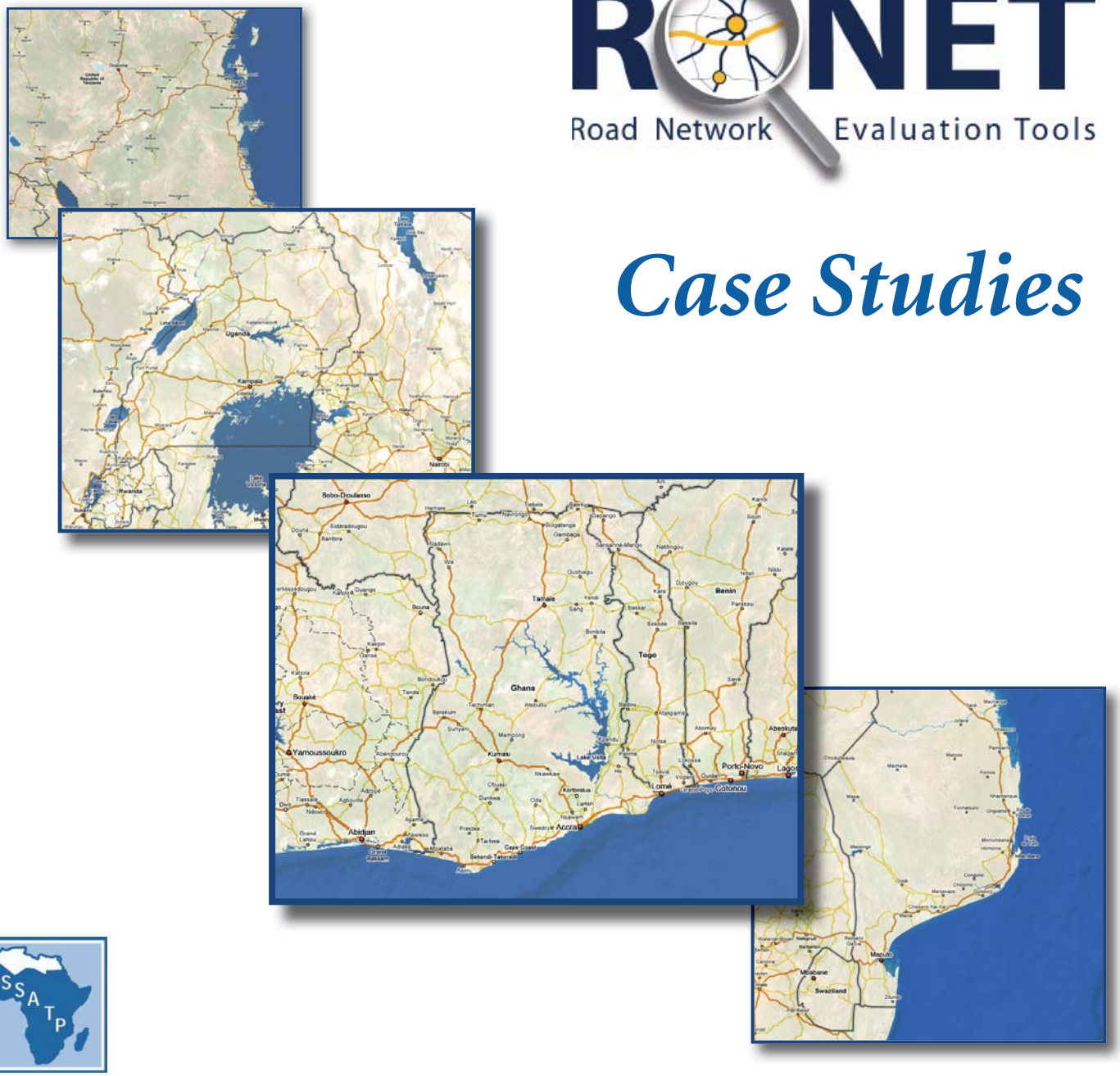
Sub-Saharan Africa Transport Policy Program
SSATP Working Paper No.85-B

RONET
Road Network Evaluation Tools

Case Studies



SSATP Working Paper No. 85-B

Application of Road Network Evaluation Tools (RONET) to Road Networks in Ghana, Mozambique, Tanzania, and Uganda

by

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A Pilot Application of RONET Version 1.0 in Ghana, Mozambique, Tanzania, and Uganda

Olav Ellevset

SSATP / The World Bank

Foreword

This report has been prepared by the Sub-Saharan Africa Transport Policy Program (SSAPT) as a part of the process of creating a tool for evaluating road networks at the macro-level. Road Network Evaluation Tools (RONET) takes the former Performance Assessment Model (PAM) created by SSATP in 2003 further, and incorporates the new PAM as a module in a set of tools designed for assessing the current characteristics of road networks and their future performance depending on different levels of interventions to the networks. This report is based on model testing and application of RONET version Beta 1.0 and RONET version 1.0 versions to road networks in four Sub-Saharan Africa countries: Ghana, Mozambique, Tanzania, and Uganda.

This new model has also triggered some interest outside the transport sector, as the model may be customized to deal with current characteristics and future forecasts for any kind of infrastructure management at the macro-level.

Zaza Manitranja Ramandimbiarison
SSATP Program Manager

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Acknowledgements

The Sub-Saharan Africa Transport Policy Program (SSATP) expresses its appreciation for contributions to this report, and the dedication and time spent by our partners in the respective road authorities and Ministries of the participating pilot countries: Ghana, Mozambique, Tanzania, and Uganda; Mr. Torben Larsen of the Royal Danish Embassy in Ghana; and Rodrigo Archondo-Callao in the Transport Anchor, ETWTR of the World Bank in Washington D.C.

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Joyce Petruzzelli of the World Bank created the graphic design and Monique Desthuis-Francis published the report.

Executive Summary

The Road Network Evaluation Tools (RONET) model is being developed for the Sub-Saharan Africa Transport Policy Program (SSATP) by the World Bank to assist decision makers to (i) monitor the current condition of the road network; (ii) plan allocation of resources; and (iii) assess the consequences of macro policies on the road network.

SSATP developed in the past two other software tools: (i) Road User Charges Model Version 3.0 (RUC), which evaluates scenarios of road user charges in a country, and (ii) Performance Assessment Model Version 1.0 (PAM), which estimates the performance of a road network under different budget scenarios

RONET is being developed to replace the functionality of the RUC and PAM models and to add new evaluation modules and output reports. RONET Version 1.0 implements the following evaluation modules:

- **Current Condition Assessment**, which calculates current road network statistics and network monitoring indicators.
- **Performance Assessment**, which evaluates the road network performance under different rehabilitation and maintenance standards (budget scenarios) and presents the consequences to the road agency, the road user, and the road infrastructure.

RONET is structured with many configuration options for use in African countries and developing countries elsewhere.

Ghana, Mozambique, Tanzania, and Uganda have been the pilot countries for upgrading and transforming the model to a modular form based on a different software platform, and this report presents the (i) compilation and main findings of the calibrations and results of applying the Beta-version of RONET 1.0 to the road networks chosen by the pilot countries, and (ii) the results of applying Version 1.0 to the respective main road networks only.

BASIC CHARACTERISTICS OF PILOT COUNTRIES

Country, Basic Characteristics				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Land area (sq km)	238,500	781,129	881,000	197,097
Total population (million persons)	21.343	19.92	36	28
Rural population (million persons)	11.99	15.98	28.8	22.4
GDP at current prices ($ Billion)	10.57	7.368	10.68	8.502
Total vehicle fleet (vehicles)	653,309	187,660	608,000	278,595

SUMMARY OF BETA-VERSION RESULTS FROM COUNTRY REPORTS

RONET gives the opportunity to use five network classes, and the lengths and utilization of the analyzed road networks are specified below.

Network Length (km) in Beta-version Calculations of Country Reports				
	Ghana	Mozambique	Tanzania	Uganda
Primary/Trunk	3,564	4,909	9,728	10,820
Secondary/Regional/District(Ug)	7,613	4,900	19,271	26,751
Tertiary/District (Tz)	29,086	12,689	0	35,000
Un-Eng.(Gh)/Vicinal (Moz)/ Feeder/ Unclassified (Ug)	11,776	6,740	0	0
Urban	5,575	0	0	3,579
Total Network	57,613	29,238	28,999	76,150
Primary/Trunk (%)	6	9	17	19
Secondary/Regional/District(Ug) (%)	13	17	66	35
Tertiary/District (Tz) (%)	50	43	0	46
Un-Eng.(Gh)/Vicinal (Moz)/ Feeder/ Unclassif. (Ug) (%)	20	23	0	0
Urban (%)	10	0	0	5
Total Network (%)	100	100	100	100

Network Utilization (Million vehicle-km) in Beta-version Calculations of Country Reports				
	Ghana	Mozambique	Tanzania	Uganda
Primary/Trunk (M veh-km)	8,205	1,928	4,513	4,344
Secondary/Regional/District (Ug) (M veh-km)	2,622	302	1,363	372
Tertiary/District (Tz) (M veh-km)	1,096	356	0	64
Un-Eng./Vicinal/Feeder/Unclassified (M veh-km)	54	88	0	0
Urban (M veh-km)	9,172	0	0	526
Total Network (M veh-km)	21,149	2,673	5,876	5,305
Primary/Trunk (M veh-km) (%)	39	72	77	82
Secondary/Regional/District (Ug) (M veh-km) (%)	12	11	23	7
Tertiary/District (Tz) (M veh-km) (%)	5	13	0	1
Un-Eng./Vicinal/Feeder/Unclassified (M veh-km) (%)	0	3	0	0
Urban (M veh-km) (%)	43	0	0	10
Total Network (M veh-km) (%)	100	100	100	100

As the above tables show, the road networks in the Beta-version analyses are very different in type, length, and traffic utilization. For example, urban roads were not evaluated in Mozambique, and in Tanzania, tertiary and rural roads were not evaluated. This has to be kept in mind when analyzing the Network Monitoring Indicators below and any country comparison using this data set will have to be carried out with caution.

In Ghana urban traffic has a very dominant role, and all the large rural road networks have very little traffic. For all the four countries 79 percent or more of the traffic takes place on roads in good and fair condition.

More than 84 percent of the paved roads in all four countries are currently in good and fair condition, and carry more than 70 percent of the analyzed traffic.

The Network Monitoring Indicators below show that more than 60 percent of the analyzed road networks in Ghana, Mozambique, and Tanzania, and about 30 percent of the substantially larger network in Uganda are in a maintainable condition.

Many road works in Ghana may be undertaken at a substantially lower cost compared with the other countries. This influences the country comparison, and also results in a lower calculated value of the road assets with a corresponding lower burden to the national economy.

The RONET's Performance Assessment Module (PAM) calculates for various scenarios and standard combinations of the costs to the road agency, the road users, and to the society, and combines these calculations into net benefits and marginal user cost increases.

Among the calculated scenarios, the Medium Standard in general appears to be the minimum desired budget to maintain the value of the assets, to keep the roads in fair condition, and to avoid increased roughness. The needs calculated by the upper standards of the model are higher during the first years due to the need for rehabilitation of the network to satisfy the chosen standard. Medium Standard average annual needs are US$2,255 per kilometer, out of which 29 percent, 49 percent, and 22 percent are rehabilitation, periodic maintenance, and recurrent maintenance respectively for the four countries. These calculated requirements are averages over a period over 20 years, and are rather low compared with how the needs are assessed in the respective countries today.

The model allocates by default only 50 percent of the recurrent unit costs of roads in fair condition to roads in poor and very poor condition. This relationship between unit costs is not reflected in the country calculations referred to above, but is used in the evaluations for the main roads only.

Network Monitoring Indicators for Beta-version Calculations in Country Reports				
Monitoring Indicator	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Network Length				
Road network length (km)	**57,613**	**29,238**	**28,999**	**76,150**
Road network length that is paved (km)	9,038	5,710	5,184	2,991
Road network length that is unpaved (km)	48,575	23,528	23,816	73,159
Road network length that is paved (%)	15.7	19.5	17.9	3.9
Network Density				
Road network per thousand land area (km/1000 sq km)	241.6	37.4	32.9	386.4
Road network per thousand total population (km/1000 persons)	2.7	1.5	0.8	2.7
Road network per thousand rural population (km/1000 persons)	4.8	1.8	1.0	3.4
Road network per thousand vehicles (km/1000 vehicles)	88.2	155.8	47.7	273.3
Road network per $ million GDP (km/million $)	5.5	4.0	2.7	9.0
Network Condition				
Percentage of road network in good and fair condition (%)	62.8	61.3	78.0	31.0
Percentage of paved road network in good and fair condition (%)	88.3	84.4	93.7	88.2
Percentage of paved road network with roughness 4 m/km IRI or less (%)	60.9	84.4	93.7	31.2
Paved roads average roughness weighted by km (IRI, m/km)	4.77	3.96	3.51	5.23
Paved roads average roughness weighted by vehicle-km (IRI, m/km)	4.62	3.80	3.18	5.22
Percentage of unpaved roads that are all-weather roads (%)	46.9	42.5	63.1	25.4
Network Standards				
Percentage of unpaved roads with 30 AADT or less (%)	50.0	46.2	20.7	73.7
Percentage of unpaved roads with 300 AADT or more (%)	4.4	1.0	10.2	4.5
Percentage of paved roads with 300 AADT or less (%)	1.6	0.4	0.1	13.5
Percentage of paved roads with 10,000 AADT or more (%)	16.6	0.1	2.5	7.3
Network Utilization				
Annual motorized vehicle utilization (million vehicle-km)	21,149	2,673	5,876	5,305
Annual freight carried over road network (million ton-km)	63,709	8,442	19,857	22,409
Annual passengers carried over road network (million pass-km)	142,853	18,308	45,032	30,919
Average network annual average daily traffic (vehicles/day)	1,006	250	555	191
Network Asset				
Current Road asset value (million $)	2,724	2,913	2,464	1,856
Current Road asset value as a share of maximum road asset value (%)	86.1	86.6	90.4	76.0
Current Road asset value as a share of GDP (%)	25.8	39.5	23.1	21.8

SEPARATE RONET VERSION 1.0 CALCULATIONS FOR MAIN ROADS ONLY

The networks analyzed in the four test runs for the Beta-version are quite different in type. On the four test runs: (i) large tertiary networks in Ghana and Uganda may, with uncertainties in unit costs, distort the calculations; (ii) urban roads were not evaluated in Mozambique and Tanzania; and (iii) tertiary roads were not evaluated in Tanzania. Therefore, it may be advisable to split up the analyses

for the main roads and the rest of the network to be able to compare only the main roads of each country.

Consequently, separate calculations have been made for the main roads part only using the new RONET Version 1.0, which has a few minor modifications compared with the Beta-version, and some adjustments have been made to road works unit costs to eliminate inconsistencies.

The tables below present the roads network length (kilometer) and network utilization (million vehicle-km) excluding urban roads, and how the main roads analyzed in this section relate to that network. The approximate length of rural roads under local authorities in Tanzania has been included under Other Roads, whereas all urban roads in all countries are excluded in the evaluations of this section.

Network Length Excluding Urban Roads (km)				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Main Roads (km)	**11,177**	**9,808**	**28,999**	**10,820**
Other Roads (km)	40,862	19,431	50,000	61,751
Total Network (km)	52,039	29,239	78,999	72,571
Main Roads (km) (%)	**21**	**34**	**37**	**15**
Other Roads (km) (%)	79	66	63	85
Total Network (km) (%)	100	100	100	100

Network Utilization Excluding Urban Roads (Million vehicle-km)				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Main Roads (M veh-km)	10,738	**2,229**	**5,876**	**4,344**
Other Roads (M veh-km)	10,322	444	1,187	436
Total Network (M veh-km)	21,060	2,673	7,063	4,780
Main Roads (M veh-km)	**51 percent**	**83 percent**	**83 percent**	**91 percent**
Other Roads (M veh-km)	49 percent	17 percent	17 percent	9 percent
Total Network (M veh-km)	100 percent	100 percent	100 percent	100 percent

The table below presents the current monitoring indicators of the **main road** networks. More than 73 percent of all main roads and more than 87 percent of paved main roads are, in all four countries, in a maintainable good or fair condition.

Network Monitoring Indicators, Main Roads				
Monitoring Indicator	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Network Length				
Road network length (km)	**11,177**	**9,808**	**28,999**	**10,820**
Road network length that is unpaved (km)	5,816	4,569	23,816	8,143
Road network length that is paved (km)	5,361	5,239	5,184	2,677
Road network length that is paved (%)	48.0	53.4	17.9	24.7
Network Density				
Road network per thousand land area (km/1000 sq km)	46.86	12.56	32.92	54.90
Road network per thousand total population (km/1000 persons)	0.52	0.49	0.81	0.39
Road network per thousand rural population (km/1000 persons)	0.93	0.61	1.01	0.48
Road network per thousand vehicles (km/1000 vehicles)	17.11	52.27	47.70	38.84
Road network per $ million GDP (km/million $)	1.06	1.33	2.72	1.27
Paved road network per thousand land area (km/1000 sq km)	24.38	5.85	27.03	41.31
Paved road network per thousand total population (km/1000 persons)	0.27	0.23	0.66	0.29
Paved road network per thousand rural population (km/1000 persons)	0.48	0.29	0.83	0.36
Paved road network per thousand vehicles (km/1000 vehicles)	8.90	24.35	39.17	29.23
Paved road network per $ million GDP (km/million $)	0.55	0.62	2.23	0.96
Network Condition				
Percentage of road network in good and fair condition (%)	73.8	83.3	78.0	82.1
Percentage of paved road network in good and fair condition (%)	95.3	87.5	93.7	88.1
Percentage of paved road network with roughness 4 m/km IRI or less (%)	64.6	53.1	58.3	24.7
Paved roads average roughness weighted by km (IRI, m/km) (%)	4.47	4.91	4.30	5.73
Paved roads average roughness weighted by vehicle-km (IRI, m/km) (%)	3.94	4.63	3.67	5.67
Percentage of unpaved roads that are all-weather roads (%)	54.0	59.5	63.1	80.1
Network Standards				
Percentage of unpaved roads with 30 AADT or less (%)	1.2	19.2	20.7	2.6
Percentage of unpaved roads with 300 AADT or more (%)	31.2	2.2	10.2	29.5
Percentage of paved roads with 300 AADT or less (%)	0.0	40.2	12.3	13.9
Percentage of paved roads with 10,000 AADT or more (%)	13.9	0.2	2.5	8.2
Network Utilization				
Annual motorized vehicle utilization (million vehicle-km)	10,738	2,229	5,876	4,344
Annual freight carried over road network (million ton-km)	32,164	6,844	19,857	18,777
Annual passengers carried over road network (million pass-km)	73,140	15,484	45,032	25,226
Average network annual average daily traffic (vehicles/day)	2,632	623	555	1,100
Network Asset				
Current Road asset value (million $)	1,390.4	2,423.0	2,463.9	1,360.2
Current Road asset value as a share of maximum road asset value (%)	90.3	90.2	90.4	86.2
Current Road asset value as a share of GDP (%)	13.2	32.9	23.1	16.0

As urban and rural roads are out of these calculations, the results are more comparable between the countries. For Ghana this calculation brings much different results for utilization and asset values

compared with those of the Beta-version for the larger network. The networks of Mozambique and Uganda have also been substantially reduced in this evaluation, but show far fewer changes in the same indicators.

Lower road works unit costs in Ghana are influencing the country comparison also for the main roads. While the asset value of the main roads in Ghana is only 13.1 percent of GDP, the corresponding value for Mozambique is about 2.5 times as high and represents a much larger burden for the national economy.

Estimated annualized requirements are for Medium standard calculated to US$4,665 per kilometer, out of which 35 percent, 47 percent, and 18 percent are rehabilitation, periodic maintenance, and recurrent maintenance respectively for the four countries. These calculated requirements are averages over a period over 20 years, and more emphasis on rehabilitation of main roads will reduce the need for routine maintenance to only about 18 percent of overall costs. Calculations show that main roads in Ghana represent the lowest burden to the GDP and per vehicle-kilometer compared with the other countries.

