REGIONAL TRADE FACILITATION PROGRAMME

PROJECT MANAGEMENT UNIT (PMU)

ECONOMIC BENEFITS OF AN EFFICIENT NORTH-SOUTH CORRIDOR

Strategic Level Analysis of Investments in the North-South Corridor Using HDM-4

FINAL REPORT

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LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
COMESA	Common Market for Eastern and Southern Africa
DfID	Department for International Development, UK
DRC	Democratic Republic of Congo
EAC	East African Community
GDP	Gross Domestic Product
GVM	Gross Vehicle Mass
HDM-4	Highway Development and Management Tool
PMU	Programme Management Unit of the Regional Trade Facilitation Programme
REC	Regional Economic Communities
RSA	Republic of South Africa
ROCKS	Road Costs Knowledge System
RTFP	Regional Trade Facilitation Programme
RUC	Road User Costs
SADC	Southern Africa Development Community

EXECUTIVE SUMMARY

Context

The primary aim of Aid for Trade is to assist developing countries to increase exports of goods and services, to integrate into the multilateral trading system, and to benefit from liberalised trade and increased market access.

The North-South Corridor is a pilot Aid for Trade programme which is being administered through the COMESA-EAC-SADC Tripartite process that focuses on transport and transit issues. The North-South Corridor runs between the port of Dar es Salaam in Tanzania to the Copperbelt of Zambia and DR Congo and down through Zimbabwe and Botswana to the ports in southern Africa, taking in 'spur' connections through Malawi and Mozambique in the east (See map in Figure 1.1). The pilot programme aims to bring together the initiatives which are taking place along this corridor and identify missing links and activities so that they can be dealt with in a coordinated manner.

The Project Management Unit (PMU) of RTFP (which provides the Secretariat to the COMESA-EAC-SADC task Team) is concerned to demonstrate that an efficient North-South Corridor is economically viable to the region or otherwise. RTFP PMU therefore proposed to undertake a study with the main objective of preparing a global overarching economic document that would satisfy donors (and private funds) that ultimately an efficient North-South Corridor is economically viable in the medium to long term period. RTFP PMU commissioned the University of Birmingham (as Consultant) to use the Highway Development and Management (HDM-4) tool to conduct a strategic level study of the North-South Corridor to illustrate the primary economic benefits of an efficient North-South Corridor.

Methodology

The methods used were based on a desk study of available data from the road agencies that manage the different sections within the North-South Corridor. The initial procedures of the study involved establishing a baseline case of the present situation within the corridor. This included a description of the various national economies and socio-economic characteristics, a representation of the road infrastructure into homogeneous sections, definition of traffic characteristics in terms of volumes, loading and growth rates, and a representation of border posts and delays. The next step was to adapt and calibrate HDM-4 to local situation within the corridor, since the reliability of the results will partly depend on this activity and partly on the input data. The set of data used for adaptation and calibration was obtained mostly from Malawi and Zambia.

The main data sets required as inputs for HDM-4 analyses were categorised under the road network, vehicle fleet, traffic, border post, and road works. The sources of data used in this study included RTFP GIS database www.rtfp.co.za; Road Agencies of Botswana, Malawi, Mozambique, Tanzania and Zambia; previous studies conducted in the region; and Internet literature review. Logical assumptions were made to fill in the gaps in cases where data were either lacking or missing. In summary 96 road sections of total length 10,547 km and 14 border posts were included in the study. A uniform traffic growth rate of 5 percent per annum was used. The border post crossings were modelled within the road network using dummy road sections with adjusted characteristics to simulate the delays experienced in real border crossing operations.

The study considered three road network improvement scenarios which were defined and compared against the base case scenario:

- *Scenario RN-1:* assumes that Road Agencies shall maintain the roads on the North-South Corridor to an *Excellent* standard (i.e. technically at an average roughness of 2 IRI).
- *Scenario RN-2*: assumes that Road Agencies shall maintain the roads on the North-South Corridor to a *Very Good* standard (i.e. technically at an average roughness of 3 IRI).
- *Scenario RN-3:* assumes that Road Agencies shall maintain the roads on the North-South Corridor to a *Good* standard (i.e. technically at an average roughness of below 4 IRI).

The improvement scenarios involved widening the roads, where necessary, to a standard width of 7.3 metres and maintaining it by applying periodic maintenance and routine maintenance such that average long-term road condition will not exceed the specified threshold value.

An important aim of the study was to quantify benefits that may result from investments to reduce current delays at border posts along the North-South Corridor. To that end, three border post improvement scenarios were defined and compared against the base case scenario of maintaining the ‘status quo’:

- *Scenario BP-1:* considers that the current observed delays at border posts will be reduced by10% after improvements
- *Scenario BP-2:* assumes that the current observed delays at border posts will be reduced by 20% after improvements
- *Scenario BP-3:* assumes that the current observed delays at border posts will be reduced by 50% after improvements are implemented

The border post improvement alternatives include investments specified to improve the infrastructure, management and operations at the border posts.

The study analysed various combinations of road section improvement and border post improvement scenarios. Two sets of analysis were carried out: one involved all the road sections on the North-South Corridor and the other excluded road sections in the Republic of South Africa.

Summary Results

Different investment scenarios were analysed separately and the following are the main conclusions from the study:

- The most viable investment scenario in economic terms is for Road Agencies to maintain all the roads on the North-South Corridor in Good condition, which is denoted Scenario “RN-3, BP-3”. Technically the long-term average road condition, over the 20-year analysis period, would be 3.1 IRI. The total financial investment required for road network improvement is US$ 9.1 billion of which US$ 5.9 billion is capital investment and US$ 3.2 billion is recurrent costs. The total financial requirement for border post improvement is US$ 0.73 billion of which US$ 0.26 billion is capital investment and US$ 0.47 billion is recurrent costs. The annualised financial requirement to improve the road network is approximately US$ 43,100 per km. The economic return on this investment (i.e. the NPV) would be US$ 29.2 billion. The benefit/capital cost ratio associated with this investment is 6.5.

- When road sections from the Republic of South Africa are excluded from the analysis, investment scenario “RN-3, BP-3” still remains the most economically attractive. The long-term average road condition, over the 20-year analysis period, would be 3.6 IRI. The total financial investment required for road network improvement is US$ 6.9 billion of which US$ 4.5 billion is capital investment and US$

2.4 billion is recurrent costs. The total financial requirement for border post improvement is US$ 0.73 billion of which US$ 0.26 billion is capital investment and US$ 0.47 billion is recurrent costs. The annualised financial requirement to improve the road network is approximately US$ 40,000 per km. The economic return on this investment (i.e. the NPV) would be US$ 13.9 billion. The benefit/capital cost ratio associated with this investment is 3.1.

- The results of sensitivity analysis have indicated that even at zero percent rate of traffic growth (to crudely assess the effect of traffic diversion to other transport modes and routes/corridors) the NPV of investment scenario “RN-3, BP-3” is still positive US$ 15.1 billion for all road sections, and positive US$ 7.6 billion when road sections in the Republic of South Africa are excluded.

- The results show that in the initial years of the 20-year analysis period, higher amounts of investment expenditures are required to eliminate maintenance backlogs and raise the road standard to an appropriate level for the North-South Corridor.

- The approximate timing when the cumulative net economic benefit of investments will become positive was determined to be Year 9 (with RSA roads included) and Year 7 (without RSA roads) for investment scenario RN-2 (i.e. the Road Agencies shall maintain the roads on the North-South Corridor to Very Good condition); and Year 7 (with RSA roads) and Year 5 (without RSA roads) for Scenario RN-3. It is important to note that this does not imply that the inclusion of road sections in RSA makes the investment cases economically less attractive. On the contrary, analysis results have shown that the benefit/ capital cost ratios are higher when road sections in RSA are included. This perhaps stresses the need for carrying out a financial analysis of the corridor roads, the results of which would indicate to the private sector when they could get seriously involved in investing in the North-South Corridor.

- The NPV of selected key routes within the North–South corridor have also been determined to show the degree of economic attractiveness of each route. A full road works programme for 20 years has also been produced showing when each section is to receive an intervention with costs.

This study has demonstrated that there is an attractive rate of return to be realised from investment in the North–South Corridor. The study was based on an appropriate methodology and a more advanced use of the highway development and management (HDM-4) tool.

The Way Forward

It should be noted that the reliability of the results of any studies using prediction models such as HDM-4 is dependent upon two primary considerations:

- How well the data provided to the model represent the reality of the current conditions and influencing factors, in the terms understood by the model; and,
- How well the predictions of the model fit the real behaviour and the interactions between various factors for the conditions prevailing in the countries and regions to which it is applied.

Although the study team made great effort to obtain reliable input data and calibrate the models, available project resources limited these tasks. Nevertheless, the rigorous sensitivity analysis conducted has confirmed the robustness of the results obtained. Largely, default HDM-4 model parameters and data obtained from desk studies were used. Confidence in using the results obtained from this study could be increased through additional studies to:

1. Calibrate HDM-4 models to conditions within the North–South Corridor to Level 2 Calibration;
2. Validate the data held by the various road agencies that manage road sections within the corridor in order to determine their appropriateness for use in future studies of the North–South Corridor;
3. Investigate the impact of overloading of goods vehicles on road deterioration; and
4. Carry out a financial analysis of investments in the North-South Corridor to assess how the private sector could get involved, for example, through Public-Private-Partnership (PPP) or other appropriate investment models.

1 INTRODUCTION

1.1 Background

Developing countries devote a considerable proportion of total infrastructure investment to roads and yet recent research suggests that isolation from regional and international markets has contributed significantly to poverty in many Sub-Saharan African countries. The international community has responded to this situation by calling for an increase in Aid for Trade in terms of resource quantities and efficiency in their utilisation. The primary aim of Aid for Trade is to assist developing countries to increase exports of goods and services, to integrate into the multilateral trading system, and to benefit from liberalised trade and increased market access.

The Regional Economic Communities (REC) of the Common Market for Eastern and Southern Africa (COMESA), the Southern Africa Development Community (SADC) and the East African Community (EAC) have long recognised the importance of improving trade facilitation in the context of deepening regional integration and in reducing the costs of cross-border transactions and so improving livelihoods. As such, the RECs have supported a number of trade facilitation instruments as well as developing plans for regional infrastructural development programmes, www.rtfp.org (October 2008).

The North-South Corridor runs between the port of Dar es Salaam in Tanzania to the Copperbelt of Zambia and Democratic Republic of Congo and down through Zimbabwe and Botswana to the ports in southern Africa, taking in ‘spur’ connections to Malawi and Mozambique in the east (See map in Figure 1.1). The pilot programme aims to bring together the initiatives which are taking place along this corridor and identify missing links and activities so that they can be dealt with in a coordinated manner.

The Project Management Unit (PMU) of RTFP is concerned to demonstrate that an efficient North-South Corridor is economically viable to the region or otherwise. RTFP PMU therefore proposed to undertake a study with the main objective of preparing a global overarching economic document that would satisfy donors (and private funds) that ultimately an efficient North-South Corridor is economically viable in the medium to long term period. RTFP PMU commissioned the University of Birmingham (as Consultant) to use the Highway Development and Management (HDM-4) tool to conduct a strategic level study of the North-South Corridor to illustrate the primary economic benefits of an efficient North-South Corridor.

This document describes the methodology and procedures used to conduct the first stage of the study and the results obtained.

Figure 1.1: Map of the North-South Corridor

1.2 Project Aim and Objectives

The main aim of the first stage of the study is to prove the feasibility of using HDM-4 to show, at the strategic level, the economic benefits of an efficient North-South Corridor in relationship to trade in the region.

The specific objectives are as follows:

- To prepare and apply HDM-4 at a strategic level to study the impact of different road investment alternatives on the North-South Corridor road network
- To determine the need for a further study of the North-South Corridor.

1.3 Scope of the Project

In order to achieve the objectives of this project, the Consultant carried out a number of tasks which are summarised as follows:

- Established a baseline case of the present economic situations within the Corridor
- Defined the link characteristics within the corridor and the network structure for HDM-4 application
- Identified, collected and processed data needed for the specific study including the present vehicle characteristics as well as expected new vehicle types that will use the corridor once it is improved.
- Adapted HDM-4 to local conditions, initially achieved a Level 1 Calibration of HDM-4 models
- Developed several investment scenarios for the North-South Corridor which took into account growth in trade, traffic and the economy.
- Specified different road improvement alternatives for the corridor and for each future scenario that was analyzed
- Carried out a number of HDM-4 runs as were necessary for all the combinations of factors and improvement alternatives, and conducted analyses of the results
- Documented the study methodology, procedures and results

1.4 Project Deliverables

The main project deliverables include the following:

- A customized HDM-4 Workspace for North-South Corridor
- Strategic level studies related to agreed future road network improvement scenarios and their financial, economic and technical impacts
- Project final report

2 STUDY METHODOLOGY

2.1 Present situation within the North-South Corridor

Economy

The economy in the region serviced by the North-South Corridor can be summarily indicated by the level and growth rates of the following parameters: gross domestic products (GDP), population, and traffic. Table 2.1 gives the GDP and population figures for the countries in the region and compares these with the totals for Sub-Saharan Africa.

Table 2.1: GDP and Population as Economic Indicators

Country	GDP (Billion US$)	GDP Growth (%)	Population (Millions)	Population Growth (%)
Botswana	12.0	4	2	1.2
Democratic Republic of Congo	9.0	6	62	3.0
Malawi	3.6	7	14	2.5
Mozambique	7.8	7	21	2.0
Republic of South Africa	278.0	5	48	0.4
Tanzania	16.0	7	40	2.4
Zambia	11.0	6	12	2.0
Zimbabwe*	3.4	-5	13	1.3
N-S Corridor Estimate	**340.8**	**5**	**212**	**1.9**
Sub-Saharan Africa	**843.0**	**6**	**800**	**2.4**

Source: World Bank (2007)
Note: * Figures for 2005

The North-South Corridor is the busiest in the region in terms of values and volumes of freight. The road network is already under pressure in relation to its design capacities and in terms of delays at strategic points, such as border posts. A number of mineral deposits within the region have become economically interesting and increased levels of mining activities will lead to increased volumes of exports and imports with consequential heavy loading of the North-South road infrastructure.

Road infrastructure

The road network comprises mainly paved roads of asphalt concrete and surface treatment. It is generally in fairly good condition although there are sections of road that are in urgent need of rehabilitation and improvement. There are also heavily trafficked sections that may create bottlenecks in terms of structural capacity, and cause closure of the whole network if blocked e.g. bridge crossings.

Table 2.2 gives a summarised distribution of the road sections included in this study. Details of the road sections are provided in Appendix A.

Table 2.2: Summary of Road Sections in the North-South Corridor

Country	Number of Sections	Length (in km)	Network Coverage (%)
Botswana	6	1,037	10
DR Congo	4	400	4
Malawi	14	1,128	11
Mozambique	4	263	2
Republic of South Africa	8	1,901	18
Tanzania	9	1,013	10
Zambia	38	2,638	25
Zimbabwe	13	2,169	21
Total	**96**	**10,547**	**100**

Traffic characteristics

Current traffic on the North-South Corridor is characterised by exports of mining and agricultural products and imports of manufactured goods. The main operating feature of the regional road transport routes identified by RTFP (2008), which affects transport efficiency, costs and tariffs, is the severe imbalance of freight flows, leading to empty return hauls. This imbalance can be seasonal and an empty return haul by road effectively means that the transport cost almost doubles. The current traffic data collected as part of the study are given in Section 2.3. Table 2.3 gives a summary of the average daily vehicle-kilometres by country. This shows that the roads in the Republic of South Africa carry over 69% of the total number of vehicle-kilometres in North-South Corridor. The number of medium and heavy goods vehicles, expressed as a percentage of the total vehicle-kilometres for each country, varies from about 21.9% in Botswana to 45.3% in DR Congo.

Table 2.3: Average Daily Vehicle-Kilometres in the North-South Corridor

Country	Average Daily Veh-km	Percent of Average Daily Veh-km	Percent of country Veh-km by Medium and Heavy Goods
Botswana	2,187,283	4.4	21.9
DR Congo	167,821	0.3	45.3
Malawi	1,671,092	3.4	26.5
Mozambique	405,542	0.8	25.9
Republic of South Africa	34,370,000	69.1	25.8
Tanzania	2,711,333	5.5	30.7
Zambia	3,993,962	8.0	26.8
Zimbabwe	4,223,500	8.5	25.9

Overloading on the Corridor is an issue based on specific studies in the region. Regional freight traffic is usually carried in large double trailer, seven-axle combination rigs, with a maximum gross vehicle mass (GVM) of 56 tonnes. In order to preserve the road infrastructure and ensure reasonable usable life times, countries in the region have generally agreed the following axle load limits (RTFP, 2008): single-steering-axle two tyres 8 tonnes, single-axle dual-tyres 10 tonnes, tandem axle four tyres 16 tonnes, tandem axle dual tyres 18 tonnes, triple axle six tyres 24 tonnes, and triple axle twelve tyres 24 tonnes. However, not all countries apply these axle loading limits. According to one report ANE (2007) of a study on axle load survey in Mozambique, it was found that 35% of trucks were overloaded by 34%.

In this study, the impacts of overloading on the Corridor were reflected in the models in terms of increased road deterioration and agency costs resulting from higher equivalent standard axle loads, and increased vehicle operation costs as a consequence of higher GVM.

Border posts and delays

It has been estimated that the cost of current delays at border post crossings in the region amount to many millions of US dollars. Table 2.4 presents the Border Posts in the North-South Corridor. Typical values of border delays at Chirundu Border Post are given in Section 2.3.

Table 2.4: Border Posts in the North-South Corridor

No	Name of Post	Countries Joined
1	Kasumbalesa	DR Congo - Zambia
2	Tunduma BP	Tanzania - Zambia
3	Songwe	Tanzania - Malawi
4	Victoria Falls	Zambia - Zimbabwe
5	Chirundu	Zambia - Zimbabwe
6	Kazangula	Zambia - Botswana
7	Mchinji	Zambia - Malawi
8	Zobue	Malawi - Mozambique
9	Dedza	Malawi - Mozambique
10	Beit Bridge	Republic of South Africa - Zimbabwe
11	Lobatse	Republic of South Africa - Botswana
12	Gabarone	Republic of South Africa - Botswana
13	Martin's Drift	Republic of South Africa - Botswana
14	Nyamapanda	Zimbabwe - Mozambique

2.2 HDM-4 as the Analytical Tool

HDM-4 was used as the analytical tool for this project. The HDM-4 analytical framework (Odoki and Kerali, 2000) is based on the concept of pavement life cycle analysis, which is typically 15 to 40 years. This is applied to predict road deterioration, road works effects, road user effects and socio-economic and environmental effects.

After its construction, a road pavement deteriorates as a consequence of several factors, most notably: traffic volume and loading, pavement design, material types, construction quality, environmental weathering and the effect of inadequate drainage systems. The rate of pavement deterioration is directly affected by the standards of maintenance applied to repair defects on the pavement surface or to preserve the structural integrity of the pavement thereby permitting the road to carry traffic in accordance with its design function. Consequently, in addition to the capital costs of road construction, the total costs that are incurred by road agencies will depend on the standards of maintenance and improvement applied.

The impacts of the road condition (as well the road design standards) on road users are measured in terms of road user costs (RUC), and other social and environmental effects. RUC comprise: vehicle operation costs (i.e., fuel, tyres, depreciation, etc.), costs of travel time for both passengers and cargo due to road condition and traffic congestion, and costs to the economy of road accidents (i.e., loss of life, injury to road users, damage to vehicles and roadside objects). The social and environmental effects comprise: vehicle emissions, energy consumption, traffic noise and other welfare benefits to the population served by the roads.

The interacting sets of costs, related to those incurred by the road authority and those incurred by the road users, are added together over time in discounted present values. Economic benefits are then determined by comparing the total cost streams for various maintenance and construction alternatives with a base case, typically a ‘do nothing’ or minimum maintenance scenario. For this research, economic benefits were calculated as the difference between the do minimum option and the various scenarios for both options. The HDM-4 model was used to simulate future changes to the North-South Corridor road system from current conditions. The reliability of the results is dependent upon two primary considerations (Bennett and Paterson, 2000):

1. How well the data provided to the model represent the reality of current conditions and influencing factors, in the terms understood by the model; and,

2. How well the predictions of the model fit the real behaviour and the interactions between various factors for the variety of conditions to which it is applied.

Application of the HDM-4 model thus involves two important initial steps:

1. *Data input*: a correct interpretation of the data input requirements, and achieving a quality of input data that is appropriate to the desired reliability of the results.

2. *Calibration of output*: adjusting the model parameters to enhance the convergence of the computed road behaviour with that observed in the field for the various interventions. Calibration of the HDM model focuses on the components that determine the physical quantities, costs and benefits predicted by the analyses.

Since HDM-4 is designed to be used in a wide range of environments, it needed to be configured to reflect the North-South Corridor characteristics. The data for this relates to traffic flows, climate zones and road types. Calibration is intended to improve the accuracy of predicted pavement performance and vehicle resource consumption. A fundamental assumption made prior to using HDM-4 is that the pavement performance models will be calibrated to reflect the observed rates of pavement deterioration on the roads where the models are applied. The extent of calibration may be defined as follows:

Level 1: *Application:* based on a desk study of available data and engineering experience of pavement performance.

Level 2: *Verification:* based on measured pavement condition data collected from a large number of road sections.

Level 3: *Adaptation:* experimental data collection required to monitor the long-term performance of pavements within the study area.

This study used Level 1 calibration, where the focus was on calibrating the key road deterioration models for cracking, rutting, and roughness-age-environmental effects; and road user effects models for vehicle speeds. The calibration data used were obtained from Malawi and Zambia. For strategic level analysis this together with HDM-4 default data was considered adequate although it would have been most useful to obtain information from the other countries.

2.3 Data Requirements

Overview

The main data sets required as inputs for HDM-4 analyses are categorised as follows:

1. *Road network data*: include inventory, geometry, pavement type, pavement strength, road condition
2. *Vehicle fleet data*: include vehicle physical characteristics, tyres, utilisation, loading and performance.
3. *Traffic data*: include details of traffic composition, volumes and growth rates, speed-flow types and traffic flow pattern.
4. *Border post data*: include delays and associated costs.
5. *Road works data*: include a range of construction and maintenance work items together with their unit costs.

