USAID | SUDAN

FROM THE AMERICAN PEOPLE

SUDAN INFRASTRUCTURE SERVICES PROJECT

IMPROVEMENT WORKS OF THE JUBA TO NIMULE ROAD FEASIBILITY STUDY

FINAL REPORT

MAY 2007
This publication was produced for review by the United States Agency for International Development.
It was prepared by The Louis Berger Group, Inc. under Contract # 650-I-00-06-00010-00.

USAID / SUDAN
INFRASTRUCTURE SERVICES PROJECT

IMPROVEMENT WORKS OF THE JUBA TO NIMULE ROAD FEASIBILITY STUDY

FINAL REPORT
MAY 2007

DISCLAIMER
This report was produced for the United States Agency for International Development (USAID) by the Louis Berger Group, Inc. under Contract # 650-I-00-06-00010-00. The author's views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

June 5, 2007

Mr. George Wagwa
Cognizant Technical Officer
USAID/Sudan

Reference: USAID IQC Contract No. 650-I-00-06-00010-00, Order No: 01
Infrastructure Services Project

Subject: Juba – Nimule Road Feasibility Study Final Report

Dear Mr. Wagwa:

We are pleased to submit, as requested, the **Juba – Nimule Road Feasibility Study Final Report**. The final draft document has been revised in line with the comments in your letter of 16 May 2007.

Set out below is our response to each of the comments raised:-

1. General comment:

We understand USAID concerns regarding the potential impact that the estimated cost of the project may have upon project viability. We believe we have incorporated the various issues such as potential re-use of the existing road bed, efficiency of construction effort and the cost of labor and equipment in our estimate. As the detailed design advances, we will refine and update the cost estimate for the project. During this process we will incorporate into our model any additional cost data that USAID may possess.

USAID's concern with the public impact of the cost estimate is certainly legitimate. Since we developed the cost estimate using an analytical approach, we have conducted a sensitivity analysis of the cost. In doing this we have established a high to low range of likely costs for the project, and this range is reflected in the report.

We agree that the issue of unit rates and costs is exceptionally important and we fully intend to re-examine our unit costs analysis during the project design and implementation. The detailed design phase will include gathering additional data on materials and developing an engineering design based on that data and accurate survey information. This will provide calculated quantities for all pay items with a very high degree of confidence.

2. Urban Pavement Recommendation:

We have removed our reference to using AC surfacing for the road sections in urban areas.

3. Bridge construction:

When we initially reviewed the roadway, the question of responsibility and ownership of the border crossing bridge was in doubt. However, since there are indications of recent repairs to the structure that would facilitate the movement of relief goods, we believe it reasonable to include this bridge in the program. Thus, 8 bridges are included. Based upon our field review of each of these bridges, we do not believe it to be cost effective to attempt to salvage any portions. Since most decks require

complete replacement, and above grade substructures are seriously deficient, the cost of including these components in future construction is not viable. We have updated the report to reflect this.

4. Construction schedule:
During the development of the feasibility study we considered various factors that would affect productivity. We did not constrain the analysis to anticipate work only by local or regional firms; however, our review suggests that issues such as plant and equipment costs, mobilization or working capital would not have an adverse impact on the project. Additionally, our experience in Africa and other remote regions suggests supports both the design-bid-build and design-build time frames. As indicated in the project schedules (figure 3.1, page 29) we did incorporate lower productivity during the rainy season. We provided the design-build approach as an alternative mechanism that would achieve the project objectives significantly earlier than the traditional design-bid-build approach. It can be accomplished within the estimated cost. Our experience suggests that risk exposure relating to cost variances and claims is not significantly greater, and in fact is often lower, than the traditional approach. We are willing to conduct separate analysis of various contract mechanisms if USAID desires and we will take the lead in initiating that discussion.

Other Comments
1. Page 30:- Ethiopian has been replaced with interim design

2. Page 30:- It is clarified that our design alternative is "for the purposes of this estimate"

3. Page 31:- It is clarified that ancillary works and drainage works in addition to culverts will be identified during the detailed design phase.

4. Page 31: 3-5 km of minor / feeder roads

We assumed that adequate connections would be provided to other roads, but we did not incorporate significant reconstruction of them. We anticipate that a program of this type of work will be created to stimulate local economies and community development in conjunction with project implementation. We do not believe that this would adversely affect the current cost estimate.

5. Page 37 contingencies

We understand that an issued task order will not depend on contingent costs.

6. Page 41 – consider 1.5m wide shoulders in rural areas

We will study this during detailed design. Since the suggested width will be less than standard, a waiver will be required should this be adopted.

7. Page 53 – Environmental costs

Table 4.2 is revised to show 3 construction camps – consistent with the reference to three contracts in the construction section. The total cost remains the same.

8. Page 59 – Cost of accidents;

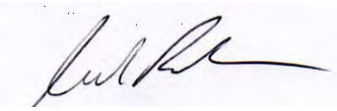
The cost of accidents has been included in the report.

9. General – the cost of clearing / cutting of tress

The cost of cutting and clearing trees is assumed to be a minor pay item, measured separately according to the specifications definition of the pay item. We indicated that "an allowance for minor pay items has been made" (Page 34 para. 2). During survey for detailed design trees of significant girth will be recorded. No change to text / report

We trust that we have addressed all of your comments and that the revised report incorporates the appropriate revisions into the study.

Sincerely,



Leslie Robertson
Chief of Party – Sudan Infrastructure Program
The Louis Berger Group, Inc

cc: Mr. Yves Kore, Contracting Officer, USAID
Ms. Karen Sayer, Senior Engineer, USAID
Mr. Andrew V. Bailey, II, IQC Manager, LBG
Ms. Margarita Cronin, IQC Contracts Manager, LBG
Project File

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1. PROJECT RATIONALE & CONTEXT 1

Project Rationale & Objectives 4
Project Rationale 4
Project Objectives 6

Description of the Regional Macroeconomic Context 8
General Profile 8
Economy and Prospect/Macroeconomic Outlook 9

Description of the Road Sections 10
Section 1: Juba to Bor Junction 11
Section 2: Bor Junction to Torit Junction 11
Section 3: Torit Road to Nimule Center 12
Section 4: Nimule Center to Ugandan Border 14
Land Mines and other Security Issues 14

2. DEMAND ANALYSIS 16

Description of the Vehicle Fleet 16

Determination of Normal Traffic 18
Existing Average Daily Traffic (ADT) 18
Corrections to Existing Traffic Volumes 20
Average Annual Daily Traffic (AADT) 23

Traffic Forecast 23
Normal Traffic Growth 24
Growth 'With-Project' situation 25

3. CONSTRUCTION WORKS & MAINTENANCE 27

Construction Works 27
Alternatives 27
Assessment and Construction Assumptions 30
Costs 33

Maintenance 39
Maintenance operations 39
Costs 39

4. ENVIRONMENTAL STUDY 41

Proposed Actions 41

Impact Identification 42

Socio-environmental Management Plan 46

Socio-Environmental Management Plan Costs **52**

5. ECONOMIC ANALYSIS & RESULTS **54**

Economic costs & benefits **54**
Construction cost 55
Maintenance costs 56
Vehicle Operating Costs 56
Cost in terms of time 57
Other Project Impacts (Qualitative Analysis) 59

Economic evaluation & base case results **60**
Economic Evaluation 61
Base Case Results 62

Sensitivity Analysis **63**
Higher Costs 63
Lower Traffic Levels 64
Combination of Higher Cost and Lower Traffic Levels 65
The "worst case" Scenario: No Diverted and Generated Traffic 66
Lower Costs 67
Analysis Considering a Reduction in the Level of Accidents 68

Annexes:

Annex 1: Results from Traffic Counts
Annex 2: Preliminary Design, Quantities and Costs
Annex 3: HDM-4 Model Engineering Input Data
Annex 4: Map 1.1 Enlargement – Project Road

EXECUTIVE SUMMARY

The 22-year civil war between the North and the South of Sudan has left Southern Sudan severely under-developed. In particular, the road sector has been adversely affected, leaving the South without any efficient, safe means of transporting goods and people. To date, less than 10 km of paved roads serve this part of the country and most of these roads are concentrated in the main city – Juba – and are in dire need of repair. The entire primary road network requires improvement and upgrading to establish both connectivity within Southern Sudan and links to neighboring countries. The Juba to Nimule Road is a vital link in this network.

The road was closed and mined during the war and only reopened in mid 2006. Since then security has remained a concern as there have been intermittent attacks and ambushes of travelers perpetrated by members of the Lords Resistance Army (LRA) in this area and along the Juba to Nimule Road. However, with additional security measures introduced in January 2007, (principally the deployment of several hundred SPLA soldiers) efforts to stabilize the area have been progressing successfully. If security issues continue to be a top priority for the government, and if the necessary infrastructure to support commercial and pedestrian traffic is properly put-in-place, the Juba to Nimule Road will not only become more attractive to the local community as a means of travel, it will eventually become a thriving corridor for access to the south of Sudan. According to the USAID Request for Task Order Proposal:

> The improvement of the […] gravel road from Juba to Nimule will reduce significantly transportation costs, improve highway safety, support the integration of Southern Sudan with its neighboring countries and generate significant social and economic benefits. Also, this road is one of the two principal corridors that integrate Southern Sudan with Uganda.

This Feasibility Study details the analysis that was used to compare and evaluate, in economic terms, the proposed investment alternatives in the road from Juba to Nimule, on the border with Uganda. It investigates and determines the technical, economic, environmental and social implications of upgrading the existing road, including its eight bridges, to a number of higher all-weather standards. It also provides the economic results associated with the proposed series of standards, as well as the Consultant's conclusions in terms of investment proposals. For the sake of the analysis, the Juba to Nimule Road was divided into four homogenous sections: (i) Juba to Bor Junction; (ii) Bor Junction to Torit Junction; (iii) Torit Junction to Nimule Center; and (iv) Nimule Center to the Ugandan Border.

Overall, the Consultant reached the following main conclusions:

- The Juba to Nimule road is a vital link for the continued development of Southern Sudan;
- Paving the road will provide sound economic benefits;
- The cost to pave the 192 km road is around US$ 59 million in the base case; and
- If the design process starts now the road will be completed and open to traffic by early 2009.

In effect, the results indicate that the entire length of the road should be paved, using a Double Bituminous Surface Treatment (DBST). Construction is expected to start in late 2007 or early 2008 at the latest, at a cost of ***US$ 58.89 million*** in the base case. The project should be implemented over a one-year period, even for the longest section: 169 km between the Torit Jct. and Nimule Center. Using a total investment cost of US$75.76 million (including contingencies) the net present value (NPV) of the project is ***US$ 30.12 million***. As is common practice, for the economic evaluation in this study physical and financial contingencies of 10 and 15 percent respectively have been added to the construction costs to give the total investment cost (these contingencies are not included in the base case calculation). The detailed results of the economic analysis for the preferred investment alternative are as follows:

Proposed Investments: Double Bituminous Surface Treatment

	NPV (US$ mil.)	**IRR** (%)	**NPV / Cost (*)**	Total cost (US$ mil.) (**)
Juba-Bor Jct	**11.10**	**55.8**	**8.42**	**1.30**
Bor Jct-Torit Jct	**2.94**	**12.9**	**0.57**	**5.44**
Torit Jct-Nimule Center	**12.19**	**10.3**	**0.25**	**52.26**
Nimule Center-Ugandan Border	**3.90**	**37.0**	**4.42**	**0.89**

Source: Consultant
(*) NPV over economic capital cost
(**) Total construction cost, including project management costs and environmental mitigation measures but excluding contingencies, in constant price 2007.

The sensitivity analysis shows that the project is feasible even with higher construction costs and/or lower levels of traffic. The only sensitivity test conducted that does not result in overall positive NPV for any of the investment alternatives proposed is with the assumption that the security condition prevailing on the road deteriorates. In this case, the demand for the project road would stay suppressed, resulting in the assumption that no traffic would divert back to the road and that upgrading to paved standard would not lead to generated traffic. This “worst case” scenario shows that investing on the Juba to Nimule road would not make economic sense in a situation where security deteriorates.

The consultant recognizes that because of the uncertainties associated with estimating construction costs in the current environment in Southern Sudan the estimated base case construction cost may be considered high. Accordingly a further sensitivity test was carried out using a lower range cost of US$50.96 million (15% below base case), which naturally shows an even better NPV. It is important to note that many costs and other contributing factors in Southern Sudan continue to fluctuate and a more refined cost estimate will be undertaken at the detailed design stage.

The main quantifiable benefits associated with the proposed investment alternative is from a reduction of vehicle operating costs, accounting for 90 percent of overall

benefits. Other quantifiable benefits are: (i) reduction in maintenance costs – 8 percent; and (ii) time savings – 2 percent. Beyond these quantifiable benefits, other impacts are important to consider, even if the Consultant has not been able to quantify them due to lack of data and time constraints. These qualitative benefits are only associated with upgrading the project road to paved standard and are as follows:

- Expected savings in the costs of road accidents – note that the Consultant attempted to quantify the benefits linked with a reduction in the level of accidents as part of the sensitivity analysis;
- Continued increased level – or perception – of security on the road linked with the LRA "incidents"; and
- Better health for the population living along the project road, due to a substantial decrease in the amount of dust produced by the traffic.

The first chapter of this feasibility study describes the project rationale and context, including the socio-economic and engineering characteristics of each of the four sections of the Juba to Nimule road. This first chapter serves as the basis of the demand analysis and the subsequent economic feasibility of the project alternatives.

Second, the report analyzes demand on the above road sections, describing the vehicle fleet and determining present and future traffic volumes. This is a key chapter of the report because traffic volumes are the main drivers of benefits. This chapter is supplemented with an Annex showing the results from the traffic counts.

Third, the report analyzes the project's construction works and maintenance requirements for each of the investment alternatives proposed. This third chapter's main outcome is a set of investment alternatives and associated cost estimates. This section is supplemented with two annexes showing: (i) the detailed analysis to arrive at the quantities and cost estimates; and (ii) the engineering input data used in the HDM-4 Model.

Fourth, the report provides the environmental study, which presents a summary of the impacts and mitigation measures for the proposed project activities identified for the Juba to Nimule road. The purpose of this chapter is to provide a socio-environmental overview to the Project for the purpose of this feasibility study. This section is supplemented by a stand-alone report providing the full environmental study performed for this project.

Fifth, the report presents the economic evaluation per se of the investment alternatives, assessing in detail the economic costs and benefits of these alternatives. The economic analysis is completed by a sensitivity analysis, which aims at assessing the reaction of the results to foreseeable changes in some critical inputs of the project, namely investment cost and demand for transport.

1. PROJECT RATIONALE & CONTEXT

This first chapter identifies the objectives of the proposed investment alternatives and reviews the background of the project. Defining the project rationale and context serves to set the stage and to determine the reasoning behind these investment alternatives. By the same token, this chapter will also serve as the basis for the demand forecasting.

Project Rationale & Objectives

The road from Juba to Nimule and the Ugandan border (see **Map 1.1** overleaf) is one of the main axes linking Southern Sudan to its southward neighboring countries and the rest of the world through the port of Mombassa. In this context, the purpose of this report is to carry out a feasibility study for a number of investment alternatives proposed for the Juba to Nimule Road in order to: (i) test if the proposed improvement works would be a good investment on economic grounds; and (ii) choose from the best investment option to serve the stated objectives of the project.

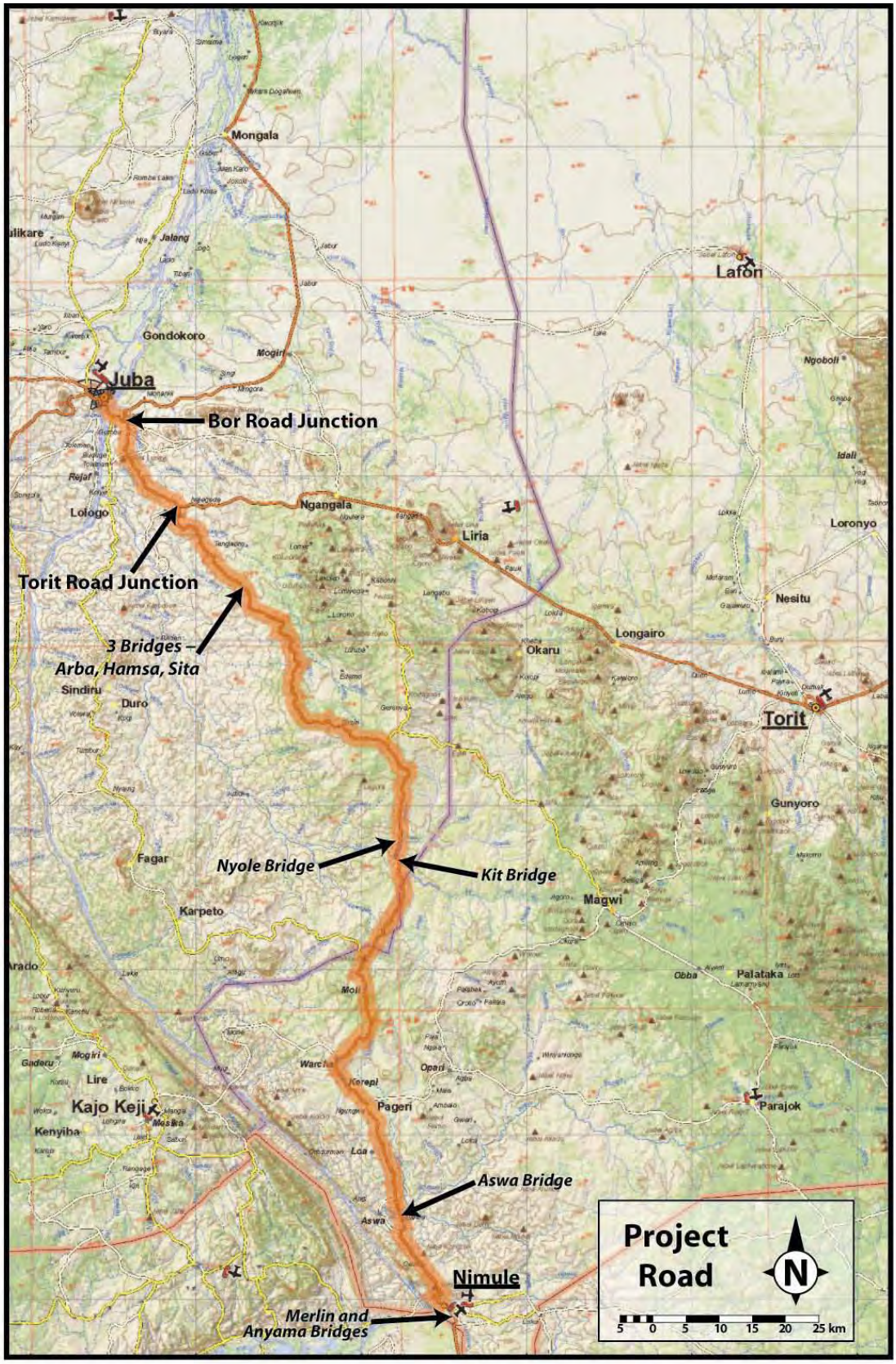
Project Rationale

The project rationale is to create a necessary means to unlock Juba Town and its hinterland and to foster the development of this region of Southern Sudan. The Juba to Nimule Road is a major artery because Juba has been designated the capital of the region of Southern Sudan and will play a major political and economic role in the future. Juba is bound to attract a significant population, from former refugees returning home, rural Sudanese in search of a better life in the city and Ugandan workers looking for job opportunities[1]. In order to play this role of regional zone of attraction, Juba needs to provide an inroad for goods and people alike. In other words, Juba needs to be connected with the rest of the region and with the surrounding countries with which it can trade. Of the many places to which Juba needs to be connected, two are key to its development: (i) in Kenya, the port of Mombassa and, on the way to Juba, the capital city of Nairobi; and (ii) in Uganda, the capital city of Kampala.

The Juba to Nimule Road is located east of the Nile River. It traverses the states of Central Equatoria and Eastern Equatoria in the southern most parts of Sudan (see project map below). The Juba-Nimule road integrates Southern Sudan with Uganda and, if history is a guide, has the potential to serve significant volumes of traffic. However, due to its deteriorated condition up to June / July 2006, and then due to chronic insecurity, traffic has consistently been suppressed since the 1980's.

[1] / Emergency Study on the Planning & Support for Basic Physical & Social Infrastructure in Juba Town and the Surrounding Areas in the Southern Sudan – Interim Report – November 2006 – Katahira & Engineers International, Japan Engineering Consultants Co. and Kokusai Kogyo Co.

Map 1.1: Project Road – From Juba to Nimule and the Ugandan Border (See Appendix 4 for larger map)



According to Norken Ltd., in a study financed by United Nations World Food Program (UNWFP),

> Nimule - Juba road is part of the international trunk road (A104), which was constructed in the early 1970's to gravel standards by the Government of Sudan, but left in state of disrepair for over 22 years of the civil war. It is one of the major relief supply routes used by United Nations (UN) UN agencies and non government organizations (NGOs) to access afflicted communities in Southern Sudan. Due to prolonged periods of neglect and intensive wars, extensive sections of this road had deteriorated and [are] also contaminated with land mines. Many sections between Nimule and Juba were bottlenecks to transportation as they were impassable, particularly during the rainy season and where land mines had not been cleared.

The road from Juba to Nimule is designated as one of the significant elements of the Government of Southern Sudan's interstate road network, and the Ministry of Transport & Roads (MTR) has indicated its desire to have the approximately 192 km roadway improved to an all-weather standard, preferably, paved.

The road has the potential to provide a vital economic corridor from Juba to adjoining Uganda and Kenya, as it is the shortest route to both Kampala and Nairobi / Mombassa. **Map 1.2**, on page 7, shows the three main corridors linking Juba to these cities.

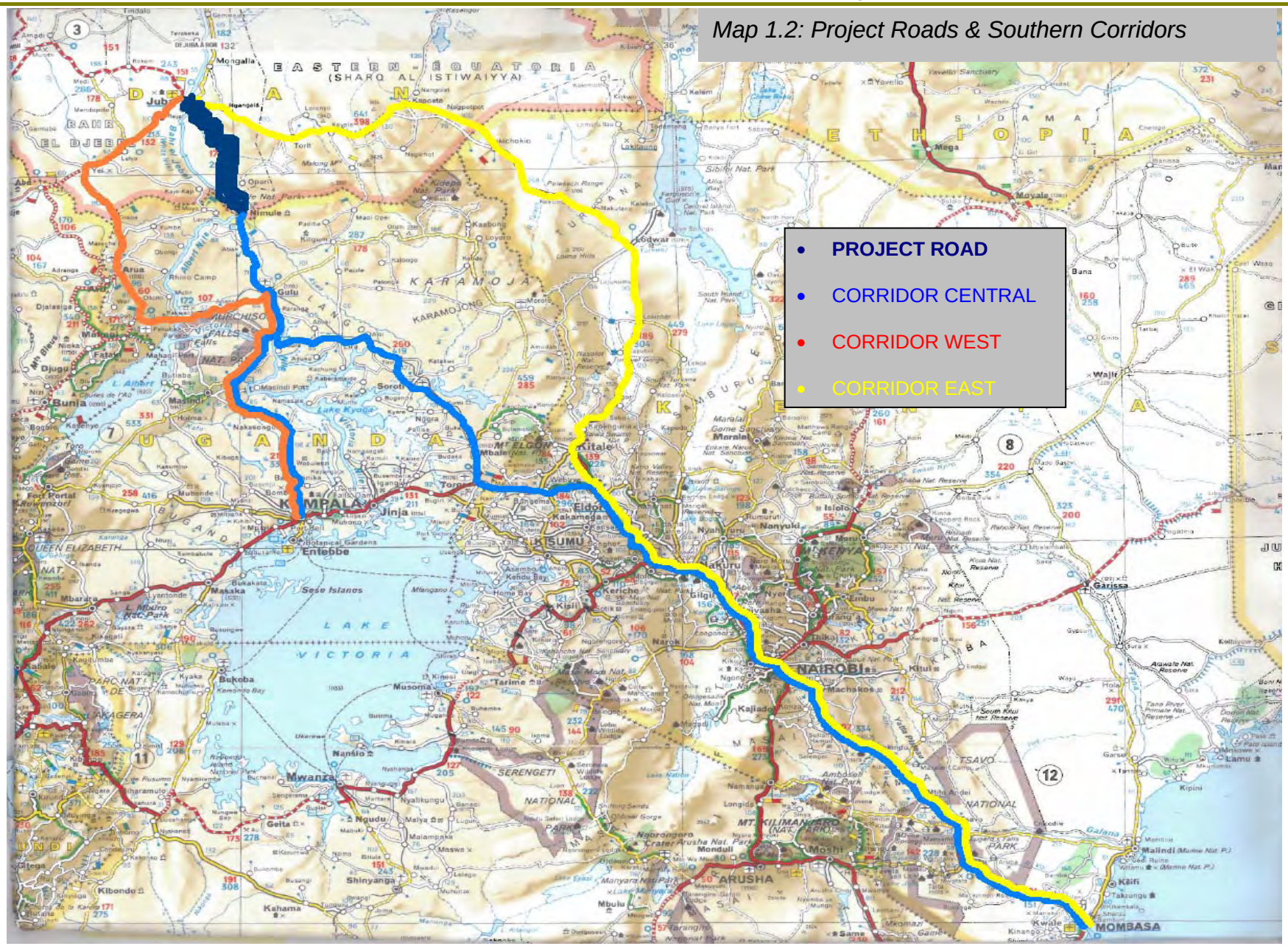
Project Objectives

The Project will have an impact on most of the aforementioned issues and challenges by achieving both broad and specific objectives.

The broad objectives of the project correspond to regional-wide objectives and are mentioned in this feasibility study to ensure that the road project contributes to their realization. The broad project objectives are to:

- Open up trade by linking up Juba with two major capitals, Nairobi and Kampala; a key port, Mombassa; and a number of regional cities, Nimule, Pageri, Magwi, etc.;
- Contribute to economic development, especially by providing markets for agricultural products, and in the meantime reduce the cost of food and food production;
- Create employment and build local capacity, as a direct outcome of construction works over the project implementation period and as a result of economic development in the longer term;
- Reduce poverty, especially in the villages presently isolated due to the deteriorated condition of the road;
- Enhance the Comprehensive Peace Agreement by providing peace dividends in the form of infrastructure improvements and their by-products;
- Enhance conflict prevention and confidence building; and
- Facilitate internally displaced people's return and resettlement.

Map 1.2: Project Roads & Southern Corridors



Specific objectives are those derived directly from the project's expected benefits, which the Consultant quantified as much as possible in the data-scarce environment that is Southern Sudan. When stating the project objectives, the Consultant was careful not to prejudge the means to obtain the objective (e.g. build an asphalt concrete road all the way from Juba to Nimule). This was in order to keep an open mind on the results of the analysis and of the various alternatives being studied. In this road project, the Consultant defined the project-specific objectives as follows:

- Stimulate and modernize the transportation sector;
- Reduce vehicle-operating costs by lowering the roughness level of the road surface and by improving the overall condition of the road base;
- Save time on journeys by increasing the travel speed;
- Lower future maintenance costs, potentially, by preventing frequent but only reactive and partial treatments of the road surfaces, which end up costing more over time;
- Decrease accidents by providing less slippery roads; wider pavement surfaces, especially in urban areas; and safeguards at major black spots; and
- Provide a healthier environment on the road zone of influence by lowering the level of dust generated by vehicles traveling on unsealed road surfaces.

Description of the Regional Macroeconomic Context

The description of the regional macroeconomic context is key to understanding the context within which the project is implemented and to perform a sound demand analysis. As such, it is undertaken at the outset of the analysis and its assumptions are explicitly stated.

However, it has proved to be particularly difficult to describe the regional macroeconomic context of Southern Sudan for two main reasons: (i) there is no data available; and (ii) Southern Sudan is not an independent country and therefore some data traditionally found with international organizations such as the World Bank and International Monetary Fund (IMF) is only available for the country as a whole and not for Southern Sudan specifically. However, according to the World Bank and IMF literature available, as well as the Consultant's experience in the field, if one wants to summarize the macroeconomic context of Southern Sudan, it could be as follows: "***the overall situation in Southern Sudan is promising, but still risky***".

The regional macroeconomic context is generally studied in terms of the general profile of the region, in terms of population, employment growth and economic activities, including trade, imports and exports potential. This section concludes with short- to medium-term prospects for the socio-economic environment.

General Profile

Southern Sudan is a region of Sudan of about 600,000 square km and a population of around 11 million. According to Wikipedia:

> The Sudanese government agreed to give autonomy to the region in the Comprehensive Peace Agreement (also known as the Naivasha Agreement) signed on January 9, 2005 in Naivasha, Kenya with the Sudan Peoples Liberation Army/Movement (SPLA/M), tentatively bringing an end to the

Second Sudanese Civil War. Southern Sudan borders Ethiopia on the east, Kenya, Uganda, and the Democratic Republic of the Congo to the south, and the Central African Republic to the west. To the north lies the predominantly Arab and Muslim [Sudanese] region directly under the control of the central government. Southern Sudan, also known as New Sudan, has nearly all of its administrative offices in Juba, the capital, while the largest city and commercial center is in Yei, towards the south.

Total population of Southern Sudan is estimated to be around 11 million and Juba County makes up an estimated 3 percent of this total. Juba County is composed of 11 "payams" (districts), out of which Juba Town itself, Kator and Munuki will probably form Juba Municipality in the near future.

Juba Municipality – simply referred to as Juba – is at the center of the present feasibility study. It is located in the Central Equatoria State and became the capital of Southern Sudan in July 2005, at the end of the civil war with the North. It was estimated to have a population of about 250,000 in 2006, although this can only be considered as an approximation since no census has been performed since the 1970s and many people have been displaced during the civil war. If the present population is not certain, Juba is expected to increase drastically in size due to the accumulation of urban functions as a capital city combined with the large number of expected returnees. In effect, according to a study commissioned by Japanese International Cooperation Agency (JICA[2]), Juba population is estimated to reach between 460,000 and 590,000 by the year 2015, considering the recent migration patterns. In the medium estimate of 510,000, most of the increase comes from refugees returning from neighboring countries (95,000), internally displaced people from Khartoum and North Sudan (76,000) and to a lesser degree from a natural population increase (57,000). Other factors of population growth are internally displaced people from Southern Sudan (19,000) and conventional migration (13,000).

Economy and Prospect/Macroeconomic Outlook

There are basically no industries or agriculture in Juba, except for a few brick makers producing for the local market and manual rock crushing, usually by the way of elderly women armed with small hammers. As a consequence, there are no exports, and all trucks that were observed during the implementation of this study arrived full of goods and left empty. All truckers that were interviewed by the Consultant confirmed this pattern. Note, however, that as of February 2007, a first stone crusher – originally from Lebanon – using mechanized equipment settled in the Juba area; hopefully a sign that small business is starting to develop in Juba.

As already mentioned above, the main trade routes are with Kenya and Uganda, as Southern Sudan seems to be looking mostly southwards to fulfill its mercantile needs. Some products, however, are still coming from Khartoum and, more generally, from the North. The vehicles coming from Khartoum and the northern regions usually, have steering wheels on the left-side while the vehicles imported from Uganda and Kenya have steering wheels on the right-side.

[2] / Emergency Study on the Planning & Support for Basic Physical & Social Infrastructure in Juba Town and the Surrounding Areas in the Southern Sudan – Interim Report – November 2006 – Katahira & Engineers International, Japan Engineering Consultants Co. and Kokusai Kogyo Co.

According to the JICA Report, quoting the World Bank, GDP growth is expected to be between 10 and 12 percent until 2011 included, and then between 8 and 10 percent until 2015. These figures assume that Southern Sudan will manage to live in peace and go forward with the major institutional, legal, economic and political reforms expected from a "new" country and they will serve as the basis for our demand analysis.

Description of the Road Sections

Southern Sudan has a rather small road network. None of the roads are paved, except for a few km in the capital city of Juba. The road from Juba to Nimule is one of three main corridors in Southern Sudan, as shown in Map 1.2. The road was included in the UNWFP road rehabilitation program and was the subject of a contract for improvement works in 2005/06. This contract was completed in December 2006 by Kirinyaga from Kenya. The contract to carry out basic works – drainage, grading, re-gravelling was supervised by Norken consultants, also from Kenya. Areas known to be mined were not worked on.

The basic characteristics of each section are described in Table 1.1 below, and include the following criteria: (i) length of the section; (ii) type of pavement; (iii) average carriageway width; (iv) average shoulder width; (v) last surfacing; (vi) overall road condition; (vii) speed limit; and (viii) average annual daily traffic (AADT). To do so, the Consultant used the Paterson table below:

Table 1.1: Description of the Levels of Roughness

IRI (m/km)	Descriptors
0.0 - 1.6	Extremely high-quality new asphalt concrete or slipform portland cement concrete pavement for high-speed motorways and airport runways ; uncommon for highways. Undulations barely perceptible at 100 km/h. Depression 0.2 mm/3 m.
1.6 - 2.5	Typical high-quality asphalt concrete or very high quality surface treatment pavements ; unpaved roads of excellent profile with fine gravel or recently bladed earth surface. Undulations barely perceptible at 80 km/h. Depressions 3-5 mm/3 m.
3.0 - 5.0	Asphalt pavements usually showing signs of deterioration (may include wide range of defects from 0% to 100% cracking, occasional patches, shallow depressions or occasional shallow potholes), or defect free surface treatment pavements of moderate to fair shape quality, or unpaved roads of good quality. Depressions or unevenness are just visually perceptible, e.g. 10-25 mm/3 m. Sharp movements or undulations perceptible at 80 km/h. Travel speed less than 100 km/h.
5.5 - 7.0	Pavements with visible irregularities and shape defects (often with extensive severe cracking or uneven patching over 20% to 50% of area), or defect free surface treatment pavements of very poor shape. Moderate depressions, 20-40 mm/3 m. Unpaved roads with shallow-moderate depressions, minor potholes, shallow corrugations (6-20 mm/1.5 m), or coarse gravel (stone size greater than 60 mm) on well-shaped surface. Sharp movements and undulations perceptible at 60 km/h, travel speeds less than 80 km/h.
8.0 - 10.0	Exceptional for paved roads, extreme deterioration, frequent depressions, extensive patching and unavoidable potholes, travel speed less than 60 km/h. Unpaved roads : clearly visible frequent transverse depressions (20-40 mm/3 m), strong corrugations (10-30 mm/0.7-1.5 m) or occasional deep depressions (40-80 mm/3 m) or potholes ; travel speeds less than 80 to 60 km/h.
12.0 - 20.0	Unpaved roads: unavoidable deep depressions (40-80 mm/3 m) or occasional very deep depressions/potholes (more than 80 mm deep), frequent transverse or diagonal erosion gullies. Travel speeds generally less than 50 km/h, and at 20m/km generally less than 35 km/h.

Source : Paterson (1986), from The Highway Design & Maintenance Standards Series ; Vehicle Operating Costs ; Evidence from Developing Countries ; Andrew Chesner and Robert Harrison ; World Bank Publication.

Overall, the road condition is assessed in terms of roughness level or IRI, which can advantageously be estimated through a subjective method consisting of a visual and comfort level survey undertaken while riding the road section at a given speed[3]. The Consultant defined the level of roughness of the project road during its field trip carried out from January 31st to February 1st, 2007.

Section 1: Juba to Bor Junction

The Juba to Nimule Road (the Project Road) starts at the Juba Bridge. The bridge has been heavily damaged and presently only offers access to one lane of traffic and pedestrians. As such queues often form as traffic waits for its turn to cross the bridge. The White Nile is approximately 500 meters wide at this point.

After crossing the bridge, the road enters the outskirts of Juba, which comprise dispersed residential areas and some small roadside stalls. The road section is 3.4 km long and can be qualified as being in a semi-urban area. The road is raised on an embankment as it appears that it is still located within the river floodplain. The topography of the road is relatively flat (450 meters above seal level). The Project Road soon leaves urbanized Juba and passes through a small village. No village homes are within ten meters of the edge of the road (which itself is between nine and ten meters in width). As such there would appear to be no need for resettlement or compensation to affected persons. This is the general rule along the entire Project corridor with all small settlements encountered set well back from the roadside. At the Bor Road Junction the surrounding landscape comprises scrubby bush. The main engineering characteristics of this road section are illustrated in Table 1.2, below:

Table 1.2: Road characteristics for the Juba to Bor Jct. section

Length	3.4 km
Type of pavement	Lateritic gravel
Average carriageway width	8.0 meters
Average shoulder width	1.0 meter each
Last surfacing	2006 by WFP
Overall road condition/roughness	Fair (IRI = 5.5)
Speed limit	50 km/hr. (not enforced)
AADT 2007 (4 wheel – motorized)	909
Motorcycles	341

Source: Consultant

Section 2: Bor Junction to Torit Junction

The Project Road continues from the Bor Junction to pass through low bush. Occasional trucks drive past at high speed on this 17.4 km road section, which can be qualified as inter-urban. Several burnt out vehicles could also be seen. This northern section of the Project Road has been notorious for ambushes by the LRA who have been attempting to disrupt traffic movements on the road since it was re-

[3] / The initial level of roughness is not as critical for an unpaved road as it is for a paved road, as it tends to vary widely over time, depending on weather conditions, traffic levels, overloading, regravelling and grading operations, etc.

opened last year. Most recently, three people were shot dead in this section of the road in January 2007 after being ambushed by armed LRA members. This incident prompted the government to step up their security efforts and deploy several battalions of SPLA to the area. The SPLA increased security levels along the road by posting soldiers at frequent intervals and there has been a noticeable improvement, with no incidents on the road reported since then. However, according to Consultant surveys many people wishing to travel between Juba and Uganda still use different routes due to what is perceived as a poor security situation on the Project Road. The road divides at KM 20.8. Eastward the road heads to Torit, then on to Kenya and eventually Nairobi. Southward the road continues to Nimule. A small village is located at this junction. The main engineering characteristics of this road section are illustrated in Table 1.3, below:

Table 1.3: Road Characteristics for the Bor Junction to Torit Junction Section

Length	17.4 km
Type of pavement	Quartzitic gravel
Average carriageway width	7.0 meters
Average shoulder width	0.5 meter each
Last surfacing	2006 by WFP
Overall road condition/roughness	Fair (IRI = 7)
Speed limit	80 km/hr. (not enforced)
AADT 2007 (4 wheel – motorized)	279
Motorcycles	5

Source: Consultant

Section 3: Torit Road to Nimule Center

This road section, totaling 169.2 km, continues to traverse the same scrubby bush environment. It is by far the longest road section, representing 88 percent of the total length of the Project Road. The Consultant did not sub-divide this road section in the analysis because it is quite homogenous both in terms of traffic patterns and engineering characteristics. The Road starts by crossing a poorly-maintained Bailey bridge, which is approximately 10 meters wide and spans a dry river. It crosses two other dry rivers via short span Bailey bridges shortly after. The occasional overloaded truck speeds past, kicking up huge plumes of dust, a considerable problem in this region. During the dry season the fine red soil particles are blown into the air by every passing vehicle and this problem is exacerbated by the large trucks traveling at high speed along the road. Fortunately the road is currently sparsely populated and as such the issue of poor air quality affecting humans is confined to the few small villages scattered along the Project Road, within the urban center of Nimule and the semi-urban environment at the outskirts of Juba.

The elevation of the road begins to rise (690 meters above sea level) as it passes through a few small sparsely-populated settlements. The bush becomes less scrubby in this section. Vegetation becomes denser and trees become more mature. A small settlement was observed at this point. There appeared to be more activity in this settlement due primarily to the increased presence of SPLA soldiers. Some small stalls were observed selling goods to travelers on the Road. The settlement is located at an elevation of 820 meters above sea level at KM 74. The elevation of the road decreases to around 675 meters above sea level and begins to traverse

scrubby bush. Much of the elephant grass that had grown close to the roadside has been burnt back. The main reason for this is to increase security and reduce areas from which LRA members can ambush vehicles.

