00	32.8	
TP28	519732.79	8330754.67	1.964	8.1	0.00	35.5	
TP29	520113.49	8331747.54	1.798	8.0	0.00	36.2	
TP30	520596.30	8332593.61	1.927	10.1	0.00	25.2	
TP31	521819.89	8332463.50	2.096	8.0	0.05	22.6	
TP32	538919.23	8328239.05	1.900	9.2	0.04	21.9	S5 (CBR 15 - 29%) Alternative route on starting point side
TP33	538533.16	8327285.36	1.953	8.7	0.04	50.2	

MDD: Maximum Dry Density, OMC: Optimum Moisture Content, (Method : 4.536kg rammer, 5 layer, 55 blows)

CBR, Swell: 4 day soak, Proctor (MDD90%) density, Subgrade Class : Refer to Table 8.2.3

* Subgrade Class and its section are recommendations in which economic efficiency is taken into consideration

3) Material Test on Candidate Sites for Borrow Pits

For subgrade constructed with fill, SATCC has recommended soaked CBR > 15% as the nominal strength. The density of this filled subgrade is 93% of MDD compacted under the modified ASSHTO.

For subbase without cementation, soaked CBR > 30% has been recommended as the nominal strength, with density of 95% of MDD compacted under the modified ASSHTO.

The four sampling sites were selected from the vicinity of the planned route, in consideration of the possibility to be candidate sites for borrow pits for fill material. These four samples were subjected to compaction tests and CBR tests.

Test results shown in Table 8.2.7 indicate that these fill materials are able to obtain soaked CBR between 26 % and 74 % when the compaction degree is 95% of MDD under quality management.

On the other hand, the CBR values of the 33 samples collected along the planed route varied violently including soil samples that cannot achieve a CBR of 15% even after compaction to a density of 95% of MDD. Especially in the samples collected from 0+00 to 150+00 and from 215+00 to 245+00, the CBR values of more than half of the samples cannot achieve CBR 15% at the density of 95% of MDD as shown in Figure 8.2.6. For this reason, if the subgrade is to be constructed with excavated soil from along the route, it is necessary to re-confirm the CBR value.

Figure 8.2.5 Location of Soil Sampling for Existing Ground and Borrow pits (Nampula Southern Bypass Road)

Table 8.2.8 Results of Compaction and CBR Tests for Materials from Candidate Borrow Pits (Nampula Southern Bypass Road)

No. NPL	Coordinates		MDD (g/cm³)	OMC (%)	Swell (%)	CBR (%)		
	X	Y				MDD 90%	MDD 95%	MDD 100%
BP1	538394.27	8327065.34	2.146	7.1	0.00	47	26	54
BP2/TP7	535293.18	8324263.20				7	9	50
BP3	527765.07	8323521.02	1.929	9.1	0.00	46	64	50
BP4/TP18	523012.03	8324236.24				17	28	33
BP5/TP26	519839.14	8328764.53				24	45	52
BP6	519401.67	8326824.70	1.930	9.1	0.00	28	53	66
BP7	519977.85	8331616.67	2.129	8.0	0.00	38	54	48

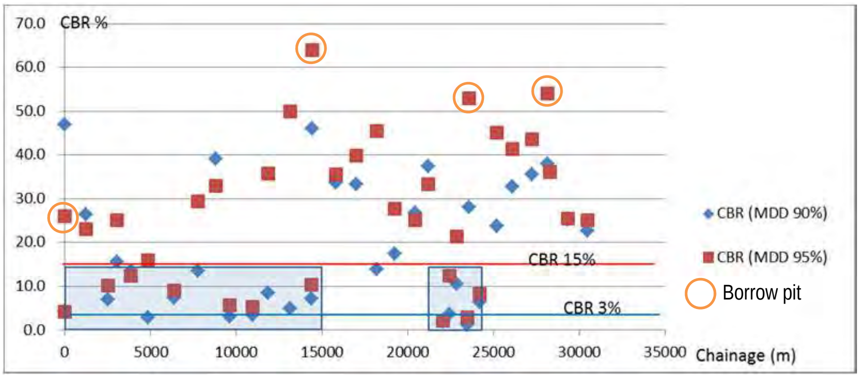


Figure 8.2.6 Variation of CBR along the Route (Nampula Southern Bypass Road)

4) Quarry Site and Test for Aggregate

No quarry site that can supply suitable aggregate for the surface or seal material for the road pavement, can be found in Nampula, and the most reliable quarry is Namialo which is located about 80 km away on the road to Nacala. Namialo is a commercially available quarry, were subjected to collection of one sample for confirmation. In addition, samples were taken from the Torrorone quarry nearest to the planned route; it was also subjected to laboratory test. The results for both of Namialo and Torrorone quarry are shown in Table 8.2.9.

Samples from Namialo are rated as good quality for the subgrade and the surface layer, but are insufficient as a sealing material. In the case of using these quarry stones as sealing material, it is necessary to check that the quality satisfies the standards. The use of aggregate from Torrorone is inappropriate.

Table 8.2.9 Results of Aggregate Tests for Nampula Southern Bypass Road

Quarry	Coordinates			Result of Test	
	X	Y	Distance from Nampula Centre (km)	TFV (kN)	ACV (%)
Namialo	606293	8352757	ENE about 80km from Nampula	190	23.6
Torrorone	536052	8325266	ESE about 7 km from Nampula	24	57.3
Standard				Subbase: 110、Surface: 180、Seal : 210	□21～29 Depending on Rock Type

ACV : Aggregate Crushing Value
TFV: Ten percent Fines Value (= 10% FACT)
Standards: STACC Section 3700s, 4200s, 4300s、SANS 1200 M:1996 (SABS)

Figure 8.2.7 Locations of Candidate Quarry Sites for Nampula Southern Bypass Road

5) Geological Conditions for Foundations of Structures

Mechanical borings were carried out at three typical points where the heavy structures are planned for construction, and at one other point where the alignment of the road crosses over the soft ground along the river.

The findings are summarized in the Boring Logs shown in Figure 8.2.9 to Figure 8.2.12. It also shows the soil test results of samples taken from the boreholes.

Name	COORDINATES		
	Y	X	Z
NPL1	539712	8327676	383.25
NPL2	520950	8325965	369.67
NPL3	521404	8332417	424.96
NPL4	539410	8326955	368.85

Figure 8.2.8 Location of Boring (Nampula Southern Bypass Road)

Findings in BH NPL 01

Location: Railway Crossing on Starting Point Side
Elevation: 383.25 m
Groundwater Level: GL - 1.0 m
Formation:

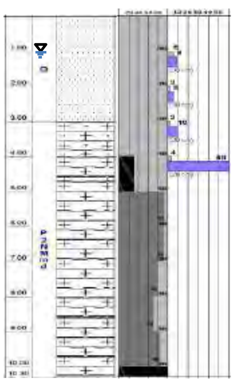
- Top Soil (0.0 – 4.0 m） is a mixture of loose fine sand with silt (N-value = 6 to 10）
- Weathered Rock (4.0 – 10.0 m/ bottom) is Slightly Weathered Gneiss (N □ 60)
- Core samples are mostly cylindrical (L>30 cm). RQD : 90 – 100%, 75% partly.

Findings in BH NPL 04

Location: Crossing over the marshy ground along the river east of the route
Elevation: 368.85 m,
Groundwater Level: GL - 0.3m
Formation:

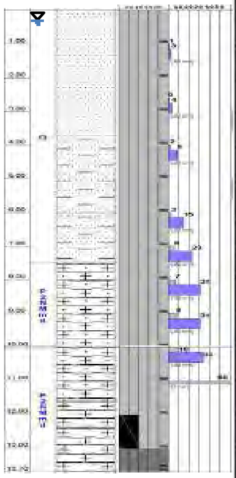
- Top Soil (0 – 1.0m) there is no cohesive middle grained sand with 5% of Clay and Silt
- Alluvium deposit: (1.0 - 4.0m) very loose sand with silt (N = 3 to 4）
  (4.0 – 6.0m) moderately stiff clay with sand (N = 9)
  (6.0 - 7.5m）moderately dense fine to medium sand (N=15 to 23)
- Highly Weathered Gneiss (7.5 to 11.5m）is like medium grain sand and its density raises with depth (N= 31 to 34）
- Weathered Gneiss (11.5～12.3m) is brittle and collected as a breccia like core, though its original texture remained.
- Gneiss (12.3 to 13.7m/ bottom) is hard rock collected as a long cylindrical core.

The degree of consolidation settlement is expected to be slight because of the moderate stiffness (N=9) of the clay in this marshy area.



NAMPULA SOUTHERN BYPASS ROAD — SYNTHETIC TABLE OF RESULTS															SITE: NAMPULA BH1
Depth (m)	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS LL	PL	PI	LSH	MC	SIEVE ANALISYS GM	MATERIAL (%) 0.075	0.075-0.150	0.425	2.00	SG gr/cm3	Triaxial ϕ (°)	C' (kpa)
1	SC		27.00	17.00	10.00	5.00	8.14	1.82	24.82	4.20	29.90	41.10	2.583		
2	SC	9	31.10	18.40	12.70	6.00	3.62	2.09	20.60	3.10	26.20	49.90	2.583		
3	SC	6	26.00	14.80	11.20	5.50	6.70	1.97	22.70	3.90	27.80	45.50	2.611		
4	SC	10	14.80	12.30	2.50	1.60	2.70	1.70	21.20	8.20	36.70	33.30			
5	WEATHERED ROCK	60 (28)													
6	WEATHERED ROCK														
7	WEATHERED ROCK														
8	WEATHERED ROCK														
9	WEATHERED ROCK														
10	WEATHERED ROCK														
11															
BH1 . NAMPULA		ELEVATION (m)		383.25		Ground Water			1.0						

Figure 8.2.9 Boring Log and Summary of Soil Test Result（NPL 1 for NSBR）



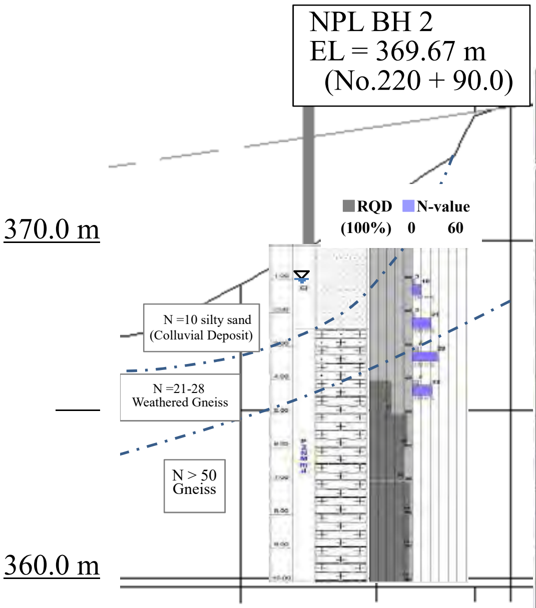
NAMPULA SOUTHERN BYPASS ROAD — SYNTHETIC TABLE OF RESULTS															SITE: NAMPULA BH4
Depth (m)	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS LL	PL	PI	LSH	MC	SIEVE ANALISYS GM	MATERIAL (%) 0.075	0.075-0.150	0.425	2.00	SG gr/cm3	Triaxial ϕ (°)	C' (kpa)
1	SW		NP	NP	NP	0	16.76	2.16	5.10	2.50	85.00	37.20	2.580		
2		3	26.80	13.50	13.30	6.70	7.16	1.69	24.40	3.60	41.30	30.40	2.600		
3	SC	4											2.555		
4	SC		41.20	27.00	14.20	7.30	19.22	0.80	56.60	3.10	23.40	14.60	2.542		
5	SC	9											2.562		
6	SC		41.60	27.50	14.10	6.70	8.17	1.98	33.60	4.00	17.90	17.40	2.484		
7	SC	15	45.30	28.30	17.00	8.30	16.20	1.16	46.10	4.90	27.80	20.30	2.498		
8	SC	23	37.20	22.00	15.20	6.00	6.01	1.26	38.00	6.10	35.50	18.50	2.471		
9	SC	31	41.60	24.70	19.60	6.70	13.67	1.38	37.80	5.50	31.80	19.80	2.454		
10	SC	31	35.30	28.60	6.76	3.70	6.97	1.63	31.50	5.60	31.00	24.60	2.545		
11	SC	34	35.30	16.30	19.00	7.80	10.96	1.55	17.60	9.10	50.80	20.00	2.537		
12	FRACT ROCK												2.518		
13	FRACT ROCK														
14	FRACT ROCK														
BH4 . NAMPULA		ELEVATION (m)		368.85		Ground Water			0.3						

Figure 8.2.10 Boring Log and Summary of Soil Test Result（NPL 4 for NSBR）

<u>Findings in BH NPL 02</u>

Location: Crossing with Road N1
Elevation: 396.67 m,
Groundwater Level: GL – 1.0 m
Formation:

- Colluvial Deposit (0.0 – 2.5 m) : silty sand medium grain (N = 10 to 21）
- Weathered Granitic Gneiss (2.5 – 4.5m) : completely weathered (N = 22 to 28)
- Slightly Weathered Granitic Gneiss (4.5 – 10.0 m/ bottom): N>60,
- Mostly collected as long cylindrical core (L > 30cm), RQD 80～100%



NAMPULA SOUTHERN BYPASS ROAD — SYNTHETIC TABLE OF RESULTS — SITE: NAMPULA BH2

Depth (m)	USCS Symbol	N Value (30cm)	Atterberg Limits LL	PL	PI	LSH	MC	Sieve Analisys GM	Material (%) 0.075	0.075-0.150	0.425	2.00	SG gr/cm3	Triaxial Φ (°)	C' (kpa)
1	SC		20.70	13.60	7.10	3.60	2.05	2.46	22.40	2.50	17.20	31.60	2.170		
2	SC	10	34.20	20.70	13.50	6.70	10.93	1.50	41.70	4.70	20.80	28.20	2.454		
3	SC	21	42.00	27.80	14.20	7.00	12.49	1.38	44.00	5.50	20.40	28.90	2.556		
4	SC	28	30.40	10.80	19.60	9.70	5.03	1.48	35.70	6.20	27.50	29.30	2.568		
5	WEATHERED ROCK	22													
6	WEATHERED ROCK														
7	WEATHERED ROCK														
8	WEATHERED ROCK														
9	WEATHERED ROCK														
10	WEATHERED ROCK														
11															

BH2 . NAMPULA — ELEVATION (m) 369.67 — Ground Water 1.0

Figure 8.2.11 Boring Log and Summary of Soil Test Result（NPL 2 for NSBR East）

<u>Findings in BH NPL 03</u>

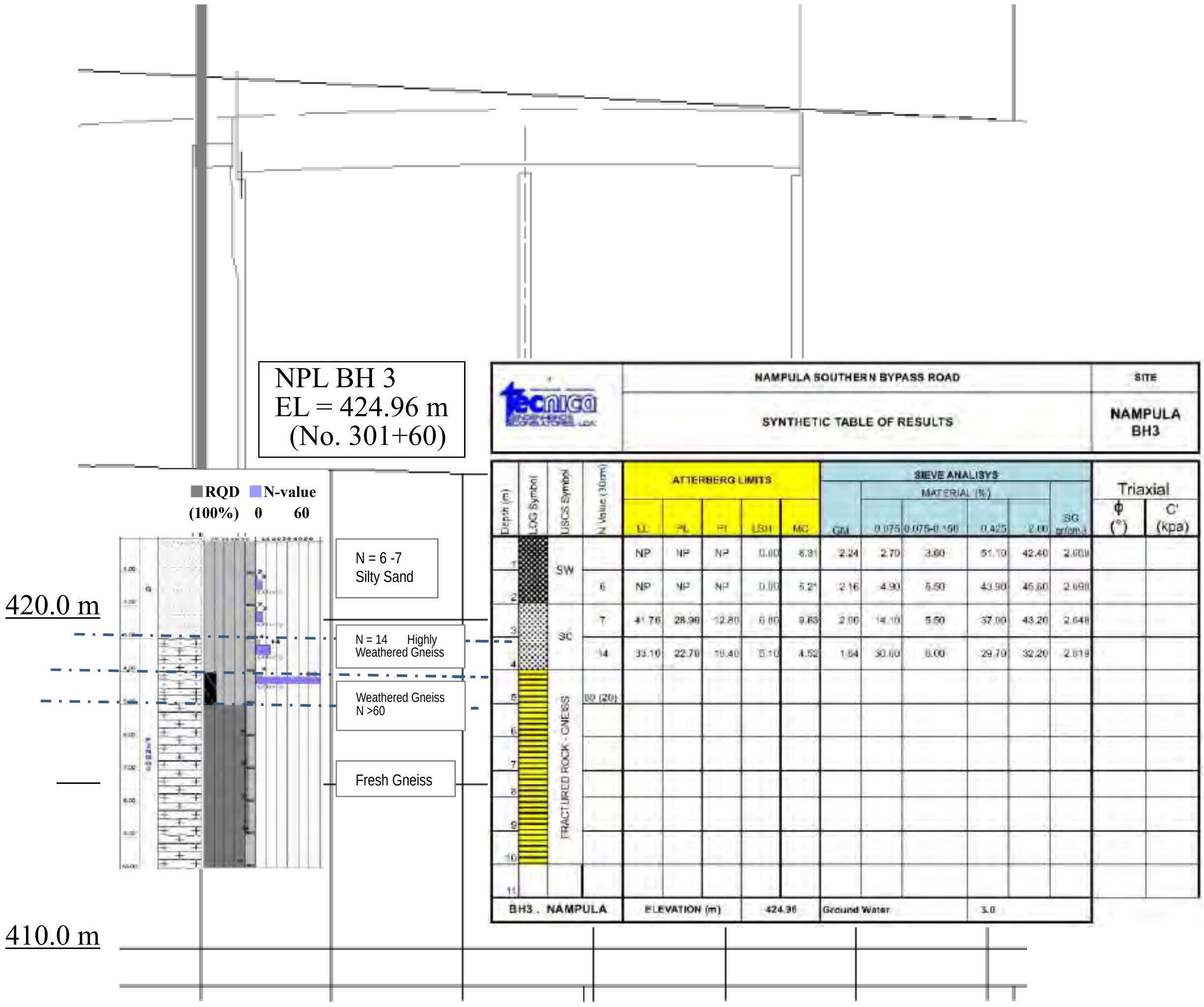
Location: Crossing Railway (on End Point side)

Elevation: 424.96 m,

Groundwater level: GL – 3.0 m

Formation:

- Top Soil (0.0 – 3.0 m): equigranular fine to medium grain sand with silt (N= 6－7)
- Highly weathered rock (3.0 – 4.0 m): like medium grain sand (N=14)
- Weathered rock (4.0 – 5.0m): breccia like or short cylindrical core (N=60)
- Hard rock (5.0 – 10.0m/ Bottom) : Gneiss as long cylindrical core, RQD>90%



Depth (m)	USCS Symbol	N Value (30cm)	LL	PL	PI	LSH	MC	GM	0.075	0.075-0.150	0.425	2.00	SG gr/cm3	Triaxial φ (°)	Triaxial C' (kpa)
1	SW		NP	NP	NP	0.00	6.31	2.24	2.70	3.60	51.10	42.40	2.669		
2	SW	6	NP	NP	NP	0.00	5.21	2.16	4.90	5.50	43.90	45.60	2.690		
3	SC	7	41.76	28.90	12.80	6.00	9.63	2.00	14.10	5.50	37.00	43.20	2.648		
4	SC	14	33.10	22.70	10.40	5.10	4.52	1.64	30.00	6.00	29.70	32.20	2.619		
5	FRACTURED ROCK - GNEISS	80 (20)													

Figure 8.2.12 Boring Log and Summary of Soil Test Result（NPL 3 for NSBR West）

(3) Cuamba Bypass Road

1) Outline of Survey

Items and quantities for Geological and Soil Survey are shown in Table 8.2.10.

Table 8.2.10 Items and Quantity for Geological and Soil Survey (Cuamba Bypass Road)

Items		Unit	Quantity	Remarks
Site Survey				
Mechanical Boring includes SPT	BH CMB 1	m	13.0	
	BH CMB 2	m	17.1	
	BH CMB 3	m	14.2	
Undisturbed Soil Sampling (UDS)		No.	5	two each from CMB 1 and 2, one from CMB 3
Test Pit & sub-grade Sampling		No.	12	One site per 1 km in average along the target road
Material Sampling (1)		No.	2	From candidates for borrow pit for fill material
Material Sampling (2)		No.	5	From candidates for quarry sites for aggregate material
Laboratory Tests				
Physical Soil Test (SPT , UDS samples)		No.	12	Gs, WC, Grain, LL/PL[*1], etc.
Mechanical Soil Test (UDS samples)		No.	5	Tri-axial compression test CD
CBR Test for sub-grade material		No.	5	From Sub-grade sampling
CBR Test for fill material		No.	2	From Material Sampling (1)
Test for aggregate material		No.	5	From Material Sampling (2)

2) CBR of Existing Surface Soil for Subgrade

The CBR tests for subgrade were carried out for 12 samples collected from 12 trial pits dug 1.0 to 1.5 m deep targeting the existing surface soil along the targeted road. Compaction Tests and CBR Tests gave good results for 12 samples. The samples for CBR Tests were prepared for three densities, 90%, 95% and 100% of Maximum Dry Density (MDD) compacted under the Modified AASHTO compaction method after 4 days of soaking. The results are shown in Table 8.2.10.

The CBR tests were carried out on the specimens which were taken from 1 m depth in the test pits and adjusted to 90% of the maximum dry density (MDD). The results of the CBR tests listed on Table 8.2.11 are evaluated as the density of existing ground for subgrade. Therefore, these CBR values shall be applied to the subgrade of road sections where the ground will be cut or banked with thickness less than around 2 m.

The planned bypass route starts at the eastern end of Cuamba, and has a length of about 12 km to the west of the edge of the city. The route crosses the Muanda river at 0 + 360, crosses paths on the northern part of the city, and crosses the railroad crossing near the end point. Dark brown or blackish brown organic soil from the starting point to the vicinity of the 6km point was observed, and the colour clearly changes to reddish brown from that point. However, in the approximately1 km long section in the vicinity of 10 ~ 11km, the black organic soil covers the surface (Figure 8.2.14).

A CBR of 2%, which is the minimum of S1 class (see Table 8.2.3), cannot be achieved with the existing ground except for a part that is not suitable as subgrade as it is. Therefore it is appropriate to carry out the formation of the subgrade by the compaction of fill material for the section of shallow cuts or low embankments.

Table 8.2.11 Result of CBR Test for Subgrade and Evaluation (Cuamba Bypass Road)

No. CMB	Coordinates		MDD (g/cm³)	OMC (%)	Swell (%)	CBR (%)	Chainage	Suitability for Subgrade *
	X	Y						
TP1	239553.00	8362227.99	1.900	12.1	3.1	1.8	0+00.00	Not Suitable
TP2	239427.00	8362461.99	1.768	15.0	6.52	1.0	2+50.00	
TP3	238340.00	8363865.99	1.852	11.9	2.76	1.7	21+40.00	
TP4	237482.00	8363947.99	1.858	10.6	5.80	0.4	30+20.00	
TP5	236474.00	8363947.99	1.907	12.1	4.55	1.0	40+30.00	
TP6	235553.00	8364215.99	1.852	12.8	2.77	1.0	50+20.00	
TP7	234671.00	8364683.99	1.928	12.2	0.56	1.0	60+00.00	
TP8	233710.00	8365230.99	1.790	16.5	1.35	4.6	71+10.00	Suitable
TP9	232907.00	8365679.99	1.613	24.2	0.48	1.9	81+00.00	Not suitable
TP10	231748.00	8365342.99	2.177	6.5	0.08	9.8	94+80.00	Suitable
TP11	230344.00	8364522.99	1.672	18.5	6.45	0.4	110+20.00	Not Suitable
TP12	229649.00	8363934.99	1.958	9.3	6.45	16.0	120+20.00	Suitable

MDD: Maximum Dry Density, OMC: Optimum Moisture Content, Compaction with 4.536kg Rammer, 5 layer, 55 tamping
CBR, Swell: Samples were prepared with compaction by the Proctor Method (90% of MDD)

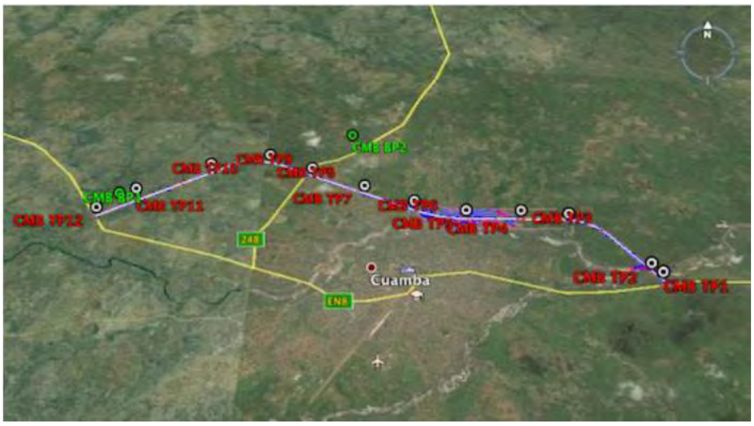


Figure 8.2.13 Location of Soil Sampling for Existing Ground and Borrow pits (Cuamba Bypass Road)

Figure 8.2.14 Ground Surface Covered with Thin Organic Soil and its Particular Cracking

3) Material Test on Candidate Sites for Borrow Pits

The two sampling sites were selected from the vicinity of the planned route, in consideration of the possibility to be candidate sites as borrow pits for fill material. These two samples were subjected to compaction tests and CBR tests.

Test results shown in Table 8.2.11 indicate that these fill materials are able to obtain soaked CBR of more than 30 % by performing compaction to 95% of MDD under quality management.

Table 8.2.12 Result of Compaction and CBR Tests for Materials from Candidates Borrow Pits (Cuamba Bypass Road)

No. CMB -	COORDINATES		MDD (g/cm³)	OMC (%)	Swell (%)	CBR (%)		
	X	Y				MDD 90%	MDD 95%	MDD 100%
BP1	230037.02	8364374.809	1.976	8.5	3.1	19	32	53
BP2	234592.69	8366420.307	2.184	4.7	0.13	23	72	95

4) Quarry Site and Test for Aggregate

There are three typical aggregate quarry sites running currently in the area surrounding Cuamba, namely Britanor 1, Britanor 2 and Vision 2000. One or two samples were taken from each site and aggregate tests were performed. The summary of the test results is shown in Table 8.2.13.

Table 8.2.13 Result of Aggregate Test for Cuamba Bypass Road

Quarry Site	Coordinates and Location			Test Results		
	X	Y	Distance and Direction from Cuamba Centre	TFV (kN)	ACV (%)	Water Absorption (%)
Britanor 1	233778	8370023	8 km North	220	20.6	0.74
				140	24.4	-
Britanor 2	246452	8363616	5.5km North	170	21.4	0.53
				140	30.6	-
Vision 2000	231556	8361290	3 km West	99	28.4	-
Standards				Subbase: 110 Surface: 180 Seal: 210	□21～29 Depend on Rock Type	

ACV: Aggregate Crushing Value
TFV: Ten percent Flakiness Value (= 10%FACT)
Standards: STACC Section 3700s, 4200s, 4300s、SANS 1200 M:1996 (SABS)

A previous aggregate survey, Cuamba - Mandimba - Lichinga Road Project, was carried out in Cuamba north about 4km, the suitability as crushed stone and as surface material have been confirmed as ACV = 17%, TFV = 190kN, and estimated volume = 1,000,000m^3. The above mentioned test was carried out in order to confirm the possibility of a new quarry in the surrounding area. As a result, in the Britanor 1, its good quality was confirmed, which means that it can be used for seal material (ACV = 20.6%, TFV = 220kN). The test results of Britanor 2, although slightly lower than previous tests have shown that the quarry material can be used for crushed stone. However, aggregate Vision 2000 was found to not have enough strength as an aggregate for the road.

5) Geological Condition for Foundations of Structures

Mechanical borings were carried out at three typical points where heavy structures are planned.

The findings are summarized in the Boring Logs shown in Figure 8.2.16 to Figure 8.2.18. It also shows the soil test results of samples taken from the boreholes.

Name	X	Y	Z
CMB BH1	239432	8362464	558.86
CMB BH2	238348	8363890	560.00
CMB BH3	236505	8363965	562.46

Figure 8.2.15 Location of Boring (Cuamba Bypass Road)

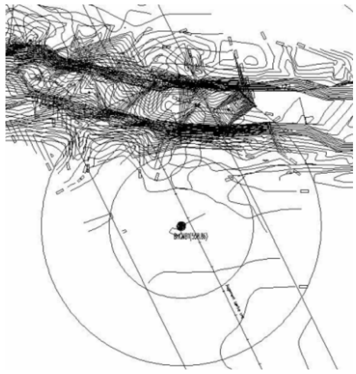
Findings in BH CMB 01

Location: Right Bank of Bridge over Muanda River

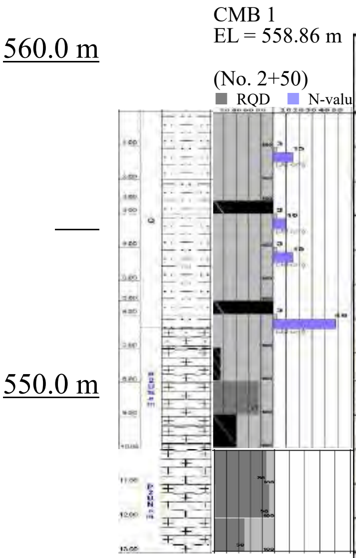
Elevation: 558.86 m

Groundwater Level: GL - 1.0 m

Formation:

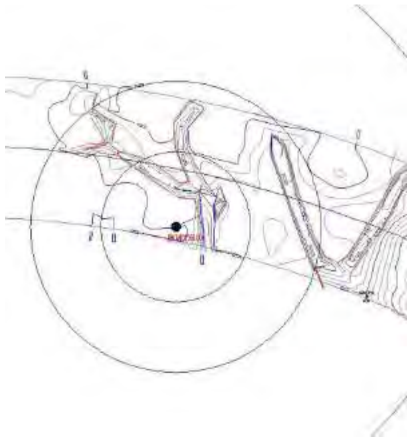


- Top Soil (0.0 – 6.0 m) is high to medium plastic Silt and Clay,
- N = 10 to 15
- Gneiss (6.0 – 13.0 m/ Bottom)
- Weathered (6.0 – 8.0m): Breccia like or cylindrical core , N= 49
- Hard rock (8.0 – 13.0m) binds crack-rich zone (8.0 – 9.3 m, 10.0 – 12.0m: RQD 77 – 90%) and breccia-like zone (9.3 – 10.0m, 12.0 -13.0 m, RQD < 50%



Depth (m)	LOG Symbol	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS					SIEVE ANALISYS						Triaxial	
				LL	PL	PI	LSH	MC	GM	MATERIAL (%) 0.075	0.075 0.150	0.425	2.00	SG gr/cm3	ϕ (°)	C' (kpa)
1		CL		43.20	20.60	22.60	11.00	21.22	0.20	73.50	14.40	10.00	1.60	2.337		
2		CL	15					23.80						2.438	16.0	31.4
3		ML		55.40	41.80	13.60	8.00	7.51	0.21	79.40	9.30	8.40	2.10	2.379		
4		ML	10	50.00	40.70	9.30	4.00	16.97	0.48	68.20	8.70	15.70	5.80	2.373		
5		ML	15					25.00						2.568	15.7	27.9
6		ML		64.70	52.40	12.30	5.00	5.39	1.23	35.70	12.40	29.70	15.80	2.291		
7		Weathered Rock Gneiss	49											2.405		
8																
9																
10																
11																
12																
13																
BH2 CUAMBA				ELEVATION (m)			558.86		Ground Water			1.0m				

Figure 8.2.16 Boring Log and Summary of Soil Test Result（CMB 1 for Cuamba BPR）



<u>Findings in BH CMB 02</u>

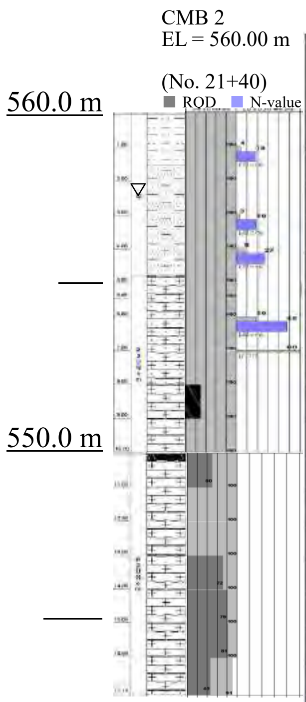
Location: Right Bank of a tributary of Manda Riv.

Elevation: 560.00 m

Groundwater Level: GL - 3.0 m

Formation:

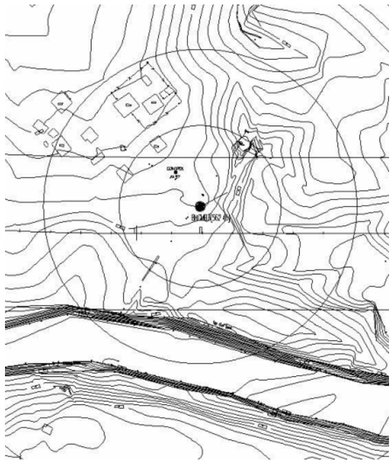
- Top Soil (0.0 – 1.5 m): Stiff moderate plastic soil, N= 18.
- Residual Soil (1.5 – 4.8m): Medium dense medium grain sand with clay and silt, N =19 to 27
- Gneiss (4.8 m or below) : Weathered zone (above 8.0m) is breccia like core, N = 48.
- Consolidated rock (8.0 – 13 m) is collected as cylindrical core. Fractured zone is found between 10.0 and 10.2 m.
- Hard Rock (below 13m) is mostly long cylindrical core with RQD 72 – 81 %.



Depth (m)	LOG Symbol	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS					SIEVE ANALISYS							Triaxial	
										MATERIAL (%)							
				LL	PL	PI	LSH	MC	GM	0.075	0.075-0.150	0.425	2.00	SG gr/cm3		Φ (°)	C' (kpa)
1		CL		34.80	19.70	15.10	7.00	7.70	1.02	43.80	9.90	30.30	14.00	2.407			
2		SC	18					19.60						2.675		22	11.8
3		SC		28.30	15.30	13.00	8.00	2.71	2.26	18.80	4.50	27.50	30.40	2.632			
4		SC	19	30.20	18.80	11.40	5.00	9.28	2.75	15.50	2.30	15.40	39.40	2.567			
5		SC	27					12.97						2.656		35.8	31.8
6		SC		25.70	18.90	6.80	3.00	5.12	1.09	36.70	16.50	27.80	14.40	2.158			
7		SM	48	NP NP	NP	NP	0.00	7.25	0.75	40.80	17.00	34.80	7.20	2.440			
8		Weathered Gneiss															
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
BH2 . CUAMBA				ELEVATION (m)			560.00		Ground Water			3.0m					

Figure 8.2.17 Boring Log and Summary of Soil Test Result（CMB 2 for Cuamba BR）

Findings in BH CMB 03



Location: 80 m left (North) of Muanda River around Mid. point of the route

Elevation: 562.46 m

Groundwater Level: GL - 3.0 m

Formation:

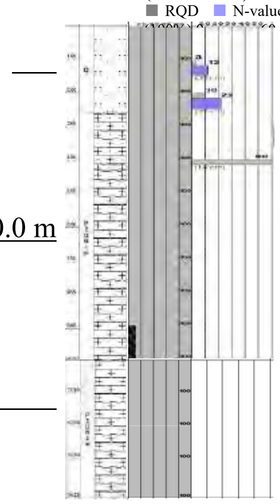
- Top Soil (0.0 – 1.0 m): less cohesive silt and sand mixture
- Residual Soil (1.0 – 3.0m) is changed from medium stiff Silt & Clay (N = 12) to medium dense sand with clay (N=22).
- Gneiss (3.0m to Bottom)
- Highly weathered (upper most 1.5m) : Stiff sandy Silt, N = 60
- Moderately weathered (4.5 – 9.0m): breccia like core
- Slightly Weathered (9.0 – 14.0m): Mostly cylindrical core with cracks. Max. core length is 30 cm.

560.0 m

CMB 3
EL = 556.46 m

(No. 40+00)
RQD N-value

550.0 m



Depth (m)	LOG Symbol	USCS Symbol	N Value (30cm)	ATTERBERG LIMITS					SIEVE ANALISYS							Triaxial	
										MATERIAL (%)							
				LL	PL	PI	LSH	MC	GM	0.075	0.075-0.150	0.425	2.00	SG g/cm3		ϕ (°)	C' (kpa)
1		SM		NP	NP	NP	0.00	17.16	0.91	29.60	16.10	48.40	9.60	2.484			
2		ML	12	52.70	42.90	9.80	5.00		1.26	43.70	9.30	22.50	11.50	2.718			
3		ML	22					23.93						2.671		15.6	21.5
4		SC	60 (14)	25.30	19.80	6.50	3.00	4.61	2.53	16.50	7.09	18.60	13.40	2.671			
5		FRACTURED ROCK - GNEISS															
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
BH3 . CUAMBA				ELEVATION (m)				562.46	Ground Water			3.0m					

Figure 8.2.18 Boring Log and Summary of Soil Test Result（CMB 3 for Cuamba BR）

8.2.2 Topographic Survey

A topographic survey was carried out for the design of the road and structures by entrusting the work to the local sub-consultant and which is summarised in the following sections. The map creating work includes identifying the obstacles, such as houses, in the expected width of the right of way. There was no participation from the local government.

For the hydrological analysis on the rivers related to the Nampula Southern Bypass Road and Cuamba Bypass Road, a hydrological interview with inhabitants was carried out together with the topographic survey.

Coordinate System is as follows;

Datum:	WGS 1984
Zone:	37 South (39E)
Geoid:	EGM 2008

The items and quantities of this topographic survey are shown below. The results were utilized in the planning of the roads and related facilities.

(1) Nacala Port Access Road

Table 8.2.14 Items and Quantity of Topographic Survey (Nacala Port Access Road)

Items	Unit	Quantity	Remarks
Establish and Measure Traverse Control Points	No.	18	1km interval in average
Making the Topographic Map using a Total Station			
• Plan survey for DTM (14.0km x 0.15km) + (1.15km x 0.1km)	km^2	2.3	W=150m for Main Route, W=100m for the existing road related to Nacala Port
• Plan survey for DTM (off shore) (0.7km x 0.15km)	km^2	0.11	
• Line mapping for related structures (14.713.5km x 0.15km)+(1.15km x 0.1km)	km^2	2.4	Include offshore survey work for L=0.7km

(2) **Nampula Southern Bypass Road**

Table 8.2.15 Items and Quantity of Topographic Survey (Nampula Southern Bypass Road)

Items	Unit	Quantity	Remarks
Establish and Measure Traverse Control Points	No.	33	1km interval in average
Making the Topographic Map using a Total Station			
• Plan survey for DTM (34.9km x 0.15km)	km^2	5.24	Include alternative route and a part of existing road to be crossed by the route
• Line mapping for related structures (32.5km x 0.1km)	km^2	5.24	
Hydrological Interview Survey	River	4	

(3) **Cuamba Bypass Road**

Table 8.2.16 Items and Quantity of Topographic Survey (Cuamba Bypass Road)

Items	Unit	Quantity	Remarks
Establish and Measure Traverse Control Points	No.	13	1km interval in average
Making the Topographic Map using a Total Station			
• Plan survey for DTM (11.8.km x 0.1km, 1.0 km x 0.6 km*)	km^2	1.85	Include a part of existing road to be crossed by the bypass. *: the width includes Cassiano Bridge and Muanda River
• Plan Survey for Muanda River (0.7km x 0.1km)	km^2	0.07	
• Line mapping for related structures [*1] (11.8 km x 0.1km, 1.0 km x 0.6 km*)	km^2	1.85	
Hydrological Interview Survey	River	1	

8.2.3 Meteorological, Hydrological and Hydraulic Survey

(1) Data Collection Items

Regarding data related to meteorology and Hydrology in Mozambique, the meteorological data is held by ARA Centro-Norte (Administração Regional de Águas), INAM (Instituto Nacional de Meteorologia) and DNA (Direcção Nacional de Águas). The hydrological data is held by ARA Centro-Norte and DNA.

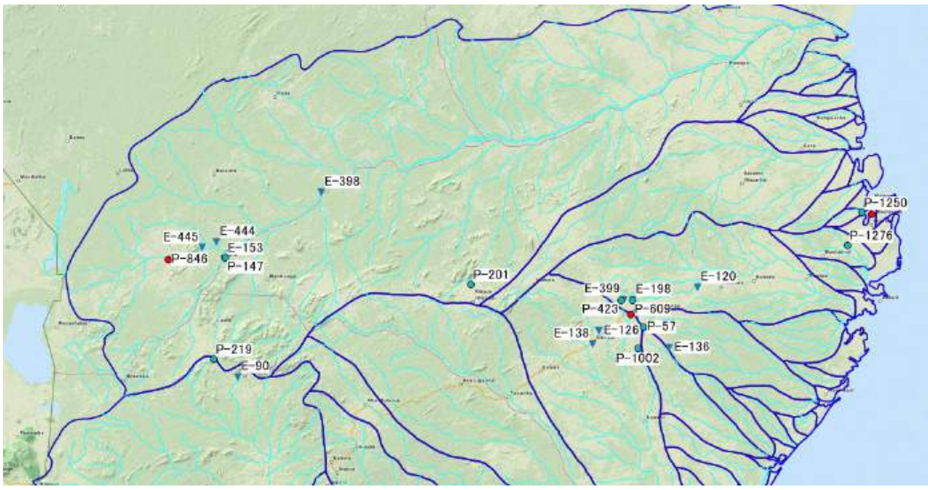
According to the information at DNA, there were, in the past in the ARA Centro-Norte region, a total of 398 rainfall stations and 135 flow gauging stations. These are relatively low figures for good monitoring of the water resources. However, the present situation is worse unfortunately, when only the stations in effective operation are considered (There were many problems during the war in Mozambique and it is believed that only the data before 1982 is relatively reliable.).

In this Study, among of them, the following data items were collected from ARA Centro-Norte. Also, in order to verify the hydrological characteristics etc., field reconnaissance, interview surveys with the residents, and the bibliographic survey including past studies are surveyed. The flow chart of this hydrological survey / study is shown in Figure 8.2.20.

Table 8.2.17 Data Collection Items and Periods

Sation ID	Station Name	Longitude	Latitude	Altitude	Collected Items and Usable Period			Remarks
		(deg.)	(deg.)	(m)	Daily Rainfall	Daily Water Level	Daily Discharge	(Drainage Area: km2)
Meteorological Station								
P- 57	Nampula	39.33333	-15.18333	-	1953-1957	-	-	
P- 147	Rio Lurio E.N.8	36.86667	-14.79167	550.0	1968-1983	-	-	
P- 201	Ribaue	38.31667	-14.94167	535.0	1950-2012	-	-	1968-2008 Gap
P- 219	Mugaua A. (Gurue)	37.80000	-17.36670	5.0	1951-2013	-	-	1975-2001 Gap
P- 423	Monapo Barrage Nampula	39.20000	-15.03330	400.0	1960-2014	-	-	
P- 609	Albufeira de Nampula	39.26667	-15.03333	32.2	1965-2014	-	-	
P- 846	Cuamba	36.53333	-14.80000	680.0	1959-1969	-	-	
P- 1002	Momola	39.30000	-15.30833	-99.0	1971-1983	-	-	
P- 1250	Nacala Porto	40.61670	-14.53330	-	1984-2013	-	-	
P- 1276	Barragem de Nacala	40.53280	-14.71888	-	1999-2004	-	-	
Hydroogical Station								
E- 90	Licungo em EN231 Gurué	36.94167	-15.46667	650.0	-	-		A=140 km2
E- 120	Monapo em Est. Nacavala Muecate	39.64972	-14.95806	230.0	(1978-81, 1985-87 Gap)	1965-2013	1965-2008	A=1350 km2
E- 126	Meluli em Murrupula Estr232	39.07000	-15.20444	270.0	-	1960-2015 (1979-80 Gap)	1961-2001	A=795 km2
E- 136	Motomode-E.N.240 Corrane Nampula	39.48500	-15.30000	260.0	-	1956-1981	1958-1981	A=186 km2
E- 138	Namaíta-Est. Murrupula Nampula	39.03611	-15.27944	420.0	-	1960-2015 (1982 Gap)	1961-1981	A=548 km2
E- 153	Lúrio em E.N.8 Malema-Cuamba	36.86361	-14.79528	525.0	-	N/A	1960-61, 1980-81	A=3250 km2
E- 198	Monapo em Albufeira de Nampula	39.26667	-15.02889	340.0	-	1955-2015 (1982 Gap)	1965-1978	A=480 km2
E- 398	Lúrio em Malapane	37.43333	-14.41667	490.0	-	1968-76, 1980-81	1965-1976	A=18590 km2
E- 399	Monapo em Mecuburi	39.21722	-15.02694	350.0	-	1968-2005 (1978-81, 84-85, 95-98 Gap)	1969-77, 86-94, 2000-05	A=477 km2
E- 444	Micuco em Serra Mitucue	36.81667	-14.70000	-	-	1971-1991 (1982-85 Gap)	1969-1972	
E- 445	Mepopolo em Planalto Mitucue	36.73333	-14.73333	-	-	1971-1986	1981-1985	

Source: ARA Centro-Norte, the Study Team



Source: ARA Centro-Norte, the Study Team

Figure 8.2.19 Location Map of Stations for Data Collection

Collection of the Meteorological observation data, the Hydrological observation data (water level, discharge, etc.) and interviews with residents reference.

↓

Understanding of the Physiographic condition, the River (Basin) morphology, and the Flooding Characteristics

↓

Formulation of this Hydrological design criteria and method

↓

Statistical analyses for the design discharge / water level

↓

Estimation of Design Discharge and Water level (from the engineering aspect, the actual event by interview, etc.)

Hydraulic Calculation (River flow, Scouring, etc)

↓

Hydraulic Assessment regarding the Bridge Scour, the Stability of the river channel, the openings (flow areas) of transversal structures, etc.

Hydrological Recommendation

Source: the Study Team

Collection of the Meteorological observation data, the Hydrological observation data (water level, discharge, etc.) and interviews with the residents

↓

Understanding of the Physiographic condition, the River (Basin) morphology, and the Flooding Characteristics

↓

Formulation of this Hydrological design criteria and method

↓

Statistical analyses for the design discharge / water level

↓

Estimation of Design Discharge and Water level (from the engineering aspect, the actual event by interview, etc.)

Hydraulic Calculation (River flow, Scouring, etc)

↓

Hydraulic Assessment regarding the Bridge Scour, the Stability of the river channel, the openings (flow areas) of transversal structures, etc.

Hydrological Recommendation

Source: the Study Team

Figure 8.2.20 Flow Chart of this Hydrological Survey and Study

(2) **Rainfall**

1) Seasonal and Annual Rainfall

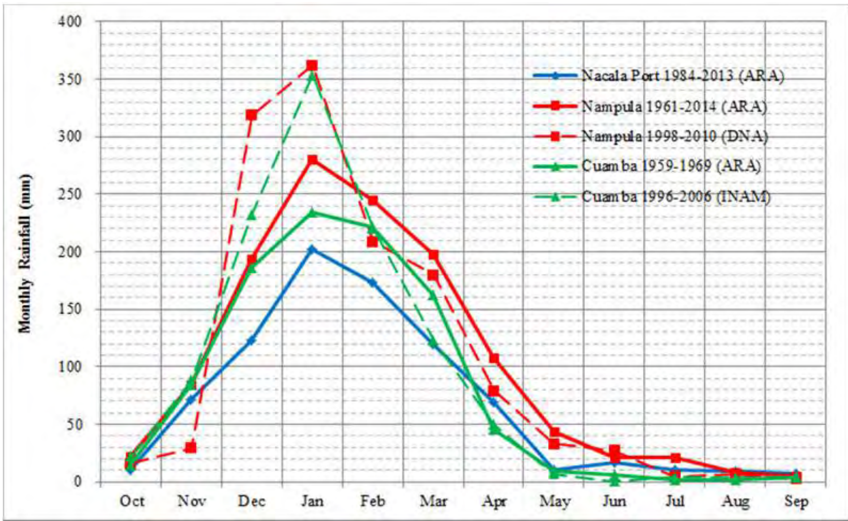
Table 8.2.2 shows the mean monthly rainfall of selected districts. Even though some difference is recognised by observed organisations, the rainfall from October to April represents more than 92% of annual rainfall. Annual rainfall is higher at Nampula, it is lower in Cuamba and lower yet in Nacala. The heaviest rainfall is registered in January and February extending into March. The total annual rainfall is up to 1,270 mm at Nampula, but in the coastal area in the district of Nacala the values are less than 830 mm.

Table 8.2.18 Monthly Mean Rainfall at Nacala, Nampula and Cuamba

Station	Period	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Remarks
Nacala Port	1984-2013	10.7	71.2	123.3	202.5	173.0	119.6	69.5	10.4	16.9	10.3	9.2	7.3	824.0	ARA centro
Nampula	1961-2014	21.8	84.3	193.6	279.8	245.3	197.4	108.1	43.1	20.8	20.7	8.2	4.5	1,227.6	ARA centro
Cuamba	1959-1969	14.6	84.6	186.3	234.1	221.7	162.9	45.9	9.7	6.1	1.7	1.3	3.8	972.5	ARA centro
Nampula	1998-2010	16.2	29.3	318.4	362.1	208.7	179.6	79.2	33.2	27.2	4.5	7.0	2.4	1,267.8	DNA
Cuamba	1996-2006	21.6	88.5	232.5	353.3	220.6	123.3	49.9	6.8	0.5	4.2	3.6	4.7	1,109.5	INAM

Source: ARA Centro-Norte, DNA, INAM, the Study Team

Note: The rainy season is in the winter season, the above table shows values from October to the next September.



Source: ARA Centro-Norte, DNA, INAM, the Study Team

Figure 8.2.21 Monthly Mean Rainfall at Nacala, Nampula and Cuamba

2) Exceedance Probability and Rainfall Intensity Curve

The exceedance probability and the intensity curve for rainfall in Mozambique are based on "Decreto 30/2003 (Regulation of the public systems for water distribution and wastewater drainage)" by the Government in 2003, as shown in Figure 8.2.22 and Table 8.2.19. The design rainfall intensity can be calculated by multiplying Maputo's value by conversion factors for each district.

Additionally, probable rainfalls at 8 stations are calculated from the past annual maximum rainfall data (extreme values) which was collected, as shown in Table 8.2.20 and Figure 8.2.23. The probable rainfall is calculated according to the following:

- Appropriate model for probability distribution is chosen from several methods.
- Distribution model selected by reference to SLSC (Standard Least Squares Criterion) value or adequacy of probability value, etc. (SLSC value of 0.04 or less is desirable.)
- Calculation of return periods for 2, 3, 5, 10, 20, 25, 30, 50, 80, 100, 150, 200, 300, 400 and 500 years.

Compared with the results of the above, the probable value of "Decreto 30/2003" is a result on the safer side (= higher) than the probability calculation from collected data.

Table 8.2.19 Rainfall Intensity by Decreto 30/2003

Rainfall intensity (mm/hr) I = K * a * t ^b < Sherman equations >

I: Rainfall intensity (mm/hr)

K: regional coefficient (K=1.5, Nacala, Nampula) (K=0.8, Cuamba) (K=1.0, Maputo)

a, b: dimensionless parameters

t: duration of rainfall (min)

T: Return period (year)

for Maputo

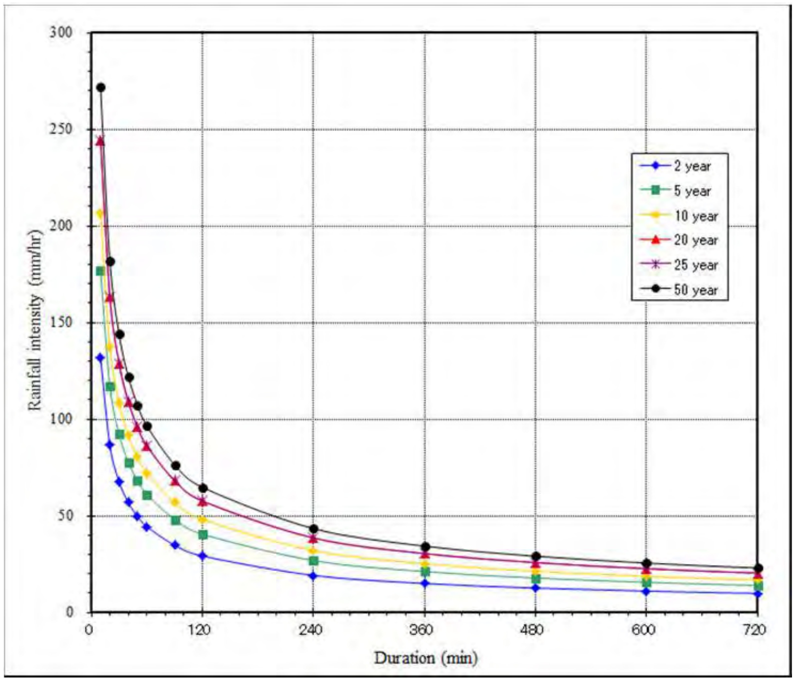
T (year)	2	5	10	20	25	50
a	534.0468	694.504	797.3841	896.5751	930.8815	1026.694
b	-0.6075	-0.59383	-0.5869	-0.58197	-0.58119	-0.57749

K= 1.00 for Maputo city

T (year)	2	5	10	20	25	50
Duration(min)						
5	200.89	267.06	310.06	351.40	365.31	405.32
10	131.85	176.95	206.43	234.76	244.18	271.61
20	86.54	117.24	137.43	156.83	163.21	182.02
30	67.64	92.15	108.33	123.86	128.95	144.02
40	56.80	77.68	91.50	104.77	109.09	121.97
50	49.60	68.04	80.27	92.01	95.82	107.23
60	44.40	61.06	72.12	82.75	86.19	96.51
90	34.70	47.99	56.85	65.35	68.09	76.36
120	29.14	40.46	48.02	55.28	57.61	64.67
240	19.12	26.81	31.97	36.93	38.51	43.34
360	14.95	21.07	25.20	29.17	30.42	34.29
480	12.55	17.76	21.28	24.67	25.74	29.04
600	10.96	15.56	18.67	21.67	22.61	25.53
720	9.81	13.96	16.78	19.49	20.33	22.98
900	8.57	12.23	14.72	17.11	17.86	20.20
1080	7.67	10.97	13.22	15.39	16.07	18.18
1260	6.98	10.01	12.08	14.07	14.69	16.63
1440	6.44	9.25	11.17	13.02	13.59	15.40

Source: Conselho de Ministros (Mozambique), the Study Team

Note: Above values show the probable rainfall for each rainfall-duration of each return-period, based on the Decreto 30/2003



Source: Conseil de Ministros (Mozambique), the Study Team

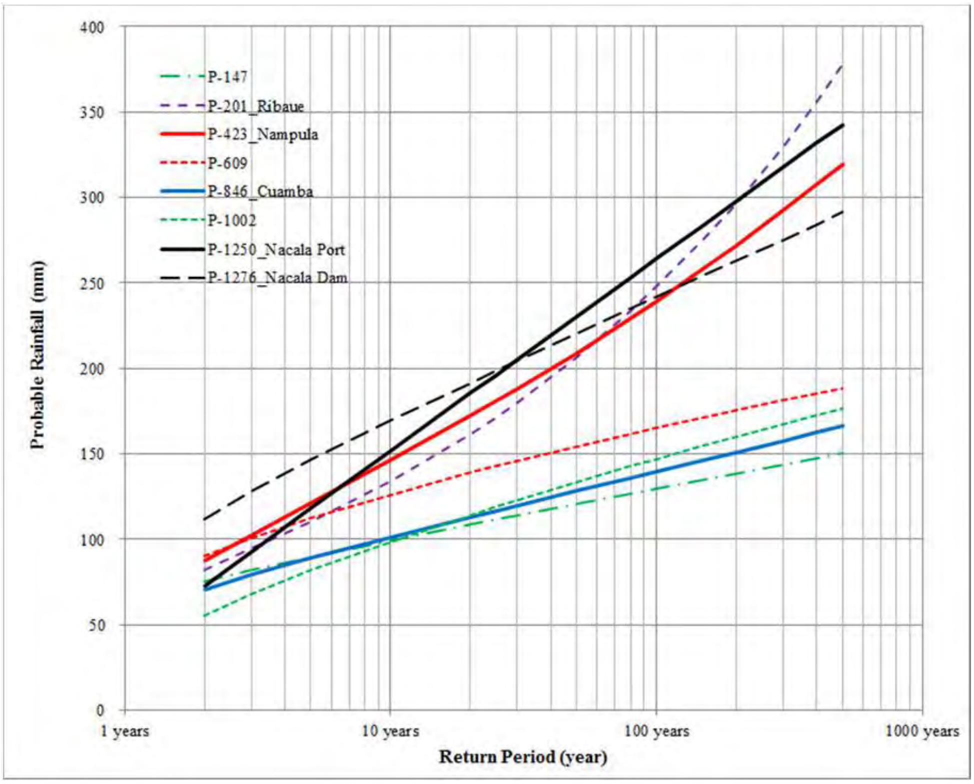
Figure 8.2.22 Rainfall Intensity Curve (at Maputo) by Decreto 30/2003

Table 8.2.20 Calculation Result of Probable Rainfall from Collected Data

Station ID			P- 147	P- 201	P- 423	P- 609	P- 846	P- 1002	P- 1250	P- 1276	Remarks
Station Name			Rio Lurio E.N.8	Ribaue	Monapo Barrage Nampula	Albufeira de Nampula	Cuamba	Momola	Nacala	Barragem de Nacala	
WMO code			8907	8907	8913	8911	8907	8911	8910	8910	
X: Longitude			36.86667	38.31667	39.20000	39.26667	36.53333	39.30000	40.61670	40.53280	
Y: Latitude			-14.79167	-14.94167	-15.03330	-15.03333	-14.80000	-15.30833	-14.53330	-14.71888	
Altitude (m)			550	535	400	32.2	680	-99	0	0	
Data No.			15	23	55	44	51	11	20	6	
Probable Rainfall (mm)	2 years	50%	75.3	82.3	87.6	90.0	70.5	55.1	73.1	111.7	
	3 years	33.3%	82.2	94.5	102.9	100.8	79.3	68.1	92.9	128.1	
	5 years	20%	89.9	110.3	121.3	112.4	89.1	82.0	117.8	146.5	
	10 years	10%	99.5	134.0	146.3	126.3	101.4	98.8	151.7	169.5	
	20 years	5%	108.7	161.6	172.3	139.0	113.1	114.3	185.5	191.6	
	25 years	4%	111.7	171.6	181.0	142.8	116.9	119.1	196.4	198.6	
	30 years	3.33%	114.1	180.1	188.2	146.0	119.9	122.9	205.3	204.3	
	50 years	2%	120.7	206.2	209.1	154.4	128.4	133.4	230.2	220.2	
	80 years	1.25%	126.8	233.4	229.4	161.9	136.1	142.7	253.2	234.8	
	100 years	1.0%	129.7	247.5	239.4	165.4	139.8	147.0	264.1	241.7	
	150 years	0.667%	134.9	275.3	258.2	171.5	146.5	154.6	283.9	254.2	
	200 years	0.5%	138.6	297.0	272.1	175.8	151.2	160.0	297.9	263.0	
	300 years	0.333%	143.8	330.4	292.5	181.6	157.8	167.3	317.7	275.5	
	400 years	0.25%	147.5	356.4	307.5	185.7	162.6	172.4	331.8	284.4	
	500 years	0.2%	150.4	377.9	319.6	188.7	166.2	176.3	342.7	291.2	
SLSC (Standard Least Squares Criterion) 99%			0.092	0.042	0.028	0.022	0.030	0.021	0.039	0.074	
Adopted Distribution Formula			Gumbel	Gev	LogP3	Gev	Gumbel	Gev	Exp	Gumbel	

Source: the Study Team by using the data of ARA Centro-Norte

Note: Station locations are shown in Figure 8.2.1. The values in the above Table show the probable daily-rainfalls for each return-period of each station, which was calculated from the collected data of the Study Team.



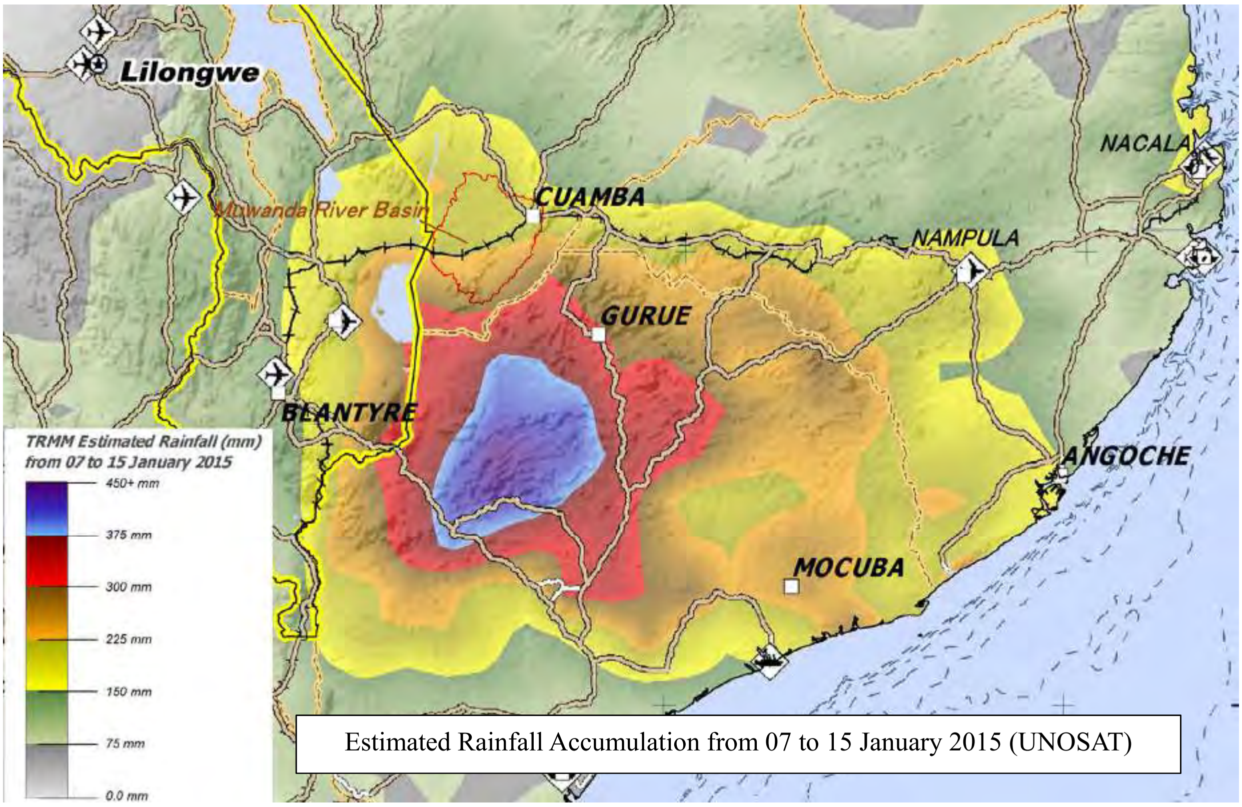
Source: the Study Team using the data of ARA Centro-Norte

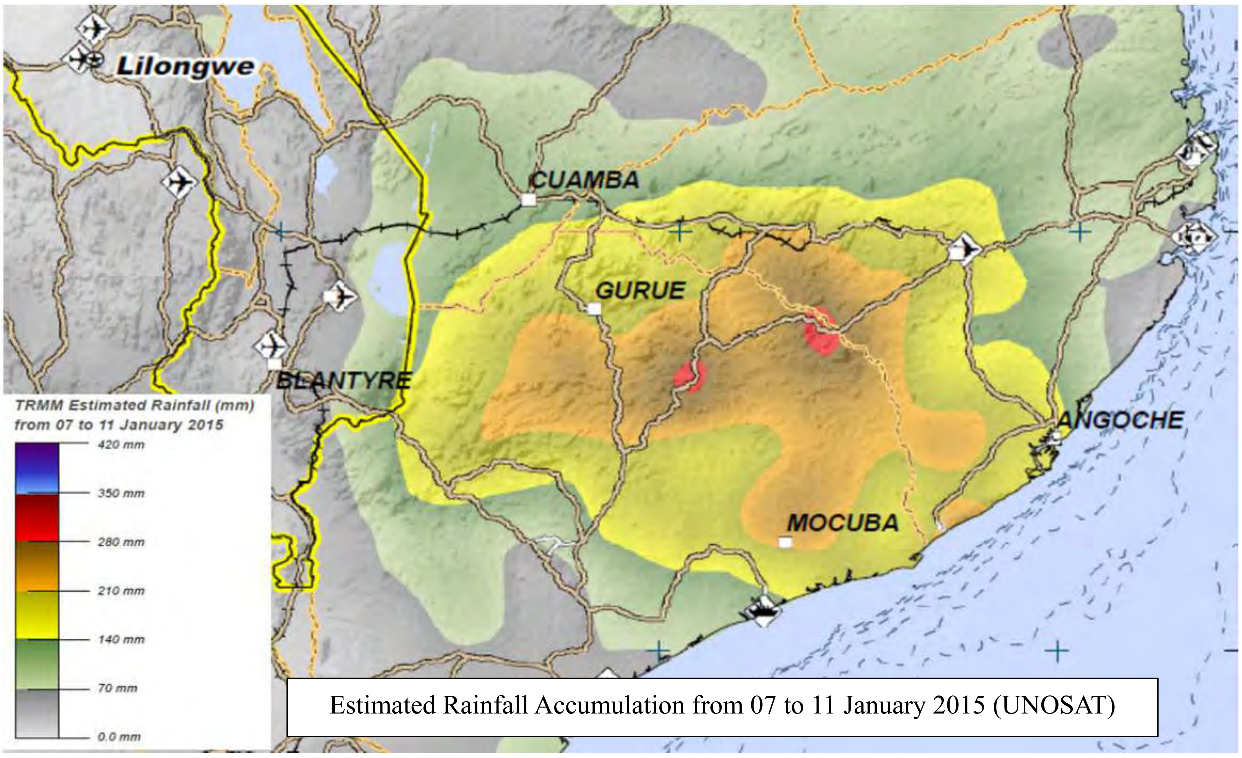
Figure 8.2.23 Calculation Result of Probable Rainfall from Collected Data

3) Record-scale Heavy Rainfall of Northern Mozambique at January 2015

The rainfall of 7-15 January 2015 which became a record heavy rain is shown in Figure 8.2.24, according to the estimation by TRMM (Tropical Rainfall Measuring Mission). From this Figure, the total rainfall of the Gurue Station during 7-15 January is estimated to have been less than 375mm. Meanwhile, the daily rainfall that became the maximum record at Gurue station of ARA-Centre-Norte was 224mm on 12th January 2015, and the total rainfall during 7-15 January was recorded as 439mm. Even assuming that there is some error, it is supposed that the observed rainfall of ARA is too large. (The difference between both Figures of this Figure, namely, the accumulated rainfall during 12-15 January can estimate as less than 165mm.)

In either case, the rainfall of this period was heavy, and the probability of this rainfall event at the Gurue can be estimated as more than 50-year probability at least, compared with Table 8.2.20.





Source: UNITAR's Operational Satellite Applications Programme (UNOSAT, UNitar)

Figure 8.2.24 Estimated Rainfall Accumulation of January 2015

(3) **Design Discharge**

1) Probable Discharge

In the same process used for the calculation of the probable rainfall, probable discharges at gauging stations are calculated from annual maximum discharges at each station. However, unfortunately, the hydrological data is poor, there are many gaps (missing data) during rainy seasons. Even though one flow record is intact for many years, most flow records are too short to get a reliable estimate of the hydrology in the catchment. Therefore, the result of probable discharge from collected data shall be set as values just for reference.