The sources of data used in this study included the following:

- RTFP GIS database www.rtfp.co.za
- Road Agencies of Malawi, Zambia, Tanzania, Mozambique, Botswana, the Republic of South Africa and Botswana
- Previous studies conducted in the region
- Internet literature review
- HDM-4 parameter default values

Road network data

The road network structure adopted in this study is based on the RTFP GIS database for the North-South Corridor www.rtfp.co.za. The roads in the North-South Corridor were defined as a series of homogeneous road sections with unique characteristics.

The Study Team defined the key data items required for HDM-4 analysis in a set of tables and sent these out to the Road Agencies of the interested countries. Some road agencies completed the tables with particular attention while others were not able to return their data in the format required. The list of sections studied and the key data required are given Table A.1 in Appendix A. The map given in Figure 1.1 shows the North-South Corridor road network. The climatic data used is given in Table A.2 in Appendix A. A major assumption made in this study was that the data provided by the different road agencies and those obtained from the RTFP GIS database were reasonably accurate for strategic network level analysis. The overall confidence level in the project data used have been qualitatively assessed and categorised by the Study Team as given in Table 2.5.

Table 2.5: Overall Confidence Level in the Data Used in this Study

Data by Country	Network Coverage (%)	Qualitative Confidence Level
Botswana	10	Low-Medium
DR Congo	4	Low
Malawi	11	Medium-High
Mozambique	2	Medium
Republic of South Africa	18	Medium-High
Tanzania	10	Medium
Zambia	25	Medium-High
Zimbabwe	21	Low-Medium

Vehicle fleet data

A representation of the vehicle fleet that use the North-South Corridor was based on grouping vehicles of similar characteristics and the types of goods they carry. This resulted in the following six vehicle categories:

(i) Cars and Utilities including Four-wheel Drives and Pick-up

(ii) Light Goods Vehicles

(iii) Mini-bus

(iv) Bus

(v) Medium Goods Vehicles

(vi) Heavy Goods Vehicles

The key vehicle fleet data used in this study were obtained from the Road Agencies and these are presented in Table B.1 given in Appendix B. HDM-4 default data were used were local data were not available.

Traffic data

The traffic data used in this study include annual average daily traffic (AADT) and composition by vehicle types for each road section, and average traffic growth rate. The AADT data were mainly obtained from the Road Agencies except for road sections in Zimbabwe and the Democratic Republic of Congo for which the AADT values were estimated. `

The AADT for the road sections in Zimbabwe and the Democratic Republic of Congo were estimated by first considering the traffic through the border posts with Zambia crossing into the respective countries. The partial AADT estimates of through borders traffic were then adjusted to full section AADT values by considering factors such as road class, junctions and socio-economic characteristics of the respective countries.

Details of two-way AADT including traffic composition for each of the sections studied are given in Table C.1 in Appendix C. In cases where two or more traffic sections were represented by a single road section in the study, a weighted average AADT value (based on section lengths) was used. The traffic data shows that 28 percent of the traffic comprises medium and heavy goods vehicles.

The main factor driving traffic growth on the North-South Corridor is trade and associated movement of goods. It is envisaged that passenger travels will also increase significantly in the years to come. A single annual traffic growth rate of 5 percent was assumed for the entire North-South Corridor although the GDP growth rate in the region would indicate a higher traffic growth rate based on the conceptual relationship that traffic growth rate approximates to 1.5*GDP. However, the use of 5 percent value is supported by several studies conducted on parts of the Corridor including one in Zambia and that by Nippon Koei and Oriental Consultants for SADC in 2007. In order to account for the effects of possible variation in traffic growth rate, sensitivity tests were carried out and this is reported under Section 3.7.

Modelling delays at border posts

The modelling of delays at border posts necessitated advanced (or special) use of HDM-4 in order to study the related impacts. The border post crossings were modelled within the road network using dummy road sections with adjusted characteristics to simulate the delays experienced in real border crossing operations. Figure 2.1 illustrates the representation of the dummy links and the traffic characteristics associated with each dummy link labelled A, B and C.

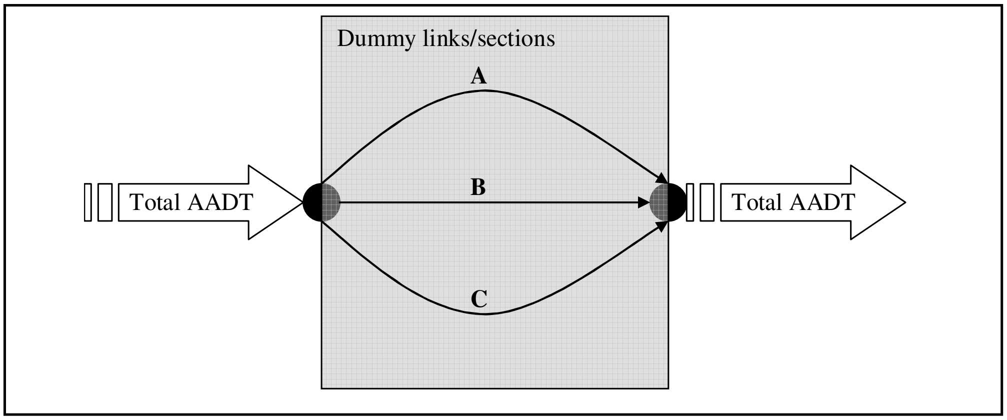

Figure 2.1: Border Post Crossing Model

The vehicles using link A are Passenger Cars, Buses, Mini-Buses, Light vehicles; the vehicles using link B are Refrigerated Trucks, Oil Tankers; and the vehicles using link C are Heavy Trucks, Containerised. The AADT for each dummy link was determined on the basis of the traffic composition on the border approach road sections.

As an example of the modelling approach described above, the details of border post delays at Chirundu are presented in Table 2.6.

Table 2.6: Border Post Delays at Chirundu

Dummy Link	Vehicles types	Travel Direction	Delays (in Hrs)
A	Passenger Cars, Buses, Mini-Buses, Light vehicles	North-bound	1
		South-bound	1
B	Refrigerated Trucks, Oil Tankers	North-bound	28.5
		South-bound	7
C	Heavy Trucks, Containerised	North-bound	40.5
		South-bound	20.5

Source: Transport Logistic Consultants

In modelling using HDM-4, the total cost of delays at border posts is calculated from the sum of the following cost components: value of goods delayed, additional vehicle crew cost, additional overhead cost, and passenger time value.

Road works and unit costs

The primary sources of the unit cost data were World Bank ROCKS and Road Agencies within the N-S Corridor. Tables 2.7 and 2.8 show the assumed border post investments and maintenance costs and a summary of the unit costs used for road works.

Table 2.7: Border Post Investment and Maintenance Costs

Border Post	Investment (Million US$)	Maintenance Cost/Year (Million US$)
Kazangula	100	1
Beit Bridge	50	1
Kasembulesa	20	1
Others	10	1

Table 2.8: Road Works and Unit Costs

Work Type	Description	Economic Costs (US$)	Financial Costs (US$)	Units
Patching Potholes	Repair of surface distresses such as potholing, wide structural cracking and ravelling	34	40	m^2
Edge Break Repair	Patching edge failures on paved roads	42.6	50	m^2
Crack Sealing	Treatment of transverse thermal cracking and wide structural cracking on paved roads	17	20	m^2
Miscellaneous Works	Includes shoulder repairs, vegetation control, road sign repairs and replacement, line marking, guardrail repair and replacement, etc.	2,125	2,500	Per km per Year
Regravelling	Regravelling existing unpaved road to a final grave thickness of 150mm	109	133	m^2
Heavy Grading	Heavy motorised grading of unpaved roads with water and light roller compaction	595	700	m^2
Spot Regravelling	Spot regravelling to unpaved roads to replace 80% of annual material loss	123	150	m^2
Cape seal	Cape seal with shape correction	12.75	15	m^2
Surface Dressing	Single sealing of the carriageway with shape correction in order to delay major intervention and to renew the skid resistance.	5.95	7	m^2
50mm Overlay	50mm overlay to existing asphalt concrete road.	21.25	25	m^2
80mm Overlay	80mm Overlay to existing asphalt concrete road.	34	40	m^2
Reconstruction (STGB)[1]	Reconstruction of existing surface treatment road comprising double surface dressing on granular base	59.5	70	m^2
Reconstruction (AMGB)[2]	Pavement reconstruction of existing asphalt concrete road comprising 50mm asphalt concrete surfacing on granular base.	85	100	m^2
Partial Widening (STGB)[1]	Widening of existing asphalt mix roads to 7.3m width where necessary and providing a 50mm overlay to existing surfacing	85,000	100,000	Per Km
Partial Widening (AMGB)[2]	Widening of existing asphalt mix roads to 7.3m width where necessary and providing a 50mm overlay to existing surfacing	127,500	150,000	Per Km
Upgrade gravel road	Upgrading existing gravel road to a 7.3m wide asphalt mix on granular base road	680,000	800,000	Per Km

1. STGB refers to road pavement type comprising Surface Treatment on Granular Base
2. AMGB refers to road pavement type comprising Asphalt Mix on Granular Base

2.4 Economic Analysis Components and Parameters

Road network improvement scenarios

The study considered three road network improvement scenarios which were defined and compared against the base case scenario. Table 2.9 gives the definition of these scenarios.

Table 2.9: Road Network Scenarios

Scenario	Target Condition
Base Case Scenario	Comprises routine maintenance works and activities
Scenario RN-1	This scenario assumes that the Road Agencies shall maintain the roads on the North – South Corridor in Excellent condition in the long-term.
Scenario RN-2	This scenario assumes that the Road Agencies shall maintain the roads on the North – South Corridor in Very Good condition in the long-term.
Scenario RN-3	This scenario assumes that the Road Agencies shall maintain the roads on the North – South Corridor in Good condition in the long-term.

For each scenario, two investment alternatives were defined as follows:

1. “Do minimum” alternative: aimed at preserving the existing asset using recurrent expenditure for routine maintenance.

2. Improvement alternative: aimed at improving the road standard and maintaining it by applying periodic maintenance and routine maintenance such that average long-term road condition will not exceed a certain threshold roughness value.

For each alternative, road work standards were defined in such a way that the objective of the scenario can be achieved. A work standard comprises one or more works item (e.g., overlay, reseal, patching), defined intervention criteria to determine the timing, design characteristics, the unit costs, and the after works effects. The unit costs of works items are given in Table 2.8. Tables 2.10 to 2.13 present the work standards defined for each road network improvement scenarios.

Table 2.10: Base Case Scenario Standard

Work Types	Intervention Criteria	After Works Effects
Patching Potholes	Potholing >= 10 no./km	Repair to 100% of potholes, TLF[1] = 2 months.
Edge Break Repair	Edge break >= $5m^2$/km	Repair to 100% of edge breaks
Crack Sealing	Wide Structural Cracking >= 1%	Repair to 100% of thermal cracks, and wide structural cracks
Miscellaneous Works	Interval >= 1 Year	N/A
Regravelling	Gravel Thickness <= 150 mm	Roughness >= 3.0 IRI
Heavy Grading	Roughness >= 5 IRI AND	N/A
	Interval >= 90 days	
Spot Regravelling	Interval >= 1 Year	

Notes:

1. TLF = Time Lapse Factor
2. Work types are described in Table 2.8

Table 2.11: Scenario RN-1 Standard

Work Types	Intervention Criteria	After Works Effects
Routine maintenance Includes: potholes, edge breaks, carriageway cracks, spot regravelling, and heavy grading	To be performed every year	Determined using HDM-4 relationships
80 mm Overlay	Roughness >= 2 IRI	Roughness = 1.8 IRI
50mm Overlay	Roughness >= 2 IRI	Roughness = 1.8 IRI
Reconstruction Asphalt Mix	Roughness >= 7 IRI	Roughness = 1.2 IRI
Reconstruction Surface Treatment on Granular Base	Roughness >= 7 IRI	Roughness = 1.2 IRI
Cape seal	Roughness >= 2 IRI	Roughness = 2.0 IRI
Surface dressing	Roughness >= 2 IRI	Roughness = 2.0 IRI
Partial Widening Asphalt Mix	AADT >= 5000 Veh/day	Roughness = 1.5 IRI
Partial Widening Surface Treatment	AADT >= 4000 Veh/day	Roughness = 1.5 IRI
Upgrade gravel road	AADT >= 500 Veh/day	Roughness = 1.5 IRI

Notes

1. Work types are described in Table 2.8

Table 2.12: Scenario RN-2 Standard

Work Types	Intervention Criteria	After Works Effects
Routine maintenance Includes: potholes, edge breaks, carriageway cracks, spot regravelling, and heavy grading	To be performed every year	Determined using HDM-4 relationships
80 mm Overlay	Roughness >= 3 IRI	Roughness = 2.5 IRI
50mm Overlay	Roughness >= 3 IRI	Roughness = 2.5 IRI
Reconstruction Asphalt Mix	Roughness >= 7 IRI	Roughness = 2.0 IRI
Reconstruction Surface Treatment on Granular Base	Roughness >= 7 IRI	Roughness = 2.2 IRI
Cape seal	Roughness >= 3 IRI	Roughness = 2.8 IRI
Surface dressing	Roughness >= 3 IRI	Roughness = 2.9 IRI
Partial Widening Asphalt Mix	AADT >= 5000 Veh/day	Roughness = 1.5 IRI
Partial Widening Surface Treatment	AADT >= 4000 Veh/day	Roughness = 1.5 IRI
Upgrade gravel road	AADT >= 500 Veh/day	Roughness = 1.5 IRI

Notes
1. Work types are described in Table 2.8

Table 2.13: Scenario RN-3 Standard

Work Types	Intervention Criteria	After Works Effects
Routine maintenance Includes: potholes, edge breaks, carriageway cracks, spot regravelling, and heavy grading	To be performed every year	Determined using HDM-4 relationships
80 mm Overlay	Roughness >= 4 IRI	Roughness = 2.5 IRI
50mm Overlay	Roughness >= 4 IRI	Roughness = 2.5 IRI
Reconstruction Asphalt Mix	Roughness >= 7 IRI	Roughness = 2.0 IRI
Reconstruction Surface Treatment on Granular Base	Roughness >= 7 IRI	Roughness = 2.2 IRI
Cape seal	Roughness >= 4 IRI	Roughness = 2.8 IRI
Surface dressing	Roughness >= 4 IRI	Roughness = 2.9 IRI
Partial Widening Asphalt Mix	AADT >= 5000 Veh/day	Roughness = 1.5 IRI
Partial Widening Surface Treatment	AADT >= 4000 Veh/day	Roughness = 1.5 IRI
Upgrade gravel road	AADT >= 500 Veh/day	Roughness = 1.5 IRI

Notes
1. Work types are described in Table 2.8

Border post improvement scenarios

An important aim of the study was to quantify benefits that may result from investments to reduce current delays at border posts along the North-South Corridor. To that end, three border post improvement scenarios were defined and compared against the base case scenario of maintaining the ‘status quo’. Table 2.14 gives the definition of these border post scenarios.

Table 2.14 Border Post Scenarios

Scenario	Target Condition
Base Case Scenario	Comprises annual lump sum costs for maintaining each border crossing without improvement to the prevailing delays
Scenario BP-1	Considers that current observed delays at border posts shall be reduced by10% of observed delays
Scenario BP-2	Assumes that current observed delays at border posts shall be reduced by 20% once improvements to border crossings are implemented
Scenario BP-3	Assumes that current observed delays at border posts shall be reduced to 50% once improvements to border crossings are implemented

For each scenario, the base alternative defined assumes that an annual lump sum amount of US$ 1 million will be used to maintain and operate each border post. The consequence of this is that delays at the border posts will not reduce; in fact it should most likely increase if traffic volume increases.

The border post improvement alternatives include investments specified to improve the infrastructure, management and operations at the border posts, the timing of the improvement works, and the effects of the improvement works in terms of reduction in delays at border crossings. It was assumed that once improvement works are implemented, an annual lump sum cost of US$ 1 million will be necessary to cover annual maintenance and operation needs at each border crossing. Table 2.15 gives the border post improvement alternatives used in the study.

Table 2.15: Border Post Investments

Border Crossing	Investment Year[1]	Investment (US$ Millions)			
		0% Reduction in Delays	10% Reduction in Delays	20% Reduction in Delays	50% Reduction in Delays
Kazangula	6^{th}	0	100	100	100
Beit Bridge	6^{th}	0	50	50	50
Kasembulesa	6^{th}	0	20	20	20
Others	6^{th}	0	10	10	10

Notes

1. Investment year means the n^{th} year from the start of the analysis period.

Since it is not known exactly what the reduction in delays would be following a given level of investment, it was necessary to test the assumptions that the same investment levels may yield different reduction amounts of delays, which have been specified as 50%, 20% and 10% of the current level of delays at each border post.

3 ANALYSIS RESULTS

3.1 General

Two sets of analysis were undertaken. The first set considered all the road sections within the North-South Corridor while the second set excluded road sections within the Republic of South Africa (RSA). The results of the analysis for the two sets are reported as "with RSA roads" and "without RSA roads".

The road network improvement scenarios defined in Section 2.4, were combined logically with the border post improvement scenarios to form different investment scenarios. For example, road network improvement scenario RN-3 was combined with border post improvement scenario BP-3 to form investment scenario "RN-3, BP-3" which was then analysed separately. The analysis results are presented under the following categories:

- *Road condition trend*: showing annual predictions of pavement performance
- *Investment Needs*: showing annual and total financial requirements, types and timing of works
- *Economic Benefits*: providing economic indicators e.g. Net Present Values
- *Cumulative Net Benefits*: showing the time when cumulative net economic benefits becomes positive
- *Net Present Value of Routes*: showing the attractiveness of investing in particular routes
- *Sensitivity Analysis*: investigating the impact of variations in key parameter on the analysis results

3.2 Road Condition Trends

The predicted average road network condition trends for the Base Case Scenario and Scenarios RN-1 (Excellent), RN-2 (Very Good) and RN-3 (Good) are shown in Figure 3.1 (without RSA roads) and Figure 3.2 (with RSA roads). The initial average roughness of about 5 IRI without RSA road sections and 4.3 IRI with RSA road sections confirms the effect of good road condition in the Republic of South Africa. The predicted average roughness values over the 20 year analysis period for these scenarios are given in Table 3.1.

Table 3.1: Predicted Average Road Condition Over 20 Years

Scenario	Without RSA Sections		With RSA Sections	
	Roughness	Description	Roughness	Description
Base Case	10.9	Poor	9.6	Poor
RN -1	2.2	Excellent	2.1	Excellent
RN -2	2.8	Very Good	2.8	Very Good
RN -3	3.6	Good	3.1	Good

The condition trends show that the requirements of achieving the three long-term condition targets are technically feasible, provided that the effects and timing of the predicted work for each scenario can be met. The financial investment requirements for each scenario are presented section 3.3.

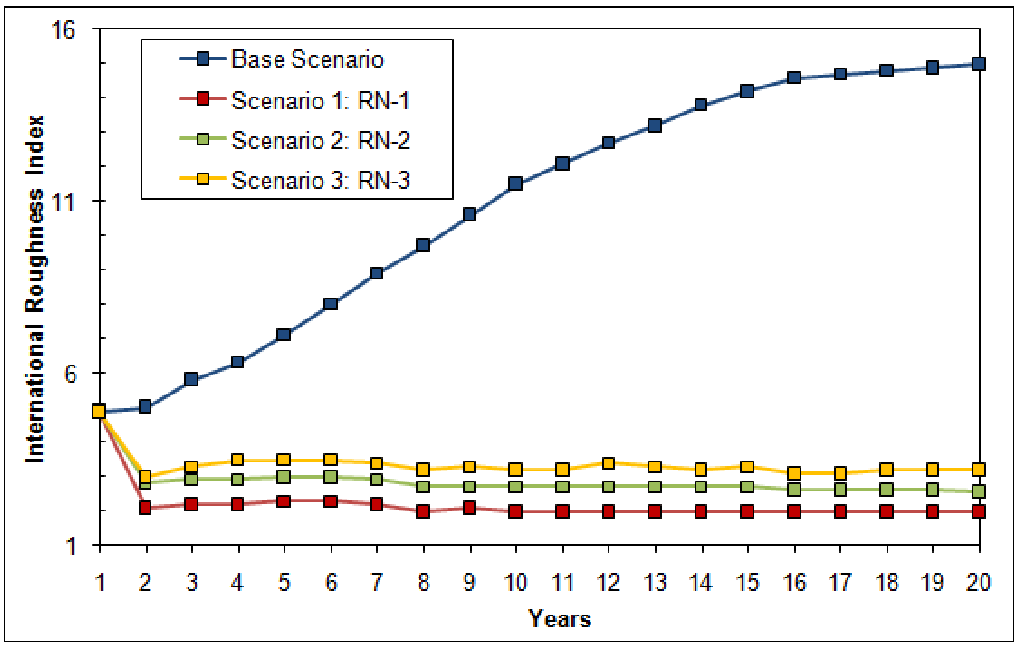

Figure 3.1: Average Condition Trend for Each Scenario without RSA Road Sections

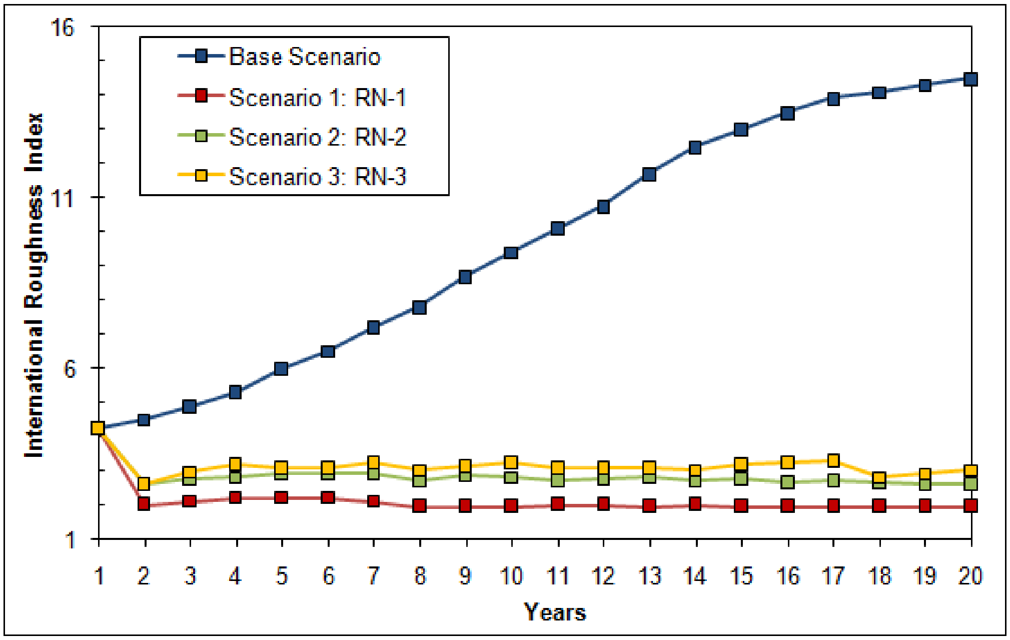

Figure 3.2: Average Condition Trend for Each Scenario with RSA Road Sections

3.3 Road Network Investment Needs

Summary of Financial Costs

The financial requirements for maintaining the North–South Corridor road network and border posts over a 20 year period are given in Table 3.2 (without RSA roads) and Table 3.3 (with RSA roads). These tables show capital and recurrent estimates for the three scenarios RN-1, RN-2 and RN-3 and border post improvement scenario BP-3. Capital works include overlay, reconstruction, upgrading, partial widening, surface dressing, cape seal, and regravelling of unsealed roads. Recurrent works comprise routine activities such as crack sealing, edge-break repair, heavy grading, and spot regravelling amongst others.