In the main road calculations, road works recurrent unit costs for roads in poor and very poor condition have been set as 50 percent of the recurrent unit costs of roads in fair condition.

RONET also computes the network performance under different road work standards over a 20 year evaluation period. Results show that in general the Medium to Low Standard will keep the average roughness weighted by kilometer in year 10 at the same level as the current network roughness. The Medium and higher standards will improve the network condition over time.

The corresponding condition calculations show that almost no roads will any longer be in poor and very poor condition, and that the majority of roads would be in fair condition.

The main road calculations for Ghana and Mozambique show that over the next 20 years only 11 percent of the annual road works requirements should be needed for routine maintenance, giving much more emphasis on periodic maintenance and rehabilitation.

The table below presents the main roads average results for the four countries.

Average Results for the Four Countries	
Network Density	
Road network per thousand land area (km/1000 sq km)	36.81
Road network per thousand total population (km/1000 persons)	0.55
Road network per thousand rural population (km/1000 persons)	0.76
Road network per thousand vehicles (km/1000 vehicles)	38.98
Road network per $ million GDP (km/million $)	1.59
Paved road network per thousand land area (km/1000 sq km)	24.65
Paved road network per thousand total population (km/1000 persons)	0.36
Paved road network per thousand rural population (km/1000 persons)	0.49
Paved road network per thousand vehicles (km/1000 vehicles)	25.41
Paved road network per $ million GDP (km/million $)	1.09
Network Asset	
Current Road asset value per kilometer (million $/km)	0.15
Current Road asset value as a share of maximum road asset value (%)	89%
Current Road asset value as a share of GPD (%)	21%
Medium Standard Rehabilitation and Maintenance Requirements	
Annual rehabilitation and maintenance requirements as share of GDP (%)	0.66%
Annual rehabilitation and maintenance requirements (US$ per Year per Km)	4,574
Annual rehabilitation and maintenance requirements (US$ per Year per Vehicle-Km)	0.016
Rehabilitation expenditures as a share of total expenditures (%)	36%
Periodic Maintenance expenditures as a share of total expenditures (%)	46%
Routine Maintenance expenditures as a share of total expenditures (%)	18%

GENERAL OBSERVATIONS

The quality of inputs is important for RONET as for any other model, and in particular data for current road conditions, the traffic bands that apply to the different portions of the network, and road works unit costs are essential for getting useful results out of the model.

If current road conditions describe well the state of the network, then road asset values, works requirements, budget forecasts, and corresponding road conditions will also be representative. The traffic bands are important for all calculations related to the calculations of network utilization, passenger and freight volumes, road users, and society costs. Poor and inconsistent unit costs can inordinately bias the country's road network asset valuation and the overall budget requirements.

The access to current and historical data is usually better for national networks than for lower level networks, and calculations related to different networks may therefore have very different accuracies. Separate calculations between the main roads, other roads, and eventually urban roads, are worthwhile considering the need to better identify and manage these uncertainties.

The RONET software is a macro tool at network level, and is useful for strategic planning, in monitoring the performance of the network, and in enabling rapid assessments of the effects of government funding decisions. It is also possible to enhance RONET by adding new modules for road user charges evaluation, life-cycle economic evaluation, axle loading impacts evaluation, and network improvements evaluation. The possibilities of linking RONET with identifiable social impacts due to transport interventions and calculations of the Rural Access Indicator (RAI) will also be considered.

The RONET as a model has interestingly enough also triggered some interest outside the transport sector. The model may be customized to deal with current characteristics and future forecasts for any kind of infrastructure management described by investments, utilization, deterioration, maintenance, and condition and value of assets at the macro-level.

1. Introduction

This report is based on the practical experience and results of the RONET model for the four pilot countries of Ghana, Mozambique, Tanzania, and Uganda in Sub-Saharan Africa, representing the only experiences with the application of RONET so far. These experiences are valuable for model upgrades, for developing new modules to become part of the model, and also provide some guidance to other practitioners considering applying this tool for road networks in other countries.

This report compiles and analyses first the country-specific results for the networks provided by the countries themselves using the Beta-version for testing the model. As the networks analyzed in the country reports are quite different, the report also compiles and analyses the main road networks only using the same country-specific calibrations. There are no differences between the two versions in terms of how results are being calculated.

As stand-alone reports, the respective country reports go into detail in describing and assessing the characteristics and implications for the analyzed road networks. The four country reports have been prepared by the four countries themselves, and are presented in section 6.

This tool makes it easier to undertake country comparisons at road network level, comparisons that previous data and tools have provided very limited possibilities for.

Background

The Road Network Evaluation Tools (RONET) model is being developed for the Sub-Saharan Africa Transport Policy Program (SSATP) by the World Bank to assist decision makers:

- monitor the current condition of the road network,
- plan allocation of resources, and
- assess the consequences of macro policies on the road network.

RONET is particularly being developed for use in the Africa region, but there are no impediments for its application to any other country worldwide. RONET includes a series of analytical tools designed to evaluate the road network and road sector of a country at a macro level by evaluating a series of representative road classes, which can be characterized, for example, as functions of: (i) functional classification, (ii) surface type, (iii) traffic level, (iv) road condition, (v) terrain, (vi) climate, and (vii) geographical region.

SSATP has developed in the past the following two other software tools designed also to evaluate an entire road network of a country by evaluating a series of representative road classes.

- Road User Charges Model Version 3.0 (RUC), which evaluates scenarios of road user charges in a country, evaluating road classes in good and fair condition differentiated

by traffic level, and estimates routine and periodic maintenance requirements derived from look-up solution tables. The RUC model represents the entire network of a country by a maximum of 160 road classes that are a function of traffic, percentage of cars, trucks loading, pavement strength, environment, level of agency costs, and vehicle operating costs.

- Performance Assessment Model Version 1.0 (PAM), which estimates the performance of a road network under different budget scenarios, evaluating road classes on any road condition but not differentiating the road classes by traffic level, and estimates routine and periodic maintenance requirements derived from a straight line deterioration model. The PAM model represents the entire network of a country by a maximum of 64 road classes based on functional classification, pavement type, and condition.

RONET is being developed to replace the functionality of the RUC and PAM models and to add new evaluation modules and output reports; therefore, RONET (i) is being developed in a modular form, (ii) characterizes the entire road network of a country in a more elaborate way by allowing the definition of a maximum of 625 road classes, and (iii) includes road deterioration models based on the Highway Design and Management Module (HDM-4) relationships. RONET version 1.0 implements the following evaluation modules:

- **Current Condition Assessment**, which calculates current road network statistics and network monitoring indicators.
- **Performance Assessment**, which evaluates the road network performance under different rehabilitation and maintenance standards (budget scenarios) and presents the consequences to the road agency, the road user, and the road infrastructure.

RONET can be enhanced in the future by, for example, adding evaluation modules such as: (i) road user charges evaluation, (ii) life-cycle economic evaluation, (iii) axle loading impacts evaluation, and (iv) network improvements evaluation.

2. Summary of Country Reports and Comparisons of Beta-Version Calculations

In this section the results from the country-specific test runs are presented together in combined tables.

The table below shows the country characteristics as collected for RONET.

Country, Basic Characteristics				
	Ghana	Mozambique	Tanzania	Uganda
Land area (sq km)	238,500	781,129	881,000	197,097
Total population (million persons)	21.3	19.9	36	28
Rural population (million persons)	12.0	16	28.8	22.4
GDP at current prices ($ Billion)	10.570	7.368	10.680	8.502
Total vehicle fleet (vehicles)	653,309	187,660	608,000	278,595

The networks analyzed in this study:

- In Ghana, 57,613 kilometers of primary, secondary, tertiary, un-engineered, and urban roads managed by the Ghana Highways Authority, the Feeder Roads Department, and Urban Roads Department;
- In Mozambique, 29,238 kilometers of primary, secondary, and vicinal roads managed by ANE;
- In Tanzania, 28,999 kilometers of trunk and regional roads managed by TANROADS; and
- In Uganda, 76,150 kilometers of national, district, community access, and urban roads managed by the new Uganda National Roads Authority (UNRA), local governments, Local Council 3 (LC3), and urban authorities.

RONET gives the opportunity of using up to five network classes, and the details of the respective classes that have been analyzed are specified in the tables below. The name and institutional responsibility for road networks varies between the countries, which in some cases are indicated in brackets. In Tanzania no roads under the management of local governments, and in Mozambique no urban roads, have been included, which make the analyzed networks in those two countries less complete than for Ghana and Uganda. Any comparison between countries in this section should take into account these differences in network size.

The tables also specify the road networks' respective utilization (million vehicle-kilometers), and the results show that Ghana has only 39 percent of the traffic on its main roads and as much as 43 percent on urban roads. Uganda has about 82 percent of the traffic on its primary network and only about 10 percent on urban roads. While tertiary roads are about half of the analyzed network in Uganda, they only have about 1 percent of the total traffic.

Network Length (km) in Country Calculations (Beta-version)				
	Ghana	Mozambique	Tanzania	Uganda
Primary/Trunk	3,564	4,909	9,728	10,820
Secondary/Regional/District(Ug)	7,613	4,900	19,271	26,751
Tertiary/District (Tz)	29,086	12,689	0	35,000
Un-Eng.(Gh)/Vicinal (Moz)/ Feeder/ Unclassified (Ug)	11,776	6,740	0	0
Urban	5,575	0	0	3,579
Total Network	57,613	29,238	28,999	76,150
Primary/Trunk (%)	6	17	34	14
Secondary/Regional/District(Ug) (%)	13	17	66	35
Tertiary/District (Tz) (%)	50	43	0	46
Un-Eng.(Gh)/Vicinal (Moz)/ Feeder/ Unclassified (Ug) (%)	20	23	0	0
Urban (%)	10	0	0	5
Total Network (%)	100	100	100	100

Network Utilization (Million vehicle-km) in Country Calculations (Beta-version)				
	Ghana	Mozambique	Tanzania	Uganda
Primary/Trunk (M veh-km)	8,205	1,928	4,513	4,344
Secondary/Regional/District (Ug) (M veh-km)	2,622	302	1,363	372
Tertiary/District (Tz) (M veh-km)	1,096	356	0	64
Un-Eng./Vicinal/Feeder/Unclassified (M veh-km)	54	88	0	0
Urban (M veh-km)	9,172	0	0	526
Total Network (M veh-km)	21,149	2,673	5,876	5,305
Primary/Trunk (M veh-km))	39 %	72 %	77 %	82 %
Secondary/Regional/District (Ug) (M veh-km)	12 %	11 %	23 %	7 %
Tertiary/District (Tz) (M veh-km)	5 %	13 %	0 %	1 %
Un-Eng./Vicinal/Feeder/Unclassified (M veh-km)	0 %	3 %	0 %	0 %
Urban (M veh-km)	43 %	0 %	0 %	10 %
Total Network (M veh-km)	100 %	100 %	100 %	100 %

The model presents the details of road conditions by network type and road surface, and the table below gives the details for roads in good and fair condition and their respective traffic utilization. The main 10,000 kilometers of roads in all the countries are in pretty good shape, but only 11 % of the 26,751 kilometers secondary network (district roads) in Uganda is in good or fair condition.

Roads in Good and Fair Condition by Network Type (km) in Country Calculations (Beta-version)				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Primary/Trunk	2,921	4,319	8,392	8,878
Secondary/Regional/District (Ug)	5,327	3,850	14,233	2,809
Tertiary/District (Tz)	25,336	7,088	0	10,000
Un-Eng./Vicinal/Feeder/Unclassified	0	2,674	0	0
Urban	2,576	0	0	1,903
Total km in Good and Fair condition	36,160	17,931	22,625	23,590
Total Length of Analyzed Network	57,613	29,238	28,999	76,150
% in Good and Fair of Analyzed Class				
Primary/Trunk	82	88	86	82
Secondary/Regional/District(Ug)	70	79	74	11
Tertiary/District (Tz)	87	56	0	29
Un-Eng./Vicinal/Feeder/Unclassified	0	40	0	0
Urban	46	0	0	53
Overall in Good and Fair condition	63	61	78	31

The table below shows that most of the traffic in all the four countries takes place on roads in good and fair condition, with about 79 percent in Uganda and 83 percent in Ghana.

Network Utilization by Network Type and Roads in Good and Fair Condition (Million vehicle-km) in Country Calculations (Beta-version)				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Traffic on Roads in Good and Fair Condition				
Primary/Trunk	7,909	1,635	4,242	3,764
Secondary/Regional/District(Ug)	2,300	267	1,088	39
Tertiary/District (Tz)	1,022	250	0	18
Un-Eng./Vicinal/Feeder/Unclassified	0	55	0	0
Urban	6,311	0	0	350
Overall Traffic on Good and Fair roads	17,542	2,206	5,330	4,171
Total Traffic on analyzed network	21,149	2,673	5,876	5,305
Percentage on Good and Fair Roads of roads in respective Class				
Primary/Trunk	96	85	94	87
Secondary/Regional/District (Ug)	88	89	80	10
Tertiary/District (Tz)	93	70	0	29
Un-Eng./Vicinal/Feeder/Unclassified	0	63	0	0
Urban	69	0	0	67
Overall Traffic on Good and Fair roads	83	83	91	79

The table below shows that most of the traffic is carried by paved roads, with about 71 percent of the overall traffic in Uganda, and as much as 91 percent in Ghana.

Network Utilization on Paved versus Unpaved Roads in Country Calculations (Million vehicle-km)				
	Ghana	Mozambique	Tanzania	Uganda
On Paved	19,346	2,200	4,317	3,768
On Unpaved	1,803	473	1,560	1,537
Total traffic (Mill veh-km)	21,149	2,673	5,876	5,305
Percentage on Paved	91	82	73	71
Percentage on Unpaved	9	18	27	29
Total	100	100	100	100

The table below presents capital road works unit costs used in the country calculations (single carriageway in US$/km), for primary paved roads, secondary gravel roads, and tertiary earth roads. Some parameters like thickness layers may differ, and full capital road works unit costs matrices for each country are presented in the main Annex 1 (Consolidated Data from all Four Countries) .

Capital Road Works Unit Costs (US$/km)					
Surface Type	Road Work	Ghana	Mozam-bique	Tanzania	Uganda
Asphalt Mix	Preventive Treatment	2,500	9,500	5,000	12,500
Primary Roads	Resurfacing (Overlay)	110,000	71,500	60,000	45,000
	Strengthening (Overlay)	170,000	250,000	100,000	130,000
	Reconstruction	250,000	400,000	300,000	350,000
	New Construction	400,000	650,000	350,000	600,000
Surface Treatment	Preventive Treatment	1,800	3,510	2,000	10,000
Primary Roads	Resurfacing (Reseal)	25,000	32,500	27,000	25,000
	Strengthening (Overlay)	60,000	107,310	80,000	75,000
	Reconstruction	160,000	300,000	254,000	250,000
	New Construction	220,000	450,000	304,000	400,000
Gravel	Spot Regraveling	900	2,400	2,708	5,000
Secondary Roads	Regraveling	12,000	45,000	8,462	10,000
	Partial Reconstruction	18,000	55,000	11,846	25,000
	Full Reconstruction	28,000	70,000	21,154	40,000
	New Construction	32,000	90,000	47,385	60,000
Earth	Spot Repairs	500	125	104	125
Tertiary Roads	Heavy Grading	600	250	426	250
	Partial Reconstruction	750	350	5,192	625
	Full Reconstruction	950	350	10,385	1,125
	New Construction	1,000	350	27,692	1,500

The capital works unit costs for Ghana are relatively low compared with the other countries, and some of Mozambique's essential capital unit costs for gravel roads are actually three times as high as

the ones of Ghana, For Mozambique high costs on gravel roads are to some extent off-set with low costs for earth roads.

Even though individual unit costs vary substantially, the capital unit costs for Tanzania and Uganda match relatively well. Tanzania has high costs for earth roads, but the current calculations are not too much influenced as earth roads represent 22 percent of the analyzed network of 28,999 kilometers under management of TANROADS.

Overall, the maintenance unit costs are also lower for Ghana than for the other countries. For Uganda, high maintenance unit costs for gravel roads will pull up the annual budget requirements for maintenance.

The table below presents the corresponding recurrent road works unit costs used in the country calculations for primary paved roads, secondary gravel roads and tertiary earth roads with different road conditions. Full recurrent road works unit costs matrices for each country are presented in Annex 2 (Consolidated Data from all Four Countries)

Recurrent Road Works Unit Costs (US$/km/year)					
Surface Type	**Road Condition**	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Asphalt Mix	Very Good	900	1,100	1,000	1,875
Primary Roads	Good	1,200	1,200	1,250	1,875
	Fair	1,500	1,300	1,500	2,500
	Poor	1,750	975	1,750	6,250
	Very Poor	750	650	2,000	12,500
Surface Treatment	Very Good	600	1,000	1,000	1,500
Primary Roads	Good	900	1,200	1,250	1,500
	Fair	1,200	1,300	1,500	2,000
	Poor	1,500	975	1,750	5,000
	Very Poor	600	650	2,000	10,000
Gravel	Very Good	375	1,200	413	1,125
Secondary Roads	Good	470	1,200	506	1,125
	Fair	580	1,200	600	2,625
	Poor	660	900	694	3,375
	Very Poor	290	600	788	5,625
Earth	Very Good	40	100	125	50
Tertiary Roads	Good	60	100	157	50
	Fair	80	125	188	50
	Poor	100	125	219	100
	Very Poor	40	125	250	100

Overall, the maintenance unit costs are lower for Ghana than for the other countries. For Uganda, high maintenance unit costs for gravel roads will pull up the annual budget requirements for mainte-

nance. This may to some extent be offset by low unit costs for earth roads, which in the case of Uganda make up 73 percent of the analyzed network.

The table below shows the Network Monitoring Indicators, which is a summary output of RONET with current characteristics of the network and its utilization, and relates these figures to other country characteristics like land area, population, vehicle fleet, and GDP.

Network Monitoring Indicators for Country Calculations (Beta-version)				
Monitoring Indicator	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Network Length				
Road network length (km)	**57,613**	**29,238**	**28,999**	**76,150**
Road network length that is paved (km)	9,038	5,710	5,184	2,991
Road network length that is unpaved (km)	48,575	23,528	23,816	73,159
Road network length that is paved (%)	15.7	19.5	17.9	3.9
Network Density				
Road network per thousand land area (km/1000 sq km)	241.6	37.4	32.9	386.4
Road network per thousand total population (km/1000 persons)	2.7	1.5	0.8	2.7
Road network per thousand rural population (km/1000 persons)	4.8	1.8	1.0	3.4
Road network per thousand vehicles (km/1000 vehicles)	88.2	155.8	47.7	273.3
Road network per $ million GDP (km/million $)	5.5	4.0	2.7	9.0
Network Condition				
%age of road network in good and fair condition	62.8	61.3	78.0	31.0
%age of paved road network in good and fair condition	88.3	84.4	93.7	88.2
%age of paved road network with roughness 4 m/km IRI or less (%)	60.9	84.4	93.7	31.2
Paved roads average roughness weighted by km (IRI, m/km)	4.77	3.96	3.51	5.23
Paved roads average roughness weighted by vehicle-km (IRI, m/km)	4.62	3.80	3.18	5.22
%age of unpaved roads that are all-weather roads (%)	46.9	42.5	63.1	25.4
Network Standards				
%age of unpaved roads with 30 AADT or less (%)	50.0	46.2	20.7	73.7
%age of unpaved roads with 300 AADT or more (%)	4.4	1.0	10.2	4.5
%age of paved roads with 300 AADT or less (%)	1.6	0.4	0.1	13.5
%age of paved roads with 10,000 AADT or more (%)	16.6	0.1	2.5	7.3
Network Utilization				
Annual motorized vehicle utilization (million vehicle-km)	21,149	2,673	5,876	5,305
Annual freight carried over road network (million ton-km)	63,709	8,442	19,857	22,409
Annual passengers carried over road network (million pass-km)	142,853	18,308	45,032	30,919
Average network annual average daily traffic (vehicles/day)	1,006	250	555	191
Network Asset				
Current road asset value (million $)	2,724	2,913	2,464	1,856
Current road asset value as a share of maximum road asset value (%)	86.1	86.6	90.4	76.0
Current road asset value as a share of GDP (%)	25.8	39.5	23.1	21.8

The table below presents for the Medium Standard the distribution of the average annualized road works requirements between rehabilitation, periodic maintenance and recurrent maintenance. The Medium Standard appears in general to be the minimum desired budget to maintain the value of the assets, keep the roads in fair condition, and not increase roughness. The requirements for Medium and higher standards are higher during the first five years due to the need for rehabilitation to satisfy the chosen standard.