Table 8.2.21 Calculation Result of Probable Discharge from Collected Data

Station ID			Q- 120	Q- 126	Q- 136	Q- 138	Q- 153	Q- 198	Q- 398	Q- 399	Q- 444	Q- 445	Remarks
Station Name			Monapo em Est. Nacavala Muecate	Meluli em Murrupula Estr232	Motomode-E.N.240 Corrane Nampula	Namaíta-Est. Murrupula Nampula	Lúrio em E.N.8 Malema-Cuamba	Monapo em Albufeira de Nampula	Lúrio em Malapane	Monapo em Mecuburi	Micuco em Serra Mitucue	Mepopolo em Planalto Mitucue	
Riverine System			Monapo	Meluli	Mongicual	Meluli	Lurio	Monapo	Lurio	Monapo	Lurio	Lurio	
X: Longitude			39.64972	39.07000	39.48500	39.03611	36.86361	39.26667	37.43333	39.21722	36.81667	36.73333	
Y: Latitude			-14.95806	-15.20444	-15.30000	-15.27944	-14.79528	-15.02889	-14.41667	-15.02694	-14.70000	-14.73333	
Altitude (m)			230.0	270.0	260.0	420.0	525.0	340.0	490.0	350.0	-99.0	-99.0	
Drainage Area (km2)			1,350.0	795.0	186.0	548.0	3,250.0	480.0	18,590.0	477.0	10.0	10.0	
Data No.			39	33	22	24	1	8	8	23	3	5	
Probable Discharge (m3/s)	2 years	50%	134	85	11	67	-	20	940	77	-	-	
	3 years	33.3%	165	116	14	100	-	31	1522	102	-	-	
	5 years	20%	195	159	18	152	-	45	2255	129	-	-	
	10 years	10%	227	225	24	241	-	69	3250	161	-	-	
	20 years	5%	254	307	32	361	-	97	4245	189	-	-	
	25 years	4%	262	337	35	407	-	107	4565	198	-	-	
	30 years	3.33%	268	364	38	449	-	116	4827	205	-	-	
	50 years	2%	283	447	46	581	-	143	5560	223	-	-	
	80 years	1.25%	296	538	56	728	-	171	6235	240	-	-	
	100 years	1.0%	301	586	61	808	-	186	6555	248	-	-	
	150 years	0.667%	311	683	71	971	-	214	7137	261	-	-	
	200 years	0.5%	317	760	79	1102	-	235	7550	270	-	-	
	300 years	0.333%	325	883	92	1313	-	268	8132	283	-	-	
	400 years	0.25%	331	981	103	1482	-	293	8545	291	-	-	
	500 years	0.2%	335	1063	112	1626	-	314	8865	298	-	-	
SLSC (Standard Least Squares Criterion) 99%			0.036	0.032	0.057	0.029	-	0.048	0.029	0.040	-	-	
Adopted Distribution Formula			Gev	Gev	Gev	LogP3	-	LN2LM	Exp	Gev	-	-	
Probable Specific Discharge (m3/s/km2)	2 years	50%	0.09926	0.10692	0.05914	0.12226	-	0.04167	0.05056	0.16143	-	-	
	3 years	33.3%	0.12222	0.14591	0.07527	0.18248	-	0.06458	0.08187	0.21384	-	-	
	5 years	20%	0.14444	0.20000	0.09677	0.27737	-	0.09375	0.12130	0.27044	-	-	
	10 years	10%	0.16815	0.28302	0.12903	0.43978	-	0.14375	0.17483	0.33753	-	-	
	20 years	5%	0.18815	0.38616	0.17204	0.65876	-	0.20208	0.22835	0.39623	-	-	
	25 years	4%	0.19407	0.42390	0.18817	0.74270	-	0.22292	0.24556	0.41509	-	-	
	30 years	3.33%	0.19852	0.45786	0.20430	0.81934	-	0.24167	0.25966	0.42977	-	-	
	50 years	2%	0.20963	0.56226	0.24731	1.06022	-	0.29792	0.29909	0.46751	-	-	
	80 years	1.25%	0.21926	0.67673	0.30108	1.32847	-	0.35625	0.33540	0.50314	-	-	
	100 years	1.0%	0.22296	0.73711	0.32796	1.47445	-	0.3875	0.35261	0.51992	-	-	
	150 years	0.667%	0.23037	0.85912	0.38172	1.77190	-	0.44583	0.38392	0.54717	-	-	
	200 years	0.5%	0.23481	0.95597	0.42473	2.01095	-	0.48958	0.40613	0.56604	-	-	
	300 years	0.333%	0.24074	1.11069	0.49462	2.39599	-	0.55833	0.43744	0.59329	-	-	
	400 years	0.25%	0.24519	1.23396	0.55376	2.70438	-	0.61042	0.45966	0.61006	-	-	
	500 years	0.2%	0.24815	1.33711	0.60215	2.96715	-	0.65417	0.47687	0.62474	-	-	

Source: the Study Team using the data of ARA centro norte
Note: Station locations are shown in Figure 8.2.19. The values in the above Table show the probable discharge and unit-discharge for each return-period of each station, which was calculated from the data collected by the Study Team.

2) Design Return Period

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

The ANE guideline in the National Roads Strategy proposes a return period appropriate to the design discharge. The return periods for major transversal structures are basically proposed to be selected for each transversal structure as shown in Table 8.4.1, which gives the return period in consideration of the recent heavy rain and climate change. Also, as another regulation of Mozambique (aforementioned Decreto 30/2003), the design return period for the small scale drainage structures (such as urban drainage or sewer) have been prescribed as "5 years flood in principal" and "10-25 years flood in duly justified cases". The Study Team confirmed that this standard of return periods is similar to other countries, including Japanese standards.

In this study, the ANE guideline will be applied for the return period of Table 8.4.1 by the structure kind.

3) Estimation of Design Discharge

There are many methods and procedures for the flood estimation in general. In this study, the flood estimation was conducted using comparative verification, in reference to the "Drainage Manual 6th edition" of the South African National Roads Agency Ltd. and the "Decreto No. 30/2003" of Mozambican law, etc..

The theories for many methods have been developed by various institutions, and are either based on measured data (statistical); or a deterministic basis; or are empirical relationships. Except for the statistical method, the methods were "calibrated" for certain regions and flood events, and are limited in terms of the size of catchment areas on which they could be applied.

In this study, five estimation methods are examined, and the size of the catchment area of each method is limited as shown in Table 8.2.22.

Table 8.2.22 Application and Limitation of Flood Estimation Methods

Methods		Recommended Maximum Area; A (km^2)					Remarks
		Comment	A<1 km^2	1<A<15	15<A<200	A>200	
1	Rational Formula by Decreto 30／2003	In general, "<15 km^2". In this study, "A< 1 km^2".	○				
2	Rational Formula by SA standard	In general, "< 15 km^2". In this Study, "1<A<200 km^2".	○	○	○		
3	Synthetic Unit Hydrograph Method (SUH) by SA standard	15 < A < 5,000 km^2			○	○	
4	Regional Maximum Flood (RMF) by SA standard	No limitation. In this study, "A> 200km^2".				○	
5	Discharge per unit drainage area by statistical method (probable discharge)	No limitation. In this study, "A> 200km^2".				○	

Note: The value of design discharge is decided from among above methods by Consultant.

Source: the Study Team

The design discharge of the final road alignment of each bypass road is calculated, in reference to the South Africa Standard. And the size of crossing-structures is also calculated. (See Table 8.2.23 and Table 8.2.24.) The freeboard (the allowance height from structures to the design high water level) of lateral crossing-structures applies the values of the same Tables. (However, the freeboard of Nacala will be increased by some margin in order to protect against the risk of sediment-flow.)

The estimation of high water level will be shown in the next Clause, after taking the hydraulic calculation / hydrological interview survey results into consideration.

Table 8.2.23 Design Discharge (1/2)

Structure ID	Struture Type	Chainage	River name	Drainage Area	Design Scale	Synthetic Unit Hydrograph Method by SA standard	Regional Maximum Flood (RMF)	Rational Formula by SA standard										Rational Formula by Decreto 30／2003							Design Discharge	Culvert Type (Necessary Bridge Width)	Remarks
						Peak Discharge (A≥15 km2)	Peak Discharge	Concentration Time: T	Inlet Time: T1	Travel Time: T2	2yrs Return Period Daily Rainfall: R24	Thunder: R	Point Rainfall	Area Reduction Factor	Average Intensity: I_T	Combined Runoff Coefficient	Peak Discharge: Qp	Concentration Time: T	Inlet Time: T1	Travel Time: T2	Flow Length	Rainfall Intensity	Runoff Coefficient	Peak Discharge: Qp			
Nacala Port Access Road				(km^2)	(years)	(m^3/s)	(m^3/s)	(hr)	(hr)	(hr)	(mm)	(days)	(mm)		(mm/hr)	(%)	(m^3/s)	(min)	(min)	(min)	(m)	(mm/hr)	-	(m^3/s)	(m^3/s)		
Nac- 1	Culvert	No.000+45.0	(Small river)	1.85	20 yrs	-	-	0.80	0.46	0.33	74	80	101.21	107.62	136.97	45.0	31.6	35.2	27.8	7.4	1,557	169.32	0.45	39.1	31.6	II	
Nac- 2	Culvert	No.005+11.0	(Small river)	1.30	20 yrs	-	-	0.76	0.46	0.30	74	80	100.13	109.08	143.12	45.0	23.2	35.2	27.5	7.7	1,612	169.29	0.45	27.4	23.2	II	from N0.7+60
Nac- 3	Culvert	No.009+29.0	(Small river)	0.03	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	120.87	277.15	42.5	1.1	15.0	0.0	0.0	0	244.07	0.45	1.0	1.0	C150-1	from No.11+0
Nac- 4	Culvert	No.011+69.0	(Small river)	1.69	20 yrs	-	-	0.82	0.40	0.42	74	80	101.96	108.11	134.74	45.0	28.5	33.8	23.8	10.0	2,092	173.31	0.45	36.7	28.5	II	
Nac- 5	Culvert	No.013+97.0	(Small river)	0.04	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	119.81	274.73	42.5	1.4	15.0	0.0	0.0	0	244.07	0.45	1.3	1.3	C150-1	
Nac- 6	Culvert	No.014+97.0	(Small river)	0.05	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	119.50	274.01	42.5	1.5	15.0	0.0	0.0	0	244.07	0.45	1.4	1.4	C150-1	
Nac- 7	Culvert	No.016+98.0	(Small river)	0.05	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	119.04	272.96	42.5	1.7	15.0	0.0	0.0	0	244.07	0.45	1.6	1.6	C150-1	
Nac- 8	Culvert	No.020+35.0	(Small river)	0.49	10 yrs	-	-	0.80	0.51	0.29	74	80	81.97	113.45	116.66	42.5	6.8	36.1	30.4	5.7	1,197	145.70	0.45	9.0	9.0	Ic	
Nac- 9	Culvert	No.021+57.0	(Small river)	0.02	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	123.43	283.01	42.5	0.5	15.0	0.0	0.0	0	244.07	0.45	0.5	0.5	C90-1	from No.22+51
Nac- 10	Culvert	No.025+88.0	(Small river)	0.89	10 yrs	-	-	0.80	0.44	0.36	74	80	81.92	110.88	114.24	42.5	12.0	33.8	26.2	7.6	1,595	151.63	0.45	16.9	16.9	II	
Nac- 11	Culvert	No.026+49.0	(Small river)	0.02	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	122.07	279.91	42.5	0.8	15.0	0.0	0.0	0	244.07	0.45	0.7	0.7	C90-1	from No.28+10
Nac- 12	Culvert	No.029+92.0	(Small river)	2.99	20 yrs	-	-	0.94	0.31	0.63	74	80	105.55	105.98	119.26	45.0	44.5	31.5	18.8	12.7	2,676	180.56	0.45	67.4	44.5	III	from No.29+63, 31+85
Nac- 13	Culvert	No.035+35.0	(Small river)	0.40	10 yrs	-	-	0.72	0.45	0.27	74	80	79.77	113.97	126.49	42.5	6.0	31.0	27.1	3.9	820	159.40	0.45	8.0	8.0	Ic	from No.33+0
Nac- 14	Culvert	No.039+04.0	(Small river)	0.84	10 yrs	-	-	0.88	0.49	0.39	74	80	84.12	111.51	106.37	42.5	10.5	36.6	29.6	7.0	1,467	144.64	0.45	15.1	15.1	Ic	
Nac- 15	Bridge	No.042+14.0	(Small river)	10.86	**50 yrs**	-	-	2.14	0.80	1.34	74	80	159.26	102.82	76.53	47.5	109.7	75.2	48.2	27.0	5,672	127.09	0.45	172.6	109.7	**(Necessary Brd. W=30m, with RTW)**	HWL=10.77m (100yrs: 10.95m)
Nac- 16	Culvert	No.044+65.0	(Small river)	0.17	10 yrs	-	-	0.57	0.35	0.22	74	80	74.75	116.75	153.75	42.5	3.1	22.8	20.9	2.0	354	190.69	0.45	4.1	4.1	Ib	
Nac- 17	Culvert	No.051+19.0	(Small river)	0.06	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	118.48	271.68	42.5	1.9	15.0	0.0	0.0	0	244.07	0.45	1.8	1.8	C150-1	
Nac- 18	Culvert	No.069+65.0	(Small river)	1.10	20 yrs	-	-	0.62	0.27	0.35	74	80	94.61	109.10	166.92	45.0	22.9	22.9	16.2	6.7	1,408	217.40	0.45	29.9	22.9	II	from No.67+45
Nac- 19	Culvert	No.080+08.0	(Small river)	0.05	10 yrs	-	-	0.35	0.33	0.02	74	80	64.59	120.42	221.07	42.5	1.2	20.1	19.9	0.2	34	205.78	0.45	1.2	1.2	C150-1	
Nac- 20	Culvert	No.082+63.0	(Small river)	0.07	10 yrs	-	-	0.27	0.23	0.04	74	80	58.81	118.08	259.07	42.5	2.1	15.0	0.0	0.0	106	244.07	0.45	2.1	2.1	C150-1	from No.81+38
Nac- 21	Culvert	No.084+58.0	(Small river)	0.27	10 yrs	-	-	0.38	0.25	0.13	74	80	66.24	113.62	197.94	42.5	6.3	17.8	15.3	2.5	523	220.98	0.45	7.4	7.4	Ic	
Nac- 22	Culvert	No.092+10.0	(Small river)	0.13	10 yrs	-	-	0.25	0.00	0.00	74	80	57.33	115.16	264.07	42.5	4.2	15.0	0.0	0.0	253	244.07	0.45	4.1	4.1	Ib	from No.93+17, 91+88
Nac- 23	Culvert	No.094+38.0	(Small river)	0.08	10 yrs	-	-	0.25	0.20	0.05	74	80	57.56	117.37	267.26	42.5	2.5	15.0	0.0	0.0	190	244.07	0.45	2.4	2.4	Ia	
Nac- 24	Culvert		(Small river)	0.00	10 yrs	-	-	0.35	0.32	0.04	74	80	64.77	#NUM!	#NUM!	42.5	#NUM!	19.4	19.0	0.4	94	209.86	0.45	0.0	0.0		
Nac- 24	Culvert	No.098+55.0	(Small river)	0.66	10 yrs	-	-	0.67	0.49	0.18	74	80	78.28	111.65	130.42	42.5	10.1	33.2	29.3	3.9	829	153.00	0.45	12.5	12.5	Ic	
Nac- 25	Culvert	No.104+74.0	(Small river)	0.66	10 yrs	-	-	0.82	0.77	0.05	74	80	82.55	112.26	113.14	42.5	8.9	46.8	46.0	0.7	155	125.21	0.45	10.4	10.4	Ic	from No.106+28
Nac- 26	Culvert	No.107+75.0	(Small river)	1.75	20 yrs	-	-	1.01	0.92	0.10	74	80	107.53	108.69	115.54	45.0	25.3	56.9	55.0	1.9	408	128.00	0.45	28.1	25.3	II	from No.108+69
Nac- 27	Culvert	No.113+19.0	(Small river)	1.92	20 yrs	-	-	0.78	0.67	0.11	74	80	100.81	107.38	138.22	45.0	33.2	42.6	40.3	2.3	476	151.50	0.45	36.4	33.2	III	from No.113+96
Nac- 28	Culvert	No.117+11.0	(Small river)	0.22	10 yrs	-	-	0.49	0.46	0.03	74	80	71.59	115.31	168.78	42.5	4.3	28.0	27.5	0.5	107	169.23	0.45	4.6	4.6	Ib	from No.117+41
Nac- 29	Culvert	No.121+71.0	(Small river)	0.76	10 yrs	-	-	0.80	0.74	0.05	74	80	81.93	111.58	114.90	42.5	10.3	45.6	44.7	0.9	181	127.15	0.45	12.1	12.1	Ic	
Nac- 30	Culvert	No.125+86.0	(Small river)	1.17	20 yrs	-	-	0.78	0.75	0.04	74	80	100.84	109.63	141.02	45.0	20.6	45.5	44.9	0.6	120	145.87	0.45	21.3	20.6	II	from No.127+32, 125+61
Nac- 31	Culvert	No.134+31.0	(Small river)	1.79	20 yrs	-	-	0.92	0.87	0.04	74	80	104.96	108.27	123.89	45.0	27.7	53.2	52.5	0.7	157	133.11	0.45	29.7	27.7	II	from No.135+31
Nac- 32	Culvert	No.137+33.0	(Small river)	0.16	10 yrs	-	-	0.44	0.28	0.16	74	80	69.34	116.17	183.06	42.5	3.5	19.8	16.8	2.9	617	207.57	0.45	4.2	4.2	Ib	from No.144+89
Nac- 33	Culvert	No.144+86.0	(Small river)	0.03	10 yrs	-	-	0.32	0.29	0.03	74	80	62.26	121.38	239.69	42.5	1.0	17.4	17.1	0.3	64	223.47	0.45	0.9	0.9	C150-1	
Nampula Bypass Road																											
Nam- 1	Culvert	No.012+15.0	(Mogincual River)	2.35	20 yrs	-	-	0.93	0.44	0.49	88	80	118.59	107.05	137.18	45.0	40.3	33.5	26.1	7.3	1,540	174.39	0.45	51.2	40.3	II	
Nam- 2	Culvert	No.023+65.0	(Monotomo River)	0.15	10 yrs	-	-	0.33	0.19	0.14	88	80	71.53	115.73	248.28	42.5	4.3	15.0	0.0	0.0	488	244.07	0.45	4.5	4.5	Ib	
Nam- 3	Culvert	No.028+68.0	(Monotomo River)	0.08	10 yrs	-	-	0.35	0.21	0.14	88	80	72.80	118.54	245.48	42.5	2.2	15.2	12.5	2.7	563	242.41	0.45	2.3	2.3	C150-1	
Nam- 4	Culvert	No.031+96.0	(Monotomo River)	5.91	20 yrs	-	-	1.32	0.51	0.81	88	80	128.99	103.96	101.97	45.0	75.3	44.8	30.5	14.3	2,999	147.15	0.45	108.7	75.3	III	
Nam- 5	Culvert	No.035+40.0	(Monotomo River)	0.05	10 yrs	-	-	0.30	0.22	0.08	88	80	69.02	119.89	275.61	42.5	1.5	15.0	0.0	0.0	212	244.07	0.45	1.5	1.5	C150-1	
Nam- 6	Bridge	No.047+98.0	Mutomote River	25.91	**50 yrs**	159.6	-	3.06	0.82	2.25	88	80	192.83	99.84	62.84	47.5	214.8	94.3	49.1	45.3	8,146	111.47	0.45	361.0	214.8	**(Necessary Brd. W= 60.0m)**	HWL= 354.95m (100yrs: 355.15m)
Nam- 7	Culvert	No.060+53.0	(Monotomo River)	1.02	10 yrs	-	-	0.97	0.57	0.41	88	80	97.16	110.96	110.91	42.5	13.4	41.4	34.0	7.4	1,552	134.49	0.45	17.2	13.4	Ic	
Nam- 8	Culvert	No.096+52.0	(Meluli River)	1.52	20 yrs	-	-	0.84	0.59	0.25	88	80	115.90	108.70	149.12	45.0	28.4	40.6	35.6	5.0	1,053	155.70	0.45	29.6	28.4	II	
Nam- 9	Culvert	No.103+46.0	(Meluli River)	0.79	20 yrs	-	-	0.56	0.32	0.24	88	80	103.67	110.21	204.41	45.0	20.2	24.6	19.3	5.3	1,118	208.53	0.45	20.6	20.6	II	
Nam- 10	Culvert	No.109+12.0	(Meluli River)	0.62	10 yrs	-	-	0.58	0.37	0.21	88	80	84.86	111.44	162.61	42.5	11.8	26.9	22.4	4.5	940	173.36	0.45	13.4	13.4	Ic	
Nam- 11	Culvert	No.115+93.0	(Meluli River)	0.75	20 yrs	-	-	0.49	0.31	0.18	88	80	99.88	110.01	223.43	45.0	21.0	22.4	18.6	3.8	797	220.21	0.45	20.7	20.7	II	
Nam- 12	Culvert	No.122+91.0	(Meluli River)	0.48	10 yrs	-	-	0.68	0.38	0.30	88	80	88.75	113.06	146.66	42.5	8.3	26.2	22.9	3.3	597	175.77	0.45	10.6	10.6	Ic	
Nam- 13	Bridge	No.126+84.0	Muepelume River	17.21	**50 yrs**	244.8	-	1.52	0.58	0.94	88	80	166.76	99.16	109.09	47.5	247.7	52.2	34.8	17.4	3,661	156.91	0.45	337.6	247.7	**(Necessary Brd. W=60m, with RTW)**	HWL= 332.74m (100yrs: 333.05m)
Nam- 14	Culvert	No.143+14.0	(Meluli River)	0.28	10 yrs	-	-	0.33	0.26	0.07	88	80	71.22	112.96	244.44	42.5	8.1	16.6	15.4	1.2	249	229.84	0.45	8.1	8.1	Ib	
Nam- 15	Culvert	No.145+68.0	(Meluli River)	0.10	10 yrs	-	-	0.31	0.26	0.05	88	80	69.47	116.97	265.65	42.5	3.2	16.1	15.4	0.7	155	233.89	0.45	2.9	2.9	C150-1	
Nam- 16	Culvert	No.152+93.0	(Meluli River)	0.12	10 yrs	-	-	0.30	0.28	0.03	88	80	69.35	116.40	265.20	42.5	3.6	17.1	16.7	0.4	84	225.86	0.45	3.3	3.3	C150-1	
Nam- 17	Bridge	No.158+86.0	Muhala River	13.85	**50 yrs**	-	-	2.21	0.65	1.56	88	80	180.77	101.74	83.13	47.5	151.9	70.4	38.9	31.5	6,622	131.98	0.45	228.5	151.9	**(Necessary Brd. W= 60.0m)**	HWL=327.15m (100yrs: 327.41m)

Source: the Study Team

Table 8.2.24 Design Discharge (2/2)

Structure ID	Struture Type	Chainage	River name	Drainage Area	Design Scale	Synthetic Unit Hydrograph Method by SA standard	Regional Maximum Flood (RMF)	Rational Formula by SA standard										Rational Formula by Decreto 30／2003							Design Discharge	Culvert Type (Necessary Bridge Width)	Remarks
						Peak Discharge (A≥15 km2)	Peak Discharge	Concentration Time: T	Inlet Time: T1	Travel Time: T2	2yrs Return Period Daily Rainfall: R24	Thunder: R	Point Rainfall	Area Reduction Factor	Average Intensity: I_T	Combined Runoff Coefficient	Peak Discharge: Qp	Concentration Time: T	Inlet Time: T1	Travel Time: T2	Flow Length	Rainfall Intensity	Runoff Coefficient	Peak Discharge: Qp			
Nam- 18	Culvert	No.163+95.0	(Meluli River)	1.04	10 yrs	-	-	0.82	0.64	0.18	88	80	93.20	110.34	124.83	42.5	15.3	41.3	38.5	2.8	578	134.78	0.45	17.5	15.3	Ic	
Nam- 19	Culvert	No.178+88.0	(Meluli River)	0.25	10 yrs	-	-	0.53	0.40	0.13	88	80	82.79	115.06	178.60	42.5	5.2	25.9	23.9	2.0	418	177.08	0.45	5.4	5.4	Ib	
Nam- 20	Bridge	No.183+49.0	Muepelume (B) River	42.56	**100 yrs**	236.6	-	3.06	0.85	2.22	88	80	222.19	97.24	70.52	50.0	416.9	-	-	-	-	-	-	-	**416.9**	**(Necessary Brd. W= 90.0m)**	HWL= 323.08m
Nam- 21	Culvert	No.191+79.0	(Meluli River)	0.40	10 yrs	-	-	0.53	0.22	0.31	88	80	82.77	113.02	175.53	42.5	8.3	19.3	13.4	5.9	1,237	210.71	0.45	10.5	10.5	Ic	
Nam- 22	Culvert	No.207+05.0	(Meluli River)	0.47	10 yrs	-	-	0.56	0.55	0.01	88	80	83.91	112.48	168.85	42.5	9.4	32.9	32.8	0.1	23	154.04	0.45	9.1	9.1	Ic	
Nam- 23	Culvert	No.218+66.0	(Meluli River)	1.91	20 yrs	-	-	0.81	0.47	0.33	88	80	114.50	107.50	152.71	45.0	36.5	33.6	28.3	5.3	1,107	173.93	0.45	41.6	36.5	II	
Nam- 24	Culvert	No.227+30.0	(Meluli River)	0.24	10 yrs	-	-	0.45	0.29	0.15	88	80	78.65	114.67	200.99	42.5	5.6	20.0	17.7	2.3	482	206.42	0.45	6.1	6.1	Ib	
Nam- 25	Culvert	No.246+36.0	(Meluli River)	0.45	10 yrs	-	-	0.62	0.60	0.02	88	80	86.37	112.98	157.51	42.5	8.4	36.2	36.0	0.2	44	145.50	0.45	8.2	8.2	Ib	
Nam- 26	Culvert	No.251+61.0	(Meluli River)	0.40	10 yrs	-	-	0.62	0.56	0.06	88	80	86.27	113.47	158.69	42.5	7.5	34.4	33.7	0.7	149	149.94	0.45	7.5	7.5	Ib	
Nam- 27	Culvert	No.259+22.0	(Meluli River)	0.37	10 yrs	-	-	0.50	0.47	0.03	88	80	81.19	113.10	184.05	42.5	8.1	28.4	28.1	0.3	61	167.70	0.45	7.8	7.8	Ib	
Nam- 28	Culvert	No.271+71.0	(Meluli River)	0.77	10 yrs	-	-	0.62	0.60	0.03	88	80	86.57	110.68	153.39	42.5	14.0	36.1	35.8	0.3	69	145.77	0.45	14.1	14.1	Ic	
Nam- 29	Culvert	No.292+37.0	(Meluli River)	0.55	10 yrs	-	-	0.56	0.53	0.03	88	80	83.96	111.83	167.61	42.5	10.9	32.0	31.5	0.5	107	156.33	0.45	10.7	10.7	Ic	
Cuamba Bypass Road																											
Cua- 1	Bridge	No.003+54.0	Muwanda River (Lurio River)	3,390	**100 yrs**	2,121	3,401	20.50	-	-	-	-	-	-	-	Statistical Unit Discharge per drainage area		0.35261			$m^3/s/km^2$	Design Q by Specific Discharge		1,195	**2,121**	**(Necessary Brd. W= 240.0m)**	Muwand River, HWL= 559.70m
Cua- 2	Culvert	No.007+05.0	(Lurio River)	0.54	10 yrs	-	-	0.70	0.50	0.19	71	80	76.90	112.62	124.14	42.5	7.9	32.7	30.3	2.4	504	82.44	0.35	4.3	4.3	Ib	
Cua- 3	Bridge	No.020+66.0	(Lurio River)	41.82	**50 yrs**	162.0	-	4.32	1.28	3.05	71	80	177.24	98.73	40.47	47.5	223.3	138.5	76.6	62.0	11,156	47.62	0.35	193.6	223.3	**(Necessary Brd. W= 90.0m)**	HWL= 561.58m (100yrs: 562.30m)
Cua- 4	Culvert	No.032+45.0	(Lurio River)	0.89	10 yrs	-	-	0.75	0.37	0.38	71	80	78.47	110.69	115.42	42.5	12.2	27.3	22.3	5.0	1,060	91.57	0.35	7.9	7.9	Ib	
Cua- 5	Culvert	No.038+91.0	(Lurio River)	1.72	20 yrs	-	-	1.06	0.48	0.58	71	80	105.71	108.94	108.55	45.0	23.3	37.7	28.6	9.1	1,901	86.79	0.35	14.5	23.3	II	
Cua- 6	Bridge	No.052+69.0	(Lurio River)	25.64	**50 yrs**	147.3	-	3.03	0.98	2.05	71	80	165.90	99.85	54.64	47.5	184.9	99.3	58.7	40.6	7,311	57.71	0.35	143.9	184.9	**(Necessary Brd. W= 90.0m)**	HWL= 563.71m (100yrs: 564.47m)
Cua- 7	Culvert	No.083+42.0	(Lurio River)	0.45	10 yrs	-	-	0.37	0.28	0.09	71	80	63.60	111.28	193.18	42.5	10.2	17.8	16.8	1.0	207	117.66	0.35	5.1	5.1	Ib	
Cua- 8	Culvert	No.101+13.0	(Lurio River)	0.54	10 yrs	-	-	0.71	0.54	0.17	71	80	77.37	112.67	122.16	42.5	7.8	33.5	32.5	0.9	120	81.26	0.35	4.3	4.3	Ib	
Cua- 9	Culvert	No.108+16.0	(Lurio River)	0.34	10 yrs	-	-	0.55	0.44	0.11	71	80	71.81	113.75	149.84	42.5	6.1	27.3	26.3	1.0	212	91.64	0.35	3.1	3.1	C150-1	
Cua- 10	Culvert	No.112+63.0	(Lurio River)	0.45	10 yrs	-	-	0.77	0.65	0.12	71	80	78.93	113.74	116.65	42.5	6.2	40.2	39.2	1.1	191	72.95	0.35	3.2	3.2	C150-1	

Note. Time of concentration is calculated by Kerby formula for Inlet time and SA standard or Kraven formula for Travel time.
Necessary Bridge Opening Width is calculated by Lacey's equation, in order to prevent contraction scour.

Assumed V= 1.0 m/s.

Combined Runoff Coefficient

Items					Return Period (year)		Combined Runoff Coefficient: 2 yrs	10 yrs	20 yrs	50 yrs	100 yrs
					Adjustment Factor: Ft		0.75	0.85	0.90	0.95	1.00
	C_S	C_P	C_V	C1	C2	C (C1 or C2)					
Nacala	0.08 +	0.16 +	0.28 =	0.52	0.50	0.50	0.375	0.425	0.45	0.475	0.50
Nampula	0.05 +	0.20 +	0.25 =	0.50	0.50	0.50	0.375	0.425	0.45	0.475	0.50
Cuamba	0.05 +	0.20 +	0.25 =	0.50	0.50	0.50	0.375	0.425	0.45	0.475	0.50

Culvert Type

	Type	B (ϕ) (m)	H (ϕ) (m)	Cell No.	Slope (%)	Area (m2)	Wetted perimeter (m)	Velocity (m/s)	Discharge capacity (m3/s)	Remarks	BoQ	
Pipe	C90-1	0.90	0.90	1	0.60%	0.55	1.99	2.18	1.19	80% depth	1	
Pipe	C150-1	1.50	1.50	1	0.30%	1.52	3.32	2.16	3.28	80% depth	6	
Box	Ia	1.50	1.50	1	0.30%	1.80	3.90	2.18	3.93	80% depth	0	
Box	Ib	2.00	2.00	1	0.30%	3.20	5.20	2.64	8.45	80% depth	11	
Box	Ic	3.00	3.00	1	0.20%	7.20	7.80	2.83	20.35	80% depth	8	
Box	II	3.00	3.00	2	0.20%	7.20	7.80	2.83	40.70	80% depth	6	
Box	III	6.00	4.50	1	0.15%	21.60	13.20	3.59	77.45	80% depth	1	
	For Nacala Road											
Pipe	C90-1	0.90	0.90	1	0.60%	0.40	1.59	2.05	0.82	60% depth	2	
Pipe	C150-1	1.50	1.50	1	0.30%	1.11	2.66	2.04	2.25	60% depth	8	
Box	Ia	1.50	1.50	1	0.30%	1.35	3.30	2.01	2.72	60% depth	1	
Box	Ib	2.00	2.00	1	0.30%	2.40	4.40	2.44	5.85	60% depth	4	
Box	Ic	3.00	3.00	1	0.20%	6.00	7.00	2.69	16.14	2m depth	7	Fb=1.00m
Box	II	3.00	3.00	2	0.20%	6.00	7.00	2.69	32.28	2m depth	8	Fb=1.00m
Box	III	6.00	4.50	1	0.15%	21.00	13.00	3.55	74.65	3.5m depth	2	Fb=1.00m

Source: the Study Team

(4) Hydraulic Calculation and Design High Water Level

1) Probable High Water Level

In the same process used for the calculation of the probable rainfall and discharge, the probable high water-levels at each gauging-station are calculated from annual maximum water-levels at each station. However, unfortunately, there are many gaps (missing data) during rainy seasons, and it is unreliable. Also, the datum of each gauge is an arbitrary datum, and there is no relationship with the topographic survey datum. Therefore, the result of probable flood-level from collected data shall be set as relative values just for reference. (Table 8.2.25)

Table 8.2.25 Calculation Result of Probable High Water-Level from Collected Data

Station Name			Monapo em Est. Nacavala Muecate	Meluli em Murrupula Estr232	Motomode-E.N.240 Corrane Nampula	Namaíta-Est. Murrupula Nampula	Namaíta-Est. Murrupula Nampula	Lúrio em E.N.8 Malema-Cuamba	Monapo em Mecuburi	Micuco em Serra Mitucue	Mepopolo em Planalto Mitucue	Remarks
River Name			Monapo	Meluli	Mogincual	Meluli	Monapo	Lurio	Lurio	Lurio	Lurio	
Station ID			E120	E126	E136	E138	E399	E153	E398	E444	E445	
Long. (X)			39.6497	39.0700	39.4850	39.0361	39.0361	36.8636	39.2172	36.8167	36.7333	
Lat. (Y)			-14.9581	-15.2044	-15.3000	-15.2794	-15.2794	-14.7953	-15.0269	-14.7000	-14.7333	
Data No. of Extreme Value			41	44	24	36	22	18	8	11	14	
Shift amount (m)			-5.66	-4.39	-1.86	-3.97	-5.20	-4.54	-7.12	-1.13	-2.74	
Probable Water Level (m)	(Year)	(%)										
	2	50%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	3	33.3%	0.41	0.48	0.21	0.45	0.34	0.58	0.72	0.25	0.10	
	5	20%	0.73	0.97	0.44	1.03	0.63	1.37	1.44	0.57	0.19	
	10	10%	1.01	1.56	0.74	1.89	0.90	2.57	2.23	1.00	0.27	
	20	5.0%	1.19	2.09	1.03	2.90	1.08	3.94	2.90	1.43	0.32	
	25	4.0%	1.23	2.26	1.12	3.26	1.12	4.43	3.09	1.57	0.34	
	30	3.33%	1.26	2.39	1.19	3.57	1.16	4.84	3.25	1.69	0.35	
	50	2.0%	1.33	2.75	1.41	4.51	1.24	6.07	3.66	2.00	0.38	
	80	1.25%	1.38	3.08	1.61	5.49	1.29	7.32	4.02	2.30	0.40	
	100	1.0%	1.40	3.23	1.70	5.99	1.32	7.95	4.18	2.44	0.41	
	150	0.667%	1.43	3.50	1.88	6.99	1.35	9.17	4.46	2.69	0.42	
	200	0.5%	1.45	3.69	2.00	7.77	1.37	10.09	4.66	2.87	0.43	
	300	0.333%	1.47	3.96	2.18	8.96	1.40	11.46	4.92	3.12	0.44	
	400	0.25%	1.49	4.15	2.31	9.88	1.41	12.50	5.10	3.30	0.45	
	500	0.2%	1.50	4.29	2.41	10.65	1.43	13.34	5.24	3.44	0.46	
Probabilistic Distributed model			Log Pearson type Ⅲ distribution (Real space method)	2-parameter log-normal distribution (Slade I, moment method)	3-parameter log-normal distribution (Quantile method)	Generalized extreme value distribution	Generalized extreme value distribution	3-parameter log-normal distribution (Quantile method)	Log Pearson type Ⅲ distribution (Logarithmic space method)	Exponential distribution	Log Pearson type Ⅲ distribution (Real space method)	

Source: the Study Team using the data of ARA Centro-Norte

2) Interview Survey Results

The water level data in gauging stations is unreliable as mentioned above, and also the locations of gauging stations are far from the bridge sites. Therefore, in order to verify the correlation between the real flood-level at sites and the hydraulic calculation results, an interview survey with the local inhabitants for actual flood levels was conducted. Locations and results of the interviews are shown in Table 8.2.26 and Figure 8.2.25 - Figure 8.2.27.

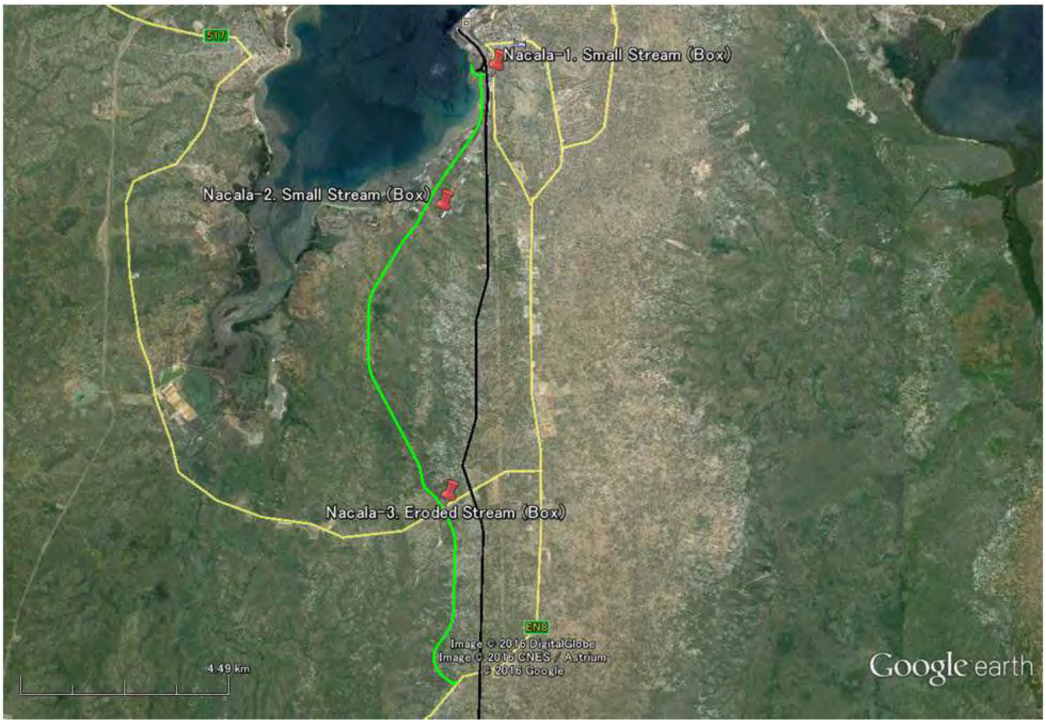
Most of the historical high flood-levels (HHWL) at the interview spots were reported to have been the flood during January to March 2015. In the Muwanda River of Cuamba, from the correlation between the water-levels reported in the interviews and the hydraulic calculation results, the historical high flood-level can be estimated as the flood-event corresponding to a 50-100 year flood. (Figure 8.2.28) In a similar way, the historical high flood-levels in the Mutomote and Muepelume B River of Nampula can be estimated as flood-events lower than a 50-year flood. (Figure 8.2.29)

Table 8.2.26 Hydrological Interview Survey Results

Interview Location		Coordinates		Interview Item	Interviewed Water Level	Interview Contents (Water Level is ...)	Interview Location Ground Level	Remarks
No.	River Name	Longitude (X)	Latitude (Y)					
		(degree)	(degree)		(m)		(m)	
< Nacala >								
1	Small Stream (Box)	40.67370	-14.55064	HHWL	-	River channel shoulder +0.3m	-	
2	Small Stream (Box)	40.66338	-14.57783	HHWL	-	GL (Road)+0.1m	-	
3	Eroded Stream (Box)	40.66484	-14.63409	HHWL	-	River channel shoulder +0.2m	-	
< Nampula >								
1	Mutomote River (Brd)	39.34142	-15.14842	HHWL	352.30	GL+0.0m	352.30	
2	Small Stream (Box)	39.33294	-15.15675	HHWL	-	GL (Road)-0.8m	-	
3	Muepelume River (Brd)	39.26924	-15.17092	HHWL	-	River channel shoulder +0.0m	-	
4	Muhala River (Brd)	39.24587	-15.16203	HHWL	328.35	GL+0.0m	328.35	Doughtful value
5	Muepelume B River (Brd)	39.24417	-15.16730	HHWL	-	River channel shoulder +0.0m	-	
		39.21963	-15.15634	HHWL	323.27	GL+0.0m	323.27	
< Cuamba >								
1	Muwanda River	36.58515	-14.79816	HHWL	558.22	GL+1.65m	556.57	
	Muwanda River (Brd)	36.57799	-14.79870	HHWL	560.20	GL+2.34m	557.86	
2	Muwanda River (Brd)	36.56781	-14.79207	HHWL	559.15	GL+0.0m	559.15	Doughtful value
3	Muwanda Tributary (Brd)	36.54147	-14.78279	HHWL	564.00	GL+0.8m	563.20	
		36.54169	-14.78244	AHWL	561.47	GL+0.7m	560.77	
4	Small stream (Box)	36.51751	-14.78869	HHWL	-	GL+0.0m	-	

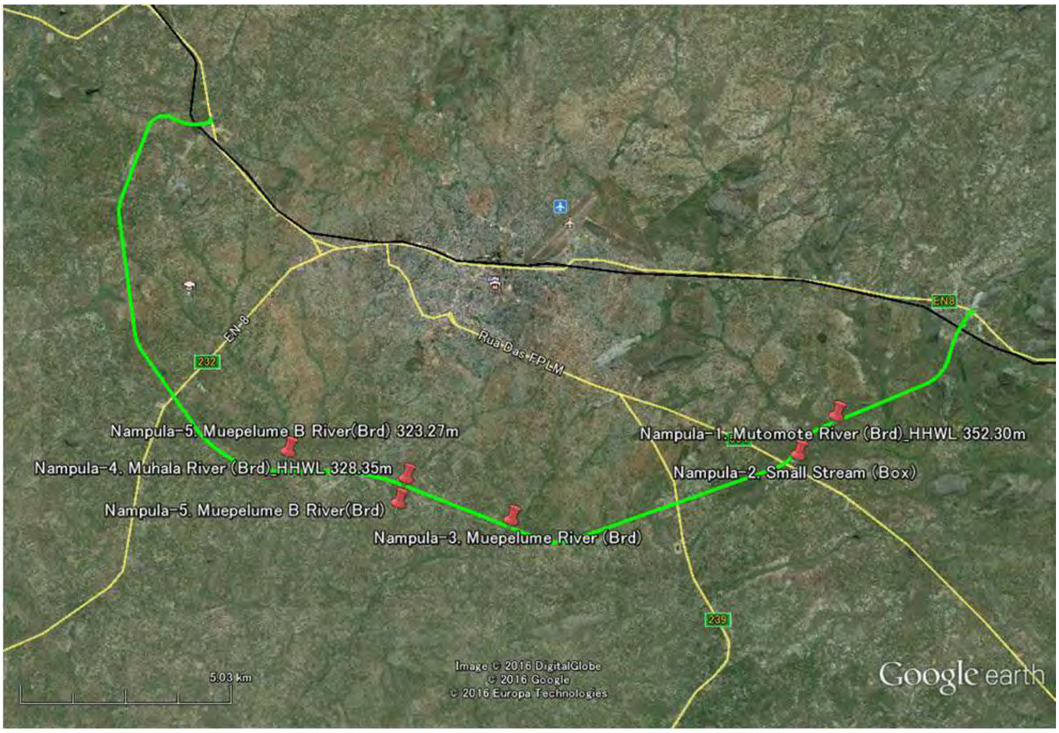
Note. HHWL means the historical maximum water level, AHWL means the annual maximum water level in local resident's recollections.

Source: the Study Team



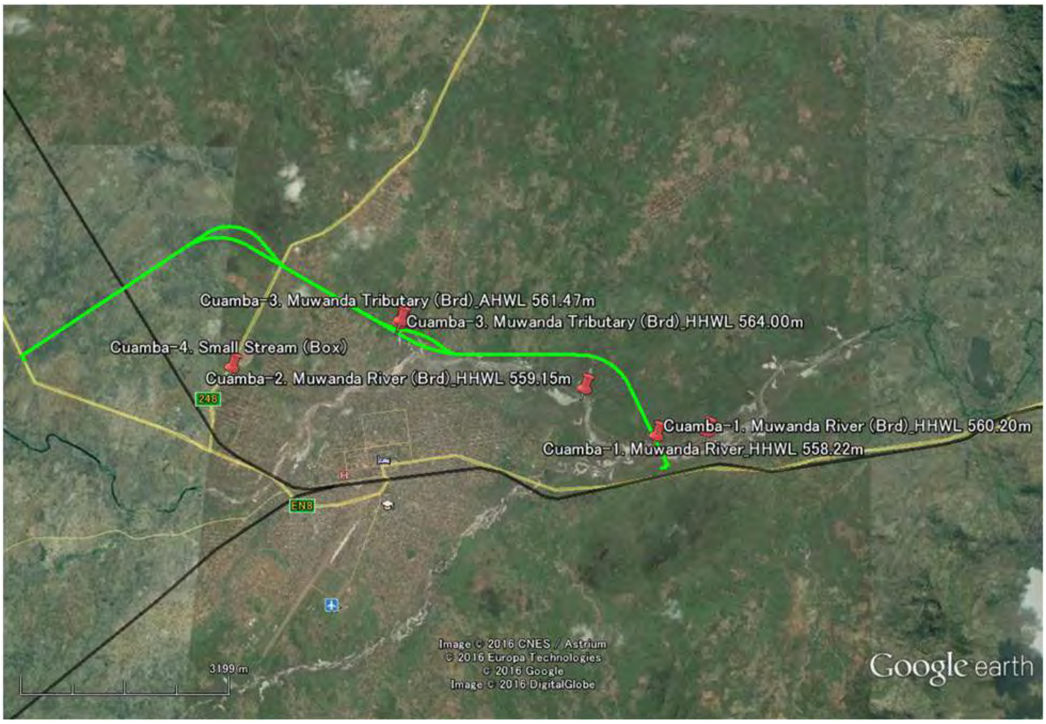
Source: the Study Team, Google Earth

Figure 8.2.25 Hydrological Interview Survey Locations at Nacala



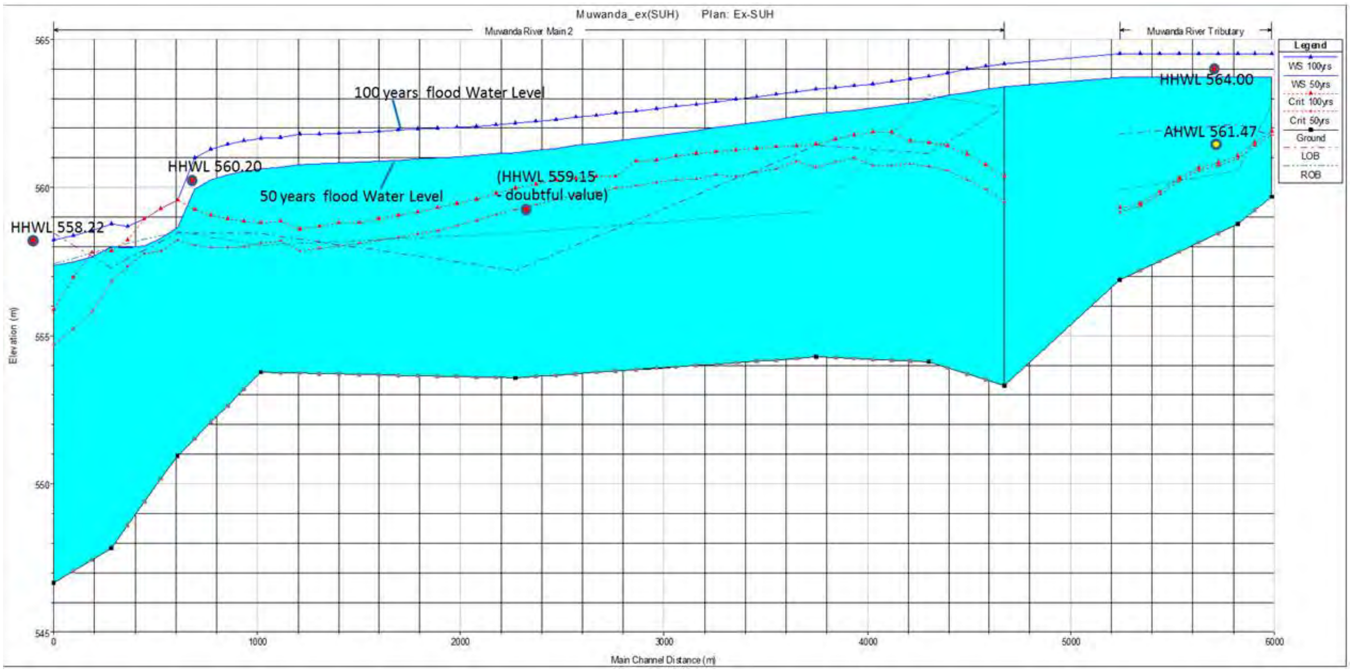
Source: the Study Team, Google Earth

Figure 8.2.26 Hydrological Interview Survey Locations at Nampula



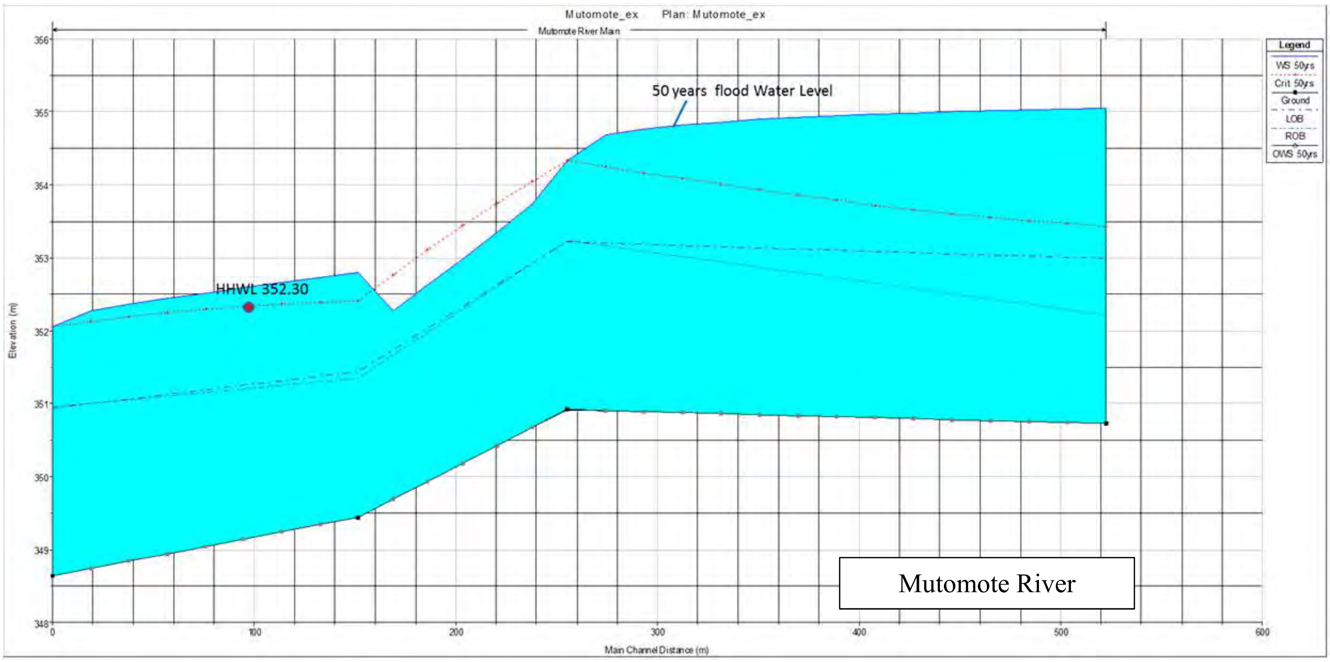
Source: the Study Team, Google Earth

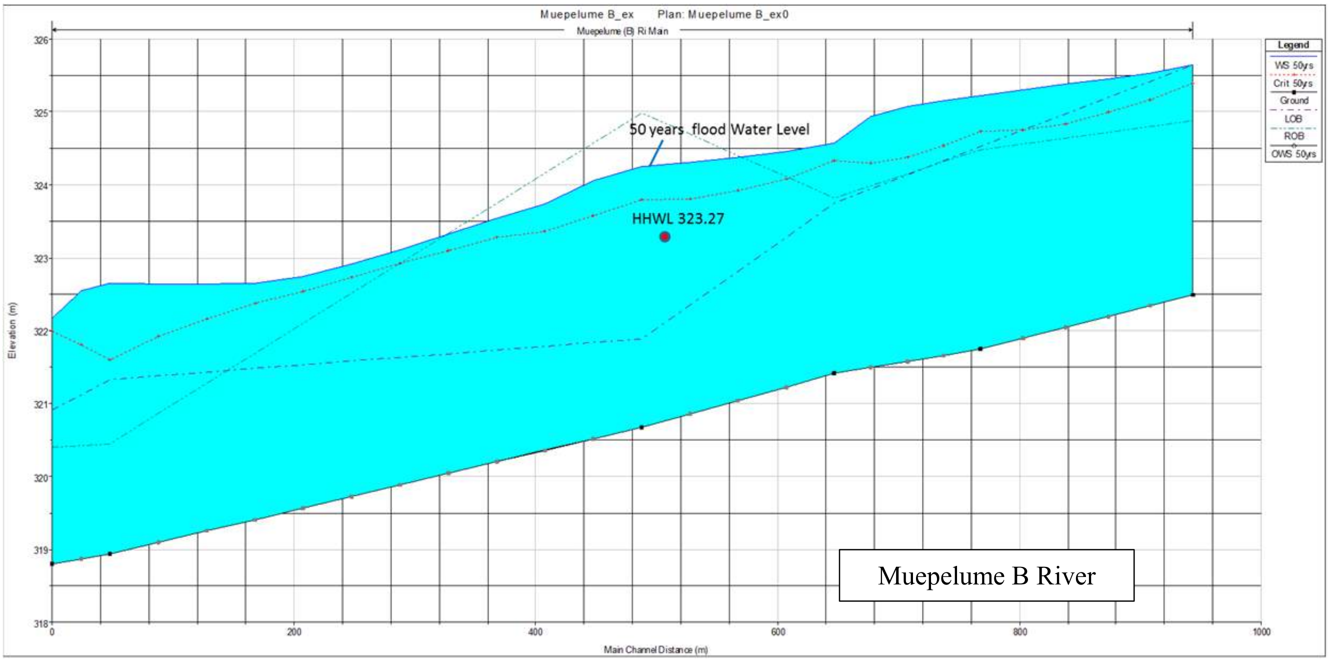
Figure 8.2.27 Hydrological Interview Survey Locations at Cuamba



Source: the Study Team

Figure 8.2.28 Correlation between the Water-Levels reported in the Interviews and the Hydraulic Calculation Results at Muwanda River of Cuamba





Source: the Study Team

Figure 8.2.29 Correlation between the Water-Levels reported in the Interviews and the Hydraulic Calculation Results at Mutomote and Muepelume B River of Nampula

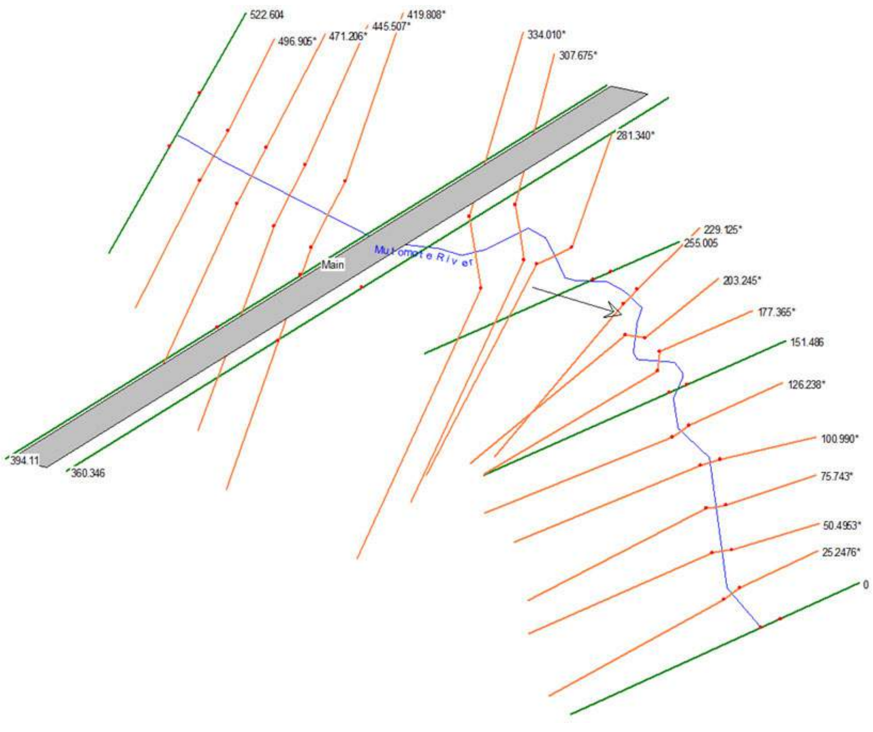
3) Hydraulic Calculations

The 1-dimensional hydraulic analyses were performed under the average flow condition for the 4 main bridges of Namupula and the 3 main bridges of Cuamba, for confirming the several hydraulic quantities and the bridge scour. For the 1-dimensional hydraulic analyses, the HEC-RAS model (Hydrologic Engineering Center - River Analysis System) developed by the US Army Corps of Engineers, was used.

The hydraulic calculation models at the 4 main bridges of Nampula and 3 main bridges of Cuamba are shown in Figure 8.2.30 to Figure 8.2.34. (In the case of the 3 main bridges of Cuamba, the calculation model was set up as a single fluvial system from the downstream to upstream of Muwanda River.) The cross-sections for hydraulic calculation are given using the topographic survey results.

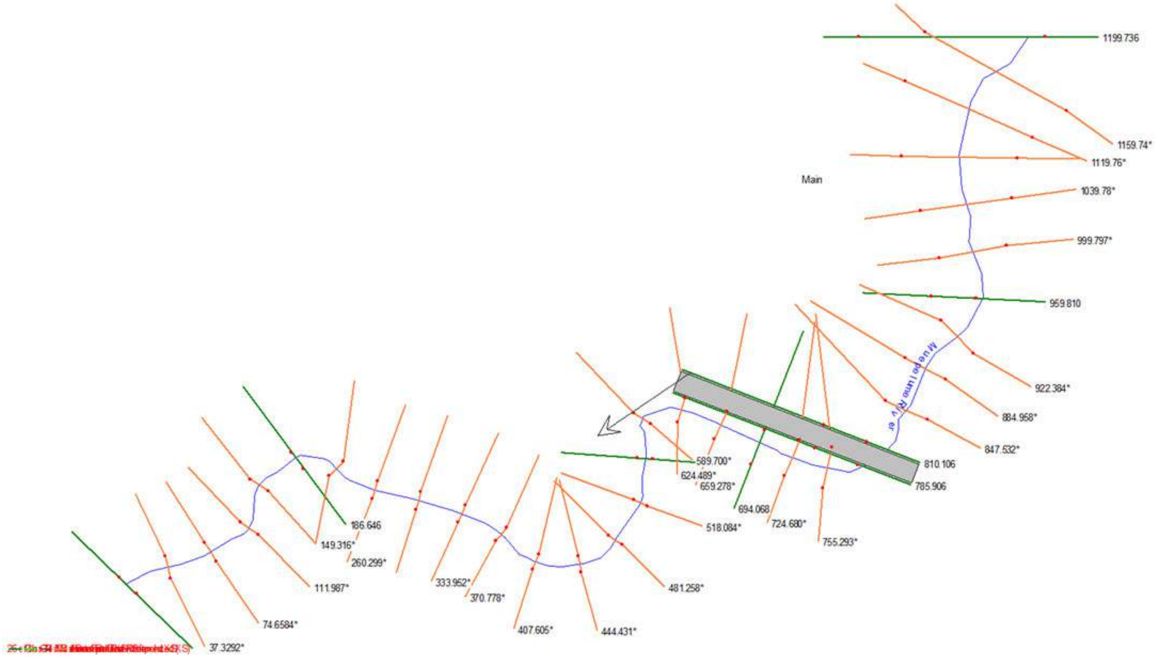
Hydraulic analysis was performed under the following conditions and its results are shown in Table 8.2.27 / Table 8.2.28 and Figure 8.2.35 - Figure 8.2.39.

- Calculation Case - 2 cases of 'With Bridge' and 'Without Bridge',
- Discharge - 50 and 100 years flood (The design scale applies a 100-year flood for No.4 bridge (Nam-20) of Namupla and No.1 bridge (Cua-1) of Cuamba, and the other bridges are 50-year floods.)