Table 3.2: Summary of Financial Costs (in Million US$) by Scenario without the RSA Road Sections

Road Network Improvement Scenarios	Road Sections Costs			Border Post Costs (BP-3[1])			Total
	Capital	Recurrent	Sub-Total	Capital	Recurrent	Sub-Total	
RN-1: Excellent Condition	15,359	2,191	17,550	260	471	731	18,281
RN-2: Very Good Condition	9,227	2,235	11,461	260	471	731	12,192
RN-3: Good Condition	4,488	2,422	6,910	260	471	731	7,641

Note:

BP-3 = Border post improvement scenario BP-3 described in Table 2.14

Table 3.3: Summary of Financial Costs (in Million US$) by Scenario with RSA Road Sections

Road Network Improvement Scenarios	Road Sections Costs			Border Post Costs (BP-3[1])			Total
	Capital	Recurrent	Sub-Total	Capital	Recurrent	Sub-Total	
RN-1: Excellent Condition	23,323	2,760	26,083	260	471	731	26,814
RN-2: Very Good Condition	13,774	2,842	16,616	260	471	731	17,347
RN-3: Good Condition	5,929	3,161	9,089	260	471	731	9,821

Note:

BP-3 = Border post improvement scenario BP-3 described in Table 2.14

Investments Required to Achieve Excellent Road Condition

The annual investment profile and the proportions of capital and recurrent expenditures necessary to keep the corridor roads (without RSA roads) in excellent condition are shown in Figures 3.3 and 3.4, respectively.

When corridor roads in the Republic of South Africa were excluded from the analysis, the financial investment required at the start of the analysis period was estimated to be US$ 2.1 billion. This investment is required to clear maintenance backlogs and to improve the road condition to an excellent level. Thereafter, an annual average investment of approximately US$ 853 million is required to maintain an excellent average road condition.

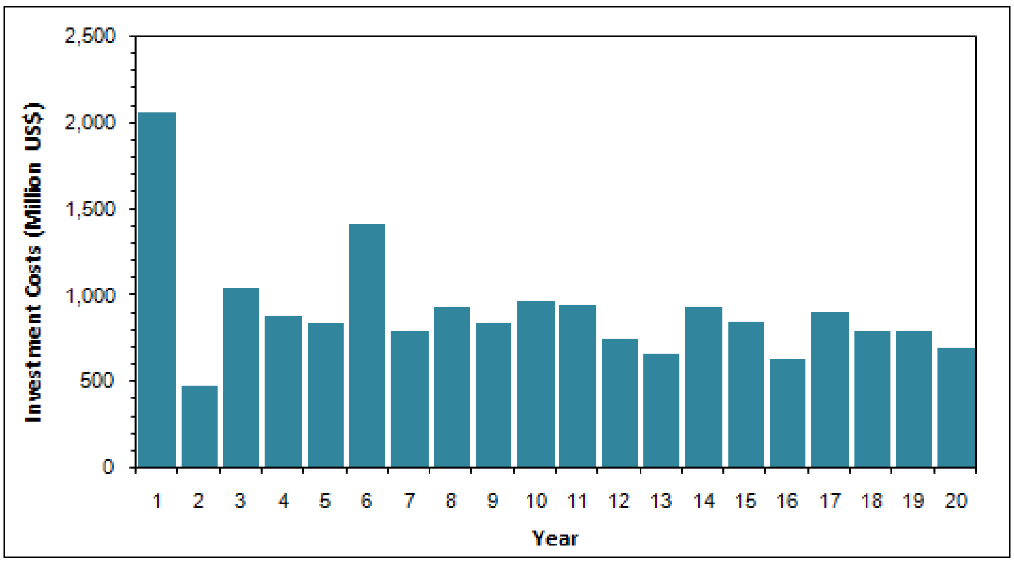

Figure 3.3: Annual Investment Profile for Scenario "RN-1, BP-3" without RSA Road Sections

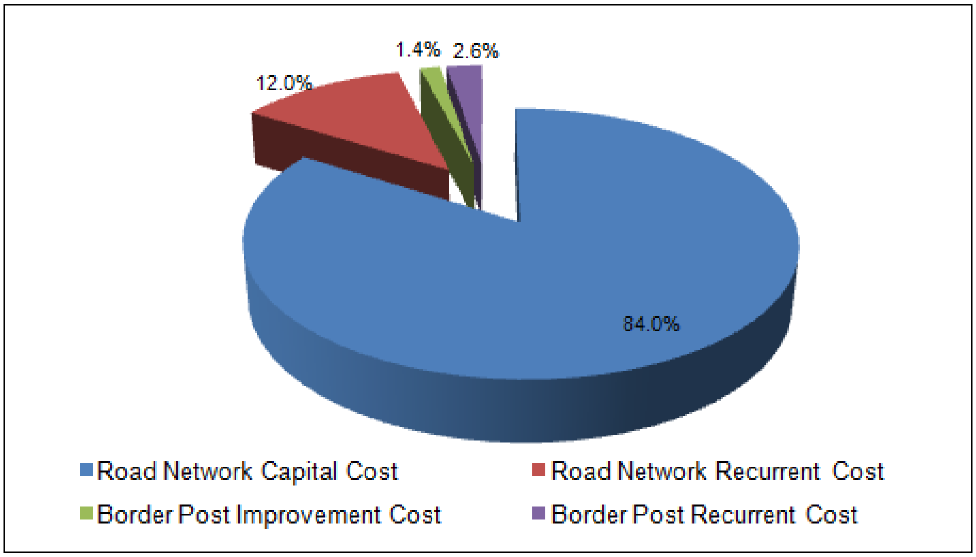

Figure 3.4: Investment Cost Proportions for Scenario "RN-1, BP-3" without the RSA Road Sections

The annual investment profile and the proportions of capital and recurrent expenditures necessary to keep the corridor roads (with RSA roads) in excellent condition are shown in Figures 3.5 and 3.6, respectively. The initial annual investment required to improve the road condition to an excellent level was estimated to be US$ 2.8 billion. Thereafter, an annual average investment of US$ 1.1 billion is required to maintain an excellent average road condition.

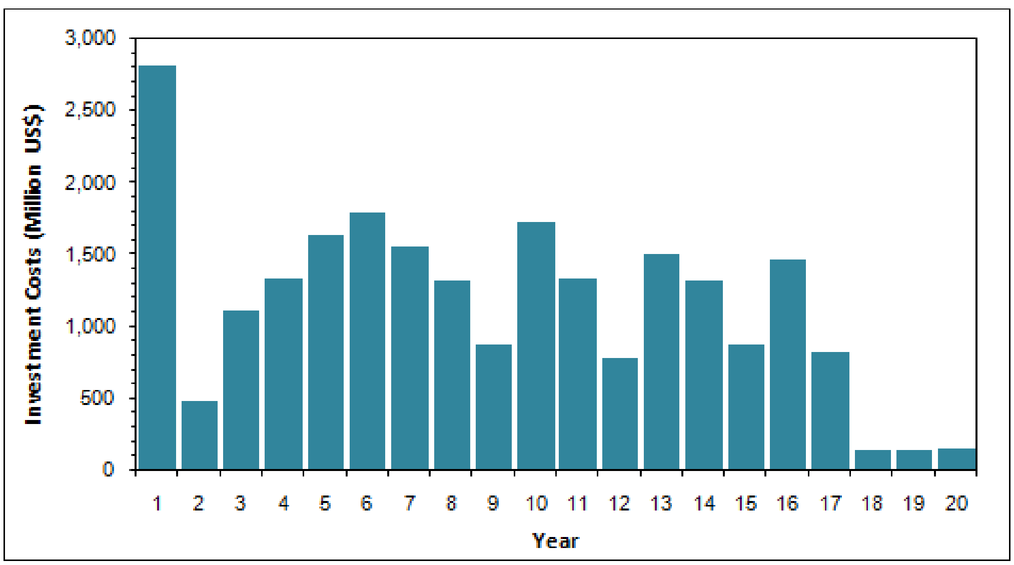

Figure 3.5: Annual Investment Profile for Scenario "RN-1, BP-3" with the RSA Road Sections

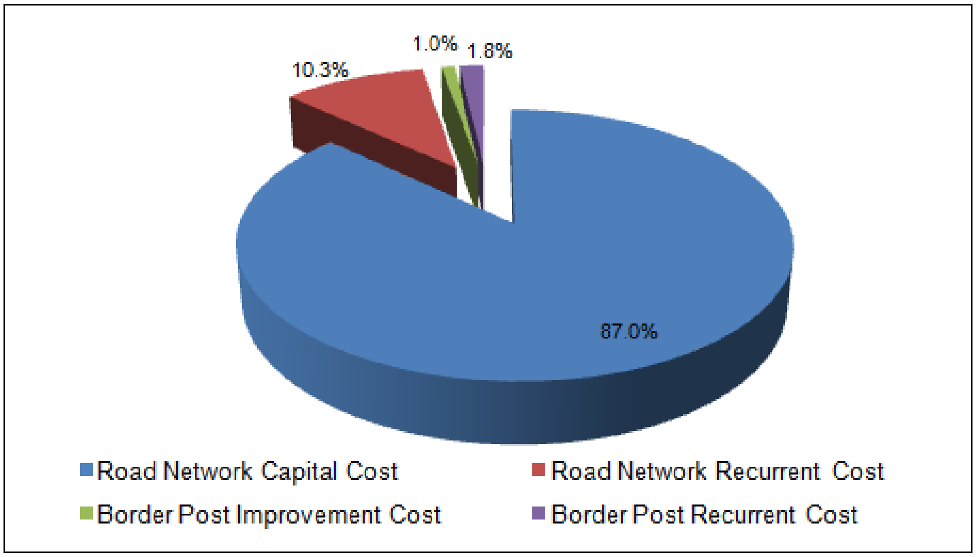

Figure 3.6: Investment Cost Proportions for Scenario "RN-1, BP-3" with the RSA Road Sections

Investments Required to Achieve Very Good Road Condition

The annual investment profile and the proportions of capital and recurrent expenditures necessary to keep the corridor roads (without RSA roads) in Very Good condition are shown in Figures 3.7 and 3.8, respectively. The financial investment requirement at the start of the analysis period was estimated to be US$ 1.8 billion, see Figure 3.7. This investment is required to clear maintenance backlogs and to improve the road condition to Very Good. Thereafter, an annual average investment of about US$ 547 million is required to maintain the corridor roads in very good condition.

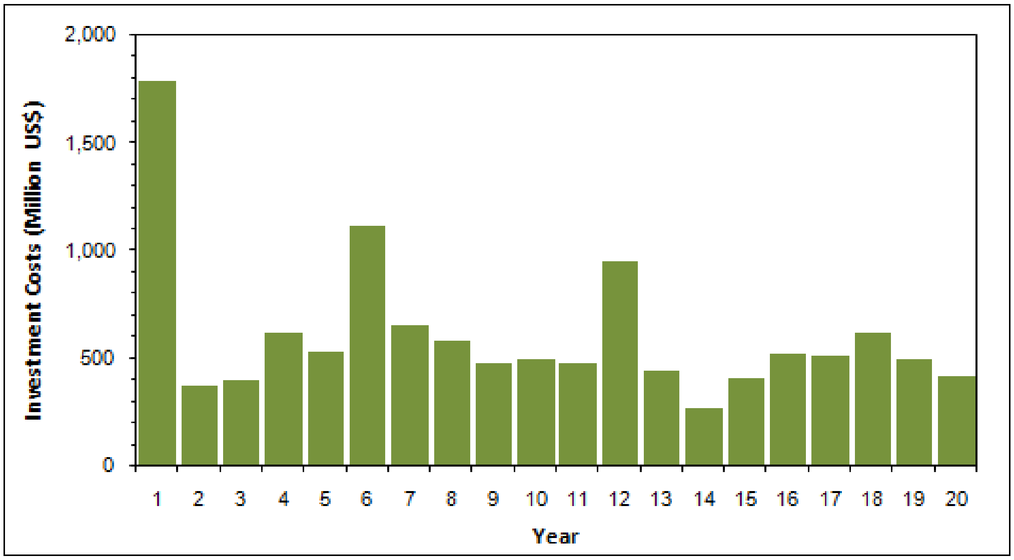

Figure 3.7: Annual Investment Profile for Scenario "RN-2, BP-3" without the RSA Road Sections

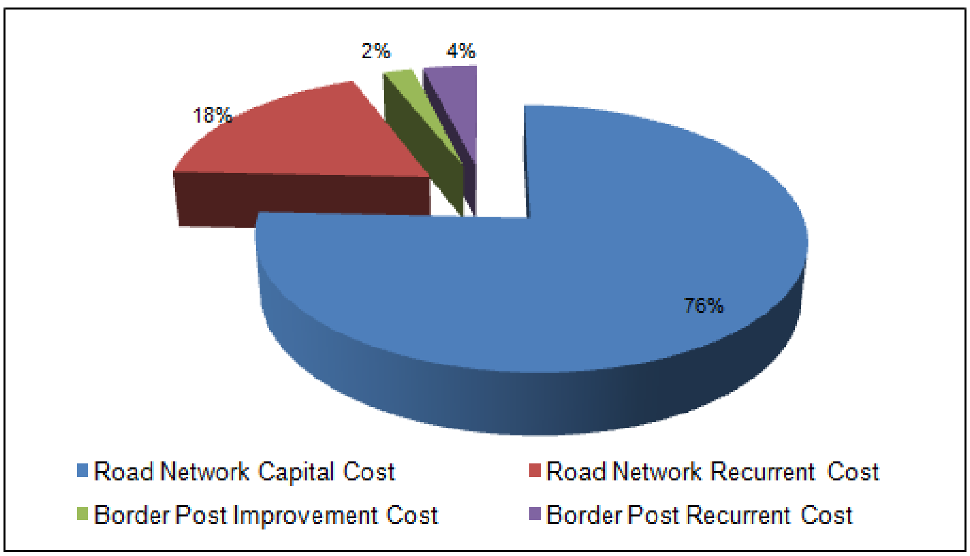

Figure 3.8: Investment Cost Proportions for Scenario "RN-2, BP-3" without the RSA Road Sections

The annual financial investment profiles and the proportions of capital and recurrent expenditures needed to maintain the roads on the North-South Corridor (with RSA roads) in Very Good condition are shown in Figures 3.9 and 3.10. The financial investment required at the start of the analysis period was estimated to be US$ 2.5 billion, see Figure 3.9. This investment is required to clear maintenance backlogs and to improve the road condition to Very Good.

Thereafter, an annual average investment of about US$ 660 million is required to maintain the road sections in very good condition.

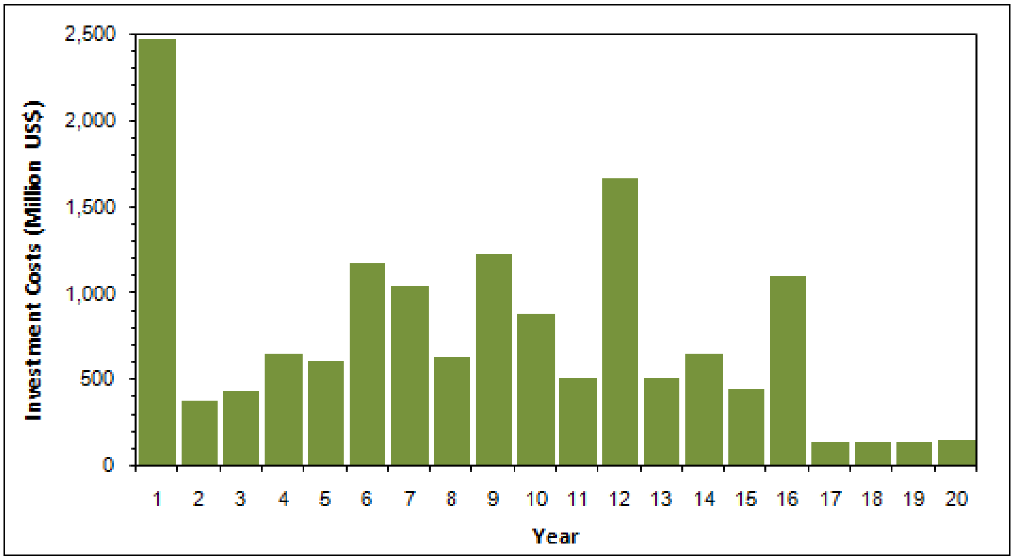

Figure 3.9: Annual Investment Profile for Scenario "RN-2, BP-3" with the RSA Road Sections

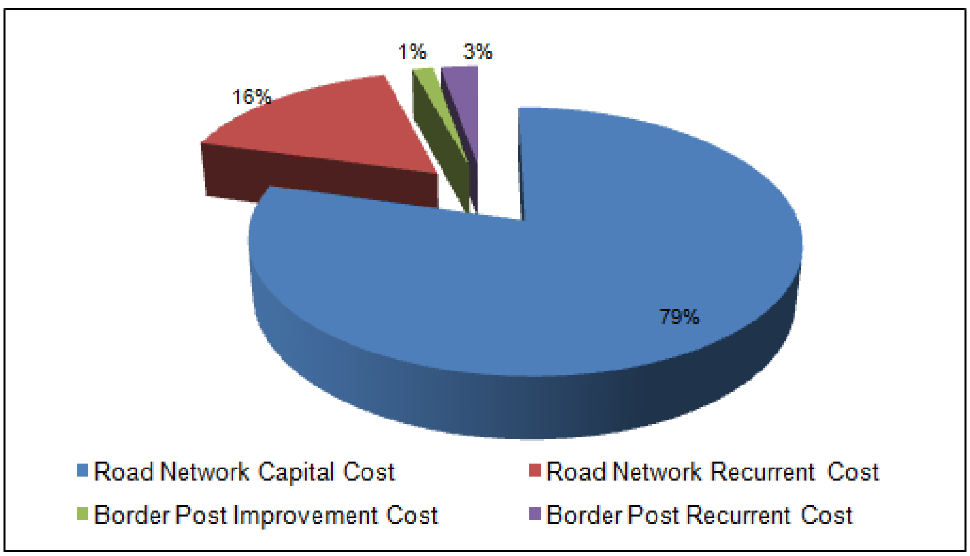

Figure 3.10: Investment Cost Proportions for Scenario "RN-2, BP-3" with the RSA Road Sections

Investments Required to Achieve Good Road Condition

The annual investment profile and the proportions of capital and recurrent expenditures necessary to keep the corridor roads (without RSA roads) in good condition are shown in Figures 3.11 and 3.12, respectively. The financial investment needed to clear maintenance backlogs and improve the road condition to Good was estimated to be US$ 1.2 billion. In order to maintain the corridor roads (without RSA roads) in good condition in the long-term, an average of US$ 328 million per year is required.

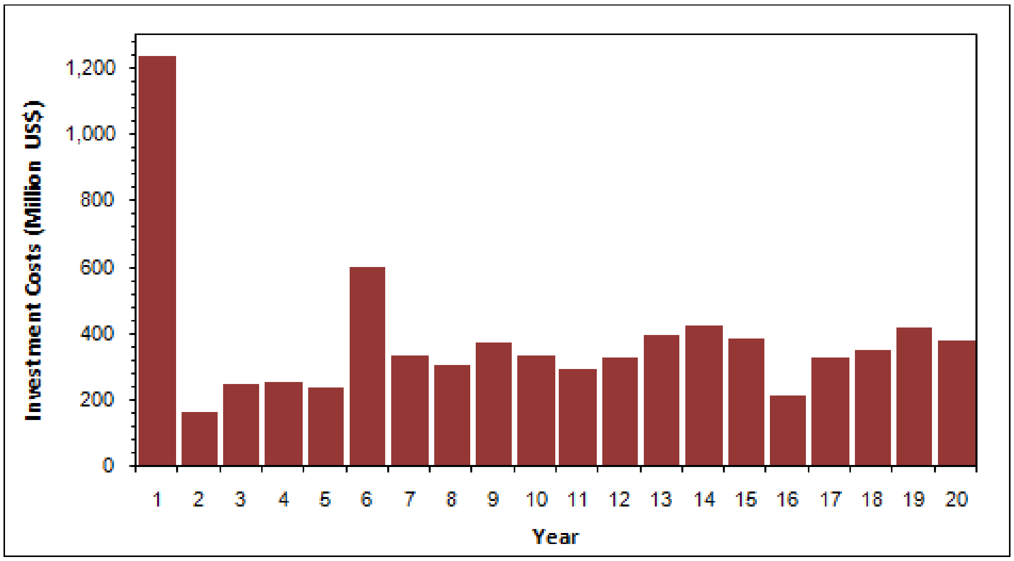

Figure 3.11: Annual Investment Profile for Scenario "RN-3, BP-3" without the RSA Road Sections

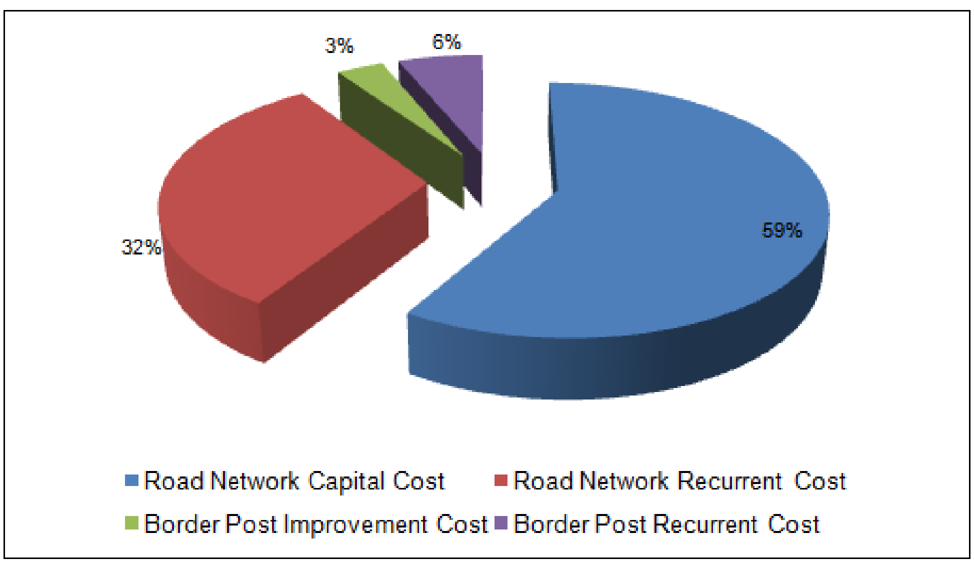

Figure 3.12: Investment Cost Proportions for Scenario "RN-3, BP-3" without the RSA Road Sections

The annual financial investment profile and the proportions of capital and recurrent expenditures needed to improve and maintain the North-South corridor roads (with RSA roads) in Good condition are shown in Figures 3.13 and 3.14. When the road sections in the Republic of South Africa were included in the analysis, the financial requirement at the start of the analysis period to clear maintenance backlogs and achieve Good road condition was estimated to be US$ 1.9 billion, see Figure 3.13. Thereafter, an annual average investment of US$ 360 million is required to maintain the corridor roads in good condition over the analysis period.