The Project Road then crosses another short span Bailey bridge. The river bed beneath the bridge is dry. The Road crosses a longer Bailey bridge at Kit, also known as the Kit River Bridge (KM 100). Flow in this tributary of the White Nile was observed although it was relatively low. Most of the settlements have functioning hand pumps; however, in some of the smaller settlements the hand pumps have fallen into disrepair and water tankers abstracting surface water from the river are the only practical supply option.

The Road then enters a heavily mined section. The road width narrows to around seven meters. Thick brush has grown adjacent to the roadside. The elevation of the road starts to rise again, reaching more than 920 meters above sea level. This section of the road comprises some sharp turns and accidents occur here on a regular basis. Marker posts have been erected on some of the sharp bends to warn drivers of the potentially dangerous alignments.

The road then enters the village of Moli (KM125), which is protected by a small garrison of the SPLA. The village is home to a few hundred people. All the properties in the village are set well back from the dusty road. There is also a small clinic within the village. As the road leaves Moli it enters rolling hills. Potential accident black spots were identified in this area and marker posts had been placed on the most dangerous bends. For several kilometers, abandoned traditional and brick properties sit adjacent to the roadside. This area looks like it was formerly some kind of important settlement; amongst the buildings a decrepit brick church was noted. The brush is much less dense in this section. Some small traditional properties were still occupied and residents appeared to be farming crops including cassava and maize.

The Project Road then enters the village of Pageri at KM 146. Pageri has a small health clinic and a primary school and is by far the biggest settlement between Juba and Nimule. The road enters a barren scrubby landscape before it reaches the fertile surroundings of the Aswa River, a tributary of the White Nile. The road crosses the Aswa Bridge, which is in a poor state of repair; its timber deck requiring serious repairs in several locations. The road starts to climb into Gordon Hill, twisting and turning until it reaches an elevation of 827 meters above sea level. There are several dangerous bends with sheer drops into the valley below. Safety posts have been erected on most of the bends. The view from the hill towards the Nile and Nimule is spectacular and by far the best vista on the route. The road winds its way down Gordon Hill until it reaches the outskirts of Nimule. The main engineering characteristics of this road section are illustrated in Table 1.4, below:

Table 1.4: Road Characteristics for the Torit Junction to Nimule Center Section

Length	169.2 km
Type of pavement	Quartzitic gravel
Average carriageway width	7.0 meters
Average shoulder width	No shoulders
Last surfacing	2006 by WFP
Overall road condition/roughness	Fair (IRI = 6.5)
Speed limit	80 km/hr. (not enforced)
AADT 2007 (4 wheel – motorized)	252
Motorcycles	3

Source: Consultant

Section 4: Nimule Center to Ugandan Border

This unpaved road section is two kilometers long and can be classified as urban, as shown by the level of activity along the road. It is mostly populated with motorcycles cruising from the city center to the border. Nimule is the home to several thousand people and comprises a hospital, schools and a market centre thriving from cross border activity. Nimule National Park is located across the White Nile from Nimule. The security situation in Nimule appears to be good due to the presence of SPLA. The road continues through Nimule, across a small Bailey bridge until it reaches the bridge border with Uganda. The main engineering characteristics of this road section are illustrated in Table 1.5, below:

Table 1.5: Road Characteristics for the Nimule Center to Ugandan Border Section

Length	2.0 km
Type of pavement	Lateritic gravel
Average carriageway width	9.0 meters
Average shoulder width	1.0 meter each
Last surfacing	2006 by WFP
Overall road condition/roughness	Fair (IRI = 6.0)
Speed limit	50 km/hr. (not enforced)
AADT 2007 (4 wheel – motorized)	535
Motorcycles	683

Source: Consultant

Land Mines and other Security Issues

According to information from the United Nations Mine Action Office (UNMAO), the road from Juba to Jubileen has not been de-mined. From Jubileen to Magwi there is an 8m corridor de-mined and from Magwi to Nimule there is a standard 26m corridor de-mined. The road was closed until July 2006 but has been well-used since and the tracked area 5-7m wide is clearly not mined. However there are sections where evidence of mines is visible on the side of the road and surrounding areas. Based on UNMAO's assessment, some areas are considered "heavily mined" with both anti tank and anti personnel mines. A contract has been let by UNWFP (with demining contractor Ronco) to carry out further de-mining and establish a 26m corridor along the full length. It is likely that most of the anticipated construction works will be within the 26m corridor but works in some areas will go beyond that limit. In addition,

prospecting for materials and water will be outside of this zone. Therefore, the Consultant suggests proceeding with surveys and construction works with the support of a de-mining company.

Security on this road has been an issue. Since the road opened and particularly in November and December 2006, and January 2007, there have been several serious attacks on civilians and vehicles traveling on this route as well as some in locations nearby. These have been blamed on the LRA and unknown militias and have been as random as they are horrific. Over 100 deaths were reported up to the end of January 2007. This insecurity has greatly reduced traffic use of the Juba to Nimule road. In mid-January Southern Sudan President Salva Kiir pledged to step up security and bring these attacks to a halt. There is now a significant presence of SPLA troops along the whole road and since January 19 no serious attacks have been reported. The presence of the SPLA soldiers and regular patrols seems to be enough to deter banditry along this road by LRA or others. The fact that security is assured on the project road is an assumption underlying the present feasibility study.

2. DEMAND ANALYSIS

The demand analysis is one of the key tasks of a feasibility study, as it defines the main drivers of benefits. This second chapter analyzes the demand for transport and is aimed at assessing present and future traffic levels on the project road sections, distinguishing between the with-project (scenarios based upon implementation of the project) and the without-project (scenarios based upon not implementing the project) situations. In doing so, the demand analysis also assists in providing the assumptions used in the Highway Design Model (HDM) regarding the typical vehicle fleet.

Description of the Vehicle Fleet

The vehicle fleet used in the project area serves as the basis for calculating vehicle operating costs (VOCs) and, through a series of parameters including occupancy and speed flows, other benefits such as time savings. The Consultant therefore described the vehicle fleet as precisely and accurately as possible, although there are basically no existing statistics describing the vehicle fleet in Southern Sudan. The vehicle fleet in Southern Sudan is small and is concentrated in the Juba area. The data pertaining to the vehicle fleet that the Consultant could gather describes the characteristics of vehicles that use the Project Road.

The vehicle fleet comprises a mix of several vehicle types that use the road project. The characteristics of the vehicle fleet are represented by grouping the vehicles into classes that the team defined according to common characteristics attributed to the vehicles. Such attributes concern the size, the type of utilization or the performance of the vehicle. Each class is hence attributed a representative vehicle.

Following the analysis of the vehicle fleet in Juba, the team defined the following categories of motorized vehicle types in Nimule and also along the Project Road, and used this information as the basis for the traffic counts. In parentheses are the representative vehicles for each category of vehicle:

- Motorcycles, (Senke);
- Saloon cars (Toyota Corolla);
- 4WD, jeeps & pickups (Toyota Land Cruiser);
- Minibuses (up to 20 seats, Toyota Hiace);
- Medium & large buses (more than 20 seats, (Nissan Diesel);
- Light trucks (less than 5 tons, 2 axles Isuzu N series);
- Medium trucks (from 5 to 10 tons, 2 axles Isuzu P series);
- Heavy trucks (more than 10 tons, 3 axles Isuzu H series); and
- Articulated trucks (4 axles or more, Scania).

Non-motorized traffic is not considered in the economic analysis because it is relatively scarce outside of towns, has little influence on traffic flow characteristics and, therefore, does not have a great impact on the economic results.

Table 2.1: Data Inputs for Determining VOC for Motorized Vehicles

Vehicle attributes	Motorcycle	Car	4WD	Minibus	Big bus	Light truck	Medium truck	Heavy truck	Articulated truck
Representative vehicle	*Senke*	*Toyota Corolla*	*Toyota Land cruiser*	*Toyota Hiace*	*Nissan Diesel*	*Isuzu NPR*	*Isuzu FTR*	*Isuzu HXR*	*Scania*
Basic characteristics									
Pass. Car Space Equiv.	0.5	1	1	1.2	1.5	1.3	1.4	1.6	1.8
No of wheels	2	4	4	4	6	6	6	10	26
No of axles	2	2	2	2	2	2	2	3	7
Tire types	Bias -ply	Bias -ply	Radial-ply	Radial-ply	Radial-ply	Radial-ply	Radial-ply	Radial-ply	Radial-ply
Base no. of recaps	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Retread cost	15%	15%	15%	15%	15%	15%	15%	15%	15%
Annual km	5,200	8,000	7,000	21,000	63,000	19,000	25,000	43,000	53,000
Working hours	2592	546	1092	2880	2184	1680	1680	2112	2304
Average life in years	5	6	7	5	6	7	9	9	12
Private use	30%	70%	85%	5%	0%	0%	0%	0%	0%
No of passengers	1	3	3	14	65	5	2	2	1
Work-related pass. Trips	35%	30%	50%	75%	80%	80%	100%	100%	100%
Equivalent standard axles	0	0	0.02	0.01	0.7	0.1	1.25	2.28	4.63
Curb weight (tons)	0.115	1.148	2.46	2.065	6.5	2.9	7.5	13	28
unit costs (USD)									
Reconditioned vehicle	900	8,000	38,000	12,000	40,000	25,000	34,000	50,000	90,000
Replacement tire	24	70	170	125	360	160	210	300	400
Gas per liter	2.50	2.50							
Diesel per liter			1.25	1.25	1.25	1.25	1.25	1.25	1.25
Lubricating oil per liter	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Maintenance labor / hour	5.0	7.5	7.5	7.5	15.0	10.0	10.0	15.0	15.0
Crew wages per hour	0.50	1.50	2.50	1.00	3.00	2.00	3.00	3.30	4.00
Annual overhead (1)	68	339	803	733	3,213	1,193	1,589	2,586	3,678
Annual interest (2)	14%	14%	14%	14%	14%	14%	14%	14%	14%
Pass. working time/hr (3)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Pass. non-work. time/hr (4)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cargo per hour	-	-	-	-	-	0.038	0.038	0.226	0.226

Source: data is from interviews with car dealers, garages and drivers.
Note 1: based on 2% of new vehicle cost and annual km: (i) 1 cent for Motorcycles, (ii) 2.5 cents for cars, 4WD, minibuses and light trucks, and (iii) 4 cents for big buses and trucks.
Note 2: for consumer loans
Note 3: based on a national per capita income of US$ 276.3 per year, 48 hours working days and 48 workweeks per year.
Note 4: based on a quarter of the working value of time
Note 5: value of cargo is only for trucks and is based on 100% of cargo being time sensitive Hourly interest 0.0016%

Vehicle operating costs are made up of the costs of (i) representative new vehicles; (ii) replacement tires; (iii) gas and diesel; (iv) lubricating oil; (v) maintenance labor; and (vi) crew wages. Cost for representative new vehicles, replacement tires and maintenance labor (including workshop consumables and overhead) came from local dealers, car repair shops and drivers. Costs for gas and diesel are based on a UN study[4]. Cost of lubricating oil is also based on recent market prices. Crew wage was based on interviews with drivers. The team's assumptions regarding vehicle operating costs for each of the pre-defined representative vehicles are provided in Table 2.1, above.

Determination of Normal Traffic

Normal traffic corresponds to the existing demand for transport on the Project Road in the without-project situation for the base year. Because of the atypical situation in which the Project Road is being studied, the Consultant has to determine "normal" traffic in several steps. Normal traffic, also referred to as Annual Average Daily Traffic (AADT), is defined as the traffic that is passing through a road when circumstances are considered normal, that is without anticipated changes that would change traffic patterns in terms of: (i) maintenance policies; (ii) new construction or rehabilitation projects; (iii) flooding or dramatic failures – such as a collapsed bridge – that would make the road impassable; and (iv) security issues that would scare-off potential road users.

The first step in defining normal traffic is to look at the existing traffic on the road and determine average daily traffic. The second step is to make the necessary corrections in order to determine "normal" traffic or AADT as defined above, which will serve as the departure point to forecast traffic during the analysis period. For the Juba to Nimule road project, these corrections are threefold as the Consultant has to consider that: (i) traffic counts were carried out during the dry season, when traffic volumes are traditionally higher than the average over the year; (ii) most of the road from Juba to Nimule is presently considered as dangerous, which has the effect of diverting some of the traffic that would otherwise take it to other – safer – routes; and (iii) the entrance bridge to Juba was damaged by an overloaded truck last year, which prevents some fully-loaded articulated trucks from using it.

Existing Average Daily Traffic (ADT)

A review of existing data in Southern Sudan showed that there is basically no traffic data and, when it exists, it is not consistent over the years and not reliable. Therefore, the team decided to carry out a series of traffic counts at strategically located stations around Juba. (See **Annex 1**: Results from Traffic Counts)

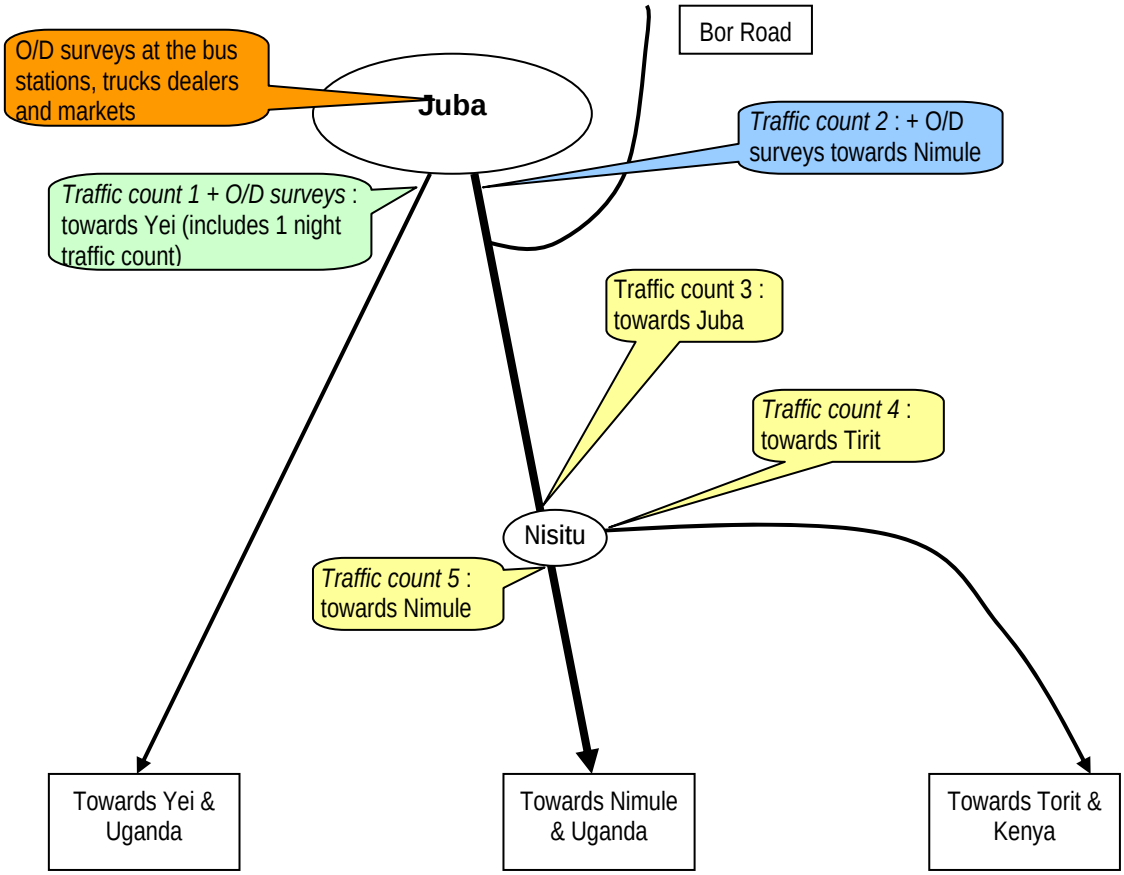
Traffic counts were performed at five key locations. These locations were defined and prioritized so as to get a full picture of existing traffic patterns on the Project Road (namely from Juba to Nimule and the Ugandan border) and on "competing corridors" (namely the Juba to Yei and Kaya Road – or Western Corridor – and the

[4] / UNJLC Sudan Fuel Survey – April 2006.

Juba to Torit Road towards Kenya – the Eastern Corridor), as well as to concentrate the team's time and resources on the most valuable road sections.

The traffic counts were implemented over a one-week period for each location, starting between February 4-7, 2007 depending on the station. Each day consisted of 12-hour counts, from 7 am to 7 pm, which roughly corresponded to daytime and therefore to main traffic movements. The seven-day / 12 hour counts were deemed appropriate to prevent any distortions due to the day of the week or the time of day. The traffic counts and Origin-Destination (O-D) surveys are organized around five key stations, as illustrated in the schematic map, Figure 2.1, below:

Figure 2.1: Locations of Traffic Counts and O-D Surveys



When the location was deemed safe enough, the traffic counts included one or two night counts to assess the night traffic ratio. These night counts were carried-out in the outskirts of Juba: (i) on the Nimule Road – two night counts; and (ii) on the Yei Road – one night count. Otherwise, and according to the results of interviews with drivers and local authorities, the Consultant made the assumption that there was no traffic during the night due to security issues.

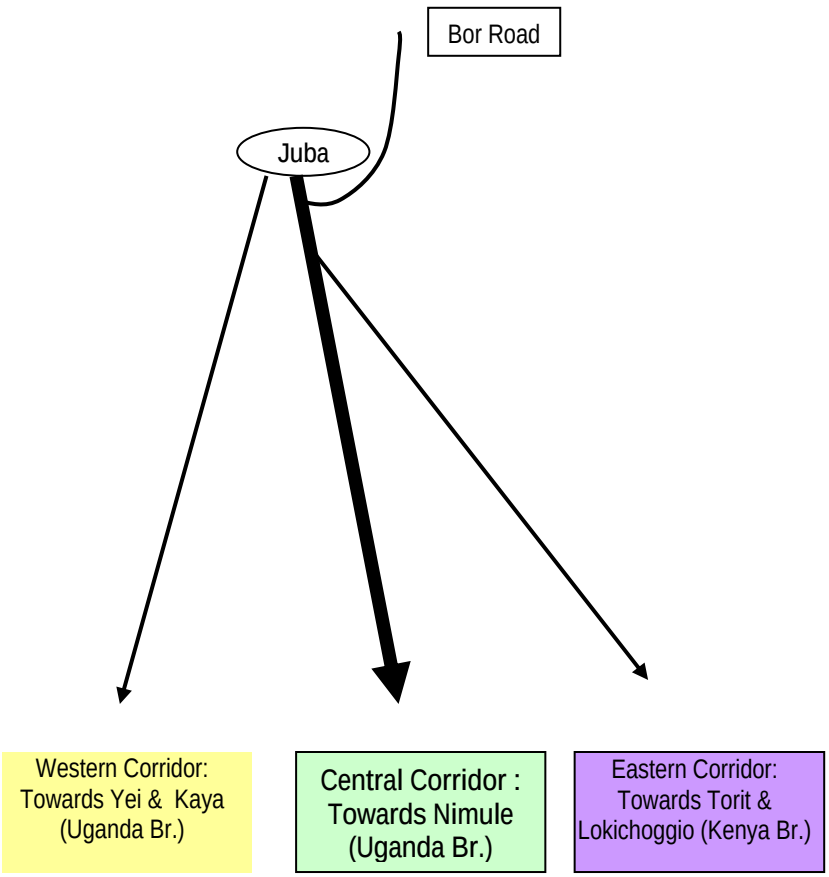
Corrections to Existing Traffic Volumes

The result of these traffic counts and O-D surveys provided the existing ADT (see **Annex 1**). However, the Consultant had to operate three corrections to assess AADT in the without project scenario – without investment: (i) correction for seasonal variation to obtain average traffic volume over the base year; (ii) correction to consider the fact that the Government will ensure security on the Juba to Nimule road, allowing most drivers to assume that the security level on the road will be acceptable to divert back to this shorter route; and (iii) correction for the deficient bridge at the entrance of Juba, as a project is being implemented to fix it and the bridge should be operational by the time the proposed road upgrading project becomes effective.

The Consultant has to consider the impact of seasonal variations on the traffic counts carried out. Interviewing a number of drivers around Juba, on the Nimule Road as well as on the Yei road, the Consultant determined that seasonal variations were minimal, as less than 10 percent of truck drivers mentioned that they would not travel during the rainy season. However, most of them acknowledged that the trip during the rainy season takes longer (usually between 20 and 40 percent longer), which means that each truck would make fewer round trips on the road over an average year compared to the period during which traffic counts and O-D surveys were carried out. Overall, the Consultant considered that traffic levels during the rainy season, which lasts for about six-months, would be on average 20 percent less than in the dry season.

The Consultant also has to take into account the fact that the road from Juba to Nimule is presently not safe – or at least is not perceived to be safe, as the effect of more soldier deployment still has to be felt. It was obvious through our interviews with truck drivers that those traveling from Kampala or Mombassa / Nairobi – the main origin of goods coming to Juba – would favor the Juba to Nimule Road over its western alternative (through Yei and Kaya) and its eastern alternative (through Torit and Lokichoggio) if the road were safe. The only scarce exceptions are for a few light and medium trucks coming from towns in the northwest part of Uganda, for which the Yei / Kaya route is shorter. The reasons are twofold, as shown in Figure 2.2, below: (i) the Juba to Nimule road is shorter – by about 150 km from Nairobi and Mombassa compared to the eastern corridor and by about 180 km from Kampala compared to the western corridor; and (ii) the central corridor is in overall better condition, with a total of “only” 782 km in poor or unpaved condition, against more than 900 km for both the eastern and western corridors. Figure 2.2 shows schematically the main distances between Juba and a number of major cities in Uganda and Sudan:

Figure 2.2: Main Corridors



Juba to Border	240 km	**192 km**	355 km
Km unpaved or in poor condition	240	**192**	355
Upgrading program Sudan	None	**None**	NA
Distance to Kampala	814 km	**632 km**	NA
Km unpaved or in poor condition - In Sudan (*) - in Uganda (*)	369 240 129	**296** **192** **104**	NA
Upgrading program Uganda	51 km under construction		NA
Juba to Nairobi	1,359 km	**1,129 km**	1,275 km
Juba to Mombassa (*)	1,839 km	**1,609 km**	1,755 km
Km unpaved or in poor condition - In Sudan (*) - in Kenya – Mombassa (*) - in Uganda (*)	908 240 465 203	**782** **192** **465** **125**	925 355 570 NA
Investment program - in Kenya (*) - in Uganda (*)	590 465 km under bid 125 km under bid	**590** **465 km under bid** **125 km under bid**	130 130 km under bid

(*) World Bank International Corridors Development Project; 2005.

In fact, beside the security issue on the Juba to Nimule road, the only reason why most drivers from Kenya would favor the Torit / Lokichoggio Road is to avoid wasting a day or so at the Kenyan / Ugandan border, which has to be crossed when coming through Nimule. Otherwise, there was very little hesitation when answering the question: "would you take the Juba to Nimule road if it were safe" with a "yes". However, it is worth noting that when asked if they would consider taking the Juba to Nimule road if it were paved – but still not safe – most drivers still answered "no", which is one of the main reasons why the Consultant considered that *security on the project road should be ensured as a precondition to implementing the project*.

For the heaviest articulated trucks, especially those carrying containers, there was another issue to consider: the fact that one of the two lanes on the access bridge to Juba crossing the White Nile was destroyed by an overloaded truck. Only one lane is presently open and fully-loaded articulated trucks are forbidden to take it. Their only alternative route to reach Juba from either Kenya or Uganda is through the Yei / Kaya road, unless of course they accept to divide up their loads onto smaller trucks before entering the capital city, which can be a cumbersome exercise. Therefore, the Consultant assumed that the number of articulated trucks diverting to the Juba to Nimule Road would be even higher than the other categories of trucks.

As a result from the O-D surveys and the subsequent traffic analysis, the Consultant concluded that the following percentage of vehicle levels would divert from the western corridors (Yei / Kaya road) and the eastern corridor (Torit / Lokichoggio road) to the Juba to Nimule road:

- Motorcycles, cars and 4WD = 0 percent;
- Minibuses = 25 percent;
- Large buses = 30 percent;
- Light trucks = 40 percent;
- Medium trucks = 50 percent;
- Heavy trucks and articulated trucks on the Torit / Lokichoggio Road = 80 percent; and
- Articulated truck on the Yei / Kaya road = 90 percent.

As a rule of thumb, the larger the vehicle the farther it has traveled, and therefore the more likely it is to take the Juba – Nimule road once it is safe and the bridge is repaired. The difference in the percentage of diverted traffic for the articulated trucks in the Torit / Lokichoggio road and Yei / Kaya road stems from the fact that in the latter road some additional articulated trucks would divert back to the Juba to Nimule road once the access bridge to Juba is repaired.

Average Annual Daily Traffic (AADT)

The AADT for the base year and for each section of the Project Road is provided in the Table below:

Table 2.3: Average Annual Daily Traffic

AADT 2007 **From** **Juba Bridge** **to** **Bor Jct.** **3.4** **km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	341	5	235	148	22	145	133	65	30	1,125
Diverted traffic	-	2	31	20	4	14	18	23	15	126
AADT base case	**341**	**6**	**266**	**167**	**26**	**159**	**151**	**89**	**45**	**1,251**
In % of AADT	27%	1%	21%	13%	2%	13%	12%	7%	4%	100%

AADT 2007 **From** **Bor Jct.** **to** **Torit Jct.** **17.4** **km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	5	6	33	2	7	19	53	23	9	158
Diverted traffic	-	2	31	20	4	14	18	23	15	126
AADT base case	**5**	**7**	**64**	**22**	**11**	**32**	**72**	**47**	**24**	**284**
In % of AADT	2%	3%	23%	8%	4%	11%	25%	16%	8%	100%

AADT 2007 **From** **Torit Jct.** **to** **Nimule Center** **169.2** **km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	3	4	11	1	7	17	44	16	6	111
Diverted traffic	-	2	31	20	4	14	23	31	18	142
AADT base case	**3**	**6**	**43**	**21**	**12**	**32**	**67**	**47**	**24**	**254**
In % of AADT	1%	2%	17%	8%	5%	12%	27%	19%	9%	100%

AADT 2007 **From** **Nimule Center** **to** **Ugandan Border** **2.0** **km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	683	2	117	74	11	73	66	33	15	1,074
Diverted traffic	-	2	31	20	4	14	23	31	18	142
AADT base case	**683**	**4**	**149**	**94**	**15**	**87**	**89**	**64**	**33**	**1,217**
In % of AADT	56%	0%	12%	8%	1%	7%	7%	5%	3%	100%

M/cycles = 2 times Juba - Bor Jct
Other vehicles = half Juba - Bor Jct

Source: Consultant

Traffic Forecast

When performing a road project feasibility study, the Consultant distinguished between the various sources of traffic growth, which are: (i) exogenous from the project, such as GDP growth, demography or changes in fuel prices; and (ii) endogenous to the project, such as diverted or generated traffic. For the purpose of this study, the traffic forecast analysis is made on the basis of: (i) growth for normal traffic, which corresponds to the growth that would occur even without improving the road network; and (ii) generated traffic, which occurs only in the case where there is a significant improvement of the road network.

Normal Traffic Growth

Normal traffic growth is the traffic growth that would happen on the project road in the future, without the proposed project being implemented. This is also referred to as the future traffic growth in the without-project scenario. The best method to forecast ***normal traffic*** is to extrapolate time series data on traffic levels and assume that growth will either remain constant in absolute terms or in percentage terms. However, the lack of wide variations and overall unreliability of time series data in Southern Sudan led the team to choose an alternative method common in developing countries.

In effect, normal traffic growth is due to exogenous factors that are expected to drive an increase (or decrease) in travel demand, such as economic growth. The Consultant therefore based its assumption of normal traffic growth on the overall performance of the Southern Sudanese economy, namely its GDP growth rate. The Consultant used official GDP growth figures, as determined by the World Bank and used in the JICA study[5]. Assumptions are as follows:

- 11 percent until 2011 included;
- 9 percent from 2012 to 2015 included; and
- 7 percent afterwards (Consultant's own assumptions).

Given the present stage of economic development in Southern Sudan, this estimate seems to be both consensual and conservative enough to be used in the economic analysis. Furthermore, better data simply does not exist and it would be beyond the scope of this study to try to assess better assumptions for GDP growth.

The traffic growth rates for the analysis period were subsequently based on elasticity factors for the national transport demand in relation to GDP growth. These elasticity factors are different for passenger vehicles (motorcycles, cars, four-wheel-drives, minibuses and large buses) and for commercial vehicles (light, medium, heavy and articulated trucks). In effect, the latter have already somewhat developed over the past decade, as witnessed when looking at the composition of the vehicle fleet on the road, while the use of personal or passenger vehicles – with the exception of motorcycles in the more urban areas – is still in its infancy. For example, our traffic counts have shown that on average on the Juba to Nimule Road: (i) six percent of the total vehicle-km is made of motorcycles – they are almost exclusively concentrated in the semi-urban areas of Juba and Nimule towns; (ii) 32 percent of vehicle-km is made of passenger vehicles; and (iii) 62 percent of vehicle-km is made of commercial vehicles.

Consequently, the Consultant decided to give more weight in terms of future growth rates to four-wheel passenger vehicles over the analysis period, compared to motorcycles and commercial vehicles, by assigning them an elasticity factor of 1.2. This elasticity factor entails a growth for cars, 4WD and buses 20 percent faster than

[5] / Emergency Study on the Planning & Support for Basic Physical & Social Infrastructure in Juba Town and the Surrounding Areas in the Southern Sudan – Interim Report – November 2006 – Katahira & Engineers International, Japan Engineering Consultants Co. and Kokusai Kogyo Co.

this of GDP. For example, if GDP grows by 10 percent, these vehicle categories will grow by 12 percent. This elasticity factor is derived from the Consultant's experience and is commonly used to assess traffic growth in data scarce environments. Motorcycles and commercial vehicles, on the other hand, are assigned a more conservative elasticity factor of 1, meaning that motorcycles and trucks of all size are forecasted to grow in line with GDP growth rates over the analysis period.

Therefore, overall normal traffic growth is assumed to be as follows:

Table 2.4: Average Annual Daily Traffic Growth Rates

	2007-2011	2012-2015	2016-2026
Motorcycles	11.0%	9.0%	7.0%
Passenger vehicles	13.2%	10.8%	8.4%
Commercial vehicles	11.0%	9.0%	7.0%

Source: Consultant

These numbers might look impressive. They are not. This is because the starting point is extremely low and there is an obvious catching up period taking place as the peace process in Southern Sudan is holding.

Growth 'With-Project' situation

The effects on travel demand of a new project can be classified into two main distinct categories: diverted and generated. A project may influence demand in any one of, or any combination of, these two categories.

If the project improves the service of a facility, either through increased speeds, lower costs, or both, this would typically divert existing demand from parallel competing facilities. However, no diverted traffic was considered in this feasibility study, as the improvements proposed are not expected to lead to obvious changes of routes for the normal traffic described above. This is because the Consultant already assumed in the without project scenario that the road would be safe and the access bridge to Juba Town repaired, and therefore that the traffic presently taking the other corridors (West and East) would eventually take the Project Road *even if the project were not implemented*. In effect, as shown in Figure 1 above, the Juba to Nimule Road is much shorter than the two other alternatives both from Kampala and Nairobi/Mombassa and the only reason why most drivers are not taking it presently is because of the security issue. Once this issue is solved, which is our assumption in the without project scenario there is no real reason to have additional diverted traffic on this route.

Generated traffic arises either because a journey becomes more attractive by virtue of a cost reduction or because of the increased development that is brought about by the road investment. Generated traffic is difficult to forecast accurately. It is only likely to be significant in those cases where the road investment brings about large reductions in transport costs, which is the case in the present study.

Consequently, the team assumed that generated traffic would represent: (i) ***0 percent*** of the levels of normal traffic when the road is upgraded to unpaved standards; and (ii) ***30 percent*** of the levels of normal traffic when the road is upgraded to bituminous standards – whether DBST or asphalt concrete. On the one hand, the Consultant's rationale for not assuming generated traffic for upgrading the existing carriageway to unpaved standard is that although the road structure will be better – and ready to be paved – it is not going to make a significant difference for the vehicles, especially as the other routes are all expected to be re-graveled and graded at least once a year too. On the other hand, the Consultant's rationale for assuming 30 percent generated traffic for upgrading the existing road to the bituminous standard is that the road will be noticeably smoother for the whole 192 km, the travel time will decrease significantly, and the road will be passable all year long, without much distinction between the rainy and dry seasons.

For the bituminous standards, generated traffic was allocated during the first year after the opening. Generated traffic was assumed to grow at the same rate as normal traffic thereafter. Overall, the team is confident that its assumptions regarding generated traffic are conservative, as driving conditions will be significantly improved whenever generated traffic has been considered in the analysis.

3. CONSTRUCTION WORKS & MAINTENANCE

The purpose of this third chapter is to define the engineering aspects of the project alternatives and to provide cost estimates. Overall, upgrading and complete rehabilitation of the Juba to Nimule road is not a significant engineering challenge. The road generally has a good alignment throughout its length. No major realignments would be required to establish a horizontal alignment to meet maximum standards for 110 km/hr. design speed. The vertical alignment is generally flat to slight grades with three or four stretches of road with more significant grades. The section over the hill into Nimule is the poorest alignment and requires approximately 3 km of improvement at the Nimule end. (**Annex 4** provides a Project Road map and selected photographs showing representative sections along the route).

Depending on the investment alternative outlined in this report, the net construction cost (excluding taxes, supervision etc.) of the project would range between US$ 26 – 80 million.

The first part of this chapter describes the construction work and corresponding cost estimates associated with each of the proposed investment alternatives for the Juba to Nimule road while the very end of this chapter sets forth the maintenance requirements and costs associated with each of these investment alternatives.

Construction Works

The preliminary engineering design starts with determining adequate road construction / rehabilitation alternatives (The Projects). It follows the engineering and traffic surveys, upon which it is based[6]. The final outcome of the preliminary engineering design is to estimate the construction and maintenance costs and schedules. To do so, the Consultant is determining: (i) the project alternatives by preparing an engineered alignment design in accordance with appropriate horizontal and vertical parameters and by adopting an appropriate construction design for pavement and structures; (ii) the quantities of the construction components; and (iii) the investment costs of each project alternative by undertaking a unit cost analysis.

Alternatives

Project alternatives comprise a series of pavement structure options that are tested for structural viability, cost and benefit. The without project scenario for this study was to carry-out no further improvements on the UNWFP graveling project completed in 2006. The purpose of the alternative studies is to give the decision makers and stakeholders the economic impact of various construction and maintenance options as well as determining which pavement alternative gives the best economic return while satisfying the demands of traffic.

[6] / In January 2007 the road was assessed by two return journeys driven along the length of the road, a video of the same and a review of available reports, mapping and other data.

The pavement structure alternatives studied included:

- The without project scenario of no rehabilitation or construction;
- Reconstruction of the road to aggregate surface standard or "unsealed" standard;
- Upgrading of the road to a "Double Bituminous Surface Treatment" standard (DBST); or
- Upgrading of the road using "Asphalt Concrete" (AC) as the surface material.

For each of these basic pavement structure alternatives, the Consultant proposed several variations for each of the four sections of the Project Road:

- ***Seven-meter*** wide carriageway with two-meter shoulders for the inter-urban sections (from the Bor Junction to Nimule Center) versus ***seven-meter*** wide carriageway plus parking lanes and curbs plus aggregate paved sidewalks for pedestrians for the semi-urban sections (from the Juba Bridge to the Bor Junction on the one hand and from Nimule Center to the Ugandan Border on the other hand). Figure 1 in **Annex 2** illustrates typical road cross sections.
- For the long section from the Torit Junction to Nimule Center (169 km), a ***one-year*** construction period versus a ***two-year*** construction period. Consideration was given to the fact that construction works using DBST could proceed more quickly than with asphalt concrete.

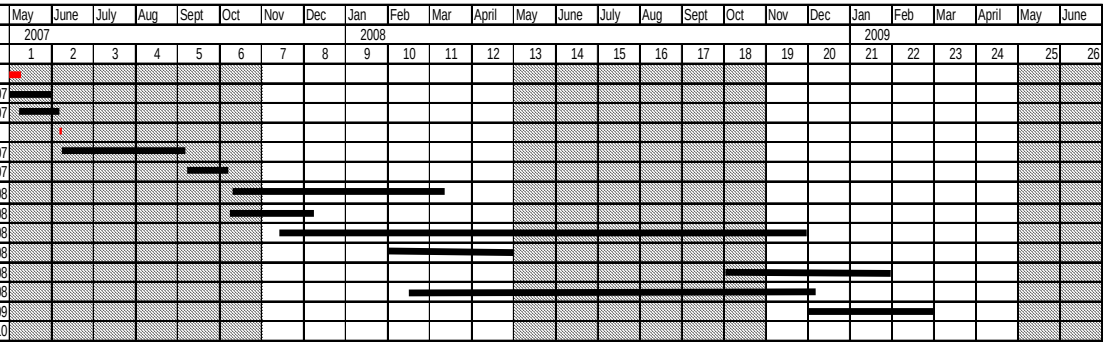
Furthermore, each project alternative comprises an initial investment and a corresponding maintenance policy applied over the lifetime of the project (refers to Section 3.2 Maintenance, page 38 below, for an estimation of maintenance needs and costs). Each alternative is a reasonable, well-founded and self-contained investment option.

The improvement policies were defined in terms of their time of intervention, engineering characteristics, condition of the carriageway after the intervention, and unit costs. For the sake of this feasibility study, the Consultant assumed a design-build method for the one-year construction period and a design-bid-build method for the two-year construction period. It is assumed that there would be three similar sized contracts, and that contractors will have to program 4-5 km per month. A draft construction schedule is presented in Figure 3.1, below:

Figure 3.1: Implementation Schedules

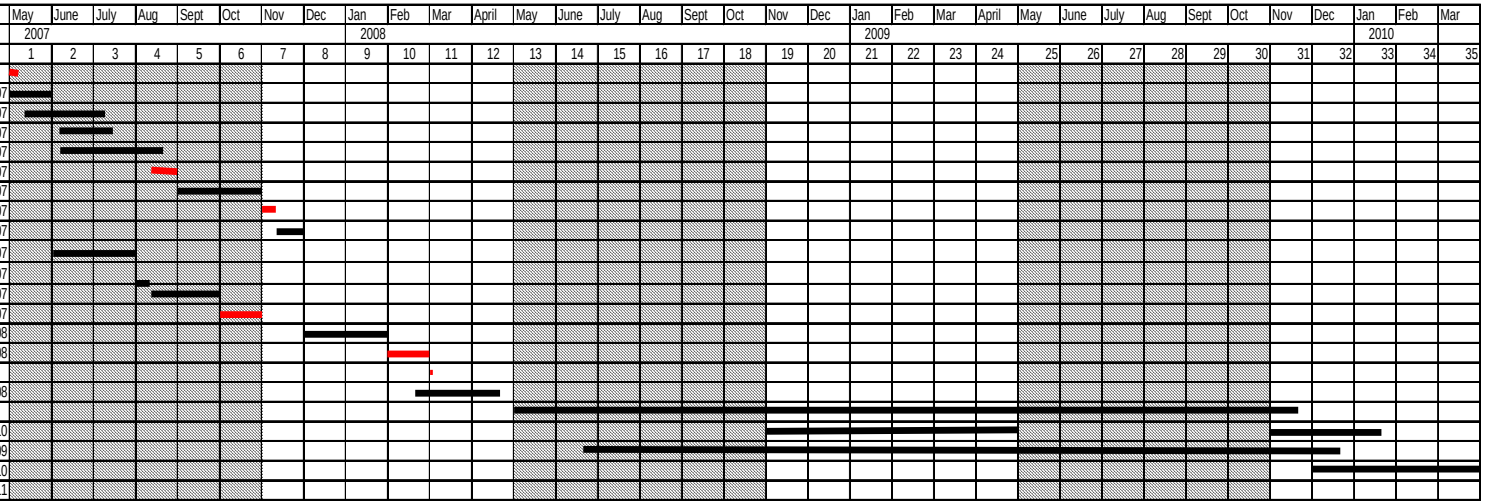
Schedule for the Implementation of the Juba to Nimule Road Design Build Method (1 year)

Description	Begin Date	End Date
Notice to Proceed with DBB Project	5/1/2007	
Preparation of Scope of Work	5/1/2007	5/31/2007
Advertise for Contractors EOI	5/7/2007	6/6/2007
Distribute SOW to Contractors	6/7/2007	
Preparation of Bids	6/8/2007	9/6/2007
Evaluation and Award	9/6/2007	10/6/2007
Begin Design, proceed ahead of constr.	11/7/2007	4/5/2008
Mobilize and Construct Camps	11/7/2007	1/6/2008
Construction of Earthworks, base	12/15/2007	10/10/2008
Pavement Season 1	1/1/2008	4/30/2008
Pavement Season 2	9/1/2007	1/29/2008
Bridges and Drainage	3/15/2008	12/10/2008
Signs, markings, clean up	12/1/2008	3/1/2009
Warranty Period	3/1/2009	2/24/2010



Schedule for the Implementation of the Juba to Nimule Road Design-Bid-Build Method (2 years)

Description	Begin Date	End Date
Notice to Proceed with Final Design	5/1/2007	
Mobilization	5/1/2007	5/6/2007
Topographic Surveys	5/7/2007	7/11/2007
Soils and Materials Surveys	5/28/2007	7/18/2007
Preliminary Design Road/Bridge	6/4/2007	8/18/2007
Field Review	8/20/2007	8/23/2007
Draft Final Design and Specifications	8/24/2007	11/1/2007
Design Review	11/1/2007	11/15/2007
Final Design and Bid Docs.	11/15/2007	11/30/2007
Advertise for Prequalification of Bidders	6/1/2007	7/31/2007
Prequalification of Construction Companies	8/1/2007	8/15/2007
Interview of Companys on Short List	8/15/2007	8/29/2007
Submission of Short List and Approval	8/30/2007	9/1/2007
Issue Bid Documents/Receive Bids	11/30/2007	1/29/2008
Evaluate and Award Contracts	1/30/2008	2/29/2008
Notice to Proceed with Construction	3/1/2008	
Mobilization and Camp Construction	3/1/2008	4/30/2008
Earthworks, Subbase and Base	5/1/2008	11/31/2009
Pavement	11/1/2008	1/31/2010
Bridges, Drainage	6/1/2008	2/26/2009
Signs, markings, clean up	12/1/2009	3/31/2010
Warranty Period	3/1/2010	2/28/2011



Note: Red bar indicates USAID Action

Rainy season

The other requirements in terms of engineering characteristics are quite detailed, and a summary is provided below.