The figures represent the average annual needs over the next 20 years. The rehabilitation part is strongly frontloaded to the first years to stabilize the network and improve the maintainability.

Annual Road Works Requirement for Medium Standard (M US$ per Year) Year 1-20				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Rehabilitation Costs (M US$ per Year)	36.7	34.1	20.1	34.7
Periodic Maintenance Costs (M US$ per Year)	92.6	46.3	41.7	32.6
Recurrent Maintenance Costs (M US$ per Year)	15.9	15.1	14.9	48.4
Total (M US$ per Year)	145.1	95.5	76.7	115.7
Rehabilitation (percent)	25	36	26	30
Periodic Maintenance (percent)	64	48	54	28
Recurrent Maintenance (percent)	11	16	19	42
Total (percent)	100	100	100	100

Average recurrent maintenance costs appear low, but the model will, during the first years, emphasize rehabilitation and periodic maintenance to improve the maintainability of the network and minimize annual maintenance costs. When comparing the figures, it is important to remember the difference in network size between the four countries, with much smaller networks analyzed for Mozambique and Uganda than for the other two.

Observations from Beta-version Tests

None of the countries have had particular problems with finding data for the model calibration, but traffic-level statistics from the feeder and local government roads is not available and has to be compiled based on network knowledge. Data is typically collected as:

- Basic characteristics from national statistical services,
- Capital road works unit costs from road agencies and compiled by the Road Cost Knowledge System (ROCKS),
- Traffic-level characteristics from the road agencies, mostly missing for sub-national roads,
- Vehicle operating cost (VOC) coefficients calculated by World Bank's Road User Costs Knowledge System (RUCKS), with basic data from HDM-4 calibration, or from studies undertaken by countries previously. "Rise and Fall" data and on "Horizontal curvature" are contained in VOC-studies.

More details can be found in the respective country reports.

The main observations from the country-specific tests by the Beta-version are as stated by the respective countries.

Ghana

The software is still in its development stage and as such there are some results that require clarification and possibly re-examination. However, it is important to note that the software is able to provide insights into the following:

- the investment required for rehabilitation, periodic maintenance, and routine maintenance over specific time periods,
- the consequences of any investment to the road agencies and road users,
- the implication for the road condition and resulting asset value, and
- the allocation to various road management agencies.

This software can be used to assess the strategic plans of road agencies and the performance of the network in the strategic period. Policy formulation in relation to the specific performance standards and investments required of each network type can only be enhanced with such a tool.

Mozambique

On the basis of this preliminary evaluation and use of RONET, it can be concluded that the model is potentially an extremely useful medium to long-term strategic planning aid. The indication of overall network standards achievable with given budget limitations is a useful corrective for overheated political expectations. RONET's overall network roughness predictions are also useful for providing international donors and road agencies with realistic monitoring guidelines and targets. Linking RONET up with an enhanced road user charges model would provide a very powerful policy tool.

Tanzania

RONET is quite a good tool in evaluating the network. In Tanzania, through the pilot work on RONET, quite useful information has already been obtained pertaining to network length, road condition, network utilization, roughness changes in relation to budget allocated, and comparison of various budget standards over a five-year period. On the other hand, this tool will assist very much in providing vital information which is required in the allocation of funds among the network types, in soliciting funds from the government and development partners, in strategic planning in the agency and the transport sector, and in monitoring of the performance of the network.

Uganda

The absence of simple operational road management systems to articulate the consequences of road-funding trends to politicians and financiers in a robust manner has often failed the Ministry in winning its argument for more funding or even justifying the adequacy/inadequacy of currently available resources. Complex models such as HDM-4, though more accurate, have tended to alienate decision

makers because of the complexity of its outputs. The RONET model provides a simple approach to the assessment of road requirements together with the consequences of the various standards.

Whereas insufficient funding for the national road network has been the case for some time since 1994, it was not possible until the introduction of the PAM and now the RONET model to carry out rapid assessments of the impacts of government funding decisions. This model is intended to make it possible for road managers, consultants, and financiers to carry out rapid macro assessments of country or organization networks, deriving vital information to guide decision making.

The RONET model is still under development and many more features that will be useful to future users will be added.

Other Observations

The networks analyzed in the four test runs for the Beta-version are quite different. As an example, large rural components in Ghana and Uganda may, with uncertainties and substantial variations in unit costs, easily distort some of the calculations. It may be difficult to find sufficient data for all unit costs in many countries, and they will also vary substantially within the country itself. But unit costs will strongly influence several parts of the RONET evaluations, and it is important to review both individual unit costs and the consistency within the cost structure.

Separating the analyses into one analysis for all roads and another one for main roads only may avoid distortions from large, low-level networks with low traffic. A combination involving a full network calculation and separate calculations for all roads under the same management institution may be another option.

The recurrent maintenance requirements for roads in poor and very poor condition can be debated. In order to better reflect the situation in most Sub-Saharan countries, the recommended approach for calibrating the model has been that lower unit costs should be applied for that part of the network. Roads in poor and very poor condition are regarded as un-maintainable and should only receive allocations that can maintain a reasonable level of accessibility. The unit costs default values of the model allocate 50 percent of the recurrent unit costs for roads in fair condition to those in good and fair condition. The unit costs used by the pilot countries do not reflect that relationship, but in the example evaluations for main roads only in the next section, this relationship has been maintained.

3. Evaluation of Main Roads in Ghana, Mozambique, Tanzania, and Uganda

Section 2 presented the combined results of the country reports from Ghana, Mozambique, Tanzania, and Uganda. As the type of networks used in these evaluations were quite different, this section provides customized RONET Version 1.0 results of the evaluation of main roads only. The main roads networks are more comparable in size and utilization.

The basic characteristics of the four countries can be found in Section 2.

The networks analyzed in this study:

(i) the main roads in Ghana represent 11,177 kilometers of primary and secondary roads managed by the Ghana Highways Authority that carry 51 percent of the total network vehicle-km;

(ii) the main roads in Mozambique represent 9,808 kilometers of primary and secondary roads managed by the National Roads Administration (ANE) that carry 83 percent of the total network vehicle-km;

(iii) the main roads in Tanzania represent 28,999 kilometers of trunk and regional roads managed by TANROADS that carry 83 percent of the total network vehicle-km; and

(iv) the main roads in Uganda represent 10,820 kilometers of national roads to be managed by UNRA that carry 91 percent of the total network vehicle-km.

The tables below present the roads network lengths (kilometers) and utilization (million vehicle-km), information about how the main roads relate to the networks analyzed in the country summaries of Section 3, and the country reports in Section 6. Urban roads are excluded in the evaluations of this section, and this has a particular effect on the evaluations as almost half of the population in Ghana lives in urban areas. However, the main road networks are quite comparable, and we can see that overall network utilization is much the same in all the four countries.

Network Length (km) excluding Urban roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Main Roads (km)	**11,177**	**9,808**	**28,999**	**10,820**
Other Roads (km)	40,862	19,431	50,000	61,751
Total Network (km)	52,039	29,239	78,999	72,571
Main Roads (km)	**21 %**	**34 %**	**37 %**	**15 %**
Other Roads (km)	79 %	66 %	63 %	85 %
Total Network (km)	100 %	100 %	100 %	100 %

Network Utilization (Million vehicle-km) excluding Urban roads				
	Ghana	Mozambique	Tanzania	Uganda
Main Roads (M veh-km)	10,738	**2,229**	**5,876**	**4,344**
Other Roads (M veh-km)	10,322	444	1,187	436
Total Network (M veh-km)	21,060	2,673	7,063	4,780
Main Roads (M veh-km)	**51%**	**83%**	**83%**	**91%**
Other Roads (M veh-km)	49%	17 %	17 %	9 %
Total Network (M veh-km)	100%	100%	100%	100%

The tables below present the details of the main roads network length per network type and corresponding surface types. Whereas Ghana, Mozambique, and Tanzania have about the same length of their main roads paved, they constitute different portions of the main roads. Uganda has substantially fewer paved roads compared with the other three countries.

Ghana Network Length by Type and Surface Type (km)-Main Roads							
	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Primary	38	954	1,212	1,360	0	3,564	32
Secondary	0	179	2,978	4,456	0	7,613	68
Total	38	1,133	4,190	5,816	0	11,177	100
Percent	0	10	37	52	0	100	

Mozambique Network Length by Type and Surface Type (km)-Main Roads							
	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Primary	0	390	3,970	549	0	4,909	50
Secondary	0	0	880	2,604	1,416	4,900	50
Total	0	390	4,850	3,153	1,416	9,808	100
Percentage	0	4	49	32	14	100	

Tanzania Network Length by Network Type and Surface Type (km)-Main Roads							
	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	1,934	2,783	4,145	865	9,728	34
Regional	0	59	407	13,153	5,652	19,271	66
Total	0	1,994	3,190	17,298	6,517	28,999	100
Percentage	0	7	11	60	22	100	

Uganda Network Length by Type and Surface Type (km)-Main Roads							
	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
National Roads	0	89	2,588	8,143	0	10,820	100
Total	0	89	2,588	8,143	0	10,820	100
Percentage	0	1	24	75	0	100	

The tables below present the main roads network length per surface type and condition. The overall condition is pretty good in all the three countries, with only 18-26 percent in poor and very poor condition.

Ghana Network Length by Surface Type and Road Condition (km)-Main Roads							
	Very Good	Good	Fair	Poor	Very Poor	Total	Percent
Concrete	0	38	0	0	0	38	0
Asphalt	60	715	349	9	0	1,133	10
S.T.	0	2,652	1,295	243	0	4,190	37
Gravel	0	1,278	1,861	2,677	0	5,816	52
Earth	0	0	0	0	0	0	0
Total	60	4,683	3,505	2,929	0	11,177	100
Percentage	1	42	31	26	0	100	

Mozambique Network Length by Surface Type and Road Condition (km)-Main Roads							
	Very Good	Good	Fair	Poor	Very Poor	Total	Percent
Concrete	0	0	0	0	0	0	0
Asphalt	234	29	28	86	13	390	4
S.T.	1,077	1,444	1,774	439	116	4,850	49
Gravel	123	1,022	1,387	454	167	3,153	32
Earth	0	221	830	177	188	1,416	14
Total	1,433	2,716	4,019	1,156	484	9,808	100
Percentage	15	28	41	12	5	100	

Tanzania Network Length by Surface Type and Road Condition (km)-Main Roads							
	Very Good	Good	Fair	Poor	Very Poor	Total	Percent
Concrete	0	0	0	0	0	0	0
Asphalt	1,003	622	286	73	10	1,994	7
S.T.	46	1,351	1,547	203	43	3,190	11
Gravel	945	4,319	8,787	2,606	642	17,298	60
Earth	331	883	2,506	1,688	1,110	6,517	22
Total	2,324	7,175	13,126	4,570	1,805	28,999	100
Percentage	8	25	45	16	6	100	

Uganda Network Length by Surface Type and Road Condition (km)-Main Roads							
	Very Good	Good	Fair	Poor	Very Poor	Total	Percent
Concrete	0	0	0	0	0	0	0
Asphalt	0	16	55	18	0	89	1
S.T.	198	447	1,642	109	191	2,588	24
Gravel	459	1,070	4,991	649	974	8,143	75
Earth	0	0	0	0	0	0	0
Total	657	1,533	6,688	777	1,165	10,820	100
Percentage	6	14	62	7	11	100	

The summary table below shows the kilometers and percentages of the respective class that are in good and fair condition, and overall between 74 percent and 83 percent of all the main roads in the four countries fall in that category.

Main Roads in Good and Fair Condition by Network Type				
	Ghana	Mozambique	Tanzania	Uganda
Primary/Trunk	2,921	4,319	8,392	8,878
Secondary/Regional/District (Ug)	5,327	3,850	14,233	0
Total km in Good and Fair Condition	8,248	8,169	22,625	8,878
Total Length of Analyzed Network	11,177	9,808	28,999	10,820
% in Good and Fair of Analyzed Class				
Primary/Trunk	82	88	86	82
Secondary/Regional/District (Ug)	70	79	74	0
Overall in Good and Fair Condition	74	83	78	82

The table below shows that most of the traffic on main roads takes place on paved roads, with as much as 94 percent in Mozambique.

Network Utilization on Paved versus Unpaved Roads (Million vehicle-km)-Main Roads				
	Ghana	Mozambique	Tanzania	Uganda
On Paved	8,117	2,098	4,317	3,559
On Unpaved	2,622	131	1,560	785
Total Traffic (Million vehicle-km)	10,738	2,229	5,876	4,344
Percentage on Paved	76	94	73	82
Percentage on Unpaved	24	6	27	18
Total	100	100	100	100

The average capital road works unit costs used for this main roads calculation are the same as those used in the country reports in Section 6 and the summaries of Section 3, but are still included below as they will impact on many of the calculations and country comparisons. The table below only

shows some of the typical unit costs for the respective types of roads while full unit cost matrices for each country are presented in Annex 1 (Consolidated Data from all Four Countries).

Capital Road Works Unit Costs (US$/km)					
Surface Type	**Road Work**	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Asphalt Mix	Preventive Treatment	2,500	9,500	5,000	12,500
Primary Roads	Resurfacing (Overlay)	110,000	71,500	60,000	45,000
	Strengthening (Overlay)	170,000	250,000	100,000	130,000
	Reconstruction	250,000	400,000	300,000	350,000
	New Construction	400,000	650,000	350,000	600,000
Surface Treatment	Preventive Treatment	1,800	3,510	2,000	10,000
Primary Roads	Resurfacing (Reseal)	25,000	32,500	27,000	25,000
	Strengthening (Overlay)	60,000	107,310	80,000	75,000
	Reconstruction	160,000	300,000	254,000	250,000
	New Construction	220,000	450,000	304,000	400,000
Gravel	Spot Regraveling	900	2,400	2,708	5,000
Secondary Roads	Regraveling	12,000	45,000	8,462	10,000
	Partial Reconstruction	18,000	55,000	11,846	25,000
	Full Reconstruction	28,000	70,000	21,154	40,000
	New Construction	32,000	90,000	47,385	60,000
Earth	Spot Repairs	500	125	104	125
Tertiary Roads	Heavy Grading	600	250	426	250
	Partial Reconstruction	750	350	5,192	625
	Full Reconstruction	950	350	10,385	1,125
	New Construction	1,000	350	27,692	1,500

As previously mentioned, the capital works unit costs for Ghana are relatively low compared with the other countries, and some of Mozambique's essential capital unit costs for gravel roads are 3 times as high as the ones of Ghana, This will impact on calculations like funding needs and asset values, and has to be kept in mind when comparing the country results.

The table below presents the average recurrent road works unit costs for a two-lane road, in US$/km/year, for primary paved roads, secondary gravel roads, and tertiary earth roads with different road conditions. The unit costs in this table are the same as the ones previously shown and used, except that recurrent maintenance unit costs for roads in poor and very poor condition are uniformly set at 50 percent of the corresponding unit costs for roads in Fair condition.

Unit costs for maintenance are also generally lower in Ghana, which compared with the other countries will result in lower budget needs for keeping the network up to standard.

Recurrent Road Works Unit Costs (US$/km/year)					
Surface Type	**Road Condition**	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Asphalt Mix	Very Good	900	1,100	1,000	1,875
Primary Roads	Good	1,200	1,200	1,250	1,875
	Fair	1,500	1,300	1,500	2,500
	Poor	750	650	750	1,250
	Very Poor	750	650	750	1,250
Surface Treatment	Very Good	600	1,000	1,000	1,500
Primary Roads	Good	900	1,200	1,250	1,500
	Fair	1,200	1,300	1,500	2,000
	Poor	600	650	750	1,000
	Very Poor	600	650	750	1,000
Gravel	Very Good	375	1,200	413	1,125
Secondary Roads	Good	470	1,200	506	1,125
	Fair	580	1,200	600	1,500
	Poor	290	600	300	750
	Very Poor	290	600	300	750
Earth	Very Good	40	100	125	50
Tertiary Roads	Good	60	100	157	50
	Fair	80	125	188	50
	Poor	40	63	94	25
	Very Poor	40	63	94	25

The table below presents the current monitoring indicators of the main road networks, but provides more indicators related to network density than the table dealing with all roads presented in Section 3. The results below are more uniform than those of that section, but the fact that Tanzania has about three times as many main roads may still be kept in mind when comparing some of the results. The length of main roads in Mozambique is about a third of the ones in Tanzania, but has the same asset value. Roads in Mozambique have about twice the value of roads in Ghana per kilometer. These differences are mainly due to the differences in major capital unit costs.

Network Monitoring Indicators (Main Road Networks)				
Monitoring Indicator	**Ghana**	**Mozambique**	**Tanzania**	**Uganda**
Network Length				
Road network length (km)	**11,177**	**9,808**	**28,999**	**10,820**
Road network length that is unpaved (km)	5,816	4,569	23,816	8,143
Road network length that is paved (km)	5,361	5,239	5,184	2,677
Road network length that is paved (percent)	48.0	53.4	17.9	24.7
Network Density				
Road network per thousand land area (km/1000 sq km)	46.86	12.56	32.92	54.90
Road network per thousand total population (km/1000 persons)	0.52	0.49	0.81	0.39
Road network per thousand rural population (km/1000 persons)	0.93	0.61	1.01	0.48
Road network per thousand vehicles (km/1000 vehicles)	17.11	52.27	47.70	38.84
Road network per $ million GDP (km/million $)	1.06	1.33	2.72	1.27
Paved road network per thousand land area (km/1000 sq km)	24.38	5.85	27.03	41.31
Paved road network per thousand total population (km/1000 persons)	0.27	0.23	0.66	0.29
Paved road network per thousand rural population (km/1000 persons)	0.48	0.29	0.83	0.36
Paved road network per thousand vehicles (km/1000 vehicles)	8.90	24.35	39.17	29.23
Paved road network per $ million GDP (km/million $)	0.55	0.62	2.23	0.96
Network Condition				
Percentage of road network in good and fair condition (percent)	73.8	83.3	78.0	82.1
Percentage of paved road network in good and fair condition	95.3	87.5	93.7	88.1
Percentage of paved road network with roughness 4 m/km IRI or less	64.6	53.1	58.3	24.7
Paved roads average roughness weighted by km (IRI, m/km)	4.47	4.91	4.30	5.73
Paved roads average roughness weighted by vehicle-km (IRI, m/km)	4.04	4.63	3.67	5.67
Percentage of unpaved roads that are all-weather roads	54.0	59.5	63.1	80.1
Network Standards				
Percentage of unpaved roads with 30 AADT or less	1.2	19.2	20.7	2.6
Percentage of unpaved roads with 300 AADT or more	31.2	2.2	10.2	29.5
Percentage of paved roads with 300 AADT or less	0.0	40.2	12.3	13.9
Percentage of paved roads with 10,000 AADT or more	13.9	0.2	2.5	8.2
Network Utilization				
Annual motorized vehicle utilization (million vehicle-km)	10,738	2,229	5,876	4,344
Annual freight carried over road network (million ton-km)	32,164	6,844	19,857	18,777
Annual passengers carried over road network (million pass-km)	73,140	15,484	45,032	25,226
Average network annual average daily traffic (vehicles/day)	2,632	623	555	1,100
Network Asset				
Current road asset value (million $)	1,390.4	2,423.0	2,463.9	1,360.2
Current road asset value as a share of maximum road asset value (%)	90.3	90.2	90.4	86.2
Current road asset value as a share of GDP (%)	13.2	32.9	23.1	16.0

RONET computes the network performance under different road work standards over a 20 year evaluation period. The table below presents the current average network roughness (IRI) weighed per kilometer or per vehicle-km for each road work standard and the current average roughness in year 10.