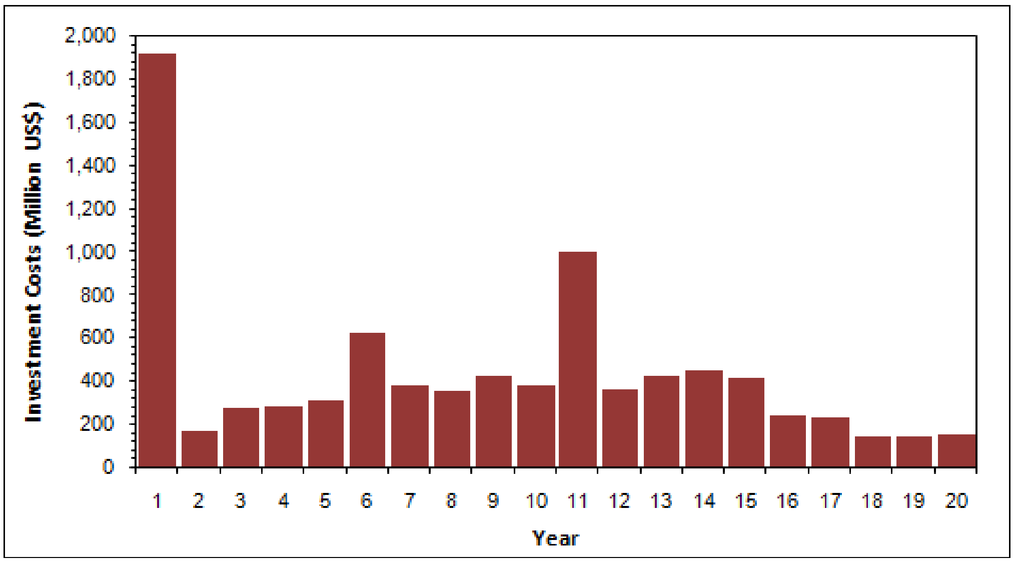

Figure 3.13: Annual Investment Profile for Scenario "RN-3, BP-3" with the RSA Road Sections

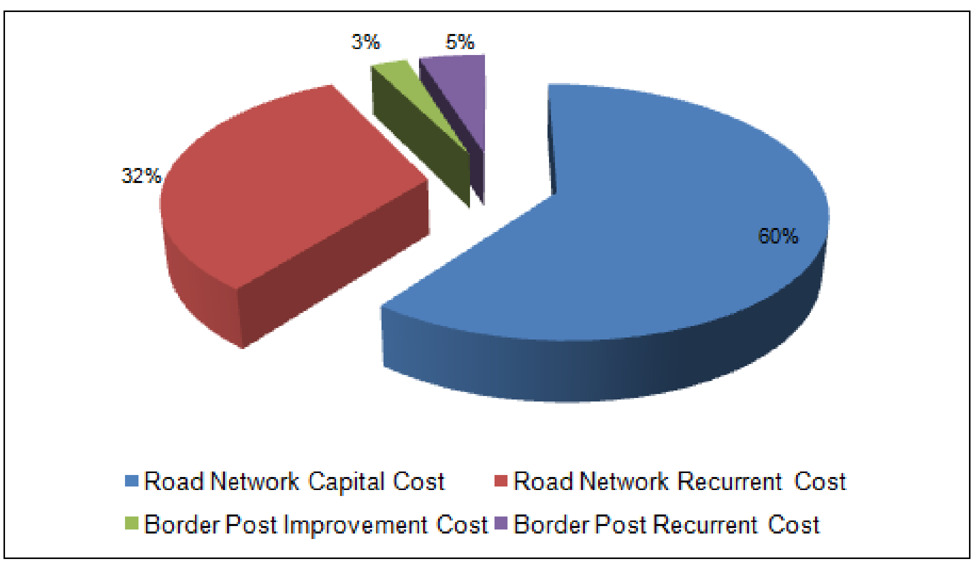

Figure 3.14: Investment Cost Proportions for Scenario "RN-3, BP-3" with the RSA Road Sections

Comparison of Investment Needs for Scenarios RN-1, RN-2, and RN-3

With the exclusion of road sections in the Republic of South Africa from the analysis, the total capital and recurrent expenditures required over 20 years to improve and maintain the corridor roads in Excellent condition (RN-1) is US$ 17.6 billion. This exceeds the total financial investment that would be needed to improve and maintain the corridor roads to Very Good (RN-2) and Good (RN-3) condition by about 53% and 154%, respectively. The average annual road network maintenance expenditure per km of road length for each scenario is approximately 40,000 US$ for Scenario RN-3, 66,300 US$ for Scenario RN-2, and 101,500 US$ for Scenario RN-1.

When road sections within the Republic of South Africa are included in the analysis, the total financial requirement to improve and maintain the corridor roads in excellent condition over 20 years increases to US$ 26.1 billion. This is more than the estimated total investment required to keep the corridor roads (with RSA roads) in Very Good and Good condition by 57% and 187%, respectively. The average annual road network maintenance expenditure per lane km of road length for each scenario is approximately 43,100 US$ for Scenario RN-3 (Good Condition), 78,800 US$ for Scenario RN-2 (Very Good Condition), and 123,700 US$ for Scenario RN-1 (Excellent Condition).

A total capital and recurrent investment of US$ 731 million, see Tables 3.2 and 3.3, over 20 years is required to reduce the current levels of delays at border posts by half.

3.4 Economic Benefits

The Net Present Values (NPVs) over a 20-year analysis period for different investment scenarios are summarised in Table 3.4 (without RSA roads) and Table 3.5 (with RSA roads). The results suggest that investment scenario “RN-3, BP-3” provides the highest amount of benefits which is equivalent to about US$ 30.0 billion (with RSA roads) and US$ 14.7 billion (without RSA roads). The road condition trends over the 20 year analysis period, discussed in Section 3.2, show that this combination would result in good road condition in the long term provided that the predicted maintenance and improvement investments are adhered to sufficiently and timely. A work programme by sections for this investment scenario is summarised in Table D.1 in Appendix D.

A summary of key economic indicators including annualised financial costs and economic benefits are given in Table 3.6 (without RSA roads) and Table 3.7 (with RSA roads).

Table 3.4: Summary of Net Present Values in Million US$ without the RSA Road Sections

Description	Scenario RN-1: Excellent			Scenario RN-2: Very Good			Scenario RN-3: Good		
	BP-1: 10% reduction in delays	BP-2: 20% reduction in delays	BP-3: 50% reduction in delays	BP-1: 10% reduction in delays	BP-2: 20% reduction in delays	BP-3: 50% reduction in delays	BP-1: 10% reduction in delays	BP-2: 20% reduction in delays	BP-3: 50% reduction in delays
Road Sections	10,512	10,512	10,512	12,708	12,708	12,708	13,875	13,875	13,875
Border Crossings	62	260	853	62	260	853	62	260	853
Total NPV	10,574	10,771	11,365	12,770	12,968	13,561	13,936	14,134	14,728

Table 3.5: Summary of Net Present Values in Million US$ with the RSA Road Sections

Description	Scenario RN-1: Excellent			Scenario RN-2: Very Good			Scenario RN-3: Good		
	BP-1: 10% reduction in delays	BP-2: 20% reduction in delays	BP-3: 50% reduction in delays	BP-1: 10% reduction in delays	BP-2: 20% reduction in delays	BP-3: 50% reduction in delays	BP-1: 10% reduction in delays	BP-2: 20% reduction in delays	BP-3: 50% reduction in delays
Road Sections	25,886	25,886	25,886	29,116	29,116	29,116	29,191	29,191	29,191
Border Crossings	62	260	853	62	260	853	62	260	853
Total NPV	25,948	26,146	26,739	29,178	29,376	29,969	29,252	29,450	30,044

Table 3.6: Summary of Annualised Costs and Benefits/Cost ratio without the RSA Road Sections

Scenario	Road Length (Km)	Total Capital Cost (Million US$)	Economic Benefits (Million US$)	Capital Cost/Km/Year (US$)	Benefits/Km/Year (US$)	Benefits/Capital Cost
Scenario RN-1: Excellent	8,646	15,359	10,512	88,819	60,790	0.7
Scenario RN-2: Very Good	8,646	9,227	12,708	53,358	73,492	1.4
Scenario RN-3: Good:	8,646	4,488	13,875	25,954	80,237	3.1

1. Benefits refers to Net Present Value (NPV)

Table 3.7: Summary of Annualised Costs and Benefits/Cost Ratio with the RSA Road Sections

Scenario	Road Length (Km)	Total Capital Cost (Million US$)	Economic Benefits (Million US$)	Capital Cost/Km/Year (US$)	Benefits/Km/Year (US$)	Benefits/Capital Cost
Scenario RN-1: Excellent	10,547	15,359	25,885	72,810	122,711	1.7
Scenario RN-2: Very Good	10,547	9,227	29,114	43,741	138,021	3.2
Scenario RN-3: Good:	10,547	4,488	29,189	21,276	138,374	6.5

1. Benefits refers to Net Present Value (NPV)

3.5 Cumulative Net Economic Benefits

An important aim of the study was to investigate the timing of positive cumulative net economic benefit to society for selected combinations of road condition and border post improvement scenarios. The results for investment scenario “RN-2, BP-3” are presented in Figure 3.15 (without RSA roads) and Figure 3.16 (with RSA roads) respectively. The results for investment scenario “RN-3, BP-3” are presented in Figure 3.17 (without RSA roads) and Figure 3.18 (with RSA roads), respectively.

Investment Scenario “RN-2, BP-3”

Figure 3.15 shows that a positive cumulative net economic benefit is expected from year 7, while Figure 3.16 indicates that a positive cumulative net economic benefit is expected from year 9.

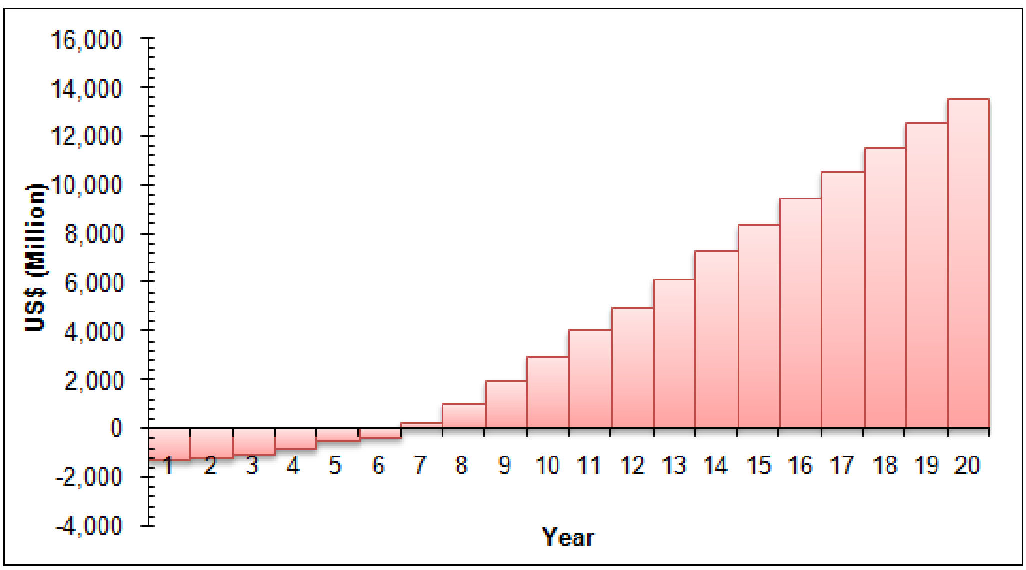

Figure 3.15: Cumulative NPV for Investment Scenario “RN-2, BP-3” without the RSA Road Sections

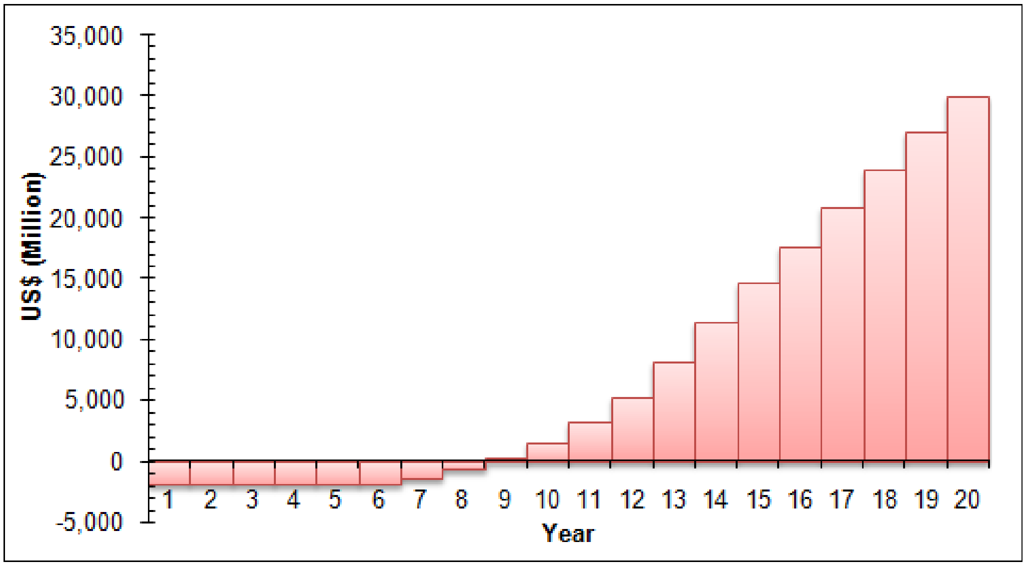

Figure 3.16: Cumulative NPV for Investment Scenario "RN-2, BP-3" with the RSA Road Sections

Investment Scenario "RN-3, BP-3"

Figure 3.17 shows that when road sections in the Republic of South Africa are excluded, a positive cumulative net economic benefit is expected from year 5, and when roads in the Republic of South Africa are included then a positive cumulative net economic benefit is expected from year 7 as shown in Figure 3.18. It is important to note that this does not imply that the inclusion of road sections in the Republic of South Africa makes the investment case economically or financially less attractive. On the contrary, Table 3.7 shows that the benefit/cost ratios are higher when road sections in the Republic of South Africa are included. Also, the annual investment profiles given in Figure 3.12 (without RSA roads) and Figure 3.13 (with RSA roads) provide useful explanation. Figure 3.13 shows that the financial investment requirements in the initial analysis period are much higher than in Figure 3.12.

In general, the year in which positive cumulative benefits may be realised could be affected by uncertainties in determining the values of the most sensitive input data used in the study as discussed in section 3.7.

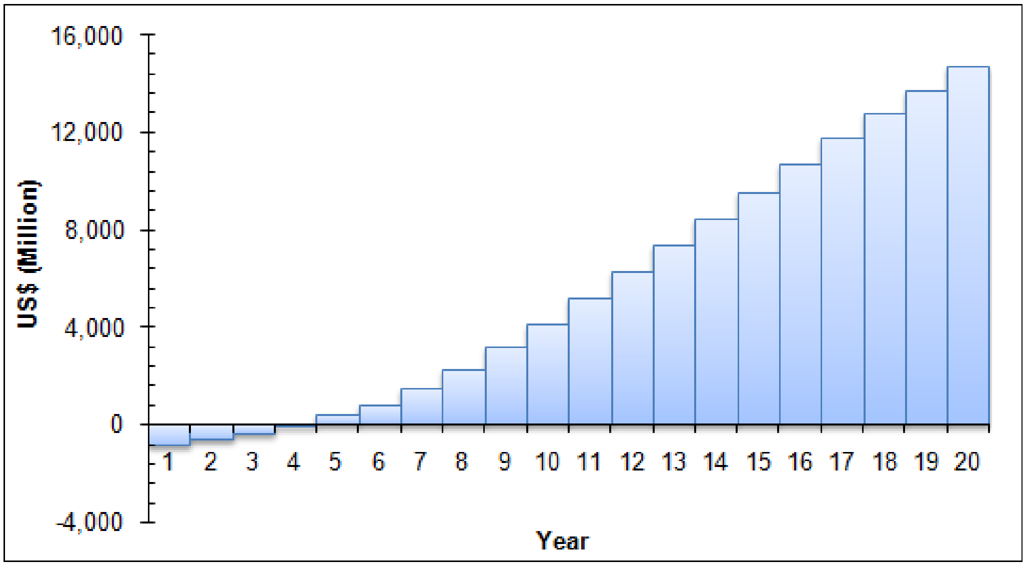

Figure 3.17: Cumulative NPV for Investment Scenario "RN-3, BP-3" without the RSA Road Sections

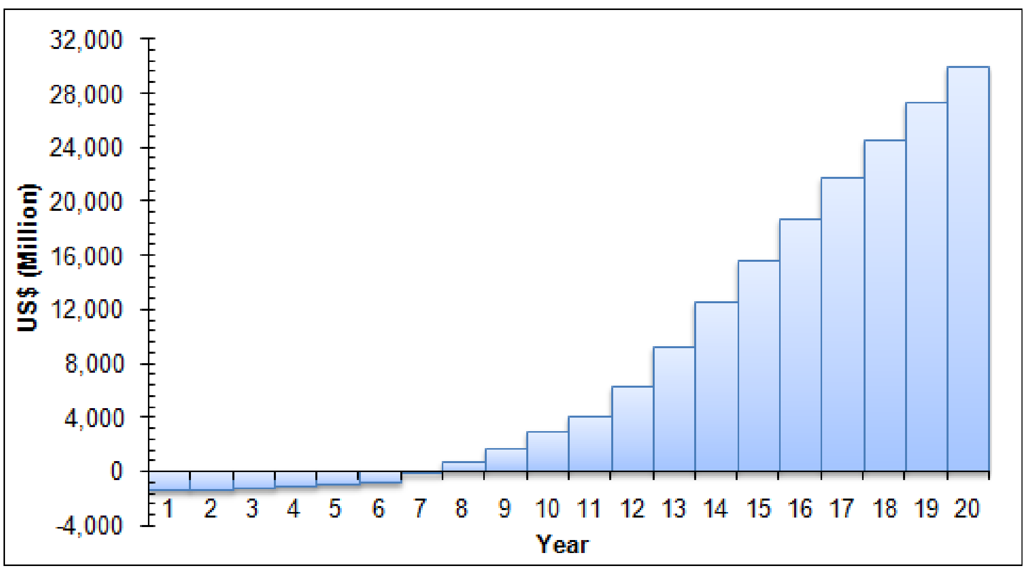

Figure 3.18: Cumulative NPV for Investment Scenario "RN-3, BP-3" with the RSA Road Sections

3.6 Comparison of Net Present Values for Selected Routes

A comparison of the total net benefits over 20-year analysis period for 7 routes within the North-South Corridor was conducted for the without and with the RSA roads analysis for the combination of Scenario RN-3 and Scenario BP-3.

Routes NPV (without RSA roads)

All seven routes have positive net benefits over a 20-year analysis period. Route 7 has the lowest NPV, while routes 1, 2, 4 and 5 are economically very attractive, see Table 3.8.

Table 3.8: Total Net Present Value for Key Routes (without the RSA Road Sections)

Route Number	Description	Total NPV (Million US$)
1	Kolwezi - Kasumbelesa –Chingola (including traffic from Solwezi) - Kapiri Mposhi – Lusaka – Chirundu – Harare – Beit Bridge	4,320
2	Kolwezi - Kasumbelesa –Chingola (including traffic from Solwezi) - Kapiri Mposhi – Lusaka – Kafue – Livingstone – Bulawayo – Beit Bridge	4,300
3	Kolwezi - Kasumbelesa –Chingola (including traffic from Solwezi) - Kapiri Mposhi – Lusaka – Kafue – Livingstone – Kazangula – Nata – Francis Town – Gaborone	3,144
4	Kolwezi - Kasumbelesa – Chingola (Including traffic from Solwezi) – Kapiri Mposhi –- Nakonde – Mbeya – Iringa – Dar es Salaam	4,177
5	Dar-es-Salaam – Mbeya – Lilongwe	4,200
6	Lilongwe – Mwanza – Nyampanda – Harare – Beit Bridge	2,077
7	Lusaka - BPMchinji - Liliongwe- Blantyre	1,096

Routes NPV (with RSA roads)

All seven routes have positive NPVs over a 20-year analysis period. Route 7 has the lowest NPV while routes 1, 2, 3 and 6 are even more attractive economically with the inclusion of road sections in the Republic of South Africa which carry high traffic volumes, see Table 3.9.