- ***Upgrading to AC standard*** is applied to the existing gravel road. Construction consists in two layers of hot mix asphalt applied on a granular road base on a gravel sub-base. Total surface material is 100 mm of asphalt concrete, with a dry season structural number of 3 and relative compaction of 98%. Roughness after construction is expected to be 2 and design speed limit is 110 km/hr.
- ***Upgrading to ST standards (DBST)*** is applied to the existing gravel road. Construction consists in a double bituminous surface treatment 30 mm thick applied on a granular road base on a gravel sub-base. Total surface material is 30 mm of double bituminous surface treatment, with a dry season structural number of 3 and relative compaction of 97%. Roughness after construction is expected to be 2.2 and design speed limit is 100 km/hr. (Figure 2 in **Annex 2** illustrates the design of the pavement structures.)
- ***Upgrading to unpaved standards*** is applied to the existing gravel road. This improvement policy consists in rebuilding the existing road structure, but stopping short of sealing the carriageway***.*** Construction consists in applying 150 mm of lateritic gravel using a mechanical compaction method. Roughness after construction is expected to be around 3 and design speed limit is 80 km/hr.

The design of the pavement was formulated using AASHTO 1993 applying the AADT derived from the project traffic counts and growth analysis. A total of 12 pavement structures were considered; 5 hot mix asphalt, 4 DBST and 3 gravel (**Annex 2** presents the pavement design calculations and analysis in detail – Tables P1 – P19).

Assessment and Construction Assumptions

There appears to be good, naturally-occurring road building gravels along most of the route. There also appears to be adequate sources of water although boreholes for construction water may be required. There are significant massive rock formations visible from the road at several locations, which indicate potential quarry sites.

It also appears that there are no roadside property encroachments into the road reserve that would limit construction efforts. Properties in settlement areas are set well-back from the road. Further, it is assumed that no land acquisition will be required to construct the road. Finally, there are no obvious environmental issues to consider and certainly the sealing of the road with bituminous pavement will reduce the level of dust and have a significant positive impact in settlement areas.

The eight bridges are 12, 18, 21 & 27 meters single span and 36 (2), 55 & 76 meters multi span bridges (see Table 1 in **Annex 2**). All bridges are steel truss bailey type bridges. The bridges are single lane approx 3.5m wide. All have steel plate decks except Aswa which has a timber deck. All of the bridges need immediate maintenance. The abutments were a mixture of earth, masonry and concrete – all showing signs of distress (cracks, erosion, and movement). Aswa and Kit have significant water courses. Some of the bridge sites have evidence of previous structures on parallel alignments. The possible presence of mines at the bridge sites is a concern.

For construction purposes it is assumed that the Project Road will basically be within the existing footprint. No major earthworks are anticipated. Where the existing road has good gravel material, it will probably be sufficient, after some regulating, to rip and re-compact the top 150mm and, for the purpose of this estimate, assume that this will provide a sub-base equivalent. This is assumed as a nominal 7m width along the length of the road. Outside of this 7m width some earthworks will be required to provide a suitable road bed to be covered with a 150mm layer of sub-base type material. This is assumed as a 5m-wide area throughout. This will give the required 12m-wide base for road construction – this will be of a sub-base standard with a CBR in excess of 30.

Depending on the pavement construction additional layers of sub-base may be required. The road base will be either a crushed stone base course 150mm thick, or a natural gravel base course stabilized with 4 percent cement. This will provide the base for sealing, with either: (i) double spray and chip – 80/100 bitumen binder with first application nominal 19mm crushed stone aggregate and a second application of nominal 9mm aggregate; or (ii) hot mix asphalt – 60mm dense bitumen macadam base and 40mm asphalt concrete wearing course. For AC pavements alternatives with hot mix asphalt base course have also been considered.

Side drainage will be provided throughout except along the ridge sections. Side drains will be simple “v” drains cut in the verges. Outfalls to existing watercourses or by simple drains to surrounding area will be used to dispose of run off. Culverts, either concrete or steel Armco type, scour protection and stone pitching will be provided as required. The existing alignment has extremely few (around 30) culverts because of the topography and well selected alignment. Nevertheless an allowance for 300 culverts has been made (one culvert every 650m). The minimum size is 900mm diameter to allow easy access for maintenance. An allowance for 25 substantial box culverts has been made, although only three culverts were actually found on the whole alignment.

It is intended that all eight bridges be completely replaced with new, two-lane bridges with 7.0m carriageway and walkways. It has been assumed that the 12m span bridge will be a simple reinforced concrete (r.c.) structure with the deck cast in place. For spans greater than 15m cast in place r.c. is unlikely to be suitable. Pre-stressed concrete technology is not commonly used in the region but would provide up to 30m spans without difficulty (but unless cast on site transport of beams would be a problem). Post tensioned pre-cast sections would also be suitable but again are not commonly in use (benefit is short sections could be cast outside and transported).

Composite decks with steel "I" beams would provide suitable structural solution but production and transport of the beams may be a problem. Alternatively, steel truss bridges could be used; simple and fast to construct Austrian / Australian trusses with reinforced concrete decks would be appropriate. The issue of maintenance for steel bridges is disadvantageous in comparison to concrete structures.

The road passes through significant settlement areas at either end (Juba suburbs and Nimule) and also through Aru, Moli, Pageri settlements on the way. It is assumed that in these areas special provisions will be made – curbed sections, bus stops, truck stops, paved areas, traffic calming measures (speed bumps) etc. Street lighting will be considered for these areas.

Safety guardrails will be provided as appropriate on embankments, tight bends and at hazards. Road markings and road studs will be provided to meet required standards. Road signs, mandatory and information signs will be erected.

The only section of road with an alignment that requires improvement is approximately 3 km at the Nimule end. As the road approaches Nimule it climbs up and around "Gordon Hill" before descending the other side, winding down into Nimule town from the north. The road is cut into the hillside for a significant part of this alignment. The hill is well weathered rock that appears to have been excavated mechanically. The road is substandard in many respects – width of carriageway, curve radii, visibility and drainage. This can be rectified but will involve a significant amount of rock excavation. An alternative alignment exists to the east which runs around the bottom of the hill and enters Nimule from the east. This is an old route now disused and almost completely obliterated. Nevertheless it may be a viable alternative to "fixing" the hillside route. This would involve about five km of new alignment and have the associated difficulties of a new section (land acquisition, checking for mines, etc.). The study of this alternative is beyond the scope of this feasibility study. It will be analyzed at the detailed design stage.

It is assumed that the main construction works will be implemented by modern, fully-mechanized construction methods. The urgency and importance of this road requires the best possible work. Nevertheless we are fully aware of the efforts to provide employment for Southern Sudanese nationals and to provide training and opportunities for Southern Sudanese contractors and business. Accordingly we foresee that simple ancillary works may be sub-contracted to local firms where possible. Further we would propose that a program of starter road construction is included in the contracts. This will involve constructing an estimated 3-5 km of minor / feeder roads from their junctions with the main route. This program can be carried-out as a labor- based construction program in partnership with the local government and will serve to provide good feeder connections to the new Project Road, employment for the local people, opportunities for local business and experience for the local government.

The project schedule shown in figure 3.1 also includes the following assumptions:

- The road will be divided into three 65 km sections for construction, to be bid as separate contracts

- There will be three topographic and two soils and materials teams conducting the surveys
- Each contractor will establish their own mobile, material testing laboratory
- Designs will be carried out by experienced, Autocad qualified engineers
- Demining of the 26m corridor will have been completed under the WFP contract before surveying begins
- A demining team will accompany each of the three topographic survey teams to allow activities outside the standard 26m corridor
- Security will be maintained by the Government of Southern Sudan
- Since the road is under traffic, only one lane will be paved at a time and traffic will not be allowed on until both courses have been put down.
- Construction of earthworks, sub-base, base and bridges can take place during the rainy season. No pavement will be put down during the rainy season.

Costs

Project costs considered in this evaluation include improvement interventions for upgrading to: (i) unpaved standards; (ii) double bituminous surface treatment; and (iii) asphalt concrete, as required by the HDM-4 Model.

Fuels, bitumen, cement and steel are readily available in Kenya and Uganda. There are plentiful natural gravels adjacent to the work site. Currently there is no stone crusher operation in Southern Sudan. An old crushing plant in Juba is being revitalized but is not yet operational. It is assumed that contractors will establish their own crushing plant(s) for implementation of this project. The large quantities of crushed stone that are required to complete the Project Road make it economical to invest in a crushing plant(s). It is also assumed that government (local or Government of Southern Sudan (GOSS)) will ensure that access to local natural materials (including water) is made available at either no cost or for a reasonable royalty.

Unit rates, from previous or ongoing construction contracts in Southern Sudan, Uganda and Kenya, have been collected from a number of sources (see Table 4 in **Annex 2**) for this study:

- WFP contracts for rehabilitation and repair works of gravel roads in Southern Sudan;
- Construction of gravel, double seal and asphalt roads in Juba town as part of Juba emergency repair works;
- Rates from a recently contracted projects contract in Kenya; and
- Rates from road agency contracts in Uganda.

It is considered that these rates give a fairly-representative range of prices that are indicative of what is likely to be bid if Juba-Nimule is tendered. It must be remembered that:

- WFP procurement was not open bid; their work items were not standard and the specifications unclear;

- The Juba emergency repair works were internationally bid and the winning contractor was the second lowest bid – nevertheless the rates are considered very high, the quantities of sealed road are low.
- Rates for Kenya and Uganda are typical for local contractors working in their own environment but rates for contractors who come North to work in Southern Sudan will necessarily involve some kind of premium, e.g. getting commercial insurance for Southern Sudan is difficult and expensive.

The costs for major pay items were determined using the quantities, specified earlier, and were based on the assumptions noted above. The construction costs of the bridges were divided between the four sections of the Project Road, proportionally to their lengths. This is because although all the bridges are in the section from Torit Junction to Nimule Center, they need to be fixed to allow normal traffic flows along the whole project road. An allowance for minor pay items has been made. It is assumed that works will be done based on the Interim Design standard specifications which are to be adopted by GOSS.

Although it has been assumed that the new road will be in the existing footprint, allowances have been made for some earthworks cut/fill and for rock cut to widen the road over Gordon Hill. Quantities for side drains and culverts, regularly spaced, are included.

The cost of three alternative pavement options has been assessed – gravel wearing course, double seal and asphalt concrete. It has been assumed that the sealed options have a natural gravel road base stabilized with cement. The available natural gravels comprise lateritic and quartzitic gravels which have a large percentage of rounded stones and pebbles. The gravel wearing course obviously excludes road markings and road studs but is otherwise the same design as a sealed road. Both of the sealed road options have a cement stabilized base as is common practice in the region. (Table 2 and Table 3 in **Annex 2** present the estimated costs and quantities used.)

The cost estimate is completed with an allowance for preliminary and general items (P&Gs). This is intended to include the contractors establishment cost, insurances, security, services for the employer (to include offices, vehicles, accommodation, laboratory, communications, etc.). This sum also allows for “extra costs” the contractor may require for working in Southern Sudan. The range of construction costs for each of the three alternative pavement options have been derived from the bills of quantities and are roughly estimated as a cost per km, below:

- From US$ 416,000 to US$ 530,000 per km for asphalt concrete (AC), with an average cost per km of ***US$ 418,000;***
- From US$ 287,000 to US$ 402,000 per km for double bituminous surface treatment (DBST), with an average cost per km of ***US$ 290,000; and***
- From US$ 136,000 to US$ 250,000 per km for an unsealed road, with an average cost per km of ***US$ 138,000.***

These rates are high in comparison to similar rates in the region. The reason they are high is because of the high cost of working in Southern Sudan with its real and perceived risks and difficulties. Further the road cross section is for a high standard including some additional work in urban areas, such as wider carriageways, non-motorized vehicle lanes and curbs. Even the gravel road option is a very high standard cross section and geometry for this type of pavement. Nevertheless for the purposes of this feasibility study and budgeting, these costs are considered a reasonable and realistic estimate of potential bid prices.

Total costs for the investment of the whole project road, before value added tax (VAT) are based on the preliminary findings from the Consultant. They include: (i) detailed design and supervision – project management costs, representing seven percent of construction costs; and (ii) environmental mitigation measures – about US$ 400 thousand for all construction alternatives. They are as follows:

- Upgrade to AC standard: ***US$ 86.36 million***;
- Upgrade to DBST standard: ***US$ 59.89 million***; and
- Upgrade to unpaved standard: ***US$ 28.82 million***.

For the economic evaluation in this feasibility study, physical and financial contingencies – representing 10 and 15 percent of construction costs respectively – were added to the above costs

More details on construction costs defined by the Consultant – total cost and cost per km – are provided in Table 3.1, Table 3.2 and Table 3.3, below:

Table 3.1: Cost estimates – Asphalt Concrete

Total Cost (in US$)

Juba to Nimule Road - Asphalt Concrete	Chainage		Length (in km)	Core costs				Others Cost		Total Financial Costs
				Cost from BOQ	Project Management Costs	Environmental mitigation measures	Net construction cost	Physical	Financial	
				1	*2 = 7%(1)*	*3*	*4 = 1 + 2 + 3*	*5 = 10%(4)*	*6 = 15%(4+5)*	*7 = 4 + 5 + 6*
Juba Bridge - Bor Jct.	Km 0.000	- Km 3.400	3.40	1,641,997	114,940	11,569	1,768,506	176,851	291,803	2,237,160
Bor Jct. - Torit Jct.	Km 3.400	- Km 20.800	17.40	7,286,981	510,089	40,131	7,837,201	783,720	1,293,138	9,914,059
Torit Jct. - Nimule Center	Km 20.800	- Km 190.000	169.20	70,349,817	4,924,487	316,763	75,591,067	7,559,107	12,472,526	95,622,699
Nimule Center - Ugandan Br.	Km 190.000	- Km 192.000	2.00	1,060,998	74,270	31,238	1,166,505	116,651	192,473	1,475,629
Total			**192.00**	**80,339,793**	**5,623,786**	**399,700**	**86,363,279**	**8,636,328**	**14,249,941**	**109,249,547**

Project & management costs =	*7%*
Physical contingencies =	*10%*
Financial contingencies =	*15%*

Notes: all bridge costs are allocated to Section 3.
Section 1 and 4 have the bulk of urban section costs (curbs, footpaths etc)

Cost per km (in US$)

Juba to Nimule Road - Asphalt Concrete	Chainage		Length (in km)	Core costs				Others Cost		Total Financial Costs
				Cost from BOQ	Project Management Costs	Environmental mitigation measures	Net construction cost	Physical	Financial	
				1	*2 = 7%(1)*	*3*	*4 = 1 + 2 + 3*	*5 = 10%(4)*	*6 = 15%(4+5)*	*7 = 4 + 5 + 6*
Juba Bridge - Bor Jct.	Km 0.000	- Km 3.400	3.40	482,940	33,806	3,403	520,149	52,015	85,825	657,988
Bor Jct. - Torit Jct.	Km 3.400	- Km 20.800	17.40	418,792	29,315	2,306	450,414	45,041	74,318	569,774
Torit Jct. - Nimule Center	Km 20.800	- Km 190.000	169.20	415,779	29,105	1,872	446,756	44,676	73,715	565,146
Nimule Center - Ugandan Br.	Km 190.000	- Km 192.000	2.00	530,499	37,135	15,619	583,253	58,325	96,237	737,815
Average			**192.00**	**418,436**	**29,291**	**2,082**	**449,809**	**44,981**	**74,218**	**569,008**

Table 3.2: Cost estimates – Double Bituminous Surface Treatment

Total Cost (in US$)

Juba to Nimule Road - Double Bituminous Surface Treatment	Chainage		Length (in km)	Core costs				Contingencies		Total Financial Costs
				Cost from BOQ	Project Management Costs	Environmental mitigation measures	Net construction cost	Physical	Financial	
				1	*2 = 7%(1)*	*3*	*4 = 1 + 2 + 3*	*5 = 10%(4)*	*6 = 15%(4+5)*	*7 = 4 + 5 + 6*
Juba Bridge - Bor Jct.	Km 0.000	- Km 3.400	3.40	1,203,838	84,269	11,569	1,299,675	129,968	214,446	1,644,089
Bor Jct. - Torit Jct.	Km 3.400	- Km 20.800	17.40	5,044,642	353,125	40,131	5,437,898	543,790	897,253	6,878,941
Torit Jct. - Nimule Center	Km 20.800	- Km 190.000	169.20	48,545,000	3,398,150	316,763	52,259,913	5,225,991	8,622,886	66,108,789
Nimule Center - Ugandan Br.	Km 190.000	- Km 192.000	2.00	803,258	56,228	31,238	890,724	89,072	146,969	1,126,765
Total			**192.00**	**55,596,738**	**3,891,772**	**399,700**	**59,888,210**	**5,988,821**	**9,881,555**	**75,758,585**

Project & management costs =	*7%*
Physical contingencies =	*10%*
Financial contingencies =	*15%*

Notes: all bridge costs are allocated to Section 3.
Section 1 and 4 have the bulk of urban section costs (curbs, footpaths etc)

Cost per km (in US$)

Juba to Nimule Road - Double Bituminous Surface Treatment	Chainage		Length (in km)	Core costs				Contingencies		Total Financial Costs
				Cost from BOQ	Project Management Costs	Environmental mitigation measures	Net construction cost	Physical	Financial	
				1	*2 = 7%(1)*	*3*	*4 = 1 + 2 + 3*	*5 = 10%(4)*	*6 = 15%(4+5)*	*7 = 4 + 5 + 6*
Juba Bridge - Bor Jct.	Km 0.000	- Km 3.400	3.40	354,070	24,785	3,403	382,257	38,226	63,072	483,556
Bor Jct. - Torit Jct.	Km 3.400	- Km 20.800	17.40	289,922	20,295	2,306	312,523	31,252	51,566	395,341
Torit Jct. - Nimule Center	Km 20.800	- Km 190.000	169.20	286,909	20,084	1,872	308,865	30,886	50,963	390,714
Nimule Center - Ugandan Br.	Km 190.000	- Km 192.000	2.00	401,629	28,114	15,619	445,362	44,536	73,485	563,383
Average			**192.00**	**289,566**	**20,270**	**2,082**	**311,918**	**31,192**	**51,466**	**394,576**

Table 3.3: Cost estimates – Unsealed

Total Cost (in US$)

Juba to Nimule Road - Unsealed	Chainage		Length (in km)	Core costs				Others Cost		Total Financial Costs
				Cost from BOQ	Project Management Costs	Environmental mitigation measures	Net construction cost	Physical	Financial	
				1	*2 = 7%(1)*	*3*	*4 = 1 + 2 + 3*	*5 = 10%(4)*	*6 = 15%(4+5)*	*7 = 4 + 5 + 6*
Juba Bridge - Bor Jct.	Km 0.000	- Km 3.400	3.40	689,671	48,277	11,569	749,517	74,952	123,670	948,139
Bor Jct. - Torit Jct.	Km 3.400	- Km 20.800	17.40	2,413,316	168,932	40,131	2,622,379	262,238	432,693	3,317,310
Torit Jct. - Nimule Center	Km 20.800	- Km 190.000	169.20	22,957,627	1,607,034	316,763	24,881,423	2,488,142	4,105,435	31,475,001
Nimule Center - Ugandan Br.	Km 190.000	- Km 192.000	2.00	500,807	35,056	31,238	567,101	56,710	93,572	717,383
Total			**192.00**	**26,561,421**	**1,859,299**	**399,700**	**28,820,420**	**2,882,042**	**4,755,369**	**36,457,832**

Project & management costs =	*7%*
Physical contingencies =	*10%*
Financial contingencies =	*15%*

Notes: all bridge costs are allocated to Section 3.
Section 1 and 4 have the bulk of urban section costs (curbs, footpaths etc)

Cost per km (in US$)

Juba to Nimule Road - Unsealed	Chainage		Length (in km)	Core costs				Others Cost		Total Financial Costs
				Cost from BOQ	Project Management Costs	Environmental mitigation measures	Net construction cost	Physical	Financial	
				1	*2 = 7%(1)*	*3*	*4 = 1 + 2 + 3*	*5 = 10%(4)*	*6 = 15%(4+5)*	*7 = 4 + 5 + 6*
Juba Bridge - Bor Jct.	Km 0.000	- Km 3.400	3.40	202,844	14,199	3,403	220,446	22,045	36,374	278,864
Bor Jct. - Torit Jct.	Km 3.400	- Km 20.800	17.40	138,696	9,709	2,306	150,711	15,071	24,867	190,650
Torit Jct. - Nimule Center	Km 20.800	- Km 190.000	169.20	135,683	9,498	1,872	147,053	14,705	24,264	186,022
Nimule Center - Ugandan Br.	Km 190.000	- Km 192.000	2.00	250,404	17,528	15,619	283,550	28,355	46,786	358,691
Average			**192.00**	**138,341**	**9,684**	**2,082**	**150,106**	**15,011**	**24,768**	**189,885**

Maintenance

This section defines the maintenance operations – routine and periodic – and their unit costs, for each of the three pavement options.

Maintenance operations

The Consultant defined three main maintenance policies, one for each of the surfaces being studied, with some variation regarding the unpaved surface depending on the following criteria: (i) maintenance in the existing situation; (ii) maintenance before improvement; and (iii) maintenance on the new gravel road structure. These maintenance policies all include routine and periodic maintenance operations. For each of the maintenance interventions, the team defined: (i) the time of intervention – scheduled or responsive to external factors, such as traffic levels or condition of the road surface; (ii) some engineering characteristics of the intervention – e.g. the thickness of the pavement; (iii) the condition of the surface after the intervention; and (iv) the financial and economic unit costs.

The minimum alternative does not necessarily mean that nothing is being done on the road. In effect, if this were the case, the road would collapse and benefits would hence be over-estimated in the with-project scenarios. Therefore, the minimum alternative is generally made of the same maintenance operations as in the enhanced investment alternative, although the quality of the works or the frequency of the interventions might be less.

A maintenance policy is made of several maintenance operations. The maintenance policy for a bituminous pavement consists of routine maintenance, including drainage, and patching. For an unsealed pavement, the maintenance policies consist of: (i) grading for routine maintenance – two times a year; and (ii) re-graveling for periodic maintenance, every year, ensuring that final gravel thickness is 150 mm.

In addition, the bituminous road options have the following periodic maintenance policies:

- *Single surface dressing with shape correction*: work is recommended when IRI reaches 4.5; the thickness of the new surfacing is 12 mm, with a dry season strength coefficient of 0.2. The result is a carriageway with a roughness of 2.2.
- *Thin overlay*: work is recommended when IRI reaches 4.5; the thickness of the new surfacing is 30 mm, with a dry season strength coefficient of 0.2. The result is a carriageway with a roughness of 2.

Costs

Project costs considered in this evaluation include routine and periodic maintenance, as required by the HDM-4 Model according to the criteria described above. Unit costs were estimated by the Consultant for the purpose of this study. For periodic maintenance, these costs include design and supervision costs.

Financial costs for the recurrent maintenance operations of unpaved roads are:

- Grading: US$ 700 per kilometer
- Regraveling: US$ 11 per cubic meter

Financial costs for the recurrent maintenance operations of bituminous roads are:

- Routine maintenance / drainage: US$ 500 per kilometer
- Patching: US$ 7.5 per square meter

Financial costs for the periodic maintenance interventions (including preparatory works) of bituminous roads are:

- Thin overlay 30 mm: US$ 8.5 per square meter
- Surface dressing simple 12 mm: US$ 4 per square meter

4. ENVIRONMENTAL STUDY

This chapter presents the Socio-Environmental Management Plan (SEMP) of the Juba - Nimule Road Rehabilitation Project. The SEMP presents a summary of the impacts and mitigation measures for the proposed project activities identified by the Juba – Nimule Environmental Study (JNES) which forms a separate report to compliment this feasibility study. The purpose of this chapter and the JNES is not to produce a document pursuant to USAID environmental regulation 22 CFR 216, but to provide a socio-environmental overview to the Project for the purpose of this feasibility study. USAID has already completed an Initial Environmental Evaluation (IEE) of the Strategic Objectives 9, 10 and 11 under their Southern Sudan Strategy. The IEE recommends that road building activities are a 'Positive Determination' and that:

> USAID will not finance road construction unless the proposed road segment has undergone a review using the environmental checklist in USAID Programmatic Environmental Assessment (PEA) […] and construction contracts include specified mitigation actions in the contract clauses.

The Consultant has completed the checklist as recommended by the PEA and has submitted its findings as an Environmental Review to USAID for their comments. Accordingly, this chapter does not address the PEA process nor does it attempt to engage in an analysis of the Consultant's obligations under 22 CFR 216.

Proposed Actions

The Project Road under consideration begins at the east bank of the Nile bridge at Juba and extends to the south bank of the Anyama Bridge at the Ugandan border in Nimule (approximately 192 km). In order to complete the project, a number of action items have been proposed:

- De-mining work will have to be completed so that the entire length of the road is certified. It is understood that this confirms a minimum width of 26m will have been checked;
- The road in the non-urban areas will have a 7.0m carriageway with 2.0m shoulders. The alignment will be improved to provide required sight distances and appropriate curve radii;
- Major river crossings will have new reinforced concrete bridges with 7.0m carriageway. Culverts will be installed / improved as required. Unlined side drains with turn outs for run off will be constructed in rural areas;
- Urban cross-section will have a 9.0m carriageway, including non-motorized traffic lanes. Pedestrian footpaths, bus stops and lay-bys will also be provided;
- The existing road will provide the road-bed for the new works. The road will be paved with AC or DBST on top of a newly constructed gravel road base; and
- Road markings and signs will be provided. There will be no street lighting on rural sections of road. Urban / semi-urban areas will be considered for street

lighting. Speed control / traffic calming measures will be constructed where the road passes through settlements.

A number of alternatives have been discussed at the planning stage. These alternatives relate to alignment and type of road rehabilitation. At this stage of the project, no significant changes to the alignment of the road are anticipated. Some small changes to the curve radii may be required for safety purposes. However, such impacts will only affect narrow portions of roadside vegetation and will not impact upon any of the roadside population. In addition, alternative surface types have been discussed and include Asphalt Concrete, Double Bituminous Surface Treatment (DBST) and Unsealed Surface. The report considers the impacts of Asphalt and DBST surfaces which both have similar environmentally-related benefits and drawbacks. Rehabilitating the road with an unsealed surface has not been considered as it is felt that from a socio-environmental point of view the benefits of such work would be minimal and that the benefits of an Asphalt road or a DBST road far outweigh the benefits of an unsealed road. An unsealed road would have increased negative air quality impacts (including continues high levels of solid particulate matter), noise impacts (asphalt and DBST surfaces are quieter), safety impacts (an unsealed surface is more dangerous to drive on) and social impacts (journey times will be greater and maintenance costs higher on an unsealed surface) than the other two surface options.

Impact Identification

Field surveys undertaken in January 2007, combined with extensive data review, produced a detailed description of the existing socio-environmental conditions in the Project Area. These existing conditions were used as a baseline and measured against a number of potential environmental impacts that will most likely occur as a result of the project. A full description of the existing conditions can be found in the JNES, but for purposes of this feasibility study, a list of the categories and a summary of the likely environmental impacts of each of the categories, is presented below:

Topography - Potential impacts to topography are most likely to occur in the construction stage due to the possibilities of:

- *Cut and Fill Requirements*. There is a possibility that cut and fill activities may occur in certain sections, particularly in the area of Gordon Hill.
- *Borrow Pit Excavations*. Embankments and other requirements for fill may necessitate the use of borrow pits in some areas.

Soils - Potential impacts to soils due to project location, project design, and operational phases include:

- *Loss of Soil for Agricultural Production*. Road rehabilitation activities may impact upon any adjacent agricultural land.
- *Erosion*. Certain types of road improvements (e.g., road widening) result increased runoff and/or increased velocities could lead to additional soil loss. In this instance, however, virtually all rehabilitation activities will be confined to the existing roadway and no significant increase in the amount of impervious surfaces and/or the quantity or velocity of runoff is anticipated.

- *Contamination Due to Spills or Hazardous Materials*. Spills of oil or other hazardous liquid wastes may occur from construction equipment and storage areas.

Geology - Geological resources could be affected due to project-induced demand for resources such as rock, sand and building materials. However, project-induced demand is unlikely to cause or contribute significantly to their depletion in this region.

Hydrology - Potential impacts to water resources are most likely to occur in the construction and operational phases of the project and include impacts to:

- *Surface Hydrological Characteristics*. Potential impacts include:
    - Suspension of river sediments resulting from construction and rehabilitation of bridges, notably at the Anyama crossing and Aswa crossing.
    - Accidental spills and leaks of oil from construction machines operating in or near the rivers. Such spills can affect water quality, particularly during the fish spawning season.
    - Exploitation of water for construction activities may reduce the availability of water for domestic or agricultural use.
    - Discharge of untreated liquid waste from construction camps into surface water courses.
    - Water quality in roadside water bodies may show slight improvements after road upgrading due to reduced erosion from improved embankment slopes and stabilization by rip-rap or other material including vegetation to prevent soil erosion.
    - Within the operational phase of the project, the proposed improvements to drainage structures, including culverts and side drains, will facilitate passage of high water flows and reduce scouring and bank erosion in the vicinity of the road, ensuring the integrity of the road surface.
- *Area Wetland Characteristics*. No significant or ecologically important wetlands exist in the project area.
- *Subsurface Hydrology*. It is anticipated that surface water courses will provide the contractor with the necessary water requirements for construction purposes, as such there will be not requirement to drill any boreholes to extract groundwater.
- *Flood and Inundation Characteristics*. Increased runoff in the both the construction and operational phases of the Project could result in adverse flooding conditions. Raising the road formation level in flood-prone areas without installing culverts or other cross drainage structures to allow floodwaters to equilibrate and pass freely could result in adverse impacts.

Climate and Air Quality – impacts are twofold: (i) during the construction period; and (ii) during operation of the road:

- *Construction Phase Impacts*: potential air quality impacts during the construction phase of the project can be anticipated due to fugitive dust generation in and around construction activities and related activities such as

quarries and rock crushing, hot-mix and asphalt plants. Emissions from construction vehicles and motorized equipment may also induce negative air quality impacts.

- *Operational Phase Impacts*: rehabilitation of the roadway to an asphalt / DBST surface will significantly reduce the dust levels produced adjacent to the project road, thus significantly improving the air quality within the project corridor.

Fauna - Consideration has been given to potential direct impact to wildlife under the following headings:

- *Habitat Loss.* All the proposed rehabilitation activities will occur within the existing roadway or previously disturbed agricultural areas adjacent to the road with little loss of habitat.
- *Habitat Fragmentation*. Habitat fragmentation occurs when a road cuts through an ecosystem. The proposed activities are confined to the existing roadway and as such, construction of the Project Road will not induce any further habitat fragmentation.
- *Wildlife Migrations*. Animals do migrate across the existing roadway and there are accidents involving animals. It is unlikely that migration patterns will be ceased or delayed as a result of an improvement to the road surface conditions. However, it is possible that an increase in traffic volumes may result in an increased incidence of road kill. In addition, the improper sitting of construction camps may impact upon migration routes.

Consideration has also been given to potential *indirect* wildlife impacts under the following headings:

- *Accessibility*. Penetration of previously unmodified areas and upgrading existing roads generally facilitates an increase in the number of people having access and is accompanied by an increase in the likelihood of impacts. In this instance, improvements to the road will increase accessibility to Nimule National Park (NNP). However, the Ministry of Environment, Wildlife, Culture and Tourism (MEWCT) are actively promoting NNP as a tourist destination and as such this increased accessibility, as long as it is controlled, will be beneficial for the local economy and the survival of the park itself.

Flora - No threatened or endangered plant species are located in the Project Road area and no adverse impacts to such species are likely to occur due to rehabilitation activities. All rehabilitation activities will be confined to the existing roadway. Construction activities will impact only a narrow band of vegetation adjacent to the existing highway. Rehabilitation activities may also require the construction of detours which may pass through vegetated areas.

Protected Areas - The Project Road does not traverse any protected area. However, as mentioned above it runs parallel to the NNP buffer zone from Aswa Bridge to Gordon Hill. The buffer zone is more than two kilometers wide and the park is located on the west bank of the White Nile. As a result of these factors, the potential for project activities to impact the park is greatly reduced.

Socio-Economic Considerations - Potential impacts to the main sectors of the economy in the project area are as follows:

- *Agriculture*. Little or no agricultural displacement will occur due to the project. Access to markets (particularly in Juba) for the remaining agricultural uses, however, will be enhanced, thereby resulting in a beneficial impact.
- *Industry*. Little industrial activity is undertaken within the vicinity of the Project Road. However, improvements to the Project Road will ultimately lead to the expansion of industrial activity in Juba because businesses will be provided with improved access to the Ugandan markets and be better-situated to import and export critical items such as heavy equipment and parts for maintenance.
- *Service Sector*. The potential of the project area for service sector employment may be enhanced as a result of expenditures and demands for services during the construction period and the facilitation of service sector activities (roadside vending, traveler services, etc.) once the rehabilitation activities are completed.
- *Resettlement and Compensation*. Project activities could result in the requirement to resettle persons living and working close to the road.

Historic and Cultural Resources - No impacts to such resources have been identified.

Public Health and Safety - Human health risks associated with road projects typically include the following issues: transmission of diseases along previously undeveloped corridors; contamination of local water supplies; air and noise pollution; and issues related to road safety and accidents. Road projects can be inadvertently instrumental in the decline in health of a local population in several ways. During either the construction or operational periods or both, it can:

- *Facilitate the transmission of diseases*. Improved access to Juba will result in more people traveling the Project Road, which, in turn will lead to an increased number of infected persons using the corridor and a potential spread of the disease within the corridor;
- *Contaminate local water supplies*. Potential impacts to local water supplies include the possibility of temporary labor camps and the water supply and wastewater disposal associated with them during the construction period;
- *Pollute the air*. Air emissions will increase with traffic volumes once the Project Road is rehabilitated. However, the benefit of a bituminous surface will significantly reduce dust levels adjacent to the Project Road. Therefore construction of the Project Road will have, overall, a beneficial impact on air quality.
- *Become a source of noise pollution with health consequences*. Potential noise issues are discussed below.

Noise - impacts are twofold: (i) during the construction period; and (ii) during operation of the road:

- *Construction Phase*. Temporary impacts in the immediate vicinity of the project may occur due to construction. The magnitude of impact will depend upon the specific types of equipment to be used, the construction methods employed

and the scheduling of the work. General conclusions can be based on the types of construction work anticipated, the types of equipment required and their associated range of noise levels. The rehabilitation activities in some areas may include excavation for foundations and grading.

- *Operational Phase*. Sources of road noise during the operational phase of road projects, generally considered in the context of road projects, include:
    - Vehicle Noise. Traffic noise will increase as traffic volumes increase. However, all the identified sensitive receptors are set well back from the Project Road and as such are unlikely to be impacted by an increased noise levels.
    - Driver Behavior. Drivers contribute to road noise by the use of horns, the playing loud music, shouting and causing tires to squeal as a result of sudden breaking or acceleration. Driver behavior in the project corridor generally appeared to be good, very little horn use was heard and most of the aging vehicles using the road do not have functioning radio equipment. As above, sensitive receptors are unlikely to be affected by such behavior.
    - Construction and Maintenance. Road construction and maintenance generally require the use of heavy machinery.
    - Wildlife Movements. Increased vehicle noise may frighten wildlife and prevent them from crossing the road as their migration patterns dictate. Noise levels may also affect feeding behavior and breeding rituals.

Aesthetics – Construction of the project is restricted to the existing corridor and involves rehabilitation only. Accordingly, there will be no impacts to the aesthetics of the surrounding environment. Moreover, it is also unlikely that the affected areas will suffer development pressure of a magnitude that will detract from their aesthetic qualities.

Solid and Liquid Waste - Solid and liquid waste will result directly from construction activities and will include solid construction waste and solid and liquid waste from construction camps (most notably from septic tanks and diesel fuel generators). There may also be a limited quantity of potentially hazardous liquid waste from machinery maintenance activities.

Mines / UXO - Mines and unexploded ordnance (UXO) within the project corridor can have fatal impacts to construction workers, vehicle users, pedestrians and wildlife.

Socio-environmental Management Plan

To ensure that the identified environmental impacts are mitigated, a Socio-Environmental Management Plan (SEMP) has been developed (See Table 4.1, immediately below).The SEMP includes an outline of the proposed mitigation measures and assigns the responsible parties to implement each task. The plan also includes details of the required monitoring to ensure that all mitigation measures are implemented according to the SEMP. In addition, the costs of the mitigation measures have been estimated and are included in the plan (See Table 4.2, within Section 4.4, below, for a breakdown of these costs).