Network Average Roughness Weighted by Km in Year 10 (IRI)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	4.6	4.6	5.1	4.6
High Standard	5.7	5.5	6.7	6.1
Medium Standard	7.8	7.6	10.2	9.1
Low Standard	10.5	10.0	14.3	12.9
Very Low Standard	13.4	13.0	18.0	16.8
Do Minimum	14.6	14.4	19.7	18.4
Current network roughness (IRI):	8.6	8.1	10.6	10.2

Network Average Roughness Weighted by Vehicle-Km in Year 10 (IRI)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	3.3	4.2	3.5	3.7
High Standard	3.7	4.4	4.2	4.0
Medium Standard	4.1	4.7	5.5	4.5
Low Standard	4.6	5.0	6.9	6.6
Very Low Standard	6.4	6.7	9.3	9.3
Do Minimum	6.6	7.3	9.9	9.9
Current network roughness (IRI):	4.4	5.0	5.7	6.7

The table shows that in general the Medium to Low Standard will keep the average roughness weighted by kilometer in year 10 at the same level as the current network roughness. The Medium and higher standards will improve the network condition over time. Weighted per vehicle-kilometer even the Low standard will be able to maintain the current roughness.

The table below presents the network current condition and the condition in year 10 for the Medium Standard, for which standard most of the roads will be in fair condition.

Network Condition for Medium Standard in Year 10-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Current Condition				
Very Good	1%	15%	8%	6%
Good	42%	28%	25%	14%
Fair	31%	41%	45%	62%
Poor	26%	12%	16%	7%
Very Poor	0%	5%	6%	11%
Condition in Year 10				
Very Good	12%	18%	5%	16%
Good	11%	7%	7%	1%
Fair	77%	69%	84%	83%
Poor	0%	5%	3%	0%
Very Poor	0%	0%	0%	0%

RONET estimates the annualized rehabilitation, periodic maintenance, and recurrent maintenance requirements for the series of road works standards. The table below presents: the annualized rehabilitation and maintenance requirements over a 20 year evaluation period, in millions of U.S. dollars per year; (ii) the annualized requirements as a percent of GDP, in percent; (iii) the annualized requirements per kilometer of the network, in U.S. dollars per year per kilometer; and (iv) the annualized requirements per network utilization, in U.S. dollars per year per vehicle-km.

Annual Rehabilitation and Maintenance Requirements (M US$ per Year)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	71.6	85.1	98.9	62.1
High Standard	58.4	75.8	86.4	54.9
Medium Standard	51.0	69.2	73.9	48.7
Low Standard	40.4	56.7	57.5	32.7
Very Low Standard	14.7	48.9	38.3	31.2
Do Minimum	8.9	39.2	22.0	14.1

Annual Rehabilitation and Maintenance Requirements (M US$ per Year as Percent of GDP)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	0.68%	1.16%	0.93%	0.73%
High Standard	0.55%	1.03%	0.81%	0.65%
Medium Standard	0.48%	0.94%	0.69%	0.57%
Low Standard	0.38%	0.77%	0.54%	0.39%
Very Low Standard	0.14%	0.66%	0.36%	0.37%
Do Minimum	0.08%	0.53%	0.21%	0.17%

Annual Rehabilitation and Maintenance Requirements (US$ per Year per Km)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	6,409	8,680	3,409	5,735
High Standard	5,228	7,729	2,980	5,074
Medium Standard	4,562	7,052	2,549	4,498
Low Standard	3,616	5,776	1,983	3,025
Very Low Standard	1,311	4,984	1,321	2,879
Do Minimum	794	4,000	758	1,299

Annual Rehabilitation and Maintenance Requirements (US$ per Year per Vehicle-Km)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	0.007	0.038	0.017	0.014
High Standard	0.005	0.034	0.015	0.013
Medium Standard	0.005	0.031	0.013	0.011
Low Standard	0.004	0.025	0.010	0.008
Very Low Standard	0.001	0.022	0.007	0.007
Do Minimum	0.001	0.018	0.004	0.003

The table shows that considering the average of the four countries and the Medium Standard: (i) the annual rehabilitation and maintenance requirements as a percent of GDP is 0.67 percent; (ii) the annual rehabilitation and maintenance requirements per kilometer of the network is US$4,665 per kilometer per year; and (iii) the annual rehabilitation and maintenance requirements per vehicle-km is US$0.015 per vehicle-km per year. Main roads in Ghana represent the lowest burden to the GDP and per vehicle-km compared with the other countries.

The table below presents the annualized rehabilitation and maintenance requirements in years 1 to 5, 6 to 20, and 1 to 20, in millions of dollars per year. The requirements for Medium and higher standards are higher during the first five years due to the need for rehabilitation to satisfy the chosen standard.

Annual Rehabilitation and Maintenance Requirements (M US$ per Year)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Years 1-5				
Very High Standard	99.3	121.3	131.1	103.4
High Standard	78.7	103.2	116.3	89.6
Medium Standard	52.8	65.4	80.4	59.8
Low Standard	23.3	65.6	65.6	46.2
Very Low Standard	12.2	38.7	36.6	29.1
Do Minimum	0.6	7.1	3.9	10.8
Years 6-20				
Very High Standard	62.4	73.1	88.1	48.3
High Standard	51.7	66.7	76.5	43.3
Medium Standard	50.4	70.4	71.8	45.0
Low Standard	46.1	53.7	54.8	28.3
Very Low Standard	15.5	52.3	38.9	31.9
Do Minimum	11.6	50.0	28.0	15.1
Years 1-20				
Very High Standard	71.6	85.1	98.9	62.1
High Standard	58.4	75.8	86.4	54.9
Medium Standard	51.0	69.2	73.9	48.7
Low Standard	40.4	56.7	57.5	32.7
Very Low Standard	14.7	48.9	38.3	31.2
Do Minimum	8.9	39.2	22.0	14.1

The table below presents the annualized rehabilitation and maintenance requirements in years 1 to 5, 6 to 20, and 1 to 20, as percent of GDP.

Annual Rehabilitation and Maintenance Requirements as Percent of GDP (%)				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Years 1-5				
Very High Standard	0.94	1.65	1.23	1.22%
High Standard	0.74	1.40	1.09	1.05%
Medium Standard	0.50	0.89	0.75	0.70%
Low Standard	0.22	0.89	0.61	0.54%
Very Low Standard	0.12	0.53	0.34%	0.34%
Do Minimum	0.01	0.10	0.04%	0.13%
Years 6-20				
Very High Standard	0.59	0.99	0.83%	0.57%
High Standard	0.49	0.91	0.72%	0.51%
Medium Standard	0.48	0.96	0.67%	0.53%
Low Standard	0.44	0.73	0.51%	0.33%
Very Low Standard	0.15	0.71	0.36%	0.37%
Do Minimum	0.11	0.68	0.26%	0.18%
Years 1-20				
Very High Standard	0.68	1.16	0.93%	0.73%
High Standard	0.55	1.03	0.81%	0.65%
Medium Standard	0.48	0.94	0.69%	0.57%
Low Standard	0.38	0.77	0.54%	0.39%
Very Low Standard	0.14	0.66	0.36%	0.37%
Do Minimum	0.08	0.53	0.21%	0.17%

The table below presents for the Medium Standard the distribution of the annualized road works requirements between rehabilitation, periodic maintenance, and recurrent maintenance. The Medium Standard appears in general to be the minimum desired budget to maintain the value of the assets, keep the roads in fair condition, and not increase roughness. The requirements for Medium and higher standards are higher during the first five years due to the need for rehabilitation to satisfy the chosen standard.

On average, rehabilitation works represent 35 percent of the expenditures, periodic maintenance works 47 percent, and recurrent maintenance works 18 percent. These calculated needs are rather small for the maintenance part of the interventions and particularly for recurrent maintenance, which for two of the countries stand only for 11 percent of total interventions.

Annual Road Works Requirements for Medium Standard (M US$ per Year) Year 1-20-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Rehabilitation (M US$ per Year)	16.5	33.5	20.0	16.5
Periodic Maintenance (M US$ per Year)	29.4	28.3	39.6	16.7
Recurrent Maintenance (M US$ per Year)	5.1	7.3	14.3	15.4
Total (M US$ per Year)	51.0	69.2	73.9	48.7
Rehabilitation (%)	32%	48%	27%	34%
Periodic Maintenance (%)	58%	41%	54%	34%
Recurrent Maintenance (%)	10%	11%	19%	32%
Total (%)	100%	100%	100%	100%

RONET computes for each road works standard the annual road user costs and the total society costs (road agency and road user costs). The table below presents: (i) the total society costs over the 20 year evaluation period, in millions of U.S. dollars; (ii) the annual society costs over the 20 year evaluation period as percent of GDP; (iii) the unit user costs increase per agency deficit of each standard compared to the Very High Standard, in U.S. dollars per U.S. dollars; and (iv) the marginal unit user costs increase per agency deficit of each standard compared with the previous more expensive standard.

Total Society Costs over 20 Year Evaluation Period (M US$)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	85,823	20,573	48,891	46,361
High Standard	86,590	20,627	50,059	47,248
Medium Standard	88,510	20,957	53,248	49,807
Low Standard	91,167	21,284	57,839	53,508
Very Low Standard	99,276	22,750	64,010	60,948
Do Minimum	100,105	23,077	65,722	62,347

Annual Society Costs over 20 Year Evaluation Period as percent of GDP (%)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	41%	14%	23%	27%
High Standard	41%	14%	23%	28%
Medium Standard	42%	14%	25%	29%
Low Standard	43%	14%	27%	31%
Very Low Standard	47%	15%	30%	36%
Do Minimum	47%	16%	31%	37%

User Costs Increase per Agency Deficit Compared to Very High Standard (US$ per US$)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	0.0	0.0	0.0	0.0
High Standard	3.9	1.3	5.7	7.2
Medium Standard	7.5	2.2	9.7	13.9
Low Standard	9.6	2.2	11.8	13.2
Very Low Standard	12.8	4.0	13.5	24.6
Do Minimum	12.4	3.7	11.9	17.7

Marginal User Costs Increase per Agency Deficit (US$ per US$)-Main Roads				
	Ghana	**Mozambique**	**Tanzania**	**Uganda**
Very High Standard	0.0	0.0	0.0	0.0
High Standard	3.9	1.3	5.7	7.2
Medium Standard	13.9	3.5	13.7	21.5
Low Standard	13.6	2.3	15.0	12.6
Very Low Standard	16.7	10.4	17.1	236.5
Do Minimum	8.2	2.7	6.2	5.1

The results show how road user and society costs strongly increase with lower standards and, over time, worsening road conditions.

The table below presents the average results of the country-specific indicators presented on the foregoing pages.

Average Results for the Four Countries-Main Roads	
Network Density	
Road network per thousand land area (km/1000 sq km)	36.81
Road network per thousand total population (km/1000 persons)	0.55
Road network per thousand rural population (km/1000 persons)	0.76
Road network per thousand vehicles (km/1000 vehicles)	38.98
Road network per $ million GDP (km/million $)	1.59
Paved road network per thousand land area (km/1000 sq km)	24.65
Paved road network per thousand total population (km/1000 persons)	0.36
Paved road network per thousand rural population (km/1000 persons)	0.49
Paved road network per thousand vehicles (km/1000 vehicles)	25.41
Paved road network per $ million GDP (km/million $)	1.09
Network Asset	
Current road asset value per kilometer (million $/km)	0.15
Current road asset value as a share of maximum road asset value (%)	89
Current road asset value as a share of GPD (%)	21
Medium Standard Rehabilitation and Maintenance Requirements	
Annual rehabilitation and maintenance requirements as share of GDP (%)	0.67
Annual rehabilitation and maintenance requirements (US$ per Year per Km)	4,665
Annual rehabilitation and maintenance requirements (US$ per Year per Vehicle-Km)	0.015
Rehabilitation expenditures as a share of total expenditures (%)	35
Periodic Maintenance expenditures as a share of total expenditures (%)	47
Routine Maintenance expenditures as a share of total expenditures (%)	18

4. Conclusions and Recommendations

The absence of simple operational road management systems to articulate the consequences of road-funding trends to politicians and financiers in a robust manner has often failed agencies and Ministries in winning their argument for more funding, or even for justifying the adequacy/inadequacy of currently available resources. Complex models, though more accurate than simpler models, have tended to alienate decision makers because of the complexity of their outputs.

Even though the RONET software is still in its development stage, the model is useful for strategic planning and for monitoring of the performance of the network, and it enables rapid assessments of the effects of government funding decisions. The software is able to provide insights into

- the funding required for rehabilitation, periodic maintenance, and routine maintenance over specific time periods,
- the consequences of any investment to the road agencies and road users,
- the implications of different levels of interventions on the road conditions and resulting asset value, and
- the funding allocation to various road management agencies.

The four pilot countries that participated in the development and testing of the model have found the tool very useful for strategic purposes. This macro-model fills a gap within the family of models, and is fairly easy to calibrate and make operational.

RONET makes possible a large number of calculations and enables many analyses, but it does so with the limitations of a simple macro model. As for any model, the quality of the results will depend on the quality of the input data.

For RONET, it is important to consider well the road works unit costs, for capital as well as maintenance works. Robust, average unit costs for different interventions may be tedious to establish, but it is worthwhile spending time with people who are familiar with construction and maintenance costs in order to ensure that values are representative for the country. Otherwise, their sheer size can inordinately bias the country's overall budget requirements and the road asset valuation.

There is often a particular lack of historical unit costs for tertiary roads, and the lower level networks are at the same time often large in kilometers. Considering the fact that many of them merely are tracks, the unit costs applied should be realistic to reflect the real value and needs of these roads. The unit costs chosen may easily distort the overall calculations of road asset values and maintenance requirements if they are not representative and fairly consistent. The model does have built-in default

values, but it is advisable to calibrate some of them to domestic conditions as described in the user's manual.

Another important calibration involves defining which traffic band different portions of the network classes belong to. Most countries will have fairly good traffic data for the national network, while that knowledge is often more scarce for the lower levels of the network. However, for a typical SSA country, that would not represent a major problem for the network utilization due to the typically low levels of traffic at that part of the network. As mentioned above, Ghana is an exception with its particular high level of urban traffic.

At the national level, access to current and historical data is better, and calculations related to that network will be much more accurate than for the rest of the network. Separate calculations among the main roads, other roads, and eventually urban roads are worthwhile when considering, better identifying, and managing these uncertainties. A combination of a full network calculation and separate calculations for all roads under the same management institution would be another option.

No country has reported any particular problems in calibrating the model except for obtaining subnational traffic level data. However, some shortcomings and planning challenges have been raised, such as:

- The planning problem related to seasonal disruptions in accessibility, mainly for the network in poor and very poor condition. In some countries that network may be the bulk of the network, and all-weather accessibility represents substantial administrative and political challenges that may benefit from tools that could assist with such considerations.
- The difficulties with average roughness values and how the model may better reflect the large step in acceptable roughness levels for paved and unpaved roads.
- How the model eventually could include planned or committed interventions such as upgrading to a higher standard.

The model will be available for any interested user or country, and any experience and suggestions for improvements are welcomed. Future corrections and upgrades will depend on that kind of feedback.

Future enhancement of RONET may involve adding new modules for road user charges evaluation, life-cycle economic evaluation, axle loading impacts evaluation, and network improvements evaluation. The possibilities of linking RONET with identifiable social impacts due to transport interventions, like the Danida-supported efforts to establish a Social Accounting Matrix (SAM) in Ghana, would be a particularly interesting path to explore further.

The RONET as a model has interestingly enough also triggered some interest outside the transport sector, specifically for management of educational infrastructure such as schools. The model may be customized to deal with current characteristics and future forecasts for any kind of infrastructure management described by investments, utilization, deterioration, maintenance, condition, and value of assets at the macro level.

5. Country Case Studies

In order to test and get experience with practical application of the RONET model, the four pilot countries, **Ghana, Mozambique, Tanzania, and Uganda,** have each undertaken independent testing and case studies.

The case studies have included country-specific data collection, unit costs, and calibration to domestic conditions as recommended in the user guide. How the four countries have undertaken those tasks, and their key findings and experiences with this first version of the model, are presented in this section.

Readers of this report should be aware that these country case studies are stand-alone reports used in the respective countries, and that they, to some extent, will repeat some general information about the model, its background, and so forth.

Ghana

Godwin Brocke

Ministry of Transportation

Ghana Case Study

BACKGROUND

In 2003, the Road Management Initiative (RMI) thematic area of the Sub-Saharan Africa Transport Policy Program (SSATP) developed the Performance Assessment Model (PAM) for discussion and guidance in the assessment of the maintenance requirements of road networks. Due to varying schools of thought on the results of the model, the World Bank referred the model to a peer review mechanism within the bank.

In September 2006, the World Bank started the process to further improve on the initial concept of the PAM and expand its capabilities for use in the field. The effort of this new initiative has culminated in the current version of Road Network Evaluation Tools (RONET). This project has been involved in the development of RONET with other SSATP member countries. RONET is still under development and further work will be undertaken during 2007 before being made available to the SSATP group.

DATA COLLECTION

Basic Configuration

The basic configuration provides information relating to the general administrative, road network classification, environmental, and geographical conditions and the traffic categorization specific to the country. RONET has provided default values to reflect conditions in Africa.

Specific data relating to Ghana has been provided where there are deviations from the default values. The country-specific data have been highlighted below.

Management and Network Type

The main agencies responsible for the administration and management of the classified network are the Ghana Highway Authority, Department of Feeder Roads, and the Department of Urban Roads. Other agencies in the local government and agriculture sectors have also been involved in the development of the road network; however, the maintenance of the network remains with the road agencies.

The Ghana Highway Authority has responsibility for the primary and secondary road network, defined as trunk or national roads and regional and inter-regional roads respectively.

The Department of Feeder Roads has responsibility for the tertiary roads defined as; inter- and intra-district roads. The un-engineered roads are tracks and lower level roads within the districts. The Department of Feeder Roads is a decentralized unit within the local government administrative structure and maintains responsibility for the un-engineered roads.

The Department of Urban Roads has responsibility of all roads within the metropolitan and municipal local government jurisdictions except the national and regional roads which traverse these areas.

Network Types			
Network Type	Terrain Type (1 to 3)	Environment Type (1 to 23)	Management Type
Primary	2	12	Highway Authority
Secondary	2	12	Highway Authority
Tertiary	2	12	Feeder Roads
Un-Eng.	2	12	Feeder Roads
Urban	2	12	Urban Roads

Terrain and Environment Type

Data from the recent calibration work on the HDM-4 in Ghana shows that the representative terrain type is hilly and the environment type is sub–humid, sub–tropical, and hot.

Road Condition Classes

The road condition classes in Ghana are limited to good, fair, and poor. All data collected on the network are therefore in these categories.

For the purposes of the RONET, the condition of asphaltic concrete roads constructed within the last two years will be described as ‘very good’. Similarly, earth roads under the feeder roads administration which are described as un-engineered will be described as ‘very poor’ as these relate to tracks.

The default values for roughness, ‘last periodic maintenance,’ and ‘transitability’ are maintained.

Traffic Level and Classes

The default values for the traffic level are considered reasonable for the Ghana condition and are maintained.

Traffic Classes

Data from the HDM-4 calibration indicates that the default values are comparable and are therefore maintained.

Standard Configuration

This configuration relates to the parameters for defining capital road works interventions. These are defined by the level of roughness and the time intervals for interventions.

The roughness levels and the appropriate capital work interventions proposed in the default values for concrete/asphalt and surface-dressed roads are acceptable.

Gravel Roads

The average roughness levels relating to periods of deferred maintenance are considered reasonable and are comparable to the data obtained during the HDM-4 calibration.

Gravel Characteristics

Gravel in Ghana in mainly lateritic and the default characteristics values are representative of the materials found in Ghana.

Earth Roads

The average roughness levels relating to periods of deferred maintenance are considered reasonable and are comparable to the data obtained during the HDM-4 calibration.