Table 3.9: Total Net Present Value for Key Routes with the RSA Road Sections

Route Number	Description	Total NPV (Million US$)
1	Kolwezi - Kasumbelesa –Chingola (including traffic from Solwezi) - Kapiri Mposhi – Lusaka – Chirundu – Harare – Beit Bridge – Johannesburg - Durban	18,047
2	Kolwezi - Kasumbelesa –Chingola (including traffic from Solwezi) - Kapiri Mposhi – Lusaka – Kafue – Livingstone – Bulawayo – Beit Bridge – Johannesburg - Durban	18,027
3	Kolwezi - Kasumbelesa –Chingola (including traffic from Solwezi) - Kapiri Mposhi – Lusaka – Kafue – Livingstone – Kazangula – Nata – Francis Town – Gaborone – Johannesburg - Durban	12,355
4	Kolwezi - Kasumbelesa – Chingola (Including traffic from Solwezi) – Kapiri Mposhi –- Nakonde – Mbeya – Iringa – Dar es Salaam	4,177
5	Dar-es-Salaam – Mbeya – Lilongwe	4,200
6	Lilongwe – Mwanza – Nyampanda – Harare – Beit Bridge – Johannesburg - Durban	15,735
7	Lusaka - BPMchinji - Liliongwe- Blantyre	1,096

3.7 Sensitivity of Key Input Data

It is important to recognise the medium and low levels of confidence in some of the data used in this study. A sensitivity analysis was therefore undertaken to determine the effects of variations in the values of key input data on NPV and the timing of positive cumulative net economic benefits. The input parameters tested are initial AADT, traffic growth rate, construction costs and travel time value. The base values used in the study were varied from -50% to +50%. The results are summarised for analysis without and with the RSA roads for Investment Scenario “RN-3, BP-3”.

Sensitivity analysis without the RSA road sections

A summary of the sensitivity analysis on the timing of positive cumulative net economic benefit is given in Table 3.10 for without RSA road sections. The results suggest, for example, that if values of initial AADT for every road section were lower by 50%, then a positive cumulative net economic benefit would be realised starting from year 7 instead of year 5. Construction cost is the most sensitive parameter with respect to the timing of positive cumulative net economic benefits, while traffic growth and travel time value are less sensitive parameters.

Table 3.10: Sensitivity of key Parameters on the Timing of Positive Cumulative Net Economic Benefits (without the RSA roads)

Parameter	Initial Year of Positive Cumulative Net Benefits				
	-50% change	-25% change	0% change	+25% change	+50% change
Initial AADT[1]	7	5	5	4	4
Traffic Growth Rate	5	5	5	4	4
Construction Cost	3	4	5	5	6
Travel Time Value	5	5	5	5	5

1. AADT = Average Annual Daily Traffic

Table 3.11 presents the results of sensitivity analysis of the selected parameters on NPV. Figure 3.19 is a “spider diagram” that illustrates the degree of sensitivity of each parameter tested on NPV. With respect to NPV, initial AADT is clearly the most sensitive parameter followed by traffic growth rate. Travel time value and construction costs are less sensitive parameters.

Table 3.11: Sensitivity of Key Parameters on Total NPV (without the RSA roads)

Parameter	Total NPV Over 20 Years in Million US$				
	-50% change	-25% change	0% change	+25% change	+50% change
Initial AADT	5,325	9,690	13,875	20,101	25,631
Traffic Growth Rate	10,585	12,465	13,875	17,353	20,520
Construction Cost	15,603	15,161	13,875	14,279	13,838
Travel Time Value	14,720	14,720	13,875	14,720	14,720

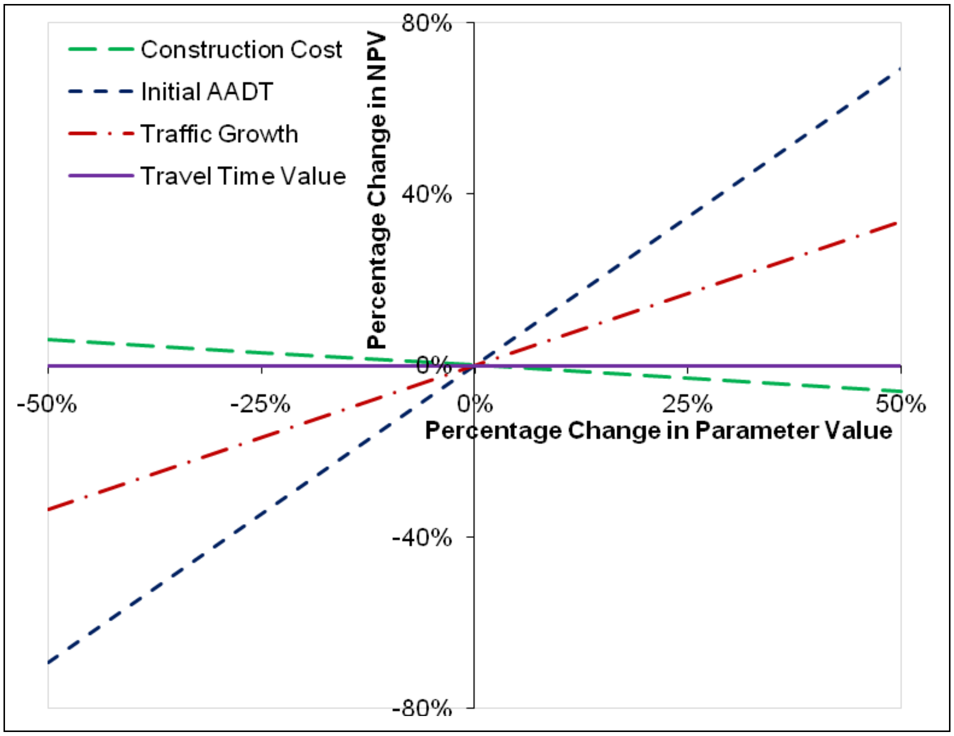

Figure 3.19: Sensitivity of Key Parameters on Total NPV (without the RSA roads)

Further sensitivity analysis was carried out to identify the smallest traffic growth rate such that the NPV still becomes positive. The reason for this is to allow for traffic either diverting onto the railways or to other routes. The results given in Table 3.12 shows that even at zero percent traffic growth rate the NPV over 20-year analysis period is positive US$ 7.647 billion for investment scenario "RN-3, BP-3".

Table 3.12: Effect of Traffic Growth Rate on total NPV (without the RSA roads)

Traffic Growth Rate (%)	Year when Cumulative Net Economic Benefit becomes Positive	Total NPV (Million US$)
0	5	7,647
1	5	8,710
2.5	5	10,585
5	5	14,720

Sensitivity analysis with the RSA road sections

Table 3.13 gives a summary of the results of sensitivity analysis on the timing of positive cumulative net economic benefits. The results suggest, for example, that if construction costs were higher by 50%, then a positive cumulative net benefit to society would start to accrue from year 9 instead of year 8. Again, construction cost and initial AADT are the most sensitive parameters with respect to the timing of net economic benefits, while traffic growth rate and travel time value are less sensitive parameters.

Table 3.13: Sensitivity of Key Parameters on Positive Cumulative Net Economic Benefits (with the RSA roads)

Parameter	Initial Year of Positive Cumulative Net Benefits				
	-50% change	-25% change	0% change	+25% change	+50% change
Initial AADT	8	7	8	8	7
Traffic Growth Rate	7	7	8	8	8
Construction Cost	6	7	8	8	9
Travel Time Value	8	8	8	8	8

Table 3.14 and Figure 3.20 present the results of sensitivity analysis carried out with respect to changes in NPV due to variation in values of the selected parameters. Again, initial AADT is clearly the most sensitive parameter followed by traffic growth rate. Travel time value and construction costs are less sensitive parameters.

Table 3.14: Sensitivity of Key Parameters on Total NPV (with the RSA roads)

Parameter	Total NPV Over 20 Years in Million US$				
	-50% change	-25% change	0% change	+25% change	+50% change
Initial AADT	12,533	20,889	29,191	40,922	57,556
Traffic Growth Rate	20,829	24,752	29,191	38,170	49,797
Construction Cost	31,282	30,656	29,191	29,402	28,775
Travel Time Value	30,029	30,029	29,191	30,029	30,029

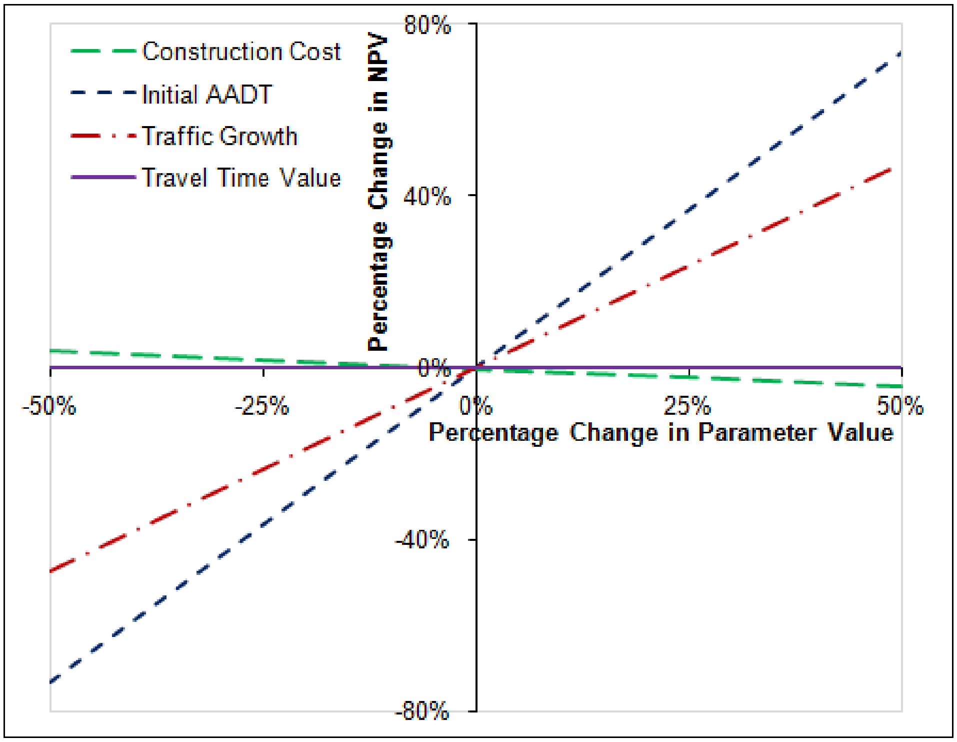

Figure 3.20: Sensitivity of Key Parameters on Total NPV (with the RSA roads)

Further sensitivity analysis was carried out to identify the smallest traffic growth rate such that the NPV still becomes positive. The reason for this is to allow for traffic either diverting onto the railways or to other routes. The results given in Table 3.15 shows that even at zero percent traffic growth rate the NPV over 20-year analysis period is positive US$ 15.135 billion for investment scenario "RN-3, BP-3".

Table 3.15: Effect of Traffic Growth Rate on total NPV (with the RSA roads)

Traffic Growth Rate (%)	Year when Cumulative Net Economic Benefit becomes Positive	Total NPV (US$ Million)
0	7	15,135
1	7	17,476
2.5	7	20,829
5	8	30,029

4 CONCLUSION AND THE WAY FORWARD

This study has demonstrated that there is an attractive rate of return to be realised from investment in the North–South Corridor. The study was based on an appropriate methodology and a more advanced use of the highway development and management (HDM-4) tool.

Two sets of analysis were carried out; one involved all the road sections on the North-South Corridor and the other excluded road sections in the Republic of South Africa. Different investment scenarios were analysed separately and the following are the main conclusions from the study:

- The most viable investment scenario in economic terms is for Road Agencies to maintain all the roads on the North-South Corridor in Good condition, which is denoted Scenario “RN-3, BP-3”. Technically the long-term average road condition, over the 20-year analysis period, would be 3.1 IRI. The total financial investment required for road network improvement is US$ 9.1 billion of which US$ 5.9 billion is capital investment and US$ 3.2 billion is recurrent costs. The total financial requirement for border post improvement is US$ 0.73 billion of which US$ 0.26 billion is capital investment and US$ 0.47 billion is recurrent costs. The annualised financial requirement to improve the road network is approximately US$ 43,100 per km. The economic return on this investment (i.e. the NPV) would be US$ 29.2 billion. The benefit/capital cost ratio associated with this investment is 6.5.
- When road sections from the Republic of South Africa are excluded from the analysis, investment scenario “RN-3, BP-3” remains the most economically attractive. The long-term average road condition, over the 20-year analysis period, would be 3.6 IRI. The total financial investment required for road network improvement is US$ 6.9 billion of which US$ 4.5 billion is capital investment and US$ 2.4 billion is recurrent costs. The total financial requirement for border post improvement is US$ 0.73 billion of which US$ 0.26 billion is capital investment and US$ 0.47 billion is recurrent costs. The annualised financial requirement to improve the road network is approximately US$ 40,000 per km. The economic return on this investment

(i.e. the NPV) would be US$ 13.9 billion. The benefit/capital cost ratio associated with this investment is 3.1.

- The results of sensitivity analysis have indicated that even at zero percent rate of traffic growth (to crudely assess the effect of traffic diversion to other transport modes and routes/corridors) the NPV of investment scenario "RN-3, BP-3" is still positive US$ 15.1 billion for all road sections, and positive US$ 7.6 billion when road sections in the Republic of South Africa are excluded.
- The results show that in the initial years of the 20-year analysis period, higher amounts of investment expenditures are required to eliminate maintenance backlogs and raise the road standard to an appropriate level for the North-South Corridor.
- The approximate timing when the cumulative net economic benefit of investments will become positive was determined to be Year 9 (with RSA roads included) and Year 7 (without RSA roads) for investment scenario RN-2 (i.e. the Road Agencies shall maintain the roads on the North-South Corridor to Very Good condition); and Year 7 (with RSA roads) and Year 5 (without RSA roads) for Scenario RN-3. It is important to note that this does not imply that the inclusion of road sections in RSA makes the investment cases economically less attractive. On the contrary, analysis results have shown that the benefit/ capital cost ratios are higher when road sections in RSA are included. This perhaps stresses the need for carrying out a financial analysis of the corridor roads, the results of which would indicate to the private sector when they could get seriously involved in investing in the North-South Corridor.
- The NPV of selected key routes within the North–South corridor have also been determined to show the degree of economic attractiveness of each route. A full road works programme for 20 years has also been produced showing when each section is to receive an intervention with costs.

The Way Forward

It should be noted that the reliability of the results of any studies using prediction models such as HDM-4 is dependent upon two primary considerations:

- How well the data provided to the model represent the reality of the current conditions and influencing factors, in the terms understood by the model; and,
- How well the predictions of the model fit the real behaviour and the interactions between various factors for the conditions prevailing in the countries and regions to which it is applied.

Although the study team made great effort to obtain reliable input data and calibrate the models, available project resources limited this. Nevertheless, the rigorous sensitivity analysis conducted has confirmed the robustness of the results obtained. Largely, default HDM-4 model parameters and data obtained from desk studies were used. Confidence in using the results obtained from this study could be increased through additional studies to:

1. Calibrate HDM-4 models to conditions within the North–South Corridor to Level 2 Calibration;
2. Validate the data held by the various road agencies that manage road sections within the corridor in order to determine their appropriateness for use in future studies of the North–South Corridor;
3. Investigate the impact of overloading of goods vehicles on road deterioration; and
4. Carry out a financial analysis of investments in the North-South Corridor to assess how the private sector could get involved, for example, through Public-Private-Partnership (PPP) or other appropriate investment models.

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Appendix A: Road Network Data

Table A.1 Road Network Data

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
Dibete - BP Gabarone	120	7.0	1.0	800	2008	3.5	3	5	2	0	0	1992	1997	7	1	STGB	2.20
Mahalpye - Dibete	81	7.0	1.0	800	2008	6.0	3	5	2	0	0	1992	1997	7	1	STGB	2.20
Palapye - Mahalpye	60	7.0	1.0	800	2008	3.5	3	5	2	0	0	1992	1997	7	1	STGB	2.20
Francis Town - Palapye	178	7.0	1.0	1,600	2008	3.0	2	3	2	0	0	1992	1997	3	1	STGB	2.20
Nata - Francis Town	187	7.0	1.0	500	2008	3.0	3	3	2	0	0	1992	1997	3	1	STGB	2.20
Pandamatenga - Nata	199	7.0	1.0	400	2008	3.0	2	5	2	0	0	1992	1997	3	1	STGB	2.20
BP Kazungula - Pandamatenga	109	7.0	1.0	400	2008	3.9	2	2	2	0	0	1992	1997	3	1	STGB	2.20
Palapye - BP Martin's Drift	103	7.0	1.0	2,000	2008	6.3	2	5	2	0	0	1992	1997	7	2	STGB	2.20
End DRC - Kasumbelesa	8	6.0	0.0	510	2008	7.0	15	100	15	5	0	1990	1994	6	3	STGB	1.40
Likasi - Kolwezi	176	4.5	0.0	389	2008	9.0	0	0	0	0	50	0	0	0	0	GRAVEL	0.00
Lubumbashi - Likasi	123	7.0	0.5	389	2008	5.0	2	300	17	10	0	1990	1994	5	4	STGB	1.40
Kasumbelesa - Lubumbashi	93	6.0	0.0	510	2008	7.0	15	100	15	5	0	1990	1994	6	3	STGB	1.40
Roundabout Karonga - BP Songwe	45	7.0	1.2	1,716	2008	3.7	6	30	5	2	0	1987	2003	4	2	STGB	1.70
Junction M1 - TOR Kasungu	120	6.6	1.0	3,092	2008	3.4	2	0	5	2	0	1987	2000	4	2	STGB	1.85
Junction M1 - TO Blantyre	191	6.4	2.0	689	2008	2.9	6	60	5	2	0	1987	2003	4	1	STGB	1.55
TO Blantyre - TO Mwanza	60	7.0	0.0	1,794	2008	5.0	2	5	5	2	0	1998	1998	6	2	STGB	1.87
TO Mwanza - Border Post Mwanza	51	7.0	0.0	1,502	2008	4.5	2	5	5	2	0	1998	1998	6	2	STGB	1.87
BP Mchinji - Junction M1	116	7.0	0.0	1,716	2008	5.0	5	20	5	2	0	1998	1998	6	1	AMGB	1.87
Bottom of Escarpment - Roundabout Karonga	56	7.0	0.5	389	2008	4.0	2	22	5	2	0	2002	2002	6	2	STGB	1.87
BP Songwe - Junction Tanzam	101	7.0	1.2	1,716	2008	3.7	6	30	5	2	0	1987	2003	4	2	STGB	1.70
Bailey Bridge - Bottom of Escarpment	63	6.6	1.0	389	2008	4.0	11	27	5	2	0	1987	2000	4	2	STGB	1.54

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
TO Rumphi - Bailey Bridge	42	6.6	1.3	510	2008	3.5	5	45	5	2	0	1987	2003	4	2	STGB	1.48
Mzuzu - TO Rumphi	57	7.0	0.0	405	2008	4.5	2	30	5	2	0	1998	1998	6	2	STGB	1.48
TOL Mzimba - Mzuzu	95	7.0	0.2	971	2008	4.5	2	25	5	2	0	1998	1998	6	2	STGB	1.48
TOR Kasungu - TOL Mzimba	131	7.0	0.2	3,617	2008	4.5	2	12	5	2	0	1998	1998	6	2	STGB	1.48
Tete Bridge - Border Post Mwanza	138	7.0	0.3	500	2008	5.0	15	1	5	2	0	1970	1990	0	2	STGB	1.60
Zobue - Tete Bridge	118	7.0	0.3	1,000	2008	8.0	10	5	5	2	0	1970	1990	0	1	STGB	1.70
Mwanza - Zobue	6	7.0	0.3	1,500	2008	8.0	10	5	5	2	0	1970	1990	0	1	STGB	1.50
Tete Bridge(West) - Tete Bridge(East)	1	7.0	1.0	1,500	2008	2.0	2	0	0	0	0	1992	1997	3	1	STGB	1.60
Pietersburg - Pretoria	261	15.2	6.0	15,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
BP - Pietersburg	179	15.2	6.0	15,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
Pretoria - Johannesburg	58	15.2	6.0	40,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
Messina - Pretoria	454	15.2	6.0	15,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
End BP Beit Bridge - Messina	19	15.2	6.0	15,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
Johannesburg - Durban	578	15.2	6.0	25,000	2008	2.0	2	0	1	0	0	1980	2003	2	0	AMGB	5.00
Zeerust R57 - Pretoria	227	15.2	6.0	15,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
BP Gabarone - Zeerust R57	125	15.2	6.0	4,000	2008	2.0	2	0	1	0	0	1980	1994	2	0	AMGB	5.00
Turn off A1 - Dar-es-salaam	91	7.0	0.5	1,502	2008	4.5	5	25	5	1	0	2001	2001	2	2	AMGB	1.80
Dar-es-salaam - Port	42	7.0	0.5	1,502	2008	4.5	5	25	5	1	0	2001	2001	2	2	AMGB	1.80
Kitonga -Turn off A1	232	7.0	1.0	1,502	2008	4.0	2	12	5	1	0	1998	1998	5	1	AMGB	1.70
Iyovi -Kitonga	86	7.0	0.0	1,502	2008	8.0	15	13	5	2	0	1993	1994	6	2	STGB	1.70
Iringa - Iyovi	61	7.0	0.0	1,502	2008	8.0	15	10	5	2	0	1993	1994	6	1	STGB	1.70
Mafinga - Iringa	76	7.0	0.0	1,502	2008	8.0	15	15	5	2	0	1993	1994	6	1	STGB	1.70
Igawa -Mafinga	142	7.0	0.0	1,502	2008	6.0	5	11	5	2	0	1996	1996	6	2	STGB	1.70