Table 4.1: Socio-Environmental Management Plan

Issue	Mitigation	Responsibility	Monitoring Method	Monitoring Frequency	Monitoring Responsibility
Topographic Conditions - Cut and Fill Requirements in the Gordon Hill Area	Mitigation measures include: - Specification that final forming and re-vegetation will be completed as soon as possible following fill placement to facilitate regeneration of a stabilizing ground cover. - Seeding with a fast growing crop and potential native seed mix immediately after fill placement will be required to prevent scour and to encourage stabilization. - Stepped embankments for embankments greater than six meters. Construction in erosion- and flood-prone areas should be restricted to the dry season. - Ensure that no earth, rock or debris is deposited on public or private rights of way as a result of its operations, including any deposits arising from the movement of Construction Plant or vehicles. - All cut to be balanced with fill where practical	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Daily during cut and fill works by CSS and weekly by MTR	MTR
Topographic Conditions – Borrow Pit Excavations	Where practical, existing borrow pits opened during the WFP rehabilitation works will be used. In the event that new borrow pits are required bid and contract documents will specify that: - New borrow areas will not be located within one kilometer of any settlements. - No borrow pits shall be excavated within the NNP buffer zone. - The excavation and restoration of the borrow areas and their surroundings, in an environmentally sound manner will be required before final acceptance and payment under the terms of contracts. - Topsoil from borrow pit areas will be saved and reused in re-vegetating the pits. - Additional borrow pits will not be opened without the restoration of those areas no longer in use.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	MTR to approve borrow pit before excavation	Prior to excavation	MTR
Soils - Erosion.	Soil erosion will be prevented by the construction of correctly designed culverts. Improvements in drainage structures will better contain the intermittent flows to existing drainage ways and reduce sheet erosion which may occur when the road is overtopped by flash flooding. Mitigation plantings will be provided to stabilize the soil and reduce erosion. As detailed in the hydrology discussion below, drainage will be upgraded and drainage ways will be adequately sized, lined and contoured to minimize erosion potential.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Daily by CSS and weekly by MTR	MTR
Soils – Contamination due to Spills	Mitigation measures include: - All fuel and chemical storage (if any) shall be sited on an impervious base within a bund and secured by fencing. The storage area shall be located away from any watercourse or wetlands. The base and bund walls shall be impermeable and of sufficient capacity to contain 110 percent of the volume of tanks. - Filling and refueling shall be strictly controlled and subject to formal procedures. - All valves and trigger guns shall be resistant to unauthorized interference and vandalism and be turned off and securely locked when not in use. - The contents of any tank or drum shall be clearly marked. Measures shall be taken to ensure that no contaminated discharges enter any drain or watercourses.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Periodic throughout construction phase	MTR

Issue	Mitigation	Responsibility	Monitoring Method	Monitoring Frequency	Monitoring Responsibility
Geology – Quarries and Aggregates	The contractor will be responsible for opening and operating their own quarries. It is recommended that the quarry only be opened once MTR has approved the quarry area after checking the location to ensure that the quarry area is not located in irrigated agriculture land, grazing land, protected areas, buffer zones, water bodies, stream and seepages areas, wetlands, or area supporting rare flora/fauna and not within 0.8 km of settlements, and in ecologically stable land. In addition, MTR will ensure that the correct compensation has been paid to the landowner of the quarry site. After project works are complete MTR will retain the responsibility for operating the site for road maintenance purposes.	Approval of the quarries sitting by the MTR. Compensation issues to be handled by MTR. Operation of quarry after Project by MTR.	MTR to approve quarry before excavation	Prior to excavation	MTR
Hydrology – Surface Hydrological Characteristics, Design Phase	It is recommended designs ensure that the road drainage provisions and new embankments do not alter the current status of natural water bodies and irrigation structures adjacent to alignments.	MTR and Design Consultants.	None	None	None
Hydrology – Surface Hydrological Characteristics, Operational Phase	Contract provisions shall ensure that: - Cofferdam techniques will be used in bridge column construction with complete isolation of work areas to minimize adverse impacts to surface water during construction. River crossing construction activities will be scheduled to the extent possible during the low flow periods. - Contract provisions will ensure that construction camps are sited at least 500 meters from surface water courses. - Any accidental leaks or spills of oil or any other hazardous chemical should be prevented by good site management. However, should a liquid spill occur then it should be stopped as quickly as possible. - During the dry season water for construction purposes may only be abstracted from the Aswa and White Nile Rivers. During the wet season water may be abstracted from any of the rivers noted within the vicinity of the Project Road. - For the Anyama and Aswa bridges, the in-water construction schedule will avoid the fish spawning season. - Rain run-off from the construction sites is not deposited directly into any watercourse, stream, or canal. - All temporary construction facilities are located at least 500 meters away from a water course, stream, or canal. - All existing stream courses and drains within, and adjacent to the Site are kept safe and free from any debris and any excavated materials arising from the Works. - Chemicals and concrete agitator washings are not deposited into watercourses.	Potential adverse impacts to surface hydrology in the construction phase of the Project will be avoided through the enforcement of contract provisions under the supervision of the MTR and the construction supervision staff.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Daily by CSS and weekly by MTR	MTR
Hydrology – Impacts to Subsurface Hydrology	Within the construction phase of the Project interference to hand pumps and wells will be avoided through the enforcement of contract provisions prohibiting the contractor from using these facilities during project works.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Periodic throughout construction phase	MTR

Issue	Mitigation	Responsibility	Monitoring Method	Monitoring Frequency	Monitoring Responsibility
Hydrology – Flood and Inundation Characteristics.	Within the operational phase the Project will ensure the provision of adequately sized drainage structures at regular intervals in flood-prone areas.	MTR and the Construction Supervision Staff.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Periodic throughout construction phase	MTR
Air Quality – Construction Related Pollution	It is recommended that bid and contract documents specify that: - Asphalt and hot-mix plants will be located at least 500 meters away from the nearest sensitive receptor (e.g., any settlements). - Blasting (if any) will be carried out using small charges, and dust-generating items will be conveyed under cover. - Trucks carrying earth, sand or stone will be covered with tarps to avoid spilling. - Construction vehicles shall not exceed 60 km per hour. - Potential significant adverse impacts to adjacent residents or site employees during construction will be mitigated by either discontinuing until favorable conditions are restored, or, if warranted, sites may be watered to prevent dust generation, particularly at crushing plants. - Open burning will be prohibited and requirements for spraying and related dust control measures and the proper use of solvents and volatile materials will be in incorporated in the contract provisions. - Any unpaved road on the site should be watered regularly to prevent dust pollution.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Periodic throughout construction phase	MTR
Air Quality – Operational Pollution	It is recommended that the MTR develop emission standards for vehicles.	MTR	None	None	None
Flora	It is recommended that detours required from the Aswa Bridge to Nimule should occur on the east side of the road and not encroach into the NNP buffer zone on the west side of the road. In addition, the stripping of vegetation around bridge site detours should be kept to a minimum		MTR to approve detours	Prior to construction	MTR
Fauna – Wildlife Migration	It is recommended that from Aswa bridge to the Gordon Hill (NNP Buffer Zone) sign posts be erected at regular intervals (once every kilometer) to indicate that wild animals may be crossing the road and that speeds should be restricted to 50 kilometers per hour in this zone. In addition, it is recommended that construction camps not be sited within five kilometers of the NNP buffer zone.	MTR shall ensure all mitigation measures are included bid and contract documents. MTR shall be responsible for erecting signage.	MTR and CSS to ensure that signs have been erected.	Periodic throughout construction phase	MTR
Fauna – Accessibility	Although beyond the scope of the Project, it is recommended that the MEWCT develop adequate management plans to control the number of visitors to NNP and to ensure that the park is adequately staffed and guarded to ensure poaching of wildlife and degradation of habitat does not occur from the resulting increased accessibility to the area.	MEWCT	None	None	None

Issue	Mitigation	Responsibility	Monitoring Method	Monitoring Frequency	Monitoring Responsibility
Fauna – *Ecological Disequilibrium*	To mitigate against this issue it is recommended that only native species be used to re vegetate sites.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Daily by CSS and weekly by MTR	MTR
Protected Areas – Construction Impacts	Contract provisions will ensure that construction camps, asphalt plants or any other potentially polluting facilities are not located within the NNP Buffer Zone. Contract documents will specifically forbid the use of wood from the buffer zone during construction activities. The contractor will be required to consult with the MEWCT before commencement of Project works within the vicinity of NNP buffer zone to ensure that all construction activities are restricted to the right of way and that no construction camps, borrow pits, plant equipment etc is located within the buffer zone region.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	MTR and MEWCT to approve construction sites	Prior to construction	MTR, MEWCT
Historical and Cultural Resources	No negative impacts identified. No mitigation actions warranted	N/A	None	None	None
Socio-Economics – Resettlement and Compensation	No resettlement and compensation issues identified. However, in the event that resettlement or compensation claims are made MTR shall follow World Bank guidelines.	MTR	MTR and CSS to make site assessments	Prior to construction	MTR
Public Health and Safety – Construction workers H&S	It is recommended that bid documents specify that contractors will be required to provide basic emergency heath facilities for workers.	MTR will ensure that the mitigation measures shall be included in all bid and contract documents.	MTR and CSS to ensure healthcare facilities in place	Prior to and periodically during construction	MTR
Public Health and Safety - STDs	Consideration of a sexually transmitted disease (STD) awareness program is recommended.	MTR to provide STD awareness program.	MTR and CSS to ensure that STD program undertaken in the area	Prior to construction	MTR
Public Health and Safety – Road Safety	Improved Road Standards. Improved signage will be provided at intersections, bridges, and railroad crossings. Installation of Safety Barriers at sharp bends and speed humps in settlement areas and through the NNP buffer zone area. Additionally, it is recommended that SPLA soldiers continue to police the Project Road until the LRA cease the ambushing of vehicles in the Project Area.	MTR to develop improved road standards, provide improved signage and install safety barriers. SPLA to continue to police the Project Road.	MTR and CSS to ensure that safety measures implemented	Prior to project completion	MTR

Issue	Mitigation	Responsibility	Monitoring Method	Monitoring Frequency	Monitoring Responsibility
Noise – Construction Noise	• Noise and vibration impacts during the construction phase will be mitigated through the use of: ▪ *Source Controls*, i.e., requirements that all exhaust systems will be maintained in good working order; properly designed engine enclosures and intake silencers will be employed; and regular equipment maintenance will be undertaken. ▪ *Site Controls,* i.e., requirements that stationary equipment will be placed as far from sensitive land uses as practical; selected to minimize objectionable noise impacts; and provided with shielding mechanisms where possible. ▪ *Time and Activity Constraints*, i.e., operations will be scheduled to coincide with periods when people would least likely be affected; work hours and workdays will be limited to less noise-sensitive times. Construction activities will be strictly prohibited between 7 PM and 6 AM in the settlement areas.	MTR will ensure that the mitigation measure shall be included in all bid and contract documents. Implementation by the Contractor.	Inspections by MTR Environmental Staff and Construction Supervision Staff	Daily by CSS and weekly by MTR	MTR
Noise – Operational Noise	It is recommended that to prevent impacts to sensitive receptors during road maintenance works that all such activities occur only during the hours of 5PM and 9AM. It is also recommended where possible that all static maintenance machinery be located more than 500 meters from sensitive receptors. Speed restrictions in the NNP buffer zone area will help to reduce traffic noise and as such reduce the impact of noise upon wildlife in this area. Although beyond the scope of this Project it is recommended that the MEWCT undertake a program of monitoring species within the buffer zone.	MTR shall e responsible for maintenance mitigation actions.	Inspections by MTR Environmental Staff.	Monthly by MTR	MTR
Aesthetics	No negative impacts identified. No mitigation actions warranted	N/A	None	None	None
Solid and Liquid Waste - Disposal	It is recommended that the contractor develop his own solid and liquid waste disposal sites, which can be transferred to GoSS ownership once the project has been completed.	MTR responsible for selecting waste sites. Contractor responsible for operation and maintenance of sites.	MTR to approve waste disposal site location	Prior to construction by MTR	MTR

Source: Consultant

It is understood that at the present time the Ministry of Transport and Roads (MTR) have limited staff and capacity to undertake the monitoring and inspection tasks listed above. The Consultant assumes that during implementation some of the MTR responsibilities will be delegated and many of these tasks will be carried out by construction supervision staff. This will include training and mentoring of MTR staff.

Socio-Environmental Management Plan Costs

The SEMP costs were calculated on the basis of similar road rehabilitation projects in Africa. The total estimated cost for implementation of the mitigation measures identified above totaled US$340,000 (a full breakdown of the costs is tabulated in the JNES). In addition to the mitigation costs it is assumed that MTR staff will require some formal training in observational monitoring of environmental issues and general environmental awareness. Such a program would be provided by an international consultant at a cost of approximately US$20,000 over a period of four weeks. MTR would also be responsible for providing two staff to oversee the observational monitoring and reporting of the SEMP.

Staffing costs associated with this position include salary, per diems, computer equipment, etc. at a cost of US$40,000 for a two-year period. Accordingly the total costs to implement the SEMP would be approximately US$400,000, which includes a US$50,000 contingency for resettlement and compensation claims.
Table 4.2 provides a breakdown of the environmental costs associated with the construction of each of the four sections of the Project Road:

Table 4.2: Environmental Cost Breakdown

Issue	Mitigation	Amount (US$)				
		Section 1	Section 2	Section 3	Section 4	Total
KM		*3.40*	*17.40*	*169.20*	*2.00*	***192.00***
Topographic Conditions - Cut and Fill Requirements in the Gordon Hill Area	Grassing @ US$3/m^2	-	-	6,000	-	6,000
	Transport of cut and fill material @ US$ 1 m^2	-	-	20,000	-	20,000
Topographic Conditions – Borrow Pit Excavations	Top soil spreading @ US$2 / m^2	100	400	2,000	200	2,700
Soils - Erosion.	Grassing @ US$3/m^2	600	1,800	18,000	1,800	22,200
	Concrete headwalls, aprons, wingwalls @ US$ 200 / m^2	800	-	13,600	4,000	18,400
Soils – Contamination due to Spills	Adequate storage facilities (sealed and bunded storage) – US$ 667 per construction camp (1)	35	181	1,763	21	2,000
Geology – Quarries and Aggregates	Compensation to landowners – $50,000 contingency budget (2)	885	4,531	44,063	521	50,000
Air Quality – Construction Related Pollution	Water bowsers to water road surfaces @ US$50/hr	5,000	10,000	50,000	5,000	70,000
	Maintenance of machinery – US$2,000 per month	1,000	8,000	32,000	4,000	45,000
Flora	Costruction detours @ US$ 80 / m	-	-	24,000	8,000	32,000
Fauna – Wildlife Migration	Sign Posts @ US$ 100 each	-	-	2,000	-	2,000
Public Health and Safety – Construction workers H&S	Emergency health facilities at camps – 667 USD for each camp (1)	35	181	1,763	21	2,000
Public Health and Safety - STDs	STD awareness program – 500 USD	500	500	500	500	2,000
Public Health and Safety – Road Safety	Road safety signs @ US$100 each	300	1,600	10,700	300	12,900
	Safety barriers @ US$1,000 each	-	-	10,000	-	10,000
	Speed Bumps @ US$250 each	1,250	2,500	12,500	1,250	17,500
Solid and Liquid Waste - Disposal	Operation of five waste disposal sites – 5,000 USD per site (includes haulage of waste to site, fencing and operation)	-	5,000	15,000	5,000	25,000
Monitoring	Training in observational monitoring	354	1,813	17,625	208	20,000
	Overseeing & reporting	708	3,625	35,250	417	40,000
TOTAL		11,569	40,131	316,763	31,238	399,700

Notes:
1. Three Camps for the entire Project Road
2. One contingency budget for entire Project Road

Source: Consultant

5. ECONOMIC ANALYSIS & RESULTS

The most fundamental role of an economic analysis is to determine whether or not a project should be implemented. This decision is based solely on the merits of the project's projected net economic benefit regardless of who will benefit from the project if it is actually implemented. Therefore, this fifth and final chapter will compare each of the proposed investment alternatives, described in the previous chapters, by calculating and then comparing the net economic benefit derived from each. Finally, the economic analysis, per se, will not only reveal the project option or alternative with the best economic results, it will also provide the decision-maker with sufficient information to answer the following questions:

- Should the project be implemented or not?
- Which option or alternative is the most suitable for implementation?
- What are the main costs and the main benefits associated with the selected alternative?
- What are the main risks associated with the project?
- What were the main assumptions made in order to arrive at the proposed investment alternative?

The results of the economic analysis for the Juba to Nimule project indicate that the entire length of the road should be paved, using DBST. Construction should be implemented as soon as possible, namely in late 2007 or early 2008 at the latest, at a total investment cost including contingencies of ***US$ 75.76 million***. The project should be implemented over a one-year period, even for the longest section: 169 km between the Torit Junction and Nimule Center. The total net present value (NPV) of the project is ***US$ 30.12 million***.

Chapter 5 will first identify and quantify the project impacts, which are either benefits to or costs borne by the society in the with-project situations, when they are compared to the without-project situation. This chapter will then provide the best investment alternative as defined by the economic evaluation using the HDM-4 Model. (**Annex 3** indicates the engineering input used for HDM4) The economic analysis will also be supplemented by a sensitivity analysis.

Economic costs & benefits

The project's benefits and costs for society are valued in economic terms, meaning that financial prices have to be transformed into economic prices. In effect, the fundamental difference between an economic analysis and a financial analysis is the fact that the former tallies all relevant costs and benefits (also termed social costs and benefits) in the decision-making process. This section is a cornerstone of the feasibility study and encompasses all the quantifiable project impacts for each investment alternative, in terms of: (i) construction costs, including environmental mitigation measures; (ii) maintenance costs; and (iii) transport costs, including vehicle operating costs and time costs. The Consultant also makes note of a number of important project impacts in qualitative terms, as they are impossible to quantify due to lack of data and time constraints.

Construction cost

In order to evaluate the economic costs of the project, the financial costs, identified at market prices, need to be adjusted using appropriate conversion factors. These adjustments account for the effects of market structure imperfections, government interventions, as well as the opportunity costs of resource use. Our starting point in terms of construction costs is already provided without VAT. Construction costs are made of ***local labor*** – representing 1.7 percent of total cost, ***foreign labor*** – representing 11.5 percent of total cost and ***tradable goods*** expressed in market prices – making up the rest, or 86.9 percent of total cost.

A shadow wage rate factor is used to adjust for the opportunity cost of labor. In Juba Municipality, unskilled labor is in surplus supply as persistent high unemployment rates indicate. Although no official figure exists for a national unemployment rate, and even less for underemployment, the 2006 Emergency Study mentioned above estimates that roughly 34 percent of the population was unemployed in Juba Municipality in 1995[7]. The Consultant kept this assumption for the purpose of the analysis. Consequently, based on the current unemployment rate, the Consultant estimated the ***shadow wage rate factor to be 0.66***[8]. Income tax for the labor is not considered for this study because a large majority of the labor hired for the project's construction work is expected to be earning less than the level of income that would require the workers to file tax returns. This conversion factor was applied to the 1.7 percent of the project's total construction cost.

For foreign labor, ***no adjustments*** were made as financial prices were already expressed in terms of border prices.

Tradable goods in domestic market prices were converted to world prices using a ***shadow exchange rate factor of 0.90***[9]. This rate corresponds to an average tax rate for the Southern Sudanese economy of: (i) 5 percent for imports; and (ii) 5 percent of sales taxes, which comes in addition to VAT. It is important to keep in mind that this overall shadow factor is a rough approximation as there is no established tax structure in Southern Sudan and taxes are only applied selectively. Taxes are a mixture of service taxes – up to 10 percent – for the more established businesses and import taxes for which the Consultant was not able to find any recorded data in spite of a visit paid to Mr. Josua Akuet, the Director of Customs in Juba.

[7] / Emergency Study on the Planning & Support for Basic Physical & Social Infrastructure in Juba Town and the Surrounding Areas in the Southern Sudan – Interim Report – November 2006 – Katahira & Engineers International, Japan Engineering Consultants Co. and Kokusai Kogyo Co.
[8] / Shadow wage = (100-34)/100.
[9] / Shadow exchange rate = ((100-(5+5))/100.

Table 5.1: Conversion factors

	Percentage of total cost	Conversion factor
Local labor	1.66%	0.66
Foreign labor	11.48%	1.00
Tradable - market price	86.86%	0.90

Conversion Factor for Construction	0.907

Source: Consultant

The economic costs of the project alternatives include detailed design, supervision, environmental mitigation measures, and physical contingencies, but exclude all taxes, transfers and financial contingencies. These costs are as follows:

- ***US$ 86.2 million:*** upgrade to asphalt concrete standard.
- ***US$ 59.8 million:*** upgrade to double bituminous surface treatment standard.
- ***US$ 28.8 million*** upgrade to unpaved standard.

Maintenance costs

Maintenance costs comprise all labor and machinery associated with repairs, equipment replacement and inspection/servicing required to keep the facility in a state of good repair throughout its life. Maintenance cost savings are usually derived from less investment required on the newly rehabilitated roads. It is important to note, however, that a road project does not necessarily lead to a reduction in maintenance costs, especially when, without project, the road is not maintained at all.

In our case, the results of the economic analysis show that over the analysis period, the present value of capital cost after the project implementation period is smaller in the with-project scenario compared to the without-project scenario, which means that maintenance cost savings occur after construction thanks to the project. This is not surprising provided the present and future levels of traffic and the percentage of heavy vehicles. An unsealed road simply cannot sustain these types of loads without heavy maintenance costs to keep the road in a good state of repair.

The Consultant used the same global conversion factor for the cost of maintenance operations as the one used for construction costs in general (0.91). The conversion factor applies to the unit maintenance costs as shown in Section 54628880.

Vehicle Operating Costs

Savings in vehicle operating costs (VOC) are the most easily measurable benefit from a road transport project. In developing countries, it is also often the main benefit. Such savings include fuel and lubricants, tires, maintenance and economic depreciation, such as vehicle wear and tear. For inter-urban projects, these costs depend mostly on the road condition (good, fair or bad) and on its topography (flat and straight, hilly and curvy, or mountainous). For urban projects, these costs depend mostly on driver behavior and traffic control, factors that are insignificant in our case.

In appraising transport infrastructure projects, the World Bank HDM model has been used to estimate VOCs for certain levels of road deterioration.

Some of the items included in the previously enumerated financial costs are not economic costs but mere transfer payments, as they transfer command over resources from one party to another without reducing or increasing the amount of resources available as a whole. Besides an overall sales tax (VAT) of 10 percent, the Consultant made the following assumption in terms of import taxes [10]:

- Vehicles other than 4WD = 5 percent
- 4WD = 10 percent
- Replacement tires = 2 percent
- Gas & diesel = 75 percent
- Lubricating oil = 3 percent

Therefore, in order to obtain economic VOCs, the Consultant used the following conversion factors, which apply to the unit costs shown in Section 0:

- Vehicles other than 4WD = 0.87
- 4WD = 0.83
- Replacement tires = 0.89
- Gas & diesel = 0.57
- Lubricating oil = 0.88

Cost in terms of time

Time is valuable and therefore wasting it has a cost. Although in developing African countries such as Sudan, the value of time saved is traditionally not the major benefit of road projects, it is still reflected in demand for faster service and the price that consumers are willing to pay for it. However, time constraints and lack of data required the Consultant to rely on a rule–of-thumb method to quantify such benefits as time savings. In effect, empirical findings have found that:

- The value of time depends on the purpose of the trip.
- Even non-working time should be considered as it has an opportunity cost.
- The value of time usually rises with earnings.

Furthermore, on certain road sections, vehicle speed is reduced due to a combination of narrow shoulders and high traffic levels. To take this element of side friction into account in the HDM Model, the Consultant reduced the speed factors of (i) motorized vehicles due to non-motorized vehicles, such as bicycles or animal carts; (ii) motorized transport due to roadside activities, such as shops or habitations; and (iii) non-motorized transport due to motorized transport.

Therefore, the value of time, as derived in the economic analysis, is made-up of two components: (i) working time; and (ii) non-working time. The value of working time

[10] / Based on the tax levels mentioned in the “Laws of The New Sudan - Customs & Excise Duties (Provisional Order) 2000”.

during productive hours was derived from the average gross national income per capita for the Juba Municipality, which is US$276.3 per year in 2007[11]. The Consultant chose to consider the average income per capita of Juba Municipality rather than Southern Sudan as a whole because the Juba to Nimule Road is really about providing an access between Juba on the one hand and Uganda and Kenya on the other hand, while the areas surrounding the zone of influence of the project are only sparsely populated. Additionally, the Consultant made the following assumptions regarding the yearly working time:

- Four weeks vacation per year;
- Fifteen days holidays; and
- Eight-hour working days.

This working schedule is derived from the Government employees' working hours. It is deemed appropriate to characterize the average working hours in the Juba region for two main reasons: (i) most of the employed work force is working for the Government – some 45 percent of the total working population; and (ii) the major – i.e. registered – businesses and shops follow the same working hour schedule as the Government's. The hourly value of working time used in the analysis is therefore ***10 cents***, considering the same shadow wage rate factor used to adjust for the opportunity cost of construction labor.

Non-working value of time was estimated to be a third of the value of working time, or ***3 cents*** per hour. This conservative assumption is commonly used to acknowledge that time is a valuable resource, even if the time is not used to earn income.

These two values were used as inputs to the HDM Model, along with other technical assumptions made on vehicle characteristics, to determine the value of time at a disaggregated level. Other vehicle characteristics considered are: (i) annual km driven; (ii) working hours per year of each representative vehicle; (iii) percentage of private use of the vehicle; (iv) work-related passenger-trips; and (v) the value of cargo. These values are shown in Section 0 of this report.

A value of cargo was also derived from our O-D surveys. The results, calculated in cents per hour and using an annual interest of 14 percent (equivalent to an hourly interest rate of 0.0016 percent), are as follows:

Table 5.2: Cargo value

	Light truck	Medium truck	Heavy truck	Articulated truck
Value of cargo, in cents per hour	0.038		0.226	

Source: Consultant

[11] / The value is derived from the following study: Emergency Study on the Planning & Support for Basic Physical & Social Infrastructure in Juba Town and the Surrounding Areas in the Southern Sudan – Interim Report – November 2006 – Katahira & Engineers International, Japan Engineering Consultants Co. and Kokusai Kogyo Co.

Other Project Impacts (Qualitative Analysis)

Other impacts are only associated with upgrading the project road to paved standard. These impacts include: (i) the expected savings in the costs of road accidents; (ii) the increased level of security on the road linked with the LRA "incidents"; and (iii) better health for the populations living along the project road, due to a substantial decrease in the amount of dust produced by traffic.

The cost of accidents

Transport projects might affect the levels and severity of accidents occurring on the infrastructure. This is because a project might change the demand for transport – quantitatively or qualitatively – and/or change the condition of the infrastructure. The impact of transport projects can be positive (reduction in accident levels) or negative (increase in accident levels) depending on the type of project being implemented. Most negative impacts occur when travel speed increases.

In the present project, the Consultant does not have the necessary data to quantify with enough certainty the benefits – or negative impacts – linked with the proposed investments in terms of accident levels and their cost to society. However, the Consultant has made sure to foresee the potential negative impacts of the project and consequently has proposed measures to mitigate the risks of accidents. Such mitigation measures include lighting, signing and safety barriers, and are an integral part of the project alternatives and their respective construction costs. Furthermore, the Consultant attempted to analyze the effect of the project on accident levels and associated costs in the sensitivity analysis. The results of this sensitivity test show that the project should have a positive – albeit small – impact on the level and overall cost of accidents born by Society.

Impact on security

The impact of the project on security is not straightforward to quantify and can only be grossly assessed in qualitative terms. It is important to reiterate that the Project Road is assumed to be secured by the time construction starts. This is because: (i) construction cannot be implemented if security is not ensured; and (ii) road users are not interested in using an unsecured road, even if it is paved. "Security comes first" has been repeated over and over again during our interviews with truck drivers who use the Yei / Kaya Road instead of the Nimule road.

However, improving the road from Juba to Nimule, especially if it is to paved standard, is likely to help the Government make the road an even safer place and therefore to generate more traffic over time. A paved road is likely to make the road even safer mostly for two main reasons. It will: (i) improve logistics by making supply to the road and its zone of influence easier for troops; and (ii) diminish the time necessary for intervention to potential hot spots. Therefore, upgrading the project road to bituminous standard is likely to help preventing the violence from the LRA and other bandit groups from starting again.

The health benefits

A 1993 U.S. Department of Transportation study by civil engineering professor Thomas Sanders cites a 1983 Forest Service estimate that for every vehicle traveling one mile of unpaved roadway once a day, every day for a year, one ton of dust is deposited along a corridor extending 500 feet out on either side of the median. The main problem linked with this dust is that particles larger than 2.5 microns can lodge in the upper respiratory area, where they may cause severe irritation. Effects may be especially pronounced in infants, the elderly, and those with preexisting conditions such as asthma. Particles this size may also be linked to some types of respiratory cancers. Particles smaller than 2.5 microns go deeper into the lungs, where they can damage epithelial cells and even pass into the bloodstream. Dust particles this small can elude all but the most specialized of filters. So those who live near unpaved roads are not the only people at risk from these particles – vehicle passengers also are exposed, even if they ride with their windows rolled up.

Other studies indicate that human health is not the only thing that suffers in the dispersion of road dust. Near unsealed roads, plants are typically dusty, and anecdotal evidence suggests that crop yields can be reduced. According to a 1996 technical report by the U.S. Army, dust on leaf surfaces increases leaf temperatures and water loss, and decreases carbon dioxide uptake. This may make vegetation susceptible to chronic decreases in photosynthesis and growth, eventually leading to accelerated erosion in areas such as roadsides from lack of adequate stabilizing vegetation.

And the dust impacts not only the air, but the water as well, as it settles into nearby streams and rivers. Biology professor Dennis Murphy of the University of Nevada released an assessment of California's Lake Tahoe, citing a 30-year decline in clarity from 102 feet to 66 feet. Much of the problem was attributed to increased algal growth triggered by atmospheric deposition of phosphorus compounds associated in part with road dust. In addition, the generation of dust means the loss of fine aggregate material, which acts as road surface binders. This represents a significant material and economic loss. Tim Trumbull, an environmental specialist with the Iowa Waste Reduction Center at the University of Northern Iowa, further points out that dust can cause low visibility on unpaved roads.

In a cost benefit study on road dust conducted in the Seattle Industrial Valley, Robert J.W. suggested in 1975 that paving roads having an average daily traffic (ADT) over 15 were the least costly methods for reducing dust, and that paving roads became a good investment once the traffic exceeded 100 ADT.

Economic evaluation & base case results

As requested by the Task Order, the economic evaluation was carried out using the World Bank's HDM-4, Version 2 model. The results are therefore outcomes from this Model. (**Annex 3** illustrates the engineering input for HDM4) The Consultant will first provide the main assumptions regarding the economic evaluation, before giving the results of the analysis.

Economic Evaluation

The Consultant carried-out a project analysis for the selected roads, covering a 20 year period beginning in ***2007*** – the base year.

Costs and benefits were valued in constant prices; that is, in terms of the price level prevailing during the base year of the project. In this respect, any expected change in the general price level is ignored and the Consultant is not expecting (or is not in a position to assess) any significant changes in relative prices over the life of the project.

The benefits are ***discounted using a rate of 8 percent***. It is necessary to discount the transport costs and benefits in each year of the analysis period to their value in the base year. This is carried out to reflect the time value of money represented by the opportunity cost of the capital invested in the road project[12]. The rate of 8 percent can be considered adequate in the context of Southern Sudan, as it takes into consideration the social aspects of development.

Discounting is performed by multiplying the cost in a given year by the discount factor for that year. Discount factors are derived from the equation below:

DF = [1+ (r/100)]^(-N)

Where:
- r is the discount rate expressed as a percentage; and
- N is the number of years from the base year.

The net present value (NPV) is then calculated by the Model and by subtracting the discounted – or actualized – benefits from the actualized costs of the project (both in terms of construction and maintenance). In the economic appraisal of road projects, benefits are derived mainly from savings in road user costs (savings in vehicle operating costs and, to some extent, time saving), but can also be derived from a reduction of future maintenance costs and of accidents.

Cost estimates are economic costs, meaning that all taxes and transfers are taken out. However, construction costs include all associated costs, such as supervision, as well as other relevant economic costs. A detailed description of maintenance operations and improvement policies are illustrated in Chapter 3.

A residual value was added to the economic benefits of the project after the 20-year analysis period when construction works consists in upgrading the carriageway to bituminous standards. In this case, the residual value was assessed at 20 percent of construction cost.

In addition to the Net Present Value (NPV), an economic internal rate of return (EIRR) is provided by the Model. The EIRR is defined as the discount rate that equalizes the present value of the project's cost and benefit streams. Projects with

[12] / For infrastructure projects, the World Bank typically uses a discount rate of 12 percent, while the European Union favors more "social" discount rates, typically between 5 and 8 percent.

high EIRR values are generally preferred as this will give positive NPV at high discount rates.

Base Case Results

The Consultant suggests upgrading the Juba to Nimule to paved standard, using a double bituminous surface treatment all the way. The Consultant suggests this investment alternative for two main reasons: (i) it has the best results for each of the sections studied; and (ii) it is the only feasible alternative for the Torit Junction to Nimule Center, the longest section by far (169 km). For this section, the Consultant further suggests implementing construction over a one-year period, as results are slightly better compared to a two-year period, although other reasons such as practicability of implementation should also, in the final analysis, be considered. The base case results using a discount rate of 8 percent are shown in Table 5.3, below:

Table 5.3: Base Case Results

	NPV (mil. of US$)	**IRR** (%)	**NPV / Cost (*)**	Total cost (**) (US$ mil.)	**Eco Ccl.**
1. Juba-Bor Jct					
- Asphalt concrete 1 year	10.86	44.8	6.45	2.24	√
- Surface treatment 1 year	**11.10**	**55.8**	**8.42**	**1.64**	√
- Unpaved 1 year	2.35	35.0	2.12	0.95	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	0.90	9.2	0.12	9.91	√
- Surface treatment 1 year	**2.94**	**12.9**	**0.57**	**6.88**	√
- Unpaved 1 year	(0.51)	5.7	(0.17)	3.32	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	(7.76)	6.9	(0.11)	95.62	x
- Asphalt concrete 2 years	(6.66)	7.0	(0.10)	95.62	x
- Surface treatment 1 year	**12.19**	**10.3**	**0.25**	**66.11**	√
- Surface treatment 2 years	11.63	10.3	0.24	66.11	√
- Unpaved 1 year	(9.32)	3.2	(0.33)	31.48	x
- Unpaved 2 years	(9.31)	2.8	(0.33)	31.48	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	3.73	30.6	3.39	1.48	√
- Surface treatment 1 year	**3.90**	**37.0**	**4.42**	**1.13**	√
- Unpaved 1 year	0.64	19.2	0.83	0.72	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

Total NPV of the proposed project alternatives – shown in bold above – is **US$ 30.12 million**, without considering any of the qualitative benefits discussed in section 0. In present value terms, most of the benefits associated with the investment alternatives proposed above are derived from vehicle operating cost savings, representing 90 percent of total economic benefits. The second largest benefit concerns maintenance

expenditures, representing 8 percent of total benefits. Finally, time savings represents 2 percent of total benefits.

Total construction cost of the proposed investment alternatives – including contingencies – is ***US$ 75.76 million,*** to be implemented in 2008.

Regarding the urban sections, Juba Bridge to the Bor Junction and Nimule Center to the Ugandan Border, the results are quasi similar in terms of NPV between surface treatment (DBST) and asphalt concrete options. This makes the investment decision more open to non-economic criteria, such as practicability of implementation, ability to sustain high traffic volumes with unreliable maintenance and ease of access to local materials. If the road is paved using asphalt concrete in the sections from Juba Bridge to the Bor Junction and from Nimule Center to the Ugandan Border (5.4 km), and surface treatment between the Bor Junction and Nimule Center (186.6 km), NPV would merely go down to ***US$ 29.88 million*** (a difference of only US$ 240,000), for a total construction cost of ***US$ 76.35 million*** (plus US$ 590,000).

Finally, it is worth noting that taken as a whole, the use of asphalt concrete (AC) on the entire stretch of the Juba to Nimule Road, is also a viable option. However, the resulting NPV for the main section of road from Torit Junction to Nimule Center, with an implementation period of 2 years, would be US$ -6.66 million (US$ 18.85 million less than DBST). Moreover, the total construction cost for the project, using asphalt concrete throughout, is approximately US$ 109 million (US$ 33.5 million more than the surface treatment option).

Sensitivity Analysis

This section introduces the concept of uncertainty and provides the way forward to mitigate for the potential sources of errors in the analysis associated with assumptions that are overly optimistic or pessimistic. The sensitivity Analysis is used to assess the reaction of the results against foreseeable changes in certain critical inputs of the project, namely investment cost, demand for transport and reduction in accident levels. The Sensitivity Analysis is carried-out to test the effects of:

- Increased construction costs;
- Lower traffic levels;
- A combination of increased construction costs and lower traffic levels; and
- No diverted and generated traffic;
- Decreased construction costs;
- Inclusion of benefits linked with a reduction of accidents.

Higher Costs

The first sensitivity test consists of studying the project alternatives by increasing construction costs by 15 percent. This sensitivity test is relevant because of the uncertainties associated with the costing of the investment alternatives at this stage of the project cycle. Also, Southern Sudan is in its primary stages of development where data is particularly scarce, making the task of costing the investment

alternatives difficult. With 15 percent higher investment costs, the main results are illustrated in Table 5.4, below:

Table 5.4: Results Using Assumptions that Increase Construction Costs

	NPV (mil. of US$)	IRR (%)	NPV / Cost (*)	Total cost (**) (US$ mil.)	Eco Ccl.
1. Juba-Bor Jct					
- Asphalt concrete 1 year	10.62	40.5	5.55	2.57	√
- Surface treatment 1 year	**10.93**	**50.4**	**7.35**	**1.89**	√
- Unpaved 1 year	2.25	31.0	1.85	1.09	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	(0.13)	7.9	(0.02)	11.40	x
- Surface treatment 1 year	**2.23**	**11.4**	**0.379**	**7.91**	√
- Unpaved 1 year	(0.87)	4.5	(0.26)	3.81	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	(17.67)	5.7	(0.22)	109.97	x
- Asphalt concrete 2 years	(16.19)	5.8	(0.21)	109.97	x
- Surface treatment 1 year	**5.35**	**8.9**	**0.10**	**76.03**	√
- Surface treatment 2 years	4.95	8.9	0.09	76.03	√
- Unpaved 1 year	(12.72)	2.0	(0.40)	36.20	x
- Unpaved 2 years	(12.59)	1.6	(0.40)	36.20	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	3.58	27.7	2.87	1.70	√
- Surface treatment 1 year	**3.78**	**33.5**	**3.80**	**1.30**	√
- Unpaved 1 year	0.56	17.0	0.67	0.82	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

The team's proposed investments are still economically feasible for all sections when upgrading to a double bituminous surface treatment standard. Total NPV would be somewhat lower at ***US$ 22.3 million***. Total construction cost – including contingencies – would then be ***US$ 87.12 million***. The Consultant notes that the section Bor Junction to Torit Junction is not feasible any longer with an asphalt concrete pavement.

Lower Traffic Levels

In this sensitivity test, the Consultant looks at the impact on the economic results of less than expected future traffic levels. The Consultant assumes that: (i) traffic growth rates are two points lower between 2007 and 2011 for all investment alternatives and (ii) generated traffic is "only" half of the 30 percent originally assumed in the investment alternatives whereas the project road is being paved. With these reduced levels of future traffic, the economic results are illustrated in Table 5.5, below:

Table 5.5: Results Using Assumptions that Lower Traffic Levels

	NPV (mil. of US$)	IRR (%)	NPV / Cost (*)	Total cost (**) (US$ mil.)	Eco Ccl.
1. Juba-Bor Jct					
- Asphalt concrete 1 year	9.08	40.0	5.39	2.24	√
- Surface treatment 1 year	**9.35**	**50.0**	**7.15**	**1.64**	√
- Unpaved 1 year	2.08	32.5	1.89	0.95	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	(0.39)	7.5	(0.05)	9.91	x
- Surface treatment 1 year	**1.63**	**10.9**	**0.317**	**6.88**	√
- Unpaved 1 year	(0.75)	4.5	(0.25)	3.32	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	(17.45)	5.3	(0.25)	95.62	x
- Asphalt concrete 2 years	(16.18)	5.4	(0.24)	95.62	x
- Surface treatment 1 year	**3.35**	**8.7**	**0.07**	**66.11**	√
- Surface treatment 2 years	**3.35**	**8.7**	**0.07**	**66.11**	√
- Unpaved 1 year	(11.00)	2.0	(0.39)	31.47	x
- Unpaved 2 years	(11.05)	1.5	(0.40)	31.47	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	3.06	27.4	2.78	1.48	√
- Surface treatment 1 year	**3.24**	**33.2**	**3.68**	**1.13**	√
- Unpaved 1 year	0.54	17.7	0.70	0.72	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

The proposed investment alternatives are still feasible for all options when paving with double bituminous surface treatment. NPV would be somewhat lower than with higher costs, at ***US$ 17.6 million***. The construction cost and investment schedule would be the same as in the base case, although results are identical between the one-year and two-year construction alternatives. The Consultant notes that the section Bor Junction to Torit Junction is not feasible any longer with an asphalt concrete pavement.