Custom Standard Configuration

Custom standard configuration is set to reflect the desirable level of performance of the network. The various network types are therefore set to perform at specific levels to give an overall performance at the desirable level.

Custom Standard Definition			
		Select a Standard per Network Type	
Code	Network Type	Standard Name	Standard No.
R	Primary	High Standard	2
S	Secondary	High Standard	2
T	Tertiary	High Standard	2
U	Un-Eng.	Very Low Standard	5
V	Urban	High Standard	2

The Ministry of Transportation has set a policy of achieving a network condition of 70 percent good, 20 percent fair, and not more than 10 percent poor by 2010. The performance levels shown below have been set to achieve this policy objective as best as possible.

Country Data

These are country-specific data and have been provided from country statistics from the Ghana Statistical Service, road agencies cost data, and traffic statistics. Data from the recent calibration of the HDM-4 have also been utilized.

Basic Characteristics

Ghana in 2005	
Land area (sq km)	238,500
Total population (million persons)	21.343
Rural population (million persons)	11.99
GDP ($ Billion)	10.570
Total vehicle fleet (vehicles)	653,309
Discount Rate (%)	12
Traffic Growth Rate (%)	5

Capital Road Works Unit Costs

The data for capital costs have been compiled from data provided by road agencies and compiled by the Road Cost Knowledge System (ROCKS) in Ghana. The details are provided in Annex A1.

Recurrent Maintenance Unit Costs

The recurrent maintenance costs have been compiled directly from the road agencies data. These are provided in Annex A2.

Traffic Level Characteristics

These have been obtained from the Ghana Highway Authority traffic statistics from 2003-2005. There is no available data for the feeder roads network. The data is summarized in the table in Annex A3.

Vehicle Fleet Unit Road User Cost Relation to Roughness

The RUCKS has been used to calculate the VOC coefficients. The basic data is from the HDM-4 calibration. The data is provided in Annex A3.

Road Network Length

The data has been obtained from the annual road network condition survey conducted by the road agencies in Ghana. The feeder roads condition survey is supplemented by the proxy relationship of speed to the road condition. A total road network of 57,613 kilometers has been recorded.

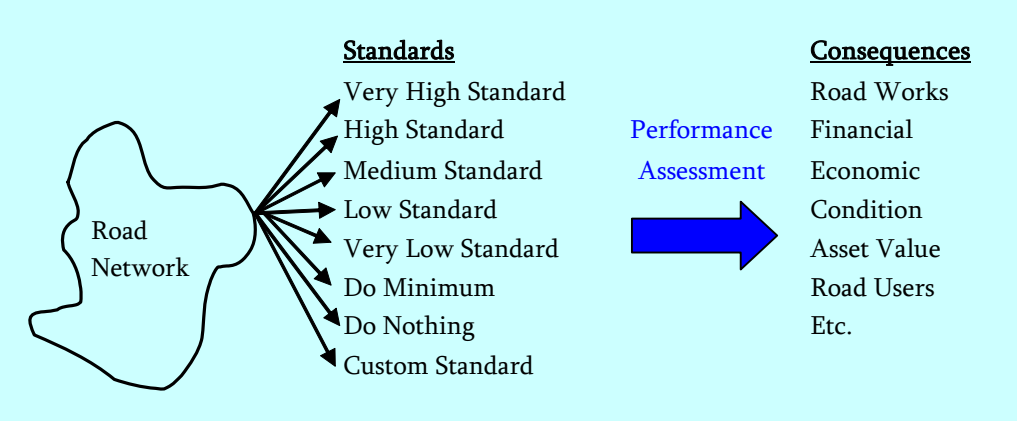
EVALUATION

Definitions

Performance Assessments

The analysis evaluates the consequences of eight different road works standards. The standards are defined by the different levels of expenditure over time. The consequences are reflected in the road works requirements, financial cost, road condition, asset value, etc. The defined standard is applied to all road networks.

The figure below illustrates the process.



The Very High Standard represents a without-budget-constraints scenario with an optimal level of periodic maintenance and rehabilitation works.

- The High, Medium, Low and Very Low standards represent scenarios of increasing reduction on the level of road works expenditures.
- The Do Minimum Standard represents a scenario where reconstruction is applied at a very high roughness.
- The Do Nothing Standard represents a scenario were no capital road works are applied over the evaluation period.
- The Custom Standard is the application of the various standards (Very High, High, Medium, Low, Very Low, Do Minimum, or Do Nothing) to each road network. The various scenarios have been chosen to reflect the Ministry of Transportation policy

of achieving a road condition of 70 percent good, 20 percent fair, and no more than 10 percent poor.

Network and Management Types

These have been defined under Performance Assessments.

Transitability

The level of 2 is adopted for roads that are deemed to be impassable during the rainy season.

Assumptions

The following assumptions have been made for the analysis.

- The vehicle population used excludes motorcycles, combine harvesters, and other off-road equipment. The official vehicle population does not take into account vehicles which have been scrapped and are no longer in circulation. It also does not include vehicles used by the security organizations. It has been assumed that the two categories offset each other. The value used in this analysis is therefore the cumulative value provided by the Driver Vehicle and Licensing Authority of Ghana.

- The traffic growth rate adopted for all the network types is 5 percent. This is the average traffic growth rate of the trunk, feeders, and urban roads network. The respective values were obtained from the HDM-4 calibration.

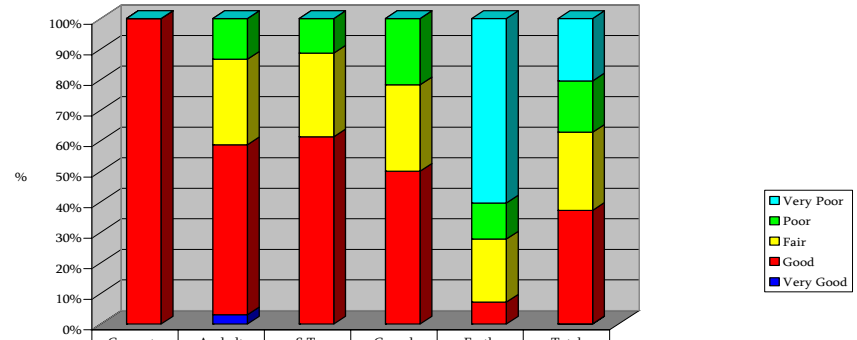
RESULTS

Network Length and Utilization

Figures 1 and 2 provide a summary of the network condition used for the analysis. There are a number of significant observations. These are the following:

- Close to 84 percent of the road network is unpaved.
- About 49 percent of the unpaved network is in good or fair condition.
- The un-engineered network constitutes 20 percent of the total network.
- About 88 percent of the paved network is in good and fair condition.

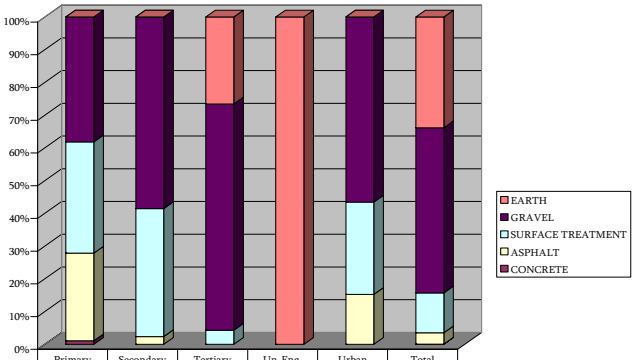
Fig. 1 National Road Network Condition



	Concrete	Asphalt	S.T.	Gravel	Earth	Total
Very Poor	0	0	0	0	11,776	11,776
Poor	0	264	797	6,314	2,303	9,677
Fair	0	554	1,921	8,224	4,026	14,726
Good	38	1,102	4,301	14,534	1,399	21,374
Very Good	0	60	0	0	0	60

SURFACE TYPE

Fig 2 Road Network by Management Type



	Primary	Secondary	Tertiary	Un-Eng.	Urban	Total
EARTH	0	0	7,727	11,776	0	19,503
GRAVEL	1,360	4,456	20,104	0	3,153	29,072
SURFACE TREATMENT	1,212	2,978	1,255	0	1,574	7,019
ASPHALT	954	179	0	0	848	1,981
CONCRETE	38	0	0	0	0	38

Table 1 shows the level of utilization of the network. The areas to note include:

- 91 percent of the traffic is on paved roads.
- 52 percent of the traffic drive on very good/good roads.
- The annual motorized vehicle utilization is about 21,150 million vehicle-km.
- About 5 percent of the annual motorized vehicle utilization is on the feeder road network.

TABLE 1: Network Utilization

Network Utilization by Road Type and Network Type (million vehicle-km)

	Primary	Secondary	Tertiary	Un-Eng.	Urban	Total	Percent
Concrete	277	0	0	0	0	277	1
Asphalt	5,741	287	0	0	5,701	11,729	55
S.T.	2,008	1,770	274	0	3,288	7,340	35
Gravel	179	565	779	0	183	1,706	8
Earth	0	0	43	54	0	96	0
Total	8,205	2,622	1,096	54	9,172	21,149	100
Percent	39	12	5	0	43	100	

Network Utilization by Road Type and Road Condition (million vehicle-km)

	Very Good	Good	Fair	Poor	Very Poor	Total	Percent
Concrete	0	277	0	0	0	277	1
Asphalt	439	5,632	4,002	1,656	0	11,729	55
S.T.	0	3,849	2,091	1,400	0	7,340	35
Gravel	0	731	492	484	0	1,706	8
Earth	0	8	20	14	54	96	0
Total	439	10,497	6,605	3,554	54	21,149	100
Percent	2	50	31	17	0	100	

Network Utilization by Road Type and Traffic Level (million vehicle-km)

	Traffic I	Traffic II	Traffic III	Traffic IV	Traffic V	Total	Percent
Concrete	0	0	0	0	277	277	1
Asphalt	0	0	72	1,002	10,654	11,729	55
S.T.	11	542	1,822	4,965	0	7,340	35
Gravel	39	203	952	513	0	1,706	8
Earth	18	65	13	0	0	96	0
Total	68	811	2,858	6,480	10,932	21,149	100
Percent	0	4	14	31	52	100	

Table 2 below shows the network monitoring indicators. Significant aspects of these indicators are as follows:

- The current road asset value is given as US$2,723.7 million, which is about 86 percent of the maximum asset value. About 14 percent of the asset value has been lost due to the current condition of the road network.
- The gravel and earth roads constitute about 20 percent of the current asset value.

- Although earth roads constitute about 34 percent of the network, their current asset value is about 15 percent of its maximum value. Only 28 percent of the earth roads are in good to fair condition.
- Gravel roads constitute about 50 percent of the network, and 78 percent are in good to fair condition. Their current asset value is 72 percent of the maximum.
- The current asset value of the road network in Ghana is close to 26 percent of the GDP.
- About 50 percent of the unpaved roads have traffic of fewer than 30 vehicles per day.

Table 2: Network Monitoring Indicators

Monitoring Indicator		Primary	Secondary	Tertiary	Un-Eng.	Urban	Overall
Network Length							
Road network length	km	3,564.3	7,612.6	29,085.9	11,776.0	5,574.4	57,613.2
Road network length that is paved	km	2,204.3	3,157.0	1,255.0	0.0	2,421.5	9,037.8
Road network length that is unpaved	km	1,360.0	4,455.6	27,830.9	11,776.0	3,152.9	48,575.4
Road network length that is paved	%	61.8	41.5	4.3	0.0	43.4	15.7
Network Density							
Road network per thousand land area	km/1000 sq km	14.945	31.919	121.953	49.375	23.373	241.565
Road network per thousand total population	km/1000 persons	0.167	0.357	1.363	0.552	0.261	2.699
Road network per thousand rural population	km/1000 persons	0.297	0.635	2.425	0.982	0.465	4.803
Road network per thousand vehicles	km/1000 vehicles	5.456	11.652	44.521	18.025	8.533	88.187
Road network per $ million GDP	km/million $	0.337	0.720	2.752	1.114	0.527	5.451
Network Condition							
Percentage of road network in good and fair condition	%	82.0	70.0	87.1	0.0	46.2	62.8
Percentage of paved roads in good and fair condition	%	95.3	95.3	93.6		69.9	88.3
Percentage of paved roads with roughness 4 m/km IRI or less	%	55.0	71.4	74.1		45.7	60.9
Paved roads average roughness weighted by km	IRI, m/km	4.36	4.54	4.61		5.52	4.77
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.95	4.40	4.58		5.27	4.62
Percentage of unpaved roads that are all-weather roads	%	60.4	52.0	67.3	0.0	28.0	46.9
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	0.0	0.0	44.9	100.0	0.0	50.0
Percentage of unpaved roads with 300 AADT or more	%	35.7	37.6	0.0	0.0	0.0	4.4
Percentage of paved roads with 300 AADT or less	%	0.0	0.0	11.5		0.0	1.6
Percentage of paved roads with 10,000 AADT or more	%	33.7	0.0	0.0		31.1	16.6
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	8,205	2,622	1,096	54	9,172	21,149
Annual freight carried over road network	million ton-km	24,412	8,035	3,771	212	27,279	63,709
Annual passengers carried over road network	million pass-km	56,426	17,260	5,864	198	63,106	142,853
Average network annual average daily traffic	vehicles/day	6,307	944	103	13	4,508	1,006
Network Asset							
Current Road asset value	million $	609.9	780.5	613.5	0.6	719.1	2,723.6
Current Road asset value as a share of maximum road asset value	%	90.9	89.8	83.3	5.0	82.1	86.1
Current Road asset value as a share of GDP	%	5.8	7.4	5.8	0.0	6.8	25.8

Consequences to Road Agency, Network Condition, and Society

The investment required by the road agencies to maintain the network at a very high standard (refer to Table 3) is about US$3,676 million over a 20 year period, or about US$184 million per year. The annual cost required in the first five years is about US$237 million. This reduces to a level of US$166 million per year from the period 6–20 years (Table 4).

The analysis shows that a higher annual investment in the region of US$117 million is required for rehabilitation in the first five years, while higher levels of investment of about US$147 million per year are required for periodic maintenance in the period 6–20 years.

This strategy will initially stabilize the road network in the five year period and then focus on a massive maintenance regime in the 6–20 years.

In Ghana, except in 2005, where investments reached a level of US$235 million, investments have been between US$85 million–US$200 million over the period 2000–2004. This level of investment corresponds to the medium to low standards. Even at such low levels, only about 44-52 percent of planned periodic maintenance has been achieved. Unless the 2005 levels of investments are main-

tained, investment levels below US$158 million per year (medium standards) over the next five years will have serious implications for the network.

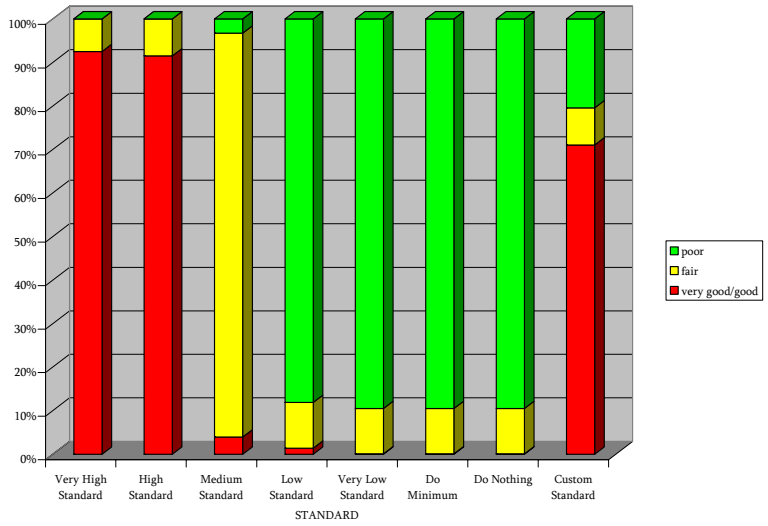
The custom standard adopted to reflect the Ministry of Transportation's policy over the medium term indicates that US$3,274 million will be required to achieve the expected road condition mix. This is about 89 percent of the projected level for a very high standard performance.

The custom standard, which requires an annual investment of US$208 million over the first five years and US$149 million over the 6–20 year period, will result in 40,942 kilometers in very good/good, 4,895 kilometers in Fair, and 11,776 kilometers in Poor condition in the first five years. The corresponding road condition mix would be 71 percent very Good/Good, 9 percent fair, and about 20 percent poor.

This deviates slightly from the policy objective but demonstrates the level of investment required to achieve the objective.

The corresponding road network condition for the other levels of performance standards are shown in Figure 3.

Figure 3. Projected Road Condition Mix (5 YRS)

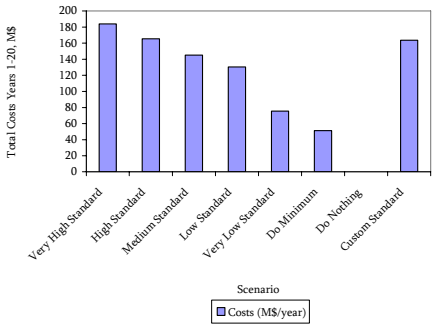


The implication to road users is shown in Table 6. At the investment level of the custom standard, road users will pay an additional US$2,583 million over a 20 year period for a US$402 million investment deficit. The marginal cost to road users for every dollar withheld by the road agencies is calculated to be US$6.43, and the net benefit to society is slightly more than US$37,000 million. The investment at a high standard provides a better marginal cost to road users of US$6.22.