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
Mbeya - Igawa	177	7.0	0.5	1,502	2008	4.5	2	12	5	1	0	2001	2001	5	1	AMGB	1.70
BP Tunduma - Mbeya	106	7.0	0.5	1,502	2008	4.5	2	13	5	1	0	2001	2001	5	1	AMAP	1.70
Turnoff T1 - Mazabuka	66	7.0	0.5	1,716	2008	4.5	2	157	15	5	0	1998	1998	4	2	AMGB	2.70
Turn off M10 - BP Kazungula	71	7.0	0.0	689	2008	4.7	15	0	15	5	0	1992	1994	6	2	STGB	2.70
Turn off M10 - BP Livingstone	9	7.0	0.0	689	2008	4.7	15	0	15	5	0	1992	1994	6	2	STGB	2.70
Zimba - Turn off M10	78	7.0	0.0	1,794	2008	4.5	15	0	0	5	0	1992	1994	6	1	STGB	2.70
Choma - Zimba	115	7.0	0.5	1,502	2008	2.5	2	79	0	5	0	1998	1998	4	1	AMGB	2.40
Monze - Choma	98	7.0	0.5	1,716	2008	2.6	2	109	0	5	0	1998	1998	4	1	AMGB	2.26
Mazabuka - Monze	64	7.0	0.5	1,716	2008	4.0	2	89	15	5	0	1998	1998	4	1	STGB	2.82
Isoka - BP Nakonde	106	7.0	0.0	389	2008	3.5	15	108	0	5	0	1993	1994	4	3	STGB	2.80
Chinsali - Isoka	129	6.0	0.0	389	2008	4.1	15	59	0	17	0	1992	1994	6	3	STGB	1.50
Mpika - Chinsali	134	6.0	0.0	510	2008	3.7	15	235	0	17	0	1992	1994	6	3	STGB	1.50
Serenje -Mpika	235	7.0	0.0	405	2008	3.4	2	392	0	5	0	1998	1998	5	3	STGB	1.50
Kapiri Moshi - Serenje	192	7.0	1.0	971	2008	2.5	2	8	0	5	0	2001	2001	5	1	AMGB	2.06
Kabwe -Kapiri Moshi	66	7.0	1.0	3,617	2008	2.7	2	0	0	0	0	1998	1998	5	1	AMGB	2.05
Lusaka SE RAB - Turnoff T1	53	7.0	1.0	3,404	2008	4.1	2	33	0	0	0	1998	1998	6	1	AMGB	3.00
Turnoff T1 - Start BP Chirundu	78	7.0	0.0	1,457	2008	3.7	2	233	0	5	0	1996	1996	5	2	STGB	2.50
Kapiri Moshi - Junction T3	77	7.0	1.0	3,617	2008	2.7	2	0	0	0	0	1998	1998	5	1	AMGB	2.50
Lusaka NE RAB - Kabwe	135	7.0	1.0	2,907	2008	2.7	2	6	0	0	0	2003	2003	5	1	AMGB	2.50
Kitwe - Chingola	50	7.0	1.2	2,510	2008	3.0	5	17	0	0	0	2001	2001	4	2	AMGB	2.04
Junction T3 - TO Luanshya	32	7.0	0.5	2,627	2008	2.8	2	1	0	0	0	2003	2003	4	2	AMGB	2.30
Chingola - Start BP Zambia	40	7.0	0.0	2,510	2008	2.7	2	11	0	0	0	1998	1998	5	2	AMGB	2.40
Chingola - Solwezi	167	7.0	1.2	2,510	2008	3.0	5	17	0	0	0	2001	2001	4	2	STGB	2.10

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
TO Luanshya - Kitwe	39	7.0	0.5	2,627	2008	2.8	2	1	0	0	0	1987	2003	4	2	AMAP	2.05
End Asphalt Overlay - BP Mchinji	256	7.0	0.0	1,716	2008	5.0	5	20	5	2	0	1998	1998	6	1	AMAP	2.60
Start Asphalt Overlay -Luangwa Bridge	33	7.0	0.5	1,849	2008	4.5	2	233	0	0	0	1998	1998	6	1	AMAP	2.20
End of Bridge - End Asphalt Overlay	97	7.0	0.5	1,849	2008	4.5	2	11	0	0	0	1998	1998	6	1	AMAP	2.20
North End Roundabout - Start Asphalt Overlay	42.5	7.0	0.5	1,849	2008	4.5	2	11	0	0	0	1998	1998	6	1	STGB	2.60
Chinhoyi - Harare CB1	101	7.0	1.5	2,500	2008	5.7	5	40	5	2	0	1992	1997	3	2	STGB	1.50
Karoi - Chinhoyi	94	7.0	1.5	2,000	2008	6.0	15	50	5	2	0	1992	1997	3	3	STGB	1.50
Makuti - Karoi	78	7.0	1.0	2,000	2008	6.0	15	50	5	2	0	1992	1997	3	2	STGB	1.50
End BP Chirundu - Makuti	75	7.0	1.0	1,500	2008	6.0	15	50	5	2	0	1992	1997	3	3	STGB	1.50
Harare - Nyamapanda	475	7.0	0.0	1,000	2008	4.7	5	40	5	2	0	1992	1997	3	2	STGB	1.50
Masvingo - Turn Off	95	7.0	1.5	2,000	2008	5.7	5	50	5	2	0	1992	1997	3	3	STGB	1.50
Chivhu - Masvingo	151	7.0	1.0	2,500	2008	5.5	5	30	5	2	0	1992	1997	3	2	STGB	1.50
Harare CB2 - Chivhu	141	7.0	1.5	3,000	2008	5.5	5	30	5	2	0	1992	1997	3	3	STGB	1.50
Turn Off - BP Beit Bridge	184	7.0	1.5	1,500	2008	6.0	15	60	5	2	0	1992	1997	3	3	STGB	1.50
Bulawayo - BP Beit Bridge	316	7.0	1.5	3,000	2008	4.0	5	10	5	2	0	1992	1997	3	3	STGB	1.50
Hwange - Bulawayo	330	7.0	1.0	2,000	2008	6.0	15	67	5	2	0	1992	1997	3	2	STGB	1.50
BP Livingstone - Hwange	110	7.0	1.0	1,500	2008	5.7	5	55	5	2	0	1992	1997	3	2	STGB	1.50
ZMEZMA BP 1 at Victoria Falls (PCs, Buses) N	1	7.0	1.5	556	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMA BP 1 at Victoria Falls (PCs, Buses) S	1	7.0	1.5	556	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMA BP 1 at Victoria Falls (Refrig, Oil Tankers) N	1	7.0	1.5	1,500	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
ZMEZMA BP 1 at Victoria Falls (Refrig, Oil Tankers) S	1	7.0	1.5	1,502	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMA BP 1 at Victoria Falls (Heavy Trucks) N	1	7.0	1.5	1,500	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMA BP 1 at Victoria Falls (Heavy Trucks) S	1	7.0	1.5	1,502	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMABP 2 at Chirundu (Heavy Trucks) S	1	7.0	1.5	1,502	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMABP 2 at Chirundu (PCs, Buses) N	1	7.0	1.5	637	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
ZMEZMABP 2 at Chirundu (PCs, Buses) S	1	7.0	1.5	637	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
ZMEZMABP 2 at Chirundu (Refrig, Oil Tankers) N	1	7.0	1.5	1,500	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMABP 2 at Chirundu (Refrig, Oil Tankers) S	1	7.0	1.5	1,502	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
ZMEZMABP 2 at Chirundu (Heavy Trucks) N	1	7.0	1.5	1,500	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
BOTZMA BP 4 at Kazangula (PCs, Buses) N	1	7.0	1.5	149	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
BOTZMA BP 4 at Kazangula (PCs, Buses) S	1	7.0	1.5	149	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
BOTZMA BP 4 at Kazungula (Refrig, Oil Tankers) N	1	7.0	1.5	19	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
BOTZMA BP 4 at Kazangula (Refrig, Oil Tankers) S	1	7.0	1.5	19	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
BOTZMA BP 4 at Kazangula (Heavy Trucks) N	1	7.0	1.5	33	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
BOTZMA BP 4 at Kazangula (Heavy Trucks) S	1	7.0	1.5	33	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 2 at Gabarone (PCs, Buses) N	1	7.0	1.5	1,113	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
RSABOT BP 2 at Gabarone (PCs, Buses) S	1	7.0	1.5	1,113	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 2 at Gabarone (Refrig, Oil Tankers) N	1	7.0	1.5	142	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 2 at Gabarone (Refrig, Oil Tankers) S	1	7.0	1.5	142	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 2 at Gabarone (Heavy Trucks) N	1	7.0	1.5	246	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 2 at Gabarone (Heavy Trucks) S	1	7.0	1.5	246	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 3 at Martin's Drift (PCs, Buses) N	1	7.0	1.5	743	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 3 at Martin's Drift (PCs, Buses) S	1	7.0	1.5	743	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 3 at Martin's Drift (Refrig, Oil Tankers) N	1	7.0	1.5	95	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 3 at Martin's Drift (Refrig, Oil Tankers) S	1	7.0	1.5	95	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 3 at Martin's Drift (Heavy Trucks) N	1	7.0	1.5	164	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSABOT BP 3 at Martin's Drift (Heavy Trucks) S	1	7.0	1.5	164	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSAZME BP 1 at Beit Bridge (PCs, Buses) N	1	7.0	1.5	5,726	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSAZME BP 1 at Beit Bridge (PCs, Buses) S	1	7.0	1.5	5,726	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSAZME BP 1 at Beit Bridge (Refrig, Oil Tankers) N	1	7.0	1.5	710	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
RSAZME BP 1 at Beit Bridge (Refrig, Oil Tankers) S	1	7.0	1.5	710	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSAZME BP 1 at Beit Bridge (Heavy Trucks) N	1	7.0	1.5	1,229	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
RSAZME BP 1 at Beit Bridge (Heavy Trucks) S	1	7.0	1.5	1,229	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAMAL BP 1 at Songwe (PCs, Buses) N	1	7.0	1.5	532	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
TZAMAL BP 1 at Songwe (PCs, Buses) S	1	7.0	1.5	532	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
TZAMAL BP 1 at Songwe (Refrig, Oil Tankers) N	1	7.0	1.5	70	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAMAL BP 1 at Songwe (Refrig, Oil Tankers) S	1	7.0	1.5	70	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAMAL BP 1 at Songwe (Heavy Trucks) N	1	7.0	1.5	150	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAMAL BP 1 at Songwe (Heavy Trucks) S	1	7.0	1.5	150	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAZMA BP 2 at Tunduma (PCs, Buses) N	1	7.0	1.5	154	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
TZAZMA BP 2 at Tunduma (PCs, Buses) S	1	7.0	1.5	154	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
TZAZMA BP 2 at Tunduma (Heavy Trucks) S	1	7.0	1.5	30	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAZMA BP 2 at Tunduma (Refrig, Oil Tankers) N	1	7.0	1.5	11	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAZMA BP 2 at Tunduma (Refrig, Oil Tankers) S	1	7.0	1.5	11	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
TZAZMA BP 2 at Tunduma (Heavy Trucks) N	1	7.0	1.5	30	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
DRCZMA BP 1 at Kasumbalesa (Heavy Trucks) S	1	7.0	1.5	72	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
DRCZMA BP 1 at Kasumbalesa (PCs, Buses) N	1	7.0	1.5	110	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
DRCZMA BP 1 at Kasumbalesa (PCs, Buses) S	1	7.0	1.5	110	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
DRCZMA BP 1 at Kasumbalesa (Refrig, Oil Tankers) N	1	7.0	1.5	22	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
DRCZMA BP 1 at Kasumbalesa (Refrig, Oil Tankers) S	1	7.0	1.5	22	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
DRCZMA BP 1 at Kasumbalesa (Heavy Trucks) N	1	7.0	1.5	72	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMA BP 1 at Mchinji (Heavy Trucks) S	1	7.0	1.5	274	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMZB BP 2 at Zobue (PCs, Buses) N	1	7.0	1.5	185	1998	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
MALZMZB BP 2 at Zobue (PCs, Buses) S	1	7.0	1.5	185	1998	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
MALZMZB BP 2 at Zobue (Refrig, Oil Tankers) N	1	7.0	1.5	24	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMZB BP 2 at Zobue (Refrig, Oil Tankers) S	1	7.0	1.5	24	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMZB BP 2 at Zobue (Heavy Trucks) N	1	7.0	1.5	41	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMZB BP 2 at Zobue (Heavy Trucks) S	1	7.0	1.5	41	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMA BP 1 at Mchinji (PCs, Buses) N	1	7.0	1.5	1,195	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
MALZMA BP 1 at Mchinji (PCs, Buses) S	1	7.0	1.5	1,195	2008	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
MALZMA BP 1 at Mchinji (Refrig, Oil Tankers) N	1	7.0	1.5	234	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MALZMA BP 1 at Mchinji (Refrig, Oil Tankers) S	1	7.0	1.5	234	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00

Table A.1 Road Network Data (Continued)

SECTION NAME	LENGTH (km)	CARRIAGEWAY WIDTH (m)	SHOULDER WIDTH (m)	AADT	AADT YEAR	ROUGHNESS (m/km)	RUT DEPTH (mm)	POT HOLE NUMBER	ALL CRACKS (%)	WIDE CRACKS (%)	GRAVEL THICKNESS (mm)	LAST CONSTR YEAR	LAST SURF YEAR	DRAIN TYPE	DRAIN COND	BITUMINOUS PAVE TYPE	STRUCTURAL NUMBER
MALZMA BP 1 at Mchinji (Heavy Trucks) N	1	7.0	1.5	274	2008	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MZBZME BP 1 at Nyamapanda (PCs, Buses) N	1	7.0	1.5	185	1998	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
MZBZME BP 1 at Nyamapanda (PCs, Buses) S	1	7.0	1.5	185	1998	2.0	2	0	0	0	0	1997	1997	3	0	DS	5.00
MZBZME BP 1 at Nyamapanda (Refrig, Oil Tankers) N	1	7.0	1.5	24	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MZBZME BP 1 at Nyamapanda (Refrig, Oil Tankers) S	1	7.0	1.5	24	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MZBZME BP 1 at Nyamapanda (Heavy Trucks) N	1	7.0	1.5	41	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00
MZBZME BP 1 at Nyamapanda (Heavy Trucks) S	1	7.0	1.5	41	1998	2.0	2	0	0	0	0	1992	1997	3	0	DS	5.00

Notes to Table A.1

1. <u>Drain Type</u>
0 = Fully Lined and Linked
1 = Surface lined
2 = V-shaped hard
3 = V-shaped soft
4 = Shallow hard
5 = Shallow soft
6 = No invert overgrown
7 = No drainage effects

2. <u>Drain Condition</u>
0 = Excellent
1 = Good
2 = Fair
3 = Poor
4 = Very poor

3. <u>Bituminous Pavement Type</u>
0 = AMGB (Asphalt Mix on Granular Base)
1 = AMAB (Asphalt Mix on Asphalt Base)
2 = AMAP (Asphalt Mix on Asphalt Pavement)
3 = AMSB (Asphalt Mix on Stabilised Base)
4 = STBG (Surface Treatment on Granular Base)
5 = STAB (Surface Treatment on Asphalt Base)
6 = STAP (Surface Treatment on Asphalt Pavement)
7 = STSB (Surface Treatment on Stabilised Base)

4. DS = Dummy section used in modelling delays at Border Posts

Table A.2 Climate Data

Region/Country	Climatic Parameters							
	Moisture classification	Moisture index	Duration of dry season (months)	Mean monthly precipitation (mm)	Temperature classification	Mean temperature (°C)	Average temperature range (°C)	No. of days with temperature greater than 32°C (days)
Botswana (Eastern)	Semi Arid	- 40	9	50	Tropical	27	15	90
Mozambique & Malawi (General)	Sub-humid	0	8.4	80	Tropical	27	5	90
Zimbabwe (General)	Sub-humid	0	7	60	Tropical	23	7	40
RSA (General)	Sub-humid	19	3	130	Sub-tropical - cool	18	12	30
Zambia, Tanzania (General) & DRC (Southern)	Sub-humid	0	8	90	Tropical	27	5	90

Appendix B: Vehicle Fleet Data

Table B.1 Typical Vehicle Fleet Data

Data Type	Unit	Description	Data Values				
			Cars	Light Vehicles	Medium Vehicles	Heavy Vehicles	Bus
Number of Axles	No	Number of axles per vehicle	2	2	2	4	2
Number of Wheels	No	Number of wheels per vehicle	4	4	6	14	6
Annual Utilisation in km	km	Average number of kilometres driven per year	22,500	45,000	80,000	100,000	75,000
Working hours	hr	Number of hours per year expended on essential tasks of complete round trips	450	1,200	1,500	1,800	1,200
Average Life	Year	Average vehicle service life	9	10	8	8	10
Equivalent Standard Axle Load Factor	-	Number of equivalent standard axles per vehicle	-	1.00	4.30	4.60	2.40
Operating Weight	Ton	Average operating vehicle of the vehicle	2.15	4.00	12.30	40.00	12.60
Cost of New Vehicle	US$	Average purchase costs (economic costs) of new vehicle of this type.	18,591	38,234	59,919	96,639	76,408
Fuel Cost	US$	Average costs of fuel per litre.	0.55	0.59	0.59	0.59	0.59
Passenger Working Time Value	US$	The average costs value of passenger working time (per hour)	0.07	0.07	0.07	0.07	0.07
Passenger Non-Working Time Value	US$	The average cost value of passenger non-working time (per hour)	-	-	-	-	-
Cargo delay costs	US$ /hr	The average costs of cargo delay per hour	-	0.02	0.02	0.02	-

Appendix C: Annual Average Daily Traffic Data

Table C.1 Annual Average Daily Traffic (AADT) Data for the Main Sections

Country	Section ID	Section Name	Data Source	Vehicle Type - AADT						Total AADT
				Car, 4WD, Pick-up	Light Goods	Mini Bus	Bus	Medium Goods	Heavy Goods	
Botswana	BOT_A1-004	(STGB)_Dibete - BP Gabarone	Sourced	1,899	810	450	110	320	260	3,849
	BOT_A1-005	(STGB)_Mahalpye - Dibete	Sourced	1,899	810	450	110	320	260	3,849
	BOT_A1-006	(STGB)_Palapye - Mahalpye	Sourced	1,899	810	450	110	320	260	3,849
	BOT_A1-008	(STGB)_Francis Town - Palapye	Sourced	1,034	441	245	61	174	143	2,098
	BOT_A3-001	(STGB)_Nata - Francis Town	Sourced	268	107	416	67	242	242	1,342
	BOT_A33-001	(STGB)_Pandamatenga - Nata	Sourced	268	107	416	67	242	242	1,342
	BOT_A33-002	(STGB)_BP Kazungula - Pandamatenga	Sourced	180	107	140	67	120	168	782
	BOT_RSABOTBP 3-A1-001	(STGB)_Palapye - BP Martin's Drift	Sourced	893	86	245	260	189	328	2,000
DRC	DRC:T3 _4	(STGB)_End DRC - Kasumbelesa	Estimated	211	20	58	60	43	118	510
	DRC:T3_1	(GRAVEL)_Likasi - Kolwezi	Estimated	101	10	28	50	68	132	389
	DRC:T3_2	(STGB)_Lubumbashi - Likasi	Estimated	101	10	28	50	68	132	389
	DRC:T3_3	(STGB)_Kasumbelesa - Lubumbashi	Estimated	211	20	58	60	43	118	510

Table C.1 Annual Average Daily Traffic (AADT) Data for the Main Sections (Continued)

Country	Section ID	Section Name	Data Source	Vehicle Type - AADT						Total AADT
				Car, 4WD, Pick-up	Light Goods	Mini Bus	Bus	Medium Goods	Heavy Goods	
Malawi	MAL:T4_1	(STGB)_Roundabout Karonga - BP Songwe	Sourced	246	16	134	6	22	41	465
	MAL:T4_11	(STGB)_Junction M1 - TOR Kasungu	Sourced	521	62	187	58	186	140	1,154
	MAL:T4_12	(STGB)_Junction M1 - TO Blantyre	Sourced	862	74	247	83	138	163	1,567
	MAL:T4_14	(STGB)_TO Blantyre - TO Mwanza	Sourced	841	81	231	314	104	224	1,794
	MAL:T4_15	(STGB)_TO Mwanza - Border Post Mwanza	Sourced	611	59	168	223	141	300	1,502
	MAL:T4_19	(AMGB)_BP Mchinji - Junction M1	Sourced	755	72	207	308	143	231	1,716
	MAL:T4_2	(STGB)_Bottom of Escarpment - Roundabout Karonga	Sourced	101	10	28	50	68	132	389
	MAL:T4_21	(STGB)_BP Songwe - Junction Tanzam	Sourced	755	72	207	308	143	231	1,716
	MAL:T4_3	(STGB)_Bailey Bridge - Bottom of Escarpment	Sourced	196	47	61	26	49	48	427
	MAL:T4_4	(STGB)_TO Rumphi - Bailey Bridge	Sourced	196	47	61	26	49	48	427
	MAL:T4_5	(STGB)_Mzuzu - TO Rumphi	Sourced	113	11	31	64	44	143	405
	MAL:T4_6	(STGB)_TOL Mzimba - Mzuzu	Sourced	349	33	96	128	145	220	971
	MAL:T4_7	(STGB)_TOR Kasungu - TOL Mzimba	Sourced	1,480	142	406	420	287	883	3,617
Mozambiqu e	MZB_N304_Btwn Moatiz	(STGB)_Tete Bridge - Border Post Nyamapanda	Sourced	986	95	270	288	209	362	2,209
	MZB_N7_Moatize - MZB	(STGB)_Zobue - Tete Bridge	Sourced	357	34	98	104	76	131	800
	MZB_N7_Tete - Tete B	(STGB)_Mwanza - Zobue	Sourced	357	34	98	104	76	131	800
	MZB_N7_Tete Bridge(W	(STGB)_Tete Bridge(West) - Tete Bridge(East)	Sourced	669	64	183	195	142	246	1,500

Table C.1 Annual Average Daily Traffic (AADT) Data for the Main Sections (Continued)