Combination of Higher Cost and Lower Traffic Levels

In this sensitivity test, the Consultant is simply considering more "pessimistic" assumptions regarding construction costs and traffic levels, although to a less dramatic extent as in the two previous sensitivity tests. In this respect, the Consultant is considering: (i) 10 percent higher investment costs; and at the same time (ii) two thirds of the generated traffic for the bituminous pavement alternatives and one point less in the traffic growth rates during the period 2007-2011 for all investment alternatives. The results are illustrated in Table 5.6, below:

Table 5.6: Results Using Assumptions that Increase Construction Costs and Lower Traffic Levels ("combination" case scenario)

	NPV (mil. of US$)	IRR (%)	NPV / Cost (*)	Total cost (**) (US$ mil.)	Eco Ccl.
1. Juba-Bor Jct					
- Asphalt concrete 1 year	9.67	39.2	5.26	2.46	√
- Surface treatment 1 year	**9.96**	**48.9**	**7.01**	**1.81**	√
- Unpaved 1 year	2.15	31.0	1.83	1.04	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	(0.53)	7.3	(0.07)	10.91	x
- Surface treatment 1 year	**1.74**	**10.8**	**0.31**	**7.57**	√
- Unpaved 1 year	(0.87)	4.3	(0.27)	3.65	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	(19.96)	5.2	(0.26)	105.18	x
- Asphalt concrete 2 years	(18.48)	5.3	(0.25)	105.18	x
- Surface treatment 1 year	1.72	8.3	0.03	72.72	√
- Surface treatment 2 years	**1.90**	**8.4**	**0.04**	**72.72**	√
- Unpaved 1 year	(12.48)	1.8	(0.41)	34.62	x
- Unpaved 2 years	(12.39)	1.3	(0.41)	34.62	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	3.24	26.9	2.70	1.62	√
- Surface treatment 1 year	**3.44**	**32.5**	**3.59**	**1.24**	√
- Unpaved 1 year	0.54	16.9	0.66	0.79	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

With a combination of higher costs and lower traffic levels over the analysis period, the project to pave the road to double bituminous surface treatment is still feasible in all four sections, although for the long section from Torit Junction to Nimule Center, the results are slightly better for an implementation period of two years instead of the one year period proposed in the base case. As a whole, the project is still healthily feasible, with an NPV of ***US$ 17 million***. In this case, total construction cost – including contingencies – would be ***US$ 83.33 million***. The Consultant notes that the section Bor Junction to Torit Junction is not feasible any longer with an asphalt concrete pavement.

The "worst case" Scenario: No Diverted and Generated Traffic

One risk associated with the project is that the Government is not able to maintain security on the Juba to Nimule Road, and that the situation returns to where it was in the second half of 2006. For the sake of the analysis, the Consultant assessed this risk by looking at the impact on the investment feasibility of not having: (i) traffic diverting back to the project road in the without project scenario; and (ii) any traffic generated by upgrading the project road to bituminous standard. In effect, as mentioned many times by a number of drivers who were not taking the road although it was a shorter route, "security comes first". In other words, in this sensitivity test, the Consultant is looking at the economic impact of the project considering existing traffic

only – as it was determined through our traffic counts – and assuming that it is growing in line with GDP as determined in the demand analysis.

With much reduced levels of present and future traffic, the economic results are illustrated in Table 5.7, below:

Table 5.7: Results Using "Worst Case" Scenario Assumptions

	NPV (mil. of US$)	**IRR** (%)	**NPV / Cost (*)**	Total cost (**) (US$ mil.)	**Eco Ccl.**
1. Juba-Bor Jct					
- Asphalt concrete 1 year	7.44	35.4	4.46	2.24	√
- Surface treatment 1 year	**7.80**	**43.9**	**5.97**	**1.64**	√
- Unpaved 1 year	1.80	29.3	1.65	0.95	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	(4.53)	-0.4	(0.63)	9.91	x
- Surface treatment 1 year	(2.34)	2.5	(0.47	6.88	x
- Unpaved 1 year	**(1.85)**	**-4.2**	**(0.65)**	**3.32**	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	(55.32)	4.8	(0.80)	95.62	x
- Asphalt concrete 2 years	(52.86)	5.2	(0.79)	95.62	x
- Surface treatment 1 year	(34.08)	2.0	**(0.71)**	**66.11**	x
- Surface treatment 2 years	(33.17)	2.2	(0.71)	66.11	x
- Unpaved 1 year	(20.64)	10.9	(0.78)	31.47	x
- Unpaved 2 years	**(20.12)**	**13.0**	**(0.77)**	**31.47**	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	1.99	21.9	1.83	1.48	√
- Surface treatment 1 year	**2.20**	**26.6**	**2.52**	**1.13**	√
- Unpaved 1 year	0.29	13.7	0.39	0.72	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

The results clearly show that the proposed investment alternatives are only feasible in the urban areas, from Juba to the Bor Junction and from Nimule Center to the Ugandan Border, where existing traffic levels are already substantial and where there is less impact of diverted and generated traffic. Even when looking at the best investment alternative for each section – surface treatment in the urban areas and unsealed surface between the Bor Junction to Nimule Center – the project is not feasible. NPV would be almost ***minus US$ 12 million***. If the project were implemented nonetheless, total construction cost – including contingencies – would then be ***US$ 37.56 million***.

Lower Costs

The first sensitivity test using more optimistic inputs compared to the base case consists of studying the project alternatives by decreasing construction costs by 15 percent. This sensitivity test is relevant because of the uncertainties associated with the costing of the investment alternatives at this stage of the project cycle. It is

important to note in this respect that a more refined cost estimate will be undertaken at the detailed design stage. With 15 percent lower investment costs, the main results are illustrated in Table 5.8, below:

Table 5.8: Results Using Assumptions that Decrease Construction Costs

	NPV (mil. of US$)	**IRR** (%)	**NPV / Cost (*)**	Total cost (**) (US$ mil.)	**Eco Ccl.**
1. Juba-Bor Jct					
- Asphalt concrete 1 year	11.09	50.4	7.63	1.90	√
- Surface treatment 1 year	**11.27**	**63.0**	**9.81**	**1.40**	√
- Unpaved 1 year	2.45	40.6	2.43	0.81	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	1.92	10.8	0.31	8.43	√
- Surface treatment 1 year	**3.65**	**14.7**	**0.82**	**5.85**	√
- Unpaved 1 year	(0.15)	7.3	(0.06)	2.82	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	2.16	8.4	0.04	81.28	√
- Asphalt concrete 2 years	2.87	8.5	0.05	81.28	√
- Surface treatment 1 year	**19.03**	**12.0**	**0.44**	**56.19**	√
- Surface treatment 2 years	18.32	12.0	0.44	56.19	√
- Unpaved 1 year	(5.91)	4.6	(0.24)	26.75	x
- Unpaved 2 years	(6.03)	4.2	(0.24)	26.75	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	3.88	34.4	4.08	1.25	√
- Surface treatment 1 year	**4.01**	**41.6**	**5.21**	**0.96**	√
- Unpaved 1 year	0.71	22.1	1.03	0.61	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

With lower construction costs, the best option based on the economic analysis is still DBST all the way, to be built over a one year period. Total NPV would be significant, at ***US$ 38 million***. Total construction cost – including contingencies – would then be ***US$ 64.4 million***. The Consultant notes that the option to upgrade the road using asphalt concrete becomes feasible using an 8 percent discount rate (NPV = US$ 19 million and construction costs = US$ 93 million).

Analysis Considering a Reduction in the Level of Accidents

This sensitivity test considers a reduction in the level of accidents in the with-project scenarios that result from paving the road surface and increasing the width of the carriageway. The cost of accidents was not included in the base case because of the lack of data available in South Sudan to assess: (i) the number of accidents with and without project situation; and (ii) the cost of these accidents. However, the Consultant did include the reduction in the level of accidents in the sensitivity analysis using simplified assumptions based on accident studies performed in Uganda and Vietnam, respectively regarding: (i) the typical number of accidents depending on the type of road; and (ii) the average cost of these accidents. These studies confirmed that

paved surfaces and wider carriageways and shoulders tend to lower the accident rate. Accident rates below (expressed in 100 million vehicle-km) are derived from international experience[13] as no such detailed statistical data is currently available in South Sudan:

- Unpaved standard two-lane carriageway in rural areas = 145
- Paved wide two-lane carriageway in rural areas = 69
- Unpaved standard two-lane carriageway in urban areas = 335
- Paved wide two-lane carriageway in urban areas = 169

The Consultant assessed the average cost of accidents through the gross output or human capital approach, thereby linking the cost of accidents to foregone earnings. The Consultant used data available for Vietnam[14] and adjusted it to South Sudan proportionally to the ratio of Gross National Income per capita (GNI per capita) for the two countries. According to the ADB-ASEAN study, the average cost of accidents in Vietnam was US$ 750 in 2004. With a GNI per capita in 2007 estimated to be half this in South Sudan, the Consultant determined the average cost of accidents to be US$ 375.

Using the above-mentioned assumptions in the HDM-4 Model, the main results are illustrated in Table 5.9, below:

[13] / Ten-Year Road Sector Development Program – Uganda – Gibb Ltd. – 2001.
[14] / The Cost of Road Traffic Accidents in Viet Nam, ADB-ASEAN Regional Road Safety Program, Accident Costing Report: AC 10, 2004

Table 5.9: Results Using Assumptions that Reduce the Level of Accidents

	NPV (mil. of US$)	IRR (%)	NPV / Cost (*)	Total cost (**) (US$ mil.)	Eco Ccl.
1. Juba-Bor Jct					
- Asphalt concrete 1 year	10.87	44.8	6.45	2.24	√
- Surface treatment 1 year	**11.11**	**55.9**	**8.43**	**1.64**	√
- Unpaved 1 year	2.35	35.0	2.12	0.95	√
2. Bor Jct-Torit Jct					
- Asphalt concrete 1 year	0.90	9.2	0.12	9.91	√
- Surface treatment 1 year	**2.95**	**12.9**	**0.57**	**6.88**	√
- Unpaved 1 year	(0.51)	5.7	(0.17)	3.32	x
3. Torit Jct-Nimule Center					
- Asphalt concrete 1 year	(7.69)	6.9	(0.11)	95.62	x
- Asphalt concrete 2 years	(6.59)	7.0	(0.10)	95.62	x
- Surface treatment 1 year	**12.26**	**10.3**	**0.25**	**66.11**	√
- Surface treatment 2 years	11.70	10.3	0.24	66.11	√
- Unpaved 1 year	(9.31)	3.2	(0.33)	31.48	x
- Unpaved 2 years	(9.31)	2.8	(0.33)	31.48	x
4. Nimule Center-Ugandan Border					
- Asphalt concrete 1 year	3.74	30.7	3.40	1.48	√
- Surface treatment 1 year	**3.90**	**37.1**	**4.43**	**1.13**	√
- Unpaved 1 year	0.64	19.2	0.83	0.72	√

(*) NPV over economic capital cost
(**) Total construction cost, including project management costs, environmental mitigation measures and contingencies, in constant price 2007. The best investment for each alternative is shown in bold.
Source: Consultant

In this case, Total NPV is **US$ 30.22 million**, meaning that accident account for an increase in benefits of about US$ 100,000 over the base case. .

ANNEX 1: RESULTS FROM TRAFFIC COUNTS

The results from the weekly traffic counts carried out by the Consultant produced the following results:

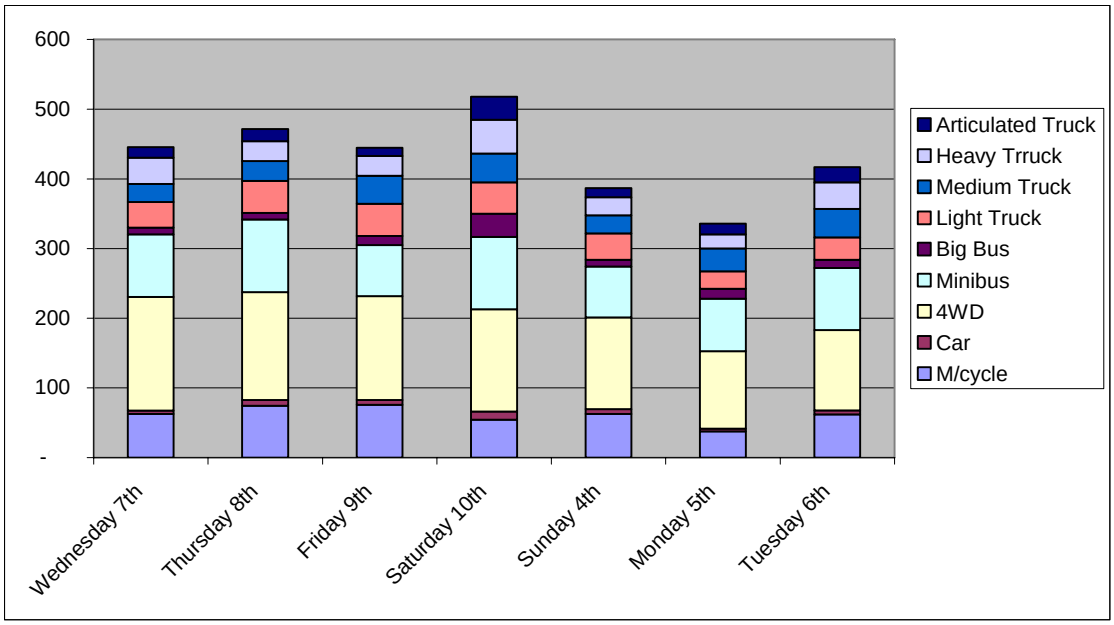
1. Non project road: from Juba to Yei & Kaya Road

Weekly Traffic Volumes **2 way(s): From Juba to Yei**

Day: 4-10 Feb	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Wednesday 7th	63	5	163	90	9	37	26	38	15	446
Thursday 8th	74	8	155	104	9	46	28	28	18	472
Friday 9th	76	7	149	73	13	46	40	28	12	445
Saturday 10th	54	12	147	104	33	45	41	48	33	518
Sunday 4th	63	7	131	73	9	38	26	26	13	387
Monday 5th	38	4	111	76	14	25	33	20	15	336
Tuesday 6th	62	6	115	89	12	32	41	38	22	417
Total	430	49	971	609	101	268	236	227	128	1,880
Average dry season	61	7	139	87	14	38	34	32	18	431
Average wet season	49	6	111	70	12	31	27	26	15	345
Average annual traffic volumes	**55**	**6**	**125**	**78**	**13**	**35**	**30**	**29**	**17**	**388**
% taking Nimule Rd.	0%	25%	25%	25%	30%	40%	60%	80%	90%	
Diverted traffic	**-**	**2**	**31**	**20**	**4**	**14**	**18**	**23**	**15**	**126**

Night factor 1.18 Wet season = 80% dry season

Weekly Distribution - Dry Season



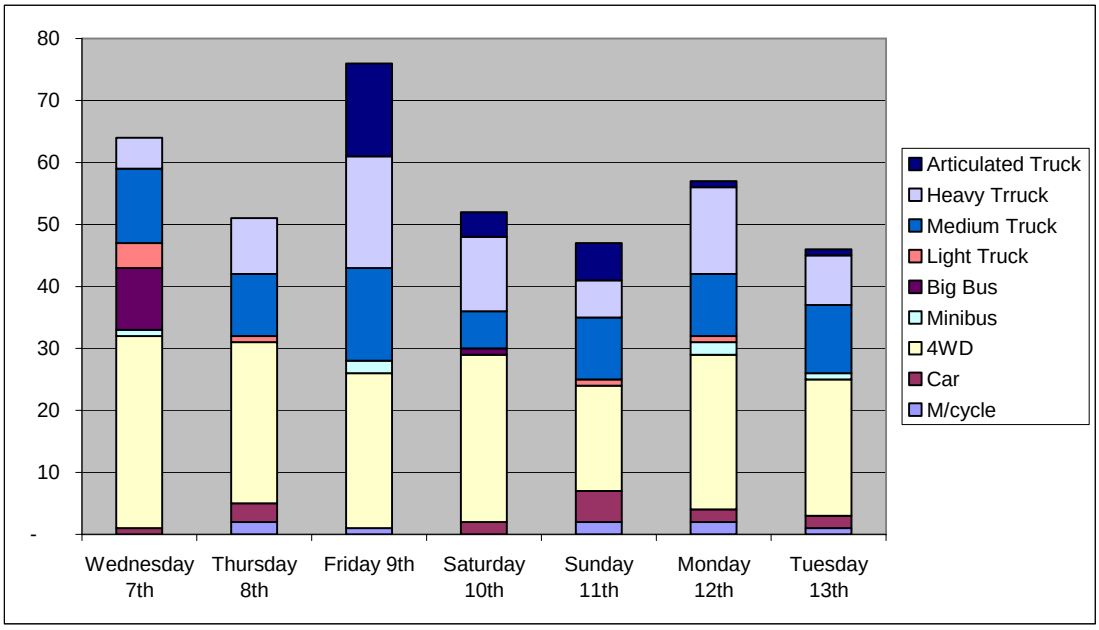
2. Non project road: from Torit Jct./Nisutu to Torit & Lokichoggio Road

Weekly Traffic Volumes **2 way(s): From** **Nisutu** **to** **Torit**

Day: 7-13 Feb	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Wednesday 7th	-	1	31	1	10	4	12	5	-	64
Thursday 8th	2	3	26	-	-	1	10	9	-	51
Friday 9th	1	-	25	2	-	-	15	18	15	76
Saturday 10th	-	2	27	-	1	-	6	12	4	52
Sunday 11th	2	5	17	-	-	1	10	6	6	47
Monday 12th	2	2	25	2	-	1	10	14	1	57
Tuesday 13th	1	2	22	1	-	-	11	8	1	46
Total	8	15	173	6	11	7	74	72	27	393
Average dry season	1	2	25	1	2	1	11	10	4	56
Average wet season	1	2	20	1	1	1	8	8	3	45
Average	**1**	**2**	**22**	**1**	**1**	**1**	**10**	**9**	**3**	**51**
% taking Nimule Rd.	0%	0%	0%	25%	30%	40%	50%	80%	80%	
Diverted traffic	**-**	**-**	**-**	**0**	**0**	**0**	**5**	**7**	**3**	**16**

Night factor 1.00 Day hours = 11 Wet season = 80% dry season

Weekly Distribution - Dry Season



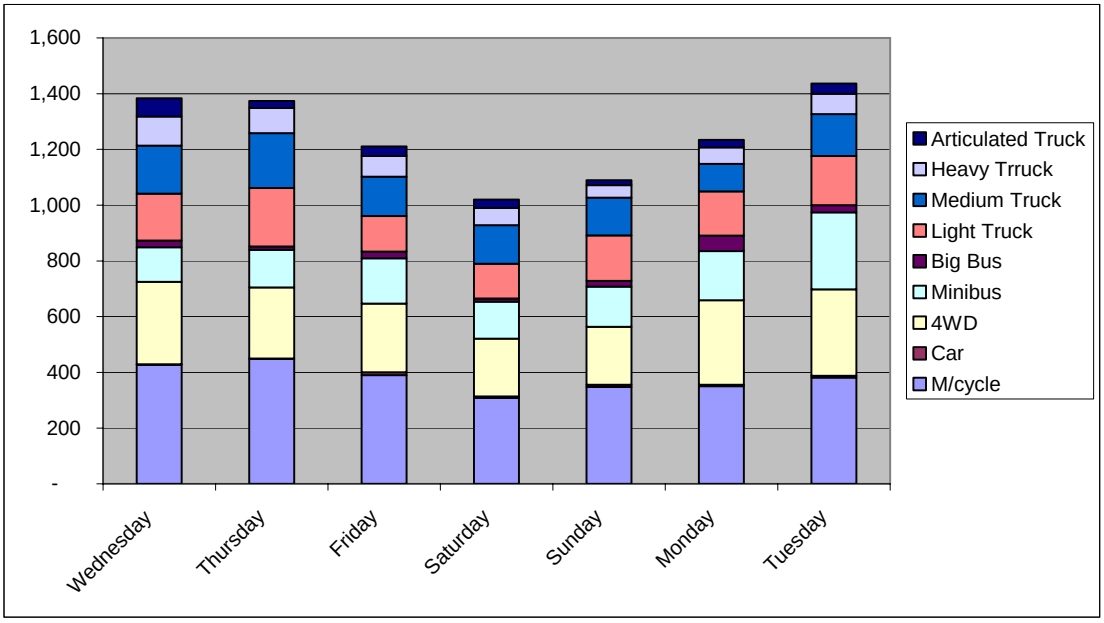
3. Project road: from Juba Bridge to Bor Jct.

Weekly Traffic Volumes **2 way(s): From Juba to Bor Jct**

Day: 7-13 Feb	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Wednesday	427	2	296	124	24	168	171	106	64	1,383
Thursday	449	1	255	134	12	210	197	90	25	1,374
Friday	390	11	246	162	24	128	141	74	35	1,211
Saturday	309	5	207	133	11	125	138	62	30	1,020
Sunday	348	7	208	144	21	163	135	45	17	1,089
Monday	350	5	303	177	55	159	99	59	26	1,234
Tuesday	382	6	310	276	26	176	151	73	36	1,436
Total	2,655	38	1,825	1,149	174	1,129	1,033	509	234	8,747
Average dry season	379	5	261	164	25	161	148	73	33	1,250
Average wet season	303	4	209	131	20	129	118	58	27	1,000
Average	**341**	**5**	**235**	**148**	**22**	**145**	**133**	**65**	**30**	**1,125**

Night factor 1.06 (already included for Friday & Saturday) Wet season = 80% dry season

Weekly Distribution - Dry Season



AADT 2007 **From Juba Bridge to Bor Jct.** **3.4 km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	341	5	235	148	22	145	133	65	30	1,125
Diverted traffic	-	2	31	20	4	14	18	23	15	126
AADT base case	**341**	**6**	**266**	**167**	**26**	**159**	**151**	**89**	**45**	**1,251**
In % of AADT	27%	1%	21%	13%	2%	13%	12%	7%	4%	100%

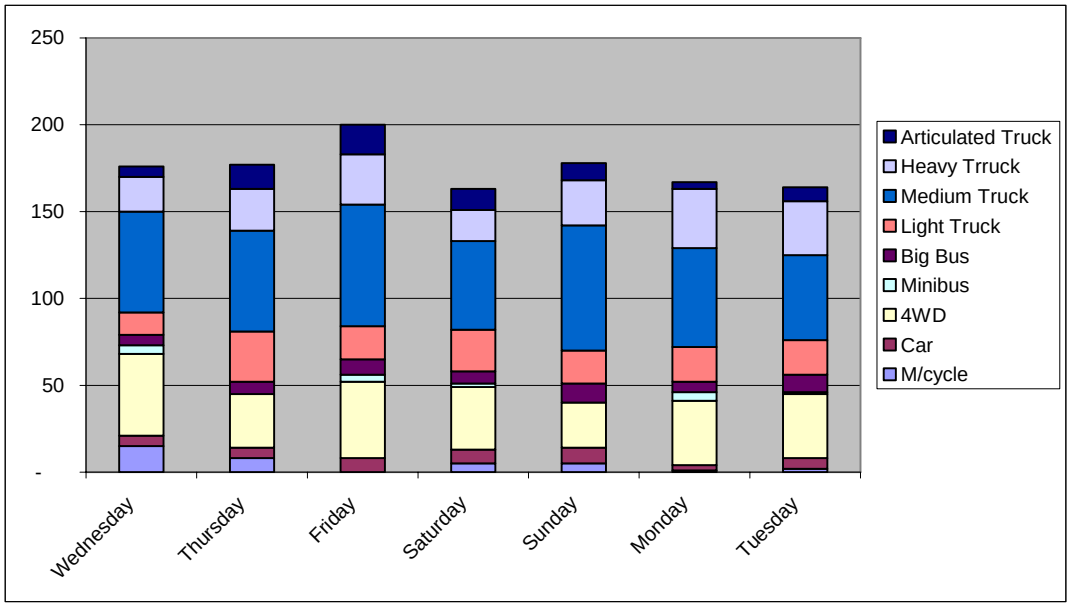
4. Project road: from Bor Jct. to Torit Jct.

Weekly Traffic Volumes **2 way(s): From** **Nesitu** **to** **Bor Jct**

Day: 7-13 Feb	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Wednesday	15	6	47	5	6	13	58	20	6	176
Thursday	8	6	31	-	7	29	58	24	14	177
Friday	-	8	44	4	9	19	70	29	17	200
Saturday	5	8	36	2	7	24	51	18	12	163
Sunday	5	9	26	-	11	19	72	26	10	178
Monday	1	3	37	5	6	20	57	34	4	167
Tuesday	2	6	37	1	10	20	49	31	8	164
Total	36	46	258	17	56	144	415	182	71	1,225
Average dry season	5	7	37	2	8	21	59	26	10	175
Average wet season	4	5	29	2	6	16	47	21	8	140
Average	**5**	**6**	**33**	**2**	**7**	**19**	**53**	**23**	**9**	**158**

Night factor 1.00 Wet season = 80% dry season

Weekly Distribution - Dry Season



AADT 2007 **From** **Bor Jct.** **to** **Torit Jct.** **17.4 km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	5	6	33	2	7	19	53	23	9	158
Diverted traffic	-	2	31	20	4	14	18	23	15	126
AADT base case	**5**	**7**	**64**	**22**	**11**	**32**	**72**	**47**	**24**	**284**
In % of AADT	2%	3%	23%	8%	4%	11%	25%	16%	8%	100%

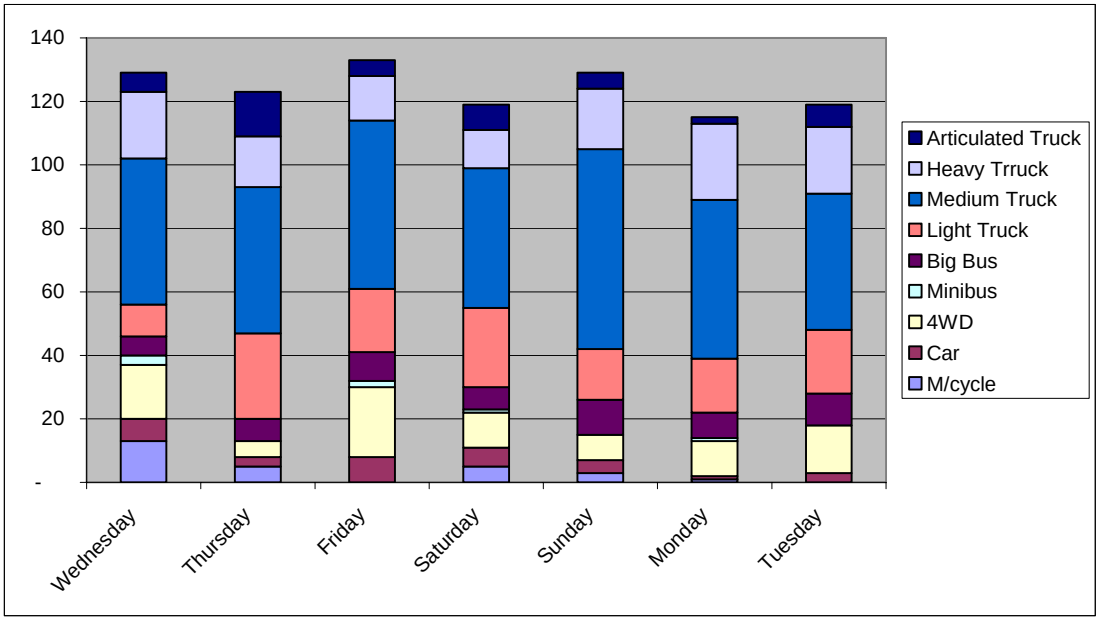
5. Project road: from Torit Jct. to Nimule Center

Weekly Traffic Volumes **2 way(s): From** **Nesitu** **to** **Nimule**

Day: 7-13 Feb	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Wednesday	13	7	17	3	6	10	46	21	6	129
Thursday	5	3	5	-	7	27	46	16	14	123
Friday	-	8	22	2	9	20	53	14	5	133
Saturday	5	6	11	1	7	25	44	12	8	119
Sunday	3	4	8	-	11	16	63	19	5	129
Monday	1	1	11	1	8	17	50	24	2	115
Tuesday	-	3	15	-	10	20	43	21	7	119
Total	27	32	89	7	58	135	345	127	47	867
Average dry season	4	5	13	1	8	19	49	18	7	124
Average wet season	3	4	10	1	7	15	39	15	5	99
Average	**3**	**4**	**11**	**1**	**7**	**17**	**44**	**16**	**6**	**111**

Night factor 1.00 Wet season = 80% dry season

Weekly Distribution - Dry Season



AADT 2007 **From** **Torit Jct.** **to** **Nimule Center** **169.2 km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	3	4	11	1	7	17	44	16	6	111
Diverted traffic	-	2	31	20	4	14	23	31	18	142
AADT base case	**3**	**6**	**43**	**21**	**12**	**32**	**67**	**47**	**24**	**254**
In % of AADT	1%	2%	17%	8%	5%	12%	27%	19%	9%	100%

6. Project road: from Nimule Center to Ugandan Border

AADT 2007 **From** **Nimule Center** **to** **Ugandan Border** **2.0 km**

	M/cycle	Car	4WD	Minibus	Big Bus	Light Truck	Medium Truck	Heavy Trruck	Articulated Truck	**Total**
Average	683	2	117	74	11	73	66	33	15	1,074
Diverted traffic	-	2	31	20	4	14	23	31	18	142
AADT base case	**683**	**4**	**149**	**94**	**15**	**87**	**89**	**64**	**33**	**1,217**
In % of AADT	56%	0%	12%	8%	1%	7%	7%	5%	3%	100%

M/cycles = 2 times Juba - Bor Jct
Other vehicles = half Juba - Bor Jct

ANNEX 2: Preliminary Design, Quantities and Costs

Preliminary Design, Quantities and Costs

This annex sets out the supporting data for the preliminary design, determination of quantities and costs estimates that were developed for the project.

As stated in the main text the Juba –Nimule Road is not considered a major engineering challenge. The existing road has a fair alignment and can be used for most of the route. No major earthworks are required with the exception of one cutting in rock. The seven bridges along the route (see **Table 1**) will be entirely reconstructed but do not present major construction challenges.

Estimate of construction quantities

Based on the assumptions set out in the main text for construction and using selected pavement designs a draft bill of quantities for major pay items was prepared. This is set out in the following section.

Figure 1	illustrates standard urban and inter-urban cross sections.
Figure 2	details the proposed pavement construction
Table 2	shows the cost summary
Table 3	shows the breakdown of cost by major pay item

Estimated costs for construction

Unit rates were selected for the major pay items in order to provide the basis of the construction cost estimate. This was summed then adjusted for minor pay items and P & G costs.

In order to determine the appropriate unit rates information was gathered from previous and ongoing projects in Southern Sudan and data was also taken fro Kenya and Uganda.

Table 4 shows the sample contract rates that were used to assist determining appropriate cost unit rates.

In addition calculations were done to build up individual unit rates from the basic labour, materials and equipment components. This was done using costs for basic components from in and around Juba.

Table 5 illustrates the build up of unit rates that was used in a review of costs.

Notes on build up of unit rates (see below)

Pavement Design

Based on the traffic data gathered by the teams survey work an exercise was carried out to determine appropriate pavement construction options using AASHTO. This involved a 20 year life cycle analysis with an initial design life of either 7 or 10 years. A total of 12 pavement structures were devised – 5 HMA, 4 DBST and 3 gravel, grouped as 5 alternatives. As well as surfacing type another major consideration was the road base. Crushed stone HMA and cement stabilised natural gravels are all considered as road base materials. Although a crushed stone base is the preferred solution for a DBST pavement the cost is substantial and the alternative with a cheaper cement stabilised natural gravel has been adopted at this stage.

Alternative 4 DBST is the recommended solution.

Table P1 Summary of Pavement Alternatives (20 year analysis)
Table P2 Alternative 1 (DBST & AC with crushed stone base)
Table P3 Alternative 2 (DBST with crushed stone base AC with HMA base)
Table P4 Alternative 2A (DBST with crushed stone base AC with HMA base)
Table P5 Alternative 3 ("perpetual asphalt pavement")
Table P6 Alternative 4 (stabilised road base)
Table P7 Alternative 5 (gravel pavements)
Table P8 Pavement Design Variables
Table P9 Pavement structural number 0 – 10 yrs
Table P10 Pavement structural number 10 – 20 yrs
Table P11 Pavement structural number 20 yrs
Table P12 Pavement structural number 7 yrs
Table P13 Pavement structural number 7- 20 yrs
Table P14 Axle loading assumptions
Table P15 ESAL for pavement design – Section 1
Table P16 ESAL for pavement design – Section 2
Table P17 ESAL for pavement design – Section 3
Table P18 ESAL for pavement design – Section 4
Table P19 Meteorological data

Pavement designs follow AASHTO 1993 procedure that uses the Present Serviceability Index (PSI) criteria. The following IRI numbers are recommended:

	After Construction Year 0			Before Rehabilitation Year 10		
	DBST	HMA	Gravel	DBST	HMA	Gravel
PSI	4.00	4.20	3.50	2.00	2.00	0.50
IRI (m/Km)	2.02	1.86	2.44	4.21	4.21	8.59

Notes on pavement design:-

Experience has shown that DBST will last between 7 to 10 years. Both solutions are shown, but it is recommended assume 7 years (Alternative 2A)
Shoulders should be sealed, minimum 1000 mm width
Due to the high air temperatures, Pen 40/50 Bitumen (PG76-10) may be needed for HMA layers. Polymer Modified Binder PG76-10 is considered in the WC to minimize ruts. This can be achieved incorporating to the available asphalt cement, 4 to 5% by weight of Styrene-Butadiene-Styrene (SBS).
To minimize rutting: The HMA base layers will use a large stone mix, with aggregates passing 100% sieve 1.5". Wearing course with aggregates passing 10% sieve 1".
Rehabilitation Overlay on DBST will require surface preparation (patches, levelling, crack filling) also Alternatives 1 and 4 with DBST. Also this solution will be prone to crack fatigue before design period.
For HMA higher thickness minimises fatigue cracks

Notes on data for unit rates (see Table 5 – Build up of unit rates)

ITEM 1: **CRUSHED STONE AGGREGATES**

There are natural gravels available along the length of the project. Although these may prove to be relatively strong it is preferred to have a crushed stone road base. Crushed stone aggregates will also be required for DBST wearing course or hot mix asphalt wearing course.

At present there is no commercial crusher operating in Southern Sudan. In Juba there is an old crushing plant that is being revitalized but is not yet operating commercially. The local population produce a lot of aggregates by hand breaking rock into various sizes, as small as 20mm. The quality of this stone is unknown but much of it is quartzitic. It will not be a suitable source for road construction.

Therefore it has been assumed that contractors bidding for the project will do so based on mobilizing and operating their own crushing plant close to the site. The quantities of crushed stone required make this a very feasible solution.

- Calculation is based on the fact that a crusher will be bought, transported and put up on the site.

- The crusher plant is 100% devalued at the end of the construction project.

- Operating cost of a medium sized crusher is **USD 35/ton (60USD/M3)** based on inquiries from contractors operating crusher plants in Juba, viz. **GTZ** and a **Lebanese** enterprise.

  The operational costs include the following;

  i) 1 no. operator
  ii) Replacement of drill bits
  iii) Spares for the machine
  iv) Fuel /lubricants
  v) Loading and crushing/blasting
  vi) Labour
  vii) Stockpiling
  viii) Royalty (if required)

- Crusher purchasing costs.

  It is assumed that **2X200tons/hr** crushing plant capacity will be required to produce about **680,000 tons (400,000m3)** of aggregates. An indicative price for a crusher plant of this capacity purchased from the **UK** is about **400,000 Sterling pounds (784,000 USD).**

- Mobilization costs from Mombasa to Juba is found to be about **USD 24,000** for **two** round trips of **100 tons** as weight of the crusher and its accessories.

- Setting up/installation costs is about **USD 20,000**.which includes 2 expatriates and a lifting crane and several helpers for about two weeks.

- Total Costs less operational costs is therefore **USD 784,000 +20,000+24,000** which equals **USD 828,000**.

- Full depreciation of the plant is assumed (it may revert to the GOSS at end of project.) for this calculation purposes.

- Cost of buying, mobilization and installing the crusher on project site is built into the total production of the aggregates for the entire project.

  i.e **828,000/400,000 USD/M3** equals **2.07 USD/M3**

- Allow a percentage of **4%** as overheads for the entire crushing operation.

  4% X 2.07=0.01USD/M3.

  Sub-total rate is **2.08USD/M3**

- Allow **15%** for insurance costs against all risks.

  Sub-total rate is now **2.4 USD/M3**

- Final rate of the aggregate(all inclusive) is therefore **60 + 2.4 = 62.4 USD/M3**

- Convert to tons/m3, is **62.4/1.7 = 36.7USD/ton**, Say **40 USD/ton**

  (Bulk Density of aggregates is assumed to be **1.7tons/m3**)

In Kenya crushed stone can be produced on site for approximately $20 per ton so the Juba cost is significantly more expensive.

<u>ITEM 2: Transportation costs- general</u>

Average transportation rate from Kenya to Sudan is assumed to be **0.11USD/Ton/Km.** this is about **220 USD per ton** up to Juba (from Mombassa).

ITEM 3: Bitumen

It is assumed that bitumen will be transported in bulk from Mombasa-Kenya.
Price used to build up the rates is **USD 714 per ton** as evidenced from the local contractors hauling bitumen from Mombasa.