Table 3: Consequences to Road Agency

Road Agency Costs (Total Costs Years 1-20)

Network	Standard	Road Agency Costs (M$)	Road Agency Costs (M$/year)	Scenario (%)
Total Network	Very High Standa	3,676	184	100%
	High Standard	3,311	166	90%
	Medium Standard	2,903	145	79%
	Low Standard	2,606	130	71%
	Very Low Standar	1,508	75	41%
	Do Minimum	1,024	51	28%
	Do Nothing	0	0	0%
	Custom Standard	3,274	164	89%



Road Agency Costs Breakdown (Total Costs Years 1-20)

Network	Standard	Total Costs Years 1-20, M$			
		Rehabilitation	Periodic Maint.	Recurrent Maint.	Road Agency
Total Network	Very High Standa	873	2,492	311	3,676
	High Standard	809	2,143	359	3,311
	Medium Standard	733	1,851	318	2,903
	Low Standard	892	1,490	224	2,606
	Very Low Standar	552	881	75	1,508
	Do Minimum	289	705	30	1,024
	Do Nothing	0	0	0	0
	Custom Standard	798	2,129	347	3,274

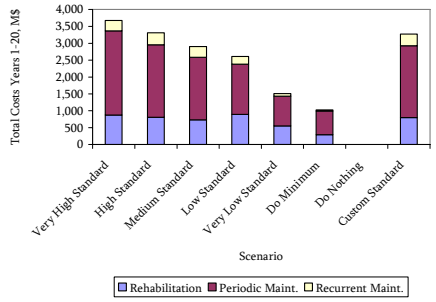
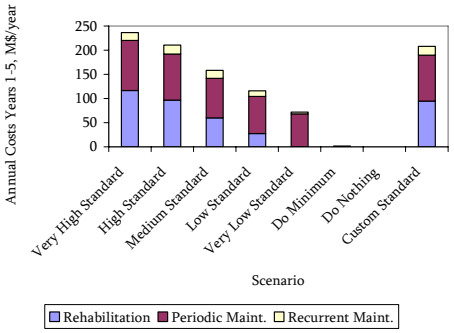


Table 4: Consequences to Annual Road Agency Costs

Annual Road Agency Costs Years 1-5 (Annual Costs Years 1-5)

Network	Standard	Annual Costs Years 1-5, M$/year			
		Rehabilitation	Periodic Maint.	Recurrent Maint.	Road Agency
Total Network	Very High Standa	117	104	16	237
	High Standard	97	95	19	211
	Medium Standard	60	82	17	158
	Low Standard	27	77	12	116
	Very Low Standar	0	68	4	72
	Do Minimum	0	0	2	2
	Do Nothing	0	0	0	0
	Custom Standard	95	95	18	208



Annual Road Agency Costs Years 6-20 (Annual Costs Years 6-20)

Network	Standard	Annual Costs Years 6-20, M$/year			
		Rehabilitation	Periodic Maint.	Recurrent Maint.	Road Agency
Total Network	Very High Standa	19	132	15	166
	High Standard	22	111	18	150
	Medium Standard	29	96	16	141
	Low Standard	50	74	11	135
	Very Low Standar	37	36	4	77
	Do Minimum	19	47	1	68
	Do Nothing	0	0	0	0
	Custom Standard	22	110	17	149

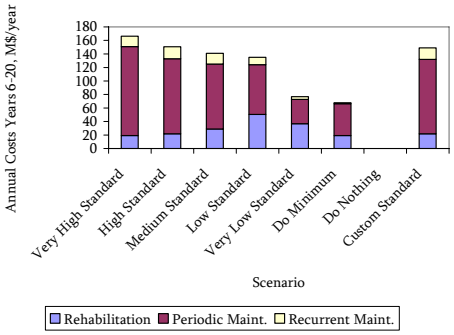
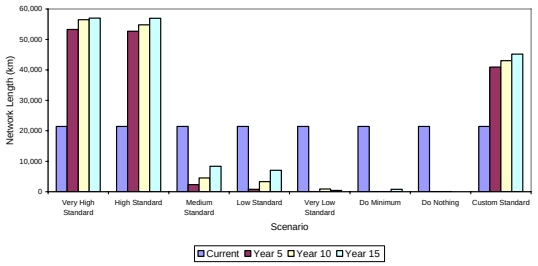


Table 5: Consequences to Network Condition

Network Length in Very Good or Good Condition

Network	Standard	Network Length in Very Good or Good Condition (km)			
		Current	Year 5	Year 10	Year 15
Total Network	Very High Standard	21,434	53,312	56,533	57,056
	High Standard	21,434	52,718	54,818	56,933
	Medium Standard	21,434	2,274	4,498	8,358
	Low Standard	21,434	790	3,274	7,051
	Very Low Standard	21,434	60	857	403
	Do Minimum	21,434	60	60	797
	Do Nothing	21,434	60	60	0
	Custom Standard	21,434	40,942	43,042	45,157



Network Length in Fair Condition

Network	Standard	Network Length in Fair Condition (km)			
		Current	Year 5	Year 10	Year 15
Total Network	Very High Standard	14,726	4,301	1,080	558
	High Standard	14,726	4,895	2,796	680
	Medium Standard	14,726	53,471	51,371	49,256
	Low Standard	14,726	6,071	3,924	1,029
	Very Low Standard	14,726	5,991	3,813	855
	Do Minimum	14,726	5,991	3,813	739
	Do Nothing	14,726	5,991	3,813	739
	Custom Standard	14,726	4,895	2,796	680

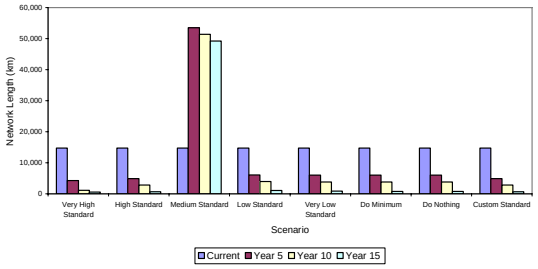
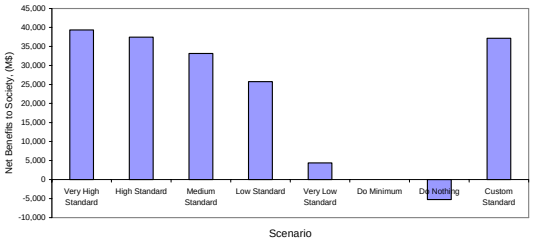


Table 6: Consequences to Society

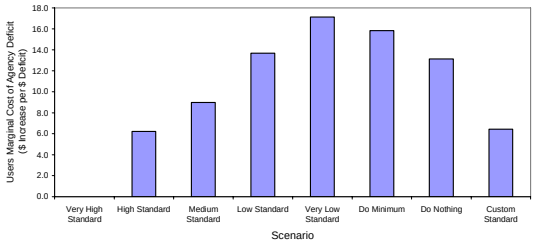
Society Net Benefits (Total Costs Years 1-20)

Comparison with Do Minimum Scenario		
Network	Standard	Net Benefits (M$)
Total Network	Very High Standard	39,344
	High Standard	37,438
	Medium Standard	33,170
	Low Standard	25,774
	Very Low Standard	4,379
	Do Minimum	0
	Do Nothing	-5,276
	Custom Standard	37,163



Road Users Marginal Cost of Agency Costs Deficit

Costs Comparison with Very High Standard				
		Total Costs Years 1-20, M$		User Costs
Network	Standard Scenario	Agency Deficit	Users Costs Increase	Increase per Agency Deficit
Total Network	Very High Standard	0	0	0.00
	High Standard	365	2,271	6.22
	Medium Standard	773	6,947	8.99
	Low Standard	1,070	14,640	13.68
	Very Low Standard	2,168	37,133	17.13
	Do Minimum	2,652	41,996	15.84
	Do Nothing	3,676	48,296	13.14
	Custom Standard	402	2,583	6.43



Road Works Distribution

Analysis from Table 7 below indicates that for the first five years, an amount of US$208 million will be required annually.

Table 7: Custom Standard Years 1-5

Road Agency Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Primary	1	29	14	0	0	44	21%
Secondary	0	4	30	17	0	51	25%
Tertiary	0	0	11	18	2	31	15%
Un-Eng.	0	0	0	0	2	2	1%
Urban	0	40	29	11	0	80	39%
Total	1	73	85	45	3	208	100%
Percent	0%	35%	41%	22%	2%	100%	

Rehabilitation Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Primary	0	0	7	0	0	8	8%
Secondary	0	0	14	11	0	25	26%
Tertiary	0	0	4	12	1	16	17%
Un-Eng.	0	0	0	0	0	0	0%
Urban	0	15	21	9	0	46	49%
Total	0	16	46	32	1	95	100%
Percent	0%	17%	49%	34%	1%	100%	

Periodic Maintenance Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Primary	1	27	6	0	0	34	36%
Secondary	0	4	14	4	0	22	23%
Tertiary	0	0	6	0	1	7	8%
Un-Eng.	0	0	0	0	1	1	1%
Urban	0	24	6	0	0	30	32%
Total	1	55	32	4	2	95	100%
Percent	1%	58%	34%	4%	2%	100%	

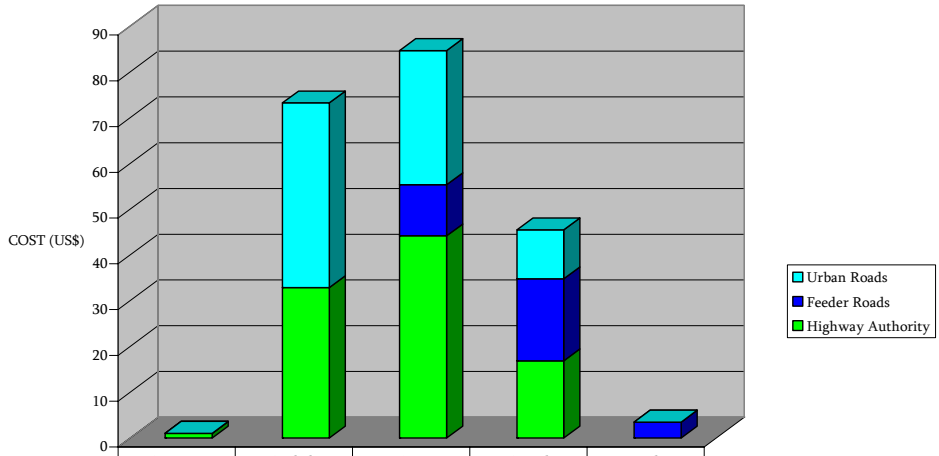
Recurrent Maintenance Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Primary	0	1	1	0	0	2	13%
Secondary	0	0	2	2	0	4	24%
Tertiary	0	0	1	6	0	7	40%
Un-Eng.	0	0	0	0	0	0	1%
Urban	0	1	2	1	0	4	22%
Total	0	2	6	10	1	18	100%
Percent	0%	12%	32%	53%	3%	100%	

US$95 million should be invested in rehabilitation works, US$95 million in periodic maintenance, and US$18 million in routine maintenance works. Sixty-six percent of the rehabilitation funds and 93 percent of the periodic maintenance funds will be provided for the paved roads.

Fifty-six percent of routine maintenance funds will also cover the unpaved roads. The corresponding amount required for the rehabilitation works, periodic maintenance, and routine maintenance in the 6-20 year period will be US$22 million, US$110 million, and US$17 million respectively. The consequence of any standard adopted can be assessed from the output of the RONET analysis. From the above analysis, the Agency allocation of funds for the road works at the custom standard performance is shown below:

Fig. 4 ROAD WORKS COSTS BY MANAGEMENT TYPE (1-5 YRS)



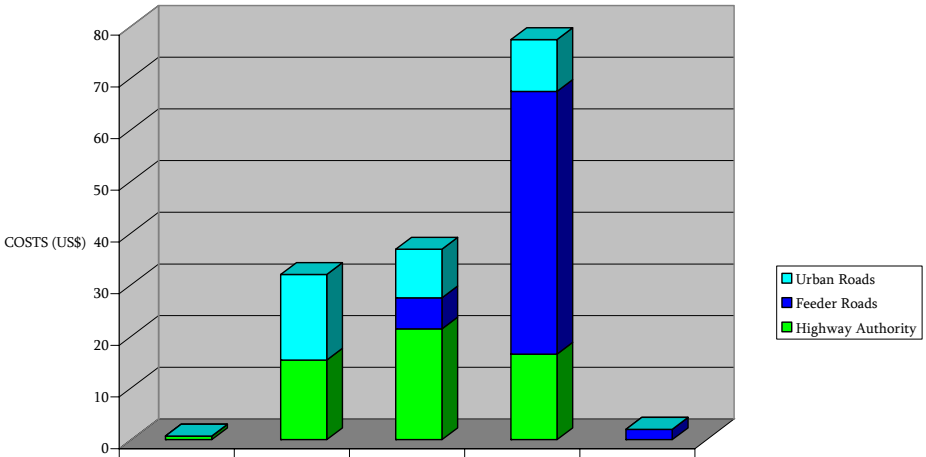
	Concrete	Asphalt	S.T.	Gravel	Earth
Urban Roads	0	40	29	11	0
Feeder Roads	0	0	11	18	3
Highway Authority	1	33	44	17	0

SURFACE TYPE

The Ghana Highway Authority, on the basis of the investment at the Custom Standard, will be allocated 46 percent of the funds in the first five years. The Department of Feeder Roads and the Department of Urban Roads will receive 16 percent and 38 percent respectively.

There will be a significant shift in the allocations due to the shift to a higher maintenance level in the period 6–20 years. The new allocation levels are shown in Figure 5 below.

Fig. 5 ROAD WORKS COSTS BY MANAGEMENT TYPE (6-20YRS)



	Concrete	Asphalt	S.T.	Gravel	Earth
Urban Roads	0	17	9	10	0
Feeder Roads	0	0	6	51	2
Highway Authority	1	15	21	17	0

SURFACE TYPE

The Department of Feeder Roads will require 39 percent of the annual funding of US$149 million for the period. The Ghana Highway Authority and the Department of Urban Roads will receive 36 percent and 24 percent.

CONCLUSIONS

The software is still in its development stage and, therefore, there are some results that require clarification and possibly re-examination. However, it is important to note that the software is able to provide an insight into the following:

a. the investment required for rehabilitation, periodic maintenance, and routine maintenance over specific time periods,
b. the consequences of any investment to the road agencies and road users,
c. the implications of different levels of interventions on the road conditions and resulting asset value, and
d. the funding allocation to various road management agencies.

This software can be used to assess the strategic plan of road agencies and the performance of the network in the strategic period. Policy formulation in relation to the specific performance standards and investments required on each network type can only be enhanced with such a tool.

ANNEX 1: CAPITAL ROAD WORKS UNIT COSTS

Surface Type	Road Condition	Road Work	Two-Lane Unit Costs of Road Works ($/km-year)				
			Primary	Secondary	Tertiary	Un-Eng.	Urban
Concrete	Very Good	Recurrent Maintenance	1,000				
	Good	Recurrent Maintenance	1,250				
	Fair	Recurrent Maintenance	1,500				
	Poor	Recurrent Maintenance	750				
	Very Poor	Recurrent Maintenance	750				
Asphalt Mix	Very Good	Recurrent Maintenance	900	800	0	0	900
	Good	Recurrent Maintenance	1,200	1,100	0	0	1,200
	Fair	Recurrent Maintenance	1,500	1,450	0	0	1,500
	Poor	Recurrent Maintenance	750	725	0	0	750
	Very Poor	Recurrent Maintenance	750	725	0	0	750
Surface Treatmeant	Very Good	Recurrent Maintenance	600	500	500	0	600
	Good	Recurrent Maintenance	900	625	625	0	900
	Fair	Recurrent Maintenance	1,200	750	750	0	1,200
	Poor	Recurrent Maintenance	600	875	875	0	600
	Very Poor	Recurrent Maintenance	600	375	375	0	600
Gravel	Very Good	Recurrent Maintenance	0	375	250	0	375
	Good	Recurrent Maintenance	0	470	300	0	470
	Fair	Recurrent Maintenance	0	580	375	0	580
	Poor	Recurrent Maintenance	0	660	440	0	660
	Very Poor	Recurrent Maintenance	0	290	200	0	290
Earth	Very Good	Recurrent Maintenance	0	0	40	40	0
	Good	Recurrent Maintenance	0	0	60	60	0
	Fair	Recurrent Maintenance	0	0	100	100	0
	Poor	Recurrent Maintenance	0	0	50	50	0
	Very Poor	Recurrent Maintenance	0	0	50	50	0

ANNEX 2: RECURRENT MAINTENANCE WORKS UNIT COSTS

Surface Type	Current Condition	Road Work	Two-Lane Unit Costs of Road Works ($/km)					Thickness	Reconstruction Characteristics	
			Primary	Secondary	Tertiary	Un-Eng.	Urban	(mm)	Structural No.	Roughness (IRI)
Concrete	Good Condition	Preventive Treatment	5,000							
	Fair Condition	Resurfacing (Overlay)	130,000					50		
	Poor Condition	Strengthening (Overlay)	180,000					100		
	Very Poor Condition	Reconstruction	400,000						3	2.0
	No Road	New Construction	600,000							
Asphalt Mix	Good Condition	Preventive Treatment	2,500	2,500			3,000			
	Fair Condition	Resurfacing (Overlay)	110,000	110,000			120,000	50		
	Poor Condition	Strengthening (Overlay)	170,000	170,000			180,000	80		
	Very Poor Condition	Reconstruction	250,000	250,000			300,000		3	2.0
	No Road	New Construction	400,000	400,000			450,000			
Surface Treatmeant	Good Condition	Preventive Treatment	1,800	1,800	1,000		1,800			
	Fair Condition	Resurfacing (Reseal)	25,000	25,000	27,000		29,000	12		
	Poor Condition	Strengthening (Overlay)	60,000	60,000	45,000		60,000	80		
	Very Poor Condition	Reconstruction	160,000	160,000	110,000		160,000		2	2.5
	No Road	New Construction	220,000	220,000	180,000		250,000			
Gravel	Good Condition	Spot Regravelling	0	1,000	1,000	0	1,000			
	Fair Condition	Regravelling	0	12,000	12,000	0	12,000	150		
	Poor Condition	Partial Reconstruction	0	18,000	15,000	0	18,000			
	Very Poor Condition	Full Reconstruction	0	28,000	21,000	0	28,000			
	No Road	New Construction	0	32,000	25,000	0	32,000			
Earth	Good Condition	Spot Repairs			500	500	0			
	Fair Condition	Heavy Grading			600	600	0			
	Poor Condition	Partial Reconstruction			750	750	0			
	Very Poor Condition	Full Reconstruction			950	950	0			
	No Road	New Construction			1,000	1,000	0			

ANNEX 3: TRAFFIC LEVELS CHARACTERISTICS AND VEHICLE FLEET UNIT COSTS

Traffic Levels Characteristics

		Traffic Level	T1	T2	T3	T4	T5	T6	T7	T8	T9
		Average Annual Daily Traffic (AADT)	5	20	65	200	650	2,000	6,500	20,000	65,000
Vehicle	quivalent Standard Axl	Payload	Passengers	Typical Traffic Composition (%)								
Type	(ESA/vehicle)	(Tons/vehicle)	(persons/vehicle	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Motorcycle	0.00	0.20	1	21.0%	21.0%	21.0%	8.7%	8.7%	2.5%	2.5%	2.5%	2.5%
Car Small	0.00	0.10	2	3.0%	3.0%	3.0%	15.3%	15.3%	21.4%	21.4%	21.4%	21.4%
Car Medium	0.00	0.30	2	5.0%	5.0%	5.0%	14.6%	14.6%	19.4%	19.4%	19.4%	19.4%
Delivery Vehicle	0.01	0.90	2	20.0%	20.0%	20.0%	15.1%	15.1%	12.7%	12.7%	12.7%	12.7%
Four-Wheel Drive	0.02	0.80	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Truck Light	0.10	2.40	1	15.0%	15.0%	15.0%	7.8%	7.8%	4.2%	4.2%	4.2%	4.2%
Truck Medium	1.25	5.70	1	12.0%	12.0%	12.0%	7.1%	7.1%	4.7%	4.7%	4.7%	4.7%
Truck Heavy	2.28	10.60	1	2.0%	2.0%	2.0%	3.7%	3.7%	4.6%	4.6%	4.6%	4.6%
Truck Articulated	4.63	22.30	1	10.0%	10.0%	10.0%	7.6%	7.6%	6.4%	6.4%	6.4%	6.4%
Bus Light	0.04	1.25	12	6.0%	6.0%	6.0%	9.5%	9.5%	11.3%	11.3%	11.3%	11.3%
Bus Medium	0.70	2.50	30	6.0%	6.0%	6.0%	8.0%	8.0%	9.0%	9.0%	9.0%	9.0%
Bus Heavy	0.80	3.20	40	0.0%	0.0%	0.0%	2.6%	2.6%	3.9%	3.9%	3.9%	3.9%
			Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
			ESA Loading (M ESA/year)	0.001	0.005	0.017	0.045	0.146	0.411	1.334	4.105	13.342
			Payload/Vehicle (tons/vehicle)	3.95	3.95	3.95	3.29	3.29	2.97	2.97	2.97	2.97
			Passengers/Vehicle (persons/vehicle)	3.68	3.68	3.68	5.83	5.83	6.91	6.91	6.91	6.91

Vehicle Fleet Unit Road User Costs Relationship to Roughness

	Traffic Level	T1	T2	T3	T4	T5	T6	T7	T8	T9
	Average Annual Daily Traffic (AADT)	5	20	65	200	650	2,000	6,500	20,000	65,000
Unit Road User Costs ($/veh-km) = a0 + a1*IRI + a2*IRI^2 + a3*IRI^3	a0 coefficient	0.18775	0.18775	0.18775	0.20572	0.20572	0.21469	0.21493	0.21862	0.32863
	a1 coefficient	0.00224	0.00224	0.00224	0.00106	0.00106	0.00046	0.00035	-0.00089	0.00586
	a2 coefficient	0.00075	0.00075	0.00075	0.00097	0.00097	0.00108	0.00111	0.00133	0.00036
	a3 coefficient	-0.00002	-0.00002	-0.00002	-0.00002	-0.00002	-0.00002	-0.00002	-0.00003	-0.00001

Mozambique

Atanasio Mugunhe

National Roads Administration (ANE)

Mozambique Case Study

EXECUTIVE SUMMARY

As part of its Sub-Saharan Africa Transport Policy Program, the World Bank has been developing the Road Network Evaluation Tool (RONET) to assist highway planners and decision makers to:

- Monitor and summarize the current condition of the road network;
- Plan future allocation of resources to the highway sector; and
- Assess the consequences of policies and budgetary constraints for the road network.