Country	Section ID	Section Name	Data Source	Vehicle Type - AADT						Total AADT
				Car, 4WD, Pick-up	Light Goods	Mini Bus	Bus	Medium Goods	Heavy Goods	
RSA	RSA: M - 10	(AMGB)_Pietersburg - Pretoria	Sourced	6,694	642	1,834	1,953	1,420	2,457	15,000
	RSA: M - 9	(AMGB)_BP - Pietersburg	Sourced	6,694	642	1,834	1,953	1,420	2,457	15,000
	RSA_N1-001	(AMGB)_Pretoria - Johannesburg	Sourced	17,85 1	1,712	4,891	5,207	3,788	6,552	40,000
	RSA_N1-003	(AMGB)_Messina - Pretoria	Sourced	6,694	642	1,834	1,953	1,420	2,457	15,000
	RSA_N1-004	(AMGB)_End BP Beit Bridge - Messina	Sourced	6,694	642	1,834	1,953	1,420	2,457	15,000
	RSA_N3-001	(AMGB)_Johannesburg - Durban	Sourced	11,15 7	1,070	3,057	3,254	2,367	4,095	25,000
	RSA_N4-001	(AMGB)_Zeerust R57 - Pretoria	Sourced	6,694	642	1,834	1,953	1,420	2,457	15,000
	RSA_R49-001	(AMGB)_BP Gabarone - Zeerust R57	Sourced	1,785	171	489	521	379	655	4,000
Tanzania	TZA:T2_1	(AMAP)_Turn off A1 - Dar-es-salaam	Sourced	611	1,383	1,075	1,495	1,198	659	6,421
	TZA:T2_10	(AMAP)_Dar-es-salaam - Port	Sourced	611	4,362	4,152	223	1,466	688	11,502
	TZA:T2_2	(AMAP)_Kitonga -Turn off A1	Sourced	611	327	168	287	407	470	2,270
	TZA:T2_3	(STGB)_Iyovi -Kitonga	Sourced	611	163	41	107	199	226	1,347
	TZA:T2_4	(STGB)_Iringa - Iyovi	Sourced	611	59	168	223	141	300	1,502
	TZA:T2_5	(STGB)_Mafinga - Iringa	Sourced	611	434	280	163	389	302	2,179
	TZA:T2_6	(STGB)_Igawa -Mafinga	Sourced	611	164	124	120	291	285	1,595
	TZA:T2_7	(AMGB)_Mbeya - Igawa	Sourced	230	304	518	206	373	279	1,910
	TZA:T2_8	(AMAP)_BP Tunduma - Mbeya	Sourced	240	409	449	67	270	260	1,695

Table C.1 Annual Average Daily Traffic (AADT) Data for the Main Sections (Continued)

Country	Section ID	Section Name	Data Source	Vehicle Type - AADT						Total AADT
				Car, 4WD, Pick-up	Light Goods	Mini Bus	Bus	Medium Goods	Heavy Goods	
Zambia	ZMA:T1_10	(AMGB)_Turnoff T1 - Mazabuka	Sourced	755	72	207	308	143	231	1,716
	ZMA:T1_11	(STGB)_Turn off M10 - BP Kazungula	Sourced	226	22	62	108	57	214	689
	ZMA:T1_5	(STGB)_Turn off M10 - BP Livingstone	Sourced	226	22	62	108	57	214	689
	ZMA:T1_6	(STGB)_Zimba - Turn off M10	Sourced	841	81	231	314	104	224	1,794
	ZMA:T1_7	(AMGB)_Choma - Zimba	Sourced	611	59	168	223	141	300	1,502
	ZMA:T1_8	(AMGB)_Monze - Choma	Sourced	755	72	207	308	143	231	1,716
	ZMA:T1_9	(STSB)_Mazabuka - Monze	Sourced	755	72	207	308	143	231	1,716
	ZMA:T2_12	(STSB)_Isoka - BP Nakonde	Sourced	101	10	28	50	68	132	389
	ZMA:T2_13	(STSB)_Chinsali - Isoka	Sourced	101	10	28	50	68	132	389
	ZMA:T2_14	(STSB)_Mpika - Chinsali	Sourced	211	20	58	60	43	118	510
	ZMA:T2_15	(STSB)_Serenje -Mpika	Sourced	113	11	31	64	44	143	405
	ZMA:T2_16	(AMGB)_Kapiri Moshi - Serenje	Sourced	349	33	96	128	145	220	971
	ZMA:T2_17	(AMGB)_Kabwe -Kapiri Moshi	Sourced	1,480	142	406	420	287	883	3,617
	ZMA:T2_19	(AMGB)_Lusaka SE RAB - Turnoff T1	Sourced	1,499	144	411	336	467	547	3,404
	ZMA:T2_20	(STGB)_Turnoff T1 - Start BP Chirundu	Sourced	635	61	174	146	138	302	1,457
	ZMA:T2_21	(AMGB)_Kapiri Moshi - Junction T3	Sourced	1,480	142	406	420	287	883	3,617
	ZMA:T2_22	(AMGB)_Lusaka NE RAB - Kabwe	Sourced	1,232	118	338	381	259	579	2,907
	ZMA:T3_10	(AMGB)_Kitwe - Chingola	Sourced	1,228	118	336	305	136	388	2,510
	ZMA:T3_12	(AMGB)_Junction T3 - TO Luanshya	Sourced	955	92	262	348	211	760	2,627
	ZMA:T3_5	(AMGB)_Chingola - Start BP Zambia	Sourced	1,228	118	336	305	136	388	2,510
	ZMA:T3_6	(STGB)_Chingola - Solwezi	Sourced	1,228	118	336	305	136	388	2,510
	ZMA:T3_8	(AMAP)_TO Luanshya - Kitwe	Sourced	955	92	262	348	211	760	2,627
	ZMA:T4_24	(AMAP)_End Asphalt Overlay - BP Mchinji	Sourced	755	72	207	308	143	231	1,716

Table C.1 Annual Average Daily Traffic (AADT) Data for the Main Sections (Continued)

Country	Section ID	Section Name	Data Source	Vehicle Type - AADT						Total AADT
				Car, 4WD, Pick-up	Light Goods	Mini Bus	Bus	Medium Goods	Heavy Goods	
Zambia	ZMA:T4_25	(AMAP)_Start Asphalt Overlay -Luangwa Bridge	Sourced	938	90	257	351	169	44	1,849
	ZMA:T4_26	(AMAP)_End of Bridge - End Asphalt Overlay	Sourced	938	90	257	351	169	44	1,849
	ZMA:T4_27	(STGB)_North End Roundabout - Start Asphalt Overlay	Sourced	938	90	257	351	169	44	1,849
Zimbabwe	ZME_A1-002	(STGB)_Chinhoyi - Harare CB1	Estimated	1,116	107	306	325	237	409	2,500
	ZME_A1-003	(STGB)_Karoi - Chinhoyi	Estimated	893	86	245	260	189	328	2,000
	ZME_A1-004	(STGB)_Makuti - Karoi	Estimated	893	86	245	260	189	328	2,000
	ZME_A1-005	(STGB)_End BP Chirundu - Makuti	Estimated	669	64	183	195	142	246	1,500
	ZME_A2-001	(STGB)_Harare - Nyamapanda	Estimated	446	43	122	130	95	164	1,000
	ZME_A4-001	(STGB)_Masvingo - Turn Off	Estimated	893	86	245	260	189	328	2,000
	ZME_A4-004	(STGB)_Chivhu - Masvingo	Estimated	1,116	107	306	325	237	409	2,500
	ZME_A4-005	(STGB)_Harare CB2 - Chivhu	Estimated	1,339	128	367	391	284	491	3,000
	ZME_A6-001	(STGB)_Turn Off - BP Beit Bridge	Estimated	669	64	183	195	142	246	1,500
	ZME_A6-A8-001	(STGB)_Bulawayo - BP Beit Bridge	Estimated	1,339	128	367	391	284	491	3,000
	ZME_A8-001	(STGB)_Hwange - Bulawayo	Estimated	893	86	245	260	189	328	2,000
	ZME_A8-005	(STGB)_BP Livingstone - Hwange	Estimated	669	64	183	195	142	246	1,500

Notes to Table C.1

Summary of Data Sources:

1. Botswana – (Roads Department, Botswana)
2. DRC – Estimated based on the following criteria:
   - AADT of the neighbour sections in Zambia
   - Traffic levels were considered higher at the DRC-Zambia border than inland towards Kolwezi to reflect existing economic activities
3. Malawi – (National Roads Authority, Malawi)
4. Mozambique – (Adminsitracao Nacional de Estradas (ANE), Project Report (2007): Consultancy Services for a Heavy Vehicle Overloading Control Study by Africon Limited)
5. RSA – (The South African National Roads Agency – Major Project Reports)
6. Tanzania (Tanzania National Roads Agency)
7. Zambia – (Roads Development Agency, Zambia)
8. Zimbabwe – Estimated based on the following criteria:
   - Generally the national level of traffic in Zimbabwe was considered similar to that of Zambia
   - AADT were estimated based on international traffic through international borders with Zimbabwe
9. Estimated AADT were adjusted to reflect local traffic especially for the sections through major economic locations