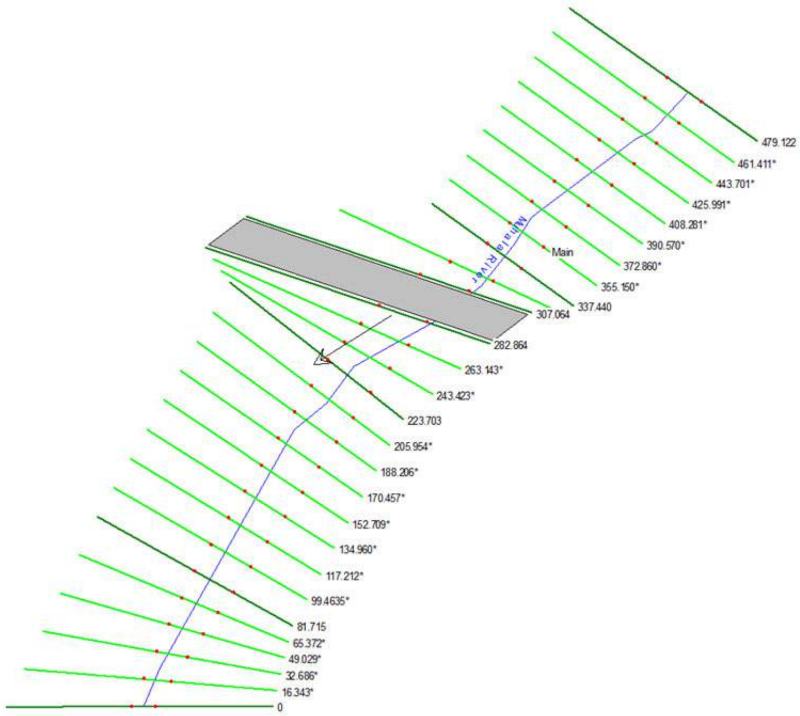
Source: the Study Team

Figure 8.2.30 Hydraulic Calculation Model of Mutomote River (Nampula)



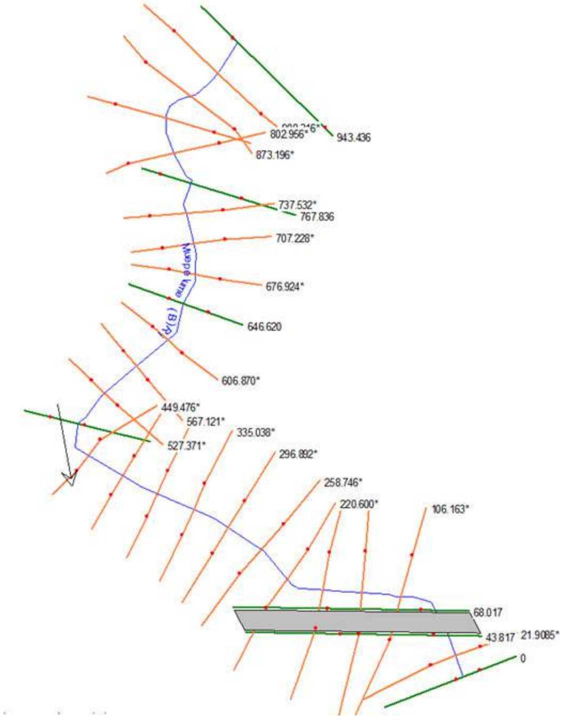
Source: the Study Team

Figure 8.2.31 Hydraulic Calculation Model of Muepelume River (Nampula)



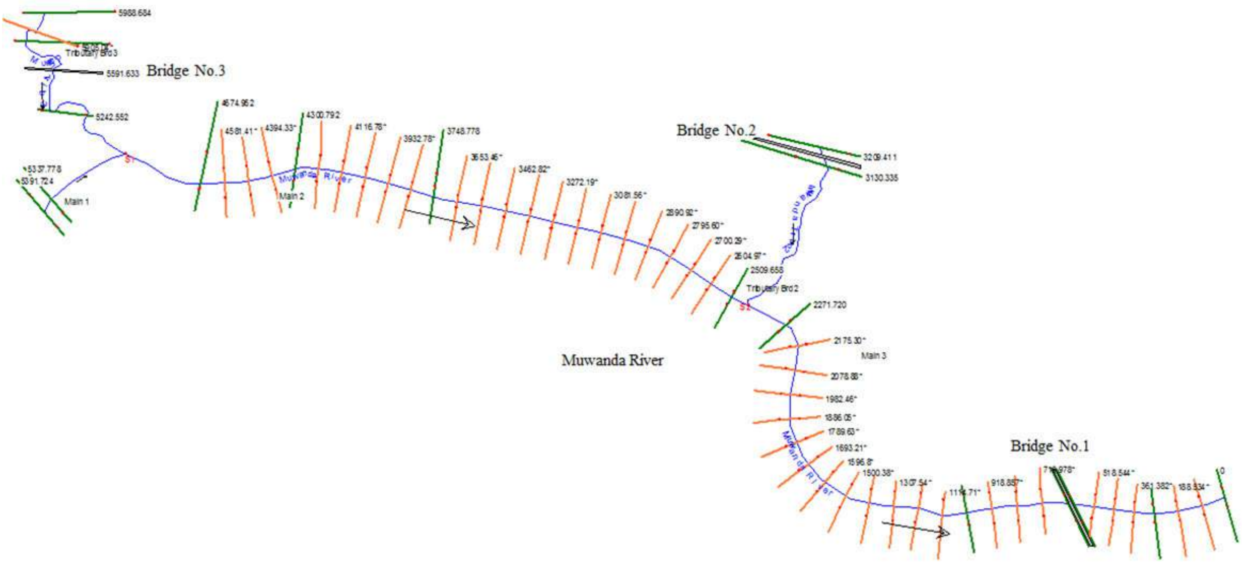
Source: the Study Team

Figure 8.2.32 Hydraulic Calculation Model of Muhara River (Nampula)



Source: the Study Team

Figure 8.2.33   Hydraulic Calculation Model of Muepelume B River (Nampula)



Source: the Study Team

Figure 8.2.34   Hydraulic Calculation Model of Muwanda River (Cuamba)

Table 8.2.27 Hydraulic Calculation Results at each Bridge (Nampula)

Plan: RTW1 Muepelume River Main RS: 798.006 Profile: 50yrs				
E.G. US. (m)	332.84	Element	Inside BR US	Inside BR DS
W.S. US. (m)	332.74	E.G. Elev (m)	332.82	332.77
Q Total (m3/s)	247.7	W.S. Elev (m)	332.54	332.53
Q Bridge (m3/s)	247.7	Crit W.S. (m)	331.48	331.33
Q Weir (m3/s)		Max Chl Dpth (m)	2.96	3.12
Weir Sta Lft (m)		Vel Total (m/s)	2.12	1.97
Weir Sta Rgt (m)		Flow Area (m2)	117.05	125.69
Weir Submerg		Froude # Chl	0.43	0.39
Weir Max Depth (m)		Specif Force (m3)	206.61	221.57
Min El Weir Flow (m)	332.47	Hydr Depth (m)	2.1	2.25
Min El Prs (m)	337.5	W.P. Total (m)	62.79	63.41
Delta EG (m)	0.11	Conv. Total (m3/s)	6031	6636.5
Delta WS (m)	0.1	Top Width (m)	55.8	55.8
BR Open Area (m2)	389.89	Frctn Loss (m)	0.03	0
BR Open Vel (m/s)	2.12	C & E Loss (m)	0.01	0.05
Coef of Q		Shear Total (N/m2)	30.84	27.08
Br Sel Method	Energy only	Power Total (N/m s)	0	0

Plan: Plan 01 Muhala River Main RS: 294.964 Profile: 50yrs				
E.G. US. (m)	327.45	Element	Inside BR US	Inside BR DS
W.S. US. (m)	327.15	E.G. Elev (m)	327.45	327.32
Q Total (m3/s)	151.9	W.S. Elev (m)	326.94	326.81
Q Bridge (m3/s)	151.9	Crit W.S. (m)	326.94	326.81
Q Weir (m3/s)		Max Chl Dpth (m)	1.78	1.78
Weir Sta Lft (m)		Vel Total (m/s)	2.94	2.94
Weir Sta Rgt (m)		Flow Area (m2)	51.67	51.75
Weir Submerg		Froude # Chl	0.76	0.76
Weir Max Depth (m)		Specif Force (m3)	83.44	83.45
Min El Weir Flow (m)	332	Hydr Depth (m)	1.09	1.09
Min El Prs (m)	329.5	W.P. Total (m)	49.17	49.17
Delta EG (m)	0.11	Conv. Total (m3/s)	2016	2021
Delta WS (m)	0.51	Top Width (m)	47.36	47.36
BR Open Area (m2)	173	Frctn Loss (m)		
BR Open Vel (m/s)	2.94	C & E Loss (m)		
Coef of Q		Shear Total (N/m2)	58.5	58.3
Br Sel Method	Momentum	Power Total (N/m s)	0	0

Plan: RTW1 Mutomote River Main RS: 364.292 Profile: 50yrs				
E.G. US. (m)	354.98	Element	Inside BR US	Inside BR DS
W.S. US. (m)	354.95	E.G. Elev (m)	354.98	354.97
Q Total (m3/s)	214.8	W.S. Elev (m)	354.92	354.92
Q Bridge (m3/s)	214.8	Crit W.S. (m)	351.79	351.79
Q Weir (m3/s)		Max Chl Dpth (m)	4.6	4.6
Weir Sta Lft (m)		Vel Total (m/s)	1.05	1.05
Weir Sta Rgt (m)		Flow Area (m2)	204.86	204.52
Weir Submerg		Froude # Chl	0.16	0.16
Weir Max Depth (m)		Specif Force (m3)	475.36	474.21
Min El Weir Flow (m)	360	Hydr Depth (m)	4.33	4.32
Min El Prs (m)	357.5	W.P. Total (m)	57.64	57.72
Delta EG (m)	0.02	Conv. Total (m3/s)	15838	15824.6
Delta WS (m)	0.02	Top Width (m)	47.36	47.36
BR Open Area (m2)	326.83	Frctn Loss (m)	0	0
BR Open Vel (m/s)	1.05	C & E Loss (m)	0	0.01
Coef of Q		Shear Total (N/m2)	6.41	6.4
Br Sel Method	Energy only	Power Total (N/m s)	0	0

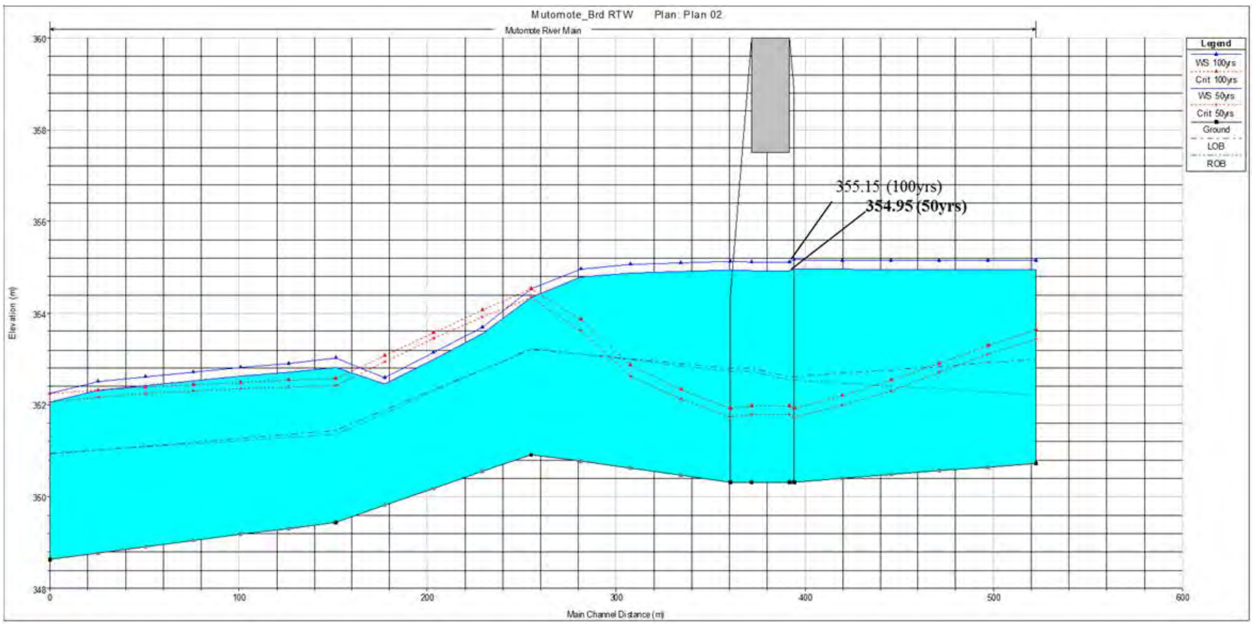
Plan: B Brd90 Muepelume (B) Ri Main RS: 55.917 Profile: 100yrs				
E.G. US. (m)	323.18	Element	Inside BR US	Inside BR DS
W.S. US. (m)	323.08	E.G. Elev (m)	323.17	323.15
Q Total (m3/s)	416.9	W.S. Elev (m)	322.98	322.97
Q Bridge (m3/s)	416.9	Crit W.S. (m)	321.61	321.49
Q Weir (m3/s)		Max Chl Dpth (m)	3.93	4.05
Weir Sta Lft (m)		Vel Total (m/s)	1.89	1.81
Weir Sta Rgt (m)		Flow Area (m2)	220.78	230.33
Weir Submerg		Froude # Chl	0.31	0.29
Weir Max Depth (m)		Specif Force (m3)	396.41	419.04
Min El Weir Flow (m)	330	Hydr Depth (m)	2.66	2.78
Min El Prs (m)	327.5	W.P. Total (m)	95.29	95.75
Delta EG (m)	0.06	Conv. Total (m3/s)	13031.8	13896.4
Delta WS (m)	0.06	Top Width (m)	83	83
BR Open Area (m2)	595.87	Frctn Loss (m)	0.02	0
BR Open Vel (m/s)	1.89	C & E Loss (m)	0	0.03
Coef of Q		Shear Total (N/m2)	23.25	21.23
Br Sel Method	Energy only	Power Total (N/m s)	0	0

Table 8.2.28 Hydraulic Calculation Results at each Bridge (Cuamba)

Plan: Brd-SUH Muwanda River Main 3 RS: 608.733 Profile: 100yrs				
E.G. US. (m)	560.15	Element	Inside BR US	Inside BR DS
W.S. US. (m)	559.7	E.G. Elev (m)	560.13	560.09
Q Total (m3/s)	2121	W.S. Elev (m)	559.54	559.56
Q Bridge (m3/s)	2121	Crit W.S. (m)	558.05	557.87
Q Weir (m3/s)		Max Chl Dpth (m)	8.51	8.72
Weir Sta Lft (m)		Vel Total (m/s)	2.82	2.67
Weir Sta Rgt (m)		Flow Area (m2)	753.29	794.94
Weir Submerg		Froude # Chl	0.37	0.35
Weir Max Depth (m)		Specif Force (m3)	2627.6	2755.02
Min El Weir Flow (m)	556.59	Hydr Depth (m)	3.86	4.07
Min El Prs (m)	562.5	W.P. Total (m)	244.24	246.8
Delta EG (m)	0.1	Conv. Total (m3/s)	50427.4	53989.8
Delta WS (m)	0.07	Top Width (m)	195.28	195.28
BR Open Area (m2)	1331.01	Frctn Loss (m)	0.02	0.01
BR Open Vel (m/s)	2.82	C & E Loss (m)	0.02	0.03
Coef of Q		Shear Total (N/m2)	53.51	48.75
Br Sel Method	Energy only	Power Total (N/m s)	0	0
Plan: Brd-SUH Muwanda Trib 2 Tributary Brd2 RS: 3168.825 Profile: 50yrs				
E.G. US. (m)	561.59	Element	Inside BR US	Inside BR DS
W.S. US. (m)	561.58	E.G. Elev (m)	561.58	561.58
Q Total (m3/s)	223.3	W.S. Elev (m)	561.54	561.53
Q Bridge (m3/s)	223.3	Crit W.S. (m)	559.49	559.49
Q Weir (m3/s)		Max Chl Dpth (m)	4.04	4.03
Weir Sta Lft (m)		Vel Total (m/s)	0.91	0.91
Weir Sta Rgt (m)		Flow Area (m2)	245.41	245.19
Weir Submerg		Froude # Chl	0.14	0.14
Weir Max Depth (m)		Specif Force (m3)	396.21	395.57
Min El Weir Flow (m)	566	Hydr Depth (m)	2.96	2.95
Min El Prs (m)	563.5	W.P. Total (m)	94.49	94.48
Delta EG (m)	0.02	Conv. Total (m3/s)	15455.8	15433.6
Delta WS (m)	0.02	Top Width (m)	83	83
BR Open Area (m2)	408.42	Frctn Loss (m)	0	0
BR Open Vel (m/s)	0.91	C & E Loss (m)	0	0.01
Coef of Q		Shear Total (N/m2)	5.32	5.33
Br Sel Method	Energy only	Power Total (N/m s)	0	0

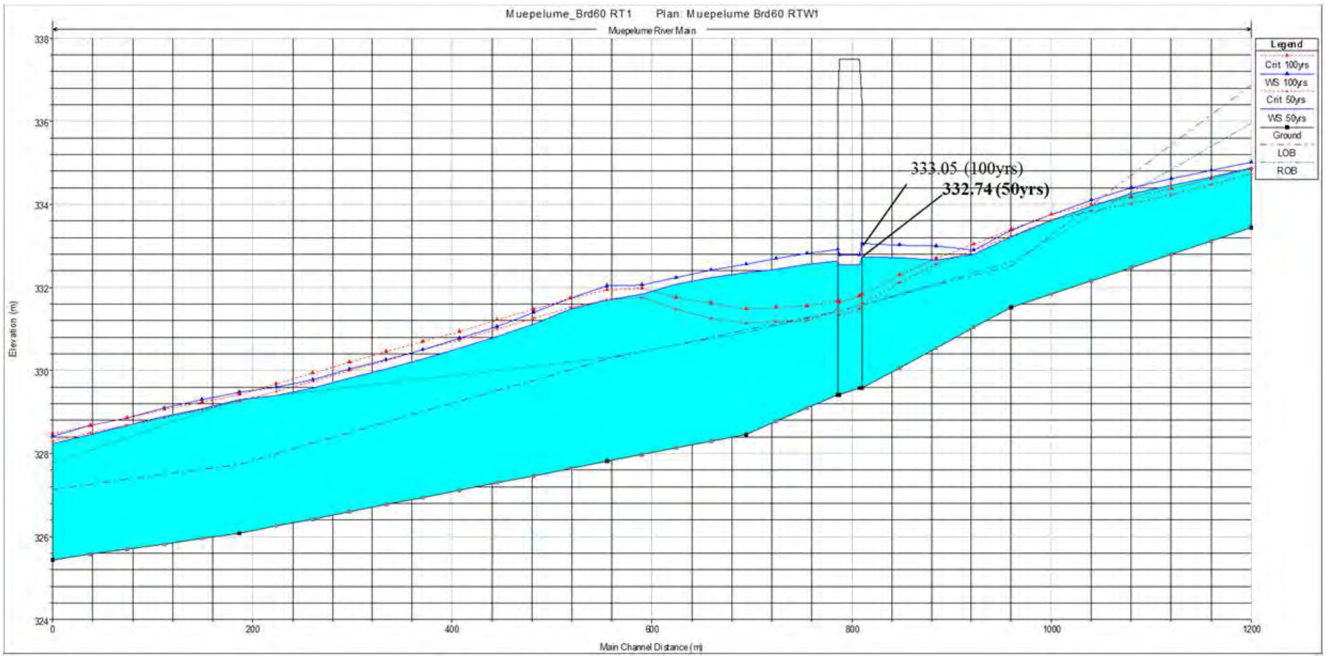
Plan: Brd-SUH Muwanda Trib 3 Tributary Brd3 RS: 5591.633 Profile: 50yrs				
E.G. US. (m)	563.71	Element	Inside BR US	Inside BR DS
W.S. US. (m)	563.71	E.G. Elev (m)	563.69	563.69
Q Total (m3/s)	184.9	W.S. Elev (m)	563.66	563.65
Q Bridge (m3/s)	184.9	Crit W.S. (m)	561.87	561.87
Q Weir (m3/s)		Max Chl Dpth (m)	2.99	2.99
Weir Sta Lft (m)		Vel Total (m/s)	0.86	0.86
Weir Sta Rgt (m)		Flow Area (m2)	214.67	214.44
Weir Submerg		Froude # Chl	0.16	0.16
Weir Max Depth (m)		Specif Force (m3)	294.77	294.19
Min El Weir Flow (m)	568	Hydr Depth (m)	2.59	2.58
Min El Prs (m)	565.5	W.P. Total (m)	93.37	93.36
Delta EG (m)	0.04	Conv. Total (m3/s)	12464.9	12443.5
Delta WS (m)	0.04	Top Width (m)	83	83
BR Open Area (m2)	367.67	Frctn Loss (m)	0	0.01
BR Open Vel (m/s)	0.86	C & E Loss (m)	0	0.01
Coef of Q		Shear Total (N/m2)	4.96	4.97
Br Sel Method	Energy only	Power Total (N/m s)	0	0

Source: the Study Team



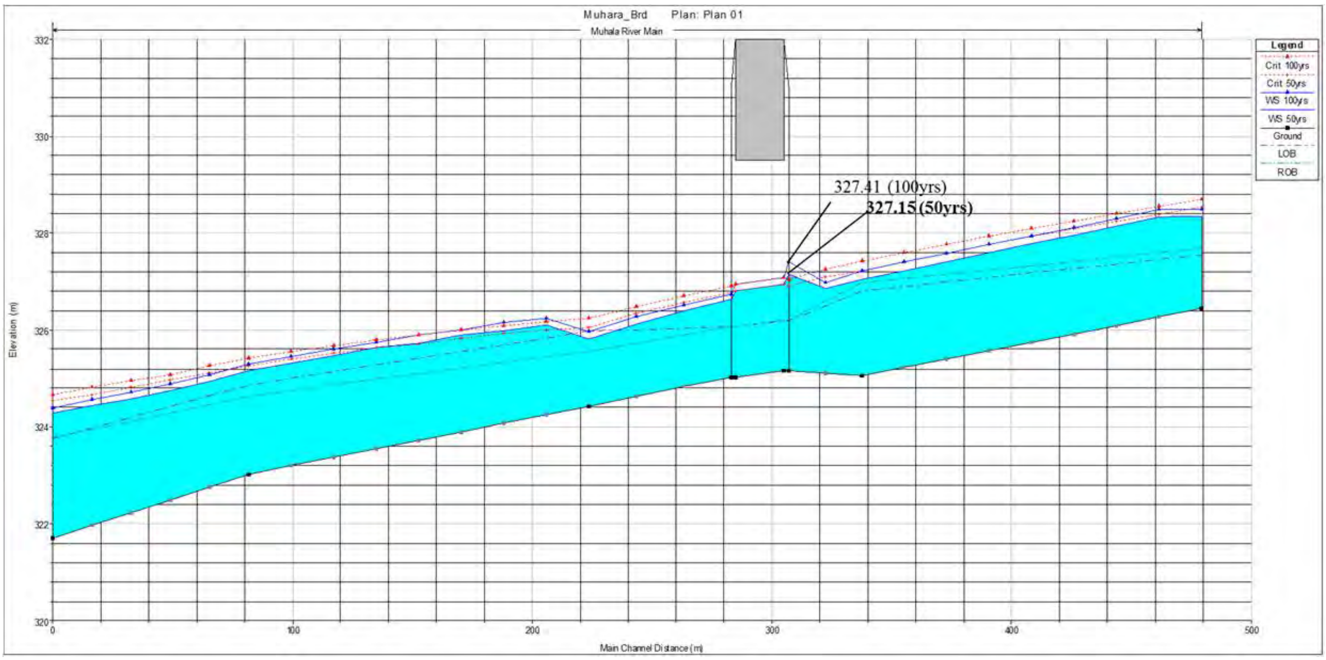
Source: the Study Team

Figure 8.2.35 Hydraulic Calculation Results of Mutomote River (Nampula)



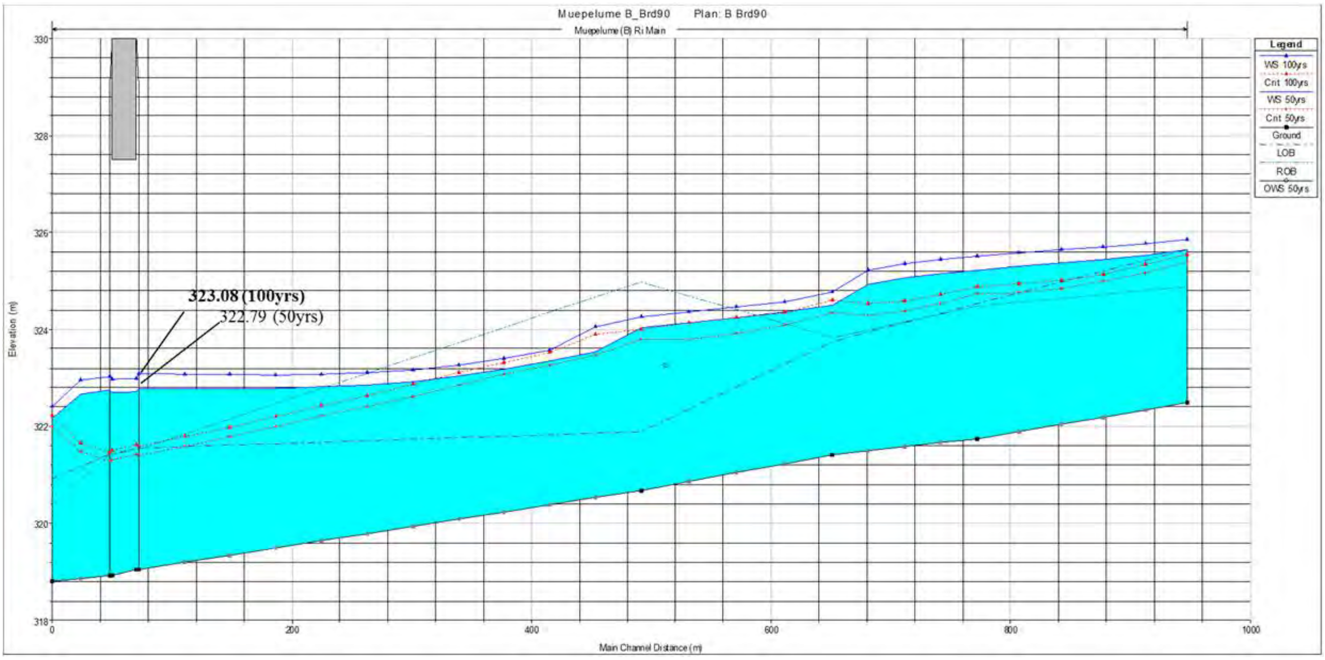
Source: the Study Team

Figure 8.2.36 Hydraulic Calculation Results of Muepelume River (Nampula)



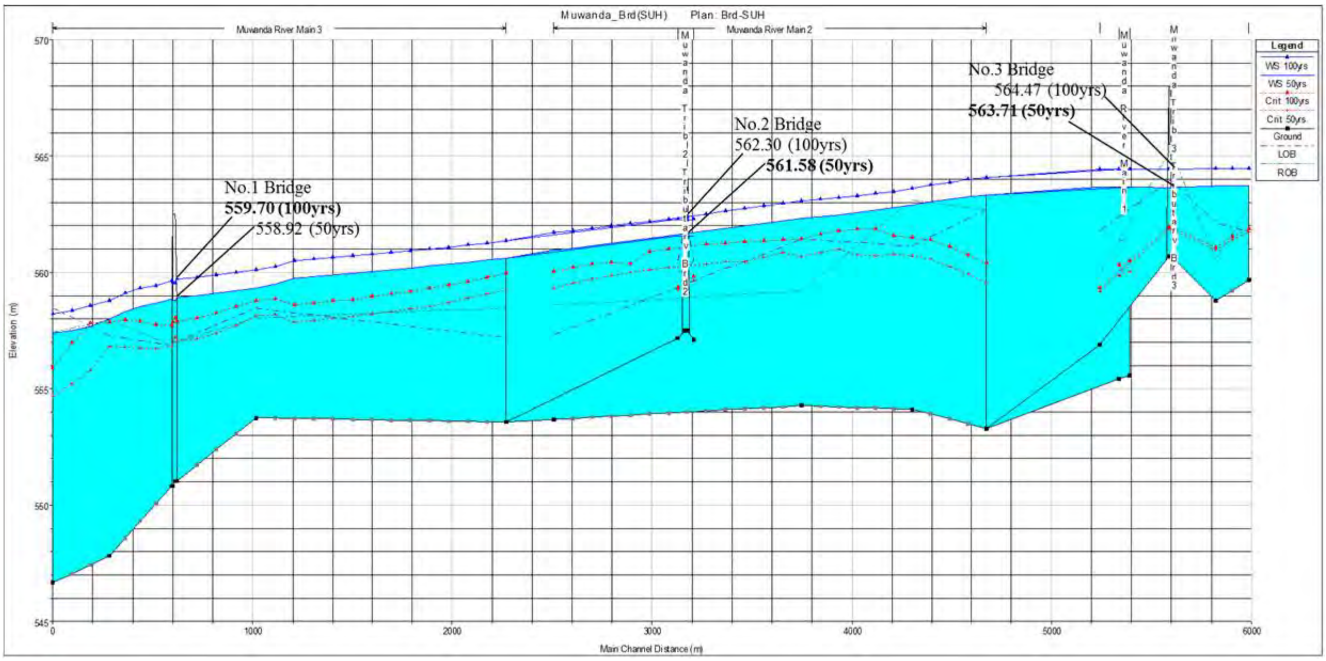
Source: the Study Team

Figure 8.2.37 Hydraulic Calculation Results of Muhara River (Nampula)



Source: the Study Team

Figure 8.2.38 Hydraulic Calculation Results of Muepelume B River (Nampula)



Source: the Study Team

Figure 8.2.39 Hydraulic Calculation Results of Muwanda River (Cuamba)

4) Design High Water-Levels

From the above calculation results, the design high water levels for the proposed bridges are decided as shown in Table 8.2.29.

Table 8.2.29 Design High Water-Level at each Bridge

ID	Chainage	Bridge / River Name	Design Return Period	Design Discharge	Design High Water Level	Remarks
< Nacala >				m^3/s	m	
Nac-15	No.042+14.0	(Small stream)	50 years	109.7	10.77	From calculation of uniform flow
< Nampula >						
Nam-6	No.047+98.0	Mutomote River	50 years	214.8	353.24	With RTW
Nam-13	No.126+84.0	Muepelume River	50 years	247.7	332.74	With RTW
Nam-17	No.158+86.0	Muhara River	50 years	151.9	327.15	
Nam-20	No.183+49.0	Muepelume B River	100 years	416.9	323.08	
< Cuamba >						
Cua-1	No.003+54.0	Muwanda River	100 years	2121	559.70	
Cua-3	No.020+66.0	(Muwanda Tributary 2)	50 years	223.3	561.54	
Cua-6	No.052+69.0	(Muwanda Tributary 3)	50 years	184.9	563.66	

Source: the Study Team

5) Scouring Calculation

The most common cause of bridge failures is from floods eroding bed material from around bridge foundations (abutments and piers). Therefore, the safe bridge design must account for scour conditions that may occur over the life of the bridge. Scour estimation by steady flow analysis of HEC-RAS is conducted, based on Hydraulic Engineering Circular No. 18 (HEC 18) of Federal Highway Administration (FHWA), USA using the value of probable maximum discharge and probable high water level.

The results of the scour estimation are shown in Table 8.2.30. For all bridges, the estimated bridge scour depth is relatively large, and the river bank/bed of each bridge will need to be protected by the appropriate protection works (Gabion or Riprap, etc.). In addition, river training works (RTW) shall be conducted for two bridges (Nam-6, Nam-13) of Nampula, in order to decrease the contraction scour.

Table 8.2.30 Computation Results of Bridge Scour

Location	Scouring Items	Nam-6	Nam-13	Nam-17	Nam-20	Cua-1	Cua-6
		Mutomote River	Muepelume River	Muhara River	Muepelume B River	Muwanda River	(Muwanda Tributary 3)
		Bridge Length L=60m	Bridge Length L=60m	Bridge Length L=60m	Bridge Length L=90m	Bridge Length L=240m	Bridge Length L=90m
Abutment-1	Conrtraction Scour	0.00	0.00	0.00	0.00	0.47	0.19
	Local Scour	3.69	1.10	2.37	1.24	4.04	4.13
	Total Scour	3.69	1.10	2.37	1.24	4.51	4.32
Pier-1	Conrtraction Scour	0.65	0.21	0.06	0.21	0.47	0.19
	Local Scour	2.41	3.05	1.66	3.07	2.37	1.44
	Total Scour	3.06	3.26	1.72	3.28	2.84	1.63
Pier-2	Conrtraction Scour	-	-	-	0.21	0.27	0.19
	Local Scour	-	-	-	2.76	3.21	1.57
	Total Scour	-	-	-	2.97	3.48	1.76
Pier-3	Conrtraction Scour	-	-	-	-	0.27	-
	Local Scour	-	-	-	-	4.01	-
	Total Scour	-	-	-	-	4.28	-
Pier-4	Conrtraction Scour	-	-	-	-	0.27	-
	Local Scour	-	-	-	-	5.12	-
	Total Scour	-	-	-	-	5.39	-
Pier-5	Conrtraction Scour	-	-	-	-	0.39	-
	Local Scour	-	-	-	-	2.20	-
	Total Scour	-	-	-	-	2.59	-
Abutment-2	Conrtraction Scour	0.00	0.02	0.06	0.21	0.39	0.19
	Local Scour	5.25	3.94	0.42	8.76	3.89	6.57
	Total Scour	5.25	3.96	0.48	8.97	4.28	6.76
Remarks		with RTW	with RTW				

Source: the Study Team

(5) Hydrological Assessment

1) Hydrological Survey Results

The results of the above-described hydrological statistical analyses, and hydraulic computations including bridge-scour and other surveys can be summarized as follows;

- At present there is too much unavailable data within the records of the hydrological observations by ARA-Centro-Norte to allow it to be of any use. Therefore, human resource development and capacity building is recommended for improvement of the gathering of the necessary hydrological observations.
- In the site reconnaissance of Nacala, the channel erosion by the sediment-flow was confirmed at 2 sites. In this study, the freeboard of the lateral crossing drainage structures of Nacala have been increased to provide a margin of safety.

- The study area of Nacala and Nampula is a hilly area. The flow regimes of Muepelume (Nam-13) and Muhara (Nam-17) rivers of Nampula are under conditions of super critical flow, and the velocity is very fast. Most of the river-bed materials will be washed out if the amount of peak flood continues as in the past. Therefore, the areas surrounding the bridge sites shall be adequately protected from erosion.
- The contraction scour will occur to the extent of 0.06m-0.65m at bridge openings. This means that the river section flow area is too small. However, the value of the contraction scour is not large and the current river section might be adequate .
- The computation results regarding the local scouring indicate that it will occur at most piers each bridge. Therefore, the riverbed around the abutments and piers which are subject to scouring must have funding for the appropriate bed-protection.

2) Hydrological Recommendations

As for hydraulic issues of the proposed bridge/road based on the above results, the following points are left as future challenges;

- The hydraulic calculations including the scouring were conducted for each bridge. In the D/D stage, the detailed study of the bridge-hydraulics shall be performed for all bridges in greater detail. Especially, regarding the sediment-flow of streams in the study area in Nacala, a further detailed survey and study will be required for verification of the hydrological morphology.
- There are many kinds of bed protection and revetment works. Therefore, comparisons of several construction methods shall be made at the D/D stage. In addition, estimation of scouring must be studied further including other prediction formulae such as the HEC formula.
- In the D/D stage, a more detailed topographic survey will be conducted in order to clarify the detailed shape of each waterway, and more cross-sectional surveys for waterways shall be added.

8.3 Pavement Design

8.3.1 Basic Conditions for the Pavement Design

(1) Design Approach

Two methods of pavement design are used to determine the pavement composition, the main method being the empirical approach with the mechanistic method used for a check.

For the empirical design method, the following standard is mainly considering for the pavement structures in South African regions.

- South Africa Transport and Communication Commission (SATCC): Draft Code of Practice for the Design of Road Pavements, 1998, Reprinted 2001

However, the design traffic loading for the design life has a possibility to exceed the applicable limit of 30 million described in the SATCC Manual. Therefore, the following standard with no limitation is applied for the pavement design. The following standard also considers the empirical method.

- American Association of State Highway and Transportation Officials (AASHTO): Guide for Design of Pavement Structures, 1993.

Regarding the Mechanistic Design Approach, several programs such as mePADS developed by CSIR of South Africa, and GAMES from Japan are available on the market to carry out this analysis. The Consultants finally proposed using these programs for determination of suitable pavement compositions in the interim.

(2) Pavement Design Life

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

Table 8.3.1 Pavement Design Life Selection Guidance

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

Target roads are mostly located in urban and peri-urban areas with reliable historic traffic data. In such cases, the potential for making significant errors in long-term traffic forecasting is not so large. Given this, a 15-20 year design life is recommended. However since target roads are completely new bypass roads, the characteristics of road usage have some parts that are unclear. Thus, a 15 year design life will be recommended finally.

(3) Vehicle Equivalent Factors (VEFs)

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

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

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

Hence axle load surveys were conducted by the JICA Study in the past. However, the number of vehicles surveyed by the JICA Study was quite limited due to the poor road condition, and this figure is not supplied with high confidence. Hence, standard VEFs recommended for use by ANE are applied for the Project.

Table 8.3.2 VEF by Vehicle Category

<table>
<tr><th>Vehicle Category</th><th>Cuamba - Lichinga (Feasibility Study)</th><th>Nampula- Cuamba (Feasibility Study)</th><th>Standard Axle (ANE*)</th></tr>
<tr><td>Medium / Large Bus</td><td>0.008</td><td>1.02</td><td>1.25</td></tr>
<tr><td>Medium Goods Vehicle</td><td>0.401</td><td rowspan="3">4.06</td><td>2.20</td></tr>
<tr><td>Heavy Goods Vehicle</td><td>4.798</td><td>3.00</td></tr>
<tr><td>Very Heavy Goods Vehicle</td><td>10.906</td><td>5.50</td></tr>
</table>

* Scott Wilson Kirkpatrick – "Short Term Consultancy Services for the Review of the Highway Network Management System in Mozambique", 1999.

(4) Design Traffic Loading for the Design Life

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

- Determine daily traffic flows for each relevant vehicle class.
- Determine average daily one-directional traffic flows.
- Forecast one-directional traffic flows.
- Determine the mean equivalence factor for each class of vehicle.
- Sum the products of the cumulative one-directional traffic flows for each vehicle class over the design life of the target roads and the mean equivalence factors to obtain the cumulative ESAL for deciding 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 y0 for both directions.

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

y = Design life of project road.

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

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

The calculation results for each package and road are listed in following Table.

Table 8.3.3 Traffic Volume and Axle Load for 15 years

Nacala Port Access

Section 1 & 2

Type of Vihicle	AADT/Direction (2015)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	0	109	124	130	137	143	151	158	166	174	183	192	202	212	222	233
Medium	719	591	642	706	776	853	938	1,032	1,134	1,247	1,371	1,508	1,658	1,823	2,004	2,204
Large	786	907	976	1,042	1,112	1,187	1,266	1,352	1,443	1,540	1,643	1,754	1,872	1,998	2,132	2,276
																2,902

Type of Vihicle	ESAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	1.25	49,911	56,575	59,390	62,344	65,446	68,701	72,119	75,707	79,473	83,427	87,578	91,934	96,508	101,309	106,349
Medium	2.20	474,735	515,526	566,834	623,247	685,276	753,478	828,467	910,920	1,001,579	1,101,261	1,210,863	1,331,374	1,463,878	1,609,570	1,769,762
Large	4.25	1,406,696	1,514,020	1,615,910	1,724,657	1,840,723	1,964,599	2,096,813	2,237,923	2,388,531	2,549,274	2,720,834	2,903,940	3,099,369	3,307,949	3,530,567
																5.09.E+07

Section 3 & 4

Type of Vihicle	AADT/Direction (2015)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	0	67	76	82	88	94	102	109	117	126	136	146	157	169	182	195
Medium	143	253	266	296	329	366	407	453	503	560	623	692	770	856	952	1,059
Large	213	360	391	415	441	469	498	529	562	597	634	673	715	759	807	857
																1,263

Type of Vihicle	ESAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	1.25	30,606	34,675	37,284	40,090	43,106	46,350	49,838	53,588	57,620	61,956	66,618	71,631	77,021	82,817	89,049
Medium	2.20	203,421	213,598	237,552	264,192	293,819	326,769	363,414	404,169	449,494	499,902	555,962	618,310	687,650	764,765	850,529
Large	4.25	559,165	606,539	644,275	684,360	726,938	772,165	820,206	871,237	925,442	983,019	1,044,179	1,109,144	1,178,150	1,251,451	1,329,311
																2.11.E+07

Nampula Southern Bypass

Type of Vihicle	AADT/Direction (2015)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	0	118	129	137	145	154	164	174	185	196	208	221	235	249	264	281
Medium	117	267	312	355	403	458	521	592	673	765	870	989	1,124	1,278	1,452	1,651
Large	127	221	262	308	363	428	504	593	698	822	968	1,140	1,342	1,580	1,861	2,191
																1,857

Type of Vihicle	ESAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	1.25	53,813	58,856	62,481	66,329	70,414	74,750	79,354	84,241	89,429	94,937	100,784	106,991	113,580	120,575	128,000
Medium	2.20	214,774	250,536	284,794	323,737	368,005	418,326	475,528	540,552	614,467	698,489	794,000	902,572	1,025,990	1,166,284	1,325,761
Large	4.25	342,732	406,428	478,551	563,473	663,466	781,202	919,832	1,083,063	1,275,261	1,501,565	1,768,028	2,081,778	2,451,204	2,886,188	3,398,362
																3.13.E+07

Cuamba Bypass

Type of Vihicle	AADT/Direction (2015)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	7	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Medium	36	226	259	269	279	290	301	313	325	337	350	364	378	393	408	423
Large	48	186	210	223	238	253	269	287	305	324	345	367	391	416	443	471
																645

Type of Vihicle	ESAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
L-Bus	1.25	456	456	489	524	562	602	645	692	741	794	851	913	978	1,048	1,123
Medium	2.20	181,203	207,977	215,990	224,313	232,955	241,931	251,253	260,934	270,988	281,429	292,273	303,534	315,229	327,375	339,989
Large	4.25	287,830	325,763	346,654	368,886	392,544	417,719	444,508	473,016	503,351	535,633	569,984	606,539	645,438	686,831	730,880
																1.13.E+07

8.3.2 Pavement Design

(1) Design Standard

As shown in Table 8.3.3 mentioned above, design axle load for Nacala Port Access (sections 1 and 2) and Numpula Southern Bypass exceed a 30 million applicable limit for utilization of the SATCC design method. Therefore, the AASHTO design guide (1993) with no limitation is applied.

In the AASHTO design guide, pavement composition is determined by the Structural Number (SN) which is based on the resilient modulus of the sub-grade and the design traffic loading (in million ESA). This empirical equation is widely used and has the following form:

$$\log_{10} W_{18} = Z_R * S_0 + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10} \dfrac{\Delta PSI}{(4.2-1.5)}}{0.4 + \dfrac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$

Where

W_{18}: Number of wheels (18kip=8t)

Z_R: Reliability coefficient=-1.282 (reliability 90%)

S_O: standard deviation=0.45 (Flexible pavement)

M_R: 1500 x CBR for CBR up to 11% and 1250 x CBR for CBR over 11% and up to 22% and 30%

PSI: primarily a function of surface roughness=Po-Pt=4.2-2.5=1.7

Po: Initial serviceability index: 4.2 from AASHTO standard

Pt: Terminal serviceability index: 2.5 from AASHTO standard

SN = Σ ai x hi (inch) x mi (drainage coefficient for base and/or sub-base)

ai :a layer coefficient that represents the relative strength of the material (Table8.3.4)

hi :layer thickness in inches

mi :a drainage coefficient

The layer and drainage coefficients are values that should reflect characteristics of the material used to construct that pavement layer. In this feasibility stage, drainage coefficient (mi) is assigned the value of 1.0 (Drainage quality: Fair and Percent of time pavement structure is exposed to moisture level; 5 -25%). And the following typical layer coefficients (ai) are applied for the calculation.

Table 8.3.4 Pavement Layer Coefficient (ai) for the AASHTO

Layer Type	CBR	Coefficient	Remarks
Asphalt Concrete	>100	0.42	-
Double Surface Treatment	-	0.20	-
Asphalt Stabilization	-	0.30	-
Crushed Hard Rock	80 – 100	0.14	G1, G2
Crushed Medium Hard Rock	60 – 80	0.13	G3, G4
River Gravel Base	40 – 70	0.12	-
Sand-gravel Mixture	20 – 50	0.11	G5
Cement Stabilization	-	0.20	-
Granular Sub-base	10 - 30	0.08	G6, G7
Capping Layer	>15	0.08	-

As a reference, the required construction materials for road construction based on the SATCC are stated below.

Table 8.3.5 Summary for Material Qualities Based on the SATCC

Structure Location	Requirements
Fill	SATCC: Depth below final surface 0.0m – 1.2m: Minimum soaked CBR = 3% at 90% modified AASHTO density 1.2m – 9.0m: Minimum soaked CBR = 3% at 100% modified AASHTO density
Capping/Selected layer	Soaked CBR>15% @ 93% mod. AASHTO density
Sub base	Granular Soaked CBR>30% @ 95% mod. AASHTO density Cemented 7 day UCS 0.75 - 1.5 MPA @ 100% mod. AASHTO density (or 0.5 - 0.75 MPa @ 97% if modified test is followed)
Base	Granular Soaked CBR>80% @ 98% mod. AASHTO density Cemented 7 day UCS*1.5 - 3.0 MPa @ 100% mod. AASHTO density (or 1.0 - 1.5 MPa @ 97% if modified test is followed) Bituminous Depending on specification

(2) **Design CBR**

In principle, target roads consist of low-embankments with 1m or more in a pardonable range of geometric standard as much as possible. In this instance, a huge amount of fill and selected materials will be taken from roadside borrow areas along the target roads and/or suitable borrow pits. In accordance with the following geotechnical survey results, most of the CBR values of the existing ground along target roads and borrow pits are categorized in class S2 (CBR3-4%) and more.

Table 8.3.6 Summary for CBT Test Results and Recommended Design CBR

Location	Survey No.	CBR	Class	Structure	Sub-grade CBR	Remarks
Nacala	NCL TP1	4.2	S2	Repeating embankment and cut	S2	Minimum requirement of fill material quality (CBR3%) is applied because embankment has a majority. And most of the existing ground is also categorized in class S2.
	NCL TP2	3.4				
	NCL TP3	3.0				
	NCL TP4	3.7				
	NCL TP5	0.9				
	NCL TP6	0.7				
	NCL TP7	1.0				
	NCL TP8	1.5				
	NCL TP9	3.4				
	NCL TP10	4.9				
	NCL TP11	39.3	S4	Repeating embankment and cut		
	NCL TP12	N/P				
	NCL TP13	10.8				
	NCL TP14	10.3				
Nampula	NPL TP1	4.3	S2	Repeating embankment and cut	S2	Minimum requirement of fill material quality (CBR3%) is applied because the embankment has a majority. And most of existing grounds are also categorized in class S2.
	NPL TP2	26.4	S4			
	NPL TP3	7.0				
	NPL TP4	15.6				
	NPL TP5	13.6				
	NPL TP6	2.8	S2			
	NPL TP7	7.3				
	NPL TP8	13.6	S4			
	NPL TP9	39.1				
	NPL TP10	3.1	S2			
	NPL TP11	3.5				
	NPL TP12	8.5				
	NPL TP13	5.0				
	NPL TP14	7.1				
	NPL TP15	33.7	S4			
	NPL TP16	33.4				
	NPL TP17	13.9				
	NPL TP18	17.4				
	NPL TP19	26.8				
	NPL TP20	37.5				
	NPL TP21	1.9	S2	Embankment	S2	Minimum requirement of fill material quality (CBR3%) is applied because embankment.
	NPL TP22	3.7				
	NPL TP23	10.5				
	NPL TP24	1.2				
	NPL TP25	6.5				
	NPL TP26	23.8	S5	Embankment	S2	Minimum requirement of fill material quality (CBR3%) is applied because embankment.
	NPL TP27	32.8				
	NPL TP28	35.5				
	NPL TP29	36.2				
	NPL TP30	25.2				
	NPL TP31	22.6				

Cuamba	CMB TP1	1.8	S2	Embankment	S2	Minimum requirement of fill material quality (CBR3%) is applied because embankment. However detailed material assessment is required in the detail design stage.
	CMB TP2	1.0				
	CMB TP3	1.7				
	CMB TP4	0.4				
	CMB TP5	1.0				
	CMB TP6	1.0				
	CMB TP7	1.0				
	CMB TP8	4.6				
	CMB TP9	1.9				
	CMB TP10	9.8	S4	Embankment		
	CMB TP11	0.4				
	CMB TP12	16.0				

Table 8.3.7 Summary for Borrow Pits Test Results

Location	Survey No.	CBR			Remarks
		90%	95%	100%	
Nacala	NCL BP1	6.2	29.6	43.4	Suitable
	NCL BP2	8.6	14.7	25.0	Suitable
	NCL BP3	7.5	21.1	41.7	Suitable
Nampula	NPL BP1	47.0	26.0	54.0	Suitable
	NPL BP2/TP7	38.0	54.0	48.0	Suitable
	NPL BP3	46.0	64.0	50.0	Suitable
	NPL BP4/TP18	17.0	28.0	33.0	Suitable
	NPL BP5/TP26	24.0	45.0	52.0	Suitable
	NPL BP6	28.0	53.0	66.0	Suitable
	NPL BP7	38.0	54.0	48.0	Suitable
Cuamba	CMB BP1	19.0	32.0	53.0	Suitable
	CMB BP2	23.0	72.0	95.0	Suitable

Taking into account the results of the road alignment plan and site survey, sub-grade CBR will be set as class S2 (3%). CBR of fill and selected materials quality will be ensured excluding Cuamba BP. Regarding Cuamba BP, a detailed material survey for fill materials along the target road will be required in the detail design stage.

The design CBR is determined by the following formulation based on the Japanese Standard. In Japan, the depth of 1m from sub-grade that responds to vehicle load is set as the roadbed.

$$CBR_m = \left[\frac{h_1 CBR_1^{\ 1/3} + h_2 CBR_2^{\ 1/3} + \cdots h_n CBR_n^{\ 1/3}}{100}\right]^3$$

Where:

CBRm : Combined CBR in depth

CBRn : CBR by layer

hn : Thickness of each layer (cm)

For example, CBR of existing ground, fill material or replaced material is 3%, and selected layer of 30cm as upper subgrade is applied in line with SATCC Guide. Both CBRs of 15% (30cm) and 3% (70cm) are combined using the formula mentioned above. As a result, the Design CBR of 5% is derived and recommended.

(3) **Calculation Results**

Using the reliability factor of 90%, standard deviation of 0.45 and the effective resilient modulus, the required structural numbers and each layer thickness by CBR class were derived as follows.

Table 8.3.8 Pavement Composition Calculated by AASHTO Method

Layer	Nacala Port Access		Nampula BP	Cuamba BP	Remarks
	1 & 2	3 & 4			
As Surface	5 cm	5 cm	5 cm	5 cm	
As Binder	5 cm	0 cm	0 cm	0 cm	
As Base	5 cm	5 cm	5 cm	5 cm	
As stabirized	10 cm	10 cm	10 cm	5 cm	
Base Course	25 cm	30 cm	30 cm	30 cm	CBR>80
Sub-base Course	40 cm	35 cm	45 cm	40 cm	CBR>30
Selected Layer	30 cm	30 cm	30 cm	30 cm	CBR>15 (G7)

(4) **Screening of the Pavement Options**

The pavement type has a significant impact on the initial investment cost and future maintenance cost of the road. Therefore, the selection of the suitable pavement type is evaluated based on the initial cost and its financial viability. And the construction experience and maintenance practices in the project region are considered. Thus, the following additional scenario (Alternative-B) using DBST which is widely applied in Mozambique is determined by the mechanistic design approach.

- Alternative-A: Asphalt Concrete (without Cemented Sub-base)
- Alternative-B: Double Surface Treatment (DBST) (with Cemented Sub-base)

However, utilization of DBST for the Nacala Port Access Road is not recommended because the predominating users of Nacala Port Access Road will be heavy goods vehicles.

(5) **Pavement Composition using the Mechanistic Design Method**

Pavement compositions using DBST are computed by the mechanistic design approach. In the Mechanistic design methods, the fundamental mechanical properties of the pavement materials are considered. The key material design parameters include the layer's elastic characteristics (for load spreading), the modulus of elasticity (E), Poisson's ratio (v) and the layer thickness. Stresses and strains are calculated simultaneously at key locations in a proposed pavement structure. These analysis conditions are as follows:

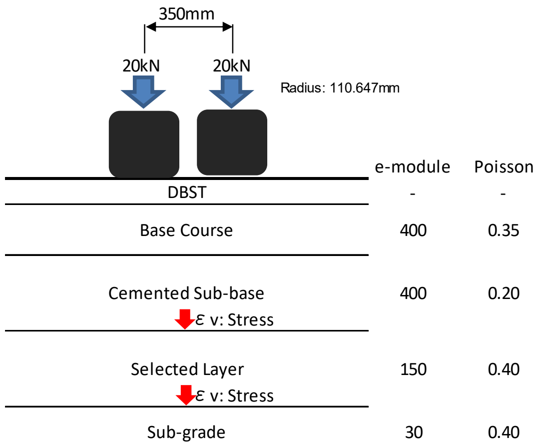


Figure 8.3.1 Design Conditions for Mechanistic Design Approach

As a result, the pavement life of the selected layer and sub-grade layers without surface treatment (Surface treatment is not basically evaluated) satisfy the required ESA with the following compositions.

Table 8.3.9 Check of DBST's Pavement by Mechanistic Design Approach

Layer	Nacala Port Access		Nampula BP	Cuamba BP	Remarks
	Nacala Port-R702	R702-N12			
DBST	Surface treatment such as DBST is not recommended because access road to international port.		3 cm	3 cm	
Base Course			30 cm	25 cm	
Cemented Sub-base			35 cm	30 cm	1.5Mpa
Selected Layer			45 cm	30 cm	CBR>15 (G7)

8.3.3 Recommended Pavement Composition

Finally, the following pavement compositions are proposed. Asphalt concrete surface is applied to Nacala Port Access Road. For Nampula Southern Bypass and Cuamba Bypass, for the time being, application of surface treatment (DBST) is recommended. And at the time of traffic increase, asphalt concrete will be laid in conjunction with full rehabilitation or shifting to 4-lane.

Table 8.3.10 Recommended Pavement Compositions

Layer	Nacala Port Access		Nampula BP		Cuamba BP		Remarks
	Nacala Port-R702	R702-N12	Initial	Mid-term	Initial	Mid-term	
As Surface	5 cm	5 cm	- cm	5 cm	- cm	5 cm	
As Binder	5 cm	0 cm	- cm	cm	- cm	- cm	
As Base	5 cm	5 cm	- cm	5 cm	- cm	5 cm	
DBST	- cm	- cm	3 cm	- cm	3 cm	- cm	
As stabirized	10 cm	10 cm	- cm	- cm	- cm	5 cm	
Base Course	25 cm	30 cm	30 cm	20 cm	25 cm	10 cm	CBR>80
Sub-base Course	40 cm	35 cm	- cm	- cm	- cm	- cm	CBR>30
Cemented Sub-base	- cm	- cm	35 cm	35 cm	30 cm	30 cm	1.5Mpa
Selected Layer	30 cm	30 cm	45 cm	45 cm	30 cm	30 cm	CBR>15 (G7)

Initial: Initial Stage, Mid-term: timing of full rehabilitation or sift to 4-lane

8.4 Drainage

8.4.1 Current Drainage Conditions/Issues

(1) Nacala Area

In Nacala area, in some eroded areas, roads and railways have collapsed due to concentrated heavy rain and they were identified as shown in the following photos.

Insufficient Size (Railway)

Inadequate Structure (Road)

Eroded Culvert (Railway)

Figure 8.4.1 Existing Drainage Structures in Nacala

There are some facilities (railway, road, factory, village, etc.) on the upstream side of the target road. The drainage systems and capacity of those facilities are sometimes insufficient and inadequate. From these situations, items requiring careful consideration for the drainage design are as follows:

- To clarify existing water streams and drainage system through visual and topographic survey
- To identify correct catchment areas, land use and soil category covering that area
- To consider sediment runoff and spring water when undertaking the capacity analysis
- To consider countermeasures against erosion on the downstream side

(2) Nampula Area

In Nampula, the bypass road passes through low land where there are some swamps and a high water table as shown in the following photos.

Swamp Area

Culverts for Small River

High Water Table

Figure 8.4.2 Swamp Area and Existing Drainage Facilities in Nampula

The bypass road will run through low land and cross some small streams. In particular, some swamp areas exist in the beginning section. Additionally, these swamp areas will have a high water table. From these situations, items requiring careful consideration for the drainage design are as follows:

- To clarify existing water streams through visual and topographic survey
- To identify correct catchment areas, land use and soil category covering that area
- To identify swamp area and seasonal water streams through interviews
- To obtain high water table section through geological survey

(3) **Cuamba Area**

In Cuamba, the bypass road will cross some small branch streams including seasonal streams as shown in the following photos.

Branch Stream | Culvert for Small River | Culverts for Seasonal Stream

Figure 8.4.3 Existing Water Streams in Cuamba

The beginning section of the bypass road will cross some branch streams because alignment is set in parallel with the main stream. Seasonal streams are also included in these branch streams. In the end section, the bypass road runs through an area close to a swamp. From these situations, items requiring careful consideration for the drainage design are as follows:

- To clarify existing water streams through visual and topographic survey
- To identify correct catchment areas, land use and soil category covering that area
- To identify swamp area and seasonal water streams through interviews
- To obtain high water table section through geological survey

8.4.2 Design Principals

(1) **Design Return Period**

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

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

Table 8.4.1 The Design Standards for Drainage Structures

Peak Discharge T=20year	Recurrence Interval (yrs)			
	Pipe Culvert	Box Culvert	Low Level Structures	High Level Structures
20m3/s > Q	5	10	10	20
20m3/s < Q < 250m3/s	10	20	20	50
Q > 250m3/s	30	30	30	100

Source: ANE's Design Standards (Draft)

(2) Analysis Methods for Design Discharge

The accumulation of run-off on roadways and shoulders constitutes the most common hydraulic road surface risk. Therefore, the drainage systems and structures should be hydraulically adequate to accommodate the expected discharge volume. Design discharge volumes for the drainage were calculated by the Rational method.

Rational Method

$Q = (1/3.6) \times C \times I \times A$

Where,

Q: Peak flow (m^3/s);

C: run-off coefficient (dimensionless);

I: average rainfall intensity over catchment (mm/hour) and

A: effective area of catchment (km^2).

Time of concentration for small catchment areas which are less than $2.0km^2$ will be set at 10 minutes.

(3) Schedule of the Transversal Structures and Longitudinal Drainage

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

Discharge of the drainage is determined by the "Manning formula" which was used throughout the world.

Manning formula

$Q = (1/n) A R^{2/3} S^{1/2}$

Where,

Q: Discharge (m^3/s)

A: Cross-sectional flow area (m^2)

R: Hydraulic radius (m)

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

N: Manning roughness coefficient

In general, the bed slope was determined to be within the parameter of 1% to 3% in accordance with the site condition.

(4) **Location and size of the Transversal Drainage Facilities**

Transversal culverts were proposed for the locations and sizes shown in Table 8.4.2 below.

Small size transversal culverts (0.9m×0.9m、1.2m×1.2m、and 1.5m×1.5m) are proposed to be made of precast concrete in consideration of workability, economy and shortening of the construction period.

Table 8.4.2 Proposed Locations and sizes for transversal culverts

For Nacala

Chainage	Drainage Area (km^2)	Design Scale (years)	Design Discharge (m^3/s)	Culvert Type	Remarks
No.00+45	1.85	20	31.6	IIIb	
No.09+90	0.03	10	1.0	Ib	
No.11+00	1.69	20	28.5	IIIb	
No.14+60	0.04	10	1.3	Ib	
No.16+00	0.05	10	1.4	Ib	
No.17+00	0.05	10	1.6	Ib	
No.20+70	0.49	20	10.3	IIc	
No.21+40	0.02	10	0.5	Ia	
No.25+90	0.89	10	16.9	IIb	
No.26+50	0.02	10	0.7	Ia	
No.29+70	2.99	20	44.5	IIIc	
No.35+30	0.40	10	8.0	IIc	
No.39+10	0.84	10	15.1	IIIa	
No.44+65	0.17	10	4.1	IIa	
No.51+20	0.06	10	1.8	Ic	
No.69+65	1.10	20	22.9	IV	
No.80+10	0.05	10	1.2	Ib	
No.82+65	0.07	10	2.1	Ic	
No.84+60	0.27	10	7.4	IIc	
No.90+45	0.11	10	3.4	IIa	
No.92+10	0.13	10	4.1	IIa	
No.94+38	0.08	10	2.4	Ic	
No.98+55	0.66	10	12.5	IIIa	
No.104+60	0.66	10	10.4	IIc	
No.108+70	1.75	20	25.3	IIIb	
No.113+20	1.92	20	33.2	Va	
No.113+90	0.02	10	0.6	Ia	
No.117+11	0.22	10	4.6	IIa	
No.121+71	0.76	10	12.1	IIIa	
No.125+65	1.17	20	20.6	IV	
No.134+30	1.79	20	27.7	IIIb	
No.135+30	0.02	10	0.6	Ia	
No.137+35	0.16	10	4.2	IIa	
No.144+90	0.03	10	1.7	Ib	

For Nampula

Chainage	Drainage Area (km^2)	Design Scale (years)	Design Discharge (m^3/s)	Culvert Type	Remarks
No.12+00	2.32	20	40.0	IIIb	
No.23+55	0.15	10	4.6	Ib	
No.28+40	0.08	10	2.3	Ib	
No.31+60	5.91	20	75.4	Vb	
No.34+60	0.05	10	1.5	Ib	
No.60+45	1.02	10	13.4	IIc	
No.96+60	1.52	20	28.4	Va	
No.100+40	0.79	20	20.6	IIb	
No.108+90	0.62	10	13.4	IIc	
No.115+95	0.75	20	20.7	IV	
No.122+80	0.48	10	10.6	IIc	
No.131+75	0.25	10	7.6	IIa	
No.143+15	0.28	10	8.1	IIa	
No.145+70	0.10	10	2.9	Ic	
No.152+90	0.12	10	3.3	Ic	
No.163+00	0.10	10	3.1	Ic	
No.164+00	1.04	10	15.3	IIIa	
No.178+90	0.25	10	5.4	IIa	
No.191+80	0.21	10	6.1	IIa	
No.198+80	0.26	10	6.8	IIa	
No.207+00	0.50	10	10.7	IIc	
No.218+60	1.91	20	36.5	IIIb	
No.227+00	0.24	10	6.1	IIa	
No.246+20	0.45	10	8.3	IIa	
No.252+60	0.40	10	8.4	IIa	
No.259+40	0.34	10	6.1	IIa	
No.270+60	0.74	10	13.4	IIc	
No.292+40	0.55	10	10.7	IIc	

For Cuamba

Chainage	Drainage Area (km^2)	Design Scale (years)	Design Discharge (m^3/s)	Culvert Type	Remarks
No.06+90	0.54	10	4.3	IIa	
No.21+50	0.02	10	0.6	Ia	
No.22+00	0.02	10	0.6	Ia	
No.29+70	0.04	10	1.2	Ib	
No.30+10	0.04	10	1.2	Ib	
No.31+00	0.04	10	1.2	Ib	
No.32+50	0.89	10	7.9	IIa	
No.39+00	1.72	20	23.3	IV	
No.46+70	0.02	10	0.6	Ia	

Source: the Study Team

Table 8.4.3 Proposed Measurement of culverts

For Nampula and Cuamba

Type	B (m)	H (m)	Cell No.	Slope (%)	Area (m2)	Wetted perimeter (m)	Velocity (m/s)	Discharge capacity (m3/s)	Remarks	BoQ
Ia	0.90	0.90	1	0.60%	0.65	2.34	2.21	1.44	80% depth	
Ib	1.20	1.20	1	0.40%	1.15	3.12	2.17	2.50	80% depth	
Ic	1.50	1.50	1	0.30%	1.80	3.90	2.18	3.92	80% depth	
IIa	2.00	2.00	1	0.30%	3.20	5.20	2.65	8.48	80% depth	
IIb	2.00	2.00	3	0.30%	3.20	5.20	2.65	25.44	80% depth	
IIc	2.50	2.50	1	0.25%	5.00	6.50	2.80	14.00	80% depth	
IIIa	3.00	3.00	1	0.20%	7.20	7.80	2.82	20.30	80% depth	
IIIb	3.00	3.00	2	0.20%	7.20	7.80	2.82	40.61	80% depth	
IIIc	3.00	3.00	3	0.20%	7.20	7.80	2.82	60.91	80% depth	
IV	3.50	3.50	1	0.15%	9.80	9.10	2.72	26.66	80% depth	
Va	4.50	4.50	1	0.15%	16.20	11.70	3.20	51.84	80% depth	
Vb	6.00	4.50	1	0.15%	21.60	13.20	3.59	77.54	80% depth	
For Nacala Road										
Ia	0.90	0.90	1	0.60%	0.49	1.98	2.05	1.00	60% depth	
Ib	1.20	1.20	1	0.40%	0.86	2.64	2.01	1.73	60% depth	
Ic	1.50	1.50	1	0.30%	1.35	3.30	2.02	2.73	60% depth	
IIa	2.00	2.00	1	0.30%	2.40	4.40	2.45	5.88	60% depth	
IIb	2.00	2.00	3	0.30%	2.40	4.40	2.45	17.64	60% depth	
IIc	2.50	2.50	1	0.30%	3.75	5.50	2.82	10.58	60% depth	
IIIa	3.00	3.00	1	0.20%	6.00	7.00	2.70	16.20	2m depth	
IIIb	3.00	3.00	2	0.20%	6.00	7.00	2.70	32.40	2m depth	
IIIc	3.00	3.00	3	0.20%	6.00	7.00	2.70	48.60	2m depth	
IV	3.50	3.50	1	0.15%	8.75	8.50	2.63	23.01	2.5m depth	
Va	4.50	4.50	1	0.15%	15.75	11.50	3.18	50.09	3.5m depth	

Source: the Study Team

(5) Longitudinal Drainage

The target road is lower than the surrounding ground and this topographic condition has resulted in erosion of the side drains and road surface. Causes of the erosion problems consist of various factors such as the materials and the accepted flow velocities. In this Survey, the proposed heights of the target roads are basically set higher in comparison with the surrounding ground. However, occurrence of some cut slopes is unavoidable due to the topographic condition. Adequate longitudinal drainage facilities should be installed in the sections with cut slopes for road protection.

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

Table 8.4.4 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 Roads (SATCC)

Slopes of longitudinal drainage for discharge are shown below.

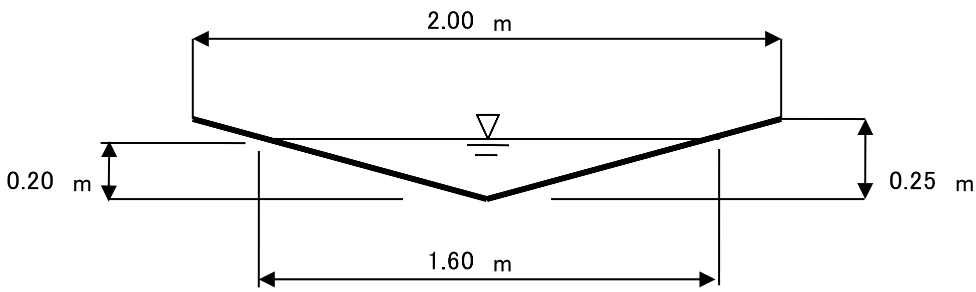


Figure 8.4.4 Proposed Concrete Lined Ditch for Cutting Section

Table 8.4.5 Scour Velocities for Various Materials

Slope (%)	Flow Velocity (m/s)	Discharge (m^3/s)
0.25	0.71	0.11
0.50	1.01	0.16
0.75	1.24	0.20
1.00	1.43	0.23
1.25	1.59	0.26
1.50	1.75	0.28
1.75	1.89	0.30
2.00	2.02	0.32
2.25	2.14	0.34
2.50	2.26	0.36
2.75	2.37	0.38
3.00	2.47	0.40

Source: the Study Team

(6) **Proposed Stone Pitting Ditch**

The ditches at the toe of the embankment slopes of the proposed road, top of cutting slopes and along the service road are closely related to the present situation of the terrain and the longitudinal plan of the road. The study area is rather hilly and many issues will arise where there is greater than maximum allowable flow velocity.

For this reason, a stone pitting ditch was planned using locally generated bone material taking into account the erosion prevention and economy.

8.4.3 Issues and Solutions at the Preliminary Design stage

The issues at the preliminary design stage of the drainage system that need to be discussed and the solutions are shown below:

Nacala Area

Table 8.4.6 Issues and Solutions for Nacala

Issues	Solutions
To determine the characteristics of the existing water streams and drainage system through visual and topographic survey	To determine the characteristics of the drainage system and drainage direction, to create a drainage system diagram. (Attached, Drainage System by Appendix-7)
To correctly identify the existing catchment areas, land use and soil category in that area	The discharge volume was calculated by land use and soil category in that area Determine the volume of transverse drainage required considering a safety factor of 40% by soil category in that area.
To consider countermeasures against erosion on the downstream side	The countermeasures against erosion on the downstream side are proposed to be concrete outlets and mat gabions.

Nampula Area

Table 8.4.7 Issues and Solutions for Nampula

Issues	Solutions
To determine the characteristics of the existing water streams through visual and topographic survey	To determine the characteristics of the drainage system and drainage direction, to create a drainage system diagram. (Attached, Drainage System by Appendix-7)
To identify the correct catchment area, land use and soil category in that area	The discharge volume was calculated by land use and soil category in that area Determine the volume of transverse drainage required considering a safety factor of 20% and the soil category in that area.
To identify swamp areas and seasonal water streams through interviews	The countermeasure against swamp area problems is underground drainage.

Cuamba Area

Table 8.4.8 Issues and Solutions for Cuamba

Issues	Solutions
To determine the characteristics of the existing water streams through visual and topographic survey	To determine the characteristics of the drainage system and drainage direction, to create a drainage system diagram. (Attached, Drainage System by Appendix-7)
To identify correct catchment areas, land use and soil category in that area	The discharge volume was calculated by land use and soil category in that area Determine the volume of transverse drainage required considering a safety factor of 20% and the soil category in that area.
To identify swamp areas and seasonal water streams through interviews	The countermeasure against swamp area problems is proposed to be underground drainage.

8.5 Structural and Road Design Concept

The Study Team set the following levels of road facilities in the provisional 2-lane stage from the 2 points of view in order to implement a preliminary design of the road structures.

- High-Specification Option : Ideal level of the road facilities in line with the future development plans described in 7.6. Note that this option may include some unnecessary facilities because of the high-specifications at the initial timing as provisional 2-lane development.
- Basic Option : Minimum level of the road facilities at the initial stage after opening based on the estimated traffic volume.

There are basically the following differences between these options, as the other sections will describe the concrete differences.

- Level of service road (with/without sidewalks or drainage facilities along the service roads)
- Connection level with major roads (At-grade or Separated grade)

8.5.1 Road Design

(1) Design Methodology

Geometric design for the target roads will follow the following design method:

- The horizontal alignment of the road centre-line, tangent points and other critical points shall be fully defined relative to stations on the baseline by co-ordinates and offsets suitable for setting out the centre-line. All points shall be co-ordinated with the National Survey Grid. Cross-sections shall be taken along the length of the road centre-line at 20-meter intervals and at any changes in the topography.
- The vertical alignment shall take into account the design standard adopted while minimising the earth works quantities. There shall be co-ordination between horizontal and vertical alignment to the greatest extent possible. Consideration shall be given to road safety standards.
- The design shall incorporate all the environmental aspects identified in the site survey. The Survey Team will investigate whether there will be any other possible impacts on the environment and make proposals for remedial measures.
- The methodologies used in the design of pavements, earthworks, drainage and structures shall conform to the latest techniques ensuring use of available construction materials. At all times, a balance must be made between capital and maintenance costs.

(2) **Road Geometric Design**

The geometric design standard for National Roads is issued by ANE (SATCC and ANE's Standards). Both the horizontal and vertical alignment of the target roads will satisfy the geometric standards for road safety. However, it is important that the impacts to both the social and natural environments are minimised. Accordingly, the following concepts of road alignment will be discussed as a general rule:

- The alignment plan should minimise the number of affected houses and people.
- The alignment plan should give consideration to minimising the negative impacts to public facilities (schools, hospitals, etc.), sanctuaries (churches, mosques, cemeteries, etc.), historical facilities (historical monuments, etc.) and social facilities as well.
- The alignment route should not encroach on the railway or high-voltage power line reserve areas as they are proposed by CFM and EDM, respectively.
- The alignment plan should give consideration to reducing the number of at-grade intersections from the aspect of road safety and mobility.
- The alignment plan should give consideration to reducing the number of level crossings including examination of separated grades from the aspect of road safety and mobility.
- The vertical alignment plan should be determined in consideration of the future land development along the roadside.
- The latest high water level determined by hydrological analysis should be reflected in the vertical alignment plan.

(3) **Cross Section for Provisional 2-lane Roads**

Nacala Port Access Road and Nampula Southern Bypass Road are finally recommended to be completed as 4-lane roads with service (frontage) roads and foot ways (sidewalks). However, from the view point of traffic demand, construction cost and construction period, these roads will provisionally start service as 2-lane roads for the time being.