ITEM 4: Cement

Information sourced from the various contractors operating in the vicinity, the rate to deliver cement to Juba is assumed to be approximately **USD 285 per ton** (from Kampala)**.**

ITEM 5: Reinforcement bars

Rate for purchase and delivery of reinforcement bars to Juba from Kenya is **USD 2,000 per ton.**

Table 1 Juba - Nimule Road - Bridges

	Bridge	Chainage	Bridge location latitude	Bridge location longitude	Width	Length	Spans	Bridge type	Deck type	Status	Water course	Clearance soffit to water/bed	Estimated Load bearing capacity
1	Kubri Arba	23 + 800	4.666	31.705	3.3	18.3	single	steel truss	sheet steel	Passable	dry	4m	47
2	Kubri Hamsa	27 + 000	4.662	31.727	3.3	12.2	single	steel truss	sheet steel	Passable	almost dry	4m	52
3	Kubri Sita	28 + 300	4.652	31.732	3.3	36.6	3 span (8/20/8)	steel truss	sheet steel	Passable	little water	4-5m	35
4	Nyole Bridge	98 + 700	4.233	32.003	3.3	27.4	single	steel truss	sheet steel	Passable		4m	62
5	Kit Bridge	101 + 300	4.211	31.996	3.3	54.9	2 span (27/27)	steel truss	sheet steel	Passable	water	6-7m	29
6	Aswa Bridge	167 + 000	3.723	31.972	3.3	76.2	3 span (24/30/22)	steel truss	timber	Passable	major river	4m	24
7	Merlin Bridge, Nimule	190 + 400	3.584	32.070	3.3	21.3	single	steel truss	sheet steel	Passable	dry	3m	42
8	Anyama Bridge - border	192 + 000	3.571	32.073	3.3	36.6	4 span (4x9)	steel truss	timber	Passable	river	4m	52

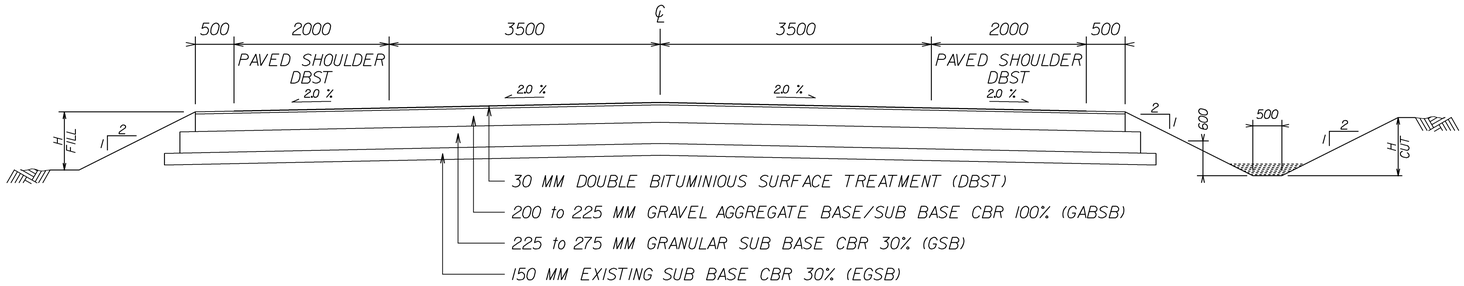
Table 1

SURVEYED BY _____
SUPERVISED BY _____
DESIGNED BY _____

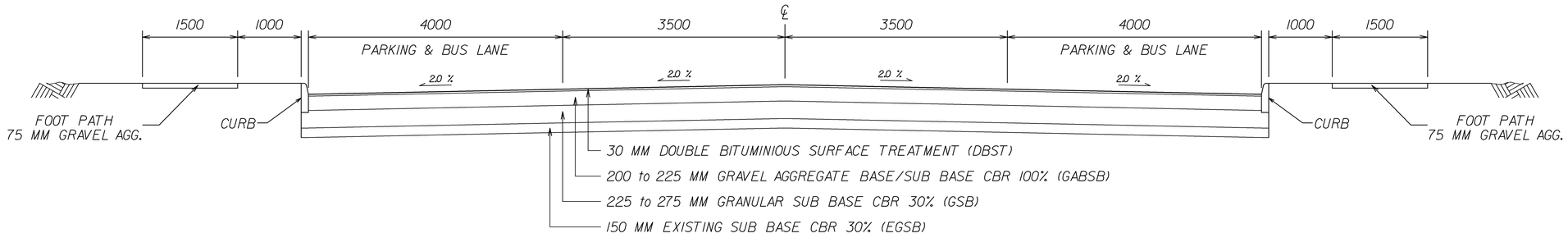
DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	FHWA REGION	STATE	FEDERAL AID PROJECT	STATE ROUTE	STATE PROJECT	SHEET NO.
			---			--

ALTERNATIVE 4 - RURAL



ALTERNATIVE 4 - URBAN



PRINTED: 3/29/2007 09:25:02

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
A			--

FIGURE 2

DESIGN
OF
PAVEMENT STRUCTURES
Alternative 4

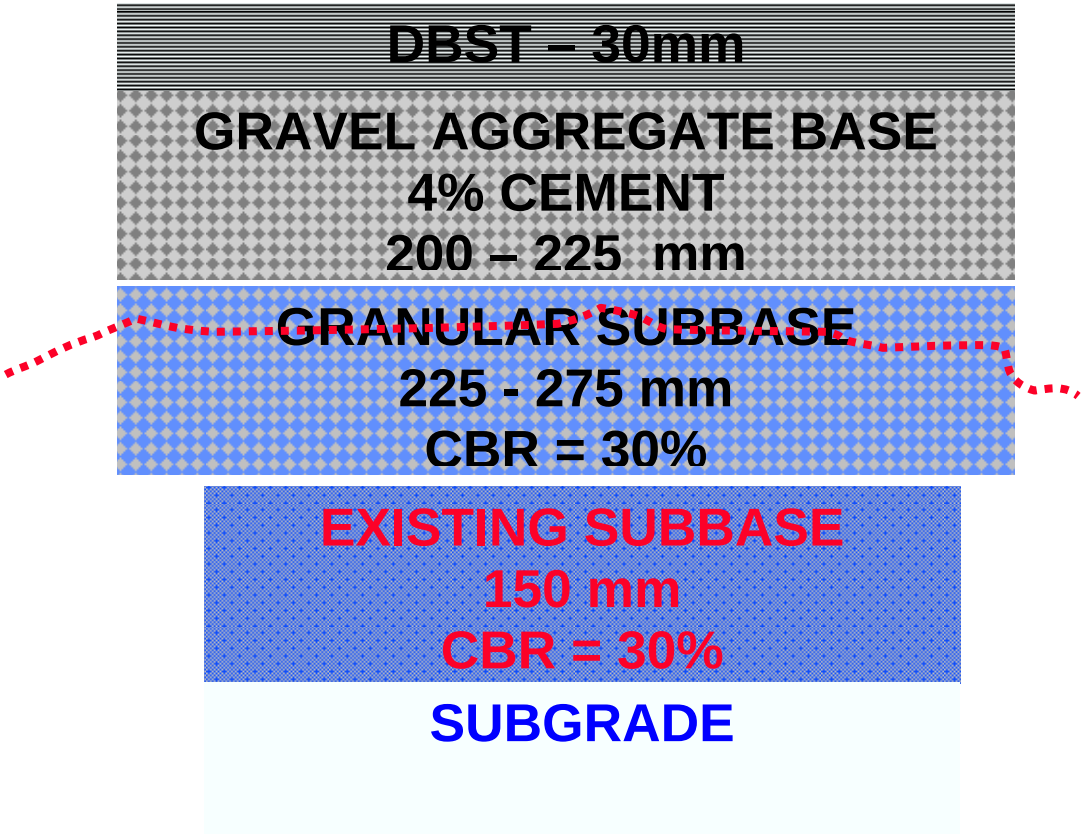


Table 2

Estimated Construction Cost for The Juba – Nimule Road (192 Km Approx.)

Pavement alternative 4

Summary costs	major pay items	plus minor pay items	Section 1	Section 2	Section 3	Section 4			
		add 15%	3.4	17.4	169.2	2	192 km		
		1.15	2%	9%	88%	1%			
Site clearance & road bed prep	2,465,856	2,835,734	50,216	256,988	2,498,991	29,539	2,835,734		
Earthworks	4,566,575	5,251,561	92,996	475,923	4,627,938	54,704	5,251,561		
Pipe Culverts	1,029,000	1,183,350	20,955	107,241	1,042,827	12,327	1,183,350		
Box culverts	200,000	230,000	4,073	20,844	202,688	2,396	230,000		
Road signs & saftey barrier	425,500	489,325	8,665	44,345	431,218	5,097	489,325		
			35%	10%	20%	35%			
Urban - kerbs, paving, ducts etc	245,000	600,000	210,000	60,000	120,000	210,000	600,000		
Road marking	1,094,400	1,258,560	22,287	114,057	1,109,106	13,110	1,258,560		
Gravel pavement	9,351,600	10,754,340	190,441	974,612	9,477,262	112,024	10,754,340		
Doubleseal pavemet	31,210,020	35,891,523	635,579	3,252,669	31,629,405	373,870	35,891,523		
AC pavement	50,769,747	58,385,209	1,033,905	5,291,160	51,451,965	608,179	58,385,209		
Bridges	2,436,900	2,802,435	49,626	253,971	2,469,646	29,192	2,802,435		
	12,463,231								
Total cost excl. P&G									
Gravel pavement	excludes road marking		626,974	2,193,924	20,870,570	455,279	24,146,747		
Doubleseal pavemet			1,094,399	4,586,038	44,131,818	730,235	50,542,490		
AC pavement			1,492,724	6,624,528	63,954,379	964,544	73,036,176		
Prelims and General									
	10%		62,697	219,392	2,087,057	45,528	2,414,675		
Mobilisation, facilities for the engineer office, laboratory, camps etc.			109,440	458,604	4,413,182	73,023	5,054,249		
security, insurances			149,272	662,453	6,395,438	96,454	7,303,618		
Total cost									
Gravel pavement			**689,671**	**2,413,316**	**22,957,627**	**500,807**	**26,561,421**		
Doubleseal pavement	stabilised natural gravel base		**1,203,838**	**5,044,642**	**48,545,000**	**803,258**	**55,596,739**		
AC pavement	stabilised natural gravel base		**1,641,997**	**7,286,981**	**70,349,817**	**1,060,998**	**80,339,793**		
Cost per km									
Gravel pavement	thousand $	cost per km	**203**	**139**	**136**	**250**	**138**	100%	
Doubleseal pavemet			**354**	**290**	**287**	**402**	**290**	209%	100%
AC pavement			**483**	**419**	**416**	**530**	**418**	302%	145%

Table 3

Estimated Construction Cost for The Juba – Nimule Road (192 Km Approx.)

Major Pay Items

Design of Road - Width and Shoulder :

1. Traffic Lane : 7.0 m
2. Shoulder Width : 2.0 m each side
3. Road length 192 km

DBST
- DBST 19.5 & 9mm
- 200 - 225 stabilised natural gravel base
- 225-275 sub base
- 150 roadbed/subbase

AC
- 40mmm AC wearing course
- 60 - 75 AC base course
- 150 stabilised natural gravel base
- 150 roadbed/subbase

Gravel
- 150 gravel wearing course
- 150 gravel base course
- 150 roadbed/subbase

Major Pay Items

	Quantity	Unit	Rate(US)	Total
Site Clearing And Earthworks				
	Quantity	**Unit**	**Rate (US)**	**Total**
1. Site Clearing : Clear 192 Km x 26m (mine cleared) ROW excluding existing road (7m wide)	365	ha	1,800.00	656,640.00
Road bed preparation				
New Road foot print (area below base course) = 192,000 x 12m = 2,304,000 x.15= 345,600				
2. Existing road -Scarify to depth 150 mm, regulating, preparing and compacting				
existing gravel surface - 192,000 x 7.0m x 0.150	201,600	cu.m	4.51	909,216.00
Area outside existing pavement (assume sub-grade width of 12m is required)				
3. Remove topsoil 50% of the area - 50% x 192,000 x 5 x 0.150	72,000	cu.m	2.50	180,000.00
4. compact subgrade 150mm (192,000 x 5 x 0.150)	144,000	cu.m	5.00	720,000.00
Earthworks				
5. Excavation in rock , 1.6 km , width 5 m , height 5 m = 40,000 cu.m	40,000	cu.m	75.00	3,000,000.00
6. Excavation in suitable, 14 km , depth 1.0 m ,width 5 m = 70,000 cu.m	70,000	cu.m	3.60	252,000.00
7. Embankment 30 km x 1.0 wide x .5m high = 150,000 cu.m	15,000	cu.m	6.50	97,500.00
8. Imported gravel sub-base 150mm thick (192,000 x 5 x 0.15)	125,370	cu.m	7.50	940,275.00
9. Side Drain Excavation , 0.346 sq.m ,Section Area , Depth 0.5 m below Sub Base Layer	69,200	cu.m	4.00	276,800.00
100 km long on both sides = 69,250.00cu.m				
Total				**7,032,431.00**

Table 3

Table 3

Estimated Construction Cost for The Juba – Nimule Road (192 Km Approx.)

Major Pay Items

Pavement

Type - A Road Pavement : Bituminous Asphalt Concrete Pavement	Quantity	Unit	Rate (US)	Total
Natural gravel base stabilised with 4% cement 150mm thick	331,800	cu.m	30.00	9,954,000.00
Prime 0.9l/m2 (192,000 x 11 x 0.9)	1,921,536	lt	1.25	2,401,920.00
Tack coat	640,512	lt	1.00	640,512.00
AC Base Course 60 - 75 mm thick to Spec. Req. = 192,000 x 11.1 x varies (.06 - .075)	129,473	cu.m	195.00	25,247,235.00
Wearing Course 40 mm thick to 98 % Compaction Spec. Req. 192,000 x 7m	1,344,000	sq.m	9.32	12,526,080.00
Total				**50,769,747.00**

Type – B Surface Dressing : Double Bituminous Surface Treatment (DBST)	Quantity	Unit	Rate (US)	Total
sub - base 225 - 275mm thick	579,128	cu/m	7.50	4,343,460.00
Natural gravel base stabilised with 4% cement 200 - 225mm thick	439,360	cu/m	30.00	13,180,800.00
Prime 0.9l/m2	1,921,536	lt	1.25	2,401,920.00
binder 1.1l/m2	2,323,200	lt	1.60	3,717,120.00
First Layer (bottom) : chippings (19 mm) , 70 sq.m / cu.m. (19,200 x 11)	2,112,000	sq.m	1.75	3,696,000.00
binder 0.8 l/m2	1,075,200	lt	1.60	1,720,320.00
Second Layer (top) : chippings(9 mm) 100 sq.m /cu.m (192,000 x 7)	1,344,000	sq.m	1.60	2,150,400.00
Total				**31,210,020.00**

Type – C Gravel Road : Gravel Surface	Quantity	Unit	Rate (US)	Total
addditional sub-base, adjustment	6,560		7.50	49,200.00
Natural gravel Aggregate Base Course 150 mm thick, 98 % MDD to Spec.Req. = 192,000 x 11.9 x .15	342,720	cu.m	11.00	3,769,920.00
Laterite Sandy Soil - gravel wearing course 150 mm thick , 98 % MDD = 192,000 x 11.3 x .150	325,440	cu.m	17.00	5,532,480.00
Total				**9,351,600.00**

Table 3

Table 3

Estimated Construction Cost for The Juba – Nimule Road (192 Km Approx.)

Major Pay Items

R.C. Pipe Culvert :	**Quantity**	**Unit**	**Rate (US)**	**Total**
10. R.C. Pipe Culvert , Size 900 mm dia. length L = 14m , (150 nos) = 2100 lin.m	2,100	lin.m	325.00	682,500.00
Included reinforcements, 30 Mpa Conc. formworks and workmanship.				
11. R.C. Pipe Culvert, Size 1200 mm dia. length L = 14 m , (50 nos.) = 700 lin.m	700	lin.m	495.00	346,500.00
Included reinforcements, 30 Mpa Conc. formworks and workmanship.				
Note : Assumed to lay one R.C. Pipe. Culvert or Box Culvert every 900 m.				
Total				**1,029,000.00**
R. C. Box Culvert :	**Quantity**	**Unit**	**Rate (US)**	**Total**
12. R.C. Box Culvert , size 3m x 3 m , length L = 14 m (10 nos) ,	300	cu.m	380.00	114,000.00
Included reinforcements, 30 Mpa Conc.,formworks and workmanship.				
13. R. C. Box Culvert, size 4 m x 4 m , length L =14 m (5 nos)	215	cu.m	400.00	86,000.00
Included reinforcements, 30 Mpa Conc. formworks and workmanship.				
Total				**200,000.00**
Ancillary Works	**Quantity**	**Unit**	**Rate (US)**	**Total**
14. Parapet Guardrail Materials, workmanship to Spec. Req. Say 600m.	600	lin.m	150.00	90,000.00
15. Road Kerb to design drawing standard	10,000	lin m	22.00	220,000.00
16. Road Markings (Thermoplastic) = 192,000 lin m x 3 x 0.1 (centre line and edge lines)	57,600.00	sq.m	19.00	1,094,400.00
17. (i) Traffic Sign (Standard) to drawing design standard = 100 nos, size < 1.0 sq.m.	100	nos	80.00	8,000.00
(ii) Traffic Sign (Standard) to drawing design standard = 50 nos, size > 1.0 sq.m.	50	nos	150.00	7,500.00
18. Directional Information Sign to drawing design standard = 100 nos	100	nos	350.00	35,000.00
19. Guardrail Safety to drawing design standard = 2500 lin m (bends , embankments and hazards)	2500	lin.m	150.00	375,000.00
20. Service Duct to drawing design standard 1000.00 lin.m	1000	lin.m	25.00	25,000.00
Total				**1,854,900.00**
Bridges (8 no.) **Total**				**2,346,900.00**
Total cost excluding pavement, minor pay items and P & G	carry forward to summary			**12,463,231.00**

Table 3

Table 4

Estimated Construction Cost for The Juba – Nimule Road Feasibility Study
Sample unit rates from previous or ongoing construction contracts in Southern Sudan, Uganda and Kenya

Company		Hayer Bishan Singh & Sons Ltd (Kenya)	Civicon Ltd (Kenya)	Civicon Ltd (Kenya)	Kenya	Civil Engineering Company International	Uganda
Project Title		**WFP Juba - Mundri Road**	**WFP Faraksika - Rumbek Road**	**WFP Wau - Abyiei Road**	**Machakos Turnoff - Nairobi - Mombasa Road**	**Emergency Rehabilitation Works In Juba (ERWJ)**	**Uganda Road Agency data**
Type of Works		**Emergency Roads Repair - gravel roads**	**Gravel Roads Routine Maintenance / Repairs**	**Emergency Roads Repair - very remote area**	**Rehabilitation Road Works**	**Rehabilitation of urban roads in Juba - ac, gravel, dbl seal**	**Road improvement / construction**
		2006	2006	2006	2005	2006	2006
Major Items of Work		**Rate US$**	**Rate US$**	**Rate US$**	**Rate US$**	**Rate US$**	
Clearing and grubbing including removal of trees as specified	ha	1,600.00	1,800.00		2,999.19	1,680.00	4,196.11
Large Tree Cutting	no.	200.00	100.00				316.00
Removal top soil	cu.m	5.85		2.27	3.59		
Cut to Fill	cu.m	6.50	5.30	6.84	4.32		
Borrow to fill	cu.m	6.50	12.60	12.36	5.30	7.00	5.56
Spoil in soft material	cu.m				11.18	12.70	
Excavation hard material rock	cu.m		76.00	165.00			
Fill in hard material	cu.m				7.72	49.00	
Spoil in hard material	cu.m				17.56	45.70	
Grading existing surface	sq.m	0.75		0.74	0.71		
Light Grading	km		6,800.00				
Heavy Grading	km		16,200.00				
Compaction of existing ground to 95 % MDD (T180)	cu.m					2.10	8.33
Compaction of 300 mm below formation level in cutting							
(i) Within upper 150 mm subgrade	cu.m					4.41	
(ii) Within lower 150 mm subgrade	cu.m					5.00	
Prepare road bed/compact to 93% of MDD(Heavy)	cu.m				2.31		3.44
Subgrade construction 95% MDD	cu.m				7.68		8.33
Sub base, granular material, 95% MDD up to 150mm thick	cu.m				19.50	14.00	13.61
Crushed stone base,98%MDD	cu.m				28.97	81.00	37.22
Hydrated lime for lime stabilization in sub base	ton				243.00	588.00	319.44
Mixing, laying compact lime stabilised sub base	cu.m				5.60		11.67
Murram / Sandy Gravel Wearing Course	cu.m	8.00	14.90	14.25			
Overhaul for transport of wearing course and rock	cu.m/km	0.75	0.52	0.61			
Provision of naturally occuring rock boulders including transport	cu.m	20.00		105.00			
Drainage - side drains							
Catch Water Drain :							
Plant intensive	lin.m		4.60				
Labour intensive	lin.m		9.20				
Excavation for manholes and outfall drain	cu.m					17.43	
Excavation For Side Drain	cu.m	6.50	4.60	5.37	10.10		5.11
Labour intensive	cu.m		9.20				

Table 4

Estimated Construction Cost for The Juba – Nimule Road Feasibility Study
Sample unit rates from previous or ongoing construction contracts in Southern Sudan, Uganda and Kenya

Company		Hayer Bishan Singh & Sons Ltd (Kenya)	Civicon Ltd (Kenya)	Civicon Ltd (Kenya)	Kenya	Civil Engineering Company International	Uganda
Project Title		**WFP Juba - Mundri Road**	**WFP Faraksika - Rumbek Road**	**WFP Wau - Abyiei Road**	**Machakos Turnoff - Nairobi - Mombasa Road**	**Emergency Rehabilitation Works In Juba (ERWJ)**	**Uganda Road Agency data**
Type of Works		**Emergency Roads Repair - gravel roads**	**Gravel Roads Routine Maintenance / Repairs**	**Emergency Roads Repair - very remote area**	**Rehabilitation Road Works**	**Rehabilitation of urban roads in Juba - ac, gravel, dbl seal**	**Road improvement / construction**
		2006	2006	2006	2005	2006	2006
Major Items of Work		**Rate US$**	**Rate US$**	**Rate US$**	**Rate US$**	**Rate US$**	
Structures							16.67
Excavation for structure works	cu.m	8.00		2.88			
Excavation in common material for structure to any depth							
Plant intensive	cu.m		1.60				10.28
Labour Intensive	cu.m		3.60				
Cast in situ concrete 25 Mpa	cu.m	330.00	495.00	820.00	152.00	456.00	283.33
Cast in situ concrete 10-15 Mpa	cu.m	295.00	230.00	330.00	125.00	309.00	194.40
Steel Reinforcement	ton	2,000.00	1,900.00				2,470.00
Corrugated Steel Pipes							
600 mm dia. T=2.7 mm	lin.m	200.00	0.00	165.00	94.36		114.00
900 mm dia. T=2.7 mm	lin.m	325.00	251.00	280.00	127.00		185.00
1200 mm dia. T = 3.5 mm	lin.m	495.00	360.00	320.00	202.90		533.00
Concrete Pipes							
Provide lay R.C.Pipe Culvert 600 mm dia.	lin.m					226.00	
Provide lay R.C.Pipe Culvert 900 mm dia.	lin.m					321.00	
provide lay R.C.Pipe Culvert 1200 mm dia.	lin.m					395.00	
Masonry works for abutment headwall wingwall etc.,	cu.m	280.00	230.00	330.00			
Grouted Stone Pitching 200 mm to 250 mm thick	cu.m	285.00	230.00	330.00	107.90		
Constructed and fill with boulders Reno 2x0.3	cu.m			280.00			
Gabion Mattresses	cu.m	180.00	240.00	280.00			
Rip-rap	cu.m		170.00		52.51		
Scour Checks	no.		5.00				
Structural Steel Bridge, provision ,painting erection	ton	3,100.00	3,600.00	4,400.00			
Steel Decking Planks for repair	ton	2,900.00		3,900.00			
Bailey Bridge, single span,max.load 50 ton,provision	Prov sum	1,072,500.00		500,000.00			
transport,erection.							
Steel Girder 1400 x 475/350 for bridge	ton				4,888.83		
Ordinary Portland Cement	ton	238.00	425.00	415.00			
Mild Steel Reinforcing Bars all dia.	ton	1,065.00	1,900.00	820.00			
High Grade Reinforcing Bar all dia.	ton	1,280.00	1,900.00	840.00			
Plywood 12 mm	sq.m	15.00	12.00	12.00			
Plywood 18 mm	sq.m		18.00				
Timber for Shuttering	cu.m	602.00		330.00			
Un-wrought timber all sizes	cu.m		330.00	58.00			
Formwork Rough	sq.m	15.00	16.00	16.00			
Sand for concrete	cu.m	15.00	35.00	35.00			
Coarse aggregates for concrete	cu.m	30.00	90.00	80.00			
Masonry Boulders	cu.m	17.50	40.00	40.00			
Rip-Rap and Gabion Boulders	cu.m	20.00	40.00	40.00			
Permanent Traffic Signs	Prov sum	7,000.00	8,000.00	7,000.00			

Table 4

Estimated Construction Cost for The Juba – Nimule Road Feasibility Study
Sample unit rates from previous or ongoing construction contracts in Southern Sudan, Uganda and Kenya

Company		Hayer Bishan Singh & Sons Ltd (Kenya)	Civicon Ltd (Kenya)	Civicon Ltd (Kenya)	Kenya	Civil Engineering Company International	Uganda
Project Title		WFP Juba - Mundri Road	WFP Faraksika - Rumbek Road	WFP Wau - Abyiei Road	Machakos Turnoff - Nairobi - Mombasa Road	Emergency Rehabilitation Works In Juba (ERWJ)	Uganda Road Agency data
Type of Works		Emergency Roads Repair - gravel roads	Gravel Roads Routine Maintenance / Repairs	Emergency Roads Repair - very remote area	Rehabilitation Road Works	Rehabilitation of urban roads in Juba - ac, gravel, dbl seal	Road improvement / construction
		2006	2006	2006	2005	2006	2006
Major Items of Work		**Rate US$**	**Rate US$**	**Rate US$**	**Rate US$**	**Rate US$**	
Sealed Pavement Construction							
AC Wearing Course 4.9 % bitumen content 0/14 mm	cu.m				194.48		233.00
AC base - dense Bitumen macadam 4.5 % bitumen content 0/30 m	cu.m				142.62		195.56
MC 30 Prime Coat at 0.8 - 1.2 l/sq.m	lt				0.97	4.33	1.39
K 1 - 70 tack coat at 0.4 - 0.6 l/sq.m.	lt					4.91	
Binder - 80/100 bitumen at a rate of 1.2 - 1.4 l/sq.m for 1st seal	lt				0.78	4.31	1.48
1st seal precoated chipping 14/20mm at a rate 80 - 120 sq.m / cu.m	cu.m				89.00	246.00	220.00
2nd seal precoated chipping 6/10mm at a rate 110 - 130 sq.m / cu.m	cu.m				91.00	214.00	233.00
Ancillary Works							
Standard information signs							
a) 400mm x 300mm	no.				156.00	337.00	267.00
b) 600 mm x 600 mm	no.				180.00	385.00	
Non Standard information signs							
a) Less than 1 sq.m.	no.					78.00	
b.) Equal or more than 1 sq.m. but less than 2 sq.m.	no.					156.00	
c) Equal or more than 2 sq.m. but less than 5 sq.m	no.					325.00	
Hot applied thermoplastic road marking paint							
a) Yellow	sq.m				12.54	10.14	20.60
b) White	sq.m				12.54	10.14	18.90
New Kerb Road Edge 100x 150 mm	lin.m				5.43	12.83	
km post	no				91.67		90.00
Guard rail	m				5.20		6.67
End anchorage	no						1,250.00
Rumble strip	m						42.22
Speed hump, conc.	m				737.68		616.67
Grassing/planting	ha				2,255.07		7,375.00
Retro reflective road studs	ea				15.48	1.94	

Table 5

Estimate of Constuction Costs for Juba - Nimule Road Feasibility Study
Build up of unit rates

Item: Site Clearance

Activities included
1. Clearing and grubbing

Output: 1.00 km per day
Clear width for widening average 8 m 8.00 m
8000.00 m^2 per day

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/ day	Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Bull dozer 110 KW (D6 or eq)	1.00	100.00	800.00	Foreman	1.00	20.00	22.00					
				Heavy plant operator	1.00	20.00	22.00					
				Labourers	8.00	6.00	64.00					
				Filter mechanic	1.00	10.00	12.00					
Total			800.00				120.00					

Total cost 920.00
Cost per m^2 0.12
Cost per ha **1,150.00**

Item: Removal of Topsoil

Activities
1. Removal of overburden and stockpiling
2. Doze and stockpile overburden

Output: 1000m /day, assume 150mm t 1050.00 m³/day

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/Day	Cost	Type	Unit	Qty	Rate	Cost/Unit
Dozer D6	1.00	100.00	800.00	Foreman	1.00	20.00	22					
Tipping Truck (10M3)	1.00	37.50	300.00	Heavy plant operator	1.00	20.00	22					
Tractor Loader	1.00	100.00	800.00	Drivers	1.00	15.00	17					
				Labourers	2.00	6.00	16					
				Filter mechanic	1.00	10.00	12					
Total			1,900.00				89.00					

Total cost 1,989.00
Cost/m³ **1.89**

Item: Earth Cut Or Borrow to Fill

Activities included
1. Cutting and stockpiling
2. Loading
3. Transport up to 8 km

Output: 1000.00 m³/day

Operations:

Cycle time	48.00	Min	Average ha 8km	
Trips	100.00	No	Truck Speed	20 km / hr
Truck capacity	10.00	M3		
Number of trucks	10.00	No		
Production (m³)	1,000.00	M3		

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/day	Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Excavator	1.00	100.00	800.00	Foreman	1.00	20.00	22.00					
Tractor Loader 1.5 m³ bucket (CAT 95	1.00	100.00	800.00	Light plant operator	0.00	0.00	-					
Tipping truck 10.0 m³	10.00	37.50	3,000.00	Heavy plant operator	2.00	20.00	44.00					
				Drivers	10.00	15.00	170.00					
				Labourers	5.00	6.00	40.00					
				Filter mechanic	1.00	10.00	12.00					
				Leveller	1.00	10.00	12.00					
				Headman	1.00	10.00	12.00					
Total			4,600.00				312.00					

Total cost 4,912.00
Cost/m³ **4.91**

Item: Earthwork Embankment

Activities
1. Transport, Spreading, Watering and Compaction

Output: 900.00 m³/day

			Operations:		
			Cycle time	53	Min
			Trips	90	No
Average width of fill	10.00	m	Truck capacity	10	M3
Working length	450.00	m per day	Number of trucks	10	No
Thickness	0.20	m	Average haul	9	Km
Production	900.00	m³	Truck Speed	20	km/hr

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/Day	Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Grader	1.00	100.00	800	Foreman	1.00	20.00	22.00					
Water tanker	1.00	37.50	300	Light plant operator	1.00	15.00	17.00					
Sheep's foot roller	1.00	100.00	800	Heavy plant operator	3.00	20.00	66.00					
Vibrating roller	1.00	100.00	800	Drivers	10.00	15.00	170.00					
Dump Truck (10 M3)	10.00	37.50	3,000	Labourers	6.00	6.00	48.00					
				Filter mechanic	1.00	10.00	12.00					
				Leveller	1.00	10.00	12.00					
				Headman	1.00	10.00	12.00					
				Surveyor	1.00	20.00	22.00					
Total			5,700.00				381.00					

Total cost 6,081.00
Cost/m³ **6.76**

Table 5

Estimate of Constuction Costs for Juba - Nimule Road Feasibility Study
Build up of unit rates

Item: Soft material cut to spoil

Activities included
1. Cutting and stockpiling
2. Loading
3. Transport up to 1.0 km

Output: 640.00 m³/day

Operations:

Cycle time	30.00	min	Average Haul 5 km
Trips	16.00	no	Truck Speed 20 km/hr
Truck capacity	10.00	m3	
Number of trucks	4.00	no	
Production (m³)	640.00	m3	

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	US$/day (8hr)	Class	No	US$/day	Cost/day	Type	Unit	Qty	Rate	Cost/Unit
Bull dozer D6	1.00	100.00	800.00	Foreman	1.00	20.00	22.00					
Tractor Loader 1.5 m³ bucket (CAT 95	1.00	100.00	800.00	Heavy plant operator	2.00	20.00	44.00					
Tipping truck 10.0 m³	4.00	37.50	1,200.00	Drivers	4.00	15.00	68.00					
				Labourers	5.00	6.00	40.00					
				Filter mechanic	1.00	10.00	12.00					
Total			2,800.00				186.00					

Total cost 2,986.00
Cost/m³ **4.67**

Item: Rock Excavation included explosive

Activities included
1. Excavating
2. Loading
3. Transport up to 1.5 km

Output: 50.00 m³/day

Operations:

Cycle time	60.00	Min	Average Haul 10 km
Trips	5.00	No	Truck Speed 20 km/hr
Truck capacity	10.00	m3	
Number of trucks	1.00	No	
Excavation Production (m³)	50.00	m3	

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/Day	Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Bull dozer D6	1.00	100.00	800.00									
Tractor Loader 1.5 m³ bucket (CAT 95	1.00	100.00	800.00	Light plant operator	1.00	15.00	17.00					
Tipping truck 10.0 m³	1.00	37.50	300.00	Heavy plant operator	1.00	20.00	22.00					
				Drivers	1.00	15.00	17.00					
				Labourers	1.00	6.00	8.00					
				Filter mechanic	1.00	10.00	12.00					
Total			1,900.00				76.00					

Total cost 1,976.00
Explosive Cost 100% 1,976.00
Cost /M3 **79.04**

Item: Scarifying and Compaction of existing ground

Activities included
1. Scarifying
2. Removal of roots
3. Watering, compaction

Output: 0.30 km per day
Equivalent 2100.00 m² per day

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/Day	Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Grader 140G-110 kw	1.00	100.00	800.00	Foreman	1.00	20.00	22.00					
Water tanker-6000l	1.00	37.50	300.00	Light plant operator	1.00	15.00	17.00					
Roller (Sheep's foot- Bomag BW 6S)	1.00	100.00	800.00	Heavy plant operator	1.00	20.00	22.00					
				Labourers	5.00	6.00	40.00					
				Filter mechanic	1.00	10.00	12.00					
				Leveller	1.00	20.00	22.00					
Total			1,900.00				101.00					

Total cost 2,001.00
Cost per m2 **0.95**

Item: Excavation Side Drain

Activities included
1. Setting out
2. Excavation and Shaping

Operations:

Cycle time	30.00	min	Average Haul 5 km
Trips	15.00	no	Truck Speed 20 km/hr
Truck capacity	10.00	m3	
Number of trucks	1.00	no	
Excavation Production (m³)	150.00	m3	

Output 150.00 m³/day

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/day	Cost/day	Type	Unit	Qty	Rate	Cost/Unit
Excavator	1.00	100.00	800.00	Heavy plant operator	1.00	20.00	22.00					
Dumper Truck	1.00	37.50	300.00	Drivers	1.00	15.00	17.00					
				Labourers	20.00	6.00	160.00					
Total			1,100.00				199.00					

Total cost 1,299.00
Cost/m³ **8.66**

Table 5

Estimate of Constuction Costs for Juba - Nimule Road Feasibility Study
Build up of unit rates

Item: Natural Gravel with 4 % Cement Stabilised for sub base

Output: 750.00 m³/day

Activities
1. Excavation, stockpile
2. Transport, Place and stabilised 4 % Cement
3. Water , Compact

Average width . 12.50 m
Working length 300.00 m per day.
Production 750.00 m³/day

Average Haul = 5 km
Cycle Time =32 min per trip
Truck speed = 20 km/hr

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	ost/day (8hr) per c	Class	No	Rate	Cost	Type	Unit	Qty	US$/ton	Cost/Day
Tipping truck (10m3)	5.00	37.50	1,500.00	Foreman	1.00	20.00	22.00	Cement	ton	54	285.00	15,390.00
Loader	1.00	100.00	800.00	Light plant operator	1.00	15.00	17.00	Water	ton	120	15.00	1,800.00
Vibratory Roller	1.00	100.00	800.00	Heavy plant operator	4.00	20.00	88.00					
Water tanker	1.00	37.50	300.00	Drivers	5.00	15.00	85.00					
Grader	1.00	100.00	800.00	Labourers	10.00	6.00	80.00					
Dozer	1.00	100.00	800.00	Filter mechanic	1.00	10.00	12.00					
				Leveller	1.00	10.00	12.00					
				Headman	1.00	10.00	12.00					
Total			5,000.00				328.00					17,190.00

Total cost 22,518.00
Cost/m³ **30.02**

Item:Natural Gravel Fill Material for sub base

Output: 750.00 m³/day

Activities
1. Excavation, Stockpile
2. Transport
3. Compact

Average Haul = 5 km
Cycle Time =32 min per trip

Average width . 12.50 m
Working length 300.00 m
Production 750.00 m³

A. Equipment				B.Labour				C. Materials				
Type	No.	US$hr	ost/day (8hr) per c	Class	No	US$/Day	Cost	Type	Unit	Qty	Rate	Cost/Unit
Tipping truck (10m3)	5.00	37.50	1,500.00	Foreman	1.00	20.00	22				-	-
Pay Loader	1.00	100.00	800.00	Light plant operator	1.00	15.00	17					
Water Tanker	1.00	37.50	300.00	Heavy plant operator	4.00	20.00	88					
Vibratory Roller	1.00	100.00	800.00	Drivers	5.00	15.00	85					
Dozer	1.00	100.00	800.00	Labourers	5.00	6.00	40					
Grader	1.00	100	800	Filter mechanic	1.00	10.00	12					
				Leveller	1.00	10.00	12					
				Headman	1.00	10.00	12					
Total			5,000.00				288.00					-

Total cost 5,288.00
Cost/m³ 7.05

Item: Surface dressing (1st seal)

Output 8,800 m²/day

800m length @ 11m wide

Activities included
1.Heat and spray bitumen
2. Transport and lay chippings
3. Roll chippings

Spread rate 0.0125 m³/m² nen 80/100 1.2 l/m²
Volume of chippings (80m²/m³) 110.00 m³
Capacity per tipper 10.00 m³
No trips rq'd 20.00
Average haul 25.00 km uck Speed 25 km/hr
Cycle time 2.00 hrs
No trips per 8hr day per truck 4.00
No trucks 5.00

A. Equipment				B.Labour				C. Materials				
Type	No.	US$ Rate/	Cost/day (8hr)	Class	No	ate/day (8h	Cost/Day	Type	Unit	Qty	US$	Cost/Day
Bitumen distributor 6000l	1.00	100.00	800	Foreman	2.00	20.00	44.00	80/100 p	l	10,560	1.00	10,560.00
Chip spreader	1.00	50.00	400	Headman	1.00	10.00	12.00	Chipping	m³	110.00	60.00	6,600.00
Tippers (20T payload)	5.00	37.50	1,500	Light plant operator	4.00	15.00	68.00					
Pneumatic tyre /Steel roller	2.00	100.00	1,600	Heavy plant operator	3.00	20.00	66.00					
Wheel loader	1.00	100.00	800	Drivers	5.00	15.00	85.00					
Water tanker	1.00	30.00	240	Labourers	10.00	6.00	80.00					
Mechanical Broom	1.00	18.75	150									
Total			5,490				355.00					17,160.00

Total cost 23,005
Allow for material waste 5% 858
Total cost 23,863
Cost/m² **2.71**

Item: Aggregate Base Course 150 mm thick

Output: 400.00 m³/day

Activities
1. Crushed Aggregate Base Course, Excavation ,Transport, Spread, Water and Compact

Production m/day
Av. width 11.60 m Average haul 6 km
Thickness 0.15 m Cycle time 36 min
Volume 400.00 m³/day Truck Speed 20 km / hr

A. Equipment				B.Labour				C. Materials				
Type	No.	US$Rate/h	Cost/day (8hr)	Class	No	US$/Day	Cost/Day	Type	Unit	Qty (ton)	Rate/ton	Cost/M3
Grader	1.00	100.00	800.00	Foreman	1.00	20.00	22	Crushed	ton	1.71	40.00	68.40
Water tanker -6000l	0.30	37.50	90.00	Light plant operator	1.00	15.00	17	Cement	ton	0	285.00	-
Vibrating roller	1.00	100.00	800.00	Heavy plant operator	3.00	20.00	66	Water	l	0.19	15.00	2.85
Steel roller	0.00	100.00	0.00	Drivers	3.00	15.00	51					
Excavator	1.00	100.00	800.00	Labourers	6.00	6.00	48					
Dump Truck (10 M3)	3.00	37.50	900.00	Mechanic	1.00	10.00	12					
Total			3,390.00				216.00					71.25

Total cost for Equiment and Labour 9.02
Total cost for Material 71.25
Unit Cost for Crushed Aggregate Base Course / M3 **80.27**

Table 5

Estimate of Constuction Costs for Juba - Nimule Road Feasibility Study
Build up of unit rates

Item: Prime coat

Output: I000 m X 11m 11,000.00 m2

Activities included
1.Heat and pump from bulk
2. Transport and spray

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/day	Cost/day	Type	Unit	Qty	US$	Cost/Day
Bitumen distributor 6000l	1.00	100.00	800.00	Foreman	1.00	20.00	22.00	MC30	l	13,200	1.00	13,200.00
Mechanical Broomer	1.00	30.00	240.00	Headman	1.00	10.00	12.00					
				Mechanic	1.00	10.00	12.00					
				Heavy plant operator	1.00	20.00	22.00					
				Labour	8.00	6.00	64.00					
Total			1,040.00				132.00					13,200.00

Total cost	14,372.00
Add 5% for material waste	718.60
Total cost	15,090.60
Cost/m2	**1.37**