The aim of RONET is to provide medium- to long-term guidance on road maintenance and rehabilitation spending levels. Many of the relationships within RONET are based on the results of analyses using HDM-4 on many projects in many different countries.

RONET has been tested by Mozambique's Administração Nacional de Estradas (ANE) using data on its 30,000 km classified road network. The results are briefly discussed in this case study. Other countries participating in this testing program are Ghana, Tanzania, and Uganda.

RONET predicts expenditure levels on recurrent and periodic maintenance and rehabilitation to achieve defined overall network standards given initial network characteristics, condition, and utilization. The predictions of annual expenditure levels and network average roughness are presented for Years 1-5, 6-10, 11-15, and 16-20.

The overall annual expenditure level required to achieve a medium quality network standard in Years 1-5 are in line with ANE's planned expenditure on road maintenance and rehabilitation civil works between 2007 and 2009, but the balance between different types of maintenance and rehabilitation is different.

A comprehensive, accurate, and up-to-date road database is a necessary basis for the use of RONET. The data used in this test of RONET was from the simplified database developed as part of a Road Sector Strategy Study in 2005.

RONET is easy to use and produces large volumes of useful data. A small number of problems and/or omissions have been identified in this test, and their solution would enhance the model. A reasonably high level of highway planning experience is required to get the best value from RONET.

RONET is potentially a very useful application. A potential linkage with an enhanced version of the World Bank's Road User Charges Model would provide a very powerful planning-policy tool.

BACKGROUND

Mozambique is a large, rapidly growing country in southern Africa with a population of around 20 million and per capita Gross Domestic Product (GDP) at current prices of US$370[1]. Over the past decade the country has achieved some of the most rapid economic growth on the continent with annual growth of real GDP fluctuating between 6 percent and 8 percent. The impact of this growth is most evident in the extreme south of the country, especially in the capital Maputo and surrounding areas.

The classified road network is divided into national roads (primary and secondary) and regional-provincial roads (tertiary and vicinal). Mozambique's classified road network is around 30,000 km of which 20 percent is paved, 43 percent gravel surfaced, and 37 percent earth roads and tracks. Over the past decade road network improvements have been largely focused on the more heavily trafficked parts of the network, the primary (national) network. The condition of the primary network has improved significantly, but it is doubtful if the tertiary and vicinal (local district) road conditions have improved at all. This situation basically reflects prioritization within a situation of strict budgetary constraints.

The results of this largely, economically rational policy is that nearly 90 percent of network vehicle-km is concentrated on the national network. Mozambique has a large network of very low traffic volume roads in poor condition serving a large, but low density, rural population. Government policy will increasingly place considerable emphasis on the reduction of absolute, largely rural, poverty. In the medium-longer term this means greater attention will be focused on improving and creating rural access by low-cost improvements.

During the 2007-2009 planning period the government plans to spend just over US$1 billion on roads (just under US$350 million a year). Maintenance will account for 25 percent of this and rehabilitation and upgrading will absorb just under 70 percent[2]. Domestic sources (Road Fund and central government) will provide one-third of planned resources and international donors will contribute two-thirds. International donor contributions will focus on rehabilitation and upgrading projects and on a certain amount of sector budget support. Domestic financial resources are mainly from road user charges (fuel levy) channeled through the Road Fund and from central government financing of specific upgrading projects and bridges.

[1] US$1,420 at purchasing power parity.

[2] The balance is accounted for by overheads.

INTRODUCTION

Up to 2003 prioritization and planning of road works in Mozambique was undertaken through use of the proprietary Highway Network Management System (HNMS) installed by consultants in the late 1990s. With the demise of the Windows operating system on which it was based, the system and, more importantly, its highway database could no longer be used.

Planning expenditure for the 2007-2009 period was initially based on the findings of a Road Sector Strategy Study (RSSS) in which HDM-4 was used to prioritize road works on the paved road network. As part of the RSSS, a simplified Excel-based road database was created reflecting network characteristics, condition, and utilization in 2005. It is this database that has been used in the first, test implementation of RONET in Mozambique. The highway network information requirements of RONET in the form needed was obtained from this simplified database via Excel pivot table analyses.

Data Collection

No special data collection effort was required for the test run of RONET since the relevant information was available in the simplified database mentioned above. However, it should be emphasized that a comprehensive, accurate, and up-to-date road database is a priority requirement for running RONET.

Vehicle fleet road user costs were already available from analyses undertaken in ANE using the HDM-4 Road User Cost Model, and no additional data collection was required. Traffic data was also based on existing classified count data by road link. This information was entered into the simplified database.

Problems and apparent uncertainties in RONET road works cost information requirements are discussed later in this Case Study. At this point it is worth mentioning that all costs entered into RONET were economic costs excluding taxes and duties, etc. Economic costs in Mozambique are around 85 percent of financial costs.

Evaluation Done

RONET was run without any notable difficulty and a preliminary evaluation of the results was made. The budget requirements for different standards of network were compared with those planned for the 2007-2009 period. The main difficulty in evaluating RONET results at this stage is that no account is taken of committed road rehabilitation and upgrading projects in the medium term. For example, unpaved roads scheduled for upgrading to paved road standard within the next three years are still entered as unpaved roads in the database. Either a “forecast” database has to be used or some method of incorporating future commitments into the RONET analysis has to be developed.

RESULTS OBTAINED

Some of the analytical tables generated via RONET are set out in the Technical Annex. The predicted annual road maintenance and rehabilitation costs and the associated network standard are the main focus of interest in summarizing the results obtained. These are compared with ANE's forecasts of annual civil works costs for the 2007-2009 period in Table 1 below.

Given ANE's predicted civil works budget for maintenance and rehabilitation for the 2007-2009 period, the RONET predicts a *Medium Standard network in Years 1-5*. The RONET prediction is for more to be spent on rehabilitation and less on maintenance. Projected expenditure would be 15 percent below that required for the Custom Standard for the network.

Table 1 - RONET Forecast of Annual Maintenance and Rehabilitation Costs

Network Standard	Years 1 - 5			
	Annual Agency Costs (US$ million)			
	Recurrent Maintenance	Periodic Maintenance	Rehabilitation	Total
Very High Standard	30.0	26.0	198.0	254.0
High Standard	30.0	25.0	182.0	237.0
Medium Standard	**22.0**	**19.0**	**146.0**	**187.0**
Low Standard	18.0	85.0	115.0	218.0
Very Low Standard	10.0	85.0	13.0	108.0
Custom Standard	**26.0**	**36.0**	**159.0**	**221.0**
ANE 2007-2009	**37.7**	**33.2**	**116.1**	**187.0**

Network Standard	Years 6 - 20			
	Annual Agency Costs (US$ million)			
	Recurrent Maintenance	Periodic Maintenance	Rehabilitation	Total
Very High Standard	29.0	80.0	37.0	146.0
High Standard	29.0	67.0	37.0	133.0
Medium Standard	**22.0**	**63.0**	**37.0**	**122.0**
Low Standard	18.0	36.0	36.0	90.0
Very Low Standard	10.0	30.0	55.0	95.0
Custom Standard	**26.0**	**72.0**	**37.0**	**135.0**
Note:	*Custom Standard (default). Primary roads - very high Secondary roads - high. Tertiary roads - medium Vicinal - low.*			

Overall network roughness with a Medium Standard network is predicted to drop from the current IRI 12.4 m/km to around 10.5 in the Year 5-15 period. However, given the concentration of traffic on the best roads, overall network roughness weighted by vehicle-km would only be IRI 5.7-6.0.

RONET predictions of average annual road agency and road user costs in years 1-20 are summarized in Table 2.

Table 2 - Road Agency and Road User Costs

Network Standard	Average Annual Costs US$ million)			% of Total	
	Road Agency	Road Users	Total	Road Agency	Road Users
Very High	173	1,846	2,019	8.6%	91.4%
High	159	1,889	2,048	**7.8%**	**92.2%**
Medium	**139**	**1,988**	**2,127**	**6.5%**	**93.5%**
Low	122	2,129	2,251	5.4%	94.6%
Very Low	98	2,330	2,428	4.0%	96.0%
Custom Standard	156	1,948	2,104	7.4%	92.6%
Annual Society Cost of not having a high standard network (US$ million)					
Medium	**-**	**20**	**99**	**79**	
Low	-	37	240	203	
Very Low	-	61	441	380	
Custom Standard	-	3	59	56	

The network asset values calculated by RONET are too high because the estimated new road construction costs were too high. This is going to be a continuing problem with so few new roads being constructed.

Conclusions

On the basis of this preliminary evaluation and use of RONET, it can be concluded that the model is potentially an extremely useful medium- to long-term strategic planning aid. The indication of overall network standards achievable with given budget limitations is a useful corrective for overheated political expectations. RONET's overall network roughness predictions are also useful for providing international donors and road agencies with realistic monitoring guidelines and targets. Linking RONET up with an enhanced road user charges model would provide a very powerful policy tool.

Problems

The main problems have less to do with what RONET does than what it does not do. The following summarizes a few of the perceived problem areas with the model or with its user instructions.

Roads Inaccessible to Through Traffic

Approximately 30 percent (10,000 km) of Mozambique's classified road network suffers from seasonal disruptions to access. The periods of disruption range from a few days to the whole year. In Mozambique, roads in poor or very poor condition, of which these usually form part, are considered not to be maintainable. At present there does not appear be any method in RONET for dealing with this planning problem. As with other required data inputs, a first essential step is to have accurate information on the duration of access disruptions and the reasons for them. Assuming that this data can be provided, how can the accessibility problem be tackled within RONET?

Economic and Financial Costs

In the RONET user instructions it should be made clear whether economic or financial costs are required.

GDP Data

In the RONET user instructions it should be made clear which form of Gross Domestic Product data are required: current price, constant price, or purchasing power parity.

Network Level Average Surface Roughness

Road surface roughness scales for paved and unpaved roads are quite different. An IRI of 12 m/km indicating the complete break up of a paved road describes a gravel road surface in fair condition. It is difficult to see what meaning can be attached to a network-wide average IRI measure.

Road Agency Costs

It is not clear from the RONET instructions whether road agency costs are purely civil works costs or whether they include agency overheads and other items.

Treatment of Road Sections Committed for Upgrading.

This has already been mentioned in Section 4 above. A solution within RONET is more likely to be successful and less messy than expecting individual users to make their own "forecast" database adjustments.

ANNEX 1: COUNTRY DATA

Land area (sq.km)	781,129
Total Population (million persons)	19.92
Rural Population (million persons)	15.98
GDP @ Current Prices - 2006 (US$million)	7,368
Total vehicle Fleet (vehicles)	187,660
Discount rate (percent)	12.0
Annual Traffic Growth Rate (percent)	5.5

ANNEX 2: TWO-LANE UNIT COSTS ROAD WORKS

Surface type	Current Condition	Road Work	Two-Lane Costs Unit Cost of Road Works (US$ / km)						Two-Lane Costs Unit Cost of Road Works (US$ / km)				
			Primary	Secondary	Tertiary	Vicinal	Urban		Primary	Secondary	Tertiary	Vicinal	Urban
Asphalt mix	Good Condition	Preventive Treatmen	9,500	8,769	8,038	7,308	-	Recurrent Maintenan	1,100	880	807	733	-
	Fair Condition	Resurfacing (overlay	71,500	66,000	60,500	55,000	-	Recurrent Maintenan	1,200	960	680	800	-
	Poor Condition	Strengthening (overl	250,000	230,769	211,538	192,308	-	Recurrent Maintenan	1,300	1,040	953	867	-
	Very Poor Conditio	Reconstruction	360,000	332,308	304,615	276,923	-	Recurrent Maintenan	1,400	1,120	1,027	933	-
	No Road	New Construction	450,000	415,385	380,769	346,154	-	Recurrent Maintenan	1,500	1,200	1,100	1,000	-
Surface Treatmen	Good Condition	Preventive Treatmen	3,510	3,240	2,970	2,700	-	Recurrent Maintenan	1,000	880	807	733	-
	Fair Condition	Resurfacing (reseal)	32,500	30,000	27,500	25,000	-	Recurrent Maintenan	1,200	960	680	800	-
	Poor Condition	Strengthening (overl	107,310	99,055	64,386	64,386	-	Recurrent Maintenan	1,300	1,040	953	867	-
	Very Poor Conditio	Reconstruction	300,000	276,932	180,000	180,000	-	Recurrent Maintenan	1,400	1,120	1,027	933	-
	No Road	New Construction	450,000	415,385	270,000	270,000	-	Recurrent Maintenan	1,500	1,200	1,100	1,000	-
Gravel	Good Condition	Spot regravelling	2,500	2,308	2,115	1,923	-	Recurrent Maintenan	1,500	1,200	900	800	-
	Fair Condition	Regravelling	50,000	46,154	20,000	20,000	-	Recurrent Maintenan	1,500	1,200	900	800	-
	Poor Condition	Partial Reconstructio	65,000	55,000	30,000	27,000	-	Recurrent Maintenan	1,500	1,200	900	800	-
	Very Poor Conditio	Full Reconstruction	80,000	73,846	40,000	32,500	-	Recurrent Maintenan	1,750	1,400	1,283	1,167	-
	No Road	New Construction	100,000	92,308	60,000	36,000	-	Recurrent Maintenan	2,000	1,600	1,467	1,333	-
Earth	Good Condition	Spot Repairs	500	462	300	300	-	Recurrent Maintenan	1,500	1,200	900	500	-
	Fair Condition	Heavy Grading	450	415	270	270	-	Recurrent Maintenan	1,500	1,200	900	500	-
	Poor Condition	Partial Reconstructio	60,000	55,385	36,000	36,000	-	Recurrent Maintenan	1,500	1,200	950	500	-
	Very Poor Conditio	Full Reconstruction	75,000	69,231	45,000	45,000	-	Recurrent Maintenan	1,750	1,400	950	700	-
	No Road	New Construction	80,000	73,846	48,000	48,000	-	Recurrent Maintenan	2,000	1,600	1,000	800	-
Concrete (none)													

ANNEX 3: TRAFFIC STRUCTURE AND CHARACTERISTICS

Vehicle type	Equivalent Standard (ESA)	Payload (tonnes / vehicle)	Passengers / vehicle	Traffic Structure (%) by Traffic Class and AADT mid-point								
				T1	T2	T3	T4	T5	T6	T7	T8	T9
				5	20	65	200	650	2,000	6,500	20,000	65,000
Car Medium	0.000	0.3	2	25.0%	28.0%	27.0%	24.0%	26.0%	25.0%	26.0%	28.0%	30.0%
Delivery Vehicle	0.010	0.9	2	30.0%	32.0%	35.0%	13.0%	20.0%	28.0%	25.0%	22.0%	20.0%
Truck Medium	1.200	5.7	1	30.0%	15.0%	6.0%	18.0%	12.0%	10.0%	10.0%	6.0%	5.0%
Truck Heavy	5.980	10.6	1	5.0%	5.0%	2.0%	10.0%	1.0%	2.0%	3.0%	1.0%	1.0%
Truck Articulated	6.540	22.3	1	4.0%	5.0%	8.0%	14.0%	5.0%	5.0%	5.0%	1.0%	1.0%
Bus Light	0.010	1.3	12	5.0%	5.0%	6.0%	14.0%	26.0%	18.0%	19.0%	20.0%	20.0%
Bus Medium	1.200	4.8	30	1.0%	10.0%	16.0%	7.0%	10.0%	12.0%	12.0%	22.0%	23.0%
Total				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
ESA Loading (M ESA / Year)				0.00	0.01	0.02	0.13	0.16	0.52	0.02	0.03	0.11
Payload / Vehicle (tonnes / vehicle)				3.59	3.41	3.58	5.91	2.97	3.03	3.12	2.26	2.24
Passengers / Vehicle (persons / vehicle)				2.39	5.05	6.92	4.94	7.22	6.99	7.08	10.08	10.37

ANNEX 4: NETWORK TWO-LANE EQUIVALENT LENGTH (KM) BY TRAFFIC RANGE ROAD SURFACE TYPE AND CONDITION

Road Class	Traffic Range (AADT)	Length (km) by Surface Type and Condition									
		Asphalt					Surface Treatment				
		Very Good	Good	Fair	Poor	Very Poor	Very Good	Good	Fair	Poor	Very Poor
Primary	100-300	0	0	0	0	0	73	538	705	159	0
	300-1000	0	0	0	0	0	525	232	283	171	10
	1000-3000	135	6	28	0	74	302	618	292	104	88
	3000-10000	0	21	0	51	0	0	34	0	0	0
	10000-30000	6	2	0	0	0	0	0	0	0	0
Secondary	100-300	0	0	0	0	0	41	0	448	114	28
	300-1000	0	0	0	0	0	0	19	22	44	0
	1000-3000	0	0	0	0	0	128	3	24	0	0
	3000-10000	0	0	0	0	0	8	0	0	0	0
	10000-30000	0	0	0	0	0	0	0	0	0	0
Tertiary	100-300	0	0	0	0	0	66	4	21	160	0
	300-1000	0	0	0	0	0	0	54	11	67	0
	1000-3000	0	0	0	0	0	0	0	0	0	0
	3000-10000	0	0	0	0	0	0	0	0	0	0
	10000-30000	0	0	0	0	0	0	0	0	0	0
Vicinal	100-300	0	0	0	0	0	0	3	0	0	0
	300-1000	0	0	0	0	0	0	0	0	0	0
	1000-3000	0	0	0	0	0	0	0	0	9	0
	3000-10000	0	0	0	0	0	0	0	0	0	0
	10000-30000	0	0	0	0	0	0	0	0	0	0
		Gravel					Earth				
		Very Good	Good	Fair	Poor	Very Poor	Very Good	Good	Fair	Poor	Very Poor
Primary	10-30	0	0	0	0	0	0	0	81	0	0
	30-100	0	113	579	205	0	0	0	0	0	77
	100-300	0	52	102	0	0	0	0	265	0	0
	300-1000	0	70	0	0	0	0	0	0	457	0
	1000-3000	0	0	0	0	0	0	0	0	0	0
Secondary	10-30	0	65	55	45	0	0	0	0	40	60
	30-100	0	670	1181	286	167	0	0	241	117	128
	100-300	0	72	0	0	0	0	162	589	20	0
	300-1000	63	0	0	0	0	0	59	0	0	0
	1000-3000	0	0	0	0	0	0	0	0	0	0
Tertiary	10-30	0	279	588	613	30	0	0	79	59	855
	30-100	49	1589	2578	706	289	0	38	303	361	1715
	100-300	0	155	113	263	0	0	350	584	468	0
	300-1000	0	0	122	15	0	0	30	0	0	0
	1000-3000	0	0	0	0	0	0	0	0	0	0
Vicinal	10-30	0	224	418	252	40	0	0	0	129	994
	30-100	0	465	610	88	0	0	149	353	843	1663
	100-300	0	0	88	0	7	0	118	131	6	35
	300-1000	0	0	0	0	0	0	115	0	0	0
	1000-3000	0	0	0	0	0	0	0	0	0	0

ANNEX 5: ROAD NETWORK LENGTH AND VEHICLE-KM BY ROAD CLASS, SURFACE TYPE, CONDITION AND TRAFFIC

Road Class	Length (km) by Surface Type						
	Asphalt	Surface Treatment	Gravel	Earth	Total	%	
Primary	359	4,134	1,121	880	6,494	*21.1%*	
Secondary	-	880	2,604	1,416	4,900	*15.9%*	
Tertiary	-	383	7,389	4,842	12,614	*41.0%*	
Vicinal	-	12	2,192	4,536	6,740	*21.9%*	
Total	359	5,409	13,306	11,674	30,748	*100.0%*	
%	*1.2%*	*17.6%*	*43.3%*	*38.0%*	*100.0%*		