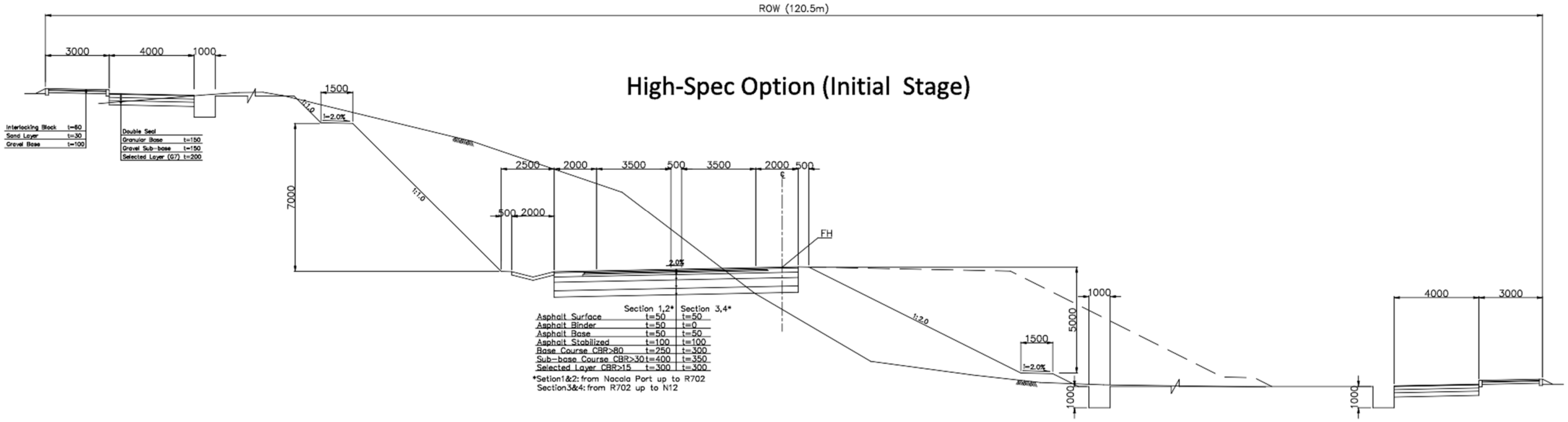
This provisional 2-lane design will be examined after completion of the 4-lane design. The geometry of the provisional 2-lane roads will be determined from the following aspects:

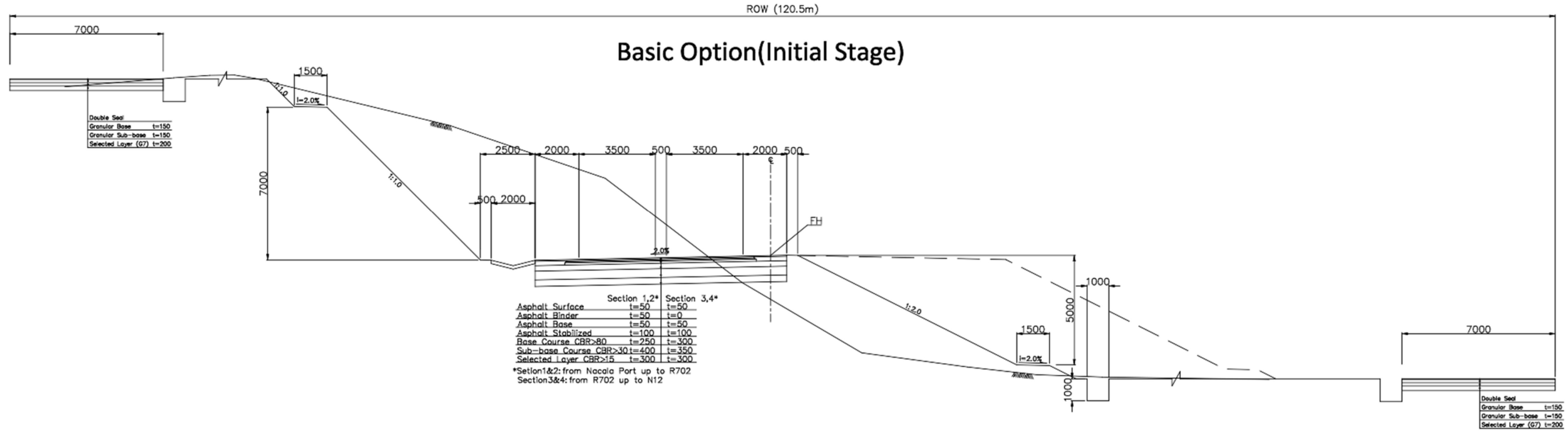
- Construction Cost
- Road Safety
- Type of Bridge (Overpass)
- Type of Intersection

For the provisional 2-lane stages 2 options were considered based on the specifications for the service road: High-Spec Option (specifications that lead to the maximum project cost) and Basic option (specifications that lead to the minimum project cost). The typical cross section of each option is shown in Table 8.5.1.

Table 8.5.1 2-Lane Temporary Stage Option (High-Spec Option/ Basic Option)

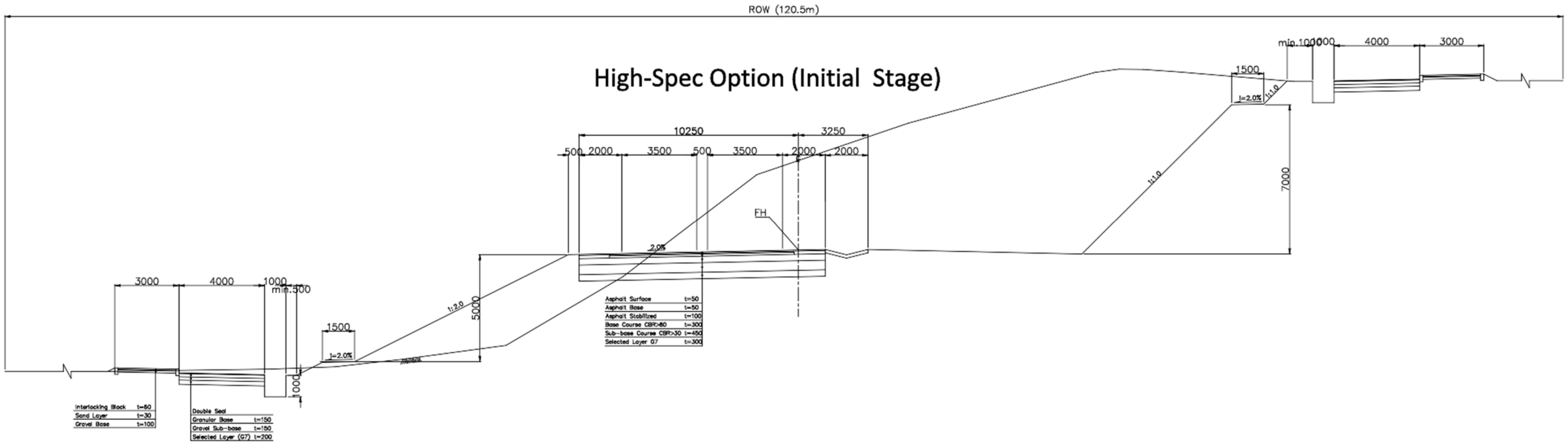
Nacala Port Access Road

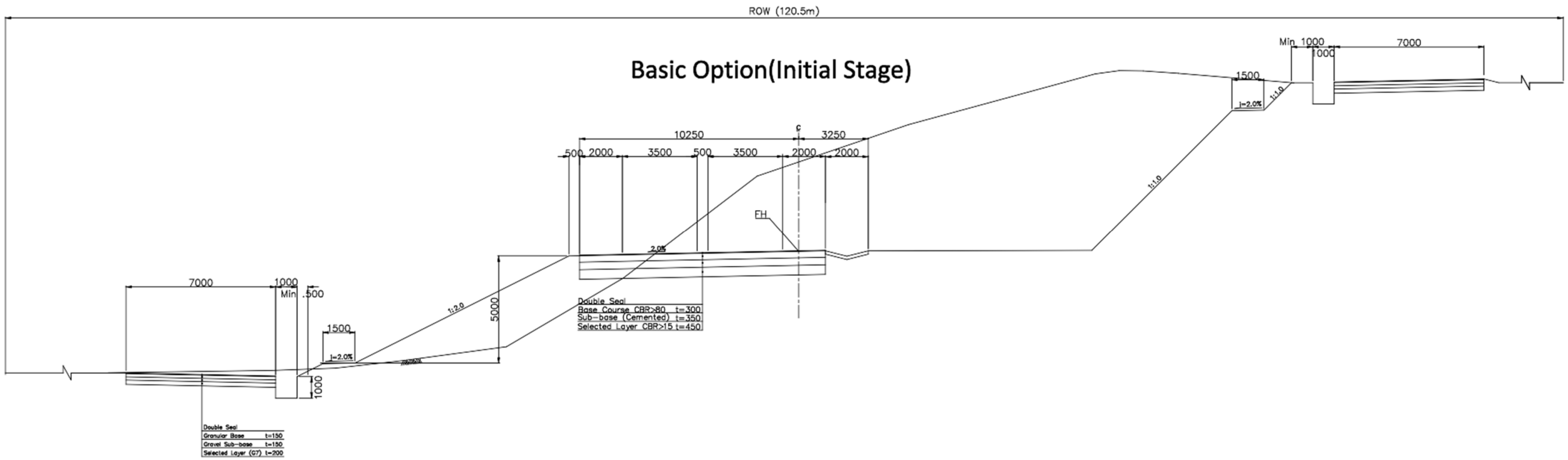




Service road with DBST pavement on the lane/walkway and no drainage structure to reduce the project cost.

Nampula Southern Bypass Road

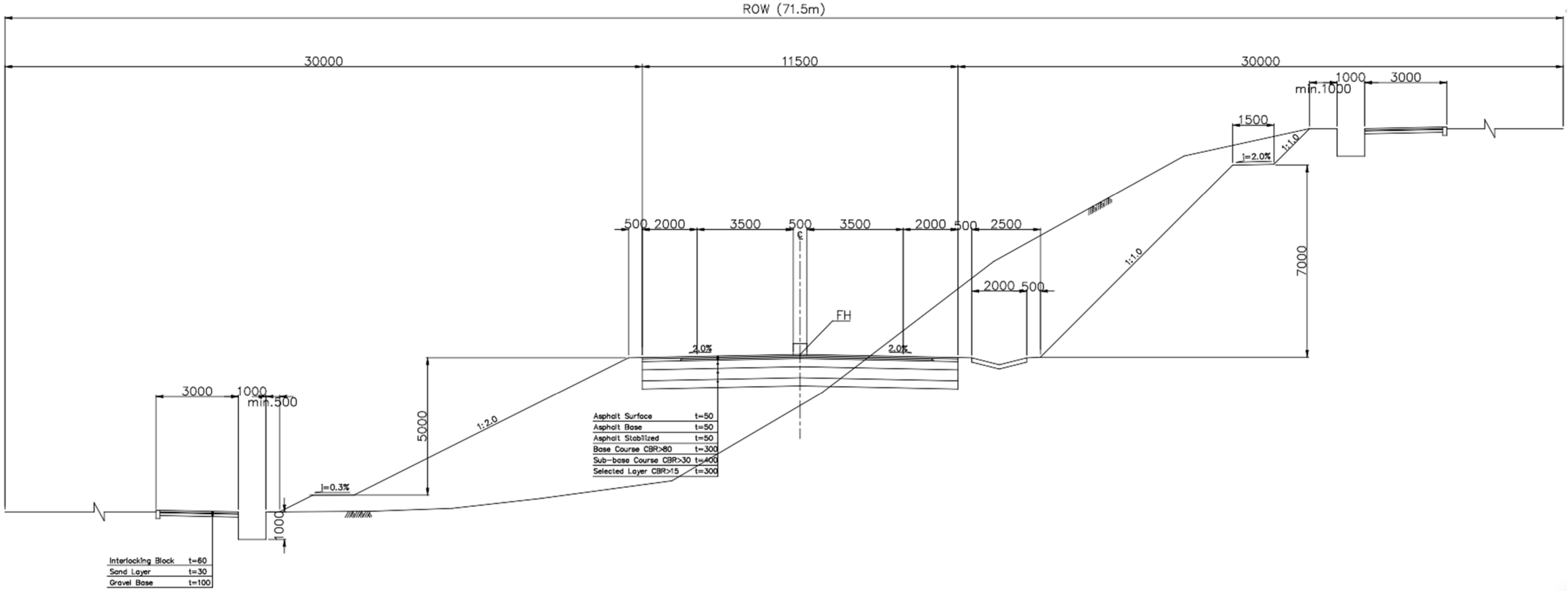




Service road with DBST pavement on the lane/walkway and no drainage structure to reduce the project cost.

Cuamba Bypass Road

High-Spec Option



Basic Option

The same as the High-Spec Option.

Table 8.5.2 shows pavement frameworks in the 3 project area.

Table 8.5.2 Pavement Framework

Option	Project Area	Pavement	
		Main Road	Service Road
High-spec	Nacala	AS	DBST
	Nampula	AS	DBST
	Cuamba	AS	DBST
Basic	Nacala	AS	DBST
	Nampula	DBST	DBST
	Cuamba	DBST	DBST

Regarding the bridge structures proposed in Chapter 7, to reduce the initial project cost in the Basic option, many three-dimensional intersection were replaced with an at grade intersection.

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8.5.2 Structural Design

(1) Applied Design Criteria for Bridges

In principle, bridge design criteria shall follow the “SATCC Code of Practice for the Design of Road Bridges and Culverts” (hereinafter referred to as “SATCC”), based on the discussion with ANE DIPRO. In addition, ANE has consulted about specific points to be adapted into the design parameters, such as seismic loads, temperature loads, etc. to meet the local conditions. Table 8.5.3 shows the criteria applied in the bridge design.

Table 8.5.3 Bridge Design Criteria

Item	Unit	Design Criteria	Notes, References
Live Load		According to NA, NB, NC loads	SATCC-SECTION 2.6
Seismic Load		vi（kh = 0.03）	SATCC-SECTION 3.10
Wind Load		Method A	SATCC-SECTION 3.8
Flooding Load		Water pressure + Debris load	SATCC-SECTION 3.9
Earth Pressure		Coulomb/Rankine Earth Pressure	Upon material properties
Temperature Load		0°～49°C	SATCC-SECTION 4.5
Construction Clearance: Earth Covering			
Bridge Clearance	m	5.5 4.5	Operation Stage Construction Stage
Railway Clearance	m	7.5	
Earth Covering	m	Roadway : 1.5 Sidewalk: 0.5 Rivers : 1.0	Install gabions in the river bed near the bridges
Concrete Nominal Resistance			
PC Girder	N/mm^2	40	
RC Slab	N/mm^2	30	
Substructure	N/mm^2	30	
Cast-in-place pile	N/mm^2	30	
Rebar Nominal Resistance			
Rebar	N/mm^2	450	
Dead Load: Unit Weight			
Plain Concrete	kN/m^3	24.0	
Reinforced Concrete	kN/m^3	25.0	
Asphalt	kN/m^3	21.0	
Steel	kN/m^3	77.0	
Backfill	kN/m^3	(19.0)	Might change according to site survey
Soil	kN/m^3	(18.0)	Might change according to site survey

Below, a brief explanation of each design load type to be considered:

Dead Load

Dead load shall be applied using the above mentioned unit weight of the materials of the structure, which are obtained from the actual experiences in Mozambique, Japanese guidelines and SATCC. Because the soil unit weight differs in the various conditions, ANE DIPRO advised that it shall be measured at the construction stage and modify the unit weight in accordance with the results.

Live Load (SATCC 2.6)

The traffic loads, such as NA, NB, NC loads, shall be in accordance with section 2.6 of the SATCC guideline. The specifications of each load are described below:

a. **NA Load (Normal Loading)**

The traffic loads, such as NA, NB, NC loads, shall be in accordance with the SATCC guideline in the section 2.6. The specifications of each load are described below:

Distributed load

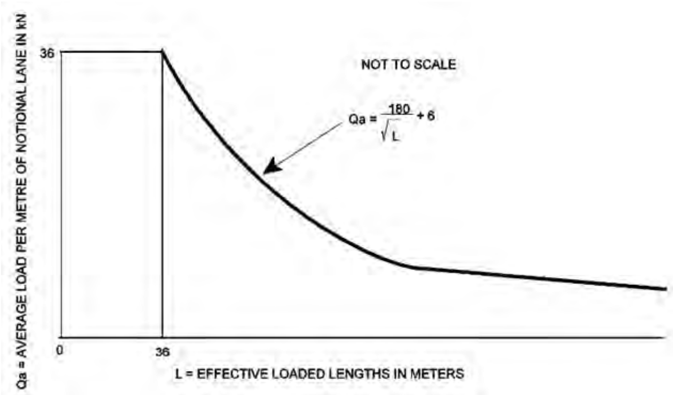


Figure 8.5.1 Loading Curve for Type-NA Loading

L ≦ 36.0m : qa = 36kN/m/Lane

L > 36.0m : Qa = (180/√L) + 6

L = Effective loaded length

Qa = Average load per meter of notional lane in kN

Axle Load

Qai = 144/√n

Qai = Axle load per meter of notional lane in kN/lane

n = Loading sequence number (i.e. n = 1 for the first lane loaded with the axle load, n = 2 for the second lane, etc.)

Tire Load

Two 100 kN wheels not less than one meter apart having circular or square contact areas of 0.10 m² each.

Tire pressure: 1,000kN/m²（100kN/0.1 m²）

Tire contact area: 316 × 316mm

b. **NB Load (Abnormal Loading)**

According to SATCC 2.6.4, the Type-NB Loading represents a single abnormally heavy vehicle and is defined according to Figure 8.5.2:

NB36 Load = 90kN/wheel = 360kN/axle = 1,440kN/vehicle

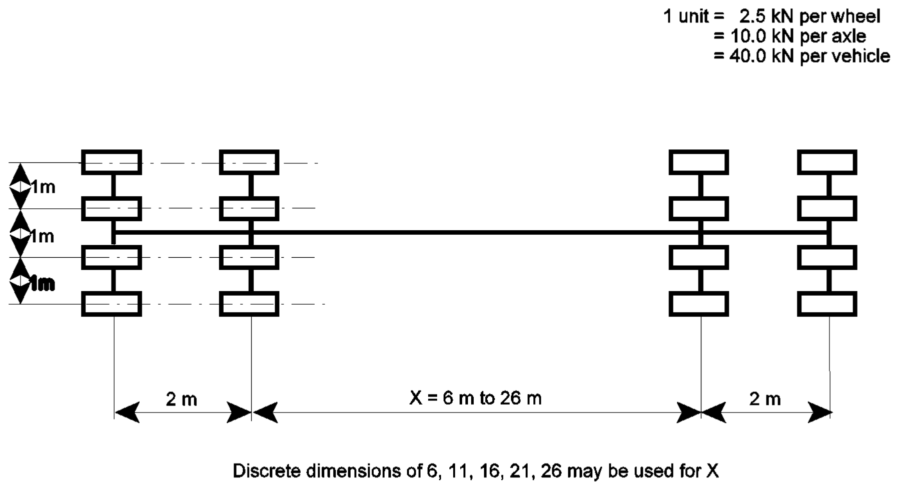


Figure 8.5.2 Type-NB 36

c. **NC Load (Super Loading)**

According to SATCC 2.6.5, the Type-NC Loading represents a multi-wheeled trailer transporting very heavy payloads. The loading with an intensity of 30 kN/m² is uniformly distributed over the area as shown in Figure 8.5.3:

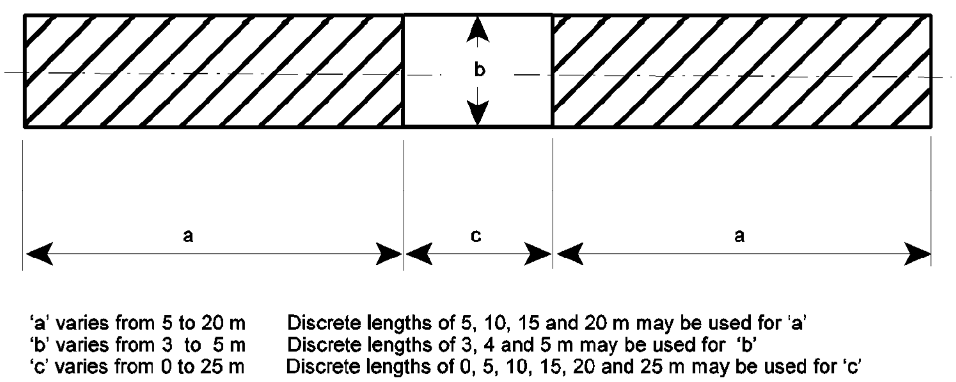


Figure 8.5.3 Type NC Loading

d. **Sidewalk and cycle track live load（SATCC 2.7）**

Span L≦25.0m Q=5.0kN/m²

Span L＞25.0m Q=25/√L , but not less than 1.5kN/m²

e. **Vehicular Breaking Load（SATCC 3.3）**

NA Loading：F=3kN/m+100kN , but not greater than 400kN

NB Loading：20% of the NB Loading adopted

NC Loading：Has no need to be considered.

<u>Seismic Load（SATCC 3.10）</u>

The target project area, according to Figure 8.5.4, is located in the Zone VI. Therefore, k_h = 0.03 must be adopted. Furthermore, this value is in line with the recent bridges completed in the Mozambique central zone.

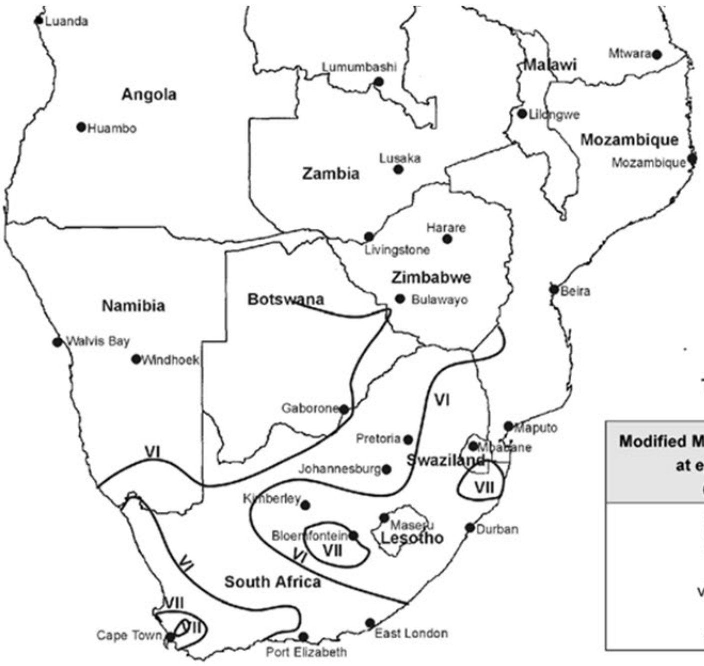


Table 3.16: Modified Mercalli classification

Modified Mercalli Intensity at epicentre (MM)	Maximum ground acceleration (A) at epicentre (g)
ii - iii	0.003
iv - v	0.01
vi	0.03
vii - viii	0.1
ix	0.3
x - xi	1.0

Source: SATCC Section 3.10

Figure 8.5.4 Earthquake Intensity Zones in terms of Modified Mercalli Scale

Wind Load (SATCC 2.8)

The wind load shall be in accordance with the Method-A described in SATCC 2.8. This method considers horizontal and vertical wind force actions, and is also applicable to small bridges.

Transverse wind load

- Case 1: 1.5kN/m² on substructures and superstructures without live load, corresponding to a wind gust speed of approximately 40m/s.
- Case 2: 1.0kN/m² on substructures and superstructures with live load, corresponding to a wind gust speed of approximately 32m/s. Furthermore, an extra 1.5 kN/m acting horizontally in the direction of the wind at a height of 2.0 m above road level shall be considered.

Vertical wind load

- A vertical force of 1.0 kN/m² upward or downward shall be considered.

Flood Load （SATCC 3.9）

The flood load shall be applied based on the following formula in accordance with SATCC 3.9.

$F = K\ A4\ v^2$

F = Flood Load（kN）

K = Coefficient of form: 0.70 for square pier ends, and 0.35 for circular pier ends

A4 = projected pier area in m²

v = velocity of flow in m/s

If the river carries debris, an additional horizontal force between 90~180 kN shall be considered on each pier, depending on the estimated degree of debris build-up.

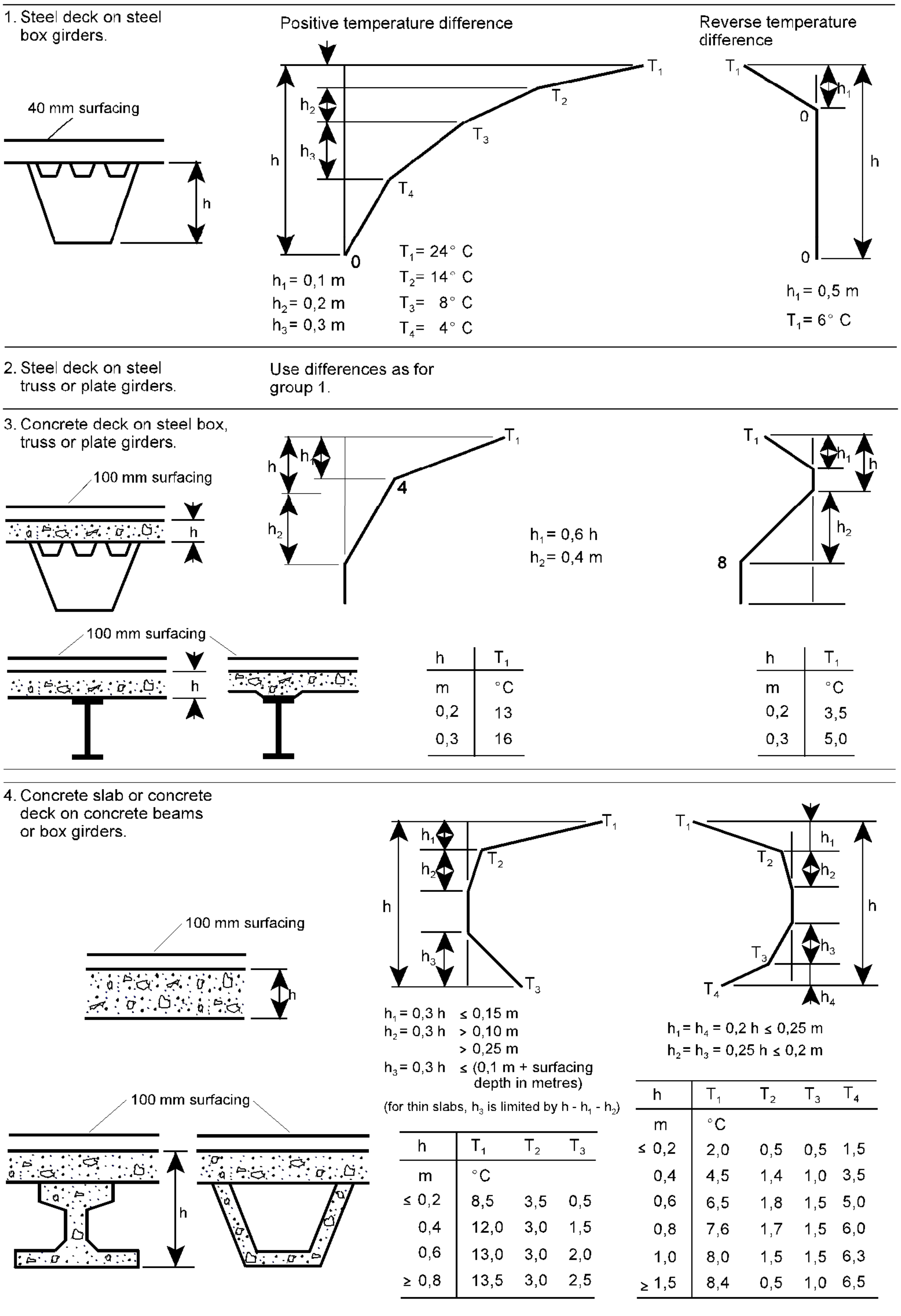
Temperature Load （SATCC 4.5）

Effective bridge temperatures range

According to SATCC section 4.5.1, the minimum and the maximum shade temperature for 50 year return periods in the target project area are 0 ˚C and 49 ˚C, respectively.

Temperature differential

According to SATCC 4.5.4, the temperature differential shall be determined according the Figure 8.5.5 below:



h	T_1
m	°C
0,2	13
0,3	16

h	T_1
m	°C
0,2	3,5
0,3	5,0

h	T_1	T_2	T_3
m	°C		
≤ 0,2	8,5	3,5	0,5
0,4	12,0	3,0	1,5
0,6	13,0	3,0	2,0
≥ 0,8	13,5	3,0	2,5

h	T_1	T_2	T_3	T_4
m	°C			
≤ 0,2	2,0	0,5	0,5	1,5
0,4	4,5	1,4	1,0	3,5
0,6	6,5	1,8	1,5	5,0
0,8	7,6	1,7	1,5	6,0
1,0	8,0	1,5	1,5	6,3
≥ 1,5	8,4	0,5	1,0	6,5

Figure 8.5.5 Temperature Difference for Different Types of Construction

<u>Other Loads</u>

The following loads shall be considered in the structural design if necessary. Details should be discussed during the preliminary design stage.

- Creep and Shrinkage (SATCC 4.2)
- Collisions with Balustrades and Piers (SATCC 3.5 and 3.7)

(2) **Locations of Structures (Proposed)**

The tentative locations where structural solutions may be necessary for each road are shown below:

1) Nacala Port Access Road

There are three locations where the structural solution shall be applied. More details are shown as follows.

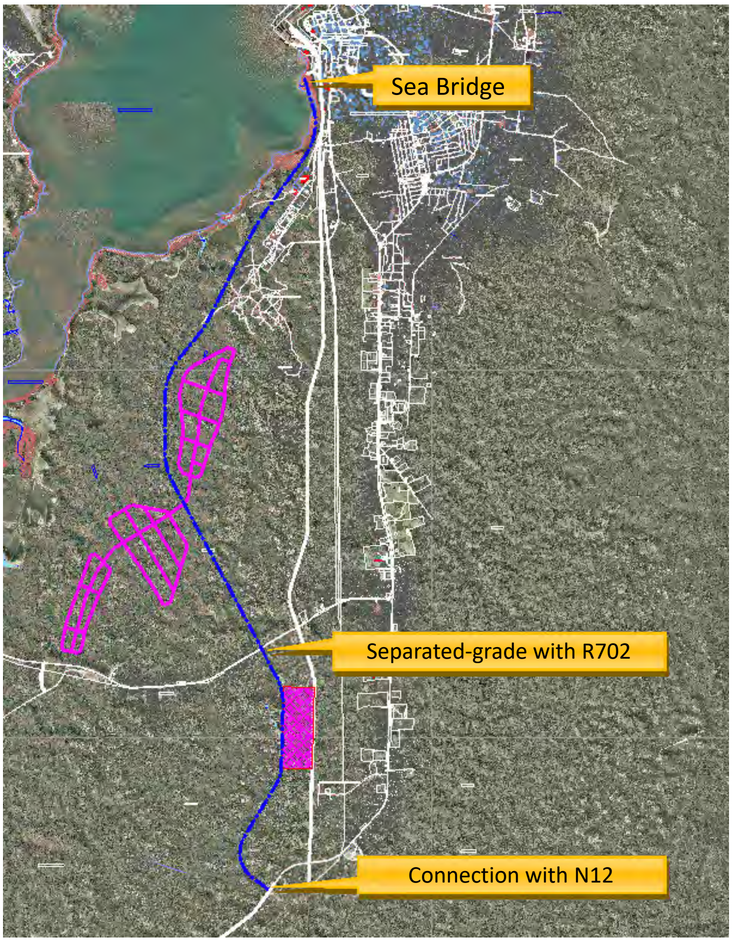


Figure 8.5.6 Locations for Structures in the Nacala Port Access Road

- Sea Bridge
  - Considering the embarkation traffic under the bridge, the minimum bottom level of the main girders considers the highest high tide level (H.H.T.L) plus a margin (minimum 2.00m).
  - For the construction of the temporary road in the sea, temporary piers or stone embankments were considered. Considering the environmental impacts the temporary pier is considered the most suitable alternative.
  - The abutment location was chosen considering the river cross section and the crossing angle between the bridge alignment and the river.
- Separated-grade with R702
  - An interchange is being planned for the completion stage. There is on a hill with a north-south slope at the east side of the proposed alignment. During the heavy rains of January 2015 the railway embankment collapsed and a huge amount of sediments were carried away. Since the bridge is located downstream and the above may occur once again, the bridge length and drainage paths should be carefully designed.
- Connection with N12
  - An at-grade solution is being considered for the provisional stage. Considering traffic growth in the future, an interchange is being considered for the completion stage. In the case of the intersection solution and choice of connecting point, it is advised to avoid the risk of traffic accidents and increasing bridge length due to the steep longitudinal profile in some section of N12.

2) Nampula Southern Bypass Road

There are multiple locations where a structural solution shall be applied. More details are shown as follows.

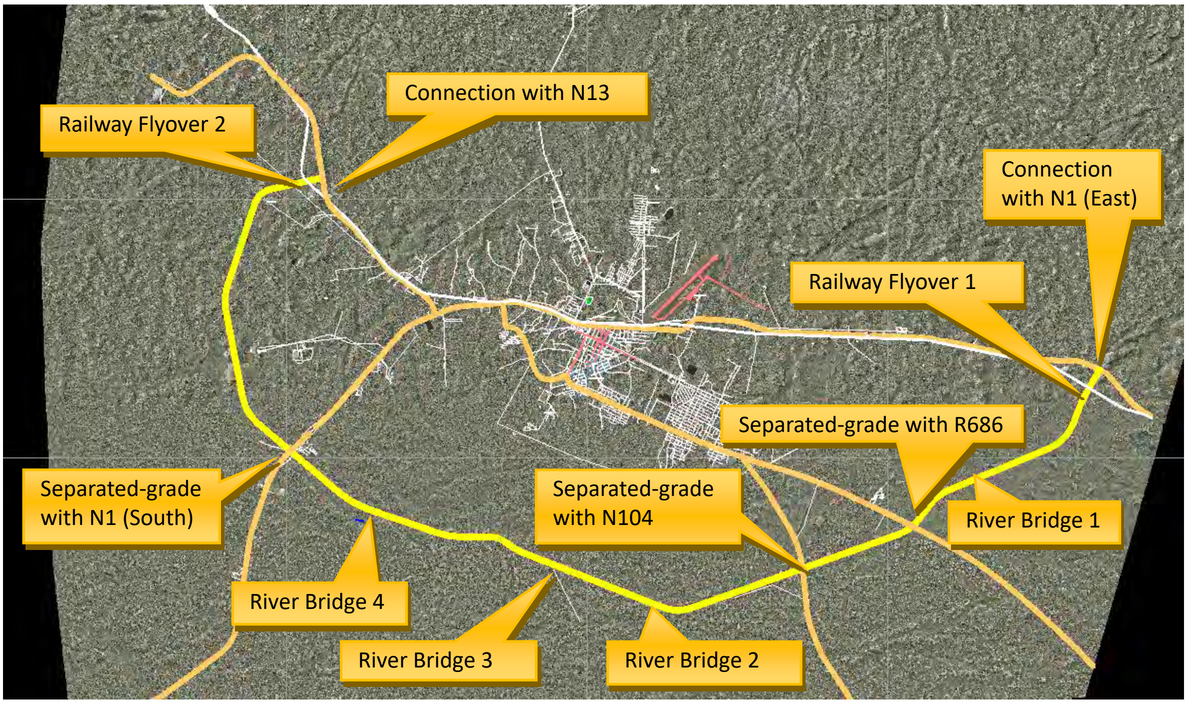


Figure 8.5.7 Locations for Structures in the Nampula Southern Bypass Road

- Railway Flyovers
  - There are 2 railway flyovers, one near the starting point and one near the ending point of Nampula Southern Bypass Road. Both flyovers are located in a region where the ground slope is approximate 4% almost parallel to the bridge longitudinal inclination, therefore a long bridge is required. To reduce the total length of the bridge, reducing the girder height as much as possible is being considered. Furthermore as discussed with CFM, railway clearances and at least 2 spans shall be considered in the bridge design.
- Separated-grade with R686
  - An interchange is being planned in the completion stage. 40m span class bridges are very likely to be a suitable alternative.
- Separated-grade with N104
  - An interchange is being planned in the provisional stage. 30m span class bridges are very likely to be a suitable alternative.
- Separated-grade with N1 (South)
  - An interchange is being planned for both the completion stage and provisional stage. 30m span class bridges are very likely to be a suitable alternative. Also, the connection with the city roads will be improved to enhance the connectivity with the residential area, which across the bypass road is taken into considered.
- Connection with N1 (East) and N13
  - An at-grade solution is being planned for the provisional stage. An interchange solution with a bridge structure will be applied in the completion stage in order to preserve the bypass function.

- River Bridges
  - The girder vertical clearance, total length and spans were defined considering the hydrologic parameters of the rivers (e.g. stream flow, H.W.L, etc.).

3) Cuamba Bypass Road

There are multiple locations where structural solutions shall be applied. More details are shown as follows.

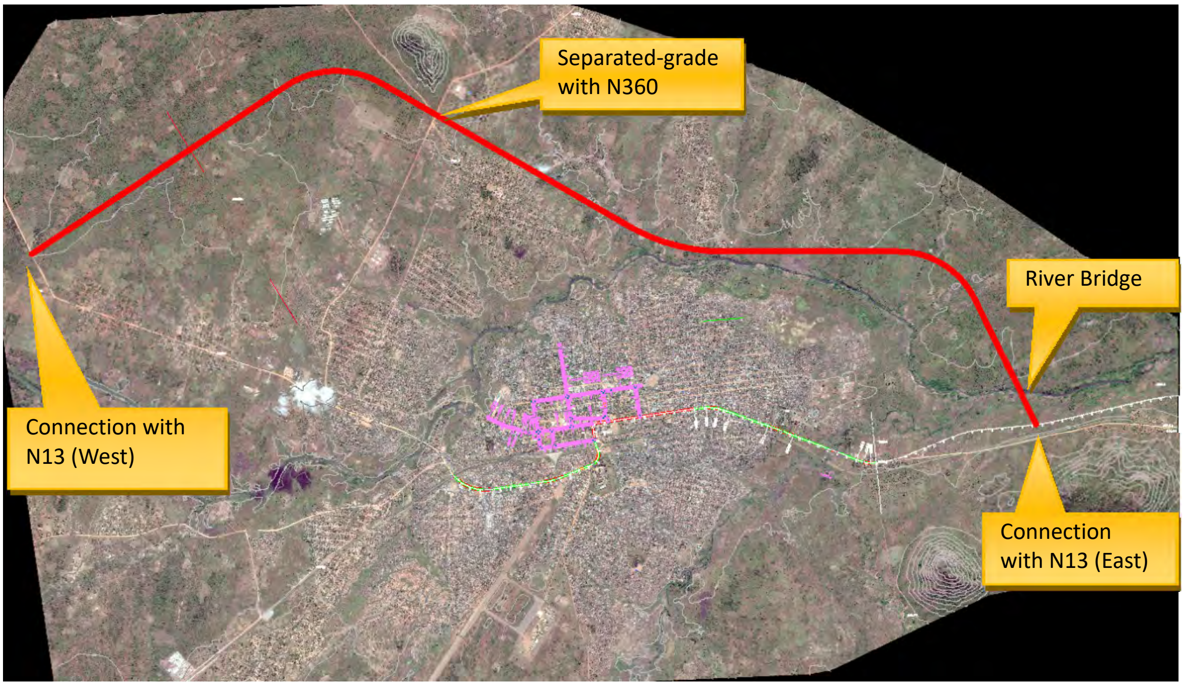


Figure 8.5.8 Locations for Structures in the Cuamba Bypass Road

- Separated-grade with N360
  - An interchange is being planned for the completion stage; the bridge structural type will be defined in this study.
- Connection with N13 (East) (West)
  - An at-grade solution is being planned for the provisional stage. An interchange solution with a bridge structure will be applied in the completion stage in order to preserve the bypass function.
- River Bridge to Rio Muanda
  - The hydrologic parameters of the river (e.g. stream flow, H.W.L, etc.) need to be investigated in order to guarantee the necessary girder vertical clearance, and design the total length and spans.
  - The use of the river as a navigation channel shall be investigated.
  - Bridge / culvert type for other branch rivers of Rio Muanda, shall be decided by the results of the hydrological analysis.

(3) Structure Type and Selection Method

Three types of bridges – Marine, River and Overpass – where compared according the following process: in the first step, the possible types of bridges were qualitatively selected considering the alignment, topographic conditions, construction clearance, etc. In the second step those types were quantitatively evaluated considering seven main points: structural stability, constructability, construction cost, maintenance, social & environmental aspects, landmark aspects and technology transfer aspects.

1) Selection Criteria

Each alternative was examined according the criteria shown in Table 8.5.4 to Table 8.5.6.

Table 8.5.4 Evaluation Criteria of Alternative Bridge Types

Category		Evaluation Criteria	Maximum Score (Points)
a	Technical Aspects (15 points)	Structural Stability	5
b		Constructability	10
c	Economic Aspects (65 points)	Construction Cost	50
d		Maintenance	15
e	Other Aspects (20 points)	Social & Environmental	5
f		Landscape	5
g		Technical Transfer (New Technology)	10
Total Points			100

Source: JICA Survey Team

Table 8.5.5 Eligible Items for Each Evaluation Criteria

Evaluation Criterion		Considered Items
a	Structural Stability	- Permanent Structure or Temporary structure - Earthquake Resistance and Ease of Travel
b	Constructability	- Construction Period - Ease of Erection Work - Ease of Substructure and Foundation Work
c	Construction Cost	- Construction Cost
d	Maintenance	- Concrete structure (maintenance free) or Steel structure - Ease of Inspection and Maintenance
e	Environment	- Number of affected houses - Negative impact on environment during construction
f	Landscape	- Symbol of local development and/or a landmark of the region
g	Technical Transfer (New Technology)	- Advanced technique, Useful technique or Common technique

Source: JICA Survey Team

Table 8.5.6 Scoring System for Evaluation of Alternative Bridge Types

Evaluation		a. Structural Stability	b. Constructability	c. Construction Cost
Grade	Rate	(5)	(10)	(50)
Good	100%	5	10	Scored by the ratio of the construction cost against the most economical alternative
Fair	50%	3	5	
Poor	20%	1	2	

Evaluation		d. Maintenance	e. Environment	f. Landscape	g. Technical Transfer (New Technology)
Grade	Rate	(15)	(5)	(5)	(10)
Good	100%	15	5	5	Advanced technique: 10
Fair	50%	8	3	3	Useful technique: 5
Poor	20%	3	1	1	Common technique: 2

Source: JICA Survey Team

2) Proposed alternatives and Evaluation Results

- Nacala Port Access Road

Located in the costal portion and might not be affected by water during the low tide. There isn't merit in increasing the spans too much to reduce the number of piers. There are no particular topographic restraining conditions. The PC Box Girder wasn't considered due the difficulties in construction of the scaffolding foundation, which is necessary in the bridge erection process. The three alternatives below were studied:

- ✓ Alternative 1: RC-I Girder (56@15m=840m)
- ✓ Alternative 2: PC-I Girder (28@30m=840m)
- ✓ Alternative 3: Continuous Steel Plate Girder (21@40m=840m)

The solution proposed is the PC-I Girder (Alternative 2) which is the best from the economic view and has the lowest maintenance cost, according to the evaluation as shown in Table 8.5.7 and Table 8.5.8.

- Nampula FO

PC Hollow Slab requires special scaffolding so considering the girder clearance aspects, it is not a suitable option. Considering the impacts in the railway operation, the three alternatives below were studied:

- ✓ Alternative 1: PC-I Girder (2@28.5m=57m)
- ✓ Alternative 2: Continuous Steel Slab Girder (2@28.5m=57m)
- ✓ Alternative 3: Continuous Composite Steel Concrete Slab (2@28.5m=57m)

The solution proposed is the Continuous Composite Steel Concrete Slab (Alternative 3) due the thickness of the girder, shortest construction period and the technology transfer with the application of weathering steel, according to the evaluation as shown in Table 8.5.9 and Table 8.5.10.

- Cuamba River Bridge

Considering that soil conditions are good, there are no merits in adopting longer spans (i.e. continuous PC box girder), there are no navigation restrictions or any other topographic restraints, the three alternatives below were studied:

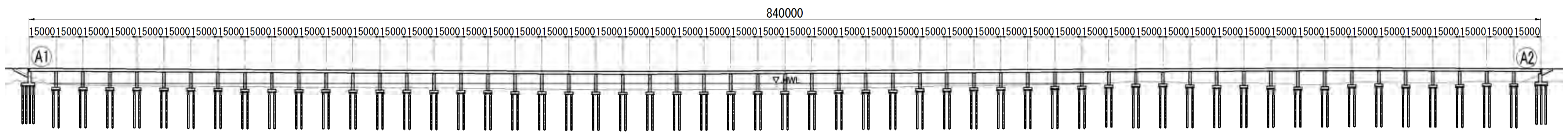
- ✓ Alternative 1: RC-I Girder (16@15m=240m)
- ✓ Alternative 2: PC-I Girder (6@40m=240m)
- ✓ Alternative 3: Continuous Steel Plate Girder (6@40m=240m)

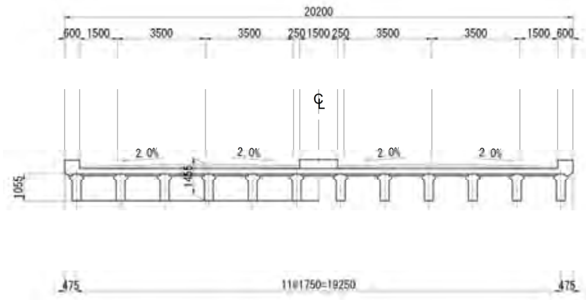
The solution proposed is the PC-I Girder due low initial cost and the fact that it is broadly adopted in Mozambique, according to the evaluation as shown in Table 8.5.11 and Table 8.5.12.

Table 8.5.7 Nacala Port Access Road – Bridge Comparison (1/2)

Profile | Cross section

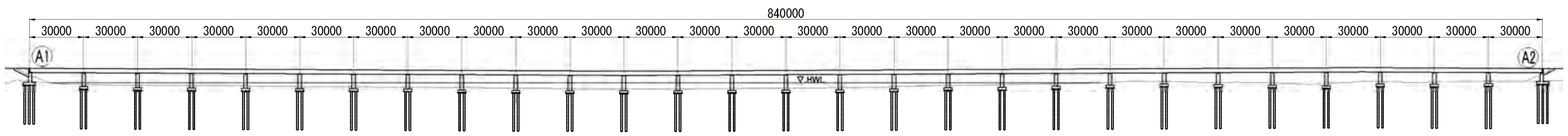
Alternative 1: RC-I Girder **L = 840m (56×15m)**

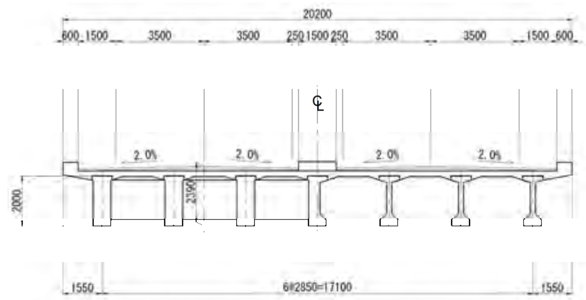




Category	Evaluation Criterion	Comments	Score	
Technical Aspects	Structural Stability	The structure is composed of simple girders, so has low earthquake resistance. The trafficability can be improved filling the joint with concrete instead of installing a joint device	Fair	3 / 5
	Constructability	Due to the large amount of girders and piers the construction period is longer than other alternatives. The estimated construction time is approximate 86 months (7.2 years)	Poor	2/ 10
Economic Aspects	Construction Cost	μ= 1.04	----	48 / 50
	Maintenance	There are too many bearing pads, so it is uneconomical when comparing with other alternatives	Fair	8 / 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. Is necessary to consider the impact in the sea environment due to the pier construction	Fair	3 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	Commonly applied in Mozambique	Poor	2/ 10
Evaluation		3rd Choice		69 / 100

Alternative 2: Continuous PC-I Girder **L = 840m (28×30m)**



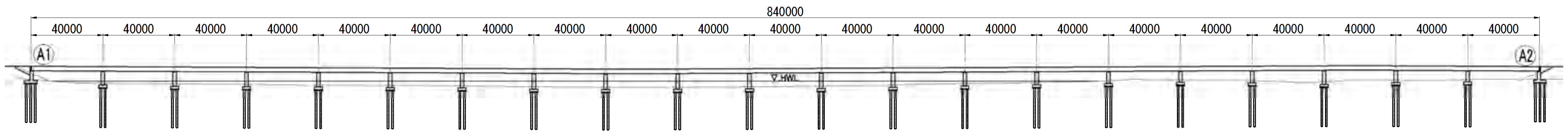


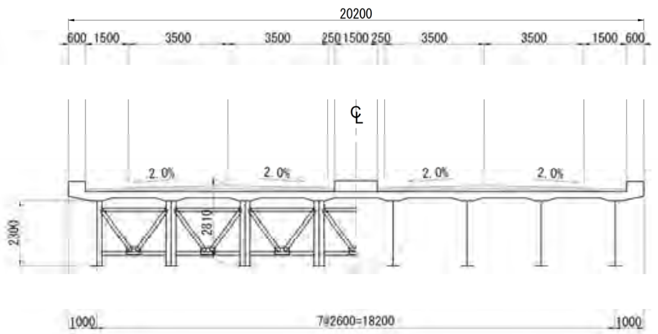
Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high due to the continuous girder properties	Good	5 / 5
	Constructability	The construction requires a 200t crane. The construction period is estimated in 55 months (4.6 years)	Fair	5 / 10
Economic Aspects	Construction Cost	μ= 1.00	----	50 / 50
	Maintenance	Since this is a concrete structure basically it is maintenance free, excepting for the joints and bearing pads	Good	15 / 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. It is necessary to consider the impact in the sea environment due the pier construction	Fair	3 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	This solution has been growing recently in Mozambique	Poor	2 / 10
Evaluation		**1st Choice**		83 / 100

Table 8.5.8 Nacala Port Access Road – Bridge Comparison (2/2)

Profile | Cross section

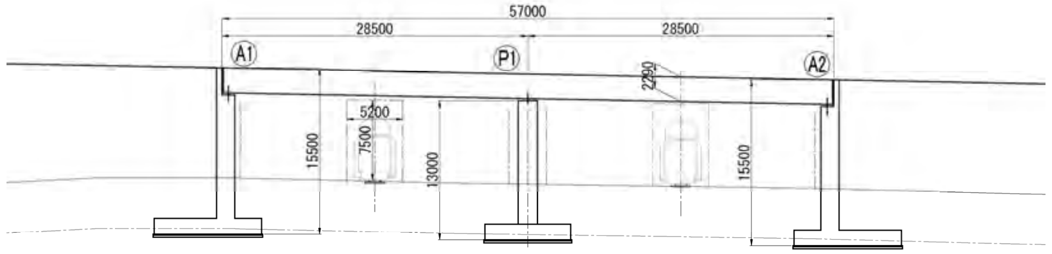
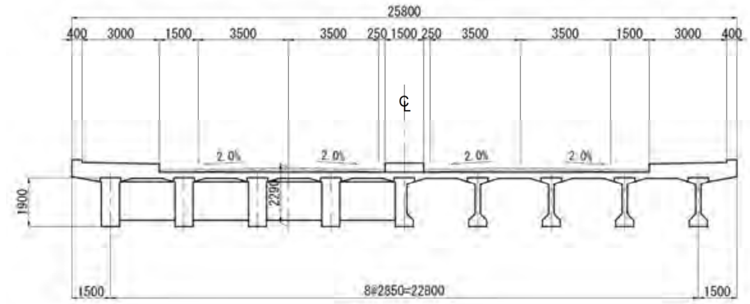
<u>Alternative 3: Continuous Steel Slab Girder</u> **L = 840m (21x 40m)**



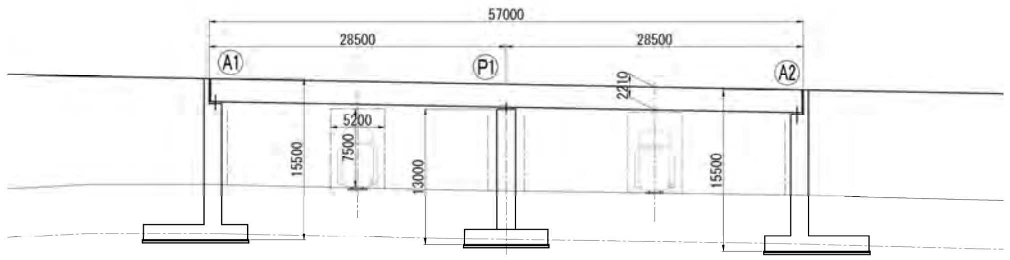
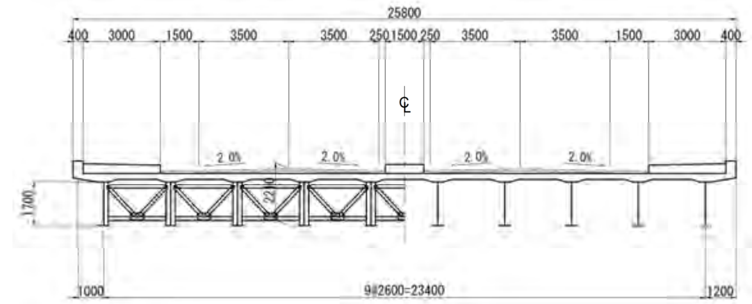


Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high/good due to the continuous girder properties	Good	5 / 5
	Constructability	The structure is lighter than concrete leading to a shorter construction time of approximate 52 months (4.3 years)	Good	10 / 10
Economic Aspects	Construction Cost	μ= 1.25	----	37 / 50
	Maintenance	It is necessary to periodically change the coating protection, joints and bearings. However, depending on the heavy-duty coating specifications the maintenance cost can be reduced.	Fair	8/ 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. It is necessary to consider the impact in the sea environment due the pier construction	Fair	3 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	Heavy-duty coating technology can be transferred	Good	10 / 10
Evaluation		2nd Choice		76 / 100

Table 8.5.9 Nampula Southern Bypass Road – Bridge Comparison (1/2)

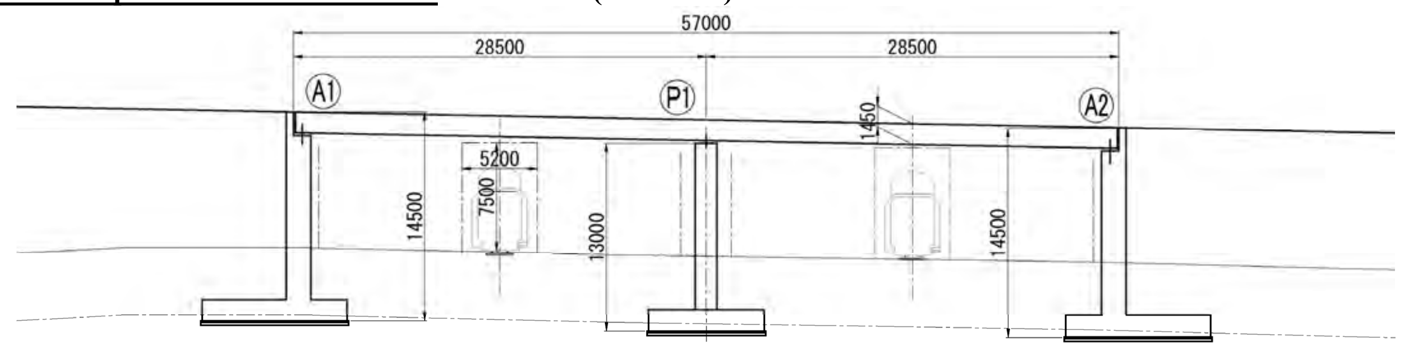
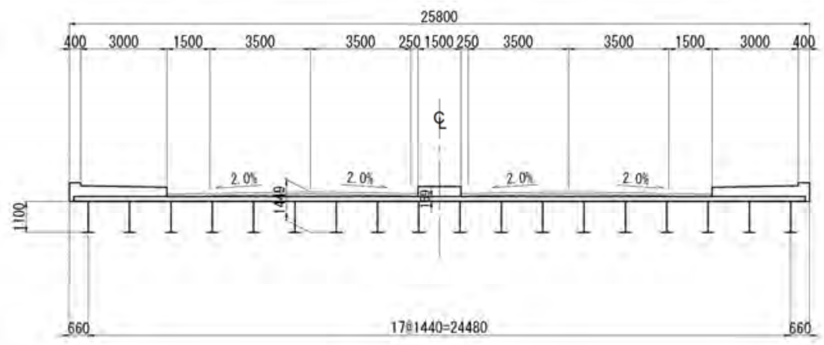
Profile	Cross section
Alternative 1: Continuous PC-I Girder L = 57m (2×28.5m) 	

Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high/good due the continuous girder properties	Good	5 / 5
	Constructability	Due the railway operations it is necessary to construct a girder (using a 200t crane with 27m working radius, the maximum lift capacity is 22 t. The segment weights 23t or more). The abutment is high, and so is the earthwork volume. The construction period is estimated at 17.5 months (1.5 years)	Poor	2 / 10
Economic Aspects	Construction Cost	μ= 1.00	----	50 / 50
	Maintenance	Since it is a concrete structure it is basically is maintenance free, excepting for the joints and bearing pads	Good	15 / 15
Other Aspects	Social & Environmental	The girder is the thickest of the 3 alternatives, so the approach extension is also longer. However this alternative is not expected to generate resettlements	Poor	1 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	This solution has been growing in acceptance recently in Mozambique	Poor	2 / 10
Evaluation		2nd Choice		78 / 100

Profile	Cross section
Alternative 2: Continuous Steel Slab Girder L = 57m (2×28.5m) 	

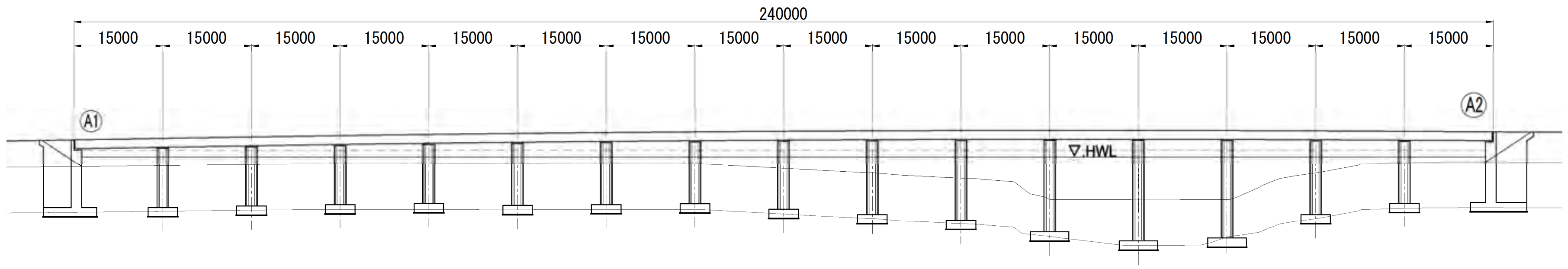
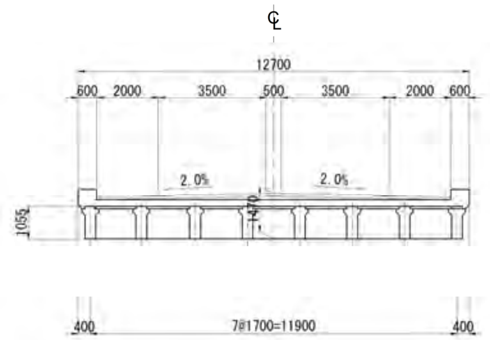
Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high/good due to the continuous girder properties	Good	5 / 5
	Constructability	The structure is lighter than concrete leading to a shorter construction time. Crane positioned before the abutments can be used in the construction. The abutment is high and so is the earthwork volume. The construction period is approximate 16 months (1.3 years)	Fair	5 / 10
Economic Aspects	Construction Cost	μ= 1.23	----	39 / 50
	Maintenance	If weathering steel is used the structure can be considered maintenance free, excepting for the joints and bearing pads	Good	15/ 15
Other Aspects	Social & Environmental	The girder is the thickest and the approach length is similar to Alt. 1. However this alternative is not expected to generate resettlements	Poor	1 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	Weathering steel technology can be transferred	Good	10 / 10
Evaluation		3rd Choice		78 / 100

Table 8.5.10 Nampula Southern Bypass Road – Bridge Comparison (2/2)

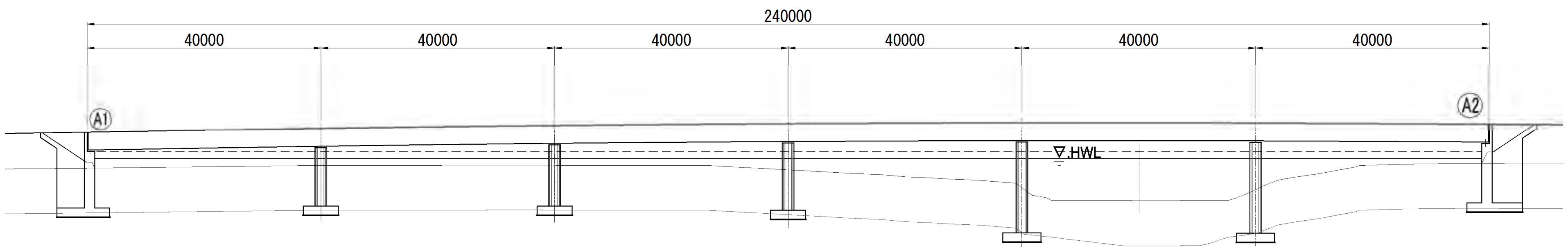
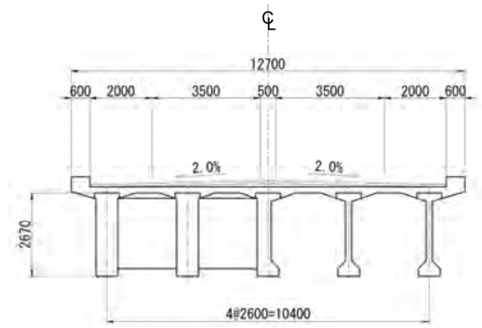
Profile	Cross section
<u>Alternative 3: Continuous Composite Steel Concrete Slab</u> **L = 57m (2×28.5m)** 	

Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high/good due to the continuous girder properties	Good	5 / 5
	Constructability	Crane and bent construction method is applied. The girder is the thinnest, there is no need for formwork or scaffold to execute the slab portion, allowing a fast construction schedule (heaviest block is 16t). Construction time is estimated 14 months (1.2 years)	Good	10/ 10
Economic Aspects	Construction Cost	μ= 1.01	----	49 / 50
	Maintenance	If weathering steel is used the structure can be considered maintenance free, excepting for the joints and bearing pads	Good	15 / 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. This is the alternative that leads to the minimum earthwork volumes, reducing the approach side lengths	Good	5 / 5
	Landscape	Simple structure with girders, this alternative has the lowest girder height/span ratio, so is the best in beauty aspects	Fair	3 / 5
	Tech. Transfer (New Techno.)	Weathering steel technology can be transferred	Good	10/ 10
Evaluation		**1st Choice**		97 / 100

Table 8.5.11 Cuamba Bypass Road – Bridge Comparison (1/2)

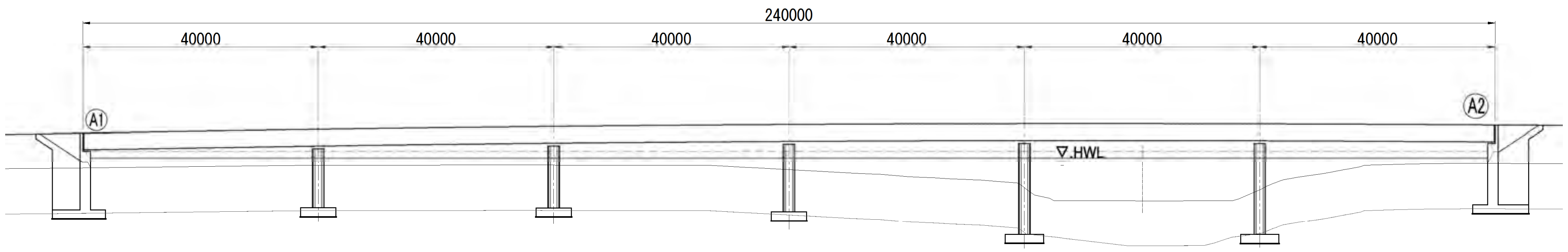
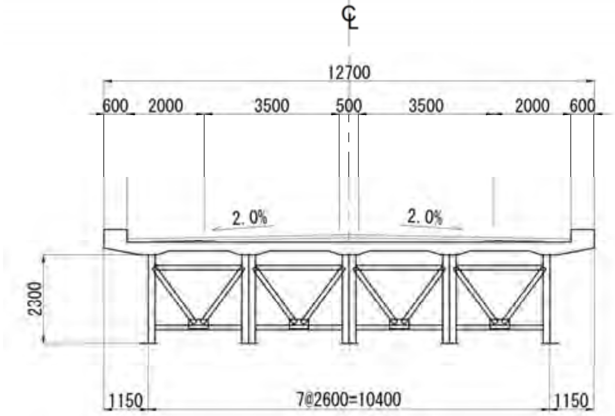
Profile	Cross section
Alternative 1: RC-I Girder **L = 240m (16×15m)** 	

Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The structure is composed of simple girders, so has low earthquake resistance. The trafficability can be improved by filling the joints with concrete instead of installing a joint device	Good	3 / 5
	Constructability	Due the large amount of girders and piers the construction period is longer than other alternatives. The estimated construction time is approximate 29 months (2.4 years)	Poor	2/ 10
Economic Aspects	Construction Cost	μ= 1.00	----	50 / 50
	Maintenance	There are too many bearing pads, so is uneconomical when comparing with other alternatives	Good	8 / 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. The quantity of piers inside the river is n, 11% of the river cross section is compromised by the piers.	Poor	1 / 5
	Landscape	The superstructure thickness has a strong design appeal, however there is a high pier number and the pier is relative	Good	3 / 5
	Tech. Transfer (New Techno.)	Commonly applied in Mozambique	Poor	2/ 10
Evaluation		3rd Choice		69 / 100

Profile	Cross section
Alternative 2: Continuous PC-I Girder **L = 240m (6×40m)** 	

Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high/good due the continuous girder properties	Good	5 / 5
	Constructability	A construction girder is necessary due the 40m span girder weight. The estimated construction time is approximate 25 months (2.1 years)	Fair	5 / 10
Economic Aspects	Construction Cost	μ= 1.00	----	50 / 50
	Maintenance	Since it is a concrete structure it is basically is maintenance free, except for the joints and bearing pads	Good	15 / 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. The quantity of piers satisfies the typical span length	Good	5 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	This solution has been growing in acceptance recently in Mozambique	Poor	2 / 10
Evaluation		**1st Choice**		85 / 100

Table 8.5.12 Cuamba Bypass Road – Bridge Comparison (2/2)

Profile	Cross section
Alternative 3: Continuous Steel Plate Girder **L = 240m (6×40m)** 	

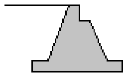
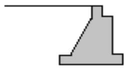
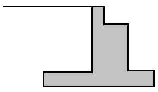
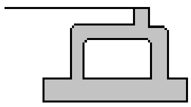
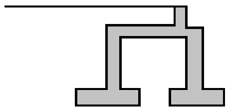
Category	Evaluation Criterion	Comment	Score	
Technical Aspects	Structural Stability	The earthquake resistance and trafficability are high/good due the continuous girder properties	Good	5 / 5
	Constructability	The structure is lighter than concrete leading to a shorter construction time, approximate 24 months (2.0 years)	Good	10 / 10
Economic Aspects	Construction Cost	μ= 1.22	----	39 / 50
	Maintenance	Is necessary to periodically change the coating protection, joints and bearings. However, applying weathering steel can reduce the maintenance cost.	Fair	8/ 15
Other Aspects	Social & Environmental	This alternative is not expected to generate resettlements. The quantity of piers satisfies the typical span length.	Good	5 / 5
	Landscape	Simple structure with girders	Fair	3 / 5
	Tech. Transfer (New Techno.)	Heavy-duty coating and weathering steel technology can be transferred	Good	10 / 10
Evaluation		2nd Choice		80 / 100

(4) **Substructure Type Selection**

1) Substructure Outline

The abutment type was selected from the types presented in the Table 8.5.13. All the abutments are between 5m and 15m, so the reverse T type abutment is proposed based on Mozambique construction achievements. The piers are proposed to be the wall type due the facility of construction independent of the pier height. In the places where direct foundations cannot be applied piles Φ1000 cast in situ are proposed as is commonly applied in other projects in Mozambique.