Item: Production of Asphalt Concrete
60 mm Bituminous Binder Course

Activities
1. Heating
2. Mixing

	for 1 ton
Bitumen (5%)	0.05 t
Filler (2%)	0.02 t
Aggregates (93%)	0.93 t

1 m3 @ A.C. Binder = 2.3 ton
Bitumen 0.115 ton

A. Equipment				B.Labour				C. Materials				
Type	No.	Rate/hr	Cost/day (8hr)	Class	No	Rate	Cost	Type	Unit	Qty(ton)	US$/ton	Cost/m3
					9.00			Bitumen	t	0.115	714.00	82.11
								Aggregat	t	2.185	40.00	87.40
Total			-				-					169.51

Total cost	169.51
Add 5% for materials wastage	8.48
Add 20% heating cost	35.60
Cost/m³	**213.58**

Item: Laying of Asphalt Concrete

Activities
1. Transport and Laying

Asphalt Batching Plant Production 800 ton per day (8 hr)

Output: A.C. Binder Course 350.00 m³/day
530 m length @ 11 m wide with 60 mm thick A.C. Base Course

Length/day	530.00	m
thickness	0.06	m
width	11.00	m
Output	350.00	m^3/day

Average haul = 6 km
Cycle time = 36 min
Truck Speed = 20 km/hr

A. Equipment				B.Labour				C. Materials				
Type	No.	US$Rate/h	US$/day (8hr)	Class	No	ate/day (8 h	S$Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Paver	1.00	100.00	800.00	Foreman	2.00	20.00	44.00					
Pneumatic Tyre Roller	1.00	100.00	800.00	Headman	2.00	10.00	24.00					
Vibratory / Static Roller	2.00	100.00	1,600.00	Heavy plant operator	4.00	20.00	88.00					
Trucks (5m3)	5.00	37.50	1,500.00	Drivers	5.00	10.00	60.00					
				Labourers	8.00	6.00	64.00					
				Filter mechanic	1.00	10.00	12.00					
Total			4,700.00				292.00					-

Total cost	4,992.00
Total cost	4,992.00
Cost/m³	14.26
Total Unit Cost for A.C. Base Course /M3	**227.85**

Item: Production of Asphalt Concrete
40 mm Bituminous Wearing Course

Output : A.C. Wearing Course 350.00 m3/day

Activities
1. Heating
2. Mixing

	for 1 ton
Bitumen (6.5	0.065 t
Filler (2%)	0.02 t
Aggregates (91.	0.915 t

1 m3 @ A.C. Wearing Course = 2.3 ton
Bitumen 0.1495 ton

A. Equipment				B.Labour				C. Materials				
Type	No.	Rate/hr	Cost/day (8hr)	Class	No	Rate	Cost	Type	Unit	Qty (ton)	US$/ton	Cost/m3
								Bitumen	t	0.1495	714.00	106.74
								Aggregat	t	2.1505	40.00	86.02
Total			-				-					192.76

Total cost	192.76
Add 5% for materials wastage	9.64
Add 20% heating cost	38.55
Cost/m³	240.95

Table 5

Estimate of Constuction Costs for Juba - Nimule Road Feasibility Study
Build up of unit rates

Item: Laying of Asphalt Concrete

Activities
1. Transport and Laying

Asphalt Batching Plant Production 800 ton per day (8 hr)

Output: A.C. Wearing Course 350.00 m³/day
1893 m length @ 7 m wide with 40 mm thick A.C. wearing course

Length/day	1,893.00	m	Average haul = 6 km
thickness	0.04	m	Cycle time = 36 min
width	7.00	m	Truck speed = 20 km/hr
Output	350.00	m^3/day	

A. Equipment				B.Labour				C. Materials				
Type	No.	US$Rate/h	US$/day (8hr)	Class	No	ate/day (8 h	$Cost/Day	Type	Unit	Qty	Rate	Cost/Unit
Paver	1.00	100.00	800.00	Foreman	2.00	20.00	44.00					
Pneumatic Tyre Roller	1.00	100.00	800.00	Headman	2.00	10.00	24.00					
Vibratory / Steel Roller	2.00	100.00	1,600.00	Light plant operator	3.00	15.00	51.00					
Trucks (5m3)	5.00	37.50	1,500.00	Heavy plant operator	2.00	20.00	44.00					
				Drivers	5.00	10.00	60.00					
				Labourers	8.00	6.00	64.00					
				Filter mechanic	1.00	10.00	12.00					
Total			4,700.00				299.00					-

Total cost 4,999.00

Total cost 4,999.00
Cost/m³ 14.28

Total Unit Cost for 40mm AC Wearing Course/M3 255.24

Item: Surface dressing (2nd seal)

Activities included
1.Heat and spray bitumen
2. Transport and lay chippings
3. Roll chippings

Output 8800.00 m²/day
1257mlength @7m wide

Spread rate	0.0090	m³/m²	men 80/100	0.9 l/m²
Volume of chippings (110 m²/m³)	79.20	m3		
Capacity Truck	10.00	m3		
No trips	8.00	no		
Average haul	25.00	km	uck Speed	25 km/hr
Cycle time	2.00	hrs		
No trips per truck	4.00			
No trucks	2.00			

A. Equipment				B.Labour				C. Materials				
Type	No.	Rate/hr	US$/Day	Class	No	US$Rate/hr	Cost/Day	Type	Unit	Qty	US$	Cost/Day
Bitumen distributor 6000l	1.00	100.00	800.00	Foreman	2.00	20.00	44.00	80/100 pe	l	7,920	1.00	7,920.00
Chip spreader	1.00	50.00	400.00	Headman	1.00	12.00	14.00	Chippings	m³	79.20	68.00	5,385.60
Tippers (20T)	2.00	37.50	600.00	Light plant operator	4.00	15.00	68.00					
Pneumatic tyre / steel roller	2.00	100.00	1,600.00	Heavy plant operator	3.00	20.00	66.00					
Wheel loader	1.00	100.00	800.00	Drivers	2.00	15.00	34.00					
Water tanker	1.00	37.50	300.00	Labourers	10.00	6.00	80.00					
Mechanical Broom	1.00	18.75	150.00									
Total			4,650.00				306.00					13,305.60

Total cost 18,262
Allow for material waste 5% 665
Total cost 18,927
Cost/m² **2.15**

Item:Class 30/20 concrete for box culverts

Activities included
1. Concrete in restricted areas
2. Mix and lay

Output 10.00 m³ Production 10.00 m³/day

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/Day	Cost	Type	Ton/M3	Qty(ton)	US$/ton	Cost/M3
Mobile Concrete Mixer	0.50	100.00	400.00	Foreman	1.00	20.00	22.00	Cement 4	ton	0.41	285.00	116.85
Vibrators with compressor	0.50	20.00	80.00	Headman	1.00	10.00	12.00	Sand	ton	0.55	30.00	16.50
Small Dumper	0.50	10.00	40.00	Light operators	1.50	15.00	25.50	Aggregat	ton	1.1	40.00	44.00
Water tanker	0.10	37.50	30.00	Driver	2.00	15.00	34.00					
Backhoe	0.50	50.00	200.00	Masons	1.00	10.00	12.00					
				Labourers	2.00	6.00	16.00					
Total			750.00				122					177.35

Total cost 264.50
Add 5% for materials wastage 8.87
Add 10% for formwork 17.74
Cost/m³ **291.10**

Item:Reinforcement

Activities included
1. Cutting and bending
2.Fixing

Output 1.00 t/day

A. Equipment				B.Labour				C. Materials				
Type	No.	US$/hr	Cost/day (8hr)	Class	No	US$/day	Cost	Type	Unit	Qty	US$/ton	Cost/Day
Bending Machine	1.00	1.50	12.00	Steel fixer	8.00	15.00	136	Reinforcet		1	2,000	2,000.00
Steel Cutter Tool	1.00	1.50	12.00	Labourers	9.00	6.00	72	Annealingt		0.1	2,000	200.00
Total			24.00				208					2,200.00

Total cost 2,432.00
Add 5% for materials wastage 110.00
Cost/t **2,542.00**

Table P-1

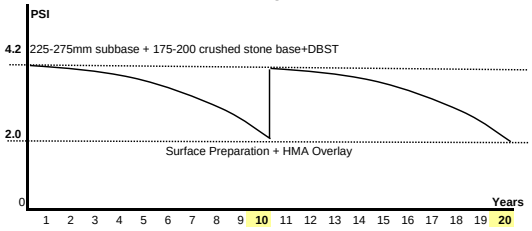
Juba - Nimule Road Feasibility Study

SUMMARY OF 20 YEAR ANALYSIS FOR ALTERNATIVE PAVEMENT DESIGNS

Note: all alternatives include 150mm of subase / road bed, assumed CBR 30%.
sug grade CBR assumed at 10%

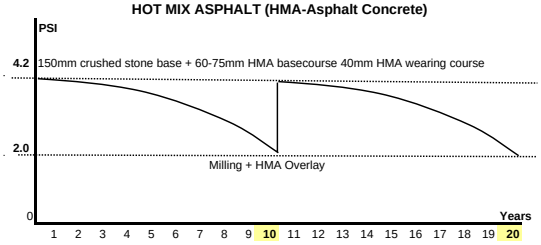
ALTERNATIVE 1

DBST



Juba - Nimule initial construction cost - approx. 63.1m

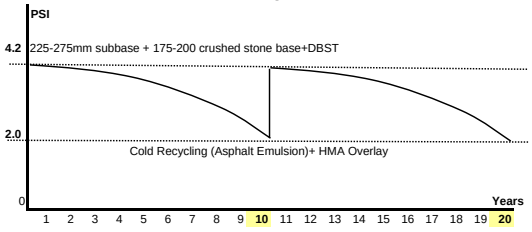
HOT MIX ASPHALT (HMA-Asphalt Concrete)



Juba - Nimule initial construction cost - approx. 93.1m

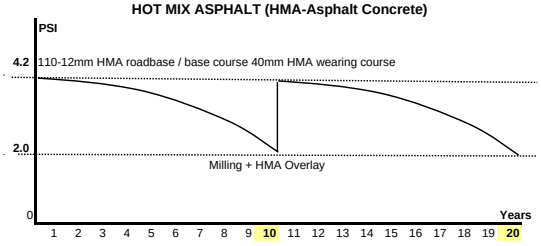
ALTERNATIVE 2

DBST



Juba - Nimule initial construction cost - approx. 63.1m

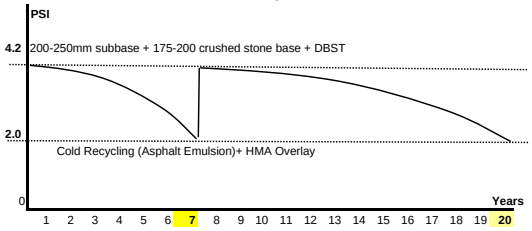
HOT MIX ASPHALT (HMA-Asphalt Concrete)



Juba - Nimule initial construction cost - approx. 94.4m

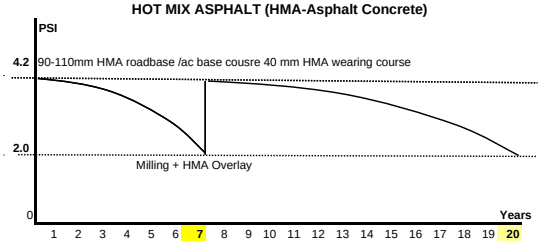
ALTERNATIVE 2A

DBST



Juba - Nimule initial construction cost - approx. 62.5m

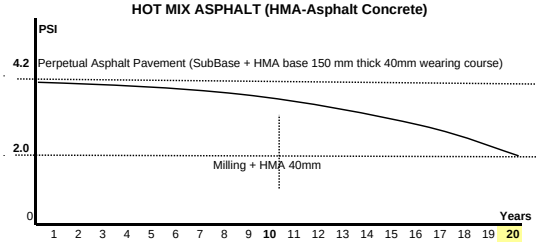
HOT MIX ASPHALT (HMA-Asphalt Concrete)



Juba - Nimule initial construction cost - approx. 84.2m

ALTERNATIVE 3

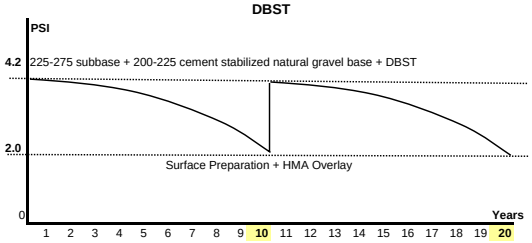
HOT MIX ASPHALT (HMA-Asphalt Concrete)



Juba - Nimule initial construction cost - approx. 115.0m

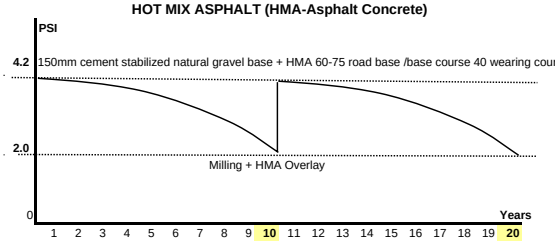
ALTERNATIVE 4

DBST



Juba - Nimule initial construction cost - approx. 55.6m

HOT MIX ASPHALT (HMA-Asphalt Concrete)



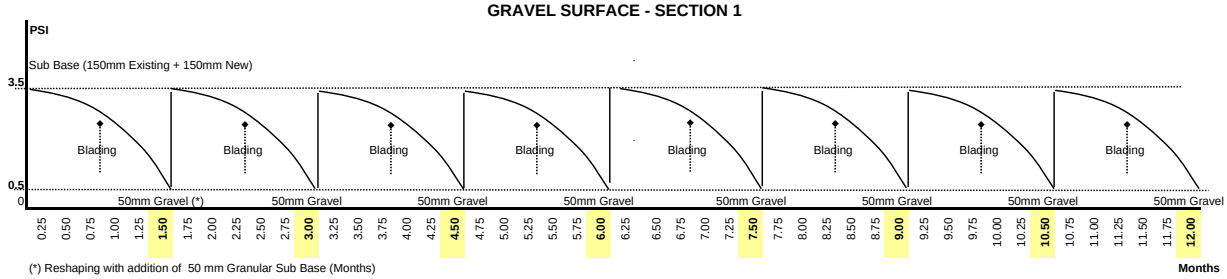
Juba - Nimule initial construction cost - approx. 80.3m

Table P-1

Juba - Nimule Road Feasibility Study

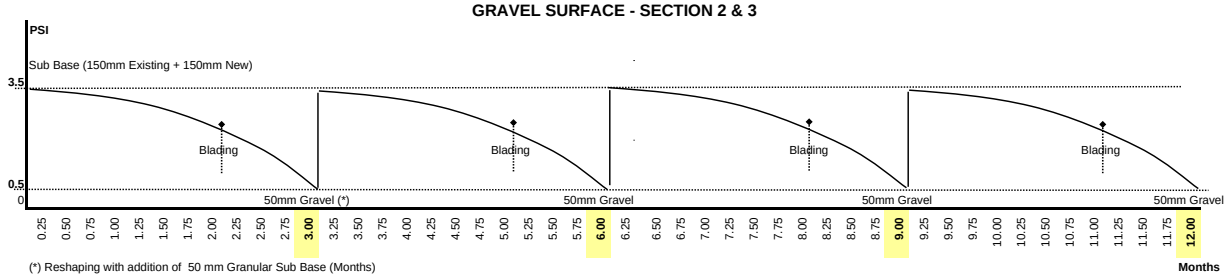
SUMMARY OF 20 YEAR ANALYSIS FOR ALTERNATIVE PAVEMENT DESIGNS

ALTERNATIVES 5
GRAVEL SURFACE - SECTION 1



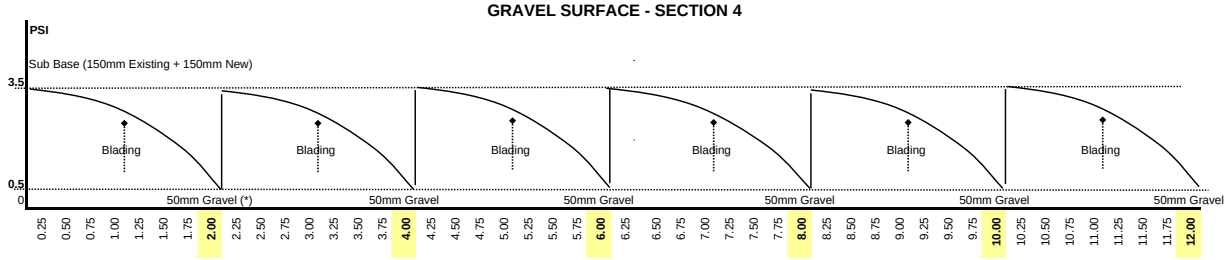
(*) Reshaping with addition of 50 mm Granular Sub Base (Months)

GRAVEL SURFACE - SECTION 2 & 3



(*) Reshaping with addition of 50 mm Granular Sub Base (Months)

GRAVEL SURFACE - SECTION 4



(*) Reshaping with addition of 50 mm Granular Sub Base (Months)

TABLE P-2 AASHTO DESIGN OF PAVEMENT STRUCTURES (AASHTO 1993) - ALTERNATIVE 1

IMPROVEMENT YEAR ZERO

AASHTO Coeficients			Layer Thickness (mm)	0 TO 10 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability								Fatigue Factor	
Structural		Drainage		DBST				HMA					
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	DBST	HMA
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70 (PMS)					40	40	40	40		0%
0.400	0.016	1.00	Base (HMA Base-Large Stone Mix 1.5") 4 %Bitumen, Pen 40/50 or 60/70					75	60	60	75		85%
0.200	0.008	1.00	Doble Bituminous Surface Treatment (DBST)	30	30	30	30					0%	0%
0.140	**0.006**	**1.00**	**Crushed Aggregate Base CBR 100% (CAB)**	**200**	**175**	**175**	**200**	**150**	**150**	**150**	**150**	**45%**	**90%**
0.110	**0.004**	**1.00**	**Granular Sub Base CBR 30% (GSB)**	**275**	**225**	**225**	**225**						
0.110	**0.004**	**1.00**	**Existing Sub Base CBR 30% (EGSB)**	**150**	**150**	**150**	**150**	**150**	**150**	**150**	**150**		
			SN Structure	**3.18**	**2.82**	**2.82**	**2.96**	**3.32**	**3.08**	**3.08**	**3.32**		
			SN Required	**3.25**	**2.90**	**2.90**	**3.05**	**3.25**	**2.90**	**2.90**	**3.05**		
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK		

REHABILITATION YEAR 10

AASHTO Coeficients			Layer Thickness (mm)	10 TO 20 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability							
Structural		Drainage		DBST				HMA			
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70	70	70	70	70	65	65	65	65
0.110	**0.004**	**1.00**	**Milling 40 mm**								
			Existing SN Structure 0 to 10 Years	**2.34**	**2.06**	**2.06**	**2.12**	**2.40**	**2.20**	**2.20**	**2.40**
			SN Structure	**3.49**	**3.22**	**3.22**	**3.28**	**3.47**	**3.27**	**3.27**	**3.47**
			SN Required	**3.55**	**3.20**	**3.20**	**3.35**	**3.55**	**3.20**	**3.20**	**3.35**
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK

Surface preparation will be needed prior to HMA overlay

Table P-2

TABLE P-3 AASHTO DESIGN OF PAVEMENT STRUCTURES (AASHTO 1993) - ALTERNATIVE 2

IMPROVEMENT YEAR ZERO

AASHTO Coeficients			Layer Thickness (mm)	0 TO 10 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability									Fatigue Factor	
Structural		Drainage		DBST				HMA						
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.		DBST	HMA
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70 (PMS)					40	40	40	40			0%
0.400	0.016	1.00	Base (HMA Base-Large Stone Mix 1.5") 4 %Bitumen, Pen 40/50 or 60/70					120	110	110	120	One layer		85%
0.200	0.008	1.00	Doble Bituminous Surface Treatment (DBST)	30	30	30	30						0%	0%
0.140	**0.006**	**1.00**	**Crushed Aggregate Base CBR 100% (CAB)**	**200**	**175**	**175**	**200**						**45%**	**90%**
0.110	**0.004**	**1.00**	**Granular Sub Base CBR 30% (GSB)**	**275**	**225**	**225**	**225**							
0.110	**0.004**	**1.00**	**Existing Sub Base CBR 30% (EGSB)**	**150**	**150**	**150**	**150**	**150**	**150**	**150**	**150**			
			SN Structure	**3.18**	**2.82**	**2.82**	**2.96**	**3.20**	**3.04**	**3.04**	**3.20**			
			SN Required	**3.25**	**2.90**	**2.90**	**3.05**	**3.25**	**2.90**	**2.90**	**3.05**			
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK			

REHABILITATION YEAR 10

AASHTO Coeficients			Layer Thickness (mm)	10 TO 20 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability							
Structural		Drainage		DBST				HMA			
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70	40	40	40	40	75	65	65	65
0.250	**0.010**	**1.00**	**Cold Recycling (Asphalt Emulsion 3.5% Residual Bitumen)**	**100**	**100**	**100**	**100**				
0.110	**0.004**	**1.00**	**Milling 40 mm**								
			Existing SN Structure 0 to 10 Years	**2.34**	**2.06**	**2.06**	**2.12**	**2.26**	**2.12**	**2.12**	**2.26**
			SN Structure	**3.98**	**3.70**	**3.70**	**3.77**	**3.50**	**3.20**	**3.20**	**3.33**
			SN Required	**3.55**	**3.20**	**3.20**	**3.35**	**3.55**	**3.20**	**3.20**	**3.35**
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK

Table P - 3

TABLE P - 4 AASHTO DESIGN OF PAVEMENT STRUCTURES (AASHTO 1993) - ALTERNATIVE 2A

IMPROVEMENT YEAR ZERO

AASHTO Coeficients			Layer Thickness (mm)	0 TO 7 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability									Fatigue Factor	
Structural		Drainage		DBST				HMA						
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.		DBST	HMA
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70 (PMS)					40	40	40	40			0%
0.400	0.016	1.00	Base (HMA Base-Large Stone Mix 1.5") 4 %Bitumen, Pen 40/50 or 60/70					110	90	90	100	One layer		85%
0.200	0.008	1.00	Doble Bituminous Surface Treatment (DBST)	30	30	30	30						0%	0%
0.140	0.006	1.00	Crushed Aggregate Base CBR 100% (CAB)	200	175	175	200						45%	90%
0.110	0.004	1.00	Granular Sub Base CBR 30% (GSB)	250	200	200	200							
0.110	0.004	1.00	Existing Sub Base CBR 30% (EGSB)	150	150	150	150	150	150	150	150			
			SN Structure	3.07	2.72	2.72	2.85	3.04	2.73	2.73	2.89			
			SN Required	3.05	2.75	2.75	2.85	3.05	2.75	2.75	2.85			
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK			

REHABILITATION YEAR 10

AASHTO Coeficients			Layer Thickness (mm)	7 TO 20 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability							
Structural		Drainage		DBST				HMA			
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70	40	40	40	40	90	85	85	85
0.250	0.010	1.00	Cold Recycling (Asphalt Emulsion 3.5% Residual Bitumen)	100	100	100	100				
0.110	0.004	1.00	Milling 40 mm								
			Existing SN Structure 0 to 10 Years	2.23	1.95	1.95	2.01	2.12	1.85	1.85	1.99
			SN Structure	3.87	3.60	3.60	3.66	3.61	3.26	3.26	3.39
			SN Required	3.65	3.30	3.25	3.45	3.65	3.30	3.25	3.45
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK

Table P - 4

TABLE P - 5 AASHTO DESIGN OF PAVEMENT STRUCTURES (AASHTO 1993) - ALTERNATIVES 3

IMPROVEMENT YEAR CERO

AASHTO Coeficients			Layer Thickness (mm)	20 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability				
Structural		Drainage		HMA				
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70 (PMS)	40	40	40	40	
0.400	0.016	1.00	Base (HMA Base-Large Stone Mix 1.5") 4 %Bitumen, Pen 40/50 or 60/70	160	150	150	150	Two Layers
0.110	0.004	1.00	Existing Sub Base CBR 30% (EGSB)	150	150	150	150	
			SN Structure	3.83	3.67	3.67	3.67	
			SN Required	3.80	3.40	3.40	3.55	
			SN Structure >= SN Requiered	OK	OK	OK	OK	

MAINTENANCE YEAR 10

AASHTO Coeficients			Layer Thickness (mm)				
Structural		Drainage		HMA			
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70	40	40	40	40
0.110	0.004	1.00	Milling 40 mm	Yes	Yes	Yes	Yes

Table P - 5

TABLE P - 6 AASHTO DESIGN OF PAVEMENT STRUCTURES (AASHTO 1993) - ALTERNATIVES 4

IMPROVEMENT YEAR CERO

AASHTO Coeficients			Layer Thickness (mm)	0 TO 10 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability								Fatigue Factor	
Structural		Drainage		DBST				HMA					
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	DBST	HMA
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70 (PMS)					40	40	40	40		0%
0.400	0.016	1.00	Base (HMA Base-Large Stone Mix 1.5") 4 %Bitumen, Pen 40/50 or 60/70					75	60	60	75		85%
0.200	0.008	1.00	Doble Bituminous Surface Treatment (DBST)	30	30	30	30					0%	0%
0.130	**0.005**	**1.00**	**Gravel Aggregate Base/Su Base - Cement 4% (SABSB)**	**225**	**200**	**200**	**225**	**150**	**150**	**150**	**150**	**45%**	**90%**
0.110	**0.004**	**1.00**	**Granular Sub Base CBR 30% (GSB)**	**275**	**225**	**225**	**225**						
0.110	**0.004**	**1.00**	**Existing Sub Base CBR 30% (EGSB)**	**150**	**150**	**150**	**150**	**150**	**150**	**150**	**150**		
			SN Structure	**3.23**	**2.88**	**2.88**	**3.01**	**3.26**	**3.02**	**3.02**	**3.26**		
			SN Required	**3.25**	**2.90**	**2.90**	**3.05**	**3.25**	**2.90**	**2.90**	**3.05**		
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK		

REHABILITATION YEAR 10

AASHTO Coeficients			Layer Thickness (mm)	10 TO 20 YEAR DESIGN PERIOD - Subgrade CBR = 10% - 75% Reliability							
Structural		Drainage		DBST				HMA			
(1/inch)	(1/mm)	mi	Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.
0.420	0.017	1.00	WC (HMA Wearing Mix 1") 5.5% Bitumen, Pen 40/50 or 60/70	70	70	70	70	70	65	65	65
			Existing SN Structure 0 to 10 Years	**2.36**	**2.08**	**2.08**	**2.14**	**2.34**	**2.14**	**2.14**	**2.34**
			SN Structure	**3.52**	**3.24**	**3.24**	**3.30**	**3.50**	**3.22**	**3.22**	**3.42**
			SN Required	**3.55**	**3.20**	**3.20**	**3.35**	**3.55**	**3.20**	**3.20**	**3.35**
			SN Structure >= SN Requiered	OK	OK	OK	OK	OK	OK	OK	OK

Surface preparation will be needed prior to HMA overlay

Solutions prone to Crack Reflection

Table P - 6

TABLE P - 7 AASHTO DESIGN OF PAVEMENT STRUCTURES (AASHTO 1993) - ALTERNATIVES 5 - GRAVEL SURFACE

Layer	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.
Granular Sub Base CBR 30% (GSB)	150	150	150	150
Existing Sub Base CBR 30% (EGSB)	150	150	150	150
Blading (Months)	0.75	2	2	1
Reshaping with addition of 50 mm Granular Sub Base (Months)	2	3	3	2

Note: Maximun Design Period, based on Maximun 100,000 ESAL (as per AASHTO, 1993)

Table P - 7

PAVEMENT DESIGN VARIABLES

AASHTO Guide for Design of Pavement Structures, 1993 (DPS) - Flexible Pavements

IRI=1.31+3.16LN(5/PSI AASHTO)
KANNEMEYER (1996)

				IRI (M/KM)	PSI
Reliability	R	75%	Reliability (Rural, 75 to 90%)		
Standard Normal Deviate	Zr	-0.674	Estándar Deviation (Flexible, Variace of Proyected Traffic)		
Overall Standard Deviation	So	0.49			
Initial Serviceability	Pi	4.2	Initial Serviciability (Flexible=4.2)	**1.86**	**4.2**
Terminal Serviceability	Pf	2	Terminal Serviciability (People Stating Unacceptable, 85%=2, 55%=2.5.)	**4.21**	**2**
Design Period (Years)	DP	7	DSBT 7 years and 10 years for HMA	2.02	4
Annual Traffic Growth Rate	n	8%		**2.02**	**4**
Directional Distribution Factor	Do	50%			
Lane Distribution Factor	DL	100%			
Subgrade CBR/Condition	CBR	10%	In Situ		
Effective Roadbed Soil Resilient Modulus (psi)	Mr=1500CBR (psi)	15,000	In Situ		

AASHTO Guide for Design of Pavement Structures, 1993 (DPS) - Gravel - Low Volumen Road

Design Period	Maximun ESAL	100,000
Initial Serviceability	Pi	3.5
Terminal Serviceability	Pf	3
Maximun Rutting	inch	2
Bladding	Maximun Trucks	8000

NVP=Numero Vehiculos Pesados (miles)
Espesor Final=Espesor por Criterio de Falla +0.5*PG

PAVEMENT DESIGN METHOD: AASHTO 1993

MATERIAL	ai (1/pulgadas)	Not Defined mi	Md (psi) at 20oC	
Typical AC	0.44	1	440,000	
Wearing Course AC	0.42	1	400,000	
Binder Course AC	0.4	1	360,000	
Binder Course AC	0.32	1	220,000	
Base Granular CBR>=120	0.15	1	32,000	
Base Granular CBR>=100%	0.14	1	30,000	
Base Granular CBR>=85%	0.135	1	27,000	
Base Granular CBR>=70%	0.13	1	26,000	
Su Base Base CBR>=70%	0.13	1	19,000	
Su Base Base CBR>=40%	0.12	1	17,000	
Su Base Base CBR>=30%	0.11	1	15,000	
Su Base Base CBR>=25%	0.1	1	13,800	
Su Base Base CBR>=20%	0.095	1	13,000	
Reciclado con Agua	0.14	1	30,000	
Reciclado con Emulsión Asfáltica (EMarshall>680 kg	0.3	1	370,000	
Reciclado con Cemento Portland (R7dias>45 kg/cm2	0.195	1	720,000	
Mezcla Asfáltica en Caliente en Reconstrucción Prof	0.44	1	440,000	
Base Granular en Reconstrucción Profunda CBR>=1	0.14	1	30,000	
Mezcla Asfáltica del Pavimento Existente	0.44*50%	1		
Capa Granular Superior del Pavimento Existente	0.14*80%	1		
Excavación en Reconstrucción Profunda				
Suelo Cemento 7d 45 Kg/cm2	0.195			
Estabilizado con Cemento Portland 7d 30Kg/cm2	0.15			

Dense-Graded Asphalt Concrete

EM at 20Oc (psi)	ai (1/inch)	ai (1/cm)	
500,000	0.460	0.181	
450,000	**0.440**	0.173	
400,000	0.420	0.165	
350,000	0.390	0.154	
300,000	0.375	0.148	
200,000	0.300	0.118	
			2.54

Bituminous-Treated Bases

EM at 20Oc (psi)	Stab Marshall (lb)	ai (1/inch)	ai (1/cm)	
400,000	1,800	0.320	0.126	
350,000	1,600	0.300	0.118	
300,000	1,400	0.270	0.106	
				E (kg/cm2)
Rubblizing PCC		0.22	0.087	
PCC Crack and Seat L=12"		0.25	0.098	16,200
PCC Crack and Seat L=24"		0.35	0.138	26,900
PCC Crack and Seat L=36"		0.44	0.173	67,400

Table P - 8

TABLE P - 9 AASHTO DESIGN OF PAVEMENT STRUCTURES - STRUCTURAL NUMBER

		Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Granular Base 80%	Granular Base 80%
	Kilometers	**3.40**	**17.40**	**169.20**	**2.00**		
	Section	1	2	3	4	1	2
	ESAL 10 Years	7,438,155	3,563,549	3,535,565	4,980,020	7,438,155	3,563,549
	R DISEÑO	75%	75%	75%	75%	75%	75%
	Zr	-0.674	-0.674	-0.674	-0.674	-0.674	-0.674
	So	0.490	0.490	0.490	0.490	0.490	0.490
	Mr	15,000	15,000	15,000	15,000	28,000	28,000
	PSi	4.2	4.2	4.2	4.2	4.2	4.2
	PSf	2	2	2	2	2	2
	DeltaPSI	2.2	2.2	2.2	2.2	2.2	2.2
	Snrequired	**3.25**	**2.90**	**2.90**	**3.05**	**2.60**	**2.30**
Log ESAL		6.871465251	6.551882771	6.548458803	6.697231099	6.871465251	6.551882771
Zr*So		-0.33026	-0.33026	-0.33026	-0.33026	-0.33026	-0.33026
9.36*Log(SN+1)		5.881720385	5.532364722	5.532364722	5.685779017	5.206991407	4.853290477
Log (Delta PSI/(4.2-1.5))		-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083
2.32*Log Mr		9.688531721	9.688531721	9.688531721	9.688531721	10.31740663	10.31740663
(SN+1)^5.19		1825.318044	1168.490835	1168.490835	1421.319029	771.2762868	491.0066205
		0.0095	0.0022	0.0056	0.0008	0.0038	-0.0153
		OK	**OK**	**OK**	**OK**	**OK**	**OK**
	Minimum HMA to Minimize Fatigue Cracking during Design Period (mm)					165	146

Table P - 9

TABLE P - 10 AASHTO DESIGN OF PAVEMENT STRUCTURES - STRUCTURAL NUMBER

		Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Granular Base 80%	Granular Base 80%
	Kilometers	**3.40**	**17.40**	**169.20**	**2.00**		
	Section	1	2	3	4	1	2
	ESAL 10 Years	13,010,907	6,233,401	6,184,450	8,711,108	13,010,907	6,233,401
	R DISEÑO	75%	75%	75%	75%	75%	75%
	Zr	-0.674	-0.674	-0.674	-0.674	-0.674	-0.674
	So	0.490	0.490	0.490	0.490	0.490	0.490
	Mr	15,000	15,000	15,000	15,000	28,000	28,000
	PSi	4.2	4.2	4.2	4.2	4.2	4.2
	PSf	2	2	2	2	2	2
	DeltaPSI	2.2	2.2	2.2	2.2	2.2	2.2
	Snrequired	**3.55**	**3.20**	**3.20**	**3.35**	**2.85**	**2.55**
Log ESAL		7.114307557	6.794725076	6.791301108	6.940073405	7.114307557	6.794725076
Zr*So		-0.33026	-0.33026	-0.33026	-0.33026	-0.33026	-0.33026
9.36*Log(SN+1)		6.158986673	5.833613358	5.833613358	5.976259445	5.479912428	5.150137385
Log (Delta PSI/(4.2-1.5))		-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083
2.32*Log Mr		9.688531721	9.688531721	9.688531721	9.688531721	10.31740663	10.31740663
(SN+1)^5.19		2600.633476	1716.579087	1716.579087	2059.487895	1092.801258	717.2741052
		0.0246	0.0414	0.0448	0.0289	0.0193	0.0264
		OK	**OK**	**OK**	**OK**	**OK**	**OK**
	Minimum HMA to Minimize Fatigue Cracking during Design Period (mm)					181	162

Table P - 10

TABLE P - 11 AASHTO DESIGN OF PAVEMENT STRUCTURES - STRUCTURAL NUMBER

		Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Granular Base 80%	Granular Base 80%
	Kilometers	**3.40**	**17.40**	**169.20**	**2.00**		
	Section	1	2	3	4	1	2
	ESAL 10 Years	20,449,062	9,796,950	9,720,015	13,691,128	20,449,062	9,796,950
	R DISEÑO	75%	75%	75%	75%	75%	75%
	Zr	-0.674	-0.674	-0.674	-0.674	-0.674	-0.674
	So	0.490	0.490	0.490	0.490	0.490	0.490
	Mr	15,000	15,000	15,000	15,000	28,000	28,000
	PSi	4.2	4.2	4.2	4.2	4.2	4.2
	PSf	2	2	2	2	2	2
	DeltaPSI	2.2	2.2	2.2	2.2	2.2	2.2
	Snrequired	**3.80**	**3.40**	**3.40**	**3.55**	**3.05**	**2.75**
Log ESAL		7.310673391	6.991090911	6.987666943	7.136439239	7.310673391	6.991090911
Zr*So		-0.33026	-0.33026	-0.33026	-0.33026	-0.33026	-0.33026
9.36*Log(SN+1)		6.376417982	6.022717052	6.022717052	6.158986673	5.685779017	5.372932666
Log (Delta PSI/(4.2-1.5))		-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083
2.32*Log Mr		9.688531721	9.688531721	9.688531721	9.688531721	10.31740663	10.31740663
(SN+1)^5.19		3432.748784	2185.341892	2185.341892	2600.633476	1421.319029	953.2839466
		0.0303	0.0211	0.0246	0.0024	0.0162	0.0415
		OK	**OK**	**OK**	**OK**	**OK**	**OK**
	Minimum HMA to Minimize Fatigue Cracking during Design Period (mm)					194	175

Table P - 11

TABLE P - 12 AASHTO DESIGN OF PAVEMENT STRUCTURES - STRUCTURAL NUMBER

		Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Granular Base 80%	Granular Base 80%
	Kilometers	**3.40**	**17.40**	**169.20**	**2.00**		
	Section	1	2	3	4	1	2
	ESAL 10 Years	4,753,053	2,277,142	2,259,260	3,182,281	4,753,053	2,277,142
	R DISEÑO	75%	75%	75%	75%	75%	75%
	Zr	-0.674	-0.674	-0.674	-0.674	-0.674	-0.674
	So	0.490	0.490	0.490	0.490	0.490	0.490
	Mr	15,000	15,000	15,000	15,000	28,000	28,000
	PSi	4.2	4.2	4.2	4.2	4.2	4.2
	PSf	2	2	2	2	2	2
	DeltaPSI	2.2	2.2	2.2	2.2	2.2	2.2
	Snrequired	**3.05**	**2.75**	**2.75**	**2.85**	**2.45**	**2.15**
Log ESAL		6.676972689	6.357390208	6.35396624	6.502738537	6.676972689	6.357390208
Zr*So		-0.33026	-0.33026	-0.33026	-0.33026	-0.33026	-0.33026
9.36*Log(SN+1)		5.685779017	5.372932666	5.372932666	5.479912428	5.03398673	4.664186783
Log (Delta PSI/(4.2-1.5))		-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083
2.32*Log Mr		9.688531721	9.688531721	9.688531721	9.688531721	10.31740663	10.31740663
(SN+1)^5.19		1421.319029	953.2839466	953.2839466	1092.801258	618.4165497	385.6841346
		0.0210	0.0463	0.0498	0.0020	0.0332	-0.0035
		OK	**OK**	**OK**	**OK**	**OK**	**OK**
	Minimum HMA to Minimize Fatigue Cracking during Design Period (mm)					156	137

Table P - 12

TABLE P - 13 AASHTO DESIGN OF PAVEMENT STRUCTURES - STRUCTURAL NUMBER

		Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimile Ctr. – Uganda Bdr.	Granular Base 80%	Granular Base 80%
	Kilometers	**3.40**	**17.40**	**169.20**	**2.00**		
	Section	1	2	3	4	1	2
	ESAL 10 Years	15,696,009	7,519,808	7,460,755	10,508,847	15,696,009	7,519,808
	R DISEÑO	75%	75%	75%	75%	75%	75%
	Zr	-0.674	-0.674	-0.674	-0.674	-0.674	-0.674
	So	0.490	0.490	0.490	0.490	0.490	0.490
	Mr	15,000	15,000	15,000	15,000	28,000	28,000
	PSi	4.2	4.2	4.2	4.2	4.2	4.2
	PSf	2	2	2	2	2	2
	DeltaPSI	2.2	2.2	2.2	2.2	2.2	2.2
	Snrequired	**3.65**	**3.30**	**3.25**	**3.45**	**2.95**	**2.60**
Log ESAL		7.195789229	6.876206748	6.87278278	7.021555077	7.195789229	6.876206748
Zr*So		-0.33026	-0.33026	-0.33026	-0.33026	-0.33026	-0.33026
9.36*Log(SN+1)		6.247359639	5.929264744	5.881720385	6.068649703	5.584148815	5.206991407
Log (Delta PSI/(4.2-1.5))		-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083	-0.088941083
2.32*Log Mr		9.688531721	9.688531721	9.688531721	9.688531721	10.31740663	10.31740663
(SN+1)^5.19		2911.258875	1939.55136	1825.318044	2317.333057	1248.357361	771.2762868
		0.0252	0.0491	0.0082	0.0334	0.0358	-0.0010
		OK	**OK**	**OK**	**OK**	**OK**	**OK**
	Minimum HMA to Minimize Fatigue Cracking during Design Period (mm)					187	165