Appendix D: 20-Year Work Programme for Scenario RN-3

Table D.1 20-Year Work Programme for Scenario RN-3

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Botswana	BP Kazungula - Pandamatenga	109	5	Cape Seal	9,728,250	11,445,000	763,000	m^2
Botswana	BP Kazungula - Pandamatenga	109	8	Overlay 50mm	16,213,750	19,075,000	763,000	m^2
Botswana	BP Kazungula - Pandamatenga	109	10	Single Surface Dressing to Existing Road	3,052,000	3,815,000	763,000	m^2
Botswana	BP Kazungula - Pandamatenga	109	10	Partial Widening ST	9,265,000	10,900,000	32,700	m^2
Botswana	BP Kazungula - Pandamatenga	109	20	Overlay 50mm	16,908,624	19,892,500	795,700	m^2
Botswana	Francis Town - Palapye	178	6	Cape Seal	15,886,500	18,690,000	1,246,000	m^2
Botswana	Francis Town - Palapye	178	10	Overlay 50mm	26,477,500	31,150,000	1,246,000	m^2
Botswana	Francis Town - Palapye	178	14	Single Surface Dressing to Existing Road	4,984,000	6,230,000	1,246,000	m^2
Botswana	Francis Town – Palapye	178	14	Partial Widening ST	15,130,000	17,800,000	53,400	m^2
Botswana	Mahalpye – Dibete	81	1	Single Surface Dressing to Existing Road	2,268,000	2,835,000	567,000	m^2
Botswana	Mahalpye - Dibete	81	1	Partial Widening ST	6,885,000	8,100,000	24,300	m^2
Botswana	Mahalpye - Dibete	81	12	Overlay 50mm	12,565,125	14,782,500	591,300	m^2
Botswana	Nata - Francis Town	187	4	Overlay 50mm	27,816,250	32,725,000	1,309,000	m^2
Botswana	Nata - Francis Town	187	13	Cape Seal	16,689,750	19,635,000	1,309,000	m^2
Botswana	Nata - Francis Town	187	18	Overlay 50mm	27,816,250	32,725,000	1,309,000	m^2
Botswana	Palapye - BP Gabarone	120	1	Single Surface Dressing to Existing Road	3,360,000	4,200,000	840,000	m^2
Botswana	Palapye - BP Gabarone	120	1	Partial Widening ST	10,200,000	12,000,000	36,000	m^2
Botswana	Palapye - BP Gabarone	120	12	Overlay 50mm	18,615,000	21,900,000	876,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Botswana	Palapye - BP Martin's Drift	103	1	Overlay 80mm	24,514,000	28,840,000	721,000	m^2
Botswana	Palapye - BP Martin's Drift	103	12	Overlay 50mm	15,321,250	18,025,000	721,000	m^2
Botswana	Palapye - BP Martin's Drift	103	15	Single Surface Dressing to Existing Road	2,884,000	3,605,000	721,000	m^2
Botswana	Palapye - BP Martin's Drift	103	15	Partial Widening ST	8,755,000	10,300,000	30,900	m^2
Botswana	Palapye - Mahalpye	60	1	Single Surface Dressing to Existing Road	1,680,000	2,100,000	420,000	m^2
Botswana	Palapye - Mahalpye	60	1	Partial Widening ST	5,100,000	6,000,000	18,000	m^2
Botswana	Palapye - Mahalpye	60	12	Overlay 50mm	9,307,500	10,950,000	438,000	m^2
Botswana	Pandamatenga - Nata	199	1	Cape Seal	17,760,750	20,895,000	1,393,000	m^2
Botswana	Pandamatenga - Nata	199	6	Overlay 50mm	29,601,250	34,825,000	1,393,000	m^2
Botswana	Pandamatenga - Nata	199	15	Cape Seal	17,760,750	20,895,000	1,393,000	m^2
Botswana	Pandamatenga - Nata	199	20	Overlay 50mm	29,601,250	34,825,000	1,393,000	m^2
DRC	Likasi - Kolwezi	176	1	Regravelling	11,586,040	14,137,095	106,294	m^3
DRC	Likasi - Kolwezi	176	6	Upgrade Gravel Road to Paved	59,840,000	70,400,000	176	km
DRC	Likasi - Kolwezi	176	7	Upgrade Gravel Road to Paved	59,840,000	70,400,000	176	km
DRC	Likasi - Kolwezi	176	20	Overlay 50mm	27,302,000	32,120,000	1,284,800	m^2
DRC	End DRC - Kasumbelesa	8	1	Cape Seal	612,000	720,000	48,000	m^2
DRC	End DRC - Kasumbelesa	8	7	Single Surface Dressing	285,600	336,000	48,000	m^2
DRC	End DRC - Kasumbelesa	8	13	Single Surface Dressing	285,600	336,000	48,000	m^2
DRC	End DRC - Kasumbelesa	8	15	Overlay 50mm	1,020,000	1,200,000	48,000	m^2
DRC	Kasumbelesa - Lubumbashi	93	1	Cape Seal	7,114,500	8,370,000	558,000	m^2
DRC	Kasumbelesa - Lubumbashi	93	7	Single Surface Dressing	3,320,100	3,906,000	558,000	m^2
DRC	Kasumbelesa - Lubumbashi	93	13	Single Surface Dressing	3,320,100	3,906,000	558,000	m^2
DRC	Kasumbelesa - Lubumbashi	93	15	Overlay 50mm	11,857,500	13,950,000	558,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
DRC	Lubumbashi - Likasi	123	1	Cape Seal	10,977,750	12,915,000	861,000	m^2
DRC	Lubumbashi - Likasi	123	7	Single Surface Dressing	5,122,950	6,027,000	861,000	m^2
DRC	Lubumbashi - Likasi	123	13	Single Surface Dressing	5,122,950	6,027,000	861,000	m^2
DRC	Lubumbashi - Likasi	123	19	Reconstruction ST	51,229,500	60,270,000	861,000	m^2
Malawi	BP Mchinji - Junction M1	116	10	Overlay 50mm	17,255,000	20,300,000	812,000	m^2
Malawi	BP Mchinji - Junction M1	116	20	Overlay 50mm	17,255,000	20,300,000	812,000	m^2
Malawi	BP Songwe - Junction Tanzam	101	9	Overlay 50mm	15,023,750	17,675,000	707,000	m^2
Malawi	BP Songwe - Junction Tanzam	101	19	Overlay 50mm	15,023,750	17,675,000	707,000	m^2
Malawi	Bailey Bridge - Bottom of Escarpment	63	1	Cape Seal	5,301,450	6,237,000	415,800	m^2
Malawi	Bailey Bridge - Bottom of Escarpment	63	7	Single Surface Dressing	2,474,010	2,910,600	415,800	m^2
Malawi	Bailey Bridge - Bottom of Escarpment	63	13	Single Surface Dressing	2,474,010	2,910,600	415,800	m^2
Malawi	Bailey Bridge - Bottom of Escarpment	63	16	Overlay 50mm	8,835,750	10,395,000	415,800	m^2
Malawi	Bottom of Escarpment - Roundabout Karonga	56	7	Cape Seal	4,998,000	5,880,000	392,000	m^2
Malawi	Bottom of Escarpment - Roundabout Karonga	56	13	Single Surface Dressing	2,332,400	2,744,000	392,000	m^2
Malawi	Bottom of Escarpment - Roundabout Karonga	56	19	Single Surface Dressing	2,332,400	2,744,000	392,000	m^2
Malawi	Junction M1 - TO Blantyre	191	1	Cape Seal	15,585,600	18,336,000	1,222,400	m^2
Malawi	Junction M1 - TO Blantyre	191	4	Overlay 50mm	25,976,000	30,560,000	1,222,400	m^2
Malawi	Junction M1 - TO Blantyre	191	10	Single Surface Dressing	7,273,280	8,556,800	1,222,400	m^2
Malawi	Junction M1 - TO Blantyre	191	14	Overlay 50mm	25,976,000	30,560,000	1,222,400	m^2
Malawi	Junction M1 - TO Blantyre	191	19	Single Surface Dressing to Existing Road	4,889,600	6,112,000	1,222,400	m^2
Malawi	Junction M1 - TO Blantyre	191	19	Partial Widening ST	16,235,000	19,100,000	171,900	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Malawi	Junction M1 - TOR Kasungu	120	2	Overlay 50mm	16,830,000	19,800,000	792,000	m^2
Malawi	Junction M1 - TOR Kasungu	120	9	Cape Seal	10,098,000	11,880,000	792,000	m^2
Malawi	Junction M1 - TOR Kasungu	120	13	Overlay 50mm	16,830,000	19,800,000	792,000	m^2
Malawi	Mzuzu - TO Rumphi	57	6	Single Surface Dressing	2,374,050	2,793,000	399,000	m^2
Malawi	Mzuzu - TO Rumphi	57	12	Single Surface Dressing	2,374,050	2,793,000	399,000	m^2
Malawi	Mzuzu - TO Rumphi	57	18	Single Surface Dressing	2,374,050	2,793,000	399,000	m^2
Malawi	Roundabout Karonga - BP Songwe	45	2	Cape Seal	4,016,250	4,725,000	315,000	m^2
Malawi	Roundabout Karonga - BP Songwe	45	8	Single Surface Dressing	1,874,250	2,205,000	315,000	m^2
Malawi	Roundabout Karonga - BP Songwe	45	14	Overlay 50mm	6,693,750	7,875,000	315,000	m^2
Malawi	TO Blantyre - TO Mwanza	60	5	Single Surface Dressing	2,499,000	2,940,000	420,000	m^2
Malawi	TO Blantyre - TO Mwanza	60	9	Overlay 50mm	8,925,000	10,500,000	420,000	m^2
Malawi	TO Blantyre - TO Mwanza	60	16	Cape Seal	5,355,000	6,300,000	420,000	m^2
Malawi	TO Blantyre - TO Mwanza	60	17	Single Surface Dressing to Existing Road	1,680,000	2,100,000	420,000	m^2
Malawi	TO Blantyre - TO Mwanza	60	17	Partial Widening ST	5,100,000	6,000,000	18,000	m^2
Malawi	TO Mwanza - Border Post Mwanza	51	5	Single Surface Dressing	2,124,150	2,499,000	357,000	m^2
Malawi	TO Mwanza - Border Post Mwanza	51	10	Overlay 50mm	7,586,250	8,925,000	357,000	m^2
Malawi	TO Mwanza - Border Post Mwanza	51	17	Cape Seal	4,551,750	5,355,000	357,000	m^2
Malawi	TO Rumphi - Bailey Bridge	42	2	Cape Seal	3,534,300	4,158,000	277,200	m^2
Malawi	TO Rumphi - Bailey Bridge	42	8	Single Surface Dressing	1,649,340	1,940,400	277,200	m^2
Malawi	TO Rumphi - Bailey Bridge	42	14	Single Surface Dressing	1,649,340	1,940,400	277,200	m^2
Malawi	TO Rumphi - Bailey Bridge	42	17	Overlay 50mm	5,890,500	6,930,000	277,200	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Malawi	TOL Mzimba - Mzuzu	95	4	Single Surface Dressing	3,956,750	4,655,000	665,000	m^2
Malawi	TOL Mzimba - Mzuzu	95	8	Overlay 50mm	14,131,250	16,625,000	665,000	m^2
Malawi	TOL Mzimba - Mzuzu	95	14	Single Surface Dressing	3,956,750	4,655,000	665,000	m^2
Malawi	TOL Mzimba - Mzuzu	95	18	Overlay 50mm	14,131,250	16,625,000	665,000	m^2
Malawi	TOR Kasungu - TOL Mzimba	131	3	Single Surface Dressing to Existing Road	3,668,000	4,585,000	917,000	m^2
Malawi	TOR Kasungu - TOL Mzimba	131	3	Partial Widening ST	11,135,000	13,100,000	39,300	m^2
Malawi	TOR Kasungu - TOL Mzimba	131	9	Overlay 50mm	20,321,376	23,907,500	956,300	m^2
Malawi	TOR Kasungu - TOL Mzimba	131	15	Single Surface Dressing	5,689,985	6,694,100	956,300	m^2
Malawi	TOR Kasungu - TOL Mzimba	131	19	Overlay 50mm	20,321,376	23,907,500	956,300	m^2
Mozambique	Mwanza - Zobue	6	1	Reconstruction ST	2,499,000	2,940,000	42,000	m^2
Mozambique	Mwanza - Zobue	6	14	Overlay 50mm	892,500	1,050,000	42,000	m^2
Mozambique	Tete Bridge - Border Post Nyamapanda	138	1	Overlay 80mm	32,844,000	38,640,000	966,000	m^2
Mozambique	Tete Bridge - Border Post Nyamapanda	138	9	Single Surface Dressing to Existing Road	3,864,000	4,830,000	966,000	m^2
Mozambique	Tete Bridge - Border Post Nyamapanda	138	9	Partial Widening ST	11,730,000	13,800,000	41,400	m^2
Mozambique	Zobue - Tete Bridge	118	1	Reconstruction ST	49,147,000	57,820,000	826,000	m^2
Mozambique	Zobue - Tete Bridge	118	14	Overlay 50mm	17,552,500	20,650,000	826,000	m^2
Tanzania	BP Tunduma - Mbeya	106	10	Overlay 50mm	15,767,500	18,550,000	742,000	m^2
Tanzania	BP Tunduma - Mbeya	106	20	Overlay 50mm	15,767,500	18,550,000	742,000	m^2
Tanzania	Dar-es-salaam - Port	42	1	Overlay 50mm to Existing Road	3,748,500	4,410,000	294,000	m^2
Tanzania	Dar-es-salaam - Port	42	1	Partial Widening AM	5,355,000	6,300,000	12,600	m^2
Tanzania	Dar-es-salaam - Port	42	11	Overlay 50mm	6,515,250	7,665,000	306,600	m^2
Tanzania	Dar-es-salaam - Port	42	19	Reconstruction AM	26,061,000	30,660,000	306,600	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Tanzania	Kitonga -Turn off A1	232	9	Overlay 50mm	34,510,000	40,600,000	1,624,000	m^2
Tanzania	Kitonga -Turn off A1	232	17	Overlay 50mm to Existing Road	20,706,000	24,360,000	1,624,000	m^2
Tanzania	Kitonga -Turn off A1	232	17	Partial Widening AM	29,580,000	34,800,000	69,600	m^2
Tanzania	Mbeya - Igawa	177	3	Overlay 50mm	26,328,750	30,975,000	1,239,000	m^2
Tanzania	Mbeya - Igawa	177	13	Overlay 50mm	26,328,750	30,975,000	1,239,000	m^2
Tanzania	Mbeya - Igawa	177	20	Overlay 50mm to Existing Road	15,797,250	18,585,000	1,239,000	m^2
Tanzania	Mbeya - Igawa	177	20	Partial Widening AM	22,567,500	26,550,000	53,100	m^2
Tanzania	Turn off A1 - Dar-es-salaam	91	1	Overlay 50mm to Existing Road	8,121,750	9,555,000	637,000	m^2
Tanzania	Turn off A1 - Dar-es-salaam	91	1	Partial Widening AM	11,602,500	13,650,000	27,300	m^2
Tanzania	Turn off A1 - Dar-es-salaam	91	11	Overlay 50mm	14,116,375	16,607,500	664,300	m^2
Tanzania	Turn off A1 - Dar-es-salaam	91	19	Reconstruction AM	56,465,500	66,430,000	664,300	m^2
Tanzania	Igawa -Mafinga	142	1	Overlay 80mm	33,796,000	39,760,000	994,000	m^2
Tanzania	Igawa -Mafinga	142	7	Single Surface Dressing	5,914,300	6,958,000	994,000	m^2
Tanzania	Igawa -Mafinga	142	11	Overlay 50mm	21,122,500	24,850,000	994,000	m^2
Tanzania	Igawa -Mafinga	142	18	Cape Seal	12,673,500	14,910,000	994,000	m^2
Tanzania	Igawa -Mafinga	142	19	Single Surface Dressing to Existing Road	3,976,000	4,970,000	994,000	m^2
Tanzania	Igawa -Mafinga	142	19	Partial Widening ST	12,070,000	14,200,000	42,600	m^2
Tanzania	Iringa - Iyovi	61	1	Overlay 80mm	14,518,000	17,080,000	427,000	m^2
Tanzania	Iringa - Iyovi	61	7	Single Surface Dressing	2,540,650	2,989,000	427,000	m^2
Tanzania	Iringa - Iyovi	61	11	Overlay 50mm	9,073,750	10,675,000	427,000	m^2
Tanzania	Iringa - Iyovi	61	18	Cape Seal	5,444,250	6,405,000	427,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Tanzania	Iyovi -Kitonga	86	1	Overlay 50mm	12,792,500	15,050,000	602,000	m^2
Tanzania	Iyovi -Kitonga	86	7	Single Surface Dressing	3,581,900	4,214,000	602,000	m^2
Tanzania	Iyovi -Kitonga	86	11	Overlay 50mm	12,792,500	15,050,000	602,000	m^2
Tanzania	Iyovi -Kitonga	86	17	Single Surface Dressing	3,581,900	4,214,000	602,000	m^2
Tanzania	Mafinga - Iringa	76	1	Overlay 80mm	18,088,000	21,280,000	532,000	m^2
Tanzania	Mafinga - Iringa	76	7	Single Surface Dressing	3,165,400	3,724,000	532,000	m^2
Tanzania	Mafinga - Iringa	76	11	Overlay 50mm	11,305,000	13,300,000	532,000	m^2
Tanzania	Mafinga - Iringa	76	13	Single Surface Dressing to Existing Road	2,128,000	2,660,000	532,000	m^2
Tanzania	Mafinga - Iringa	76	13	Partial Widening ST	6,460,000	7,600,000	22,800	m^2
Zambia	Chingola - Start BP Zambia	40	7	Overlay 50mm	5,950,000	7,000,000	280,000	m^2
Zambia	Chingola - Start BP Zambia	40	15	Overlay 50mm to Existing Road	3,570,000	4,200,000	280,000	m^2
Zambia	Chingola - Start BP Zambia	40	15	Partial Widening AM	5,100,000	6,000,000	12,000	m^2
Zambia	Choma - Zimba	115	6	Overlay 50mm	17,106,250	20,125,000	805,000	m^2
Zambia	Choma - Zimba	115	16	Overlay 50mm	17,106,250	20,125,000	805,000	m^2
Zambia	End Asphalt Overlay - BP Mchinji	256	2	Overlay 50mm	38,080,000	44,800,000	1,792,000	m^2
Zambia	End Asphalt Overlay - BP Mchinji	256	12	Overlay 50mm	38,080,000	44,800,000	1,792,000	m^2
Zambia	End of Bridge - End Asphalt Overlay	97	10	Overlay 50mm	14,428,750	16,975,000	679,000	m^2
Zambia	End of Bridge - End Asphalt Overlay	97	20	Overlay 50mm	14,428,750	16,975,000	679,000	m^2
Zambia	Junction T3 - TO Luanshya	32	5	Overlay 50mm	4,760,000	5,600,000	224,000	m^2
Zambia	Junction T3 - TO Luanshya	32	14	Overlay 50mm to Existing Road	2,856,000	3,360,000	224,000	m^2
Zambia	Junction T3 - TO Luanshya	32	14	Partial Widening AM	4,080,000	4,800,000	9,600	m^2
Zambia	Kabwe -Kapiri Moshi	66	2	Overlay 50mm	9,817,500	11,550,000	462,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Zambia	Kabwe -Kapiri Moshi	66	7	Overlay 50mm to Existing Road	5,890,500	6,930,000	462,000	m^2
Zambia	Kabwe -Kapiri Moshi	66	7	Partial Widening AM	8,415,000	9,900,000	19,800	m^2
Zambia	Kabwe -Kapiri Moshi	66	17	Overlay 50mm	10,238,250	12,045,000	481,800	m^2
Zambia	Kapiri Moshi - Junction T3	77	3	Overlay 50mm	11,453,750	13,475,000	539,000	m^2
Zambia	Kapiri Moshi - Junction T3	77	7	Overlay 50mm to Existing Road	6,872,250	8,085,000	539,000	m^2
Zambia	Kapiri Moshi - Junction T3	77	7	Partial Widening AM	9,817,500	11,550,000	23,100	m^2
Zambia	Kapiri Moshi - Junction T3	77	18	Overlay 50mm	11,944,625	14,052,500	562,100	m^2
Zambia	Kapiri Moshi - Serenje	192	5	Overlay 50mm	28,560,000	33,600,000	1,344,000	m^2
Zambia	Kapiri Moshi - Serenje	192	15	Overlay 50mm	28,560,000	33,600,000	1,344,000	m^2
Zambia	Kitwe - Chingola	50	1	Overlay 50mm	7,437,500	8,750,000	350,000	m^2
Zambia	Kitwe - Chingola	50	11	Overlay 50mm	7,437,500	8,750,000	350,000	m^2
Zambia	Kitwe - Chingola	50	15	Overlay 50mm to Existing Road	4,462,500	5,250,000	350,000	m^2
Zambia	Kitwe - Chingola	50	15	Partial Widening AM	6,375,000	7,500,000	15,000	m^2
Zambia	Lusaka NE RAB - Kabwe	135	5	Overlay 50mm	20,081,250	23,625,000	945,000	m^2
Zambia	Lusaka NE RAB - Kabwe	135	12	Overlay 50mm to Existing Road	12,048,750	14,175,000	945,000	m^2
Zambia	Lusaka NE RAB - Kabwe	135	12	Partial Widening AM	17,212,500	20,250,000	40,500	m^2
Zambia	Lusaka SE RAB - Turnoff T1	53	1	Overlay 50mm	7,883,750	9,275,000	371,000	m^2
Zambia	Lusaka SE RAB - Turnoff T1	53	8	Overlay 50mm to Existing Road	4,730,250	5,565,000	371,000	m^2
Zambia	Lusaka SE RAB - Turnoff T1	53	8	Partial Widening AM	6,757,500	7,950,000	15,900	m^2
Zambia	Monze - Choma	98	5	Overlay 50mm	14,577,500	17,150,000	686,000	m^2
Zambia	Monze - Choma	98	15	Overlay 50mm	14,577,500	17,150,000	686,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Zambia	Start Asphalt Overlay -Luangwa Bridge	33	7	Overlay 50mm	4,908,750	5,775,000	231,000	m^2
Zambia	Start Asphalt Overlay -Luangwa Bridge	33	18	Overlay 50mm	4,908,750	5,775,000	231,000	m^2
Zambia	TO Luanshya - Kitwe	39	7	Reconstruction AM	23,205,000	27,300,000	273,000	m^2
Zambia	TO Luanshya - Kitwe	39	14	Overlay 50mm to Existing Road	3,480,750	4,095,000	273,000	m^2
Zambia	TO Luanshya - Kitwe	39	14	Partial Widening AM	4,972,500	5,850,000	11,700	m^2
Zambia	Turnoff T1 - Mazabuka	66	1	Overlay 50mm	9,817,500	11,550,000	462,000	m^2
Zambia	Turnoff T1 - Mazabuka	66	11	Overlay 50mm	9,817,500	11,550,000	462,000	m^2
Zambia	Zimba - Turn off M10	78	11	Overlay 50mm	12,099,750	14,235,000	569,400	m^2
Zambia	Chingola - Solwezi	167	3	Overlay 50mm	24,841,250	29,225,000	1,169,000	m^2
Zambia	Chingola - Solwezi	167	9	Single Surface Dressing	6,955,550	8,183,000	1,169,000	m^2
Zambia	Chingola - Solwezi	167	10	Single Surface Dressing to Existing Road	4,676,000	5,845,000	1,169,000	m^2
Zambia	Chingola - Solwezi	167	10	Partial Widening ST	14,195,000	16,700,000	50,100	m^2
Zambia	Chingola - Solwezi	167	18	Overlay 80mm	41,449,400	48,764,000	1,219,100	m^2
Zambia	Chinsali - Isoka	129	1	Cape Seal	9,868,500	11,610,000	774,000	m^2
Zambia	Chinsali - Isoka	129	4	Overlay 50mm	16,447,500	19,350,000	774,000	m^2
Zambia	Chinsali - Isoka	129	10	Single Surface Dressing	4,605,300	5,418,000	774,000	m^2
Zambia	Chinsali - Isoka	129	14	Overlay 50mm	16,447,500	19,350,000	774,000	m^2
Zambia	Isoka - BP Nakonde	106	1	Cape Seal	9,460,500	11,130,000	742,000	m^2
Zambia	Isoka - BP Nakonde	106	8	Overlay 50mm	15,767,500	18,550,000	742,000	m^2
Zambia	Isoka - BP Nakonde	106	19	Overlay 50mm	15,767,500	18,550,000	742,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Zambia	Mazabuka - Monze	64	1	Overlay 50mm	9,520,000	11,200,000	448,000	m^2
Zambia	Mazabuka - Monze	64	12	Overlay 50mm	9,520,000	11,200,000	448,000	m^2
Zambia	Mazabuka - Monze	64	18	Single Surface Dressing to Existing Road	1,792,000	2,240,000	448,000	m^2
Zambia	Mazabuka - Monze	64	18	Partial Widening ST	5,440,000	6,400,000	19,200	m^2
Zambia	Mpika - Chinsali	134	1	Cape Seal	10,251,000	12,060,000	804,000	m^2
Zambia	Mpika - Chinsali	134	4	Overlay 50mm	17,085,000	20,100,000	804,000	m^2
Zambia	Mpika - Chinsali	134	11	Cape Seal	10,251,000	12,060,000	804,000	m^2
Zambia	Mpika - Chinsali	134	15	Overlay 50mm	17,085,000	20,100,000	804,000	m^2
Zambia	North End Roundabout - Start Asphalt Overlay	42.5	1	Overlay 50mm	6,321,875	7,437,500	297,500	m^2
Zambia	North End Roundabout - Start Asphalt Overlay	42.5	10	Cape Seal	3,793,125	4,462,500	297,500	m^2
Zambia	North End Roundabout - Start Asphalt Overlay	42.5	15	Overlay 50mm	6,321,875	7,437,500	297,500	m^2
Zambia	North End Roundabout - Start Asphalt Overlay	42.5	16	Single Surface Dressing to Existing Road	1,190,000	1,487,500	297,500	m^2
Zambia	North End Roundabout - Start Asphalt Overlay	42.5	16	Partial Widening ST	3,612,500	4,250,000	12,750	m^2
Zambia	Serenje -Mpika	235	1	Cape Seal	20,973,750	24,675,000	1,645,000	m^2
Zambia	Serenje -Mpika	235	3	Overlay 50mm	34,956,248	41,125,000	1,645,000	m^2
Zambia	Serenje -Mpika	235	9	Single Surface Dressing	9,787,750	11,515,000	1,645,000	m^2
Zambia	Serenje -Mpika	235	13	Overlay 50mm	34,956,248	41,125,000	1,645,000	m^2
Zambia	Serenje -Mpika	235	20	Cape Seal	20,973,750	24,675,000	1,645,000	m^2
Zambia	Turn off M10 - BP Kazungula	71	1	Cape Seal	6,336,750	7,455,000	497,000	m^2
Zambia	Turn off M10 - BP Kazungula	71	7	Single Surface Dressing	2,957,150	3,479,000	497,000	m^2
Zambia	Turn off M10 - BP Kazungula	71	12	Overlay 50mm	10,561,250	12,425,000	497,000	m^2
Zambia	Turn off M10 - BP Kazungula	71	20	Cape Seal	6,336,750	7,455,000	497,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Zambia	Turn off M10 - BP Livingstone	9	1	Overlay 50mm	1,338,750	1,575,000	63,000	m^2
Zambia	Turn off M10 - BP Livingstone	9	9	Cape Seal	803,250	945,000	63,000	m^2
Zambia	Turn off M10 - BP Livingstone	9	14	Overlay 50mm	1,338,750	1,575,000	63,000	m^2
Zambia	Turnoff T1 - Start BP Chirundu	78	4	Overlay 50mm	11,602,500	13,650,000	546,000	m^2
Zambia	Turnoff T1 - Start BP Chirundu	78	11	Cape Seal	6,961,500	8,190,000	546,000	m^2
Zambia	Turnoff T1 - Start BP Chirundu	78	16	Overlay 50mm	11,602,500	13,650,000	546,000	m^2
Zimbabwe	BP Livingstone - Hwange	110	1	Overlay 80mm	26,180,000	30,800,000	770,000	m^2
Zimbabwe	BP Livingstone - Hwange	110	9	Cape Seal	9,817,500	11,550,000	770,000	m^2
Zimbabwe	BP Livingstone - Hwange	110	14	Overlay 50mm	16,362,500	19,250,000	770,000	m^2
Zimbabwe	Bulawayo - BP Bait Bridge	316	1	Overlay 80mm	75,208,000	88,480,000	2,212,000	m^2
Zimbabwe	Bulawayo - BP Bait Bridge	316	6	Single Surface Dressing to Existing Road	8,848,000	11,060,000	2,212,000	m^2
Zimbabwe	Bulawayo - BP Bait Bridge	316	6	Partial Widening ST	26,860,000	31,600,000	94,800	m^2
Zimbabwe	Bulawayo - BP Bait Bridge	316	17	Overlay 50mm	49,019,500	57,670,000	2,306,800	m^2
Zimbabwe	Chinhoyi - Harare CB1	101	1	Overlay 80mm	24,038,000	28,280,000	707,000	m^2
Zimbabwe	Chinhoyi - Harare CB1	101	8	Cape Seal	9,014,250	10,605,000	707,000	m^2
Zimbabwe	Chinhoyi - Harare CB1	101	10	Single Surface Dressing to Existing Road	2,828,000	3,535,000	707,000	m^2
Zimbabwe	Chinhoyi - Harare CB1	101	10	Partial Widening ST	8,585,000	10,100,000	30,300	m^2
Zimbabwe	Chinhoyi - Harare CB1	101	18	Overlay 50mm	15,667,625	18,432,500	737,300	m^2
Zimbabwe	Chivhu - Masvingo	151	1	Overlay 80mm	35,938,000	42,280,000	1,057,000	m^2
Zimbabwe	Chivhu - Masvingo	151	8	Cape Seal	13,476,750	15,855,000	1,057,000	m^2
Zimbabwe	Chivhu - Masvingo	151	10	Single Surface Dressing to Existing Road	4,228,000	5,285,000	1,057,000	m^2
Zimbabwe	Chivhu - Masvingo	151	10	Partial Widening ST	12,835,000	15,100,000	45,300	m^2
Zimbabwe	Chivhu - Masvingo	151	18	Overlay 50mm	23,423,876	27,557,500	1,102,300	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Zimbabwe	End BP Chirundu - Makuti	75	1	Overlay 80mm	17,850,000	21,000,000	525,000	m^2
Zimbabwe	End BP Chirundu - Makuti	75	9	Cape Seal	6,693,750	7,875,000	525,000	m^2
Zimbabwe	End BP Chirundu - Makuti	75	14	Overlay 50mm	11,156,250	13,125,000	525,000	m^2
Zimbabwe	Harare - Nyamapanda	475	1	Overlay 50mm	70,656,248	83,125,000	3,325,000	m^2
Zimbabwe	Harare - Nyamapanda	475	9	Cape Seal	42,393,752	49,875,000	3,325,000	m^2
Zimbabwe	Harare - Nyamapanda	475	14	Overlay 50mm	70,656,248	83,125,000	3,325,000	m^2
Zimbabwe	Harare CB2 - Chivhu	141	1	Overlay 80mm	33,558,000	39,480,000	987,000	m^2
Zimbabwe	Harare CB2 - Chivhu	141	6	Single Surface Dressing to Existing Road	3,948,000	4,935,000	987,000	m^2
Zimbabwe	Harare CB2 - Chivhu	141	6	Partial Widening ST	11,985,000	14,100,000	42,300	m^2
Zimbabwe	Harare CB2 - Chivhu	141	17	Overlay 50mm	21,872,624	25,732,500	1,029,300	m^2
Zimbabwe	Hwange - Bulawayo	330	1	Overlay 80mm	78,540,000	92,400,000	2,310,000	m^2
Zimbabwe	Hwange - Bulawayo	330	8	Cape Seal	29,452,500	34,650,000	2,310,000	m^2
Zimbabwe	Hwange - Bulawayo	330	13	Overlay 50mm	49,087,500	57,750,000	2,310,000	m^2
Zimbabwe	Hwange - Bulawayo	330	15	Single Surface Dressing to Existing Road	9,240,000	11,550,000	2,310,000	m^2
Zimbabwe	Hwange - Bulawayo	330	15	Partial Widening ST	28,050,000	33,000,000	99,000	m^2
Zimbabwe	Karoi - Chinhoyi	94	1	Overlay 80mm	22,372,000	26,320,000	658,000	m^2
Zimbabwe	Karoi - Chinhoyi	94	8	Cape Seal	8,389,500	9,870,000	658,000	m^2
Zimbabwe	Karoi - Chinhoyi	94	13	Overlay 50mm	13,982,500	16,450,000	658,000	m^2
Zimbabwe	Karoi - Chinhoyi	94	15	Single Surface Dressing to Existing Road	2,632,000	3,290,000	658,000	m^2
Zimbabwe	Karoi - Chinhoyi	94	15	Partial Widening ST	7,990,000	9,400,000	28,200	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
Zimbabwe	Makuti - Karoi	78	1	Overlay 80mm	18,564,000	21,840,000	546,000	m^2
Zimbabwe	Makuti - Karoi	78	8	Cape Seal	6,961,500	8,190,000	546,000	m^2
Zimbabwe	Makuti - Karoi	78	13	Overlay 50mm	11,602,500	13,650,000	546,000	m^2
Zimbabwe	Makuti - Karoi	78	15	Single Surface Dressing to Existing Road	2,184,000	2,730,000	546,000	m^2
Zimbabwe	Makuti - Karoi	78	15	Partial Widening ST	6,630,000	7,800,000	23,400	m^2
Zimbabwe	Masvingo - Turn Off	95	1	Overlay 80mm	22,610,000	26,600,000	665,000	m^2
Zimbabwe	Masvingo - Turn Off	95	8	Cape Seal	8,478,750	9,975,000	665,000	m^2
Zimbabwe	Masvingo - Turn Off	95	13	Overlay 50mm	14,131,250	16,625,000	665,000	m^2
Zimbabwe	Masvingo - Turn Off	95	15	Single Surface Dressing to Existing Road	2,660,000	3,325,000	665,000	m^2
Zimbabwe	Masvingo - Turn Off	95	15	Partial Widening ST	8,075,000	9,500,000	28,500	m^2
Zimbabwe	Turn Off - BP Bait Bridge	184	1	Overlay 80mm	43,792,000	51,520,000	1,288,000	m^2
Zimbabwe	Turn Off - BP Bait Bridge	184	9	Cape Seal	16,422,000	19,320,000	1,288,000	m^2
Zimbabwe	Turn Off - BP Bait Bridge	184	14	Overlay 50mm	27,370,000	32,200,000	1,288,000	m^2

Table D.1 20-Year Work Programme for Scenario RN-3 (Continued)

COUNTRY/ BORDER	SECTION NAME	LENGTH (KM)	YEAR	WORKS	ECONOMIC COSTS (US$)	FINANCIAL COSTS (US$)	WORK QUANTITY	UNITS
RSA/Zimbabwe	Bait Bridge	-	6	Border Post Improvement	42,500,000	50,000,000	-	-
Zambia/Zimbabwe	Chirundu	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
RSA/Botswana	Gaborone	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
DRC/Zambia	Kasumbalesa	-	6	Border Post Improvement	17,000,000	20,000,000	-	-
Zambia/Malawi	Kazangula	-	6	Border Post Improvement	85,000,000	100,000,000	-	-
RSA/Botswana	Martin's Drift	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
Zambia/Malawi	Mchinji	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
Zimbabwe/Mozambique	Nyamapanda	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
Tanzania/Malawi	Songwe	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
Tanzania/Zambia	Tunduma	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
Zambia/Zimbabwe	Victoria Falls	-	6	Border Post Improvement	8,500,000	10,000,000	-	-
Malawi/Mozambique	Zobue	-	6	Border Post Improvement	8,500,000	10,000,000	-	-