Table 8.5.13 Abutment Type and Applicable Conditions

Abutment	Type	Applicable conditions	Characteristics
Gravity type		$H \leq 5m$	-Simple structure -Simple construction -Heavy weight
Semi gravity type		$H \leq 5m$	-Simple structure -Simple construction -Heavy weight
Reverse T type		$5m \leq H \leq 17m$	-Low cost -Simple construction
Box type		$12m \leq H \leq 20m$	-Expensive -Complex structure
Rigid frame type		$15m \leq H \leq 25m$	-Expensive -Complex structure

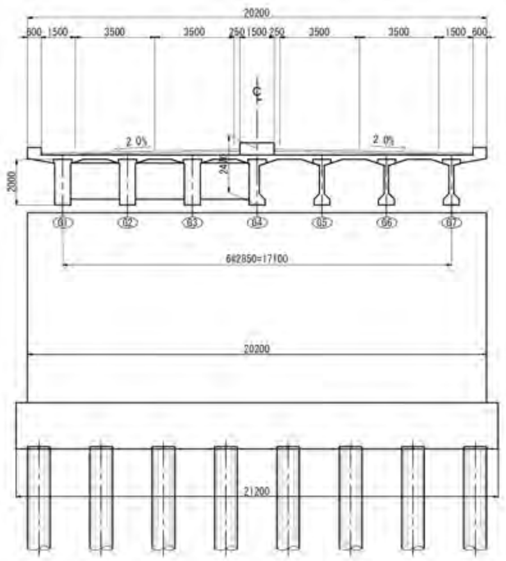
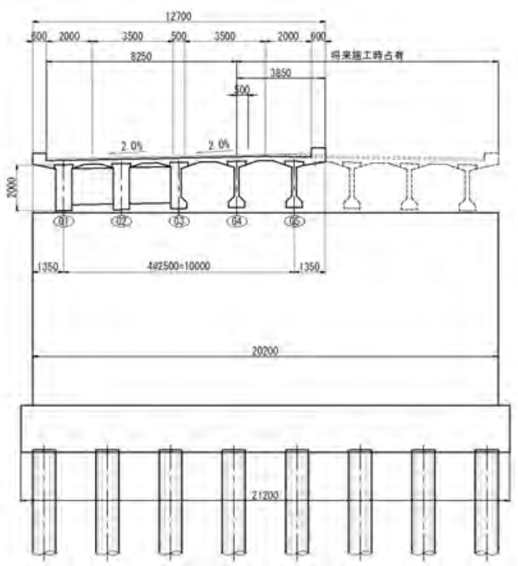
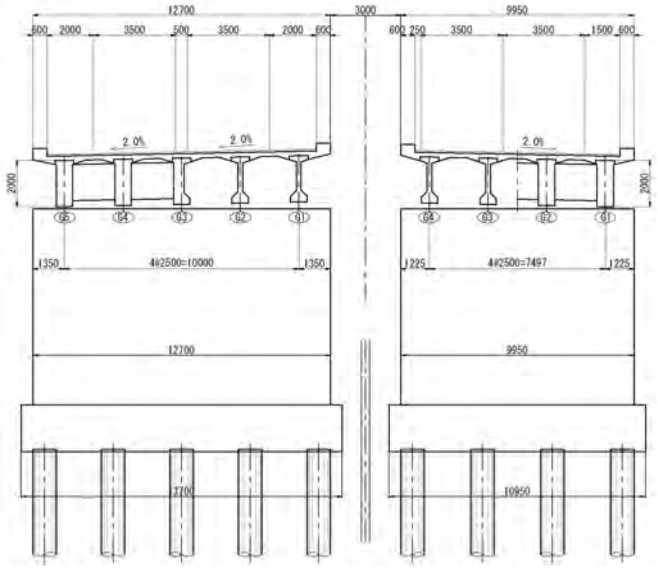
(5) **Sub/Superstructure Staged Construction Consideration**

For Nacala Port Access Road and Nampula Southern Bypass Road the temporary and the complete stage alternatives are being studied. Also regarding transitional/complete construction for the bridges 3 alternatives were also studied regarding the advantage/disadvantages as shown in Table 8.5.14.

- Alternative 1: Sub/Superstructure Complete Construction
- Alternative 2: Superstructure Partial Construction
- Alternative 3: Sub/Superstructure Partial Construction

The comparison conclusion is that the Superstructure Partial Construction is not very suitable because during the construction of the 2^{nd} stage the one remaining lane open for traffic is not adequate. Regarding the other 2 alternatives there are no concerning issues.

Table 8.5.14 Stage Construction Evaluation

	Sub/Superstructure Complete Construction	Superstructure Partial Construction	Sub/Superstructure Partial Construction
Overview			
Structural Stability	The bridge is wide, so there is superstructure stiffness in the transversal direction. Construction joints are necessary in the substructure to control concrete shrinkage cracking. For the river bridges, this alternative has the highest stability against water flow pressure due to the high self-weight and the large base	In the complete stage, the difference between the old section and the new section concrete age might generate problems due to differential shrinkage. Construction joints are necessary in the substructure to control concrete shrinkage cracking. For the river bridges, this alternative has the highest stability against water flow pressure due the high self-weight and the large base	During the completion stage construction it will be necessary to be careful to not damage the existing structure (in particular not loosen the ground around the existing piles foundations)
Constructability	Crane erection depends on the girder weight. Also, the horizontal displacement is large due the substructure width. In case of construction inside river temporary coffering is necessary, but since the full substructure is constructed it is a very efficient alternative.	For crane erection a temporary jetty is necessary in the transitional/ completion stage. Might be necessary to have part of the cross beam over hang the future PC strand connection/extension. For the construction of the central portion, a part of the bridge section that was constructed in the provisional stage is used, so there will be problems with the remaining width that is open to traffic. In the river bridges the temporary coffering is only necessary in the provisional stage for the substructure construction, so it is an efficient alternative.	In the river bridges temporary coffering is necessary in the transitional/completion stage. During the completion stage construction there will be influence from the transitional portion that might interfere in constructions activities. During excavation activities it will be necessary to monitor displacements in the existing structure.
Initial Cost	Due the complete construction of the sub/superstructure the initial cost is the highest between the 3 alternatives, however the mobilization/ completion works cost is the lowest	The superstructure section in the provisional stage is 60~70% of the complete stage, therefore the initial cost is lower than the Alternative 1	The sub/superstructure section in the provisional stage is 60~70% of the complete stage, therefore the initial cost the lowest between the 3 alternatives
Total Cost	The initial and the total cost is the same, however the maintenance cost is a little higher than other alternatives until the complete stage	In the completion stage a temporary jetty for crane erection and other construction activities is necessary. The total cost is higher than Alternative 1	In the completion stage a temporary jetty and temporary coffering are necessary. The total bridge is wider, therefore, the total cost is the highest between the 3 alternatives
Evaluation	The initial cost is the highest from the 3 alternatives; also the maintenance cost is a little higher. However the total cost is the lowest, also during the provisional stage the remaining width can be actively used as a holding area or a side walk	Since for the completion stage construction it is necessary to use part of the provisional stage lanes, it is not possible to guarantee sufficient space for traffic (in case of an accident only one side can be used for vehicle passage). The evaluation is also negative considering the longer construction period. A complete separate superstructure is also possible, but is an uneconomical alternative	Comparing the cross section of the provisional stages this is the most expensive alternative, due to the larger shoulder width (the total bridge width is 2.45m larger than the other alternatives). The total cost is the most expensive; however the maintenance cost is the cheapest. This alternative has no big issues concerning safety aspects
	○	△	○

8.5.3 Preliminary Design for Bridges

(1) Bridge specifications

Considering all the results described in the previous sections, the bridge outline design was carried out. For a general view of the main bridges and details regarding the others refer to the collected DD drawings.

As described in Chapter 7, the details of the provisional stage intersection conditions and the bridge specifications are shown in the tables below:

Table 8.5.15 Bridge specifications for the provisional stage (High-Spec Option)

Nacala Port Access Road

NO	Station No	Bridge type	Superstructure type	Bridge length	Main span length	Foundation type	Remarks
1	0+60	Sea bridge	PC-I girder (semi-continuous)	L=840m	30m	CCP Φ1000	
2	42+00	River bridge	Simple PC-I girder	L=34m	34m	CCP Φ1000	
3	104+0 (R702)	Fry over (road)	PC-I girder (semi-continuous)	L=210m	30m	Spread foundation	

Nampula Southern Bypass Road

NO	Station No	Bridge type	Superstructure type	Bridge length	Main span length	Foundation type	Remarks
4	5+00	Fry over (railway)	Continuous steel -concrete composite slab bridge	L=57m	28.5m	Spread foundation	
5	47+80	River bridge	PC-I girder (semi-continuous)	L=60m	30m	CCP Φ1000	
6	60+40 (R686)	Fry over (road)	Simple steel -concrete composite slab bridge	L=40m	40m	CCP Φ1000	
7	88+00 (N104)	Fry over (road)	Simple PC-I girder	L=30m	30m	CCP Φ1000	
8	126+70	River bridge	PC-I girder (semi-continuous)	L=60m	30m	CCP Φ1000	
9	158+70	River bridge	PC-I girder (semi-continuous)	L=60m	30m	CCP Φ1000	
10	183+30	River bridge	PC-I girder (semi-continuous)	L=90m	30m	CCP Φ1000	
11	221+00 (N1)	Fry over (road)	Continuous steel -concrete composite slab bridge	L=240m	30m	Spread foundation	
12	301+60	Fry over (railway)	Continuous steel -concrete composite slab bridge	L=86m	44m	Spread foundation	

Compensation Bridges

1	30+00	Divided Community	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
2	118+00	Divided Community	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
3	144+00	Divided the current road	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
4	204+00	Divided Community	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
5	234+90	Divided the current road	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
6	263+30	Divided the current road	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
7	278+20	Divided the current road	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	

Cuamba Bypass Road

NO	Station No	Bridge type	Superstructure type	Bridge length	Main span length	Foundation type	Remarks
13	1+70	River bridge	PC-I girder (semi-continuous)	L=240m	40m	直接基礎	
14	20+00	River bridge	PC-I girder (semi-continuous)	L=90m	30m	CCP Φ1000	
15	52+00	River bridge	PC-I girder (semi-continuous)	L=90m	30m	CCP Φ1000	
16	72+20 (N360)	Fry over (road)	Simple steel -concrete composite slab bridge	L=35m	35m	CCP Φ1000	

Note: Flyovers were consider in the major intersections and the bridge sections with 4 lanes, even if the provisional stage road has only 2 lanes.

As explained in section 8.5, to reduce total project cost as much as possible – Basic Option – many of the flyovers were replaced by at grade intersections in the transitional 2 lane stage, reducing the earthwork volume. The bridges removed in this process are shown in the table below:

Table 8.5.16 Bridge specifications for the provisional stage (Basic Option)

Nacala Port Access Road

NO	Station No	Bridge type	Superstructure type	Bridge length	Main span length	Foundation type	Remarks
1	0+60	Sea bridge	PC-I girder (semi-continuous)	L=840m	30m	CCP Φ1000	
2	42+00	River bridge	Simple PC-I girder	L=34m	34m	CCP Φ1000	
~~3~~	~~104+0 (R702)~~	~~Fry over (road)~~	~~PC-I girder (semi-continuous)~~	~~L=210m~~	~~30m~~	~~Spread foundation~~	

Nampula Southern Bypass Road

NO	Station No	Bridge type	Superstructure type	Bridge length	Main span length	Foundation type	Remarks
4	5+00	Fry over (railway)	Continuous steel -concrete composite slab bridge	L=57m	28.5m	Spread foundation	
5	47+80	River bridge	PC-I girder (semi-continuous)	L=60m	30m	CCP Φ1000	
~~6~~	~~60+40 (R686)~~	~~Fry over (road)~~	~~Simple steel -concrete composite slab bridge~~	~~L=40m~~	~~40m~~	~~CCP Φ1000~~	
7	88+00 (N104)	Fry over (road)	Simple PC-I girder	L=30m	30m	CCP Φ1000	
8	126+70	River bridge	PC-I girder (semi-continuous)	L=60m	30m	CCP Φ1000	
9	158+70	River bridge	PC-I girder (semi-continuous)	L=60m	30m	CCP Φ1000	
10	183+30	River bridge	PC-I girder (semi-continuous)	L=90m	30m	CCP Φ1000	
~~11~~	~~221+00 (N1)~~	~~Fry over (road)~~	~~Continuous steel -concrete composite slab bridge~~	~~L=240m~~	~~30m~~	~~Spread foundation~~	
12	301+60	Fry over (railway)	Continuous steel -concrete composite slab bridge	L=86m	44m	Spread foundation	

Compensation Bridges

~~1~~	~~30+00~~	~~Divided Community~~	~~PC-I girder (semi-continuous)~~	~~L=80m~~	~~30m~~	~~CCP Φ1000~~	
2	118+00	Divided Community	PC-I girder (semi-continuous)	L=80m	30m	CCP Φ1000	
~~3~~	~~144+00~~	~~Divided the current road~~	~~PC-I girder (semi-continuous)~~	~~L=80m~~	~~30m~~	~~CCP Φ1000~~	
4	~~204+00~~	~~Divided Community~~	~~PC-I girder (semi-continuous)~~	~~L=80m~~	~~30m~~	~~CCP Φ1000~~	
~~5~~	~~234+90~~	~~Divided the current road~~	~~PC-I girder (semi-continuous)~~	~~L=80m~~	~~30m~~	~~CCP Φ1000~~	
~~6~~	~~263+30~~	~~Divided the current road~~	~~PC-I girder (semi-continuous)~~	~~L=80m~~	~~30m~~	~~CCP Φ1000~~	
~~7~~	~~278+20~~	~~Divided the current road~~	~~PC-I girder (semi-continuous)~~	~~L=80m~~	~~30m~~	~~CCP Φ1000~~	

Cuamba Bypass Road

NO	Station No	Bridge type	Superstructure type	Bridge length	Main span length	Foundation type	Remarks
13	1+70	River bridge	PC-I girder (semi-continuous)	L=240m	40m	直接基礎	
14	20+00	River bridge	PC-I girder (semi-continuous)	L=90m	30m	CCP Φ1000	
15	52+00	River bridge	PC-I girder (semi-continuous)	L=90m	30m	CCP Φ1000	
~~16~~	~~72+20 (N360)~~	~~Fry over (road)~~	~~Simple steel -concrete composite slab bridge~~	~~L=35m~~	~~35m~~	~~CCP Φ1000~~	

Note: Flyover was considered with 2 lanes. In Nampula Southern Bypass Road flyover was considered only in 2 places.

(2) **Interchange study at bypass starting/ending points in the completion stage (alternative)**

Since the traffic volume is expected to grow, an independent intersection at the staring/ending point of each bypass is necessary in the completion stage. In order to achieve an economical project, the embankment height in the bridge approach was reduced as much as possible, limited to 5m height. The considerations for future interchange plans are shown below:

1) Nacala Port Access Road

Interchange with N12

Nacala Port Access Road connects with N12 and the existing ground level in the area has a difference of more than 15 m that can be effectively used in an independent intersection. Currently, there are no major obstacles/restrictions in the region.

The Interchange recommended is the Alternative 2: open cut tunnel (Ramp B) and bridge structure (Ramp C). The analysis is shown below:

Alternative 1

Plan View

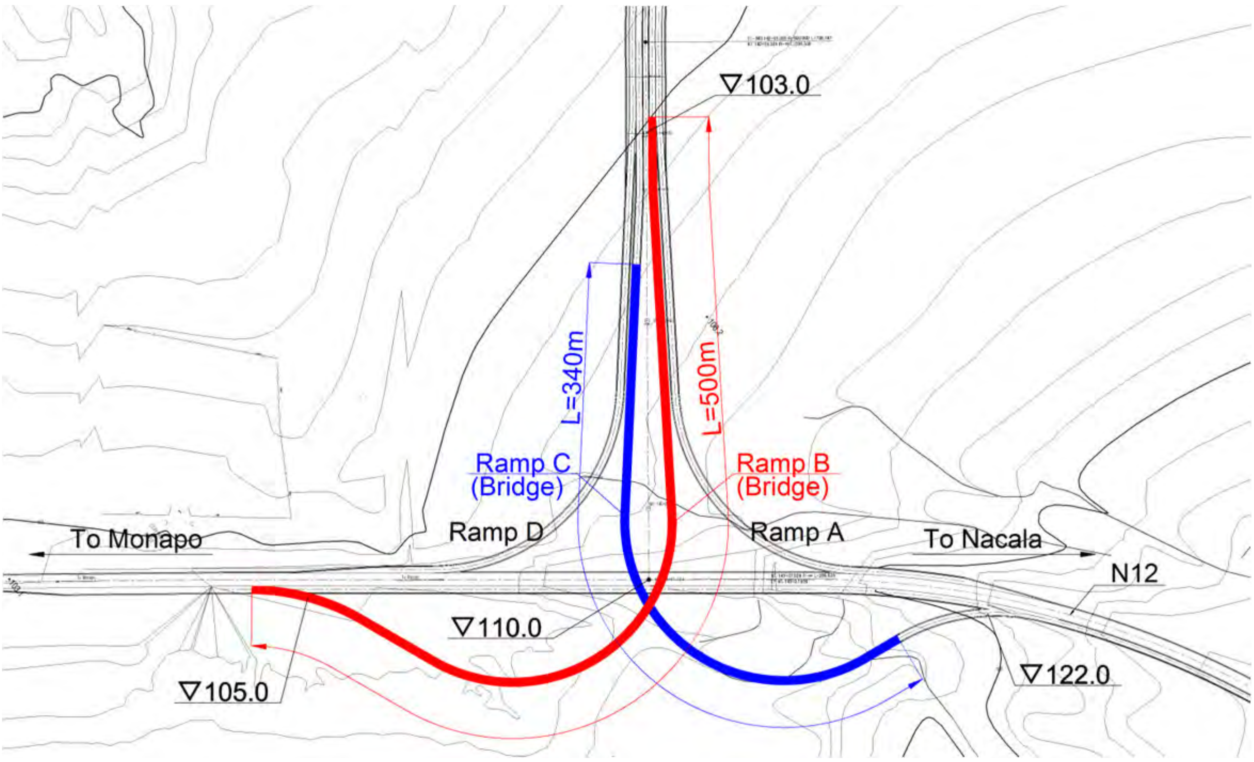
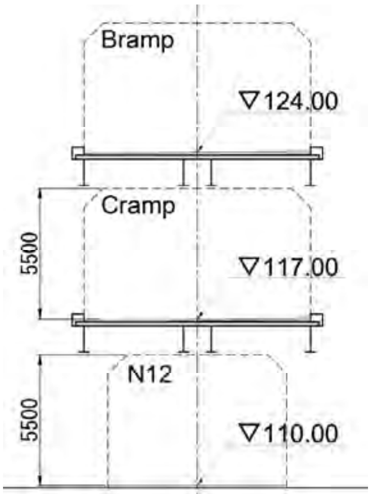


Figure 8.5.9 Nacala Port Access Road Interchange N12 – 1

Cross Section



Ramp B: Bridge Ramp C: Bridge

Ramp B (3F level)

Length = 500m, Maximum longitudinal slope = 9.0%

Since this is the highest layer of the 3-level intersection with 9.0% longitudinal slope, it is possible that the speed of heavy vehicles transporting goods will fall too suddenly.

Ramp C (2F level)

Length = 340m, Maximum longitudinal slope = 6.5%

The second level has a 6.5% longitudinal slope, which is quite steep; however there are no problems regarding traffic speed.

The Ramp B is not recommended because the longitudinal slope is not realistic; also the longer ramp length leads to a higher cost.

Alternative 2

Plan View

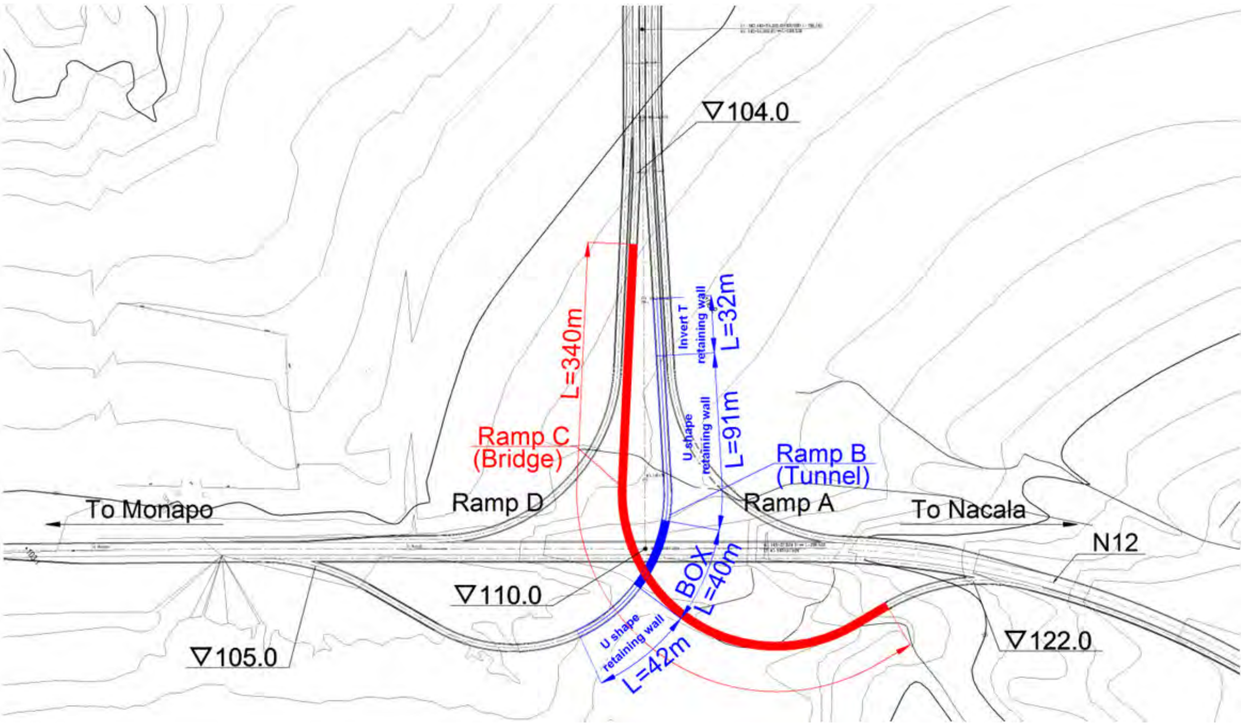
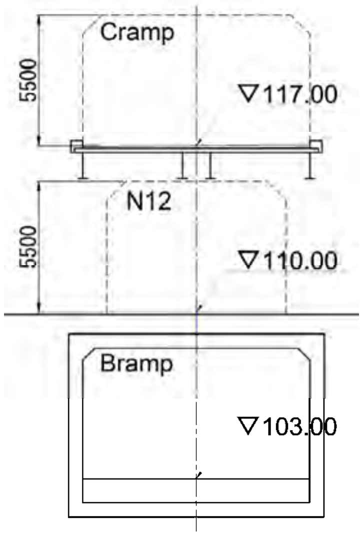


Figure 8.5.10 Nacala Port Access Road Interchange N12 – 1

Cross Section



Ramp B: Open cut tunnel   Ramp C: Bridge

Ramp B (-1F level)

Box length = 40m, U shape retaining wall = 133m, Invert T retaining wall = 32m, Maximum longitudinal slope = 1.0%

Considering the N12 level, an underground crossing is the more appropriate since the longitudinal slope is not steep.

Ramp C (2F level)

Length = 340m, Maximum longitudinal slope = 6.5%

The second level has a 6.5% longitudinal slope which is quite steep; however there are no problems regarding traffic speed.

This alternative has adequate ramp longitudinal slopes; an underground structure is cheaper than a bridge ramp. During the construction period a detour in N12 is necessary.

2) Nampula Southern Bypass Road

Interchange with N1 (east side)

The interchange with N1 in the east side is expected to generate resettlement, since the area is currently occupied. Ramp A and Ramp C were planned as composite steel concrete slab bridges as shown below:

Plan View

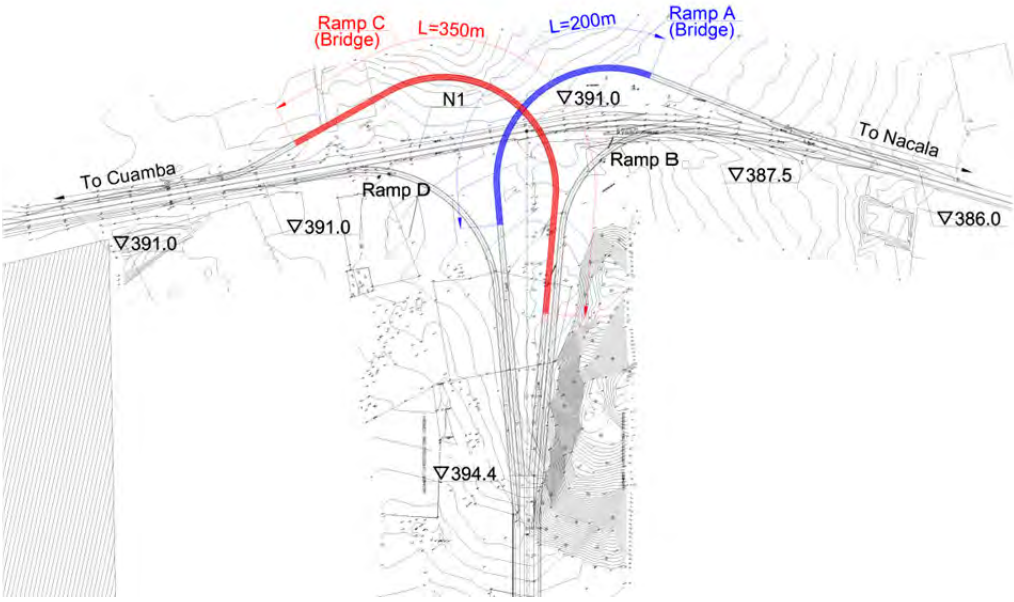
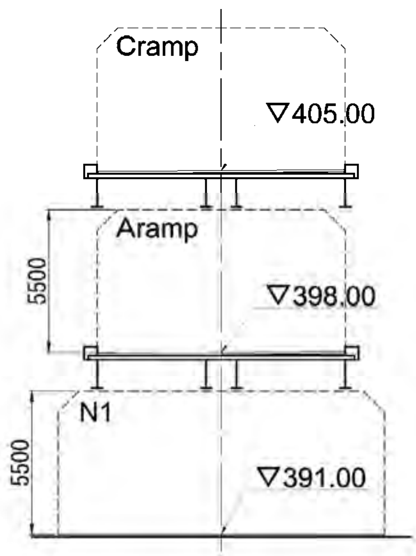


Figure 8.5.11 Interchange N1 (east side)

Cross Section



Ramp A: Bridge Ramp C: Bridge

<u>Ramp A (2F level)</u>

Length = 200m, Maximum longitudinal slope = 4.0%

The difference between the main alignment and N1 height is only 4m, so the ramp was planned with 200m length and 4.0% longitudinal slope.

<u>Ramp C (3F level)</u>

Length = 350m, Maximum longitudinal slope = 6.0%

Since is the highest layer of the 3-levels intersection, the ramp has 6.0% longitudinal slope.

Ideally a non-stop intersection is better; however considering that the main traffic will use the Ramp A, it can be cost efficient to build only the Ramp A Bridge. Or consider the Ramp A bridge with an at grade Ramp C in the first stage and when the traffic volume increases, build the Ramp C. It is necessary to define a policy to balance the project cost, resettlements and benefits.

Interchange with N13

An independent interchange was planned at the end point with N13. Currently, to build the ramps it will be necessary to resettle a few houses. Ramp A and Ramp C were planned as composite steel concrete slab bridges with 190~220m length. In the future it is also necessary to consider a rail overpass in the southern part of Ramp A. The planned intersection is shown below:

Plan View

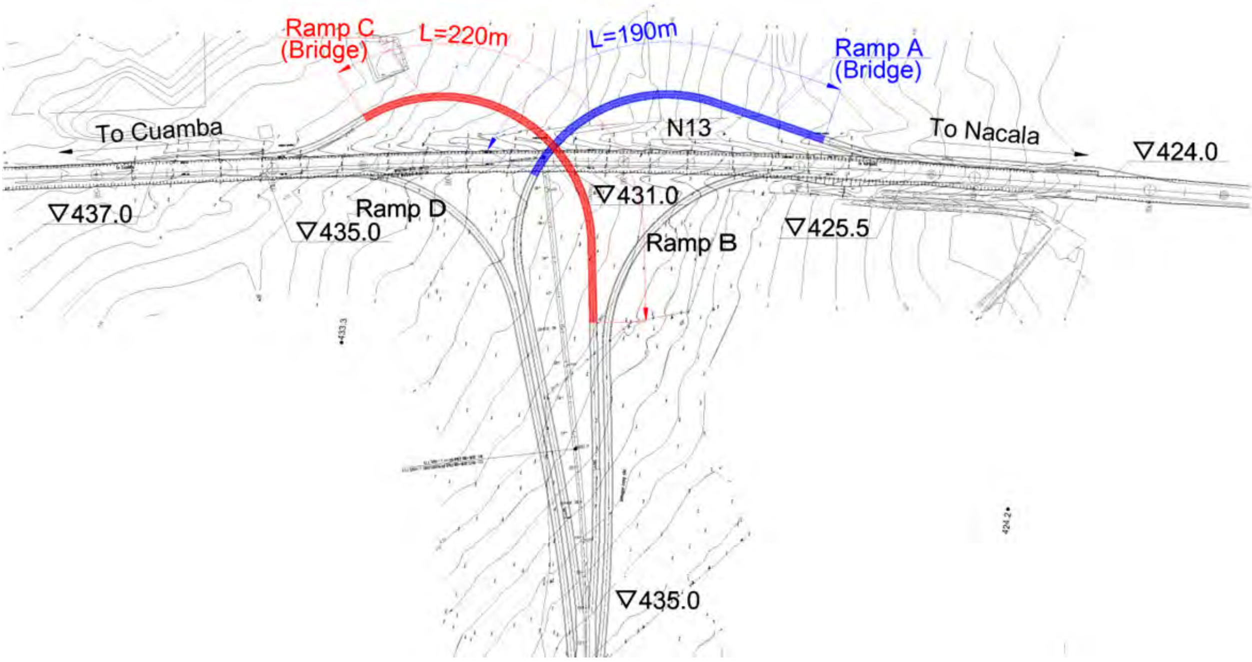
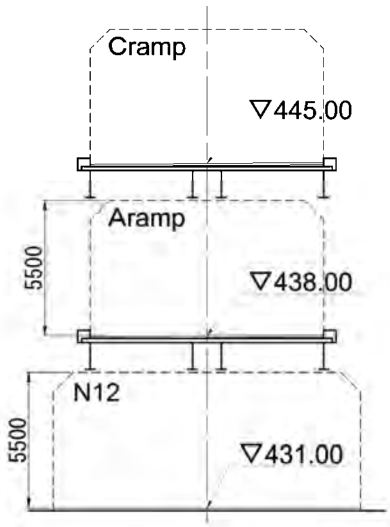


Figure 8.5.12 Interchange N13

Cross Section



Ramp A: Bridge   Ramp C: Bridge

Ramp A (2F level)

Length = 190m, Maximum longitudinal slope = 6.0%

The difference of levels between the ramp end (▽435.0m) and the N13 crossing point (▽438.0m) is only 3m so 4.0% longitudinal slope is enough. From the intersection until N13 level (▽424.0m) the difference is higher so a 6.0% ramp is necessary.

Ramp C (3F level)

Length = 220m, Maximum longitudinal slope = 6.0%

Since this is the highest layer of the 3-levels intersection, the ramp has 6.0% longitudinal slope.

Is possible to consider first building the Ramp C in the 2F level and in the future, when the traffic volume increases, build the Ramp A.

3) Cuamba Bypass Road

<u>Interchange with N13 (east side)</u>

An independent interchange was planned at the starting point with N13. The region is constrained by Muanda River and on the opposite side a hill region. Is difficult to design a longitudinal alignment that does not interfere with the river section. The planned intersection is shown below:

Plan View

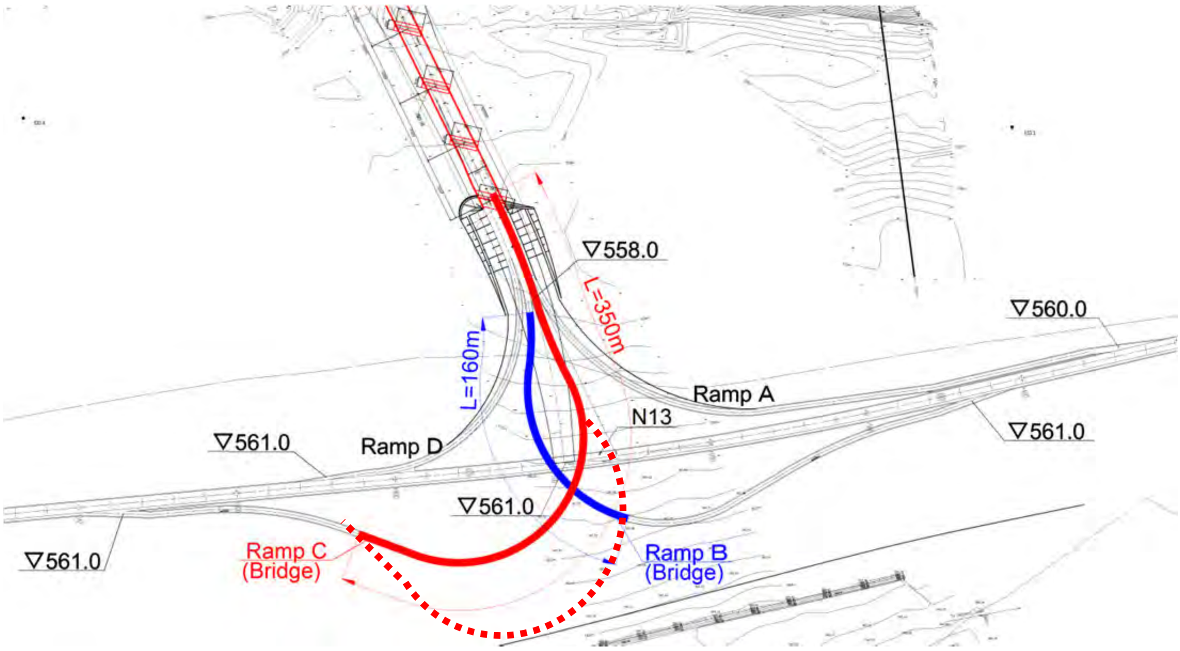
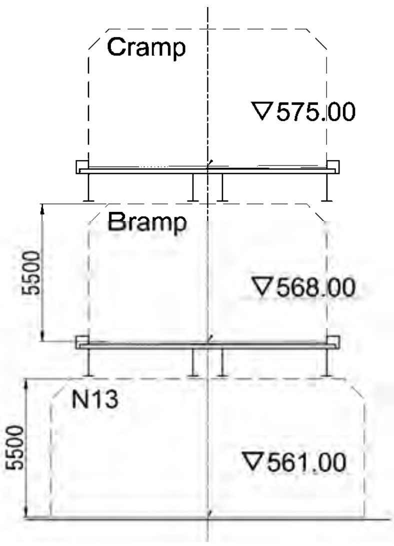


Figure 8.5.13 Interchange N13 (east side)

Cross Section



Ramp B: Bridge   Ramp C: Bridge

<u>Ramp B (2F level)</u>

Length = 160m, Maximum longitudinal slope = 6.0%

<u>Ramp B (3F level)</u>

Length = 350m, Maximum longitudinal slope = 6.0%

If a ramp with 6.0% longitudinal slope is set from the highest point of Ramp C the extremity will only reach the middle of the river. To avoid this situation, it is possible to plan the ramp in the hill area (dotted red line), however this would require a large amount of land and to clear the landscape. However, the recommendation is to only build the Ramp B bridge that will be used by the main traffic and for the Ramp C consider an at grade semaphore intersection.

Interchange with N13 (west side)

An independent interchange was planned at the end point with N13. The region has neither topographic restraints nor other majors obstacles. The planned intersection is shown below:

Plan View

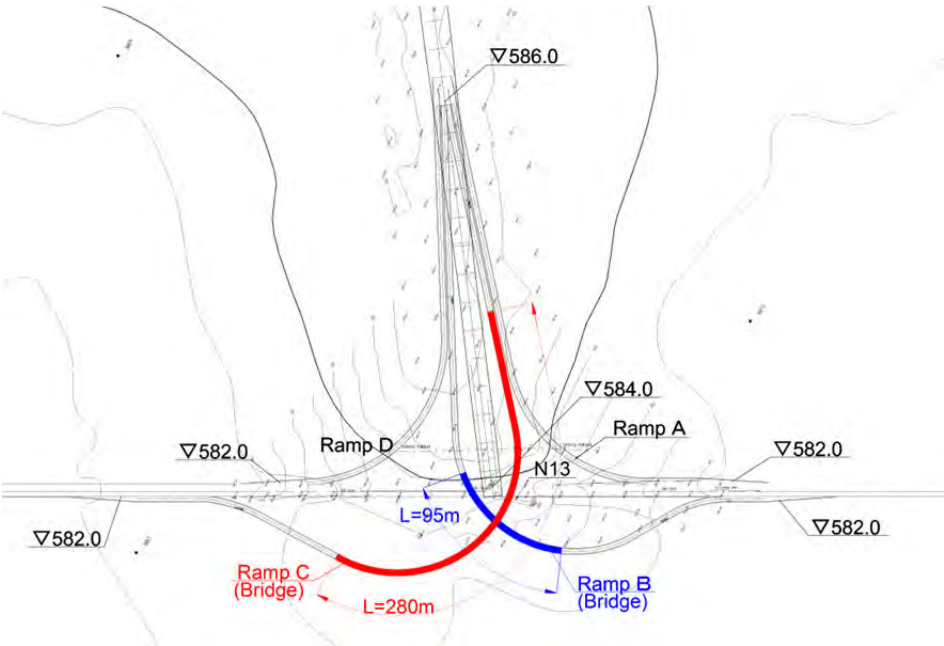
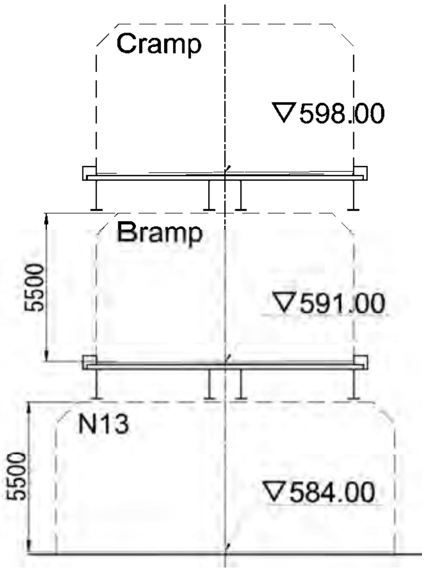


Figure 8.5.14 Interchange N13 (west side)

Cross Section



Ramp B: Bridge Ramp C: Bridge

Ramp B (2F level)

Length = 95m, Maximum longitudinal slope = 6.0%

The difference of levels between the ramp starting point (▽586.0m) and the N13 crossing point (▽591.0m) is only 5m so 4.0% longitudinal slope is enough. From the intersection until N13 level (▽582.0m) the difference is higher so a 6.0% ramp is necessary to make the ramp shorter.

Ramp C (3F level)

Length = 280m, Maximum longitudinal slope = 6.0%

Since this is the highest layer of the 3-level intersection, the ramp has a 6.0% longitudinal slope.

The main ramp geometry is not a problem considering structural and construction aspects.

(3) **Cassiano Bridge plan (reference)**

Located in the proximity of the planned bypass, Cassiano Bridge was washed out during Jan/2015 heavy rains. As a reference a restoration plan was elaborated, Cassiano Bridge is basically a pedestrian bridge, however the design considers the passage of 2 wheel vehicles and emergency vehicles, as well as the ability to resist a 100 year return period flood as shown below:

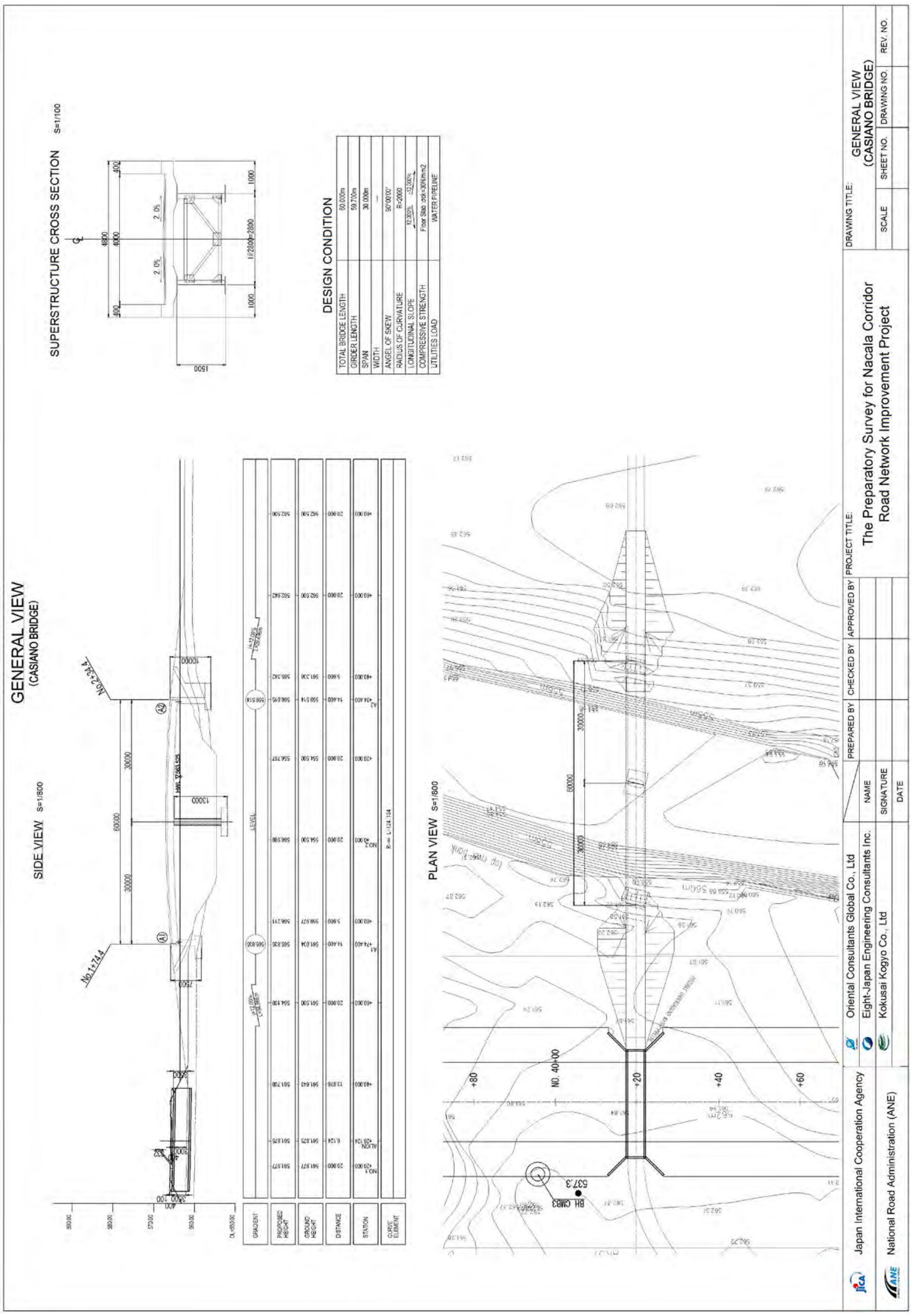


Figure 8.5.15 Cuamba Bypass Road – Cassiano Bridge

8.6 Traffic Safety and Ancillary Facilities

8.6.1 Required Road Facilities

(1) Approach

It is now a requirement around the World for all roads to provide appropriate traffic safety facilities in view of the increase in traffic deaths. The Mozambique government, "especially ANE", is also challenged to decrease traffic accidents by both enhancement of safety facilities and traffic safety education.

According to the concept of the target roads, these will have the bypass road function for heavy goods vehicles and through traffic with high speed service, whilst Non-Motorised Transport (NMT) infrastructure for vulnerable road users should be considered because these roads are located in peri-urban areas consisting of some small villages. Therefore the Survey Team will propose solutions involving systematic and effectual traffic safety facilities. Each facility proposed in the process of examination will be designed in the preliminary design.

(2) Considerable Facilities

So far, the following fundamental road safety facilities will be considered for road users.

- Traffic Safety Signs, Information Signs and Standard Worded Signs
- Road Marking and Road Studs
- Guardrails
- Road Lighting
- Space for Utilities
- Bus Bays (if required)

In addition to these, the following facilities will be examined for user convenience, road protection, land development and local economic activities in the near future.

- Footbridges
- Weighbridges
- Roadside Stations (Michinoeki) and/or Truck Terminals
- Intelligent Transport System (ITS)

8.6.2 Design Concept for each Facility

(1) Traffic Signs and Road Marking

The need for, and layout of, traffic signs and road markings is an integral part of the design process. Advance direction and warning signs will be provided, and care is taken with the positioning and size of signs, so that they do not interfere with the drivers' visibility requirements. Advance signing on minor roads is given particularly careful consideration. The policy and detailed guidance on these aspects will be derived from the SATCC Road Traffic Signs Manual, and reference is always made to the Manual for comprehensive advice.

Clear and efficient signing is an essential part of highway and traffic engineering. The Signing includes not only signs on posts but also carriageway markings, bollards and other devices.

The Signs have been placed with a view to controlling and guiding traffic and to promote road safety. They have been used where they can usefully serve these functions and the Survey Team will be aware that there is movement towards regional harmonisation in respect of road signage and markings, and traffic signalisation.

Furthermore, in order to perform the function for which they are intended, the signs must be capable of transmitting their message clearly and at the right time to road users travelling at the design speed for the road. This has been the justification for having the correct legibility distance, appropriate target value, simplicity of content and layout and the effective illumination or reflectorisation where necessary.

(2) **Road Studs**

The function of road studs is similar to road marking. They are fixed on the road surface to mark the centre line, lane line, etc., and mark the line brightly, and now they are widely accepted as essential for controlling traffic flow with a clear message to the driver.

Lanes on roads are traditionally marked in a passive way with reflecting road-studs and high visibility paint, often coupled with other reflectors on short posts at the sides of the highway. However, in night time, car drivers could not see where the road ends and where the alignment of the road changes in direction. Without a sufficient number of road lights, it is necessary to provide some means to guide the drivers along dark roads. Recently some new “powered road-studs” (active road studs) have appeared as options for roadway designs. These make it possible to identify road conditions and alignment in darkness.

The target roads will mostly lie in unlit areas. So, utilisation of the following self-emitting/solar LED road stud will be examined.

Figure 8.6.1 Self-emitting Road Stud (Example)

(3) **Guardrails**

The purpose of placing guardrails is to reduce the severity of potential accidents caused by an errant vehicle leaving the roadway. The roadway may be abutted by embankments or side slopes, or it may be lined with trees, bridge piers, retaining walls, or utility poles. Sometimes it is not feasible to remove those things. In those cases, guardrails should be installed. They can make roads safer and lessen the severity of crashes.

This is not to say that guardrails can completely protect against the countless situations drivers may find themselves in. The size and speed of the vehicle can affect guardrail performance. So can the vehicle's orientation when it strikes the guardrail. There are many other factors.

The use of highway guardrails is recommended at high embankment sections, approach sections to a bridge and at intersections. Pedestrian guardrails are used to prevent pedestrians from walking into the road and are generally situated at potentially hazardous locations, such as Pedestrian Crossings, Schools, Village areas etc. In general, pedestrian guardrails shall be used to assist, rather than to impede, pedestrians by channelling them to the point at which they may cross a road at specifically designated locations, and therefore with the greatest safety. Conversely, such guardrails should also be considered for locations where, for safety reasons and for the avoidance of adverse effects on traffic flows, pedestrians must be prevented from crossing the road indiscriminately.

(4) **Road Lighting**

An aspect of planning any lighting scheme is the positive contribution it can make to the improvement of the night-time environment. Efficient lighting for traffic and pedestrian safety is essential; consideration of the whole visual scene at night is highly desirable for many reasons. In lighting main roads, service roads, and pedestrian ways, however, environmental requirements should always be given consideration and there should be an evaluation of the assistance that lighting can offer to crime prevention.

(5) **Space for Utilities**

After opening to traffic, urban and commercial areas will be developed along the road. In that case, demand for life lines such as electric and communication facilities will increase rapidly. Given this expectation, utilities space along the road will be considered within the ROW.

8.6.3 Proposed Road Facilities

(1) Traffic Signs, Road Marking and Road Studs

As a result of the study, we propose the traffic signs and road markings shown below.

Table 8.6.1 Proposed Traffic Signs, Road Marking and Road Studs

Road Ancillary Facilities	Proposal
Traffic Safety Signs	The traffic safety signs proposed include warning signs, mandatory signs and any other signs.
Information Signs	The information signs proposed include the name of the city and name of a river,
Level Crossing sign	Locations of level crossing signs are proposed to advise of the at grade crossing in Cuamba road.
Road Marking	The road making proposed yellow line for shoulder (solid line) and white line for road centre (dashed line).
Road studs	Location of self-emitting road studs is proposed for the intersections and cross to the bridge. For other locations the standard type (cat's eye) is proposed.

Additionally, studies were made on the use of the Road Separation Signs on the road centre for the temporary two lanes on the Cuamba road, Nacala and Nampula roads.

However, this would make it difficult for the passage of large trailers if a trailer stops (or parks) on the shoulder. As a safety measure, road markings and road studs could be used instead of the separation sign.

Figure 8.6.2 Japan's separation sign (Not apply to temporary two lanes)

(2) Guardrails

Locations of the proposed guardrails include the intersections, cross to the bridge and places where the embankment height is 2m or more. In addition, in the low embankment sections of the full spec type it is proposed to provide pedestrian access prevention fences in the central separator zone.

(3) **Road Lighting**

Road lighting is proposed for the intersections, and the bridge and two-level crossovers. Type of lighting unit is the LED lighting of the low power consumption type.

(4) **Space for Utilities**

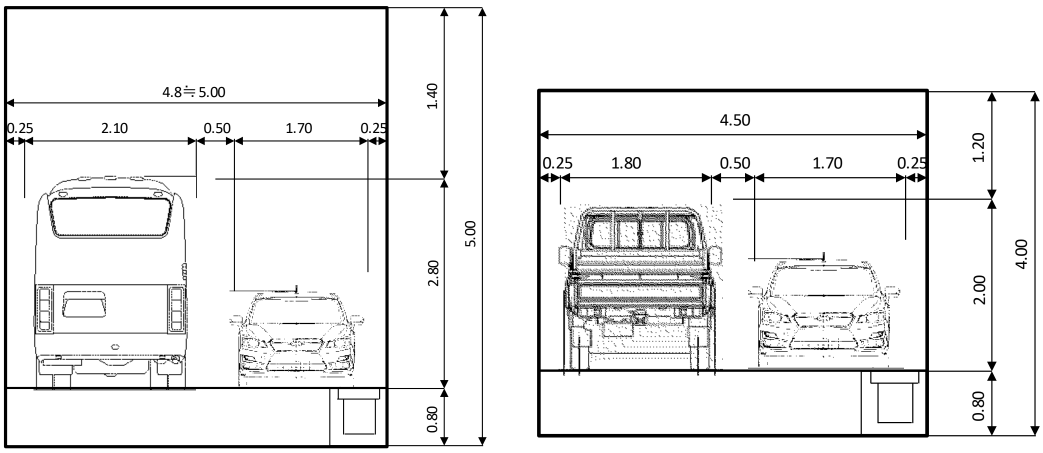
In all the roads of the whole line, it is proposed to provide a conduit for electrical and communication cable in a facility zone.

(5) **Box Culverts**

Box culverts proposed three types of box culvert by the utilization situationy of existing road as function compensation due to the fact that the existing road separated.

Table 8.6.2 Proposed Box Culverts

Box Culverts	width (m)	Height (m)	Target
Primary Box Culvert	5.0	5.0	It would make it possible for a large car and the small car to pass each other.
Secondary Box Culvert	4.5	4.0	It would make it possible for two small cars to pass each other.
Minor Box Culvert	3.0	3.0	It is mainly for pedestrians and emergency vehicles



Primary Box Culvert **Secondary Box Culvert**

Figure 8.6.3 Measurements of Box Culverts

Proposed road ancillary facilities are as follows.

Table 8.6.3 Proposed Road Ancillary Facilities

Road Ancillary Facilities	Nacala	Nampula	Cuamba
Box Culverts (On vehicle)	○	○	○
Box Culverts (On Pedestrian)	—	—	○
River Capture	—	○	—
Consolidation of Foundation	○	—	○
Mat Gabions	○	○	○
Concrete Kerbs	○	○	○
Guardrails	○	○	○
Pedestrian Access Prevention Fence	○	○	○
Road Marking	○	○	○
Traffic Safety Signs	○	○	○
Level Crossing signs	—	—	○
Information Signs	○	○	○
KM Posts	○	○	○
Road Studs	○	○	○
Road Lighting	○	○	○
Traffic Signs	○	○	○
Space for Utilities	○	○	○

8.6.4 Future Planned Road Facilities

Considering the non-target road facilities in this project which Chapter 7 suggested for construction, this section shows the outline of each of the facilities and the basic idea of their construction.

(1) Footbridges

The main purpose of footbridges on the main road will be to facilitate and encourage walking and cycling whilst ensuring safety for all road users. The type of crossing provided will therefore be such as to encourage people to use it, taking into account the likely pedestrian flows and movements, and to encourage people to regard walking or cycling as an acceptable mode of transport in line with the NMT consideration.

(2) Weighbridges

Overloading heavy vehicles is causing serious damage to the road structures (pavement and bridges), and also becomes a traffic hazard, especially failure of breaking system mechanisms, bursting of tires, instability due to shifting of centre of gravity etc. Every vehicle which passes over a road causes a momentary, very small, but significant deformation of the road pavement structure. The passage of many vehicles has a cumulative effect which gradually leads to pavement deformation and road surface deterioration by cracking. Therefore the effect of overloading could not be felt in one day but will be felt over a period years of the pavement performance.

Based on this common cognition, ANE is operating 15 weighbridges as of the end of 2014. The table below shows the location of each weighbridge.

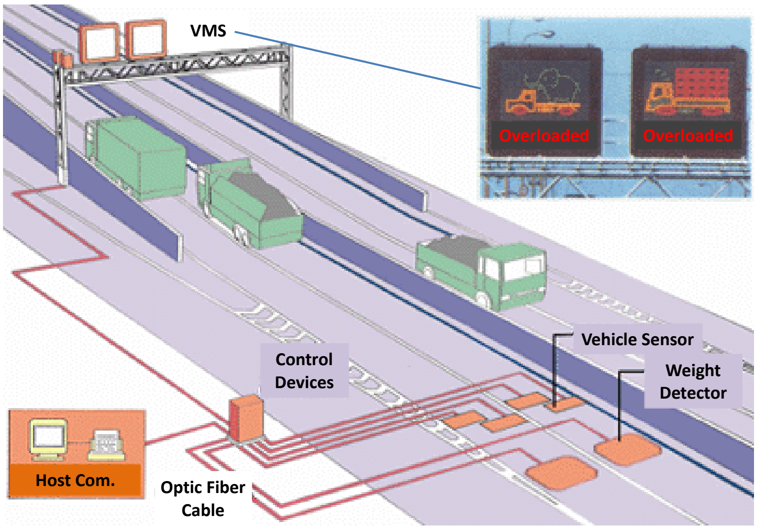
Table 8.6.4 Current Locations of the Weighbridges in 2014

Weighbridge Name	Location / Road	Province
Matola Rio	N2	Maputo
Texlom	N4	Maputo
Michafutene / Zimpeto	N1	Maputo
Macia	N1	Gaza
Inharrime	N1	Inhambane
Save	N1	Inhambane
Dondo	N6	Sofala
Inchope	N1	Sofala
Vanduzi	N7	Manica
Matundo	N7	Tete
Mussacama	N7	Tete
Maue	N304	Tete
Nicoadala	N1	Zambezia
Nacala	N12	Nampula
Sunate	N1	Cabo Delgado
Pemba	N1	Cabo Delgado

The target roads are designed to be bypasses, therefore, many heavy vehicles will use these roads. Hence, installation of weighbridges for overload control should be examined in consideration of ANE's weighbridge plan and trunk road network.

Chapter 7 has shown the position of the vehicle weighing stations that are candidates for exact locations. Facility maintenance has not reviewed specific installation positions and installation content because facility development is not a subject of this project.

In this occasion, a conventional weighbridge system and advanced technology such as "Weigh-in motion" will be examined from the view point of maintenance capacity, staff performance, road function and ANE's plan. Weigh-in-motion devices are designed to capture and record axle weights and gross vehicle weights as vehicles drive over a measurement site.



Source: Ministry of Land, Infrastructure, Transport and Truism (MILT), Japan

Figure 8.6.4 Image of Weigh-in-Motion System

(3) Roadside Station (Michinoeki) and Logistics Facilities

After opening to traffic, it is highly expected that the target area could enhance development potential and attract investments in various economic sectors, including logistics, commercial and manufacturing sectors. Given this expectation, promotion facilities for economic development should be considered. Of the possible promotion facilities, Michinoeki and logistics facilities have positive impacts on local economies, job creation, and provision of public services for the local community and regional integration is evident throughout the country.

"Michinoeki" can be defined as a multi-functional road side facility for both drivers and rural communities. Whereas, for the drivers, it offers rest and refreshment spaces, for rural communities it provides income generation opportunities by offering an open market space, which would encourage the rural economy as well as social activities though the participation of rural people in not only the planning but also the operating of Michinoeki.

In regard to logistics facilities, in order to establish an effective and efficient transportation and logistics system for a wide region, one of the important issues is to develop logistics facilities and services for connecting different transport modes, such as warehouses and multi-modal terminals.

Therefor multi-modal terminals will be examined for integration of different transport systems at Nacala, Nampula, and Cuamba.

Michinoeki

Possible Functions

・Rest area for truck drivers (Rest area, restaurants)

・Maintenance and repair for trucks (with fuel station)

・Community market (with delivered goods, farmers' market)

Logistics Facility

Possible Functions

・Parking for container and general cargo trucks from Nacala port and various other places

・Break Bulk and transfer to smaller distribution trucks

・Temporary storage of cargo and containers in [rental] warehouse (general/cool/refrigerated warehouse)

・Consolidation of LCL (Less-than-Container Load) cargo

・Stuffing and stripping (unstuffing) of containers

Figure 8.6.5 Image and Functions for Michinoeki and Logistics Facilities

Note that the Guideline for "MICHINOEKI" in Mozambique was prepared during the feasibility study of Nampula - Cuamba road upgrading in 2007, which was a summary of the pilot project at Ancilo Michinoeki and of the technical information regarding planning, designing and operation/management.

(4) Intelligent Transport System (ITS)

An Intelligent Transport System (hereinafter, ITS) is a system that aims to enhance the road transportation by solving various issues related to road transportation with the application of telecommunications technology. In the Survey, the need for or benefit of ITS introduction on the target roads in the near future will be examined. ITS will provide road information such as "Road Closed" to the driver and help the driver in determining a plan of action.

When broadly classified, ITS consists of "Collection", "Processing" and "Provision". It is carried out mostly from the control centre in cases where a great deal of "Processing" has to be done. The main ITS equipment corresponding to "Collection" and "Provision" that are installed on road-side are shown below.

Table 8.6.5 Typical ITS Facilities

Name	Description	Image
VMS (Variable Message Signboards) [Purpose] Displaying road and traffic information	(Graphic Type) Information is provided by simple graphic image	
	(Message Type) Information is provided by message	
ATCC (Automatic Traffic Counting and Classification) [Purpose] Measuring traffic volume, vehicle speed, occupancy	(Ultrasonic Type) Vehicles are monitored by reflected ultrasonic waves	
	(Camera Type) Vehicles are monitored by image processing	
CCTV (Closed Circuit Television) [Purpose] Monitoring road and traffic conditions	(High-end Type) It is generally used for monitoring outdoors environment with high resolution, by either fixed or rotating cameras	
	(Low-end Type) It is generally used for security purposes, usually with all-round view. It is cheaper than the above.	

8.7 Construction Planning

8.7.1 Construction Outline

The construction outline is described in the table below:

Table 8.7.1 Construction Outline

Project	Construction	
Nacala Port Access Road	Road earthworks	Road length: L=15,203m Road (asphalted) width: W=11.50m (Main road: asphalt pavement Service road: DBST pavement)
	Sea Bridge	28 spans, Continuous PC-I girder L=840m
	River bridge	Simple PC-I girder L=34m
	Overpass bridge	High-Spec Option: 7 spans, continuous PC-I bridge L=210m Basic Option: at-grade intersection
Nampula Southern Bypass Road	Road earthworks	Road length: L=30,590m Road (asphalted) width: W=11.50m (Main road: PBST pavement Service road: DBST pavement)
	Railway overpass bridge	Composite steel concrete slab L=57m L=86m
	Overpass bridge	High-Spec Option: simple PC-I girder L=40m (R686), 240m (N1)[2], 30m (N104) Basic Option: at-grade intersection
	River bridge	Continuous PC-I girder L=60m L=60m L=60m L=90m
	Compensation bridge	High-Spec Option: Simple PC-I girder L=30m L=80m×6=480m Basic Option: Simple PC-I girder L=30m
Cuamba Bypass Road	Road earthworks	Road length: L=12,050m Road (asphalted) width: W=11.50m (Main road: DBST pavement Service road: DBST pavement)
	Bridges	High-Spec Option: Continuous PC-I girder L=240m L=90m L=90m Composite steel concrete slab L=35m Basic Option: Continuous PC-I girder L=240m L=90m L=90m

Source: JICA Study Team

8.7.2 Construction Method

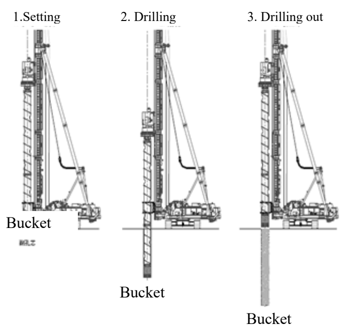
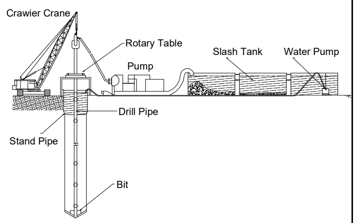
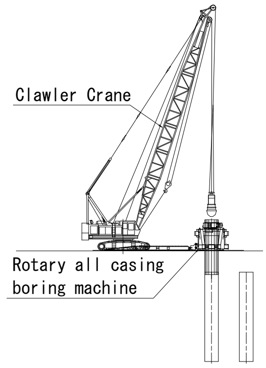
For this project, general methods shall be used for earthworks and pavement construction. Other sections that require special construction methods are briefly described below:

[2] The detailed information of design is provided at Appendix-8

(1) **Bridge foundation: cast in situ pile**

The comparison of general pile construction methods is shown in the table below. A reverse method for pile construction is recommended for the construction of the bridges, because it is expected that the ground-water level is high around the riversides.

Table 8.7.2 Cast in situ pile construction methods

Method	Earth Drill Method	Reverse Method	All casing Method (All casing boring machine)
Concept			
Pile diameter	0.8m～3.0m	0.8m～3.0m	0.8m～3.0m
Standard length	30m～60m	30m～60m	20m～40m
Underground water level	Difficult	No problem	No problem
Hard layer soil	Difficult in hard soils	Not possible	Possible in almost any type of soil
Cost	Low	Standard	High
Construction	Fast	Slow	Standard
Evaluation	Not recommended	Recommended	Not recommended

Source: JICA Study Team

Regarding Nacala Port Access Road sea bridge, it is supposed to be constructed by using a temporary jetty and sheet pile cofferdam, considering that the sea depth is only ~4.0m at high tide. If impermeable materials around the joint are used to reduce the sea-water inflow to the cofferdam, it can be expected to reduce the negative environmental impacts caused by the construction in Nacala Bay, minimizing water contamination and reducing the amount of excavated soil and in the bay.

(2) **Bridge superstructure**

Most of the bridges of this project have less than around 30m spans, and there are no restrictions around the PC girder fabrication sites, so the PC girder crane erection whose procurement of materials is considered easy is considered as an economical solution.

However, for the Muranda Bridge with 6 spans of 40m located in Cuamba Bypass Road the construction using cranes is considered difficult due to the river width and water flow volume, so in this case the Erection Beam Method is more appropriate.

(3) Sea bridge

For the construction of the sea bridge for Nacala Port Access Road a temporary bridge – as described previously – that can be constructed during the low tide, when the water depth is near 0m is necessary. Therefore, the use of barges is not considered necessary. The construction steps are shown below:

1) Construction of temporary bridge (during low tide)
2) Construction of cofferdam (use impermeable materials)
3) Excavation (use pump to remove water)
4) Foundation and substructure
5) Superstructure
6) Remove cofferdam
7) Remove temporary bridge

(4) Road construction

Expected construction road

For this project, because the roads to be constructed are all new, the access ways to the constructions zones will be from the intersections with the existing roads as shown below:

- Nacala Port Access Road: 3 Places (the start point, R702, and the end point)
- Nampula Southern Bypass Road: 4 Places (the start point, R686, N104, N1, and the end point)
- Cuamba Bypass Road: 3 Places (the start point, N360, and the end point)

Earthworks construction steps

For this project, there is also a service road starting in one of the intersections with the existing roads to provide access during the construction of the main alignment earthworks portion. As the construction advances – from both the main and service road – will be possible to use the service road as a construction road, therefore, no other detour or construction road is required. Also it is possible to work on multiple sides to reduce the construction period.

As the project policy of the preliminary design, it was considered necessary to import the following amounts of earth fill, however, these turned out to be inadequate, even though cut and fill were balanced as closely as possible.

- Nacala Port Access Road: 21,700m^3 (High-Spec Option) 110,000m^3 (Basic Option)
- Nampula Southern Bypass Road: 86,000m^3 (High-Spec Option) 0 m^3 (Basic Option)
- Cuamba Bypass Road: 312,000m^3 (High-Spec Option) 64,000m^3 (Basic Option)

Railway overpass bridge

For the bridges crossing the railway a composite steel concrete slab bridge was proposed to reduce the girder weight allowing the crane construction method, and also this type of bridge doesn't require formworks, scaffolding or falsework allowing the operation of the railway as much as possible even during the construction period. During the substructure construction works close to the rails, it will be necessary to closely monitor any rail movement, either horizontal or vertical and etc. This will guaranty more safety of the railway operation.

Road overpass bridge

For the road overpass bridges, if the existing roads are decided to be raised, it will be possible to use the service roads of the main bridges as temporary detours.

(5) Construction yard, temporary site and future diversion space

Because a construction yard is necessary for the construction (standard size: 10,000~30,000m^2), the Study Team recommends that ANE create one or more, as necessary, within the ROW or other lands along the roads that belong to Mozambique and provide them for the contractor's use.

It is considered advantageous to use the temporary yards in the future as "Vehicle overload detection stations" or "Road Side Stations (Michinoeki)" as proposed in Chapter 7.