Table P - 13

Table P - 14

AXLE LOAD ASSUMPTIONS - ESAL PER VEHICLE (EV)

Vehicle Load Condtion	Cars	PickUp & MB	BUS	TRUCK 2A Single	TRUCK 2A Tandem	TRUCK 3A Tandem	TRUCK 2A Tridem	TRUCK 3A Tandem Tridem	Load Condition Incedence
Empty	0.000365	0.003700	1.300052	0.433802	0.085575	0.058129	0.056767	0.034317	20%
Normal	0.000365	0.003700	2.070433	1.422974	1.877078	2.877078	1.877078	2.877078	45%
50%OW	0.000365	0.003700	13.568792	9.325600	12.301619	18.855219	12.301619	18.855219	35%
EV (Load Incidence)	0.000365	0.0037	5.941	3.991	5.167	7.906	5.162	7.901	

EQUIVALENT SINGLE AXLE LOAD 8.2 MT (ESAL)

	AADT	Cars & PickUp & Mini Bus	Big Bus	Light Truck	Medium Truck	Heavy Truck	Articulated Truck	AADT	ESAL 10 Years	ESAL 20 Years	ESAL 10 to 20 Years	ESAL 7 Years	ESAL 7 to 20 Years	Km	Trucks
Section 1	Juba – Bor Jct.	439	26	159	151	89	45	909	7,438,155	20,449,062	13,010,907	4,753,053	15,696,009	3.4	399
Section 2	Bor Jct – Torit Jct.	93	11	32	72	47	24	279	3,563,549	9,796,950	6,233,401	2,277,142	7,519,808	17.4	151
Section 3	Torit Jct. – Nimule Ctr.	70	12	32	67	47	24	252	3,535,565	9,720,015	6,184,450	2,259,260	7,460,755	169.2	146
Section 4	Nimile Ctr. – Uganda Bdr.	247	15	87	89	64	33	535	4,980,020	13,691,128	8,711,108	3,182,281	10,508,847	2	240
	ESAL per Vehicle	0.0037	5.941	1.423	2.877	12.302	7.901								

		40%	38%	22%
		21%	48%	31%
		22%	46%	32%
		36%	37%	27%
		30%	42%	28%
Motorcycle	341	5	3	683
Car	6	7	6	4
4WD	266	64	43	149
Minibus	167	22	21	94
Big Bus	26	11	12	15
Light Truck	159	32	32	87
Medium Truck	151	72	67	89
Heavy Truck	89	47	47	64
Articilated Truck	45	24	24	33
	1250	284	255	1218

Table P - 14

TABLE P - 15
ESAL FOR PAVEMENT DESIGN - SECTION 1

	LIGHT VEHICLES	TRUCKS & TRAILER					
AADT YEAR 2007	**Cars&PickUp&MB**	**Big Bus**	**Light Truck**	**Medium Truck**	**Heavy Truck**	**Articulated Truck**	
	439	26	159	151	89	45	909
Annual Traffic Growth Rate	8	8	8	8	8	8	
	48.3%	2.9%	17.5%	16.6%	9.8%	5.0%	
	51.2%	48.8%					
ESAL PER VEHICLE (EV)	0.0037	5.9408	1.4230	2.8771	12.3016	7.9009	

DESIGN PERIOD (YEARS)	ESAL
1	929,463
3	2,013,588
5	3,278,113
7	4,753,053
10	7,438,155

EQUIVALENT SINGLE AXLE LOAD 8.2 MT (ESAL)

DD= DIRECTIONAL DISTRIBUTION FACTOR (0.3,0.5,0.7):	0.5
DL= LANE DISTRIBUTION FACTOR (NUMBER OF LANES IN ONE DIRECTION:1=1, 2=0.8 A 1, 3=0.6 A 0.8):	1.0

	Year	ars&PickUp&M	Big Bus	Light Truck	Medium Truc	Heavy Truck	ticilated Tru	AADT	ESAL	ESAL a	DESIGN PERIOD	DESIGN ESAL
AADT 2007	1	439	26	159	151	89	45	909	827,513	413,757		
2008 - Construction	2	913	54	331	314	185	94	1891	1,721,228	860,614		
2009	3	1425	84	516	490	289	146	2951	2,686,439	1,343,220	1	929,463
2010	4	1978	117	716	680	401	203	4096	3,728,868	1,864,434	2	1,450,677
2011	5	2575	153	933	886	522	264	5333	4,854,690	2,427,345	3	2,013,588
2012	6	3220	191	1166	1108	653	330	6668	6,070,579	3,035,289	4	2,621,533
2013	7	3917	232	1419	1347	794	402	8111	7,383,738	3,691,869	5	3,278,113
2014	8	4669	277	1691	1606	947	479	9669	8,801,951	4,400,975	6	3,987,219
2015	9	5482	325	1986	1886	1111	562	11351	10,333,620	5,166,810	7	4,753,053
2016	10	6360	377	2303	2187	1289	652	13168	11,987,823	5,993,911	8	5,580,155
2017	11	7307	433	2647	2513	1481	749	15131	13,774,362	6,887,181	9	6,473,424
2018	12	8331	493	3017	2866	1689	854	17250	15,703,824	7,851,912	10	7,438,155
2019	13	9436	559	3418	3246	1913	967	19539	17,787,643	8,893,822		
2020	14	10630	630	3850	3656	2155	1090	22011	20,038,168	10,019,084		
2021	15	11920	706	4317	4100	2417	1222	24681	22,468,735	11,234,367		
2022	16	13312	788	4822	4579	2699	1365	27565	25,093,747	12,546,874	15	12,133,117
2023	17	14816	878	5366	5096	3004	1519	30679	27,928,760	13,964,380		
2024	18	16441	974	5955	5655	3333	1685	34042	30,990,574	15,495,287		
2025	19	18195	1078	6590	6258	3689	1865	37675	34,297,333	17,148,667		
2026	20	20090	1190	7276	6910	4073	2059	41598	37,868,633	18,934,317		
2027	21	22136	1311	8017	7614	4488	2269	45834	41,725,637	20,862,819	20	20,449,062
2028	22	24346	1442	8818	8374	4936	2496	50410	45,891,202	22,945,601		
#REF!		0.003700	5.940783	1.422974	2.877078	12.301619	7.900875					
Annual Traffic Growth Rate		8.00	8.00	8.00	8.00	8.00	8.00					

Table P - 15

TABLE P - 16
ESAL FOR PAVEMENT DESIGN - SECTION 2

	LIGHT VEHICLES	TRUCKS & TRAILER					
AADT YEAR 2007	**Cars&PickUp&MB**	**Big Bus**	**Light Truck**	**Medium Truck**	**Heavy Truck**	**Articilated Truck**	
	93	11	32	72	47	24	279
Annual Traffic Growth Rate	8	8	8	8	8	8	
	33.3%	3.9%	11.5%	25.8%	16.8%	8.6%	
	37.3%	62.7%					
ESAL PER VEHICLE (EV)	0.0037	5.9408	1.4230	2.8771	12.3016	7.9009	

DESIGN PERIOD (YEARS)	ESAL
1	445,297
3	964,691
5	1,570,512
7	2,277,142
10	3,563,549

EQUIVALENT SINGLE AXLE LOAD 8.2 MT (ESAL)

DD= DIRECTIONAL DISTRIBUTION FACTOR (0.3,0.5,0.7):	0.5
DL= LANE DISTRIBUTION FACTOR (NUMBER OF LANES IN ONE DIRECTION:1=1, 2=0.8 A 1, 3=0.6 A 0.8):	1.0

	Year	ars&PickUp&M	Big Bus	Light Truck	Medium Truc	Heavy Truck	ticilated Tru	AADT	ESAL	ESAL a	DESIGN PERIOD	DESIGN ESAL
AADT 2007	1	93	11	32	72	47	24	279	396,454	198,227		
2008 - Construction	2	193	23	67	150	98	50	580	824,624	412,312		
2009	3	302	36	104	234	153	78	906	1,287,047	643,524	1	445,297
2010	4	419	50	144	324	212	108	1257	1,786,465	893,232	2	695,006
2011	5	546	65	188	422	276	141	1637	2,325,836	1,162,918	3	964,691
2012	6	682	81	235	528	345	176	2047	2,908,356	1,454,178	4	1,255,951
2013	7	830	98	286	642	419	214	2489	3,537,479	1,768,739	5	1,570,512
2014	8	989	117	340	766	500	255	2968	4,216,931	2,108,465	6	1,910,238
2015	9	1161	137	400	899	587	300	3484	4,950,739	2,475,369	7	2,277,142
2016	10	1347	159	464	1043	681	348	4042	5,743,252	2,871,626	8	2,673,399
2017	11	1548	183	533	1198	782	399	4644	6,599,165	3,299,583	9	3,101,356
2018	12	1765	209	607	1366	892	455	5295	7,523,552	3,761,776	10	3,563,549
2019	13	1999	236	688	1548	1010	516	5997	8,521,890	4,260,945		
2020	14	2252	266	775	1743	1138	581	6756	9,600,095	4,800,048		
2021	15	2525	299	869	1955	1276	652	7575	10,764,556	5,382,278		
2022	16	2820	334	970	2183	1425	728	8460	12,022,175	6,011,087	15	5,812,860
2023	17	3139	371	1080	2430	1586	810	9416	13,380,402	6,690,201		
2024	18	3483	412	1198	2696	1760	899	10449	14,847,288	7,423,644		
2025	19	3855	456	1326	2984	1948	995	11564	16,431,525	8,215,763		
2026	20	4256	503	1464	3295	2151	1098	12768	18,142,501	9,071,250		
2027	21	4689	555	1614	3630	2370	1210	14068	19,990,355	9,995,177	20	9,796,950
2028	22	5157	610	1775	3993	2606	1331	15472	21,986,037	10,993,018		
#REF!		0.003700	5.940783	1.422974	2.877078	12.301619	7.900875					
Annual Traffic Growth Rate		8.00	8.00	8.00	8.00	8.00	8.00					

Table P - 16

TABLE P - 17
ESAL FOR PAVEMENT DESIGN - SECTION 3

	LIGHT VEHICLES	TRUCKS & TRAILER					
AADT YEAR 2003	**Cars&PickUp&MB**	**Big Bus**	**Light Truck**	**Medium Truck**	**Heavy Truck**	**Articilated Truck**	
	70	12	32	67	47	24	252
Annual Traffic Growth Rate	8	8	8	8	8	8	
	27.8%	4.8%	12.7%	26.6%	18.7%	9.5%	
	32.5%	67.5%					
ESAL PER VEHICLE (EV)	0.0037	5.9408	1.4230	2.8771	12.3016	7.9009	

DESIGN PERIOD (YEARS)	ESAL
1	441,800
3	957,115
5	1,558,179
7	2,259,260
10	3,535,565

EQUIVALENT SINGLE AXLE LOAD 8.2 MT (ESAL)

DD= DIRECTIONAL DISTRIBUTION FACTOR (0.3,0.5,0.7):	0.5
DL= LANE DISTRIBUTION FACTOR (NUMBER OF LANES IN ONE DIRECTION:1=1, 2=0.8 A 1, 3=0.6 A 0.8):	1.0

	Year	ars&PickUp&M	Big Bus	Light Truck	Medium Truc	Heavy Truck	rticilated Tru	AADT	ESAL	ESAL a	DESIGN PERIOD	DESIGN ESAL
AADT 2007	1	70	12	32	67	47	24	252	393,340	196,670		
2008 - Construction	2	146	25	67	139	98	50	524	818,148	409,074		
2009	3	227	39	104	218	153	78	818	1,276,940	638,470	1	441,800
2010	4	315	54	144	302	212	108	1136	1,772,436	886,218	2	689,548
2011	5	411	70	188	393	276	141	1478	2,307,571	1,153,786	3	957,115
2012	6	514	88	235	492	345	176	1849	2,885,517	1,442,759	4	1,246,088
2013	7	625	107	286	598	419	214	2249	3,509,699	1,754,849	5	1,558,179
2014	8	745	128	340	713	500	255	2680	4,183,815	2,091,908	6	1,895,237
2015	9	874	150	400	837	587	300	3147	4,911,861	2,455,930	7	2,259,260
2016	10	1014	174	464	971	681	348	3651	5,698,150	2,849,075	8	2,652,405
2017	11	1165	200	533	1115	782	399	4195	6,547,342	3,273,671	9	3,077,001
2018	12	1328	228	607	1271	892	455	4782	7,464,470	3,732,235	10	3,535,565
2019	13	1505	258	688	1440	1010	516	5417	8,454,968	4,227,484		
2020	14	1695	291	775	1622	1138	581	6102	9,524,706	4,762,353		
2021	15	1901	326	869	1819	1276	652	6842	10,680,023	5,340,011		
2022	16	2123	364	970	2032	1425	728	7642	11,927,765	5,963,882	15	5,767,212
2023	17	2363	405	1080	2261	1586	810	8505	13,275,326	6,637,663		
2024	18	2622	449	1198	2509	1760	899	9437	14,730,693	7,365,346		
2025	19	2901	497	1326	2777	1948	995	10444	16,302,489	8,151,244		
2026	20	3203	549	1464	3066	2151	1098	11532	18,000,028	9,000,014		
2027	21	3530	605	1614	3378	2370	1210	12707	19,833,371	9,916,685	20	9,720,015
2028	22	3882	665	1775	3716	2606	1331	13975	21,813,381	10,906,690		
#REF!		0.003700	5.940783	1.422974	2.877078	12.301619	7.900875					
Annual Traffic Growth Rate		8.00	8.00	8.00	8.00	8.00	8.00					

Table P - 17

TABLE P - 18
ESAL FOR PAVEMENT DESIGN - SECTION 4

	LIGHT VEHICLES	TRUCKS & TRAILER					
AADT YEAR 2003	**Cars&PickUp&MB**	**Big Bus**	**Light Truck**	**Medium Truck**	**Heavy Truck**	**Articilated Truck**	
	247	15	87	89	64	33	535
Annual Traffic Growth Rate	8	8	8	8	8	8	
	46.2%	2.8%	16.3%	16.6%	12.0%	6.2%	
	49.0%	51.0%					
ESAL PER VEHICLE (EV)	0.0037	5.9408	1.4230	2.8771	12.3016	7.9009	

DESIGN PERIOD (YEARS)	ESAL
1	622,297
3	1,348,145
5	2,194,773
7	3,182,281
10	4,980,020

EQUIVALENT SINGLE AXLE LOAD 8.2 MT (ESAL)

DD= DIRECTIONAL DISTRIBUTION FACTOR (0.3,0.5,0.7):	0.5
DL= LANE DISTRIBUTION FACTOR (NUMBER OF LANES IN ONE DIRECTION:1=1, 2=0.8 A 1, 3=0.6 A 0.8):	1.0

	Year	ars&PickUp&M	Big Bus	Light Truck	Medium Truc	Heavy Truck	rticilated Tru	AADT	ESAL	ESAL a	DESIGN PERIOD	DESIGN ESAL
AADT 2007	1	247	15	87	89	64	33	535	554,040	277,020		
2008 - Construction	2	514	31	181	185	133	69	1113	1,152,402	576,201		
2009	3	802	49	282	289	208	107	1737	1,798,634	899,317	1	622,297
2010	4	1113	68	392	401	288	149	2411	2,496,565	1,248,282	2	971,262
2011	5	1449	88	510	522	375	194	3139	3,250,329	1,625,165	3	1,348,145
2012	6	1812	110	638	653	469	242	3925	4,064,395	2,032,198	4	1,755,178
2013	7	2204	134	776	794	571	294	4774	4,943,587	2,471,793	5	2,194,773
2014	8	2627	160	925	947	681	351	5691	5,893,113	2,946,557	6	2,669,537
2015	9	3084	187	1086	1111	799	412	6681	6,918,602	3,459,301	7	3,182,281
2016	10	3578	217	1260	1289	927	478	7750	8,026,130	4,013,065	8	3,736,045
2017	11	4111	250	1448	1481	1065	549	8905	9,222,260	4,611,130	9	4,334,110
2018	12	4687	285	1651	1689	1215	626	10153	10,514,080	5,257,040	10	4,980,020
2019	13	5309	322	1870	1913	1376	709	11500	11,909,246	5,954,623		
2020	14	5981	363	2107	2155	1550	799	12955	13,416,025	6,708,013		
2021	15	6707	407	2362	2417	1738	896	14526	15,043,347	7,521,673		
2022	16	7490	455	2638	2699	1941	1001	16223	16,800,854	8,400,427	15	8,123,407
2023	17	8336	506	2936	3004	2160	1114	18056	18,698,962	9,349,481		
2024	18	9250	562	3258	3333	2397	1236	20036	20,748,919	10,374,459		
2025	19	10237	622	3606	3689	2653	1368	22174	22,962,872	11,481,436		
2026	20	11303	686	3981	4073	2929	1510	24483	25,353,941	12,676,971		
2027	21	12454	756	4387	4488	3227	1664	26976	27,936,296	13,968,148	20	13,691,128
2028	22	13698	832	4825	4936	3549	1830	29669	30,725,239	15,362,620		
#REF!		0.003700	5.940783	1.422974	2.877078	12.301619	7.900875					
Annual Traffic Growth Rate		8.00	8.00	8.00	8.00	8.00	8.00					

Table P - 18

Table P - 19 Average weather statistics for Juba

Juba, Sudan

Month	Average Sunlight (hours)	Temperature Average Min	Temperature Average Max	Temperature Record Min	Temperature Record Max	Discomfort from heat and humidity	Relative humidity am	Relative humidity pm	Average Precipitation (mm)	Wet Days (+0.25 mm)
Jan	9	20	37	16	42	High	54	26	5	1
Feb	8	22	38	16	43	High	56	28	15	2
March	7	22	37	16	42	High	65	34	33	6
April	7	22	36	18	42	High	75	44	122	9
May	8	22	33	17	44	High	82	54	150	10
June	7	21	33	16	38	High	83	56	135	9
July	6	20	31	17	37	High	87	60	122	10
Aug	7	20	31	16	36	High	88	59	132	9
Sept	8	20	33	16	38	High	83	53	107	8
Oct	8	20	34	14	39	High	80	48	94	8
Nov	8	20	36	13	41	High	75	40	36	4
Dec	9	20	37	15	41	High	64	33	18	1

969

PMS

The following bar chart for **Juba, Sudan** shows the years average weather condition readings covering rain, average maximum daily temperature and average minimum temperature.

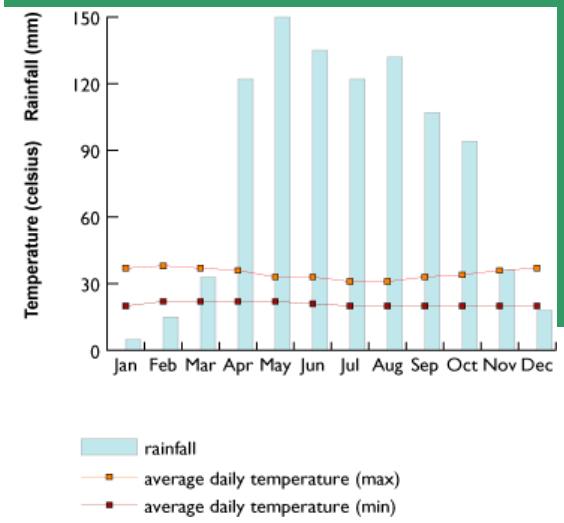


Table P - 19

Average weather statistics for Juba   Table P - 19

------------------INTERNATIONAL STATION METEOROLOGICAL CLIMATE SUMMARY-------------------

:STA 629410 | HSSJ | JUBA , ,SU-Telecom Summary

:LAT 04 52N :LONG 031 36E :ELEV 1499(ft) 457(m) :TYPE NAVY SMOS V3 21051996

42 - Foreign STATION CLIMATIC SUMMARY (Derived from Hourly Data)

POR: (HOURLY): 1973-1982

TEMPERATURE (DEG F)|REL HUM|VAP|DEW| PR |WIND (KTS) |TOT| MEAN NO. OF DAYS WITH (&)
MEANS |EXTREME|PERCENT|PR |PT.| ALT| |SKY| TEMP (DEG F) | PRECIPITATION | OBSTR TO VISION |
| | | | | (LST) |IN.|(F)| FT.|PREVAIL|MAX|CVR|MAX|MAX|MIN|MIN| |FRZ | |HAIL| |TH |FOG|SMOK|BLOW|DUST| OBS|
MAX|MIN|AVG|MAX|MIN| | |HG.| | $ |DIR|SPD|SPD| + | >=| >=| <=| <=|R/DZ|R/DZ|SNOW|/SLT|PRCP|STM| * |HAZE|SNOW|SAND| VIS|
| 02| 14| | 95| 85| 75| 65|

JAN 86 81 83 102 66 *** 24 .44 55 180 NE 4 17 BRK 6 14 7 0 1 0 0 0 1 # # 0 0 7 7
FEB 87 81 84 106 64 51 21 .43 55 185 NE 4 13 BRK 8 15 6 # 1 0 0 0 1 1 0 0 0 5 5
MAR 89 83 86 108 70 65 32 .56 62 185 S 4 41 BRK 10 19 4 0 3 0 0 0 3 1 0 # 0 4 4
APR 85 81 83 106 70 79 49 .71 69 180 S 5 14 BRK 5 12 7 0 3 0 0 0 3 2 # 0 0 1 1
MAY 83 79 81 100 70 83 53 .74 70 175 S 4 40 BRK 3 12 11 0 3 0 0 0 3 5 0 0 0 1 1
JUN 81 77 79 95 68 I 58 .73 70 170 S I 24 BRK 1 9 16 0 1 0 0 0 1 3 0 # 0 1 1
JUL 79 76 77 102 68 88 I .74 70 170 S 3 10 BRK # 7 20 0 5 0 0 0 5 4 # 1 0 1 2
AUG 79 75 77 99 66 93 60 .75 70 170 S 4 20 BRK # 7 22 0 3 0 0 0 3 4 # 1 0 # 2
SEP 79 76 78 104 66 87 I .74 70 175 S I 13 BRK 1 7 18 0 2 0 0 0 2 4 # 0 0 # 1
OCT 83 78 80 99 68 87 43 .72 69 180 S 4 11 BRK 3 11 15 0 3 0 0 0 3 2 0 0 0 # #
NOV 83 78 80 100 64 84 50 .64 66 175 S 3 10 BRK 4 10 11 # 2 0 0 0 2 2 # # 0 2 2
DEC 85 78 82 108 56 64 27 .49 58 180 NE 5 40 BRK 7 12 11 1 1 0 0 0 1 # 0 0 0 5 5
ANN 83 79 81 108 56 77 42 .62 65 180 S I 41 BRK 48 136 149 1 28 0 0 0 28 28 4 2 0 27 31
POR 5 5 5 5 5 1 1 1 1 1 1 1 10 0 5 5 5 5 4 4 4 4 4 4 4 4 4 4 4

T = TRACE AMOUNTS (< .05 < .5 INCHES

= MEAN NO. DAYS < .5 DAYS

$ = PRESSURE ALTITUDE IN TENS OF FEET (I.E. 50 = 500 FEET)

@ = NAVY STATIONS REPORT HAIL AS SNOWFALL; ALSO NWS FROM JULY,1948-DEC.,1955

+ = THE PREDOMINANT SKY CONDITION

* = VISIBILITY IS NOT CONSIDERED

& = ANN TOTALS MAY NOT EQUAL SUM OF MONTHLY VALUES DUE TO ROUNDING

^ = 24 HR MAX PRECIP AND SNOWFALL ARE DAILY TOTALS (MID-NIGHT TO MID-NIGHT)

I = EXCESSIVE MISSING DATA - VALUE NOT COMPUTED

" = INCHES

----------------------------FEDERAL CLIMATE COMPLEX ASHEVILLE----------------------------

ANNEX 3: HDM-4 MODEL ENGINEERING INPUT DATA

The engineering data can be divided into two broad categories: (i) description of the existing road network / sections; and (ii) determination of the improvement and maintenance policies, including unit costs.

1. Road Network

The data pertaining to the existing road consists in the description of the following characteristics: (i) geometry; (ii) pavement

1.1 Overall characteristics

Each road section needs to be defined in terms of the basic characteristics shown in the Table below:

Overall Characteristics	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
Surface class	unsealed	unsealed	unsealed	unsealed
Length (km)	3.4	17.4	169.2	2.0
Carriageway width (m)	8	7	7	9
Shoulder width (m)	1	0.5	0	1

Source: Consultant

1.2 Geometry

The information pertaining to the geometry consists in defining: (i) rise & fall, in m/km; (ii) average horizontal curvature, in degree/km; (iii) speed limit, in km/h; (iv) altitude &; (v) drain type.

The geometry inputs, especially the rise & fall and average horizontal curvature, can be defined through the determination of average types of terrain for each section. The Table below provides the data used for each section:

Geometry	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
Rise & fall (in m/km)	1	10	10	1
# of rises & falls / km	1	2	2	1
Super-elevation (%)	2.0	2.5	2.5	2.0
Hor. Curvature (deg/km)	3	15	15	3
Speed limit (km/h)	60	80	80	60
Altitude (m)	500	500	750	700

Source: HDM 4/Consultant

1.3 Pavement

The modeling of the deterioration of unsealed roads requires detailed data on layer material gradation and plasticity index. There is a wide variation in materials from place to place, making the provision of sensible default materials in HDM-4 difficult. Users must therefore define specific detailed data for layer materials that can be retrieved when aggregate data are specified. For unsealed roads, structural adequacy and surface condition are both represented by the thickness of the surfacing material, gravel.

The Consultant has to assume one of the following surface materials for unsealed pavements: (i) lateritic gravel; (ii) quartzitic gravels; (iii) volcanic gravels angular; (iv) coral

gravels angular; or simply (v) earth. Earth is usually representative of an abandoned road, with no more bituminous pavement or gravel. Earth roads typically have 0 mm gravel thickness and high roughness levels.

The subgrade is made of one of the following materials: (i) well-graded gravel sands with small clay content; (ii) gravel-sand mixtures with excess of fines; (iii) sands with excess fines; (iv) clayey silts – inorganic; (v) clays – inorganic – of medium plasticity; and (vi) clays (inorganic) of high plasticity. The Consultant also has to determine if the compaction method is mechanical or non-mechanical. Finally, and for each section, the Consultant has to define the last regravel year.

The Consultant also has to define material gradation for surface and subgrade materials, in terms of: (i) maximum particle size; (ii) plasticity index; (iii) percent passing 2 mm sieve; (iv) percent passing 0.425 mm sieve; and (v) percent passing 0.075 mm sieve.

The detailed information used for the project is described in the table below:

Pavement	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
Pavement type	lateritic	quartzitic	quartzitic	lateritic
Subgrade materials	sands with excess fines	Gravel-sand mixtures with excess of fine		sands with excess fines
Compaction method	mechanical			
Last regravel year	2006			

Source: Consultant

1.4 Condition

Road condition data for unsealed roads are grouped as follows: (i) ride quality; and (ii) surface distress.

- *Ride quality*

Ride quality is an indication of the roughness of the road. It is an important parameter for indicating road condition and maintenance needs, and for predicting vehicle operating costs. At the aggregate level, ride quality is defined in terms of qualitative measures: good, fair, poor & very poor. The detailed data values related to these are in terms of roughness IRI (m/km), and are assigned by road class.

For each road surface class, the user should define the number of qualitative measures of ride quality that should be used, and their names. Then for each qualitative measure, and for each of the pre-defined road classes, the user should define the mean roughness value, IRI, in m/km.

- *Surface condition* / distresses

Surface condition is modeled by a number of distress modes. At the aggregate level surface condition can be defined by a qualitative measure (new, good, fair, poor & very poor) that represents several distress modes. These distress modes differ depending on whether the surface class is bituminous, concrete or unsealed.

For unsealed roads, surface condition and structural adequacy are both related to the traffic level and are represented by the thickness of the gravel surfacing. The Consultant will use gravel thickness at the end of 2006 as the yardstick to measure surface condition.

Condition at end of 2006	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
Roughness (IRI – m/km)	5.5	7.0	6.5	6.0
Gravel thickness (mm)	100			

Source: Consultant

2. Improvement & Maintenance Policies

The Consultant has to define improvement and maintenance policies. Below is what was assumed.

2.1 Improvement policies

HDM-4 can be used in order to determine the optimum investment strategies. It is too early at this stage to design detailed improvement strategies for the road investments, but the Consultant can provide a broad idea of such investments in the context of the HDM-4 Model.

The investment strategy consists in upgrading the pavement type (from unsealed roads to asphalt concrete, surface treatment or another unsealed surface but with better structure). The intervention is scheduled to start in 2008 and to last either two years or one year with all construction works implemented in 2008.

The Consultant first has to define the surfacing material type of the new carriageway, using the following list:

- Asphalt mix or asphalt concrete on: (i) asphalt base; (ii) asphalt pavement; (iii) granular base; and (iv) stabilized base,
- Surface treatment on: (i) asphalt base; (ii) asphalt pavement; (iii) granular base; and (iv) stabilized base.
- Unsealed surface: (i) lateritic gravel; (ii) quartzitic gravel; (iii) coral gravel angular; and (iv) volcanic gravels angular.

The strength of bituminous pavements is defined by their structural adequacy to carry traffic loading. At aggregate data level, structural adequacy can be defined in terms of qualitative descriptors/measures, such as good, fair, poor. The detailed data values relating to these are in terms of the Adjusted Structural Number of the Pavement (SNP).

The construction quality for bituminous pavements is described at the aggregate data level by values such as good, fair, poor, etc. The actual data details to be specified relate to construction defect indicators. The user defines the number of construction quality classes to be used, between good, fair-brittle, fair-soft, poor-brittle and poor-soft.

For each of the paved road surface classes, the user may define the number of qualitative measures of surface condition that may be used, and their names. Then for each qualitative measure, and for each of the pre-defined road classes, the user may define the mean values of the relevant distress modes. The Consultant specified a set of data for each individual road class.

At the aggregate data level, surface texture can be defined by a qualitative measure (good, fair, slippery) that gives an indication of the texture depth and skid resistance of the surface. In the current version of HDM-4, these parameters are modeled only for bituminous pavements.

For bituminous pavements, the user defines the number of qualitative measures of surface texture that should be used, and their names. Then for each qualitative measure, and for each of the surface types (AM or ST), the user assigns mean values of the sand patch texture depth and skid resistance at 50 km/h (SCRIM).

Overall, the Consultant used the following assumptions for asphalt concrete:

Upgrading to AC standards	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
New pavement type	Asphalt mix on granular base			
Surface materials	Asphaltic concrete			
Dry season structural number	3			
Surface thickness (mm)	100 mm			
Relative compaction (%)	98%			
After works carriageway width	9	7	7	9
After works shoulder width (each side)	2 + curves	2	2	2 + curves
Speed limit (km/hr.)	50	110	110	50
Costs (in US$)	450,000	400,000	400,000	450,000
Condition after works (IRI)	2			

Source: Consultant

Overall, the Consultant used the following assumptions for surface treatment:

Upgrading to ST standards	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
New pavement type	Surface treatment on granular base			
Surface materials	Double bituminous surface treatment			
Dry season structural number	3			
Surface thickness (mm)	30 mm			
Relative compaction (%)	97%			
After works carriageway width	9	7	7	9
After works shoulder width (each side)	2 + curves	2	2	2 + curves
Speed limit (km/hr.)	50	100	100	50
Costs (in US$)	250,000	200,000	200,000	250,000
Condition after works (IRI)	2.5			

Source: Consultant

Overall, the Consultant used the following assumptions for unsealed surface:

Upgrading to ST standards	Juba – Bor Jct.	Bor Jct – Torit Jct.	Torit Jct. – Nimule Ctr.	Nimule Ctr. – Uganda Bdr.
New pavement type	Gravel			
Surface materials	Lateritic gravel			
Gravel thickness	150 mm			
Max particle size	10.1%			
% passing 2.00mm sieve	51.1%			
% passing 0.425mm sieve	41.6%			
% passing 0.075mm sieve	25.5%			
After works carriageway width	9	Same as existing		9
Speed limit (km/hr.)	50	80	80	50
Costs (in US$)	150,000	100,000	100,000	150,000
Condition after works (IRI)	4			

Source: Consultant

2.2 Maintenance policies

The Consultant defined maintenance policies, including in the situation without project (base case alternative). To do so, the Consultant chose among the various interventions offered by HDM-4. For unsealed road sections, we will determine the following maintenance policy: (i) existing; (ii) improved/reconstructed gravel road; (iii) before construction. For bituminous road sections, we will determine the following maintenance policy: (i) surface treatment; and (ii) asphalt concrete.

❖ *Unsealed Road*

For the maintenance of gravel roads, the Consultant will perform the following interventions:

- Grading two times a year, using heavy motorized grading with water and light roller compaction, at a cost of $ 700 per km.
- Regravelling / resurfacing, every year using 150 mm of lateritic gravel with the following material properties[1]: (i) max. particle size = 21.9; (ii) plasticity index = 10.1%; (iii) % passing 2.00mm sieve = 51.1%; (iv) % passing 0.425mm sieve = 41.6%; and (v) % passing 0.075mm sieve = 25.5%; the unit cost is $ 11 per cubic meter.

Maintenance in the without project situation (which is supposed to represent the existing situation) is repeated every year during the analysis period. Maintenance before construction is only performed in 2007 and then stops. It is replaced after construction by a new maintenance policy adequate with the road being constructed. In the case of a reconstructed unsealed road, the maintenance policies are basically the same as in the existing situation, except that the road is kept in a better condition due to the investment that was undertaken.

❖ *Bituminous Road*

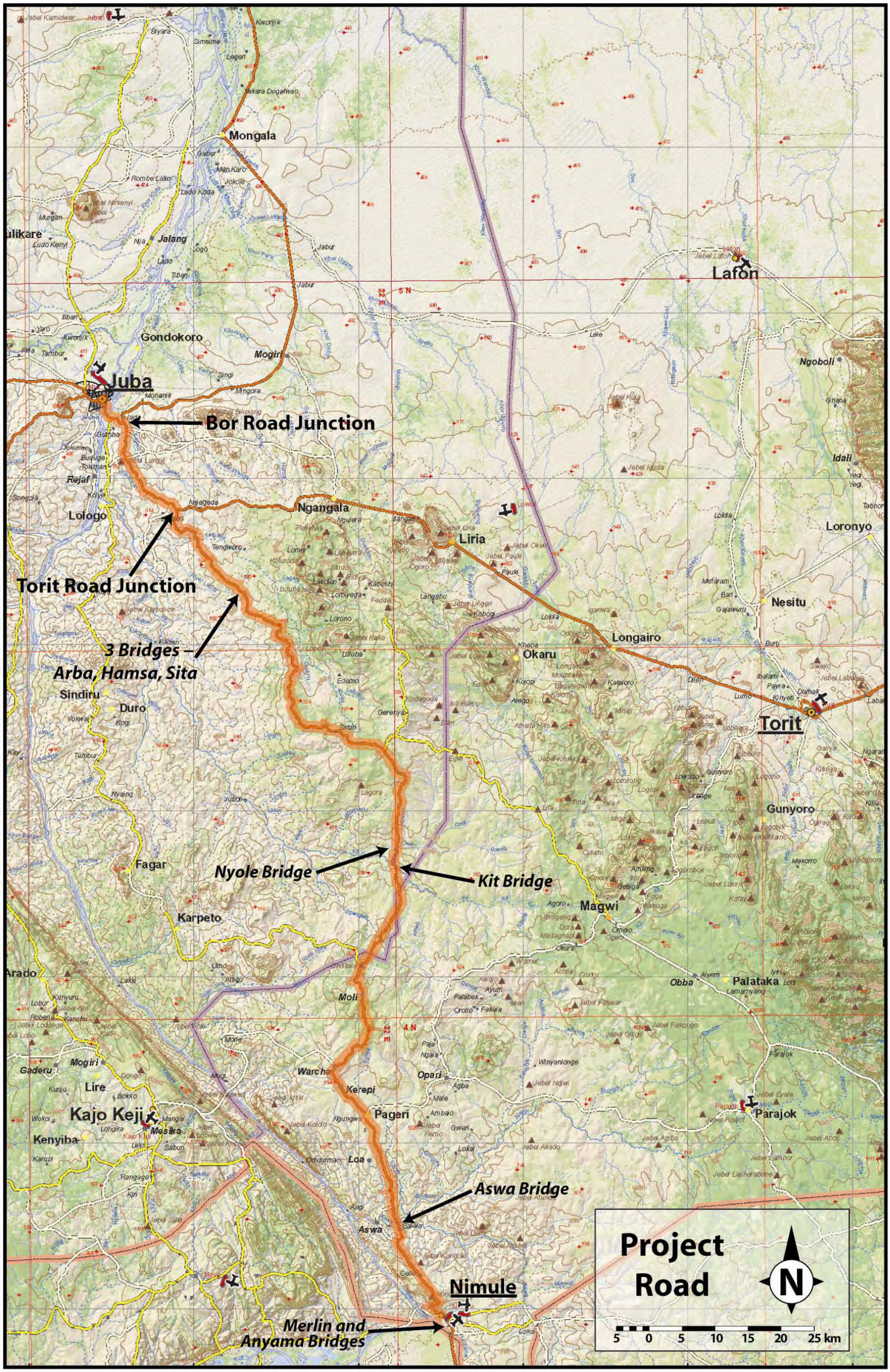
For the maintenance of bituminous roads, we chose the following interventions:

- Drainage / routine maintenance every year, at a cost of US$500 per km (both surface treatment and asphalt concrete);

[1] / From HDM default values

- Patching, when the number of potholes exceeds 50 no. per km, at a cost of US$ 7.5 per square meter (both surface treatment and asphalt concrete);
- Surface dressing simple with shape correction – 12 mm, when roughness reaches 4.5, at a cost of US$ 4 per square meter (surface treatment). The effect is a new surface with a roughness of 2.2.
- Thin overlay – 30 mm, when roughness reaches 4.5, at a cost of US$ 8.5 per square meter (asphalt concrete). The effect is a new surface with a roughness of 2.

ANNEX 4: PROJECT ROAD MAP


Juba
Bor Road Junction
Torit Road Junction
3 Bridges –
Arba, Hamsa, Sita
Nyole Bridge
Kit Bridge
Aswa Bridge
Merlin and
Anyama Bridges
Mongala
Lafon
Ngangala
Liria
Longairo
Okaru
Torit
Nimule
Magwi
Gondokoro
Mogiri
Lologo
Jalang
Ngoboli
Idali
Loronyo
Nesitu
Gunyoro
Palataka
Parajok
Pageri
Opari
Kerepi
Warcha
Moli
Karpeto
Fagar
Sindiru
Duro
Kenyiba
Kajo Keji
Mesika
Lire
Gaderu
Arado
Aswa
Project
Road
N
5 0 5 10 15 20 25 km

1 *1. Typical cross section (km 24) in areas not yet de-mined or only de-mined for 8m width*

2 *2. Red lateritic gravels (km 88)*

3 *3. Kit Bridge (km 101); 2 span – 27, 27m*

Juba - Nimule Road
Site photographs January 2007.

4 *4. Aswa Bridge (km 167); 3 span –24, 30, 21m*

5 *5. Km 181, coming over Gordon Hill into Nimule*

6 *6. Nimule main street*