8.7.3 Construction Schedule Plan

Mozambique weather can be defined as: rainy season (from Oct. to Mar.) and dry season (from Apr. to Sep.). There are sections inside wetlands or river areas that should be constructed during the dry season. However, the critical path is believed to include the bridge superstructures that can be built even during the rainy season. For shortening the construction period, it is supposed that earthworks and substructure works can be done in the first and last month of the rainy season, therefore it is supposed that the construction during Nov. to Feb. is not possible due to rain.

Because the construction of more than one bridge at the same time is considered to be technically possible because the 3 road projects are mainly composed of the road construction, the necessary construction period of time was estimated by assuming the following construction teams:

- Nacala Port Access Road: 4 years (48 months) Road: 2 teams Bridge: 3 teams
- Nampula Southern Bypass Road: 5 years (60 months) Road: 2 teams Bridge: 2 teams
- Cuamba Bypass Road: 3 years (36 months) Road: 1 teams Bridge: 1 teams

Furthermore, depending on the lot division of each bypass, the extra teams are expected to reduce the construction time necessary for the project completion.

8.7.4 Procurement Plan

(1) Main materials procurement plan

The origin of the main materials used in the construction of the main road and the bridges are shown in Table 8.7.3. Cement, aggregate, sand, etc. can be found in Mozambique; steel, PC strands, etc. should be imported from Japan or other country.

Table 8.7.3 Main materials procurement plan

Material	Supplier Origin		Remarks
	Mozambique	Japan or other country	
Earthworks			
Earth	○		
Crushed stone	○		
Concrete			
Cement	○		
Coarse aggregate	○		
Fine aggregate	○		
Sand	○		
Fresh concrete	○		
Rebar		○	Including anti rust materials
Steel materials			
Steel plate		○	For steel girder
H shapes		○	For temporary bridge, steel girder
Steel pipe		○	For pile foundation
Bolts, nuts, etc.		○	
Welding materials		○	
Coating material		○	
Temporary materials			
Steel sheet		○	Marine cofferdam
Lining plate		○	Marine temporary bridge
H shapes		○	Marine temporary bridge pile
Bent		○	
Bridge materials			
Bearing pad		○	
Expansion joint		○	
Parapet		○	Stainless
Waterproof layer		○	
PC Strands		○	Including anti-rust materials
Road materials			
Illumination		○	
Guardrail		○	
Semaphore		○	
Drainage materials		○	
Combustible	○		
Asphalt	○		

Source: JICA Study Team

(2) **Main equipment's procurement plan**

General construction equipment can be found in Mozambique, but it is necessary to import much of the equipment, such as pile drivers, for the main bridge construction from other countries. Depending on the quantity required, it might also be necessary to import dump trucks. The procurement plan for the main equipment is shown in Table 8.7.4 below:

Table 8.7.4 Main equipment procurement plan

Equipment	Supplier Origin		Remarks
	Mozambique	Japan or other country	
Backhoe	○		$0.8m^3$, $1.4m^3$
Bulldozer	○		21t, 32t
Rough terrain crane	○	○	25t
Truck crane	○	○	50t～150t
Crawler crane	○	○	55t
Concrete pump vehicle	○		$90～110m^3/h$
Pile driver		○	Cast in situ reverse pile
Vibro hammer		○	60kw
Motor grader	○		3.1m
Tire roller	○		8～20t
Vibration roller	○		3～4t
Road roller	○		10～12t
Asphalt finisher	○		2.4～6.0m
Dump truck	○	○	10t
PC Bridge Construction Equipment		○	Anti-rust materials

Source: JICA Study Team

8.8 Cost Estimation

8.8.1 Cost Estimate Prerequisites

(1) **Cost estimate procedure**

The project cost has been estimated on the basis of approximate quantities calculated by the outcome of the previous preliminary design. The steps adopted to elaborate the cost estimate are shown as follows. This section shows just the results as follows:

- Research of Materials and Suppliers
  - Contracted unit cost indicated in ANE bidding documents and achievements in nearby countries were used as reference/validation. Also, major suppliers in Mozambique and possible suppliers in other countries were considered.
  - Material, equipment, labour costs, as well as BQ unit costs were included in this study.

- Cost Estimate Basic Parameters
  - Exchange rate, price escalation, and indirect/overhead costs were considered.
  - There is no prescribed ratio for indirect/overhead costs in Mozambique, so the ratio according to the Ministry of Land, Infrastructure and Transport (MLIT) guidelines was applied for the calculation.
- Cost Estimation
  - The cost estimation based on the Work Breakdown Structures method (WBS) requires identifying all the activities compounding the project, subdividing hieratically each one into manageable segments.

(2) **Project costs calculation**

After the construction costs were estimated, the following costs were estimated in order to obtain the total project cost:

- Preparation costs, equipment mobilization costs: considered in the indirect costs.
- Design costs, construction supervision costs: considered in the consultants costs.
- Contingency: was also considered.
- Government burden costs: land acquisition and resettlement costs.
- Project administration costs: considered in the business maintenance costs

(3) **Cost estimation conditions**

The conditions adopted for this cost estimate are shown below:

- Cost estimate date: May/2015 (instant when unit costs were obtained)
- Exchange rate: 1 USD = 120.4 JPY (Apr/2016)
- Price escalation rate: 1.8% (external currency) and 5.1% (local currency)
- Contingency: 10% of construction costs and 5% of consultant fee
- Construction interest rate: 0.01% of construction costs and 0.01% of CS costs
- Project administration costs: 5% of the construction cost + 5% of the consultant fee
- Import tax: the understanding is that the contracted unit costs include import tax (if locally-procured materials are deemed to be difficult to obtain then the import tax should be considered separately).

8.8.2 Cost Estimate Results

(1) **Construction base cost (provisional)**

The construction cost was considered as the sum of three parts: direct cost, indirect cost and overhead. The results are shown below for both the High-spec plan and the Basic Option at the time of the opening of the provisional 2-lanes.

- High-Spec Option: independent intersections at the main junctions, service road with sidewalk and lane separation (with drainage facilities)
- Basic Option: priorities at grade intersections (see section 8.5.3), service road (BDST pavement), no sidewalk or lane separation (no drainage facilities) (see section 8.5.3 (3))

Table 8.8.1 Construction Base Cost (provisional)

Breakdown	High-Spec Option (USD million)	Basic Option (USD million)	Remarks
Nacala Port Access Road	128.0	85.1	Sea Bridge and Road
Nampula Southern Bypass Road	150.9	93.7	Bridge and Road
Cuamba Bypass Road	65.4	48.3	Bridge and Road
Total	344.3	227.0	

Source: JICA Study Team

(2) **Project cost (provisional)**

The estimated project total cost is shown in Table 8.8.2. The following hypotheses were adopted in the cost estimation:

- Inflation rate, physical contingency, etc. were considered under the current economic conditions.
- The dispute committee board fee was considered during the construction period plus 1 year. For Nacala Port Access Road and Nampula Southern Bypass Road the costs for 3 members were considered, for Cuamba Bypass Road 1 member was considered.
- Consultant fee was estimated at 9% of the construction cost.
- Land acquisition and resettlement costs will be defined after the RAP study. The estimate for those costs adopted 3% of the construction cost.
- Utilities reallocation is not expected to be a serious cost, however this shall be confirmed after the RAP study.
- There is no need to remove the existing bridges.
- The import tax for materials that can’t be found locally is not expected to be significant.

Under the current/above circumstances, the project total cost is expected to be between 294.4 million USD (Basic Option) and 446.2 million USD (High-Spec Option).

Table 8.8.2 Project Cost (provisional)

	Proportion	High-Spec Option (USD million)			Basic Option (USD million)		
		Nacala Port Access Road	Nampula Southern Bypass Road	Cuamba Bypass Road	Nacala Port Access Road	Nampula Southern Bypass Road	Cuamba Bypass Road
I Construction Cost		**141.8**	**167.2**	**72.4**	**94.3**	**103.8**	**53.5**
(1) Base cost	-	128	150.9	65.4	85.1	93.7	48.3
(2) Price escalation rate	0.008	1.0	1.2	0.5	0.7	0.7	0.4
(3) Contingency	0.1	12.8	15.1	6.5	8.5	9.4	4.8
(4) Dispute board	-	0.8	1.0	0.2	0.81	0.972	0.216
II Consultant Service		**24.1**	**28.4**	**12.3**	**16.0**	**17.6**	**9.1**
(5) D/D and CS	0.09	11.5	13.6	5.9	7.7	8.4	4.3
(6) Price escalation rate	0.008	0.1	0.1	0.0	0.1	0.1	0.0
(7) Contingency	0.1	1.2	1.4	0.6	0.8	0.8	0.4
III Utilities relocation	-	0	0	0	0	0	0
IV Removal of existing bridges	-	0	0	0	0	0	0
VI Land acquisition	0.03	4.3	5.0	2.2	2.8	3.1	1.6
VII Project administration costs	0.05	7.1	8.4	3.6	4.7	5.2	2.7
VIII Import tax	-	0	0	0	0	0	0
Total (I～VIII)		**165.9**	**165.9**	**195.6**	**84.7**	**110.3**	**121.4**
		446.2			**294.4**		

Source: JICA Study Team

CHAPTER 9 Technologies to enhance the Project Effects

9.1 Proposed Technologies

This chapter discusses one of the advanced technologies, developed by Japan, which can affect excellent impacts for economic aspects and environmental aspects, contribute to ensure the efficiency and construction quality in the construction period, and be an effective tool for maintenance after completion of the project.

The survey team proposes the application of the following technologies based on the local environments and characteristics;

- AT-1: Steel-Concrete Composite Slab Girder Bridge with Weathering Steel
- AT-2: Resin Coating Film (Coating) for Pre-stressed Concrete (PC) Steel/ Rebar (Epoxy Resin, Polyethylene Injection, etc.)
- AT-3: Temporary Cofferdam by combined use of Special Steel Sheet Pile and Expandable Water Cut-off Material
- AT-4: Multi-functional Slope Protection Mat
- AT-5: ICT Monitoring and Measurement for construction supervision of impacts around construction site
- AT-6: Pavement Management by Mobile Mapping System, including road assets management

The summary of each proposed advanced technology is described in the following table.

Table 9.1.1 Summary of Proposed Advanced Technology

Type of Technology	Outline of the Technology	Advantages in Japanese Technology	Applicable Roads	Cost and Other Effectives
AT-1: Composite Slab Girder with Weathering Steel	This thin and light slab girder reduces civil work volume and impact for railway operation during the construction. Weathering steel realises maintenance-free bridge.	There are many experiences in Japan with various research and development.	For two overpass bridges for railway at Nampula Southern Bypass Road	Construction cost is almost equivalent with conventional method, and a reduced construction period is realised.
AT-2: Resin Coating PC Steel/Rebar	PC cable applied by this technology ensures high durability against salt corrosion.	This coated PC cable is popular and standardized in Japan.	For PC steel in sea bridge at Nacala Port Access Road	The small increase in cost of this material provides durability against salt damage for bridges.
AT-3: Temporary Cofferdam with combination of Special Steel Sheet Pile and Expandable Water Cut-off Material	These special materials and steel plate stop leaking water in temporary cofferdams during the pier construction.	This is a major countermeasure developed in Japan.	For pier construction for sea bridge at Nacala Port Access Road	It reduces the pumping of sludge water into Nacala Bay which is a sensitive area for the environment.
AT-4: Multi-functional Slope Protection Mat	This mat can effectively protect the slope where erosion may occur due to embankment and cutting.	It is registered as a new technology system in Japan.	For slope along Nacala Port Access Road and Nampula Southern Bypass Road	Preventing erosion is an essential issue. This mat can protect the slope properly and is maintenance-free.
AT-5: ICT Monitoring and Measurement for Construction	Applied ICT technology for construction equipment ensures the quality of civil works even with un-skilled operators, as well as remote monitoring for supervising.	This is newly started for applying in Japanese construction sites.	All road construction sites, such as Nacala Port Access Road, Nampula Southern Bypass Road and Cuamba Bypass Road	It produces high-quality civil work outputs as un-counted value of effects.
AT-6: Mobile Mapping System	Mobile acquiring system for surrounding images and processing to 3-D measurable images can be utilized as road management tool.	There are various MMS in the world but the one from Japan is more flexible and is patented.	All of the roads such as Nacala Port Access Road, Nampula Southern Bypass Road and Cuamba Bypass Road	It saves time for inventory and road surface condition surveys and provides high accuracy. Also recorded images can be utilized for appropriate road management.

The following section depicts the details of each technology and advantages in terms of construction costs and construction periods.

9.2 Steel-concrete Composite Slab Girder Bridge with Weathering Steel

(1) Summary of Technology

There are a lot of examples of the use of reinforced concrete (RC) bridges in the rural areas of Mozambique, and in recent years, post-tension typed I-shaped girders and pre-stressed concrete slab girders have become as popular because of in-situ manufacturing in the construction yard. In contrast, there are no examples of use of a steel bridge with less than 40m span. This is because there is no facility to manufacture the steel girders, nor are the roads for transporting this material in the rural areas capable of withstanding the load, and that the maintenance technology for steel bridges is not yet locally available.

In recent years, the trunk roads connecting with major cities such as Nampula and Cuamba have been constructed or improved and the capacity for transportation was dramatically improved. In addition, maintenance-free steel has been developed, such as weathering steel, has increased the viability of steel bridges, if cost is allowed to apply for the steel bridge.

One of the approaches for reducing the cost of the steel bridges is to apply a "thin and light" slab to reduce the steel weight and reduce the size of the substructures. The composite slab girders have all the advantages of these characteristics and there are many applications and technical development in Japan.

As being discussed in this Chapter 9 regarding bridge type selection, the composite slab girder had advantages and was selected among PC-I girder or continuous steel girder for installation at overpass bridges for road and railway due to reduced impacts under the girder (less disruption to railway operation), potential of minimization of construction period, and excellence of reducing construction costs (thin girder can reduce earthwork volume and cost).

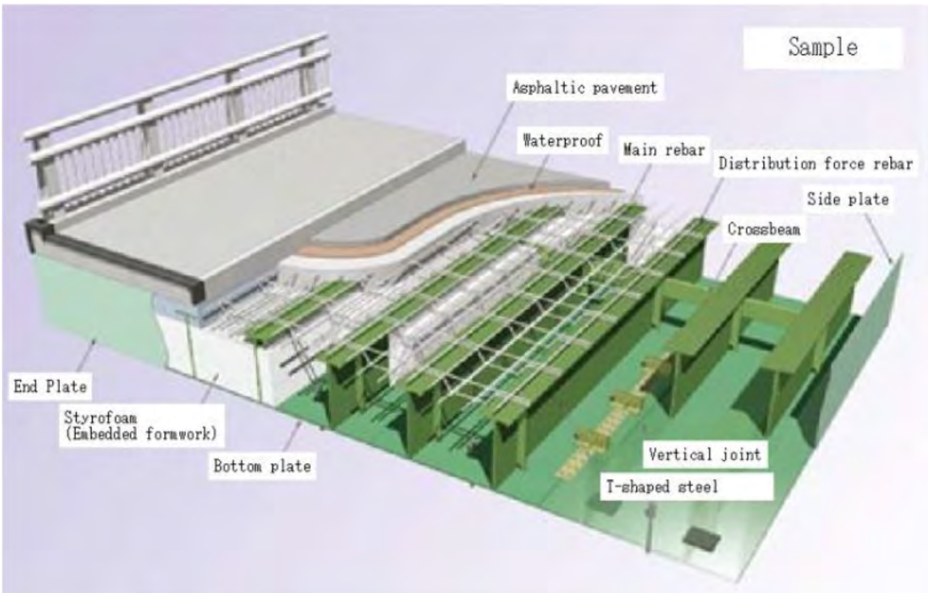


Figure 9.2.1 Schematic Diagram of Steel-Concrete Composite Slab Girder

It should be noted that this type of bridge has been visited by the ANE director general and others to view how thin the slab could be during the period of the technical study tour in Japan.

(2) Application of Weathering Steel (exposure test)

The survey team recommends that the steel applied to this bridge shall be withering steel, for which maintenance is not required on the rusting of the steel after completion. Weathering steel contains small amounts of Cu, Cr, and Ni which are effective elements for weather resistance improvement, and they form a layer of dense "rust" on its surface. This layer of rust can protect the surface of the steel material, and it is capable of suppressing the long-term corrosion depletion of the steel.

Since January 2016, patch tests (exposure tests) have been conducted at the following four locations in Mozambique as an activity of this feasibility study to confirm the applicability of the anti-corrosion performance in the local environment of the weather resistant steel.

- ANE headquarters
- Nampula province ANE delegation office
- Nacala Bay ANE guesthouse
- Katembe Bridge construction office

By monitoring the corrosion situation of the weathering steel and general steel for one year and two years passed, it is possible to confirm the applicability of the anti-corrosion performance of weather resistant steel. In case of Japan, the weathering steel regulated in the Japanese standard has been carried out in a number of field tests, and is approved to apply at more than 20km from the coast. The result of weathering exposure test in Mozambique, weathering steel (SMA-W/JIS G3114) is applicable in Mozambique even it is located near the seaside. Appendix-9 shows the result of this testing.

(3) Advantages of Cost and Construction Period

As described in the Chapter 9, the steel-concrete composite slab bridge is only 1.05 times the cost of the PC-I girder bridge, but it has a large advantage in shortening the construction period from 17.5 months to 3.5 months.

9.3 Resin Coating Film (Coating) for Pre-stressed Concrete (PC) Steel/ Rebar (Epoxy Resin, Polyethylene Injection, etc.)

(1) Summary of Technology

In case of the sea bridge for the Nacala Port Access Road (840m), the PC-I girder bridge has been adopted as the most economical bridge. Steel material for the PC (Pre-Stress Concrete) is used in this PC-I girder, since it is located on a coast, durability against salt damage greatly impacts the lifetime of this PC-I bridge.

Especially for the PC cable, improved steel cable that is protected against corrosion by coating with a resin that has been developed in Japan, and there have been a number of applications recently in Japan.

This new material was developed as a countermeasure against trouble caused by scattered failures during injection of the grout into the sheath for the PC cable. The PC steel cable with the coating film (coating) are appropriate to maintain the pre-stress for this application.

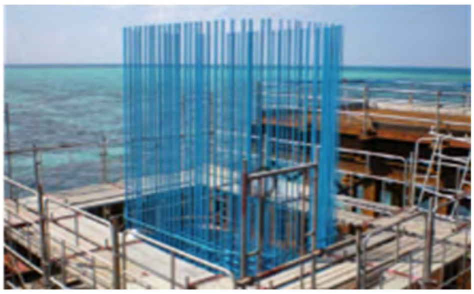
Currently, there are two similar technologies; one is the PC steel covered by an epoxy resin system, the other is the PC cable with high density polyethylene filled system. In Japan, there are several steel makers and contractors that can handle this technology.

High-density filling polyethylene-based

Epoxy resin system

Figure 9.3.1 Image of PC Steel Material with Resin Coating Film (Coating)

In addition, application of rebar painted with an epoxy resin, as well as application of spraying the anti-salt damage inhibitor on concrete surfaces, are recommended as techniques to prevent the concrete deterioration due to salt damage.



Epoxy Resin Coated Reinforcing Bar

Anti-Corrosion Coating on Concrete Structure

Figure 9.3.2 Examples of Applicable Techniques related to Salt Damage Prevention

(2) Advantages of Cost and Construction Period

Application of PC steel with resin painting and inhibitor is, itself, higher in cost compared to the general product. However, it has the advantage that there is no need to be concerned about the deterioration of the PC steel even with poor quality control during construction, and, there are methods to ensure their long life. These benefits overcome its higher costs.

9.4 Temporary Cofferdam by combined use of Steel Sheet Pile and Expandable Water Cut-off Material

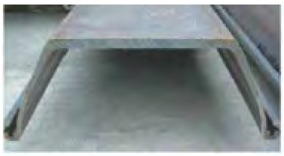
(1) Summary of Technology

The sea bridge located at the Nacala Port Access Road is constructed on the sea bed and its foundation is established in the shallow waters. The temporary cofferdams do not need steel pipe piles, which are expensive; the application of steel sheet piles is suitable. In addition, because the Nacala Bay is an environmentally closed bay system, in order to minimize the sludge discharge during the construction period, it is necessary to stop water outflow from the temporary cofferdams.

Under such circumstances, it should not be necessary to pump out the infiltrating water with a drainage pump, the application of the double cofferdam installation or expandable water cut-off material can be considered as adequate water stop measures.

The following images depict a combination of a special steel sheet pile (steel vertical impervious wall with a claw portion) and an expandable water cut-off material. This method is cheaper than the temporary double cofferdam, and it is possible to minimize the leaking water during construction.

Steel Wall for Vertical Impervious facility



Expandable water cut-off material (water expandable rubber, silicon, bentonite, etc.)

Figure 9.4.1 Recommended Technology for Temporary Cofferdam for Sea Bridge

(2) Advantages in Cost and Construction Period

As mentioned above, cost reduction is expected due to minimizing the time required for preparing the coffer dams and the reduction in the amount of steel material required when compared to a double coffer dam. The cheapest method is to pump the sludge constantly, however, this is not recommended in the aspect of environmental damages.

9.5 Multi-function Slope Protection Mat

(1) Summary of Technology

The area along the Nacala Port Access Road is an area which is easily damaged by surface water and erosion can be seen in the rainy season. Protection against erosion during the rainy season as well as slope conservation are important issues after the cutting and filling of the road construction.

In the above circumstances, multi-function mat, which a Japanese slope protection technology, is recommended for the slope of the embankments and cut sections.


After 3months, After 3 years and 7months,


Source: NETIS New Technology Information System in Japan

Figure 9.5.1 An example of a multi-functional Slope Protection Mat

This mat has the advantage that it starts its anti-erosion protection function immediately after laying rather than the conventional method such as vegetation spraying or vegetation mat/sheet. It is also expected to promote the establishment of vegetation more than the others.

(2) Advantages of Cost and Construction Period

Compared to other spraying methods, since it is only laying and pin fixed, is assumed to be similar to the other methods in cost. In addition, since there is no need for maintenance after lying, it costs much less for installation and maintenance.

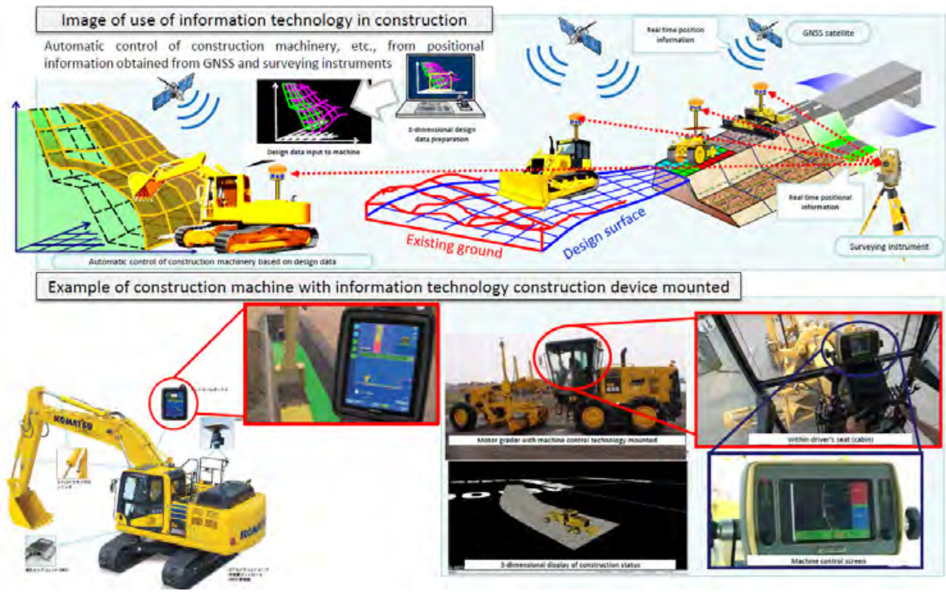
9.6 ICT Monitoring and Measurement for construction supervision of impacts around construction site

(1) Summary of Technology

In Japan, if the road works are in an urban area, it is required to measure their effects on the surroundings at time of construction. Especially, it is required to measure the subsidence and displacement of railways or the elevations of residential areas due to embankment and cutting civil works.

The Nampula Southern Bypass Road has two overpass bridges across the railway line. Because the bridge construction is required to continue coal transporting (with 2km wagon length) and other cargo and passenger railway operations, it is important to check the impact on this railway track by continuously measuring and monitoring of its foundations and approach embankments during construction. As an example in Japan, measuring the obital such as gauge width, horizontal displacement, and vertical displacement should be measured every 5m interval, at a frequency of 2 times per day, and management criteria as such as orbital variation (caution level, construction stop level and limit value) was set and applied to monitor during the construction. It is recommended to apply this kind of monitoring in the implementation of the overpass construction.

In addition, the "Information Technology Construction" is recommended. ANE saw this technology in Japan where it has newly started its introduction. This could help an unskilled operator of construction machinery to grade the layer surfaces with accuracy. It can also grasp the productivity of civil works even at a remote construction site. There are two possibilities to let the contractor manage by GPS measurements and use the construction equipment with these functions.



Source: Presentation Materials for Japan Study Tour (Ministry of Land, Infrastructure, Transport and Tourism (MILT), Kanto Regional Development Bureau, Northern Metropolitan National Highway Office)

Figure 9.6.1 Application Image for Information Technology Construction

Figure 9.6.2 Photo of Site Visiting by ANE Director General at Ken-o-Do Construction Site

(2) Advantages of Cost and Construction Period

If the cost for application of these technologies shall be put into the construction supervision, as well as the experiences of this type of construction equipment and its holdings shall be as the pre-condition to the contractor, the quality of construction will be expected a certain level of achievement.

9.7 Pavement Management by Mobile Mapping System, including road assets management

(1) Summary of Technology

In order to perform the appropriate road maintenance where it is required to function as the international corridor, ANE's current method of road management such as periodic visual confirmation and IR measurement by vehicle, shall be improved so that a video image of the entire circumstance should be captured periodically and be measured for acquiring the road surface conditions, as well as the tool for managing the road assets on it.

Since the target roads are located far from the ANE provincial delegation office and headquarters office, this technology has the advantage that it can conduct remote technical judgement from ANE headquarters employing an integrated system to utilize images 360^0 around and geographical location information and three (3) dimensional data and coordinates, which can be captured effectively and speedily.

As a one of the solutions for the above issues, a Mobile Mapping System (MMS) is recommended as an advanced road maintenance and management system. This system contains the following technical functions.

- Generating an entire 360^0 image in conjunction with the topographical map
- Acquiring the three-dimensional absolute coordinates from the captured images
- Measuring the location, distance and area of any three-dimensional position directly from the captured images
- Tagging the asset information for road related facilities into the captured images

If this system is applied to the project roads as an introduction, it is expected that it will be expanded to use on all the roads for Nacala international corridor as unified road maintenance tools.

(2) Advantages of Cost and Construction Period

Comparing with the current road maintenance scheme, the recommended MMC tool has sufficient features such as ease of measurement (video shooting for an entire 360^0 video), short required time for analysis of the data after the video shooting, ensuring planning quality with instinctive analysis tool even by various officials, and effective use for output management of maintenance work.

In addition, the easy acquiring of 360^0 images and its coordinates from the video can apply other usage, such as the identification of relocation houses for new road development, because this shooting equipment is not dependant on the vehicle but also be used on a motorcycle, UAV or carried by a surveyor.

CHAPTER 10 Project Evaluation

10.1 Overview

This chapter appraises the economic viability of the projects from the viewpoint of the national economy and employing the standard discounted net cash-flow methodology, which compares the quantified project benefits with the economic cost of the projects.

The Economic internal rate of return (EIRR), the net present value (NPV), and the benefit-cost ratio (B/C ratio) are used as appraisal indicators in order to assess the economic evaluation results.

In addition to the above mentioned appraisal indicators, a qualitative evaluation is considered for the projects impact on regional development, reduction of traffic accidents and CO_2 emission reduction.

10.2 Assumptions

10.2.1 Standard Conversion Factor

The estimated construction cost includes tax and customs, because it is based on market price. For the economic evaluation, financial costs are converted to economic costs by deducting the tax and customs portion and/or any other transfer payments. Based on the statistics of the "Customs Office, Ministry of Finance", a standard conversion factor (SCF) was estimated at a factor of 0.8811, which was the average value over the period 2007 to 2014 (Table 10.2.1).

Table 10.2.1 Standard Conversion Factor

Year	2007	2008	2009	2010	2011	2012	2013	2014	Average
1. Import	96,603	109,424	123,944	159,389	209,578	339,800	405,108	401,483	230,666
2. Export	74,638	81,948	89,990	108,659	127,587	140,228	146,451	162,981	116,560
3. Import Duties	17,292	19,587	22,186	28,531	37,515	60,824	72,514	71,865	41,289
4. 1+2	171,242	191,372	213,934	268,049	337,165	480,028	551,559	564,464	347,226
5. 1+2-3	153,950	171,785	191,748	239,518	299,651	419,204	479,044	492,599	305,937
6. SEC	1.1123	1.1140	1.1157	1.1191	1.1252	1.1451	1.1514	1.1459	1.1350
7. SCF	0.8990	0.8977	0.8963	0.8936	0.8887	0.8733	0.8685	0.8727	**0.8811**

Source: Customs Office, Ministry of Finance
Note: SEC: Shadow Exchange Coefficient
SCF: Standard Conversion Factor

10.2.2 Basic Assumptions

Other Assumptions are defined as follows.

1)	Construction start year	: from 2019 (Nacala, Nampula), 2020 (Cuamba)
2)	Operation start year	: 2024 (All Locations)
3)	4 lane operation start year	: 2035 (Nacala, Nampula)
4)	Project life	: 30 years after the start of operation
5)	Price	: 2016 constant price
6)	Residual value	: Nothing
7)	Discount rate	: 12 %
8)	Exchange rate	: 120.45 JPY/USD

10.3 Economic Benefits of the Projects

The economic benefits are defined as the difference in travel cost between the "With Project" and "Without Project" cases. In this project, the travel cost consists of vehicle operation cost (VOC) and travel time cost of passengers and for freights.

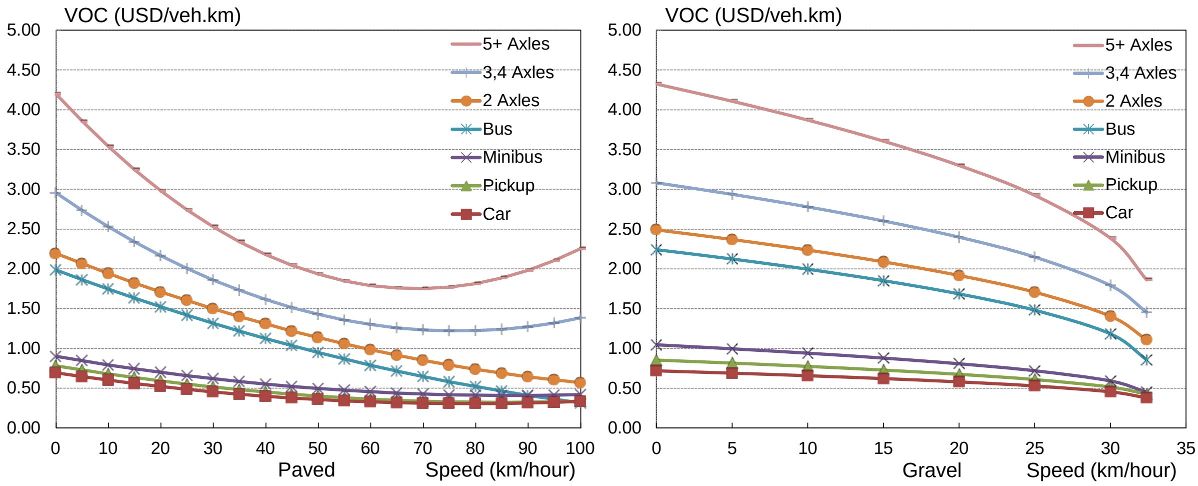
There is no difference between "With Project" and "Without Project" except the implementation of the proposed project.

10.3.1 Reduction of Vehicle Operation Cost (VOC)

The reduction of VOC, with reduction of travel distance and improvement of travel speed, is the main component of the economic benefits. It is calculated from "Vehicle-Km by vehicle type and by travel speed" and "Unit VOC by vehicle type and by travel speed".

The "Vehicle-Km by vehicle type and by travel speed" is an output from the network traffic assignment discussed in Chapter 5.

The "Unit VOC by vehicle type and by travel speed" is shown in Figure 10.3.1.



Source: JICA Study Team

Figure 10.3.1 VOC-Travel Speed by Vehicle Type (Left: paved, Right: unpaved)

Table 10.3.1 Cost Item by Vehicle Type

	Cost				Life and Utilization			
	Op. weight	New Vehicle	Tyre cost	Crew cost	Annual driven	Annual Driven	Service Life	Private Use
Vehicle type	tons	price $	$/unit	$/hour	km	hours	years	%
Medium Car	1.4	20,400	95	0.5	25,000	450	8	100
Pickup, 4 wheel-drive	2.3	24,150	183	0.5	30,000	750	10	50
Medium bus <20 seats	7	25,900	175	1.3	60,000	1,500	8	0
Large Bus 50 seats	11	125,600	536	2	35,000	750	10	0
Medium Truck 2 axle	15	95,150	480	1.7	40,000	1,000	12	0
Heavy Truck 3 axle	22	105,700	480	1.95	75,000	1,750	12	0
Articulated Truck(5-axle) incl. Trailer	44	136,500	536	1.95	80,000	1,750	12	0

Source: ANE 2015, ANE Road User Costs In 2006

Table 10.3.2 Cost Items Common to All Vehicle Types

Fuel per litre (gasoline)	USD	1.29
Fuel per litre (diesel)	USD	1.04
Lube oil per litre	USD	4.5
Workshop Labour incl. overhead	USD/hour	4
Annual Interest vehicles	% per year	5.00%
Passenger Work Time	USD/hour	0.695
Passenger Non-Work time	USD/hour	0.208

Source：ANE 2015

10.3.2 Reduction of Passenger Travel Time Cost

The reduction of travel time cost is likewise a main component of the economic benefits. Because it is opportunity cost of working time, it is considered as an economic benefit. This is based on the way of thinking that people can work longer by the reduction of travel time, and it leads to growth of GDP.

The travel time cost is calculated from "Travel Time by vehicle type", "Average Occupancy by vehicle type" and "Unit Value of Passenger Travel Time". The "Travel Time by vehicle type" is an output from the network traffic assignment discussed in Chapter 5.

The values of "Average Occupancy by vehicle type" and "Value of Travel Time" are defined based on the discussions with ANE (Table 10.3.3). According to a World Bank Database, the "gross-national income (GNI)" on a per capita basis, and using "purchasing power parity (PPP)" (current international $) in 2014 was 1,120 USD. If average working days are 20 days in a calendar month and the average working time is 7 hours, the wage is 0.7 USD/hour. This means that the value of travel time for a business trip has validity. The value of travel time for non-business trips also has some validity, because it is typically 1/3 of that of a business trip. However, some passengers occupying a passenger car, minibus or bus have a business trip purpose, and travel time cost is underestimated for these vehicle types.

Table 10.3.3 Average Occupancy and Value of Travel Time

	Passengers (pax. /veh.)	Time Cost ($/pax.-hr)
Passenger Car	2	0.21
Pickup	2	0.7
Minibus	13	0.21
Bus	30	0.21
2 Axles Truck	1	0.7
3,4 Axles Truck	1	0.7
5+ Axles Truck	1	0.7

Source：ANE 2015

10.3.3 Reduction of Freight Transport Time Cost

Freight travel time cost is considered as the rate of yield which can be saved when the time to the market is shortened. The freight travel time cost is calculated from "Travel Time by vehicle type", "Average load capacity by vehicle type" and "Unit Value of Freight Transport Time". The "Travel Time by vehicle type" is an output from the network traffic assignment described in Chapter 5.

Table 10.3.4 and Table 10.3.5 show the adopted values of "Average load capacity by vehicle type" and "Unit Value of Freight Transport Time". The method of calculating the "Unit Value of Freight Transport Time" is described below.

The unit price of goods is based on the value of freight handled at Nacala Port (Table 10.3.5). The average of value of “free-on board (FOB)” and “cost-insurance-freight (CIF)” is adopted, based on the assumption that the behaviour of land transport of import and export is almost the same. The interbank interest rate of 15.60% of the Banco de Mozambique is adopted for the interest rate.

To translate the bulk and container value to the value of freight transport time by vehicle, the ratio of truck and container trailer is assumed based on the freight handling volume at Nacala Port. The average weight of one “Twenty-Foot Equivalent Unit (TEU)” is assumed to be 11.5 ton/TEU, which was the average weight between the years 2008 and 2014. The ratio of 3 or 4 axle trucks and 5 or more axle trucks is assumed as 4:6 based on the results of the classified traffic count survey at all locations in this study. As shown in Table 10.3.6, the ratio of container trailers in all large vehicles is different in each year. However, to make it simplified, it is fixed to 0.6 for the calculation of the value of freight in Table 10.3.5.

Table 10.3.4 Unit Value of Freight Transport Time

Vehicle type	Op. weight	Time Value
	ton	USD/veh-hour
Pickup, 4 wheel-drive	2.3	0.029
Medium Truck 2 axle (<15t)	15	0.192
Heavy Truck 3 axle (<22t)	22	0.199
Artic. Truck (5-axle) incl. trailer	44	0.397

Source: JICA Study Team

Table 10.3.5 Value of Freight Handled at Nacala Port

Bulk Value	(USD/ton)	(USD/ton/hour)
FOB basis for Exports	901	0.02
CIF basis for Import	533	0.01
Container Value	(USD/TEU)	(USD/TEU/hour)
FOB basis for Exports	8,065	0.14
CIF basis for Import	8,092	0.14

Source: the Project for Improvement of Nacala Port

Table 10.3.6 Ratio of Container and Bulk Freight Handled at Nacala Port

	2017	2025	2035
Freight Handling Volume at Nacala Port (vehicle transport)			
Container (10^3 ton)	1,064	2,204	5,376
Bulk (10^3 ton)	1,376	2,104	4,471
Freight Handling Volume at Nacala Port (vehicle transport)			
Container Trailer (veh.) 3or4 axle 20ft	36,886	76,406	186,370
Container Trailer (veh.) 5+ axle 40ft	27,664	57,304	139,777
Other Trucks (veh.) 3or4 axle	25,018	38,255	81,291
Other Trucks (veh.) 5+ axle	18,764	28,691	60,968
Ratio of Container Trailers	60%	67%	70%

Source：PEDEC, the Project for Improvement of Nacala Port, JICA Study Team

10.4 Economic Analysis

10.4.1 Nacala Port Access Road

(1) Investment Cost

The economic analysis is conducted for both the 1) High-spec option and 2) Basic option, based on the cost estimation in Chapter 8.

1) High-spec Option

- Initial Construction Cost : 169.5 mil. USD
- Cost for Upgrading to 4 Lane : 135.6 mil. USD (80% of initial construction cost)
- Operation and Management : 1.05 mil USD/year

2) Basic Option

- Initial Construction Cost : 111.5 mil. USD
- Cost for Upgrading to 4 Lane : 89.2 mil. USD (80% of initial construction cost)
- Operation and Management : 0.90 mil USD/year

All the above costs are in financial prices. In the economic analysis, the cost must be converted to economic cost by multiplying the financial cost by the Standard Conversion Factor of 0.881.

(2) Economic Benefits

The economic benefits are calculated based on the results of the network traffic assignment presented in Chapter 5 (Table 10.4.1).

Table 10.4.1 Economic Benefit (Nacala)

Year	Planned Road	VOC	VOT Passenger	VOT Freight	**Annual Benefit**
2025	Without	44,890	2,009	97	
2025	2 Lane	37,720	1,236	56	**7,984**
2025	4 Lane	38,291	1,213	55	**7,437**
2035	Without	119,815	15,439	785	
2035	2 Lane	73,993	3,151	137	**58,757**
2035	4 Lane	73,652	2,797	113	**59,477**

Unit：1,000 USD/ Year
Source: JICA Study Team

(3) Results of Economic Analysis

Table 10.4.3 show the cash flow of the high-spec and basic option of the project. The economic internal rate of return (EIRR), which is calculated from the net cash flow between 2016 and 2053, is 12.92% in the high-spec option and 17.11% in the basic option. These values indicate that the project is beneficial for the national economy, both in high-spec and basic option form, since these rates are higher than the social discount rate of 12%.

The cost benefit ratio (B/C) is 1.10 in the high-spec option and 1.66 in the basic option. The net present value (NPV) is 9.78 mil. USD in the high-spec option and 42.33 mil. USD in the basic option.

Table 10.4.2 Nacala Economic Benefit (High-spec option)

JPY/USD 120.45 JPY/USD Unit (mil. USD 2016 Economic Price)

Year	No. of Lanes	Yrs. after Operation	Cash-Out Construct	O&M	Total	Cash-In VOC	Pax. TTC	Fre. TTC	Total	Net Cash Flow
Total			149	28	296	1,129	300	16	1,445	**1,149**
NPV			156	7	97	209	52	3	107	**9.78**
B/C										**1.10**
EIRR										**12.92%**
2016					0.0				0.0	0.00
2017					0.0				0.0	0.00
2018					0.0				0.0	0.00
2019			14.9		14.9				0.0	-14.93
2020			39.8		39.8				0.0	-39.82
2021			39.8		39.8				0.0	-39.82
2022			39.8		39.8				0.0	-39.82
2023			14.9		14.9				0.0	-14.93
2024	2	1		0.9	0.9	6.0	0.7	0.0	6.7	5.78
2025	2	2		0.9	0.9	**7.2**	**0.8**	**0.0**	8.0	7.06
2026	2	3		0.9	0.9	11.0	1.9	0.1	13.1	12.14
2027	2	4		0.9	0.9	14.9	3.1	0.2	18.1	17.22
2028	2	5		0.9	0.9	18.8	4.2	0.2	23.2	22.29
2029	2	6		0.9	0.9	22.6	5.4	0.3	28.3	27.37
2030	2	7	11.9	0.9	12.9	26.5	6.5	0.3	33.4	20.50
2031	2	8	31.9	0.9	32.8	30.4	7.7	0.4	38.4	5.67
2032	2	9	31.9	0.9	32.8	34.2	8.8	0.5	43.5	10.75
2033	2	10	31.9	0.9	32.8	38.1	10.0	0.5	48.6	15.82
2034	2	11	11.9	0.9	12.9	42.0	11.1	0.6	53.7	40.81
2035	4	12		0.9	0.9	**46.2**	**12.6**	**0.7**	59.5	58.56
2036	4	13		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2037	4	14		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2038	4	15		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2039	4	16		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2040	4	17		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2041	4	18		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2042	4	19		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2043	4	20		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2044	4	21		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2045	4	22		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2046	4	23		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2047	4	24		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2048	4	25		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2049	4	26		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2050	4	27		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2051	4	28		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2052	4	29		0.9	0.9	46.2	12.6	0.7	59.5	58.56
2053	4	30		0.9	0.9	46.2	12.6	0.7	59.5	58.56

Source: JICA Study Team

Table 10.4.3 Nacala Economic Benefit (Basic option)

JPY/USD 120.45 JPY/USD Unit (mil. USD 2016 Economic Price)

Year	No. of Lanes	Yrs. after Operation	Cash-Out			Cash-In				Net Cash Flow
			Construct	O&M	Total	VOC	Pax. TTC	Fre. TTC	Total	
Total			98	24	201	1,129	300	16	1,445	**1,245**
NPV			103	6	64	209	52	3	107	**42.33**
B/C										**1.66**
EIRR										**17.11%**
2016					0.0				0.0	0.00
2017					0.0				0.0	0.00
2018					0.0				0.0	0.00
2019			9.8		9.8				0.0	-9.82
2020			26.2		26.2				0.0	-26.20
2021			26.2		26.2				0.0	-26.20
2022			26.2		26.2				0.0	-26.20
2023			9.8		9.8				0.0	-9.82
2024	2	1		0.8	0.8	6.0	0.7	0.0	6.7	5.91
2025	2	2		0.8	0.8	**7.2**	**0.8**	**0.0**	8.0	7.19
2026	2	3		0.8	0.8	11.0	1.9	0.1	13.1	12.27
2027	2	4		0.8	0.8	14.9	3.1	0.2	18.1	17.35
2028	2	5		0.8	0.8	18.8	4.2	0.2	23.2	22.43
2029	2	6		0.8	0.8	22.6	5.4	0.3	28.3	27.50
2030	2	7	7.9	0.8	8.6	26.5	6.5	0.3	33.4	24.72
2031	2	8	21.0	0.8	21.7	30.4	7.7	0.4	38.4	16.70
2032	2	9	21.0	0.8	21.7	34.2	8.8	0.5	43.5	21.78
2033	2	10	21.0	0.8	21.7	38.1	10.0	0.5	48.6	26.86
2034	2	11	7.9	0.8	8.6	42.0	11.1	0.6	53.7	45.03
2035	4	12		0.8	0.8	**46.2**	**12.6**	**0.7**	59.5	58.69
2036	4	13		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2037	4	14		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2038	4	15		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2039	4	16		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2040	4	17		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2041	4	18		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2042	4	19		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2043	4	20		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2044	4	21		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2045	4	22		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2046	4	23		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2047	4	24		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2048	4	25		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2049	4	26		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2050	4	27		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2051	4	28		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2052	4	29		0.8	0.8	46.2	12.6	0.7	59.5	58.69
2053	4	30		0.8	0.8	46.2	12.6	0.7	59.5	58.69

Source: JICA Study Team

10.4.2 Nampula Southern Bypass Road

(1) Investment Cost

The economic analysis is conducted for both the 1) High-spec option and the 2) Basic option, based on the cost estimation discussed in Chapter 8. The costs are all financial costs. In the economic analysis, the costs must be converted to economic cost by multiplying them by the Standard Conversion Factor of 0.881.

1) High-spec Option

- Initial Construction Cost : 207.7 mil. USD
- Cost for Upgrading to 4 Lane : 166.2 mil. USD (80% of initial construction cost)
- Operation and Management : 1.50 mil USD/year

2) Basic Option

- Initial Construction Cost : 122.4 mil. USD
- Cost for Upgrading to 4 Lane : 97.9 mil. USD (80% of initial construction cost)
- Operation and Management : 1.31 mil USD/year

(2) Economic Benefits

The economic benefits are calculated based on the results of the network traffic assignment described in Chapter 5 (Table 10.4.4).

Table 10.4.4 Economic Benefit (Nampula)

Year	Planned Road	VOC	VOT Passenger	VOT Freight	**Annual Benefit**
2025	Without	70,077	3,595	144	
2025	2 Lane	61,923	2,625	102	**9,166**
2025	4 Lane	62,098	2,585	100	**9,033**
2035	Without	199,391	24,576	1,511	
2035	2 Lane	151,838	9,549	524	**63,568**
2035	4 Lane	158,400	9,281	514	**57,284**

Unit：1,000 USD/Year Source: JICA Study Team

(3) Results of Economic Analysis

Table 10.4.5 and Table 10.4.6 show the cash flow of the high-spec and basic options of the project. The economic internal rate of return (EIRR), which is calculated from the net cash flow between 2016 and 2053, is 11.24% in the high-spec option and 16.53% in the basic option. While the EIRR in the high-spec option is lower than the social discount rate of 12%, the option is not economically feasible, if the EIRR=12% is the only criteria. On the other hand, the EIRR in the basic option is higher than 12% and the option is beneficial for the national economy.

The cost benefit ratio (B/C) is 0.92 in the high-spec option and 1.54 in the basic option. The net present value (NPV) is -9.01 mil. USD in the high-spec option and 38.76 mil. USD in the basic option.

Table 10.4.5 Nampula Economic Benefit (High-spec option)

JPY/USD 120.45 JPY/USD Unit (mil. USD 2016 Economic Price)

Year	No. of Lanes	Yrs. after Operation	Cash-Out			Cash-In				Net Cash Flow
			Construct	O&M	Total	VOC	Pax. TTC	Fre. TTC	Total	
Total			183	40	369	1,045	364	24	1,433	**1,064**
NPV			191	11	119	206	63	4	110	**-9.01**
B/C										**0.92**
EIRR										**11.24%**
2016					0.0				0.0	0.0
2017					0.0				0.0	0.0
2018					0.0				0.0	0.0
2019			18.3		18.3				0.0	-18.3
2020			48.8		48.8				0.0	-48.8
2021			48.8		48.8				0.0	-48.8
2022			48.8		48.8				0.0	-48.8
2023			18.3		18.3				0.0	-18.3
2024	2	1		1.3	1.3	7.1	0.9	0.0	8.0	6.7
2025	2	2		1.3	1.3	**8.2**	**1.0**	**0.0**	9.2	7.8
2026	2	3		1.3	1.3	12.1	2.4	0.1	14.6	13.3
2027	2	4		1.3	1.3	16.0	3.8	0.2	20.0	18.7
2028	2	5		1.3	1.3	20.0	5.2	0.3	25.5	24.2
2029	2	6		1.3	1.3	23.9	6.6	0.4	30.9	29.6
2030	2	7	14.6	1.3	16.0	27.9	8.0	0.5	36.4	20.4
2031	2	8	39.0	1.3	40.4	31.8	9.4	0.6	41.8	1.4
2032	2	9	39.0	1.3	40.4	35.7	10.8	0.7	47.2	6.9
2033	2	10	39.0	1.3	40.4	39.7	12.2	0.8	52.7	12.3
2034	2	11	14.6	1.3	16.0	43.6	13.6	0.9	58.1	42.2
2035	4	12		1.3	1.3	**41.0**	**15.3**	**1.0**	57.3	56.0
2036	4	13		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2037	4	14		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2038	4	15		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2039	4	16		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2040	4	17		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2041	4	18		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2042	4	19		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2043	4	20		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2044	4	21		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2045	4	22		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2046	4	23		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2047	4	24		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2048	4	25		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2049	4	26		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2050	4	27		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2051	4	28		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2052	4	29		1.3	1.3	41.0	15.3	1.0	57.3	56.0
2053	4	30		1.3	1.3	41.0	15.3	1.0	57.3	56.0

Source: JICA Study Team

Table 10.4.6 Nampula Economic Benefit (Basic option)

JPY/USD 120.45 JPY/USD Unit (mil. USD 2016 Economic Price)

Year	No. of Lanes	Yrs. after Operation	Cash-Out			Cash-In				Net Cash Flow
			Construct	O&M	Total	VOC	Pax. TTC	Fre. TTC	Total	
Total			108	35	229	1,045	364	24	1,433	**1,204**
NPV			113	9	72	206	63	4	110	**38.76**
B/C										**1.54**
EIRR										**16.53%**
2016					0.0				0.0	0.0
2017					0.0				0.0	0.0
2018					0.0				0.0	0.0
2019			10.8		10.8				0.0	-10.8
2020			28.8		28.8				0.0	-28.8
2021			28.8		28.8				0.0	-28.8
2022			28.8		28.8				0.0	-28.8
2023			10.8		10.8				0.0	-10.8
2024	2	1		1.2	1.2	7.1	0.9	0.0	8.0	6.9
2025	2	2		1.2	1.2	**8.2**	**1.0**	**0.0**	9.2	8.0
2026	2	3		1.2	1.2	12.1	2.4	0.1	14.6	13.5
2027	2	4		1.2	1.2	16.0	3.8	0.2	20.0	18.9
2028	2	5		1.2	1.2	20.0	5.2	0.3	25.5	24.3
2029	2	6		1.2	1.2	23.9	6.6	0.4	30.9	29.8
2030	2	7	8.6	1.2	9.8	27.9	8.0	0.5	36.4	26.6
2031	2	8	23.0	1.2	24.2	31.8	9.4	0.6	41.8	17.6
2032	2	9	23.0	1.2	24.2	35.7	10.8	0.7	47.2	23.1
2033	2	10	23.0	1.2	24.2	39.7	12.2	0.8	52.7	28.5
2034	2	11	8.6	1.2	9.8	43.6	13.6	0.9	58.1	48.3
2035	4	12		1.2	1.2	**41.0**	**15.3**	**1.0**	57.3	56.1
2036	4	13		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2037	4	14		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2038	4	15		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2039	4	16		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2040	4	17		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2041	4	18		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2042	4	19		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2043	4	20		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2044	4	21		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2045	4	22		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2046	4	23		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2047	4	24		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2048	4	25		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2049	4	26		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2050	4	27		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2051	4	28		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2052	4	29		1.2	1.2	41.0	15.3	1.0	57.3	56.1
2053	4	30		1.2	1.2	41.0	15.3	1.0	57.3	56.1

Source: JICA Study Team

10.4.3 Cuamba Bypass Road

(1) Investment Cost

The economic analysis is conducted for both the 1) High-spec option and the 2) Basic options, based on the cost estimation provided in Chapter 8. The costs are all financial costs. In the economic analysis, the costs must be converted to economic cost by multiplying them by the Standard Conversion Factor of 0.881.

1) High-spec Option

- Initial Construction Cost : 85.4 mil. USD
- Operation and Management : 0.37 mil USD/year

2) Basic Option

- Initial Construction Cost : 62.9 mil. USD
- Operation and Management : 0.36 mil USD/year

(2) Economic Benefits

The economic benefits are calculated based on the results of the network traffic assignment presented in Chapter 5 (Table 10.4.7).

In the target area, there are some level crossing points with the railway and road, as described in Chapter 5. Therefore, reduction of the waiting time cost could be considered as an economic benefit. For example, 35 % of the vehicles wait for trains passing through and the average waiting time is assumed to be 4.5 minutes, considering 28 pairs of trains pass through the crossing points each day in 2035. The waiting time cost could be calculated from the average waiting time, "value of time by vehicle type" and "number of vehicles passing through the crossing points".

Table 10.4.7 Economic Benefit (Cuamba)

Year	Planned Road	VOC	VOT Passenger	VOT Freight	Railway Waiting	**Annual Benefit**
2025	Without	19,746	659	89	9	
2025	With 2 Lane	16,995	578	77	5	**2,848**
2035	Without	43,061	1,077	175	24	
2035	With 2 Lane	35,787	867	138	14	**7,531**

Source: JICA Study Team

(3) Results of Economic Analysis

Table 10.4.8 and Table 10.4.9 show the cash flow of the high-spec and the basic options of the project. The economic internal rate of return (EIRR), which is calculated from the net cash flow between 2016 and 2053, is 5.49% in the high-spec option and 7.72% in the basic option. Since the EIRRs in both options are lower than the social discount rate of 12%, these are not economically feasible. One of the main reasons is that the traffic volume in the target year is still small. If the operation start year is 2034, the EIRR is 7.77% in the high-spec option and 10.86% in the basic option.

Therefore, it is considered better to conduct the project when the traffic volume has increased enough, as a result of economic evaluation with quantitative benefits. The timing should be judged based on the development of the international corridor from current Nampula-Cuamba-Mandimba to Malawi and Zambia, and the volume of international land transport.

Table 10.4.8 Cuamba Economic Benefit (High-spec option)

JPY/USD 120.45 JPY/USD Unit (mil. USD 2016 Economic Price)

Year	Yrs. after Operation	Cash-Out			Cash-In					Net Cash Flow
		Construct	O&M	Total	VOC	Pax. TTC	Fre. TTC	Railway Crossing	Total	
Total		75	10	85	189	5	1	0	195	**110**
NPV		55	3	36	40	1	0	0	17	**-19.49**
B/C										**0.46**
EIRR										**5.49%**
2016				0.0					0.00	0.00
2017				0.0					0.00	0.00
2018				0.0					0.00	0.00
2019				0.0					0.00	0.00
2020		7.5		7.5					0.00	-7.52
2021		22.6		22.6					0.00	-22.57
2022		22.6		22.6					0.00	-22.57
2023		22.6		22.6					0.00	-22.57
2024	1		0.3	0.3	2.5	0.1	0.01	0.00	2.56	2.24
2025	2		0.3	0.3	2.8	0.1	0.01	0.00	2.85	2.53
2026	3		0.3	0.3	3.2	0.1	0.01	0.00	3.32	2.99
2027	4		0.3	0.3	3.7	0.1	0.02	0.00	3.78	3.46
2028	5		0.3	0.3	4.1	0.1	0.02	0.01	4.25	3.93
2029	6		0.3	0.3	4.6	0.1	0.02	0.01	4.72	4.40
2030	7		0.3	0.3	5.0	0.1	0.02	0.01	5.19	4.87
2031	8		0.3	0.3	5.5	0.2	0.03	0.01	5.66	5.34
2032	9		0.3	0.3	5.9	0.2	0.03	0.01	6.13	5.80
2033	10		0.3	0.3	6.4	0.2	0.03	0.01	6.59	6.27
2034	11		0.3	0.3	6.8	0.2	0.03	0.01	7.06	6.74
2035	12		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2036	13		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2037	14		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2038	15		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2039	16		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2040	17		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2041	18		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2042	19		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2043	20		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2044	21		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2045	22		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2046	23		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2047	24		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2048	25		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2049	26		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2050	27		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2051	28		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2052	29		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21
2053	30		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.21

Source: JICA Study Team

Table 10.4.9 Cuamba Economic Benefit (Basic option)

JPY/USD 120.45 JPY/USD Unit (mil. USD 2016 Economic Price)

Year	Yrs. after Operation	Cash-Out Construct	O&M	Total	Cash-In VOC	Pax. TTC	Fre. TTC	Railway Crossing	Total	Net Cash Flow
Total		55	9	65	189	5	1	0	195	**130**
NPV		41	3	27	40	1	0	0	17	**-10.24**
B/C										**0.62**
EIRR										**7.72%**
2016				0.0					0.00	0.00
2017				0.0					0.00	0.00
2018				0.0					0.00	0.00
2019				0.0					0.00	0.00
2020		5.5		5.5					0.00	-5.54
2021		16.6		16.6					0.00	-16.62
2022		16.6		16.6					0.00	-16.62
2023		16.6		16.6					0.00	-16.62
2024	1		0.3	0.3	2.5	0.1	0.01	0.00	2.56	2.25
2025	2		0.3	0.3	2.8	0.1	0.01	0.00	2.85	2.53
2026	3		0.3	0.3	3.2	0.1	0.01	0.00	3.32	3.00
2027	4		0.3	0.3	3.7	0.1	0.02	0.00	3.78	3.47
2028	5		0.3	0.3	4.1	0.1	0.02	0.01	4.25	3.94
2029	6		0.3	0.3	4.6	0.1	0.02	0.01	4.72	4.41
2030	7		0.3	0.3	5.0	0.1	0.02	0.01	5.19	4.87
2031	8		0.3	0.3	5.5	0.2	0.03	0.01	5.66	5.34
2032	9		0.3	0.3	5.9	0.2	0.03	0.01	6.13	5.81
2033	10		0.3	0.3	6.4	0.2	0.03	0.01	6.59	6.28
2034	11		0.3	0.3	6.8	0.2	0.03	0.01	7.06	6.75
2035	12		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2036	13		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2037	14		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2038	15		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2039	16		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2040	17		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2041	18		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2042	19		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2043	20		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2044	21		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2045	22		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2046	23		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2047	24		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2048	25		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2049	26		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2050	27		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2051	28		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2052	29		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22
2053	30		0.3	0.3	7.3	0.2	0.04	0.01	7.53	7.22

Source: JICA Study Team

10.4.4 Sensitivity Analysis

Table 10.4.10 shows the results of the sensitivity analysis of the EIRR by location and by case. To monitor the sensitivity, EIRRs for “Cost +10%”, “Benefit -10%” and “Cost +10% and Benefit -10%” are calculated.

Additional cases are examined for the sensitivity analysis, cases of “2 lane operation without upgrading to 4 lane” in Nacala and Nampula, and cases of “postpone the operation start year until 2034” in Cuamba.

Major findings are as follows.

- EIRRs exceed 12% in almost all cases in Nacala. Only in the high-spec option “2→4 Lane” case, the EIRR is lower than 12% if “Benefit -10%” or “Cost +10% and Benefit -10%”.
- EIRRs exceed 12% in most cases in Nampula. In the high spec option, EIRR of “2→4 Lane” case and “2 Lane” case with “Cost +10% and Benefit -10%” are lower than 12%.
- EIRR of the basic option for Cuamba Bypass Road is higher than 10% in case the operation start in 2034, but EIRR is lower than 12% in any case.

Table 10.4.10 Results of Sensitivity Analysis

			EIRR	EIRR Sensitivity		
Location	**Cost**	**Case**		**Cost +10%**	**Benefit -10%**	**Cost +10% Benefit -10%**
Nacala	High	2→4 Lane	12.92%	12.01%	11.91%	11.03%
		2 Lane	14.46%	13.63%	13.54%	12.74%
	Basic	2→4 Lane	17.11%	16.09%	15.99%	15.00%
		2 Lane	18.33%	17.38%	17.28%	16.37%
Nampula	High	2→4 Lane	11.24%	10.34%	10.25%	9.37%
		2 Lane	13.41%	12.60%	12.52%	11.73%
	Basic	2→4 Lane	16.53%	15.49%	15.38%	14.37%
		2 Lane	18.21%	17.25%	17.16%	16.23%
Cuamba	High	2024 Open	5.49%	4.80%	4.73%	4.06%
		2034 Open	7.77%	6.87%	6.77%	5.92%
	Basic	2024 Open	7.72%	6.96%	6.88%	6.14%
		2034 Open	10.86%	9.80%	9.69%	8.68%

Source: JICA Study Team

10.5 Other Effects of Project

The effects of the implementation of the projects are not limited to the above mentioned quantitative evaluation. This section describes other effects as qualitative evaluations.

(1) Area Development Effect

The proposed roads are deeply connected to the development of the target areas. It is possible to restrict large vehicles entering into the city centre by implementation of the bypass roads. Economic revitalization and smoother freight transportation are expected by promoting industrial development along the bypass roads. The area development effect of each area is identified as follows.

- Nacala Port Access Road: The function as a port city is improved by promoting development of distribution bases and industrial zones, and by restricting large vehicles passing through the city centre.
- Nampula Southern Bypass Road: Economic growth of the expanding provincial capital is expected by accumulating industrial functions with land use control along the bypass road.
- Cuamba Bypass Road: Efficient city formulation is expected taking advantage of the location at the strategic place of international transportation. By nurturing agricultural products a processing industry is expected along the bypass road. Niassa province is a large agricultural production area.

(2) Reduction of Traffic Accidents

An increase in number of traffic accidents is anticipated in the future in these areas if the projects are not implemented. Mitigation of the expected increase is an important benefit, even though it is difficult to quantitatively express this. The reason for the potential increase is as follows.

- With the increase of traffic volume entering the city centre, the number traffic accidents increases.
- The risk on residential roads is increased when vehicles flow into residential roads, which have many blind areas, when those arterial roads are highly congested

The following effects are expected by implementation of the projects.

- Development of the planned roads with good alignment will lead to a decrease in the number of accidents per unit traffic volume.
- The number of vehicles entering into the city centre and residential roads is reduced. These areas are known as high risk locations for traffic accidents.

(3) Environment (Reduction of CO_2 Emission)

It is expected that the implementation of the planned roads will reduce the CO_2 emissions which are caused by a decrease in travel speed.

In general, CO_2 emission is reduced by 40% when the travel speed is improved from 20 km/h to 60 km/h. As described in Chapter 5, it is estimated that the travel speed will be lower than 20 km/h in the major road sections in Nacala and Nampula city if the planned roads are not implemented in 2025 or 2035. CO_2 emissions are significantly reduced if the travel speed is improved to 60~80 km/h with the implementation of the planned road.

In addition to that, it is expected that the air pollution inside the city will be mitigated with the implementation of the bypass roads.

10.5.1 Operation and Effect Indicators

JICA introduced operation and effect indicators from 2000 as performance indicators to enable project monitoring and evaluation through comparison with data that has been consistently measured in previous pre- and post-stages of a project. Operation and effect indicators are comparable to outcome indicators used by the World Bank. The year of monitoring and evaluation for the project is 2015 and 2 years after the operation of the project in 2026.

(1) Operation Indicator

An Operation Indicator is defined as an indicator to quantitatively measure the operational status of a project. In this study, the annual average daily traffic on each section of the planned roads (vehicle/day, both ways) is adopted (Table 10.5.1). Sections in each road are shown in Figure 10.5.1

Table 10.5.1 Operation Indicator Annual Average Daily Traffic (veh./day)

		Nacala		Nampula		Cuamba	
		Large Truck	Total	Large Truck	Total	Large Truck	Total
2015	Section 1	(788)	(2,376)	(176)	(847)	(108)	(460)
	Section 2	(788)	(2,376)	(156)	(1,134)	(102)	(399)
	Section 3	(214)	(1,106)	(188)	(1,356)	(94)	(508)
	Section 4	(214)	(1,106)	(84)	(716)	(94)	(482)
2026	Section 1	2,131	9,769	590	3,493	419	1,455
	Section 2	1,939	9,659	599	3,991	408	1,439
	Section 3	817	5,338	626	4,387	418	1,914
	Section 4	833	5,374	439	2,897	439	1,677

Source: JICA Study Team

Note: values in ( ) are based on the results of traffic assignment for 2015 with 2 Lane Case. Traffic volume in 2026 is a linear interpolation of the results of traffic assignment in 2025 and 2035 (With 2 Lane Case). Large Truck means 3 or more axle trucks

(2) Effect Indicator

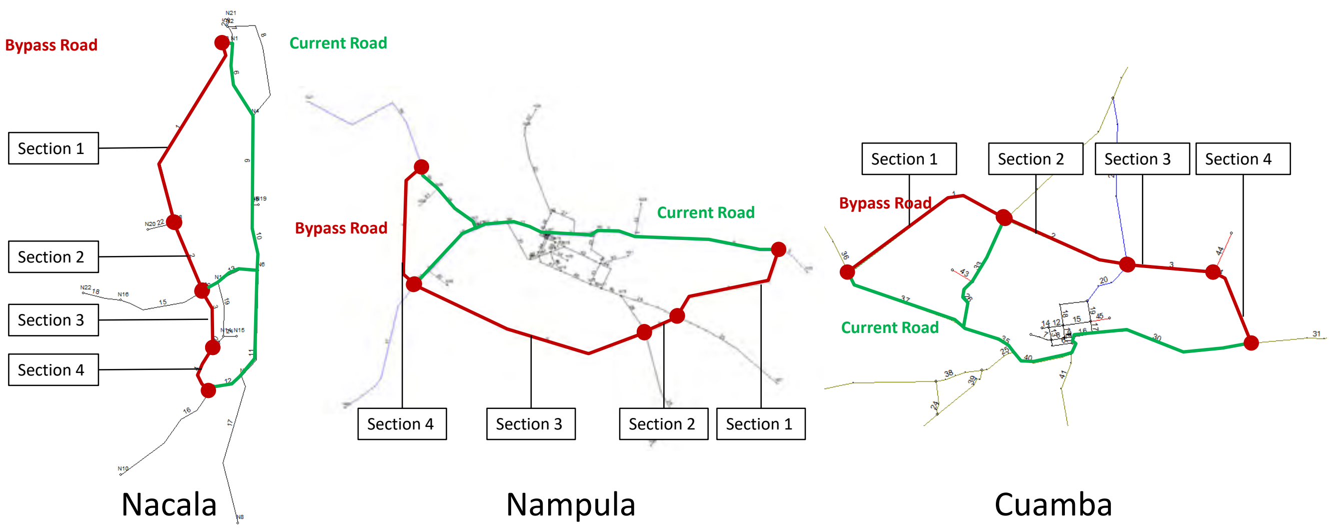
An effect indicator is defined as an indicator to quantitatively measure the effects generated by a project. In this study, travel time is adopted for the effect indicator on the planned roads and the current roads in parallel with the planned roads (Table 10.5.2). The target section is sections 1~4 shown in Figure 10.5.1.

Table 10.5.2 Effect Indicator Travel Time (min.)

	Year	Without	With 2 Lanes	
		Current	Bypass	Current
Nacala	2015	11.0	(8.8)	10.9
	2026	25.2	9.4	11.2
Nampula	2015	15.4	(18.2)	14.9
	2026	44.8	18.6	19.6
Cuamba	2015	20.8	(8.9)	20.8
	2026	20.8	8.9	19.8

Source: JICA Study Team

Note: values in ( ) are based on the results of traffic assignment for 2015 with 2 Lane Case. Traffic volume in 2026 is a linear interpolation of the results of traffic assignment in 2025 and 2035 (With 2 Lane Case).



Source: JICA Study Team

Figure 10.5.1 Road Section of Planned Road and Current Road

For Nampula Southern Bypass Road, it is proposed to add development along the planned road (area of commercial zone) as an effect indicator, even though it is difficult to measure.

CHAPTER 11 Implementation Plan

11.1 Implementation Organization

11.1.1 Establishment of PMU

The JICA Survey Team recommended the establishment of a Project Management Unit (PMU) under DIPRO in ANE in order to facilitate smooth execution of the project. In the case of Nampula-Cuamba Road Upgrading Project (3 sections) co-financed by JICA and the Africa Development Bank (AfDB) and also Massangulo-Lichinga Road Upgrading Project solely financed by JICA, the projects were implemented under the representatives in charge of each section in DIPRO.

However, in this proposal, the PMU will be established before the commencement of detailed design and all tasks to be carried out for the project will be managed by the PMU. As the Project involves new technology that Mozambique has no experience with, the employment of a consultant with plentiful experience in this technology is desirable.

The PMU is responsible for the following:

- Procurement of Consultant and Pre-Construction Services
- Detailed Design
- Land Acquisition and Relocation/Resettlement
- Construction Management

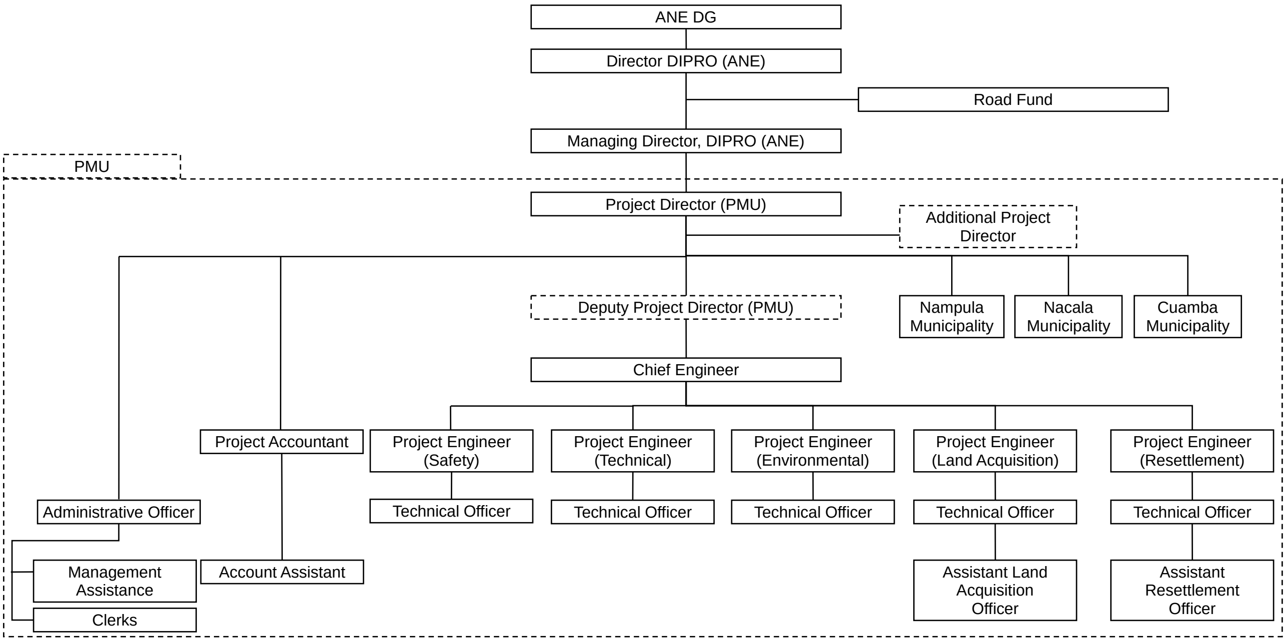
Specific project implementation activities that should be secured are as follows:

- the establishment objectives and specific key performance indicators for the project
- the coordination of regular progress meetings with relevant parties including the consultant and the contractor;
- the associated project management administrative functions from the procurement of the consultant, the contractor evaluation through to completion of the project.
- the cross-cutting coordination between the relevant parties
- the management of cash flows and committed project expenditures

A suitably qualified project director and/or deputy project director will control the PMU on a full-time basis. Some officials from each city government will be assigned to the PMU to coordinate and address the issues that arise in the implementation of the project. The PMU will be expected to place dedicated human resources from state governments.

The organizational structure of the PMU is shown in Figure 11.1.1. The following personnel are required to fulfil the functions of the PMU:

- Project Manager;
- Chief Engineer/ Project Engineers;
- Technical Officer;
- Representatives from City Government;
- Project Accountant;
- Administrative Officer



Source: JICA Survey Team

Figure 11.1.1 Proposed Organization Chart of the PMU (Draft)

11.1.2 Operational Responsibilities for the PMU

(1) Employment for PMU

It is recommended that internal staff from ANE should be utilized, rather than hiring external staff, because the PMU shall serve an integral role with ANE and the city governments (or state governments).

(2) Project Director (PD) / Deputy Project Director (DPD)

The primary responsibilities of the PD/ DPD are shown as follows. The PMU should be located under ANE DIPRO and the PD should periodically report to them. The PD/ DPD should be responsible for overall operation and management of the project, and should coordinate the implementation of the project.

- Integrating, coordinating, project-managing and financially administering (especially payments) the project in his area of jurisdiction;
- Ensuring project compliance with all applicable legislation, policies and conditions;
- Conducting project performance and cash flow reviews;
- Liaising with the state government and responsible ministers of state government as well as other line function departments through formal regular progress meetings and on an ad hoc basis;
- Submitting monthly, quarterly, bi-annual, annual and ad hoc reports to PW as determined in applicable legislation or as required by the Japan ODA Guideline;
- Managing the PMU team and coordinate the respective personnel of other parties

(3) Officials from State Government

State government officials' responsibilities include:

- Administrative and coordination support to the PD/DPD in liaison with the state government;
- Assisting with other related government projects;
- Addressing issues that may arise regarding the project in each state.

(4) Project Engineers

Each project engineer's responsibilities include:

- Delivering technical support and evaluating outcomes for each responsible task and duty in line with the Contract (project drawings and specifications);
- Arranging regular project progress meetings;
- Ensuring compliance with all legal aspects and conditions, as required by the various aspects of government;
- Conducting site visits/meetings to ensure compliance with the contract;
- Verifying payment certificates and preparing monthly payment scheduled documentation;
- Maintaining project performance data in a track record database;
- Assisting with other related government projects.

(5) Project Accountant

Project accountant's responsibilities include:

- Performing final compilation of monthly, quarterly, bi-annual and annual financial reports to ANE;
- Monitoring the consolidated cash flow performance reports on the project;
- Review and administer the monthly claims and expenditures.

(6) Administration Officer

Administration officer's responsibilities include:

- Supporting and assisting with all administrative duties required for the PMU;
- Processing related correspondence and assisting with report generation;
- Coordinating the relevant stakeholders: site-visit reports, procurement, operation and maintenance. etc.

11.1.3 Capacity Requirements of PMU

ANE has a responsibility to ensure that the PMU is to be established and functional prior to the implementation of the project. ANE should be responsible for training suitable officials assigned to the PMU, in terms of proficient communication in the English language, technical and financial capacity, contract administration using FIDIC MDB version (Guideline for Procurement under Japan ODA loan) and monitoring of the project.

11.2 Project Packaging

11.2.1 Objective of Project Packaging

This project is composed of 3 different roads, and is very large scale with new bypass/circular roads including a sea bridge and railway flyovers. Therefore, it is necessary to conduct construction supervision methods that are different from other major road improvement projects by ANE.

In addition, due to the consideration of more than 200km apart from each construction site, the requirements of different materials and equipment procurement, and needs to improve the construction productivity with proper construction step/procedures, separated sections for construction are recommended for smooth implementation of the project.

Therefore, this section discusses the packaging of the project from the technical point of view, especially proper construction plans. The following are depicted with the results of the recommended packaging ideas.

11.2.2 Nacala Port Access Road (3 packages)

Nacala Port Access Road intersects with Road R702, and can establish the construction service roads towards two different directions. In addition, because the sea bridge, which has an amount of construction volume, is supposed to be another package, the project is recommended to be divided into 3 packages as adequate construction packages. The outline of each package and its location are depicted in the table and figures below.

Table 11.2.1 Nacala Port Access Road (3 packages)

Recommended packages	Length *(m)*	Construction Base Cost (mil. USD)	Outline of Package
Package 1 Sea bridge	840	36.5	Includes only the sea bridge, also requires an appropriate connection to Nacala Port Expansion Project. In addition with Package 2, allows accessing Nacala Port from road R702.
Package 2 Sea bridge end ～R702	10,233	32.0	Mainly composed of earthworks activities, it is expected that the construction starts from road R702 (part of the service road already exist). From Nacala Port to Package 1 and 2 it is possible to take a shortcut route to Nacala-a-Velha on the opposite side of the bay.
Package 3 R702～N12	4,130	16.6	Smallest traffic volume from the 3 packages, composed mainly of earthworks activities.

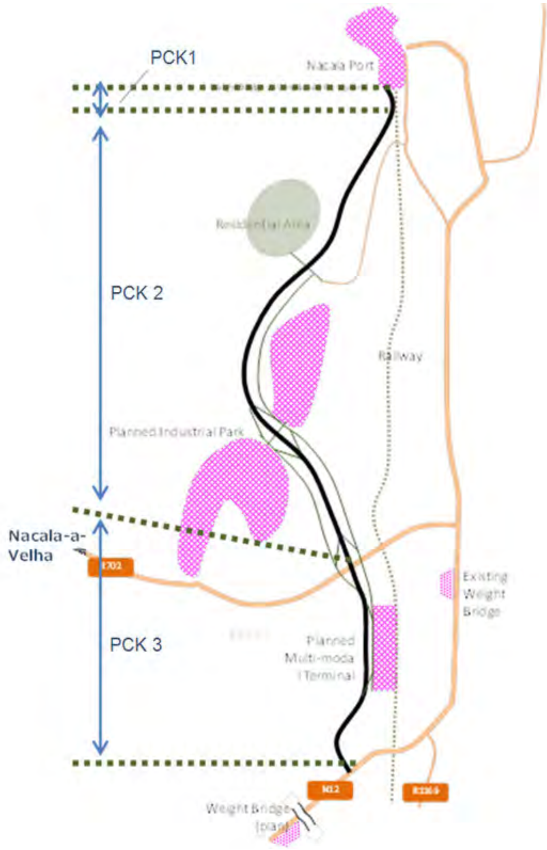


Figure 11.2.1 Section of Packaging for Nacala Port Access Road

With the consideration of local construction capabilities, the construction period of the Nacala Port Access Road done in a single package requires 4.0 years. If the construction section is divided into three packages, the construction period can be reduced to 3.5 years because of the parallel construction. Note that the planned frontage road makes establishing a temporary construction road unnecessary. This affects the reduction of the construction periods by approx. 2 years.

The following table shows the construction period under one package and the reduction of construction period by multiple divided packages.

Table 11.2.2 Construction Periods for Nacala Port Access Road (with divided construction section)

1 Package Alternative

Item	Quantity	Unit	Construction Capability	Unit	Required Period month	Package Part Parts	Construction period year	Total period year
Cutting	605,000	m^3	370	m^3/day	54.5	2	2.3	4.0
Embankment	639,000	m^3	370	m^3/day	57.6	2	2.4	
Road Base Works	166,900	m^3	820	m^3/day	6.8	1	0.6	
Pavement Works	166,900	m^3	1700	m^3/day	3.3	1	0.3	
Bridge 1 (Oversea)	28	Spans	3.5	Months/Span	98.0	4	2.0	
	29	Piers	3.0	Months/Pier	87.0	4	1.8	
Bridge 2 (River)	1	Spans	4.0	Months/Span	4.0	1	0.3	
	2	Piers	3.0	Months/Pier	6.0	1	0.5	

3 Packages Alternative

【PCK 1】

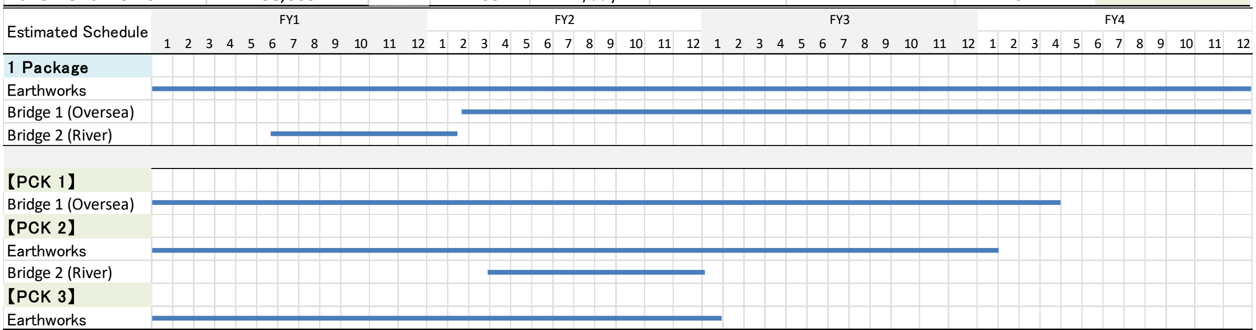
Item	Quantity	Unit	Construction Capability	Unit	Required Period month	Package Part Parts	Construction period year	Total period year
Bridge 1 (Oversea)	28	Spans	3.5	Months/Span	98.0	4	2.0	
	29	Piers	3.0	Months/Pier	87.0	4	1.8	

【PCK 2】

Item	Quantity	Unit	Construction Capability	Unit	Required Period month	Package Part Parts	Construction period year	Total period year
Cutting	420,000	m^3	370	m^3/day	37.8	2	1.6	3.5
Embankment	531,000	m^3	370	m^3/day	47.8	2	2.0	
Road Base Works	108,900	m^3	820	m^3/day	4.4	1	0.4	
Pavement Works	108,900	m^3	1700	m^3/day	2.1	1	0.2	
Bridge 2 (River)	1	Spans	4	Months/Span	4.0	1	0.3	
	2	Piers	3.0	Months/Pier	6.0	1	0.5	

【PCK 3】

Item	Quantity	Unit	Construction Capability	Unit	Required Period month	Package Part Parts	Construction period year	Total period year
Cutting	184,700	m^3	370	m^3/day	16.6	1	1.4	2.1
Embankment	107,900	m^3	370	m^3/day	9.7	1	0.8	
Road Base Works	58,000	m^3	820	m^3/day	2.4	1	0.2	
Pavement Works	58,000	m^3	1700	m^3/day	1.1	1	0.1	



The above construction schedule shows the appropriate schedule with simultaneous construction of 3 different packages. Note that the package-2 and pakage-3 can be implemented independently because the current road (R702) can be utilized as the construction road. Package-3 could also be implemented after the completion of package-2.

11.2.3 Nampula Southern Bypass Road (Three Package)

Is possible to access the construction road not only in the extremities (N1 and N13), but also in all the points where there is a crossing between the project alignment and existing roads. Dividing it into 3 packages where Packages 1 and 3 include an overpass bridge and Package 2 the section in between. Particular details and position are shown for each package below:

Table 11.2.3 Nampula Southern Bypass Road (3 packages)

Recommended packages	*Length (m)*	Construction Cost (mil. USD)	Outline of Package
Package 1 N1 (east)~R686 including Railway Flyover	6,050	23.1	Including the railway flyover, it provides partial traffic diversion route using R686 from Nacala into the central area.
Package 2 R686~N1 (west)	16,070	48.3	Comparing Package 1 and 3, the completion of only this section has less effect for bypassing the urban area. Only if this section is connected with package-1 and 3 provides full capability of the bypass effects. There are no significant large bridges, mainly composed of earthwork activities with long construction site with limited point of construction road.
Package 3 N1 (west) ~N13 including Railway Flyover	8,477	22.3	Including the railway flyover, even if only this section is opened to traffic it is expected to act as bypass from N13 to N1 (south)

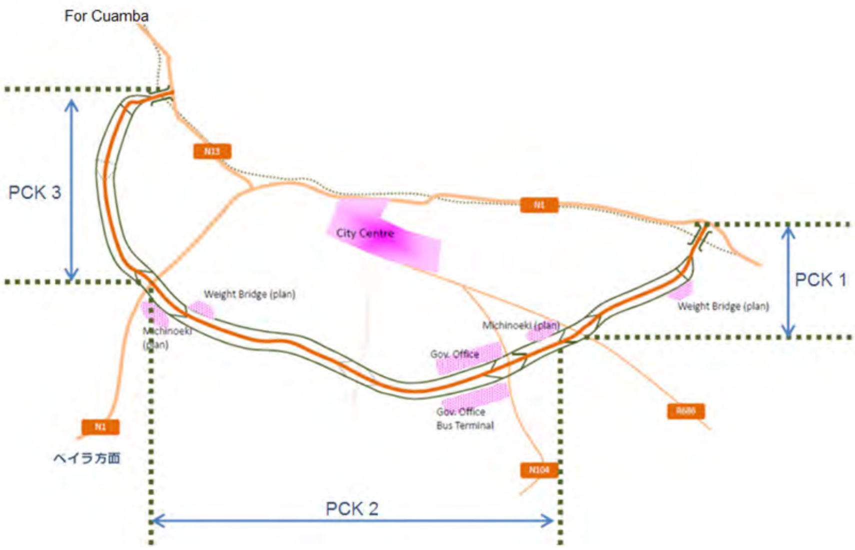


Figure 11.2.2 Section of Packaging for Nampula Southern Bypass Road

With the consideration of the local construction capabilities and number of parties involved in the construction works, the construction period in the case of 1 package is 5.0 years. In the case of being divided into 3 packages and parallel construction, it reduces the total construction to 3.8 years. Since a service road is planned, it is not necessary to establish a construction road, therefore it has already reduced the construction period by approx. 2 years.

The following table shows the construction period under 1 package and the reduction of construction period by multiple divided packages.

Table 11.2.4 Construction Periods for Nampula Southern Bypass Road (Reduction of construction period by packaging)

1 Package Alternative

Item	Quantity	Unit	Construction Capability	Unit	Required Period (month)	Package Part (Parts)	Construction period (year)	Total period (year)
Cutting	1,189,000	m^3	370	m^3/day	107.1	2	4.5	5.0
Embankment	1,070,000	m^3	370	m^3/day	96.4	2	4.0	
Road Base Works	370,000	m^3	820	m^3/day	15.0	1	1.3	
Pavement Works	370,000	m^3	1700	m^3/day	7.3	1	0.6	
Bridge 1 (overpass)	2	Spans	2.5	Months/Span	5.0	1	0.4	
	3	Piers	2.0	Months/Pier	6.0	1	0.5	
Bridge 2	2	Spans	3.5	Months/Span	7.0	1	0.6	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	
Bridge 3	1	Spans	4	Months/Span	4.0	1	0.3	
	2	Piers	2.0	Months/Pier	4.0	1	0.3	
Bridge 4	2	Spans	3.5	Months/Span	7.0	1	0.6	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	
Bridge 5	2	Spans	3.5	Months/Span	7.0	1	0.6	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	
Bridge 6	3	Spans	3.5	Months/Span	10.5	1	0.9	
	4	Piers	3.0	Months/Pier	12.0	2	0.5	
Bridge 7 (overpass)	2	Spans	2.5	Months/Span	5.0	1	0.4	
	3	Piers	2.0	Months/Pier	6.0	1	0.5	
	2	Spans	4.0	Months/Span	8.0	1	0.7	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	

3 Packages Alternative

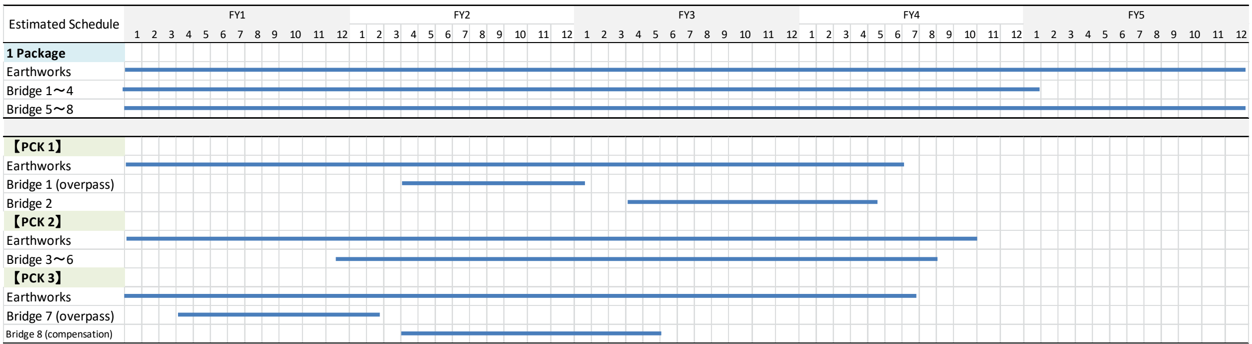
【PCK 1】

Item	Quantity	Unit	Construction Capability	Unit	Required Period (month)	Package Part (Parts)	Construction period (year)	Total period (year)
Cutting	383,000	m^3	370	m^3/day	34.5	2	1.4	3.5
Embankment	187,000	m^3	370	m^3/day	16.8	2	0.7	
Road Base Works	75,000	m^3	820	m^3/day	3.0	1	0.3	
Pavement Works	75,000	m^3	1700	m^3/day	1.5	1	0.1	
Bridge 1 (overpass)	2	Spans	2.5	Months/Span	5.0	1	0.4	
	3	Piers	2.0	Months/Pier	6.0	1	0.5	
Bridge 2	2	Spans	3.5	Months/Span	7.0	1	0.6	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	

【PCK 2】

Item	Quantity	Unit	Construction Capability	Unit	Required Period (month)	Package Part (Parts)	Construction period (year)	Total period (year)
Cutting	890,000	m^3	370	m^3/day	80.2	2	3.3	3.8
Embankment	543,000	m^3	370	m^3/day	48.9	2	2.0	
Road Base Works	189,000	m^3	820	m^3/day	7.7	1	0.6	
Pavement Works	189,000	m^3	1700	m^3/day	3.7	1	0.3	
Bridge 3	1	Spans	4.0	Months/Span	4.0	1	0.3	
	2	Piers	2.0	Months/Pier	4.0	1	0.3	
Bridge 4	2	Spans	3.5	Months/Span	7.0	1	0.6	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	
Bridge 5	2	Spans	3.5	Months/Span	7.0	1	0.6	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	
Bridge 6	3	Spans	3.5	Months/Span	10.5	1	0.9	
	4	Piers	3.0	Months/Pier	12.0	2	0.5	

【PCK 3】								
Item	Quantity		Construction Capability		Required Period	Package Part	Construction period	Total period
		Unit		Unit	month	Parts	year	year
Cutting	77,000	m^3	370	m^3/day	6.9	1	0.6	3.6
Embankment	339,000	m^3	370	m^3/day	30.5	1	2.5	
Road Base Works	100,000	m^3	820	m^3/day	4.1	1	0.3	
Pavement Works	100,000	m^3	1700	m^3/day	2.0	1	0.2	
Bridge 7 (overpass)	2	Spans	2.5	Months/Span	5.0	1	0.4	
	3	Piers	2.0	Months/Pier	6.0	1	0.5	
Bridge 8 (compensation)	2	Spans	4.0	Months/Span	8.0	1	0.7	
	3	Piers	3.0	Months/Pier	9.0	1	0.8	



Even if package-1 and 3 are constructed by the same contractor, the same schedule can be held if each earthwork and bridge work of each package is scheduled alternately (see above construction scheduling table).

It is also possible to start construction of the package-2 after completion of the packages-1 and 3, which can reduce the number of construction related vehicles.

11.2.4 Cuamba Bypass Road

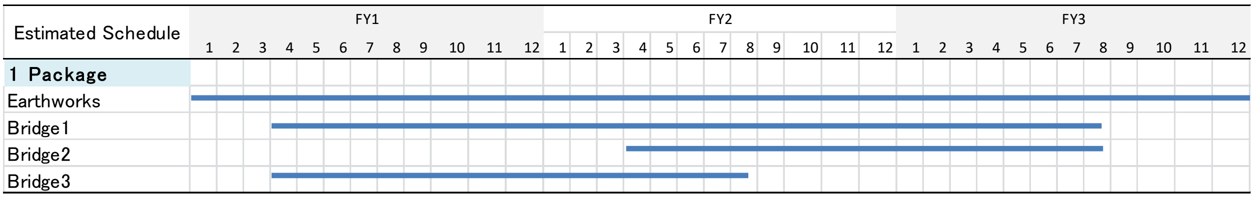
Because the Cuamba Bypass Road is not so extensive (12,050m) and there are no large structures, it does not have any advantage in being divided into smaller packages. The only possibility is to separate the section of the river bridge with a different contractor. However, it still requires the construction road for the river bridge, so that 1 package is enough for this project.

The following table shows the construction period with consideration of the local construction capabilities. It is expected to be finished within approximately 3.0 years.

Table 11.2.5 Construction Period of Cuamba Bypass Road

1 Package Alternative

Item	Quantity		Construction Capability		Required Period	Package Part	Construction period	Total period
		Unit		Unit	month	Parts	year	year
Cutting	35,700	m^3	370	m^3/day	3.2	1	0.3	3.0
Embankment	239,000	m^3	370	m^3/day	21.5	1	1.8	
Road Base Works	140,000	m^3	820	m^3/day	5.7	1	0.5	
Pavement Works	140,000	m^3	1700	m^3/day	2.7	1	0.2	
Bridge 1	6	Spans	2.5	Months/Span	15.0	1	1.3	
	7	Piers	2.0	Months/Pier	14.0	2	0.6	
Bridge 2	3	Spans	3.5	Months/Span	10.5	1	0.9	
	4	Piers	3.0	Months/Pier	12.0	2	0.5	
Bridge 3	3	Spans	4	Months/Span	12.0	1	1.0	
	4	Piers	2.0	Months/Pier	8.0	2	0.3	



11.3 Project Implementation Schedule

The preconditions considered regarding the project implementation schedule are shown below. In the next stage, the items bellow shall be discussed and probably will need to be adjusted.

Table 11.3.1 Preconditions for consideration of Implementation Schedule

Items	Preconditions
Financial Arrangement	Will be discussed with Financers
Consultant Selection	Usually done in 12 months
Detailed Design	Defined by the consultant (depending on the project scale)
Contractor selection	Depending on the implementation agency. Estimated in 15 months If PQ is required, 12 months if not.
Construction Period	Number of months depending on project scale
Land acquisition/ Resettlement	Depending on the implementation agency. Shall be completed before the beginning of the construction works

The following diagram gives the implementation schedule of the project.

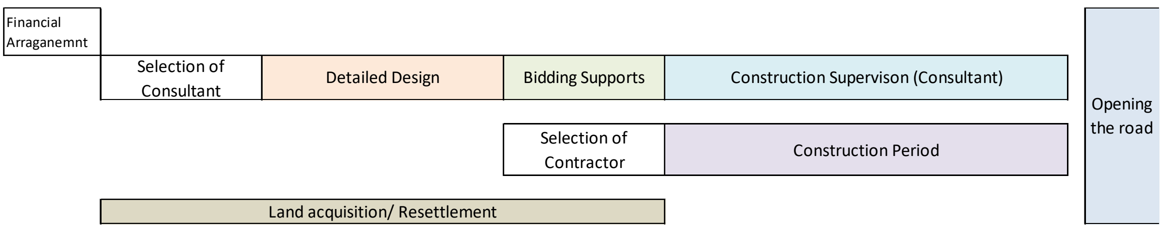


Figure 11.3.1 Project Implementation Schedule

11.4 Management Plan

11.4.1 Outline

The 3 target routes are by-pass roads or a harbour access road located in the important points for traffic on Nacala international corridor. Therefore, a plan for suitable maintenance should be drawn up and also implemented, because it is important for the facilities to be well kept and it is necessary for traffic flow to be smooth as always. As mentioned, the Directorate of Maintenance (DIMAN) is in charge of the road maintenance in ANE. There are 3 categories of maintenance as follows in the maintenance of the target routes of this project.

- Routine Maintenance
- Periodic Maintenance
- Emergency Maintenance

Routine Maintenance

Routine Maintenance includes removing those things which could be an obstacle for traffic such as garbage, debris, soil and stones, mowing on slopes, cleaning drainage facilities and etc. The frequency of routine maintenance varies from every 1 day to every 1 year and usually depends on some conditions such as traffic volume. However, it is desirable for the roads in this project to be cleaned and maintained at least every 1 week, because they are forecast to have a large amount of traffic in the future as the main roads.

ANE has a guideline for maintenance/ evaluation of roads and bridges, and the subcontract consultants are supposed to implement it 3 times per week.

Moreover, a repair will be implemented as soon as possible if they find any of the following damages.

- Rut/ Pot hall（Small patching）
- Crack（Small Sealing）
- Damage on Shoulder（Partial repair or fairing）
- Clog in Drainpipe
- Dirt on Culvert or Side Wall
- Damage on Guardrail or Street Lamp
- Peeled Pavement from Guardrail or damaged Traffic Sign

Periodic Maintenance

Periodic Maintenance includes overall repairs in the mid-and-long term such as the whole repair of pavement and repaving, and a large-scale patching, sealing and etc. and it is supposed to be implemented about every 15-20 years in general. The traffic should be regulated on a comparably large scale by this maintenance.

Emergency Maintenance

Emergency Maintenance will be implemented when the road or bridge structures suffer severe damage and need to be repaired as soon as possible because of natural disasters, big accidents and etc. This maintenance is necessary in unanticipated accidents such as the following examples in Mozambique.

- Landslide of Embankment/ Cut because of Heavy Rain
- Damage to Bridge, Embankment, Pavement, Sidewall and etc. because of the collision of Big Vehicles

In many cases, this Emergency Maintenance should be divided into 2 stages in order to minimize its influence on suspending traffic flow. The 1st stage includes an implementation of emergency measures enabling traffic to flow temporarily, and the 2nd stage includes implementation of the overall repair enabling structures to ensure to have stable strength in the future.

11.4.2 Proposed Management Framework and System

In the current management system for national roads each state is in charge of selecting consultants and they will maintain and evaluate them on the basis of the outcome of the maintenance and drawn up maintenance plan, and implement management for the procurement of routine maintenance under the approval of ANE DIMAN. Also, the headquarters of ANE is in charge of the procurement of periodic maintenance.

As the international main roads will have been constructed on Nacala Corridor, ANE should formulate a management system focusing on them due to the increasing total length of roads to be maintained.

Concretely, the constructed management system should be able to deal with the following points.

- Infrequent checks on site due to the distant location of the administrative offices or ANE headquarters
- Constant comprehension of damage situations from the unified point of view the same as the visual inspection by engineers
- Accumulation of the necessary accurate data to change the maintenance system to a preventive one
- Prevention from overlapping and unproductiveness under the repair history on the basis of the location coordinates

As one of the technologies for their needs noted above, the Study Team recommends the installation of the integrated system to utilize 360^0 images, and comprehend damage situations and maintenance features with 3-dimension data as shown in Chapter 9.7. This will enable ANE headquarters to make the procurement of engineers, surveys and maintenance tasks more efficient than before, and naturally decrease the cost for the maintenance.

11.4.3 Cost Estimation for Maintenance

The cost for maintenance in both the High-spec and Basic-spec plans at the time of starting the operation of the temporary two-lanes has been estimated in following way. This estimation result will be calculated as the cost in the economic analysis.

- Annual cost for pavement maintenance: 3% of initial cost for pavement (in distinction from main lanes to side lanes)
- Large-scale repair (cutting overlay): every 15 years (just for surface and binder courses)
- Annual cost for bridge maintenance: 16% of the initial construction cost for bridges is assumed to be equal to the total maintenance cost for 30 years. (on the basis of Japanese experience)

Averaging the total cost for 30 years year by year, the estimation result of the maintenance cost for 1 year is shown as follows

Table 11.4.1 Cost Estimation for Maintenance（million JPY/ Year）

	High-Spec Plan	Basic-Spec Plan
Nacala Port Access Road	**124.9**	**107.3**
Maintenance of Main-lane Pavement	61.3	61.3
Maintenance of Side-lane Pavement	6.1	6.1
Large-scale Repair of Pavement	23.4	23.4
Maintenance of Bridge	34.1	16.5
Nampula Southern Bypass Road	**180.0**	**157.9**
Maintenance of Main-lane Pavement	61.1	61.2
Maintenance of Side-lane Pavement	23.1	23.1
Large-scale Repair of Pavement	62.1	62.1
Maintenance of Bridge	33.7	11.4
Cuamba Bypass Road	**43.6**	**42.7**
Maintenance of Main-lane Pavement	19.0	19.1
Maintenance of Sidewalk Pavement	0.5	0.5
Large-scale Repair of Pavement	14.1	14.1
Maintenance of Bridge	10.0	9.0

Source: JICA Survey Team

CHAPTER 12 Environmental and Social Considerations

12.1 Introduction

Activities associated with environmental and social considerations of the project from procurement of the environmental consultants, implementation of the natural and social environmental surveys, convening of the public consultation, to preparation and submission to the Ministry of Land, the Environment and Rural Development (MITADER)/Provincial Directorate of Land, Environmental and Rural Development (DPTADER) of the environmental reports have all been carried out directly by the project promoter (i.e. ANE) under their responsibility in this project. JICA Study Team provided technical support and advice to ANE throughout this process, including reviewing and commenting on the reports produced by the environmental local consultant, so that the work could be carried out in a way that better meets both the requirements set forth in the legislation in Mozambique and importantly those internationally-recognized good practice primarily the Japan International Cooperation Agency Guidelines for Environmental and Social Considerations (April 2010).

At the outset of the project, all three projects shown in '12.2.1 Summary of the Project Components' were to be subject to the environmental investigation carried out under this study. However, environmental consultants' procurement was continuously being delayed. In view of this situation, JICA confirmed internally that the three projects are separable in nature and Nacala Port Access Road Project should be considered Category B in accordance with JICA Environmental Guidelines (cf. others are considered to be Category A). Based on this understanding, JICA and ANE agreed on June 28, 2016 that JICA concentrates its technical support for environmental and social considerations on the Nacala Port Access Road Project leaving the other two projects out of its scope.

After the consultant was procured, the environmental work commenced and the Simplified Environmental Report (SER) and Resettlement Plan (PR) were produced by the consultants and submitted to DPTADER for the Nacala Port Access Road Project. But the reports needed to be improved in JICA's view in order for the organization to provide financial assistance for the project. JICA hence decided to step up its support and not only review the reports but make modifications to them to the extent feasible within the time and resources available. This was done by JICA Study Team in November, 2017 in Mozambique in close consultation with ANE and the local consultant. The reports produced as a result of this work are shown in Appendix 10 and 11.

In this chapter, major results of the preliminary study carried out by the JICA Study Team (i.e. study made up to submission of the Interim Report) will be presented including the information and comments given to and by the Working Group of the JICA Advisory Committee held on July 13, 2015. Despite the improvements made by JICA Study Team to the SER and PR, some important limitations still remain for especially the PR and in the way in which the survey was carried out to produce it. These points will be elaborated in the section that follows in hope that they will serve as a reference when carrying out a supplementary study for project implementation in the future. Finally, the current state in which Nacala Port Access Road Project lies as well as that of the projects in Nampula and Cuamba will be described in brief.

12.2 Results of the Environmental Study Carried out by JICA Study Team

12.2.1 Summary of the Project Components

Summary and location map of the projects is shown below:

- Nacala Port Access Road: approximately 15.2 km[1] (2 lanes for each direction)
- Nampula Southern Bypass Road[2]: approximately 30.6 km[3] (2 lanes for each direction)
- Cuamba Bypass Road[4]: approximately 12.1 km[5] (1 lane for each direction)

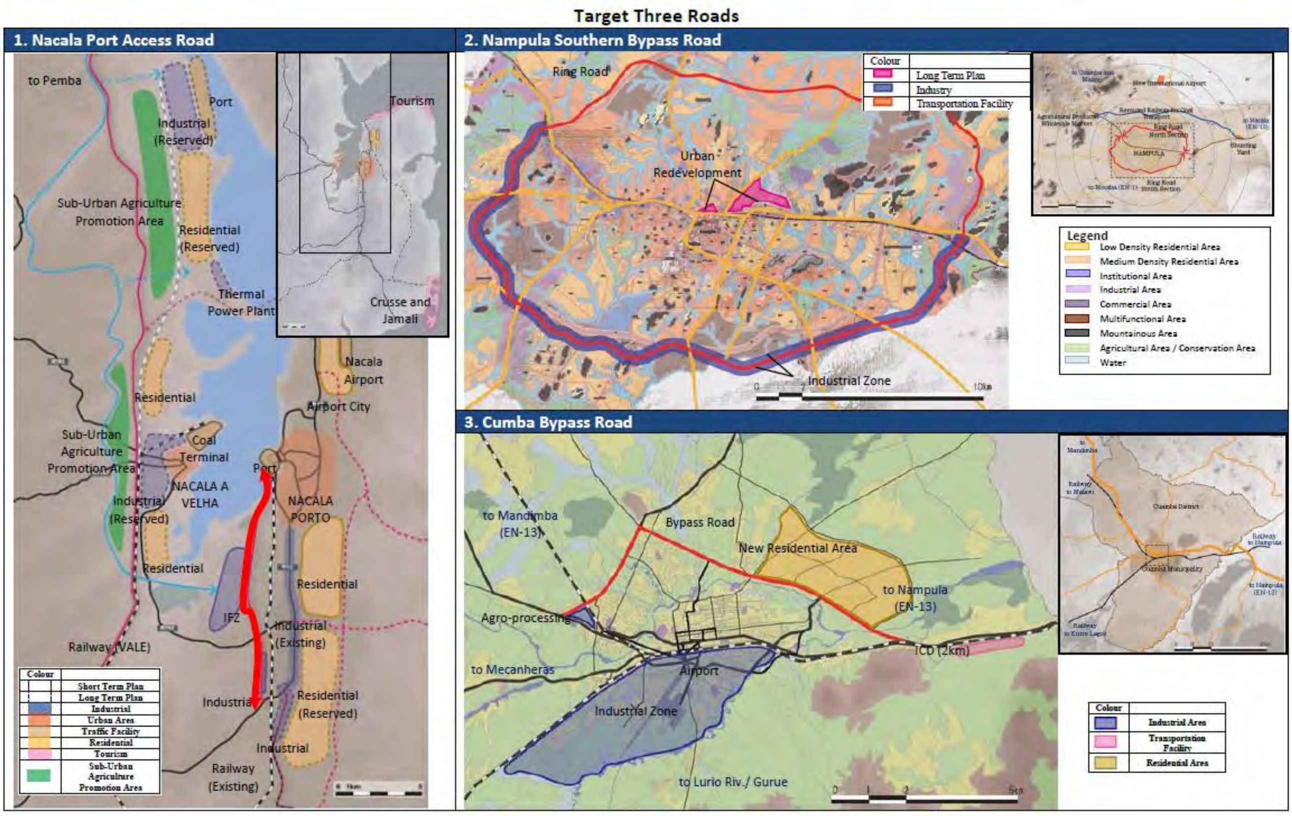


Figure 12.2.1 Three Target Roads

As it will be explained in the latter section, Nacala Port Access Road and Nampula Southern Bypass Road belongs to "50m from a road shoulder" and Cuamba Bypass Road corresponds to "30m from a road shoulder" under the Land Law (No. 19/1997). Accordingly, 120.5m is set to be the ROW of Nacala Port Access Road and Nampula Southern Bypass Road and 67.0m is set to be the ROW of Cuamba Bypass Road. A typical cross section (draft) for the two types of road is shown below.

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[1] The latest planned length of road is shown here.
[2] This project is out of the scope of the environmental investigation at the moment.
[3] The latest planned length of road is shown here.
[4] This project is out of the scope of the environmental investigation at the moment.
[5] The latest planned length of road is shown here.

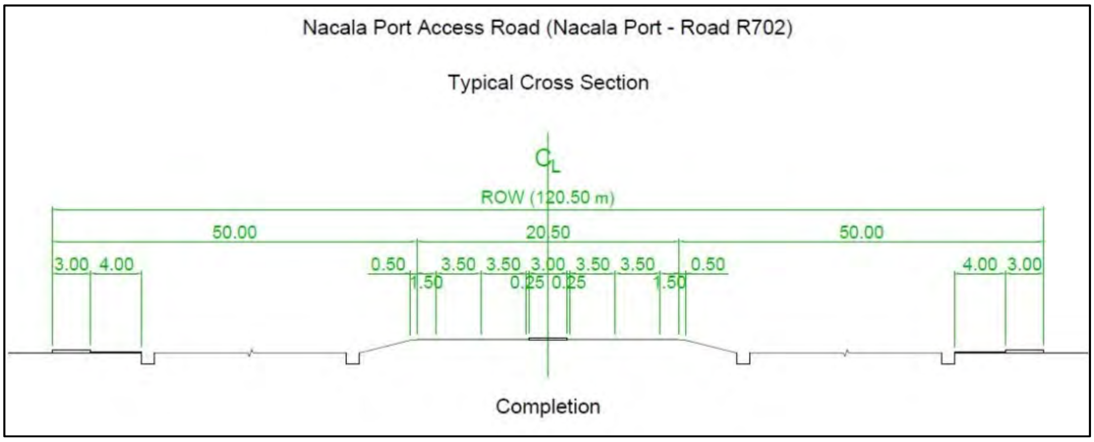


Figure 12.2.2 Typical Cross Section (draft/two lanes on each side, ROW = 120.5m/Nacala Port Access Road and Nampula Southern Bypass Road)

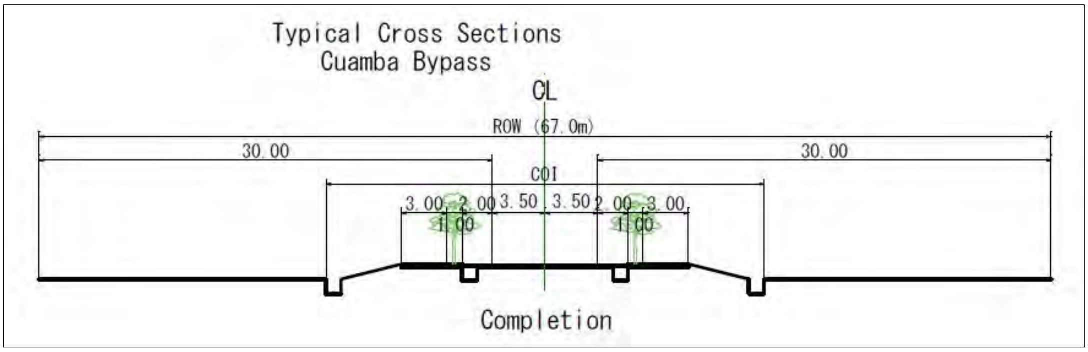


Figure 12.2.3 Typical Cross Section (draft/one lane on each side, ROW = 67.0m/Cuamba Bypass Road)

12.2.2 Current State of the Environment in the Subject Area

(1) Natural Environmental Condition

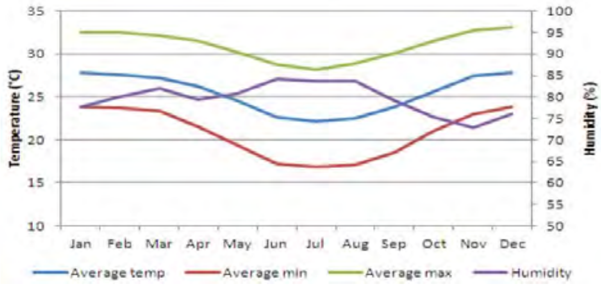
a) Climate

Mozambique is located from 10 ° 27' to 26 ° 52' of south latitude, and from 30 ° 12 to 40 ° 51' of the east longitude. The total area of the land is 786,380km^2. Nacala corridor is located in the northern region of Mozambique. The corridor extends for approximately 900km from the north to south and approximately 1,100km from east to west. There is a rainy season and a dry season in Mozambique. The rainy season is from November to April during which time it is warm and humid. The dry season is cool and dry and is from May to October. The following figure shows the average temperature and monthly precipitation/humidity in Nampula province (Nacala City and Nampula City) and Niassa province (Cuamba City).

Nacala City

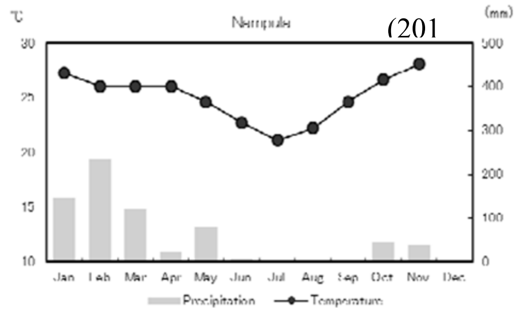
This data is related to the Lumbo because there is no existing data related to NacalaCity.

Source: Environmental Impact Study (EIS) for Rehabilitation and Extension of Nacala Port, 2012/9)

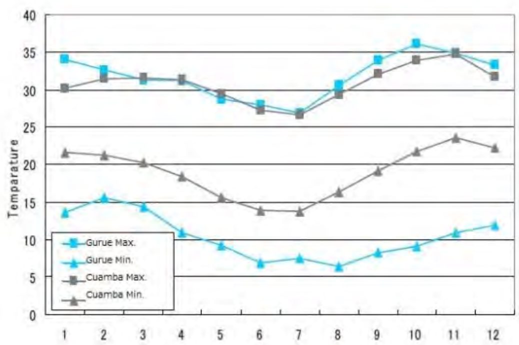


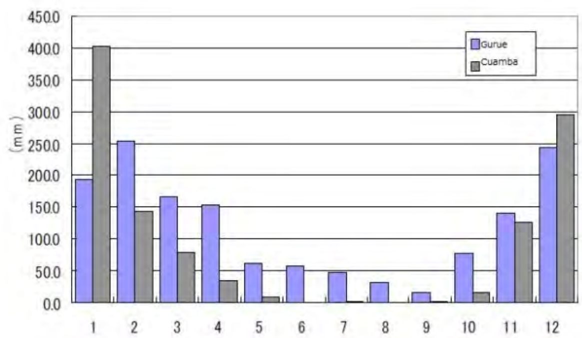
Nampula City

Source: PEDEC-Nacala



Cuamba City





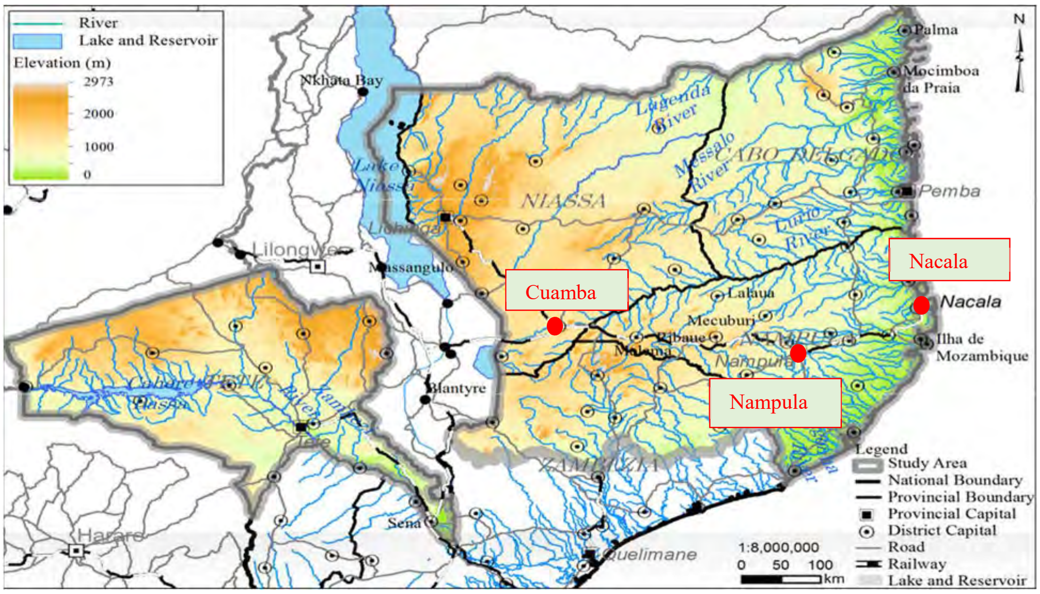
Source: PEDEC-Nacala

Figure 12.2.4 Average Monthly Temperature and Precipitation/Humidity in Nampula and Niassa Province

b) Geography

Regarding the geography of the Nacala Corridor region, It is divided into three segments, the land near the coastal lowlands from the east of Nacala City (elevation 0~200m), the middle of the plateau at Nampula City (elevation 200~500m), and the Plateau area of Cuamba City (500~1,000m).

Northern Mozambique is a Bedrock Zone except for the coastal areas, the geology is a metamorphic complex rock body formed in the late Precambrian, and it is called the Mozambique Band. The Mozambique Band is divided into north and south by the structure line which is called the Lurio belt formed by the Paleozoic early crustal movement. There are various intruded igneous rocks in the southern Nampula zone. On the other hand, there are relatively few intrusive rocks in the northern area called Marupa. Sedimentary rocks formed later are classified as the Karoo system formed in the Paleozoic age and are widely distributed in southern Mozambique. Sedimentary rocks in a sedimentary basin were formed by the crustal deformation associated with the East African Rift Valley after the Mesozoic. Mudstone, sand stone and limestone deposed from the end of the Mesozoic to the Tertiary Cenozoic is distributed in the northern coastal area.



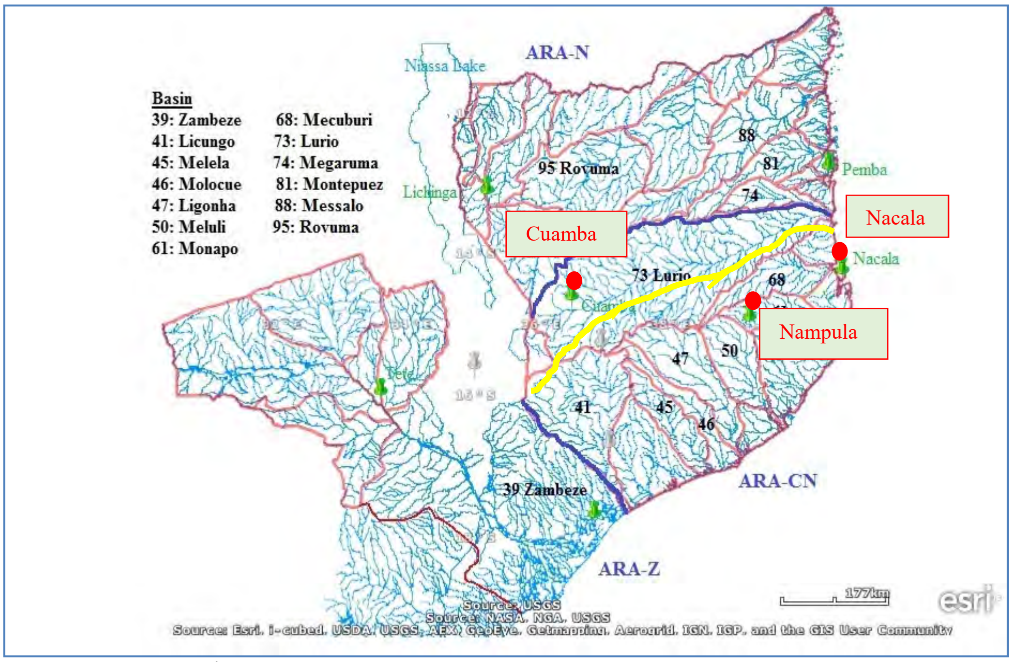
Source: PEDEC-Nacala

Figure 12.2.5 Elevation Map in Nacala Corridor Region

c) Rivers and Niassa Lake

Annual precipitation level across the Nacala Corridor region is 1,030mm in the Lurio river basin, 900 ~ 1100mm in the Rovuma river basin and 1,400mm in Licungo river basin. Precipitation level in the Luia tributary area in the upstream region of the Zambezi basin is 615~753mm less than the other regions. Related rivers and Niassa Lake in Nacala corridor region are as follows:

- Zambezi river: Catchment area 1,390,000 km^2, Outflow 107,979 million m^3/year, 3,424 m^3/sec
- Rovuma river: Catchment area 155,500 km^2, Outflow 14,980 million m^3/year, 475 m^3/sec
- Lúrio river: Catchment area 61,423 km^2, Outflow 8,722 million m^3/year, 277 m^3/sec
- Niassa lake: Dimension 29,600 km^2, storage capacity 8,400 km^3



Source: PEDEC-Nacala

Figure 12.2.6 Rivers and Niassa Lake in Nacala Corridor Region

The Lurio river basin is located in the study area. There is Muwanda River that is a tributary of Lurio River at Cuamba (yellow Line). The river basins around Nacala and Nampula feed small rivers.

The water source for Nacala is Muecula dam (Nacala dam) located approximately 28km away from the centre of the city. This dam supplies water of 7,200m^3/day, but it is short of the demand of 10,200m^3/day of Nacala City. The water source of Nampula is Monapo dam on Monapo River located 9km from the centre of the city. The average supply is 17,000m^3/day but it is expected to experience a water shortage in the near future so renovation is ongoing. The water source of Cuamba is Mepopolo dam in Mepopole River that is a Lurio river tributary. It is located approximately 30km away from the city centre. It is expected that there will be a water shortage in Cuamba too.

d) Biodiversity and Protected Areas

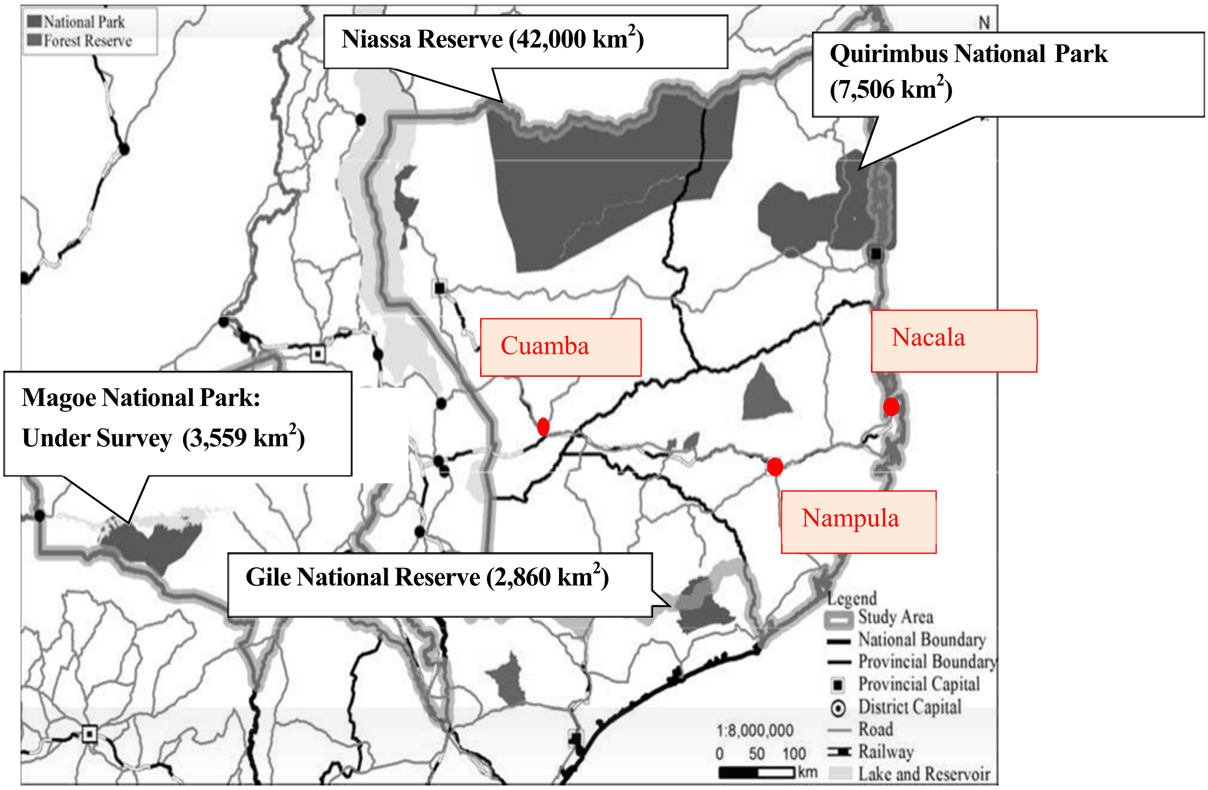
There are regions having rich ecosystem such as the Gorongoza Mountains and Quirinbus Islands in Mozambique. About 685 kinds of birds, 195 species of mammals, 228 species of reptiles, 59 types of amphibians and 5,700 kinds of plants have been found to be endemic. There are six categorised protected areas as shown in the following table. The total area is 147,345 km^2 and occupy approximately 18% of the country.

Table 12.2.1 Classification of Protected Areas

	Classification	Location	Dimension (km²)	Occupancy (%)
1	National Park	6	37,476	4.68
2	National Reserve	6	47,700	5.95
3	Game Controlled Area	2	2,700	0.34
4	Hunting Area	12	50,017	6.24
5	Forest Reserve	26	9,452	1.18
6	Zones of use and historic and cultural value	0	0	0
Total			147,345	18.38

Source: MICOA (2009) "4th National Report on Implementation of the Convention on Biological Diversity in Mozambique."

There are four protected areas (one area is under scrutiny) in the northern area as shown in the following figure. The subject roads are not located in those protected area. The nearest protected area is Quirimbus National Park located around 250km from Nacala Port Access Road.



Source: PEDEC-Nacala

Figure 12.2.7 Protected Areas near Nacala Corridor

(2) Social and Economic Conditions

a) Population

Population and its growth rate in Nampula and Niassa province are shown below.

Table 12.2.2 Population and Population Growth Rate in Nampula and Niassa Province

Province	Population		Annual Growth Rate (%) 1997 - 2007
	1997	2007	
Niassa	808,572	1,213,398	4.14
Nampula	3,063,456	4,084,656	2.92
Mozambique (all the Country)	16,075,708	20,632,434	2.53

Source: PEDEC-Nacala

The populations in the urban areas and rural areas are shown in the following table. The rate of urbanisation in Nampula and Niassa Province is lower than the rate of all the country.

Table 12.2.3 Population living in Urban and Rural Areas in in Nampula and Niassa Province (2007)

Province	Urban area (%)	Rural area (%)	Total
Niassa	277,838 (23%)	935,560 (77%)	1,213,398
Nampula	1,167,813 (29%)	2,916,843 (71%)	4,084,656
Mozambique (all the country)	6,269,621 (30%)	14,362,813 (70%)	20,632,434

Source: PEDEC-Nacala

b) Ethnic Distribution

Around 40 ethnic groups exist in Mozambique and Makua-Lomwe people account for approximately half of the population. Other groups include Xisonga-Xironga people (24%), Yangja-Sena people (12%), Shona (6%), Portuguese and Indian people. Ethnic distribution in the Nacala Corridor region is the same as nationwide where Makua-Lomwe makes up a bulk of the population. Other groups include Maconde, Yao, Nyanja, Nguni and Shona people. Makua-Lomwe people and Maconde people in the Nacala corridor region had been in conflict politically during the civil war but there is no such conflict now.

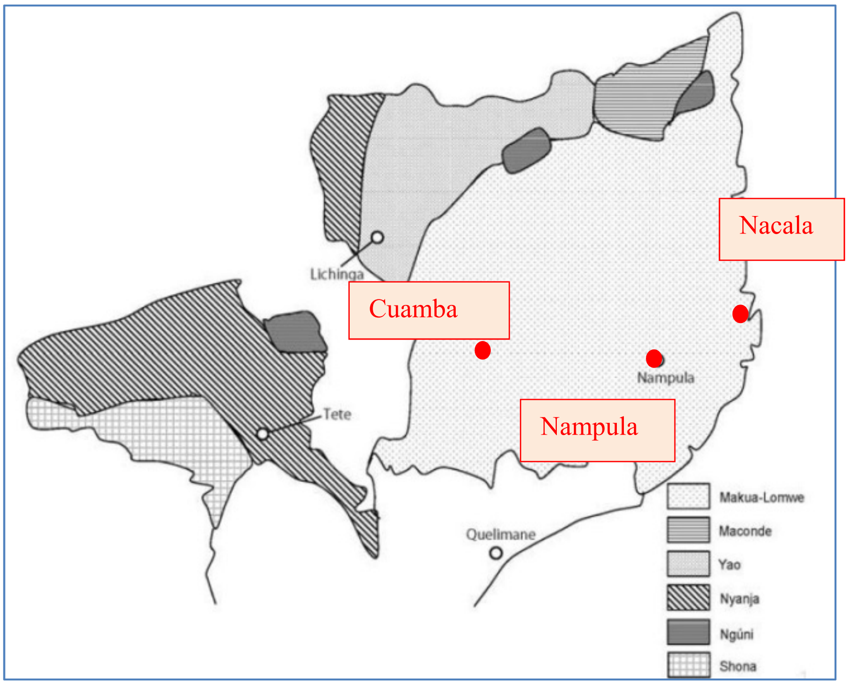


Figure 12.2.8 Ethnic Distribution in Nacala Corridor Region

c) Poverty Rate and Gender Equality

GDP per capita is 1,561 USD in Maputo (2009), which is equivalent to the number seen in middle income countries. On the other hand, per capita GDP in the Northern five provinces is 271 USD, which is less than the national average of 453 USD (2009). There are large gaps in terms of poverty rate, which was 53% (2009) in the northern area compared to the rate in Maputo (36.2%/2009). In terms of gender equality, the illiteracy rate of women is more than 60%. Even though the maternal mortality rate is 550/100,000 people that is less than the average of Sub-Sahara Africa (640), it is still considered to be very high. The ratio of female heads of households is 62.5% and around 62% of women are dedicated to agricultural production. Many women engage in labour-intensive works in Nacala corridor region.

d) Economic Condition

The Gross Regional Domestic Product (GRDP) is shown in the following table.

Table 12.2.4 GRDP and Annual Economic Growth Rate in Niassa and Nampula Province

Province	GRDP (Million MZN, 2003)				Average Annual Growth Rate (%)		
	1997	2000	2007	2011	1997-2000	2000-2007	2007-2011
Niassa	2,368.3	2,651.9	4,587.0	5,930.7	3.8	8.1	6.6
Nampula	10,634.7	13,118.0	22,192.3	29,321.3	7.2	7.8	7.2
All the country	69,073.7	84,989.3	151,299.9	197,524.4	7.2	8.6	6.9

Source: PEDEC-Nacala

Sectoral GRDP in 2000 and 2011 are shown in the following table.

Table 12.2.5 Sectoral GRDP in Niassa and Nampula Province

Province	2000 (%)				2011 (%)			
	Agriculture	Industry	Service	Total	Agriculture	Industry	Service	Total
Niassa	47.6	10.2	42.2	100.0	49.5	7.2	43.4	100.0
Nampula	38.7	15.4	45.9	100.0	39.9	17.0	43.1	100.0
All the country	27.9	21.5	50.7	100.0	27.7	23.7	48.6	100.0

Source: PEDEC-Nacala

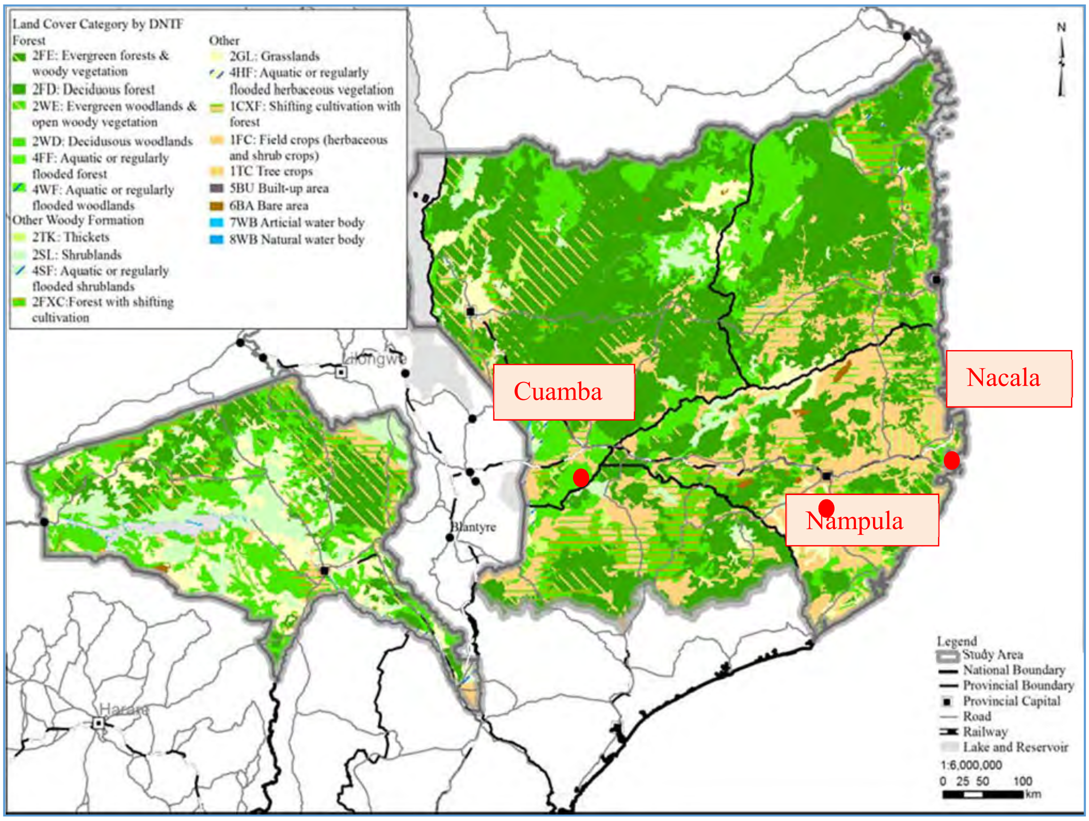
e) Land Use

The current land use status in Nacala Corridor region is shown in the following table. Around 58% of the area is composed of dense and open forest according to a survey carried out by the Ministry of Agriculture named Zoneamento Agro-Eocológico Nacional (ZAE). There have been changes in land use from 1994 to 1995 and from 2004 to 2005. During that time, deforestation has been progressing especially around the main road in Lurio River basin in Nampula province.

Table 12.2.6 Land Use in Nacala Corridor Region

Classification	Dimension (km^2)	%
Dense Forest	58,836	13.6
Open Forest	192,809	44.5
Prairies	43,911	10.1
Aquatic or Regularly Flooded Woodlands, Bushes, and Mangrove	1,647	0.4
Forest with Shifting Cultivation	52,648	12.2
Agriculture	65,425	15.1
Built-up area and Bare area	5,514	1.2
Water	12,285	2.8
Total	433,072	100.0

Source: PEDEC-Nacala



Source: PEDEC-Nacala

Figure 12.2.9 Land Use in Nacala Corridor Region

(3) Pictures of Target area

a) Nacala Port Access Road

Nacala Port. There are two hulks near the coast.

The coast near Nacala Port when it is low tide.
It is flooded when the tide is high

Soil erosion area at existing road away around 1km from the planned route. People and car cannot pass here.

South-East side of Nacala Port. There is an oil pipeline and a grave (under a tree).

This is an existing road and central part of the planned route.
Bridge construction is planned around here.

Along the planned route at south parts.
There are women who are washing clothes.

Figure 12.2.10 Pictures of Site for Nacala Port Access Road

(4) Nampula Southern Bypass Road


House located near existing road. There are fruit trees and agricultural land around here.


Farmland located west side of planned route. Cassava, maize, and beans are cultivated.


Existing well in a community located on the Westside of the planned route. This well cannot be used during dry season.


Railway located on the eastside of the planned route. There are some houses around here.


Vegetation area located near the eastside of the planned route. Power line passes near this point.

Existing road located on the eastside (R104: unpaved). Dust is clouded when car pass this road

Figure 12.2.11 Pictures of Site for Nampula Southern Bypass Road

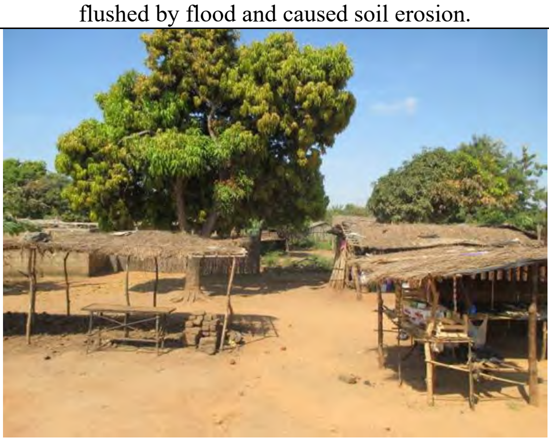
(5) Cuamba Bypass Road

Muanda River located eastside of planned route. There are farmlands at the Southside of river.

Cassiano Bridge which connected the Njane and Adine 3 area fell down last January by flood so the residents are currently using a thin unstable iron bar as an emergency alternative.

The area near Cassiano Bridge. Some buildings had been flushed by flood and caused soil erosion.

Planned route (existing road, N13). Water Purification Plant is under construction supported by AfDB.



Huts located at west side of existing road (N13). Some small shops are opened and people come here to buy.

Houses and Farmlands located near north side of planned route. Maize and beans are cultivated.

Figure 12.2.12 Pictures of Site for Cuamba Bypass Road

12.2.3 Relevant Laws and Regulations

(1) Laws and Regulations in Mozambique

a) Framework

Laws and regulations in Mozambique are shown below.

Table 12.2.7 Classification of Laws and Regulations

Rank	Law and Regulation	Related authorities
1	Constitution	Assembly of the Republic（Parliament）
2	Law	Assembly of the Republic
3	Decree-Law	Council of Ministers
4	Decree	Council of Ministers
5	Presidential Decree	President of Republic
6	Ministerial Resolution	Ministry or Ministers, jointly
7	Ministerial Oder	Minister

Source: SADC Environmental Legislation Handbook 2012

b) Environmental Administration and the Master Plan

The National Environmental Commission (NEC) was established in 1990. Development of laws and policies related to the environment that have been delayed were started. The Ministry of Coordination of Environmental Affairs (MICOA) was established in 1995 and the National Environmental Management Programme has been enacted as a Master plan. In January 2015, reorganisation of government ministries began implementation. A new ministry named MITADER was created to be responsible for environmental administration.

c) Laws related to Environmental Issues

The Environmental Law (No. 20/1997) as a basic law related to environmental protection was enacted in October 1997. Decree 45/2004 is the law that regulates Environmental Impact Assessments (EIA). Other laws and regulations are shown below.

Table 12.2.8 Laws and regulations related to Environmental and Social Considerations

Legal Framework	
Constitution of the Republic of Mozambique (16 Nov. 2004)	Constitution and responsibility
National Environmental Policy (Resolution 5/1995)	Environmental Policy
Environmental Law (Decree 20/1997)	Basic framework
Environmental Impact Assessment Regulations (Decree 45/2004, 42/2008)	EIA, regulation and framework
Environmental Standards	
Regulation on Environmental Quality and Emission Standards (Decree 18/2004)	Air, water and soil etc.
Approval, Permission, Inspection and Audit	
(Environmental Law: Decree 20/1997)	Environmental permission
Regulations regarding water licensing and Concessions (Decree 43/2007)	Water rights
Regulations on Industrial Activity Licensing (Decree 22/2014)	Permission (implementation of EIA and preparation of TOR)
Regulation on Environmental Inspection (Decree 11/2006)	Monitoring and audit
Regulation on Environmental Audit (Decree 25/2011)	Definition and organisation
Air, Water Quality and Biodiversity	
Air Quality regulations on Environmental Quality and Effluent Emission Standards (Decree 18/2004, amended Decree 67/2010)	Standard for air pollution
Regulation regarding the Management of Substances that Destroy the Ozone Layer (Resolution 78/2009)	Measures for Ozone layer
Regulations on Water Quality for Human Consumption (Ministerial Diploma 180/2004)	Water quality and protection
Regulation for the Prevention of Marine and Coastal Environmental Pollution (Decree 45/2006)	Protection for coastal areas
Regulation regarding Standards for Environmental Quality and Discharge of Effluent (Decree 18/2004)	Handling of industrial waste
Forest and Wildlife Law (Law 10/1999)	National parks and protected areas
Fisheries Act (Law 3/1990)	Regulation for fishery
Enabling Regulation for Forest and Wildlife Law (Decree 12/2002)	Protected animals
Regulation regarding Sport and Recreational Fishing (Decree 51/1999)	Regulation for marine animals
Regulation regarding the control of Invasive Alien Species (Decree 25/2008)	Invasive Alien Species
Management of Waste	
Regulations on Solid Waste Management (Decree 13/2006)	Waste treatment
Land Planning and Resettlement	
Land Law (Law 19/1997) and Land Law Regulations (Decree 66/1998)	Definition and landownership etc.
Law on Spatial Planning (Law 19/2007)	RoW, compensation
Regulations on the Resettlement Process resulting from Economic Activities (31/2012)	Basic regulation for resettlement
The Resettlement Process (Ministerial Resolution 155/2014)	Establishment of committee etc.
The Process of preparing and Implementing Resettlement Plans (MR 156/2014)	Process of resettlement etc.
Cultural Heritage	
Law for Protection of Cultural Assets (Decree 10/1988)	Protection for heritage etc.

Treaties related to ESC that Mozambique government had ratified are as follows ;

Air Pollution

- Vienna Convention for the Protection of the Ozone Layer
- Montreal Protocol to Protect the Ozone Layer (including 1990 and 1999 amendments) United Nations Framework Convention on Climate Change (UNCCF) and the 1992 and 1997 Kyoto Protocol.

Biodiversity

- African Convention on the Conservation of Nature and Natural Resources/1968
- Convention on Wetlands of International Importance, especially the Water Fowl Habitats of Aquatic Birds (Ramsar Convention)
- Convention on Migratory Species of Wild Animals 1979 and amendments
- Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region/1985
- The Protocol concerning Protected Areas and Wild Life Fauna and Flora in the Eastern Africa Region; and the Protocol for Cooperation in Fighting Pollution in Emergency Situations/1985
- United Nations Convention on Biological Diversity (CBD)/1992
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade/1998
- SADC Protocol on Wildlife Conservation and Law Enforcement/1999
- SADC Protocol on Fisheries/2001
- Agreement related to the Application of the Dispositions of the United National Convention on the Law of the Sea regarding the Conservation and Management of Straddling and Highly Migratory Fish Species/2001
- SADC Protocol on Forestry Activities/2002
- African Convention on the Conservation of Nature and Natural Resources. Revised version 2003/2009

Aquatic Animals and Resources

- Convention for the Prevention of Marine Pollution from Land-based Sources (Paris Convention)/1974
- International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC)/1990
- International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (ICIFCOPD)/1992
- International Convention on Civil Liability for Oil Pollution Damage (CLC Protocol)/1992

Cultural Heritage

- UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage/1972

Hazardous Waste

- Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal./1992
- Convention on the Ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (Bamako Convention)/1991

Pesticide

- Stockholm Convention on Persistent Organic Pollutants/2002

(2) EIA System and Approval Procedure in Mozambique

The procedure for approval of EIA is regulated by Decree 45/2004 (Decree 42/2008 amended). It is categorised by the sector of the project. The classifications are as follows:

Table 12.2.9 EIA Procedure by Classification

Contents	Category A/A+[6] (EIA Study)	Category B (EIA or SER Study)	Category C (SER Study)
1. Application	Yes	Yes	Yes
2. Pre-assessment	-	Yes	-
3. EPDA*	Yes	-	-
4. TOR for EIA/SER	Yes	Yes	-
5. EIA study	Yes	-	-
6. SER**	-	Yes	-
7. Public Participation Programme	Yes	△***	-
8. Review by TAC****	Yes	Yes	-

* EPDA: Environmental Pre-Viability Report and Scope Definition

** SER: Simplified Environmental Report

***This shall be required whenever the project causes permanent or temporary resettlement of the populations or communities (Decree 45/2004, Article14).

****TAC：Technical Assistance Committee

[6] Category A+ has been added to the current legislation.

- **Application:** All proponents (irrespective of which category of project they may be proposing) must submit the following information to the central EIA. In this study, ANE has submitted the application to Nampula and Niassa provincial departments.
- **Pre-assessment:** Only Category B projects need to be pre-assessed. The number of affected people and nature and type of affected ecosystem and so on will be assessed. If the project is found to be exempt from an EIA or SER, MITADER will issue a Declaration of Exemption within five working days. (Decree 45/2004, Article 7)
- **EPDA and Scoping:** EPDA is compulsory for all Category A projects. It is required if there is the possibility of a serious impact due to the project and to consider the TOR of the EIA. EPDA will be submitted to DNAIA (Nacional Directorate of Environmental Impact Assessment) and TAC will review it. Duration for review of EPDA is 30 working days. And the EPDA will be disclosed in the public participation process (Decree 45/2004, Article 10, 15).
- **TOR for EIA and SER:** TOR should be submitted before starting EIA and SER. Period for approval is 30 days for EIA and 15 days for SER (Decree 45/2004, Article 11, 16).
- **EIA:** EIA report should be submitted to DNAIA for review. SER report should be submitted to DPCA (Provincial Directorate for Coordination of the Environmental Affairs). Period for approval is 45 days for EIA, and 30 days for SER (Decree 45/2004, Article 12, 13).
- **Public Participation Process:** Public Participation is mandatory for Category A Projects. During the review and study, the project proponent will collect the public comments and feedback to the project. It is not mandatory for Category B projects. The need for public consultation depends on the number of people who may need to be resettled (Decree 45/2004, Article 14). The flow of EIA is shown in the following figure.

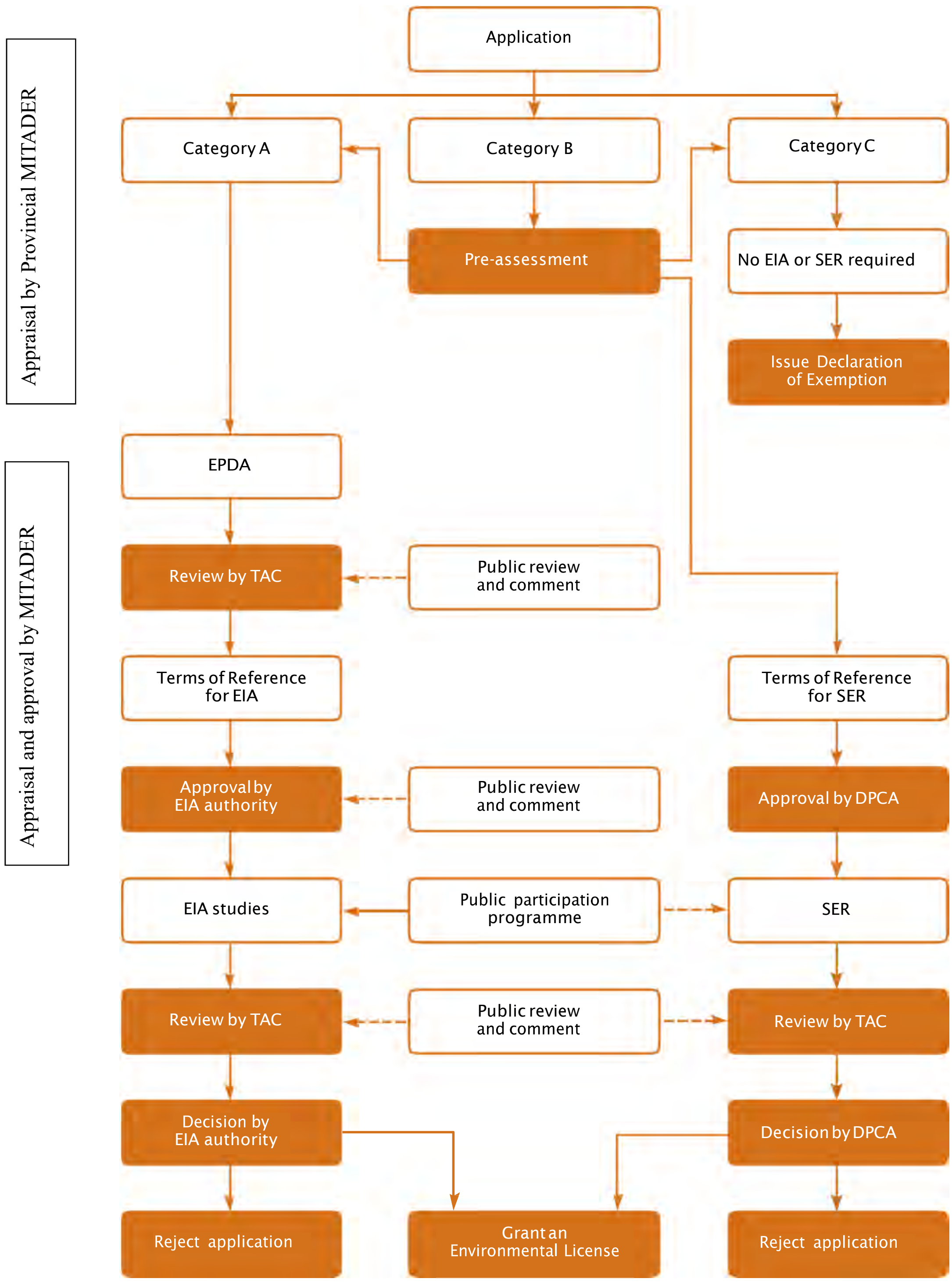


Figure 12.2.13 Procedure for EIA

In accordance with the law abovementioned, ANE applied to Nampula Provincial Environmental office and Niassa Provincial Environmental office for implementation of this project in May 2015. As of the end of July 2015, Nampula Provincial Environmental Office categorised Nacala Port Access Road as category-B and Nampula Southern Bypass Road as category-A. Niassa Provincial Office categorised Cuamba Bypass Road as category-A.

(3) Laws related to Involuntary Resettlement and Land Acquisition in Mozambique

The law, policy, and other regulations related to resettlement and land acquisition in Mozambique are shown in the table below.

Table 12.2.10 The law, policy and other regulations related to the resettlement and land acquisition

Law, Policy and Regulations	Content
Land Law (No. 19/1997)	The objective of this law is to consolidate the right to use the land and to generate the benefit and to form the conditions for implementation, conversion, settlement and determination of the rights. This law defines the authority and the responsibility of the land related public organization over land ownership on public land, the right to use the land, and the benefit of using the land. This law defines the ROW as 50m from the both road shoulders in the motorways and four lane highways, 30m from both road shoulders in the intercity and regional primary road, 15m from the both road shoulder in the secondary and tertiary road connecting among regional towns (Chapter 2, Article 8 (Partial Protection Zones)（g）.
Land Law Regulations (No. 66/1998)	This regulation defines the Land Law 19/97 and establishes the condition and the right to use public land. It shows the obligation and the right of international and domestic stakeholders and the cost to obtain the license for using the land.
Resolution No. 10/1995 on the National Land Policy	This resolution defines the domestic land policy. It especially confirms the priority of the country and provides the classification of the land use for agriculture, manufacturing, and mining. It mentions the national land ledger system same as the development of the tourism public projects and improvement of infrastructure.
Decree No. 31/2012	This decree defines the process and the basic rule for the people who resettle to be able to improve the quality of their life. It includes the rule of the social equality and benefit and public participation.
Ministerial Resolution No. 155/2014	This resolution defines the establishment of the committee to manage and monitor the resettlement process. The committee is composed of representatives of the sector, expert, and individuals, and makes the rule of the number and the date of constant meeting, organization and the position to support the committee.
Ministerial Resolution No. 156/2014	This resolution defines the process of the resettlement plan in detail. The report should be created and submitted in three steps. It also defines the public participation and public discussions. Public participation needs to take place four times in the RAP (separate from the stakeholder meeting of EIA).
ANE Resettlement Policy Framework for the Road Sector 2006	It defines the approach and the objective of involuntarily resettlement in ANE's project. It was prepared with support from the World Bank（WB）and is based on the World Bank Operation Policy（OP 4.12）.

The following figure shows a comparison between JICA Environmental Guidelines and the policy in Mozambique related with resettlement and land acquisition (the gap analysis).”The Resettlement Policy Framework for Road Sector 2006” is created in the WB project, and followed the WB OP 4.12. Thus, there is no significant gap between JICA’s guideline. If the gap appears in the process of implementing the RAP, it will be examined through the survey.

Table 12.2.11 Comparison between JICA Guidelines and the Policy in Mozambique related to Resettlement and Land Acquisition

	JICA Environmental Guidelines / WB OP 4.12	Related Policy in Mozambique	Policy Applied to the Project
1	Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives (JICA Environmental Guidelines)	There are four related policy shown below. -Decree No. 31/2012 (D 31/2012) -Ministerial Resolution No. 155/2014(MR 155/2014) -Ministerial Resolution No. 156/2014(MR 155/2014) -ANE Resettlement Policy Framework(ANE RPF) No policy mentions avoiding resettlement.	According to the laws mentioned here, a resettlement plan is required. Involuntary resettlement will be avoided as much as possible.
2	When population displacement is unavoidable, effective measures to minimize the impact and to compensate for the losses must be agreed upon with the people who will be affected (JICA Environmental Guidelines).	(Article and Section 1 of D 31/2012) (MR 156/2014 of 3) Creation of RP:Resettlement Plan, The plan, the procedure, the item, and the obligation of the stakeholders are written in (ANE RPF 2.1)Basic Principles.	There is no difference. Follow the policy and procedure in Mozambique.
3	People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported by project proponents, etc., in a timely manner so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels (JICA Environmental Guidelines).	(D 31/2012 Ar. 4,10,16) Principles:People who resettle should reconstruct the basic level of the livelihood. (MR156/2014 - 2.2) The right of the people who are affected:Maintain and reconstruct the level of receiving the service(ANE RPF 2.1)Basic Principles。	There is no difference. Follow the policy and procedure in Mozambique.
4	Compensation must be provided based on the full replacement cost prior to displacement wherever possible (JICA Environmental Guidelines).	(ANE RPF 7.2) The calculation of the compensation price is based on the repossession price.	There is no mention in the D31/2012 and MR but replacement cost survey will be carried out following the RPF.
5	Compensation in the form of land and cash and other support must be made prior to resettlement	(ANE RPF 7.3) Payment of the cash by selection of the individual and household. There is no mention for the timing.	Following the policy and procedure in Mozambique, compensation will be made prior to resettlement.
6	For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public (JICA Environmental Guidelines).	(D 31/2012 Section 1-3) (MR156/2014 - 3) Implement of the creation of the resettlement plan, public discussion/ listening. (ANE RPF 3) Creation of the RAP, Review and permission, implementation of citizen participation and public discussion,	There is no difference. Follow the policy and procedure in Mozambique.

	JICA Environmental Guidelines / WB OP 4.12	Related Policy in Mozambique	Policy Applied to the Project
7	In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance (JICA Environmental Guidelines).	(D 31/2012 Section 1-3) (MR156/2014 - 3, 4) Implement of the creation of the resettlement plan, public discussion/ listening. (ANE RPF 3)Creation of the RAP, Review and permission, implementation of citizen participation and public discussion,	There is no difference. Follow the policy and procedure in Mozambique.
8	When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people (JICA Environmental Guidelines).	Nothing. MR156/2014:RP should be created with Portuguese.	There is no mention of the language and the style to be used in the consultation. Consultations will be carried out using the local language following to the MR.
9	Appropriate participation of affected people must be promoted in the planning, implementation, and monitoring of resettlement action plans (JICA Environmental Guidelines).	(D 31/2012 - 13, 14) Public participation process(MR156/2014 - 4) Public discussion and participation process is important.(ANE RPF)The public participation is the process, which determine the compensation.	There is no difference. Follow the policy and procedure in Mozambique.
10	Appropriate and accessible grievance mechanisms must be established for the affected people and their communities (JICA Environmental Guidelines).	(MR156/2014 - 3) Analyze the compliant procedure through the social and economic Analysis. (ANE RPF 10)The mechanism of compliant procedure (the figure of flow including the ANE and other local government)	There is no difference. Follow the policy and procedure in Mozambique.
11	Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advantage of such benefits (WB OP 4.12 Para.6).	(MR156/2014 - 3) Target place / number, social and economic survey, status inquiry are implemented in the first step of RP. (ANE RPF 9.1)Creation of resettlement plan. Setting the cut-off date in the first level, and specify the target person. Implementation of the status inquiry and social and economic survey.	There is no difference. Follow the policy and procedure in Mozambique.
12	Eligibility for benefits includes the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who do not have formal legal rights to land at the time of the census but who have a claim to such land or assets, and the PAPs who have no recognizable legal right to the land they are occupying (WB OP 4.12 Para.15).	(D 31/2012 - 10) The right of the people who are directly affected. Income and Physical space and so on.(MR156/2014 - 3)The right of the people who are directly affected by the project. This includes not only physical space, but also the access to the local resource(ANE RPF)The compensation requirement is applied based on the WB OP.	There is no difference. Follow the policy and procedure in Mozambique.
13	Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based (WB OP 4.12 Para.11).	(ANE RPF) The compensation requirement is applied based on the WB OP.	There is no difference. Follow the policy and procedure in Mozambique.

	JICA Environmental Guidelines / WB OP 4.12	Related Policy in Mozambique	Policy Applied to the Project
14	Provide support for the transition period (between displacement and livelihood restoration/WB OP 4.12 Para.6).	(ANE RPF) Verify the process of the resettlement plan in the process of the 12 monitoring evaluation.	There is no reference about the support after the resettlement in the D31/2012 and MR. Confirm the ANE RPF, and consider applying JICA guideline.
15	Particular attention must be paid to the needs of the vulnerable groups especially those below the poverty line, landless, elderly, women and children, ethnic minorities, etc. (WB OP 4.12 Para.8).	(D 31/2012) Identify the vulnerable people through the social and economic survey. (ANE RPF 5.3) The standard of the requirement of the target people includes the support for the vulnerable people.	There is no difference. Follow the policy and procedure in Mozambique.

12.2.4 Analysis on Project Alternatives

Please refer to 'Chapter 7 Route Selection (Alternative Analysis)' for an analysis on project alternatives.

12.2.5 Environmental Impact Assessment

This draft scoping matrix shown below has been prepared based on a field survey that took place from March 23 to May 6, 2015 with reference to the JICA Guidelines for Environmental and Social considerations (April, 2010) and the law, regulations and policies in Mozambique. A more detailed survey will be conducted during the EIA and RAP study.

Table 12.2.12 Scoping Matrix (Nacala Port Access Road)

Category	№	Environment Item	Evaluation		Reason for Evaluation
			Pre-construction/ Construction Stages	O&M Stage	
Living Environment (Nuisance)	1	Air pollution	B－	B±	Construction: Temporary increase in dust and exhaust gas is expected by the construction vehicles and machinery. O&M: Air pollution is expected to decrease as a result of improvement in traffic congestion. On the other hand, volume of exhaust gas could increase as a result of an increase in the number of vehicles.
	2	Water Pollution	B－	D	Construction: Water may become turbid as a result of construction and excavation in the ocean and rivers. Organically polluted water may be generated if a base camp is set. O&M: Impact is considered to be insignificant as there is no construction.
	3	Waste disposal	B－	D	Construction: Construction waste and the waste from cut trees by the excavation are expected. General waste may be an issue if there is the base camp. O&M: Impact is considered to be little because there is no construction.

Category	№	Environment Item	Evaluation		Reason for Evaluation
			Pre-construction/ Construction Stages	O&M Stage	
	4	Soil pollution	D	D	Construction / O&M: Impact is considered to be little because an outflow of the massive chemical is not expected while changes in configuration of the ground could take place as a result of cutting and filling.
	5	Noise and Vibration	B－	B－	Construction: Noise and vibration level may increase during construction by vehicle and machines in the construction area, surrounding area, borrow pits and quarry sites. O&M: Noise and vibration level may increase due to increase in traffic volume.
	6	Ground Subsidence	D	D	Construction / O&M: No impact is expected since no activity will be carried out that will cause ground subsidence such as pumping up a large volume of underground water.
	7	Odors	D	D	Construction / O&M: No impact is expected since no activity that generates offensive odor will take place.
	8	Bottom sediment	B－	C	Construction: There is a possibility of accumulation of soil and mud as a result of construction and excavation in the ocean. O&M: The level of the impact to the ocean is unknown at present.
Natural Environment	9	Protected areas	D	D	Construction / O&M: No impact is expected since the protected areas designated by the Mozambique government such as national park, designated place, historical and cultural reserve do not exist in or near the planned area.
	10	Ecosystem	C	C	Construction / O&M: The habitat of valuable animals and plants and protected areas in the ocean and land (the bridge on the ocean and planned route) have not been confirmed but impact on the animals and plants in the ocean and coastal area, vegetation clearance by large-scale tree cutting may take place during construction. The existence and level of impact will be confirmed during the survey.
	11	Hydrology	C	C	Construction / O&M: Temporary change in the flow of the ocean and river may take place by construction of the bridge.
	12	Topography and geology	B－	D	Construction: The configuration of the ground may be changed in the area due to cutting and filling. O&M: It is considered there is little impact because there is no activity for the land that changes the shape and/or geological features.

Category	№	Environment Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Reason for Evaluation
Social Environment	13	Resettlement	B－	C	Pre-construction / Construction: Resettlement and land acquisition are required. The survey for the resettlement (making the resettlement plan) is required. O&M: Little impact is expected. Measurements for supporting the livelihood and monitoring plan, which will be prepared and documented in the resettlement plan, are required to be checked.
	14	Poverty Group	C	C	Pre-construction / Construction / O&M: The level of impact is unknown at present. Survey related to the resettlement will be implemented to confirm this.
	15	Ethnic minorities ・ Indigenous people	C	C	Pre-construction / Construction / O&M: The level of impact is unknown at present. The survey related to the resettlement will be implemented to confirm this.
	16	Local Economy such as Employment, livelihood etc.	B±	B＋	Pre-construction / Construction: Livelihood may be affected by resettlement and land acquisition. Increase in employment opportunity may result in improvement in income but people engaged in fishery may not be able to continue with their job or may need to change the place of fishing. The level of impact will be confirmed in the survey related to resettlement. O&M: Reinvigoration of the local economy by the improvement of the access road is expected.
	17	Land Use and Utilization of Natural Resources	B－	B＋	Pre-construction / Construction: Impact on agriculture and vegetation may take place because most of the places have farmland and vegetation (woodland and shrub). O&M: Social and economic development is expected because there are existing factories, planned industrial area along the planned line.
	18	Water Usage	B－	C	Construction / O&M: Construction and excavation may affect the aquifer (muddiness). The level of impact will be confirmed during the survey on resettlement.
	19	Existing Social Infrastructure and Services	C	B＋	Pre-construction / Construction: Impact such as access to religious facilities, school, graveyard, and other public facilities may take place. Survey related to the resettlement will be implemented to confirm this. O&M: Access to social infrastructure will be improved.
	20	Social Institutions such as Social Infrastructure and Local Decision making institutions	C	C	Pre-construction / Construction / O&M: RAP survey will be carried out to check the existence of local social organization and the process of decision making.

Category	№	Environment Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Reason for Evaluation
	21	Misdistribution of Benefits and Damages	C	C	Pre-construction / Construction / O&M: Misdistribution is not expected to take place at any large scale. The survey related to resettlement will be implemented to confirm this.
	22	Conflict of Interest in the Region	C	C	Pre-construction / Construction / O&M: Conflict of interest in the region is assumed not to take place. The survey related to resettlement will be implemented to confirm this.
	23	Cultural Heritage	D	D	No impact is expected because no historical spot or cultural heritage exists around the project site.
	24	Landscape	B±	C	Construction: Change in landscape will take place because construction will take place approximately 1.5km from the coast line. O&M: The impact such as the change of the roadside landscape is unknown at present.
	25	Gender	B−	C	Construction / O&M: Minor impact is expected such as impact on access to washing area because there are women who wash near the planned route. The RAP survey will confirm this.
	26	Rights of Children	D	D	No impact is expected since child labor is not expected to take place.
	27	Infectious Diseases	B−	D	Construction: Infectious diseases may spread among people who work in the food and drink industry because of the inflow of the construction workers. O&M: Impact is considered to be little because there is no construction.
	28	Working Condition (including working safety)	B−	D	Construction: The exhaust and the dust from the construction may harm the workers' health. O&M: Impact is considered to be little because there is no construction.
Others	29	Accident	B−	B−	Construction: The number of traffic accident may increase in the field survey area because of the construction vehicles. O&M: The number of traffic accidents may increase because of an increase of the amount of traffic.
	30	Trans-boundary Impacts and / or Climate Change	C	C	Construction: Greenhouse gas may increase because of cutting trees and disappearance of the vegetation but the magnitude of impact is considered to be limited. O&M: Even though the Greenhouse gas increase, the amount of the gas may be reduced in the entire region because of the improvement in the traffic congestion.

A+/-：Significant positive / negative impact is expected
B+/-：Positive / negative impact is expected to some extent
C：Extent of positive / negative impact is unknown and the future survey is required
D：No impact insignificant, the survey in the future is not expected.

Table 12.2.13 Scoping Matrix (Nampula Southern Bypass Road)

Category	No	Environment Item	Evaluation		Reason for Evaluation
			Pre-construction/ Construction Stages	O&M Stage	
Living Environment (Nuisance)	1	Air pollution	B−	B±	Construction: Temporary increase in dust and exhaust gas is expected by the construction vehicles and machinery. O&M: Air pollution is expected to decrease as a result of improvement in traffic congestion. On the other hand, volume of exhaust gas could increase as a result of an increase in the number of vehicles.
	2	Water Pollution	B−	D	Construction: Water may become turbid as a result of construction and excavation in the rivers. Organically polluted water may be generated if a base camp is set. O&M: Impact is considered to be little because there is no construction.
	3	Waste disposal	B−	D	Construction: Construction waste and the waste from cut trees by the excavation are expected. General waste may be an issue if there is a base camp. O&M: Impact is considered to be little because there is no construction.
	4	Soil pollution	D	D	Construction/O&M: Impact is considered to be minor because an outflow of a large volume of chemical is not expected. But changes in ground configuration could take place as a result of cutting and filling during construction.
	5	Noise and Vibration	B−	B−	Construction: Noise and vibration level may increase during construction by vehicle and machines in the construction area, surrounding area, borrow pits and quarry sites. O&M: Noise and vibration level may increase due to increase in traffic volume.
	6	Ground Subsidence	D	D	Construction / O&M: No impact is expected since no activity will be carried out that will cause ground subsidence such as pumping up a large volume of underground water.
	7	Odors	D	D	Construction / O&M: No impact is expected since no activity that generates offensive odor will take place.
	8	Bottom Sediment	C	C	Construction: The impact to the river is unknown at present. O&M: Impact on the river bottom is unknown at present.
Natural Environment	9	Protected areas	D	D	Construction / O&M: No impact is expected since the protected areas designated by the Mozambique government such as national park, designated place, historical and cultural reserve do not exist in or near the planned area.
	10	Ecosystem	C	C	Construction / O&M: The habitat of valuable animals and plants and protected areas are not confirmed along the planned route but the impact will be confirmed in the EIA.
	11	Hydrology	C	C	Construction: Temporary change in the river flow may take place by construction of the bridge. Also, change will take place in the lowland (submerged land) where the river course is not yet provided.
	12	Topography and geology	B−	D	Construction: The configuration of the ground may be changed in the area due to cutting and filling. O&M: Little impact is expected because there is no activity that will alter the land shape and geological features at a large scale.

Category	No	Environment Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Reason for Evaluation
Social Environment	13	Resettlement	A－	C	Pre-construction / Construction: It is assumed that about 300 households will be affected due to the road construction. RAP survey is required. O&M: Little impact is expected. Measurements for supporting the livelihood and monitoring plan, which will be prepared and documented in the resettlement plan, are required to be checked.
	14	Poverty Group	C	C	Pre-construction / Construction / O&M: Level of impact is unknown at present. RAP survey will be implemented to confirm this.
	15	Ethnic minorities・Indigenous people	C	C	Pre-construction / Construction / O&M: Level of impact is unknown at present. RAP survey will be implemented to confirm this.
	16	Local Economy such as Employment, livelihood etc.	B±	B+	Pre-construction / Construction: Livelihood may be affected by resettlement and land acquisition. Increase in employment opportunity may result in improvement in income but people engaged in fishery may not be able to continue with their job or may need to change the place of fishing. The level of impact will be confirmed in the survey related to resettlement. O&M: Reinvigoration of the local economy by improvement of access is expected.
	17	Land Use and Utilization of Natural Resources	B－	D	Pre-construction / Construction: The land use will be largely changed including disappearance of vegetation because most of the area, which the road crosses are agricultural land and vegetated land (shrub, fruit tree planting). O&M: The impact is assumed to be little since there is no land acquisition.
	18	Water Usage	B－	C	Construction / O&M: Construction and excavation may affect the aquifer (muddiness). Also the well may disappear as a result of construction. RAP survey will be implemented to confirm the level of impact.
	19	Existing Social Infrastructure and Services	C	B＋	Pre-construction / Construction: Impact such as access to religious facilities, school, graveyard, and other public facilities may take place. Survey related to the resettlement will be implemented to confirm this. O&M: Access to social infrastructure will improve.
	20	Social Institutions such as Social Infrastructure and Local Decision making institutions	C	C	Pre-construction / Construction / O&M: RAP survey will be carried out to check the existence of local social organization and the process of decision making.
	21	Misdistribution of Benefits and Damages	C	C	Pre-construction / Construction / O&M: Misdistribution is not expected to take place at any large scale. The survey related to resettlement will be implemented to confirm this.

Category	№	Environment Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Reason for Evaluation
	22	Conflict of Interest in the Region	C	C	Pre-construction / Construction / O&M: Conflict of interest in the region is assumed not to take place. The survey related to resettlement will be implemented to confirm this.
	23	Cultural Heritage	D	D	No impact is expected because no historical spot or cultural heritage exists around the project site.
	24	Landscape	C	C	Construction: Since the project does not involve developing large scale buildings, little impact is expected to the landscape. But the level of impact is unknown. O&M: The impact such as the change of the roadside landscape is unknown at present.
	25	Gender	B－	C	Construction / O&M: Minor impact is expected such as impact on access to washing area because there are women who wash near the planned route. The RAP survey will confirm this.
	26	Rights of Children	D	D	No impact is expected since child labor is not expected to take place.
	27	Infectious Diseases	B－	D	Construction: Infectious diseases may spread among people who work in the food and drink industry because of the inflow of the construction workers. O&M: Impact is considered to be little because there is no construction.
	28	Working Condition (including working safety)	B－	D	Construction: Exhaust and dust from the construction may harm workers' health. O&M: Impact is considered to be little because there is no construction.
Others	29	Accident	B－	B－	Construction: The number of the traffic accidents may increase in the field survey area because crossing of construction vehicles. O&M: The number of the traffic accident may increase because of an increase in the number of the traffic.
Others	30	Trans-boundary Impacts and / or Climate Change	C	C	Construction: Greenhouse gas may increase because of cutting trees and disappearance of the vegetation but the magnitude of impact is considered to be limited. O&M: Even though the Greenhouse gas increase, the amount of the gas may be reduced in the entire region because of the improvement in the traffic congestion.

A+/-：Significant positive / negative impact is expected

B+/-：Positive / negative impact is expected to some extent

C：Extent of positive / negative impact is unknown and the future survey is required

D：No impact insignificant, the survey in the future is not expected.

Table 12.2.14 Scoping Matrix (Cuamba Bypass Road)

Category	No	Environment Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Reason for Evaluation
Living Environment (Nuisance)	1	Air pollution	B－	B±	Construction: Temporary increase in dust and exhaust gas is expected by the construction vehicles and machinery. O&M: Air pollution is expected to decrease as a result of improvement in traffic congestion. On the other hand, volume of exhaust gas could increase as a result of an increase in the number of vehicles.
	2	Water Pollution	B－	D	Construction: Water may become turbid as a result of construction and excavation in the rivers. Organically polluted water may be generated if a base camp is set. O&M: Impact is considered to be little because there is no construction.
	3	Waste disposal	B－	D	Construction: Construction waste and the waste from cut trees by the excavation are expected. General waste may be an issue if a base camp is set. O&M: Impact is considered to be little because there is no construction.
	4	Soil pollution	D	D	Construction/O&M: Impact is considered to be minor because an outflow of a large volume of chemical is not expected. But changes in ground configuration could take place as a result of cutting and filling during construction.
	5	Noise and Vibration	B－	B－	Construction: Noise and vibration level may increase during construction by vehicle and machines in the construction area, surrounding area, borrow pits and quarry sites. O&M: Noise and vibration level may increase due to increase in traffic volume.
	6	Ground Subsidence	D	D	Construction / O&M: No impact is expected since no activity will be carried out that will cause ground subsidence such as pumping up a large volume of underground water.
	7	Odors	D	D	No impact is expected since no activity that generates offensive odor will take place.
	8	Bottom Sediment	C	C	Construction / O&M: The impact is little since there is no excavation.
Natural Environment	9	Protected areas	D	D	Construction / O&M: No impact is expected since the protected areas designated by the Mozambique government such as national park, designated place, historical and cultural reserve do not exist in or near the planned area.
	10	Ecosystem	C	C	Construction / O&M: The habitat of valuable animals and plants and protected areas are not confirmed along the planned line but the impact will be confirmed in the EIA.
	11	Hydrology	C	C	Construction: Temporary change in the river flow may take place by construction of the bridge. O&M: The flow of the surface water may be changed by the new banking soil.

Category	No	Environment Item	Evaluation		Reason for Evaluation
			Pre-construction/ Construction Stages	O&M Stage	
	12	Topography and geology	B−	D	Construction: The configuration of the ground may be changed in the area due to cutting and filling. O&M: Little impact is expected because there is no activity that will alter the land shape and geological features at a large scale.
Social Environment	13	Resettlement	B−	D	Pre-construction / Construction: It is assumed that several to dozens of households will be affected due to the road construction. RAP survey is required. It is assumed that there is impact on several to dozens of households in the affected area. The survey for the resettlement (making the resettlement plan) is required. O&M: Little impact is expected. Measurements for supporting the livelihood and monitoring plan, which will be prepared and documented in the resettlement plan, are required to be checked.
	14	Poverty Group	C	C	Pre-construction / Construction / O&M: Level of impact is unknown at present. RAP survey will be implemented to confirm this.
	15	Ethnic minorities・Indigenous people	C	C	Pre-construction / Construction / O&M: Level of impact is unknown at present. RAP survey will be implemented to confirm this.
	16	Local Economy such as Employment, livelihood etc.	B±	B+	Pre-construction / Construction: Livelihood may be affected by resettlement and land acquisition. Increase in employment opportunity may result in improvement in income but people engaged in fishery may not be able to continue with their job or may need to change the place of fishing. The level of impact will be confirmed in the survey related to resettlement. O&M: Reinvigoration of the local economy by improvement of access is expected.
	17	Land Use and Utilization of Natural Resources	B−	D	Pre-construction / Construction: Most of the area, which the road crosses are vegetated land and existing road. The impact such as disappearance of the vegetation is expected. O&M: Impact is considered to be minor as there is no land acquisition.
	18	Water Usage	B−	C	Construction and excavation may affect the aquifer (muddiness). Also the well may disappear as a result of construction. RAP survey will be implemented to confirm the level of impact.
	19	Existing Social Infrastructure and Services	C	B+	Pre-construction / Construction: Impact such as access to religious facilities, school, graveyard, and other public facilities may take place. Survey related to the resettlement will be implemented to confirm this. O&M: Access to social infrastructure will improve.
	20	Social Institutions such as Social Infrastructure and Local Decision making institutions	C	C	Pre-construction / Construction / O&M: RAP survey will be carried out to check the existence of local social organization and the process of decision making.

Category	No	Environment Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Reason for Evaluation
	21	Misdistribution of Benefits and Damages	C	C	Pre-construction / Construction / O&M: Misdistribution is not expected to take place at any large scale. The survey related to resettlement will be implemented to confirm this.
	22	Conflict of Interest in the Region	C	C	Pre-construction / Construction / O&M: Conflict of interest in the region is assumed not to take place. The survey related to the resettlement will be implemented to confirm this.
	23	Cultural Heritage	D	D	No impact is expected because no historical spot or cultural heritage exists around the project site.
	24	Landscape	C	C	Construction: Since the project does not involve developing large scale buildings, little impact is expected to the landscape. But the level of impact is unknown. O&M: Impact such as the change of the roadside landscape is unknown at present.
	25	Gender	B－	C	Construction: Minor impact is expected such as impact on access to washing area because there are women who wash near the planned route. The RAP survey will confirm this.
	26	Rights of Children	D	D	No impact is expected since child labor is not expected to take place.
	27	Infectious Diseases	B－	D	Construction: Infectious diseases may spread among people who work in the food and drink industry because of the inflow of the construction workers. O&M: Impact is considered to be little because there is no construction.
	28	Working Condition (including working safety)	B－	D	Construction: Exhaust and dust from the construction may harm workers' health. O&M: Impact is considered to be little because there is no construction.
Others	29	Accident	B－	B－	Construction: The number of traffic accident may increase in the field survey area because of crossing of the construction vehicle. O&M: The number of traffic accident may increase because of an increase in the volume of traffic.
Others	30	Trans-boundary Impacts and / or Climate Change	C	C	Construction: Greenhouse gas may increase because of cutting trees and disappearance of the vegetation but the magnitude of impact is considered to be limited. O&M: Even though the Greenhouse gas increase, the amount of the gas may be reduced in the entire region because of the improvement in the traffic congestion.

A+/-：Significant positive / negative impact is expected

B+/-：Positive / negative impact is expected to some extent

C：Extent of positive / negative impact is unknown and the future survey is required

D：No impact insignificant, the survey in the future is not expected.

12.2.6 Terms of Reference of the EIA Survey (draft)

The Terms of Reference (TOR/draft) of the environmental survey prepared based on the result of scoping, literature review, relevant laws and regulations such as the legislation in Mozambique and the JICA Guidelines for Environmental and Social Considerations are shown in the table below. The content will be reconfirmed before procurement of the local environmental consultant[7].

Table 12.2.15 Methodology of the Survey and Impact Assessment

Category	№	Environmental Item	Evaluation: Pre-construction/ Construction Stages	Evaluation: O&M Stage	Methodology of the Survey	Methodology of Evaluation
Living Environment (Nuisance)	1	Air pollution	B−	B±	✓ Measurement in the field (7points：Nacala 5, Nampula 7, Cuamba 5 are estimated) ✓ Items：CO, CO2, NO2, SO2, SPM ✓ Existing resources・Literature review	✓ Quantitative analysis ✓ Comparison with other case
	2	Water Pollution	B−	D	✓ Measurement in the field (17 points：Nacala 3, Nampula 7, Cuamba 5 are estimated) ✓ Items：BOD, pH, SS, water temperature ✓ Existing resources・Literature review	✓ Quantitative analysis ✓ Comparison with other case
	3	Waste disposal	B−	D	✓ Collecting waste disposals / situation of disposal / illegal dumping are surveyed ✓ Existing resources・Literature review	✓ Estimation of the amount of soil waste
	5	Noise and Vibration	B−	B−	✓ Measurement in the field (7points：Nacala 5, Nampula 7, Cuamba 5 are estimated) ✓ Existing resources・Literature review	✓ Quantitative analysis ✓ Comparison with other case
	8	Bottom Sediment	B−[8] C[9]	C	✓ Using the result of the water quality analysis (There going to be one analysis in the Nacala bay ocean) ✓ Existing resources・Literature review	✓ Quantitative analysis ✓ Comparison with other case

[7] Please refer to 'Appendix-12 TOR (draft) of the Environmental Survey submitted from JICA Study Team to ANE' for the TOR updated and submitted to ANE by JICA Study Team upon procurement of the environmental consultant.
[8] The evaluation of Nacala Port Access Road is assumed to be B-.
[9] The evaluation of Nampula, Cuamba Bypass Road is assumed to be D.

Category	№	Environmental Item	Evaluation		Methodology of the Survey	Methodology of Evaluation
			Pre-construction/ Construction Stages	O&M Stage		
Natural Environment	10	Ecosystem	C－	C－	✓ Literature review (checking the vegetation, flora and fauna / valuable species list, distribution condition) ✓ Field exploration (as necessary)	✓ Qualitative analysis based on literature review
	11	Hydrology	C－	C－	✓ Data and literature review	✓ Qualitative analysis based on hydrologic characteristics analysis
	12	Topography and geology	B－	D	✓ Existing resources・Literature review	✓ Qualitative analysis
Social Environment	13	Resettlement	A－[10] B－[11]	D	✓ Literature review and RAP survey: lost asset inventory survey, census, social and economic survey, market price survey etc.	✓ Acquiring information on the level of impact based on RAP survey
	14	Poverty Group	C±	D	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	15	Ethnic minorities・Indigenous people	C±	D	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	16	Local Economy such as Employment, livelihood etc.	B±	D	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	17	Land Use and Utilization of Natural Resources	B－	B+[12] D[13]	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	18	Water Usage	B－	C	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	19	Existing Social Infrastructure and Services	C±	D	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey

[10] The evaluation of Nampula Bypass Road is assumed to be A-.
[11] The evaluation of Nacala Port Access Road is assumed to be B-.
[12] The evaluation of Nacala Port Access Road is assumed to be B+.
[13] The evaluation of Nampula, Cuamba Bypass Road is assumed to be D.

Category	No	Environmental Item	Evaluation		Methodology of the Survey	Methodology of Evaluation
			Pre-construction/ Construction Stages	O&M Stage		
	20	Social Institutions such as Social Infrastructure and Local Decision making institutions	C±	C±	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	21	Misdistribution of Benefits and Damages	C±	D	✓ RAP survey and information gathering in the stakeholder meeting	✓ Acquiring information on the level of impact based on RAP survey
	22	Conflict of Interest in the Region	C±	D	✓ RAP survey and information gathering in the stakeholder meeting	✓ Acquiring information on the level of impact based on RAP survey
	24	Landscape	B-[14] C[15]	C	✓ Existing resources・Literature review	✓ Qualitative analysis
	25	Gender	B－	D	✓ Literature review and RAP survey	✓ Acquiring information on the level of impact based on RAP survey
	27	Infectious Diseases	B－	D	✓ RAP survey and information gathering in the stakeholder meeting	✓ Qualitative analysis
	28	Working Condition (including working safety)	B－	D	✓ Existing resources・Literature review	✓ Qualitative analysis
Others	29	Accident	B－	B－	✓ Existing resources・Literature review (Number of accidents)	✓ Qualitative analysis
Others	30	Accident	C	C	✓ Acquiring the information of the tree species by using satellite imagery and RAP survey	✓ Qualitative and quantitative analysis

A+/-：Significant positive / negative impact is expected
B+/-：Positive / negative impact is expected to some extent
C：Extent of positive / negative impact is unknown and the future survey is required
D：No notable impact is expected. Further survey is not required.

[14] The evaluation of Nacala Port Access Road is assumed to be B-.
[15] The evaluation of Nampula, Cuamba Bypass Road is assumed to be D.

12.2.7 Consideration of Environmental Mitigation Measures

Mitigation measures will be formulated as part of the EIA. Based on the field survey (e.g. field reconnaissance survey, literature review and measurement) and results of the assessment/evaluation, those items that are expected to have large impacts on the natural and/or social environment will be identified and mitigation measures to reduce those impacts explored. The frequency, cost and structure of implementation will be examined in the EIA as well as the content and methodology of the measures.

12.2.8 Consideration of Environmental Management Plan

An environmental management plan (EMP) will also be prepared during the EIA. Based on the field survey and impact evaluation, mitigation measures will be put forward. An environmental monitoring plan will be designed in accordance with the EMP. The time and frequency, cost and structure (i.e. responsible entity) for carrying out the activities will be stipulated in the plans.

12.2.9 Terms of Reference of the RAP Survey (draft)

The scale of land acquisition and resettlement is expected to be as shown below. This is based on the premise that the projects will be implemented adopting the recommended alignment.

1) Nacala Port Access Road: around 20 affected households; 1.67km^2 subject to land acquisition
2) Nampula Southern Bypass Road: around 170 affected households; 1.41km2 subject to land acquisition
3) Cuamba Bypass Road: around four affected households; 3.88km2 subject to land acquisition

The RAP should include the following in accordance with the JICA Environmental Guidelines and World Bank's OP 4.12.

a. Analysis of the legal framework related to resettlement
b. Description of the necessity of resettlement
c. Result of the social and economic survey (i.e. population census, lost asset inventory and socioeconomic/livelihood surveys)
d. Compensation policy for the loss and measures for livelihood restoration
e. Plan for preparing the place to resettle in
f. Grievance redress mechanism
g. Implementation structure
h. Implementation schedule
i. Results of estimation of the cost and financial source
j. Methodology for monitoring and ex-post evaluation
k. Results of public participation and consultation

12.2.10 Schedule for EIA and RAP

In accordance with the EIA law in Mozambique (Decree 45/2004 of Annex 4 of form : Ficha de Informação Ambiental Preliminar), ANE applied to the Department of Environment in Nampula State and Niassa State the three subject projects. As of June, 2015, ANE is waiting to hear from them the result of the categorizations. According to ANE, procurement of the local consultants is expected to be completed in October, 2015 and EIA and RAP study are expected to commence in December, 2015.

12.2.11 Discussion Points for EIA

On July 13, 2015, the Working Group of the JICA Advisory Committee for the project was held at JICA Headquarters in Japan. Here, committee members and JICA discussed this study and the committee finalized their comments on this study in August 2015. The Study Team explained those comments to ANE Cross Cutting Issues Office. At the same time, the JICA Mozambique office is going to send those comments to ANE as an official letter. The comments made by the committee are as follows[16].

(1) Comments from JICA Advisory Committee

JICA establishes the Advisory Committee for Environmental and Social Considerations as an independent council composed of external experts with the knowledge necessary to provide advice regarding support for and examinations of the environmental and social considerations of cooperation projects[17].

Working Group (WG) of the Advisory Committee related to the Preparatory Survey for Nacala Corridor Road Network Upgrading Project in the Republic of Mozambique has held on July 13, 2015. Comments from the Advisory Committee Members on that WG has been made at the General Meeting held on August 3, 2015. Comments from the committee are as follows;

(2) Scoping Matrix

- It is recommended to consider carrying out the census survey during the RAP study with ethnic groups or tribes living at the planned route and along/around the area to confirm how many people are expected to be affected by this project.

(3) Natural Environment

- It is necessary to sufficiently consider mitigation measures against floods and coastal erosion because the risk of the natural disaster is high at the target area of this project.
- Considering deforestation and overcutting the forests along the main road in this country, it is recommended to set countermeasures regarding the prevention for deforestation along the planning route of this project as needed.

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[16] Please refer to 'Appendix-13 Actions Taken for Nacala Port Access Road Project in Response to Comments made by the Advisory Committee for Environmental and Social Considerations' for the actions taken by JICA Study Team in response to the comments made by the Advisory Committee.
[17] Source: "JICA Environmental and Social Consideration Guideline, April 2010, P11"

- It is recommended to consider adopting countermeasures for the following items at the basic design stage. Because the risk of natural disaster is high and the road may collapse.
  a. Plan a route away from the river as much as possible
  b. Carry out river bank protection along the river
  c. Set the road height higher than flooding level
  d. Plan a stability gradient for the road slope gradient
  e. Construct road slope protection works
- Natural Disasters occur frequently in the target area. Considering the role of road as a flood control channel at this time of disaster, it is recommended to consider the set of drainage canal and ditch.
- It is recommended to confirm measures to minimise the impact for the natural environment by the generation of waste and sewage from base camp.

(4) Social Environment

- It is recommended that the survey confirms loss of means of livelihood, occupation of the affected people and family structure etc. through the socio economic survey during the RAP study.
- It is recommended to consider avoiding important social infrastructure and cultural facilities such as oil pipelines, cemeteries and wells when selecting the detail route of this project.

(5) Stakeholders Meeting and Information Disclosure

- It is recommended to consider the times of meeting, amount of meeting places, the way for well-known and language to consider the distribution and character of ethnic people when stakeholder meetings are held.
- It is recommended that Study Team asks to the implementation agency (ANE) about the compensation for livelihood due to the loss of their farmlands and add this to the content of public consultations.

12.3 Points of Improvement for SER and PR

An evaluation and revision was made by the JICA Study Team of the content of the SER and PR prepared by the local consultant. The evaluation and major points considered to be improved into the future are shown in Table 12.3.1 for SER and Table 12.3.2 for PR, respectively.

Table 12.3.1 JICA Study Team's Comments on the Simplified Environmental Report

Items	Comments and Way Forward (applicable page No.)
Components of the Project with Environmental Impacts	・No notable point is made under this section.
Baseline Conditions of the Environment and Society	・No notable point is made under this section.
Legislations and Organizations concerned with the Environment	・No notable point is made under this section.
Alternatives of the Project	・No notable point is made under this section.
Scoping and TOR of the Environmental Survey	・No notable point is made under this section.
Results of the Environmental Survey	・No notable point is made under this section.
Environmental Impact Assessment	・Under the EMP, discovery of historical and archeological traces are regarded as a positive impact of the project. However, the project site is not located in an area where such discovery is expected. In light of the low probability, it is considered more appropriate to judge that such impact is not foreseeable in order to avoid undue confusion. It should be noted that graves and worship places should be considered different from such historical sites (Section 7.1; P160). ・Some numbers written in the SER are different from those written in the PR (cf. number of project-affected trees is said to be 22,984 in the SER but 22,971 according to the PR/Section 6.13.1; P143). ・There is no forest to be seen in the project area. Hence, the use of 'deforestation' as a word to refer to vegetation clearance as part of the project impact is considered misleading (Section 6.3.1/P109-110; Section 6.20/P150; Section 7.3.2/P174). ・Spillage in the 'shipyard' is considered to be out of the scope of this road project (*It should be considered part of Nacala Port Development Project). Accordingly, it should be deleted (Section 6.20/P157).
Mitigation Measures and Costs for Mitigation	・Measures to be taken are described in case historical or archaeological traces have been found. However, as previously mentioned, the project site is not located in an area where such discovery is expected. It is hence considered not necessary, and potentially misleading, to include this information in the mitigation measures (Section 7.3.2/P177).
Monitoring Plan	・It is recommended to prepare and attach an environmental monitoring form (sample) based on the environmental monitoring plan prepared in the SER so that it serves as a reference in the construction stage for the contractor in carrying out environmental monitoring (Section 7.7).
Stakeholder Meeting	・No notable point is made under this section.

Table 12.3.2 JICA Study Team's Comments on the Resettlement Plan

Items	Comments and Way Forward (applicable page No.)
Necessity of Land Acquisition and Resettlement	・ No notable point is made under this section.
Legal Framework related to Land Acquisition and Resettlement	・ No notable point is made under this section.
Scale and Extent of Impact of Land Acquisition and Resettlement	・ The size of the farmland was determined based on that claimed by the project-affected persons (PAPs) instead of by visual observation of the experts as, assertedly, the crops were not readily observable on site during the dry season. Given that the PAPs generally possess an incentive to claim for a larger size of land in order to receive greater amount of compensation, the result may well be an overestimate. Further study should be carried out at a time when the crops can be observed to allow more accurate estimation to be made based on visual observation supplemented by interviews to the PAPs (Section 2.2.3/P11). ・ PAPs with an official land title (i.e. DUAT) were identified in the survey based solely on an interview with the PAPs. Hence, the result may have likely missed out those that had not been interviewed and/or may have unduly included those that in fact do not possess a DUAT in the project-affected area. The method of survey aimed at confirming the DUAT holders needs to be improved in a way that produces more accurate results by, for example, confirming the official record of Nacala Municipality supplemented by an interview with the PAPs (Section 2.2.2/P11). ・ Some numbers written in the report were inconsistent with those written in other parts of the report or in other data sets provided by the consultant (e.g. the number of PAPs and farmland size). *The PR attached to this report reflects JICA Study Team's observation of the most likely number found in the report (throughout the report).
Compensation and Support Measures	・ While PR proposes provision of land in Nacala Port for PAPs with DUAT and land in Nacala Velha District for those without DUAT (yet with customary rights to claim), no agreement has been made to date between ANE and Nacala Port and Nacala District government. Candidate sites have not been selected either and hence the condition of such sites is unknown. When the project approaches implementation, ANE should discuss with relevant government organizations (e.g. Nacala Port and Nacala District governments) to reach an agreement so that pieces of land are provided and handed over to the eligible people that have lost them. The candidate sites should also be checked visually to make sure that they are not less favorable than the land currently used by the PAPs (Section 5.2.1/P43). ・ It was made apparent through the survey that those people that lose their religious place have various views on who should be involved in carrying out the transfer of graves and bodies, who should be making decisions on the compensation process and where the graves and bodies should be transferred. Given the sensitivity of the issue over affected graves and places of worship, it is recommended that decisions be made carefully involving all relevant stakeholders including at the minimum the PAPs, local leaders and local authorities to reach a consensus amicably (Section 2.2.6/P13). ・ In accordance with the PR, compensation is planned to be made through bank transfer. However, more than 90 % of the PAPs do not even possess a bank account. While bank transfer is a transparent way of delivering cash and it may also result in more careful spending, if the process of opening and withdrawing from a bank account requires too much time and effort, the payment process may be delayed possibly generating concerns and frustration among the PAPs. It is hence considered worth confirming, given that a large portion of the PAPs do not possess a bank account, whether bank transfer adopted in the PR is the most suitable approach for all PAPs for delivering cash (Section 2.3.6/P16).

Items	Comments and Way Forward (applicable page No.)
Mechanism for Redressing Grievance	・ No notable point is made under this section.
Implementation Structure	・ No notable point is made under this section.
Implementation Schedule	・ No notable point is made under this section.
Cost and Source of Funding	・ In estimating the amount of compensation for crops, an average price of the five main crops grown in the area (i.e. corn, cassava, sesame, okra and sweet potatoes) is applied uniformly to the total area of farmland affected instead of applying the unit price of each crop. However, each PAP needs to be compensated based on exactly what they have lost and the way of estimation adopted in the PR is considered inaccurate. Compensation should be calculated based on the exact number (or land size) of crops (or farmland) affected by the project in the study to be held in the latter stage (Section 6.3/P50). ・ The price table produced by the Ministry of Agriculture and Food Security under Nampula provincial government is adopted in the PR to be used for assessing the value (i.e. unit price) of the crops and trees affected by the project. While this is claimed by law to be based on the market price, no survey has been carried out to verify that it indeed is equivalent with the market price. Hence, a market survey should be carried out in the latter stage of the survey to confirm if the price table shows the market value and to make sure that the PAPs receive a fair compensation (Section 5.2.2/P44). ・ For those crops whose price was not on the list provided by Nampula provincial government (e.g. baobab, Zizyphus mauritania and Trichilia emetic), the consultant has applied the unit prices used in past projects funded by the Millennium Challenge Corporation. However, the consultant could not specify the project or year in which the study was carried out making it impossible to verify their validity. In the future study, price of the crops that are not on the list should be confirmed through a market survey as much as possible (Section 6.4/P51). ・ Compensation for the building and fence was estimated based on the price in Maputo. This is not considered appropriate for the project site (i.e. Nacala). Material and labour cost for building the affected building and fence should be based on the cost in Nacala in the latter stage (Section 6.5/P51-52). ・ It is not clearly shown how the compensation amount of religious places (i.e. graves and places of worship) was estimated (i.e. coffin, transportation, food and healer services). These costs should be clarified based on market and other surveys including interviews in the supplementary study to be held in the latter stage (Section 6.6/P52-53).
Monitoring System	・ No notable point is made under this section.
Public Consultation	・ No notable point is made under this section.

12.4 State of Nacala Port Access Road Project

In September, 2017, MITADER/DPTADER gave their comments to ANE on the SER and PR submitted to DPTADER pointing out that they do not satisfy the conditions for obtaining the environmental license and that the project has been re-categorized to A[18]. In response, ANE issued an official letter to MITADER in December, 2017 arguing that, while there were also some faults on their side, most of the points raised by MITADER appear to stem from the misunderstanding of MITADER/DPTADER. As of February, 2018, ANE is waiting for MITADER's reaction. The major points raised by MITADER/DPTADER in September, 2017 and the understanding of ANE on them are shown below.

Table 12.4.1 Major Points raised by MITADER/DPTADER and Understanding of ANE

No.	Points made by MITADER/DPTADER	Understanding of ANE/Consultant
1	SER has not been prepared in accordance with relevant laws in Mozambique.	It has been prepared in accordance with all relevant laws in Mozambique.
2	MITADER/DPTADER was not made aware of involuntary resettlement.	Involuntary resettlement does not take place under the project.
3	MITADER/DPTADER was not made aware of the fact that a bridge with a length of 840m would be built.	It is written in the TOR submitted from ANE and approved by DPTADER in December, 2016.
4	A stakeholder meeting was held in the absence of officials from DPTADER and Nacala Municipality.	Such officials were present at the meeting. They just did not sign the attendance list. The consultant will make an arrangement to correct the list.

12.5 State of the Remaining Two Projects

As of February 2018, the situation regarding the environmental studies on Nampula Southern Bypass Road Project and Cuamba Bypass Road Project are as follows, according to ANE.

(1) Nampula Southern Bypass Road

- Contract entered into force on August 25, 2017
- Kick-off meeting was held on September 21, 2017
- Work commenced on September 28, 2017
- Inception Report was submitted to ANE in October, 2017
- Environmental Pre-Viability Report and Scope Definition (EPDA) is currently in preparation
- First Public Consultation is being prepared (*currently waiting for the Municipality authorities to indicate the venue)

(2) Cuamba Bypass Road

- EPDA and TOR have been approved by MITADER
- EIA report and RAP are currently in preparation

[18] Decree No. 54/2015 stipulates that projects that involve a road bridge with a length of 100m of more should be categorized A. The project includes a bridge with a length of 840m. Presumably, this is the reason why MITADER/DPTADER considers the project needs to be re-categorized to be A.

CHAPTER 13 Findings and Recommendation

13.1 Findings

This Report summarizes the results of Feasibility Study for Nacala Corridor road network upgrading project which consists of the Nacala Port Access Road, Nampula Southern Bypass Road and Cuamba Bypass Road for future project. As the summary of the result, following points are the findings of the project:

1) The three road projects which include civil works for bypass road with bridges and frontage roads were designed as a technically and economically suitable and effective solution for the introduction of bypass roads by the ANE to alleviate future road traffic congestion due to heavy tracks as international corridor, and to form new urban residence along to the bypass roads. Followings shows the each result of economic viability;

   a. Nacala Port Access road project: The project costs for the implementation of the project under both high and basic development levels will be economically covered by the large amount of benefits from the project road. It means the Project is the economical viable one, especially it is most recommendable project among three sections.

   b. Nampula Southern Bypass Road project: The project costs for the implementation of the project by only basic development level will have economical viability. However, the high level development with future widening will not cover the costs, therefore, it should take into consideration of some additional effects and benefits from the integrated urban developments along the road.

   c. Cuamba Bypass Road project: Among the three sections, this project faces the worst case for economic analysis due to less traffic volume for current and future traffic estimation. Since it is still under rehabilitation between Malema to Cuamba, so that the demand of traffic is not envisioned at this moment. However, this diversion route for avoiding through traffic such as international and intercity cargo may help to alleviate future traffic congestion and provide further potential of urban development.

2) In terms of operation and maintenance of the Project roads, it is envisioned that proper maintenance organization should be setup and appropriate budgets should be secured. In addition, because the heavy traffic volume is estimated to use these roads, safety measurements and devices are also required.

3) In terms of environment and social aspect, EIA study revealed that the potential impacts of the proposed project take place mainly during the construction stage, especially protecting the erosion of embankment and cutting area. Latest technical solutions for construction method proposed by the Study team will help to mitigate these impacts.

4) Social study revealed that a certain scale of agricultural land and graves at Nacala Port Access Road, and of residences along the Nampula Southern Bypass Road. However, the number of houses and commercial establishments to be relocated due to the project is relatively low, since these routes are mainly through un-developed area.

Therefore, the project is expected to be implemented as new bypass roads not to avoid future congestion, but to promote and form to future integrated urban development along the roads.

13.2 Recommendations on the Project

(1) Nacala Port Access Road Project

Since this road aims to connect directly to Nacala Port to ease heavy cargo traffic related to the port, it is highly recommended to coordinate with port expansion project which is implemented by JICA ODA loan. The connected sections and operational methods around the port are carefully designed during the detailed design stage.

In addition, the area along this road is planned as integrated development together with industrial park, shunting yards and track terminal to promote the industry of exporting and processing goods for the people in Nacala corridor. Therefore, it is recommended to coordinate with relevant stakeholders and institutions to share the same view for development along the road. Note that water and electricity are essential items for development, so that these utility lines can be installed in/along the roads.

For Nacala Port Access Road, considering the local environments and characteristics, the application of the following technologies, which is introduced in Chapter 9, is recommended.

- Resin Coating Film (Coating) for Pre-stressed Concrete (PC) Steel/ Rebar (Epoxy Resin, Polyethylene Injection, etc.)
- Temporary Cofferdam by combined use of Special Steel Sheet Pile and Expandable Water Cut-off Material
- Multi-functional Slope Protection Mat
- ICT Monitoring and Measurement for construction supervision of impacts around construction site
- Pavement Management by Mobile Mapping System, including road assets management

(2) Nampula Southern Bypass Road Project

It is envisioned that the proposed bypass road runs at outside of urbanization area and will form the new urban area along the road in line with logistics and transport related facilities. This road can also provide a inter-city public transport terminal. Therefore, the coordination with urban development plan and inter-city transport related facilities are essential at the implementation stage.

In addition, there are two points where it flyovers the railway, the technical solution for bridges may affect the cost and construction period. Therefore, it is recommended that proposed

Japanese technology such as steel-concrete composite slab girder bridge shall be applied to reduce the height of approach and its civil work's cost.

(3) Cuamba Bypass Road

Cuamba has not been urbanized and is envisioned once the Nacala corridor will be opened as intentional corridor. Since the North-side area made the limitation of urbanization and causes the difficulties of flood control, this road will play a role of opportunity to create the new urban area and protection barrier for its flooding. In addition, the west-side of road has enough vacant area for future industrial development for agro-processing to encourage the regional economy. Therefore, the integrated considerations together with urban planning and industrial development are recommended. The close communication with local government is an essential to realize the new urban are with this bypass road.

(4) Environmental and Social Considerations

1) Early Mobilization of the Supplementary Environmental Survey

Given that the project is not expected to be implemented any time soon, a supplementary survey is considered necessary to be carried out in the future before project implementation in order to update the ARAP[1]. Among others, it is particularly important to confirm and update the information on the people, land, crops, religious places and other assets that are expected to be affected by the project, and to estimate the amount of compensation to be made to the PAPs through a census, lost-asset inventory and socioeconomic survey. These surveys should be carried out with in mind the points raised in '12.3 Points of Improvement for SER and PR and Way Forward'. In light of the volume of work needed for this environmental survey, it is recommended that commencement of the survey precedes other technical surveys that may be needed in order to secure enough time to complete it in a rigorous manner and to avoid any delay in commencement of the project.

2) Stakeholder Involvement based on Patience, Due Diligence and Sincerity

In light of the fact that the project involves impact on some sensitive issues (e.g. graves and worship places) and that consensus is far from being reached to date, it is considered particularly important for ANE to ensure that decisions related to this issue and others are made based on a sense of trust with, and support for the project from, the local people. While the project, as more or less any other infrastructure development projects, entails some negative impacts, the benefits accrued from the project are expected to largely outweigh the costs. This point should be clearly explained and understood by the local community. Consensus building with the community should not be carried out in haste. Instead, every step should be taken with patience, due diligence and sincerity. This best ensures ANE to earn people's endorsement and avoid social problems from arising.

[1] ARAP is considered valid for approximately two years.