Road Class	Network Utilization by Surface Type (million vehicle-km)					
	Asphalt	Surface Treatment	Gravel	Earth	Total	%
Primary	418	1,504	49	40	2,011	*74.2%*
Secondary	-	199	76	26	301	*11.1%*
Tertiary	-	50	206	55	311	*11.5%*
Vicinal	-	7	41	39	87	*3.2%*
Total	418	1,760	372	160	2,710	*100.0%*
%	*15.4%*	*64.9%*	*13.7%*	*5.9%*	*100.0%*	

Road Class	Length (km) by Surface Condition						
	Very Good	Good	Fair	Poor	Very Poor	Total	%
Primary	1041	1687	2335	1182	249	6494	*21.1%*
Secondary	241	1049	2560	667	383	4900	*15.9%*
Tertiary	115	2500	4399	2712	2889	12615	*41.0%*
Vicinal	0	1074	1600	1327	2739	6740	*21.9%*
Total	1,397	6,310	10,894	5,888	6,260	30,749	*100.0%*
%	*4.5%*	*20.5%*	*35.4%*	*19.1%*	*20.4%*	100.0%	

Road Class	Network Utilization by Surface Condition (million vehicle-km)						
	Very Good	Good	Fair	Poor	Very Poor	Total	%
Primary	496	719	380	295	121	2011	*74.2%*
Secondary	131	36	100	27	7	301	*11.1%*
Tertiary	6	75	123	85	21	310	*11.4%*
Vicinal	0	25	30	17	16	88	*3.2%*
Total	633	855	633	424	165	2,710	*100.0%*
%	*23.4%*	*31.5%*	*23.4%*	*15.6%*	*6.1%*	*100.0%*	

Road Class	Length (km) by Traffic Level (AADT)						
	Traffic 1	Traffic 2	Traffic 3	Traffic 4	Traffic 5	Total	%
Primary	1556	2230	2066	633	8	6493	*21.1%*
Secondary	896	2875	998	130	0	4899	*15.9%*
Tertiary	2753	7761	1933	167	0	12614	*41.0%*
Vicinal	2060	4171	394	115	0	6740	*21.9%*
Total	7,265	17,037	5,391	1,045	8	30,746	*100.0%*
%	*23.6%*	*55.4%*	*17.5%*	*3.4%*	*0.0%*	100.0%	

Road Class	Network Utilization by Traffic Level (million vehicle-km)						
	Traffic 1	Traffic 2	Traffic 3	Traffic 4	Traffic 5	Total	%
Primary	108	320	1220	302	61	2011	*74.2%*
Secondary	47	78	137	39	0	301	*11.1%*
Tertiary	31	173	72	35	0	311	*11.5%*
Vicinal	9	50	21	8	0	88	*3.2%*
Total	195	621	1,450	384	61	2,711	*100.0%*
%	*7.2%*	*22.9%*	*53.5%*	*14.2%*	*2.3%*	*100.0%*	

Note:

	Paved				Unpaved		
Traffic 1	AADT	100-300		Traffic 1	AADT	10-30
Traffic 2	AADT	300-1000		Traffic 2	AADT	30-100
Traffic 3	AADT	1000-3000		Traffic 3	AADT	100-300
Traffic 4	AADT	3000-10000		Traffic 4	AADT	300-1000
Traffic 5	AADT	10000-30000		Traffic 5	AADT	1000-3000

Tanzania

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Tanzania Case Study

INTRODUCTION

Background

Tanzania is among the four pilot countries in Sub-Saharan Africa which are participating in the development of a model called Road Network Evaluation Tools (RONET). The model is being developed for the Sub-Saharan Africa Transport Policy Program[1] (SSATP) by the World Bank and is intended to assist decision makers in:

- monitoring the current condition of the road network,
- planning allocation of resources, and
- assessing the consequences of macro policies on the road network.

RONET is being developed for use in the Africa region, but there will be no impediments for its application on any other country worldwide. RONET includes a series of analytical tools designed to evaluate the road network and road sector of a country at a macro level by evaluating a series of representative road classes, which can be characterized, for example, as functions of: (i) functional classification, (ii) surface type, (iii) traffic level, (iv) road condition, (v) terrain, (vi) climate, and (vii) geographical region.

SSATP has developed in the past the following two other software tools designed also to evaluate an entire road network of a country by evaluating a series of representative road classes.

- Road User Charges Model Version 3.0 (RUC) that evaluates scenarios of road user charges in a country, evaluating road classes in good and fair condition differentiated by traffic level, and estimates routine and periodic maintenance requirements derived from look-up solution tables. The RUC model represents the entire network of a country by a maximum of 160 road classes that are a function of traffic, percentage of cars, trucks loading, pavement strength, environment, level of agency costs, and vehicle operating costs.
- Performance Assessment Model Version 1.0 (PAM) estimates the performance of a road network under different budget scenarios, evaluating road classes on any road condition but not differentiating the road classes by traffic level, and estimates routine and periodic maintenance requirements derived from a straight line deterioration model. The PAM model represents the entire network of a country by a maximum of 64 road classes that are functions of functional classification, pavement type, and condition.

RONET is being developed to replace the functionality of the RUC and PAM models and to add new evaluation modules and output reports; therefore, RONET (i) is being developed in a modular form, (ii) characterizes the entire road network of a country in a more elaborate way, by allowing the defi-

nition of a maximum of 625 road classes, and (iii) includes road deterioration models based on the Highway Design and Management Module (HDM-4) relationships. RONET version 1.0 implements the following evaluation modules.

- **Current Condition Assessment** that calculates current road network statistics and network monitoring indicators.
- **Performance Assessment** that evaluates the road network performance under different rehabilitation and maintenance standards (budget scenarios) and presents the consequences to the road agency, the road user, and the road infrastructure.

RONET can be enhanced in the future by, for example, adding the following evaluation modules: (i) road user charges evaluation, (ii) life-cycle economic evaluation, (iii) axle loading impacts evaluation, and (iv) network improvements evaluation.

Test Running of RONET

RONET Beta Version 1.0 was received in late December 2006 from the World Bank. Thereafter, data collection relevant for inputting in this system began. Most of the data were obtained within the agency for the primary and secondary roads. The local government which manages the tertiary, unclassified, and urban was unable to complete the data collection and processing in time. Therefore, this report is covering the work done in test running of RONET by using data for primary and secondary network and excludes the tertiary and other type of network.

The data collection, processing, and review of outputs were carried out by a team comprising two Maintenance Engineers, three RMMS Engineers, and Manager Maintenance Programming at TANROADS headquarters.

DATA COLLECTION

Data required for inputting into RONET included those required for basic configuration, standard configuration, country-specific data, and the road network. These were mainly obtained from the database kept by the agency TANROADS. The agency operates Road Maintenance Management System (RMMS) with software called Road Mentor 5. In this system traffic, condition, unit costs, and other road network data are stored.

Also, the agency in year 2004 completed the Vehicle Operating Costs (VOC) study and this was a reliable source of the configuration data. Other configuration data were obtained from the HDM-4 calibration and configuration carried in the agency while carrying out the strategic and program analysis.

Other statistical and economical data were obtained from the agency planning section and Tanzania Revenue Authority.

Basic Configuration

Data which are country-specific were entered in the various tables for basic configuration. Those data that were found compatible with default values were unchanged. The data input included the network type, terrain type, environment types, roads condition class, and traffic levels.

Network Types

Network types used in Tanzania were entered and include the trunk, regional, district, feeder, and urban. The terrain type 2 which represents hilly type was selected for the country. This terrain was considered to be the average of the three types which exists in the country. The environment type was chosen from the provided table and type 11 was selected as representative type for the country. Management type was assigned accordingly from the options given in the first table. It should be noted that in Tanzania the district, feeder, and urban roads are managed under Prime Ministers Office Regional Administration and Local Government (PMORALG), while the trunk and regional roads are under the central government in the Ministry of Infrastructure Development.

Terrain Types

The data on 'Rise and Fall' and on 'Horizontal Curvature' were obtained from the recent VOC study carried out in the country in 2004.

Environment Types

Type 11 was selected as representative data for the country. However, the rainfall average in the country from HDM calibration data was used. In Tanzania we have three types: Tanzania Dry with mean monthly precipitation of 50 mm; Tanzania Moderate with mean monthly of 100 mm; and lastly Tanzania Wet with mean monthly rate of 150 mm. The mean monthly for the country correlated well with the default value in RONET. On the other hand, there was no adjustment to environmental coefficient.

Road Condition Class

In the table any changes were made and the default values were maintained.

Traffic Levels

The default figures for traffic levels for Asphalt ST, Gravel, and Earth were found adequate. The structural numbers of recent HDM-4 workspaces were compared to the default values in RONET and found to correlate; hence, the default values were maintained.

Standard Configuration

The review was based on experience and latest HDM configurations carried out while analyzing strategy and program analysis in 2006.

The default values in RONET were found to correlate well with those we have set in TANROADS.

The changes were made on the Custom Standard Configuration Table where network types were assigned a budget standard. Trunk, regional, and urban type were assigned High Standard. District was assigned Medium Standard while feeder type was assigned Low.

Country Data

BASIC CHARACTERISTICS.The data were mostly obtained within the agency from the feasibility studies and those kept by the transport economist. Table 1 shows the collected country basic data.

Table 1: Basic Characteristics

Land area (sq km)	881,000
Total population (million persons)	36.000
Rural population (million persons)	28.80
GDP ($ Billion)	10.680
Total vehicle fleet (vehicles)	608,000
Discount Rate (percent)	12
Traffic Growth Rate (percent)	4

Capital Road Works Unit Costs

Review of unit costs covered only three surface types: Asphalt, Surface Treatment, and Gravel. The unit costs of the remaining types, Concrete and Earth, were unchanged.

The unit costs entered in the table were based on the data from the recent completed projects and some were computed.

Trunk unit costs were determined for the three types of surfaces and some data were adjusted to obtain those for regional roads, district, and feeder, based on the proportionality of carriage width. Trunk width is 6.5m, regional 5.5m, district and feeder 4.5m, while urban is the same as trunk roads. Table 2 shows the derived capital road works unit costs.

Table 2: Capital Road Works Unit Costs

Surface Type	Current Condition	Road Work	Two-Lane Unit Costs of Road Works ($/km)	
			Trunk	Regional
Concrete	Good Condition	Preventive Treatment	5,000	4,231
	Fair Condition	Resurfacing (Overlay)	45,000	38,077
	Poor Condition	Strengthening (Overlay)	130,000	110,000
	Very Poor Condition	Reconstruction	230,000	194,615
	No Road	New Construction	350,000	296,154
Asphalt Mix	Good Condition	Preventive Treatment	5,000	4,231
	Fair Condition	Resurfacing (Overlay)	60,000	50,769
	Poor Condition	Strengthening (Overlay)	100,000	84,615
	Very Poor Condition	Reconstruction	300,000	253,846
	No Road	New Construction	350,000	296,154
Surface Treatment	Good Condition	Preventive Treatment	2,000	1,692
	Fair Condition	Resurfacing (Reseal)	27,000	22,846
	Poor Condition	Strengthening (Overlay)	80,000	67,692
	Very Poor Condition	Reconstruction	254,000	214,923
	No Road	New Construction	304,000	257,231
Gravel	Good Condition	Spot Regraveling	3,200	2,708
	Fair Condition	Regraveling	10,000	8,462
	Poor Condition	Partial Reconstruction	14,000	11,846
	Very Poor Condition	Full Reconstruction	25,000	21,154
	No Road	New Construction	56,000	47,385
Earth	Good Condition	Spot Repairs	150	127
	Fair Condition	Heavy Grading	615	521
	Poor Condition	Partial Reconstruction	7,500	6,346
	Very Poor Condition	Full Reconstruction	15,000	12,692
	No Road	New Construction	40,000	33,846

Recurrent Maintenance Works Unit Costs

Similar to item 2 above, the same approach was followed. The data on the maintenance unit costs collected in TANROADS from contracts and experience was applied.

The exercise analyzed those for trunk first and then, for other types, was proportionally computed following a similar approach used by RONET. Regional was 75 percent, district and feeder 50 percent, while urban retained the same values as for trunk.

Table 3: Recurrent Maintenance Works Unit Costs

Surface Type	Road Condition	Road Work	Two-Lane Unit Costs of Road Works ($/km-year)	
			Trunk	Regional
Concrete	Very Good	Recurrent Maintenance	1,000	750
	Good	Recurrent Maintenance	1,250	938
	Fair	Recurrent Maintenance	1,500	1,125
	Poor	Recurrent Maintenance	1,750	1,313
	Very Poor	Recurrent Maintenance	2,000	1,500
Asphalt Mix	Very Good	Recurrent Maintenance	1,000	750
	Good	Recurrent Maintenance	1,250	938
	Fair	Recurrent Maintenance	1,500	1,125
	Poor	Recurrent Maintenance	1,750	1,313
	Very Poor	Recurrent Maintenance	2,000	1,500
Surface Treatment	Very Good	Recurrent Maintenance	1,000	750
	Good	Recurrent Maintenance	1,250	938
	Fair	Recurrent Maintenance	1,500	1,125
	Poor	Recurrent Maintenance	1,750	1,313
	Very Poor	Recurrent Maintenance	2,000	1,500
Gravel	Very Good	Recurrent Maintenance	550	413
	Good	Recurrent Maintenance	675	506
	Fair	Recurrent Maintenance	800	600
	Poor	Recurrent Maintenance	925	694
	Very Poor	Recurrent Maintenance	1,050	788
Earth	Very Good	Recurrent Maintenance	275	188
	Good	Recurrent Maintenance	338	235
	Fair	Recurrent Maintenance	400	281
	Poor	Recurrent Maintenance	463	328
	Very Poor	Recurrent Maintenance	525	375

Traffic Level Characteristics

The nine traffic levels (T1 to T9) as proposed in RONET were maintained. The traffic composition for each traffic level and vehicle type was determined from the database in Road Mentor 5. The data for vehicle type or fleet, ESA/vehicle, payload, and passengers for Tanzania was obtained from the HDM VOC study report of 2004. Annex 1 provides details of the traffic level characteristics.

Vehicle Fleet Unit Road User Costs Relationship to Roughness

The coefficients were computed using the RUC Model ver1.0 and then copied into RONET. The data for running RUC model were those from HDM configuration and VOC in Tanzania. Annex 2 provides details of the coefficients.

Road Network Length

For trunk and regional roads, the Road Mentor database was used to transform the traffic and condition data into the RONET matrix. The database is in MS Access and, therefore, query tool was applied to prepare the matrix.

The data for district, feeder, and urban roads under the local government could not be obtained. The inventory and condition survey project was in the final stage while traffic data from district engineers was yet to be entered.

Therefore, analysis for Tanzania is based on trunk and regional roads data which is under TANROADS.

Tables 4 to 11 show the derived matrices for four road types: Asphalt, Surface Treatment, Gravel, and Earth.

Table 4: Trunk

Asphalt

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		2	3	4.5	8	12
Traffic I	100-300	0	0	0	0	0
Traffic II	300-1000	159	318	100	32	8
Traffic III	1000-3000	429	122	77	13	0
Traffic IV	3000-10000	354	116	85	24	2
Traffic V	10000-30000	30	41	20	4	0
						1,934

Table 5: Regional

Asphalt

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		2	3	4.5	8	12
Traffic I	100-300	2	2	1	0	0
Traffic II	300-1000	17	13	1	0	0
Traffic III	1000-3000	10	4	1	0	0
Traffic IV	3000-10000	0	0	0	0	0
Traffic V	10000-30000	2	5	1	0	0
						59

Table 6: Trunk

S.T.

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		3	4	5.5	9	13
Traffic I	100-300	1	208	328	36	12
Traffic II	300-1000	0	782	650	82	12
Traffic III	1000-3000	8	145	270	9	10
Traffic IV	3000-10000	27	118	65	1	0
Traffic V	10000-30000	2	4	11	2	0
						2,783

Table 7: Regional

S.T.

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		3	4	5.5	9	13
Traffic I	100-300	0	19	24	5	0
Traffic II	300-1000	8	73	120	64	9
Traffic III	1000-3000	0	0	71	4	0
Traffic IV	3000-10000	0	2	2	0	0
Traffic V	10000-30000	0	0	6	0	0
						407

Table 8: Trunk

Gravel

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		5	7	11	16	20
Traffic I	10-30	35	30	38	9	10
Traffic II	30-100	57	216	400	98	4
Traffic III	100-300	91	588	1,286	345	89
Traffic IV	300-1000	52	274	308	85	44
Traffic V	1000-3000	7	16	28	26	10
						4,145

Table 9: Regional

Gravel

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		5	7	11	16	20
Traffic I	10-30	116	483	952	358	105
Traffic II	30-100	374	1,487	2,764	838	206
Traffic III	100-300	187	915	2,265	735	125
Traffic IV	300-1000	22	252	584	64	38
Traffic V	1000-3000	4	57	163	49	11
						13,153

Table 10: Trunk

Earth

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		7	9	13	18	22
Traffic I	0-10	1	1	15	35	82
Traffic II	10-30	24	91	180	131	23
Traffic III	30-100	3	24	141	59	24
Traffic IV	100-300	3	4	8	9	6
Traffic V	300-1000	0	0	0	0	0
						865

Table 11: Regional

Earth

	Condition (IRI)	Very Good	Good	Fair	Poor	Very Poor
Traffic (AADT)		7	9	13	18	22
Traffic I	0-10	80	86	145	106	148
Traffic II	10-30	125	265	568	423	254
Traffic III	30-100	56	295	886	538	304
Traffic IV	100-300	24	88	414	318	203
Traffic V	300-1000	14	28	150	69	66
						5,652

RESULTS-CURRENT CONDITION ASSESSMENT

The model is designed to synthesize input network data and come up with a number of outputs of current network condition assessment in several tables. The relevant outputs information of the network is presented as follows:

Network Length

The percentage of trunk roads is 34 percent while for regional roads is 66 percent of the total length. The percentage of paved roads is 18 percent (7 percent for Asphalt and 11 percent for S.T.) while for unpaved is 82 percent (60 percent are Gravel and 22 percent are Earth). Table 12 summarizes the network length data.

Table 12: Network Length by Road Type and Network Type (km)

	Trunk	Regional	District	Feeder	Urban	Total	percent
Concrete	0	0	0	0	0	0	0
Asphalt	1,934	59	0	0	0	1,994	7
S.T.	2,783	407	0	0	0	3,190	11
Gravel	4,145	13,153	0	0	0	17,298	60
Earth	865	5,652	0	0	0	6,517	22
Total	9,728	19,271	0	0	0	28,999	100
Percent	34	66	0	0	0	100	

Network Condition

Overall, 33 percent of the network is in good condition, 45 percent in fair condition, and 22 percent in poor condition. Table 13 shows the network condition according to road type and length.

Table 13: Network Length by Road Type and Road Condition (km)

	Very Good	Good	Fair	Poor	Very Poor	Total	Percent
Concrete	0	0	0	0	0	0	0
Asphalt	1,003	622	286	73	10	1,994	7
S.T.	46	1,351	1,547	203	43	3,190	11
Gravel	945	4,319	8,787	2,606	642	17,298	60
Earth	331	883	2,506	1,688	1,110	6,517	22
Total	2,324	7,175	13,126	4,570	1,805	28,999	100
Percent	8	25	45	16	6	100	

Network Utilization

Utilization on trunk roads is 77 percent (4,513 million vehicles-km) and 23 percent on regional roads (1,363 million vehicles-km). Utilization on paved roads is 73 percent while on unpaved is 27 percent. Utilization is therefore high on the trunk roads and low on the regional roads. Table 14 shows the network utilization data.

Table 14: Road Network Utilization (Million Vehicles-km)

	Trunk	Regional	District	Feeder	Urban	Total	Percent
Concrete	0	0	0	0	0	0	0
Asphalt	2,696	77	0	0	0	2,773	47
S.T.	1,367	177	0	0	0	1,543	26
Gravel	439	893	0	0	0	1,332	23
Earth	12	216	0	0	0	228	4
Total	4,513	1,363	0	0	0	5,876	100
Percent	77	23	0	0	0	100	

Network Asset Value

The maximum value of the network asset value of trunk and regional roads is US$2,727 million. This is the value of roads in their as-built state or new construction or very good condition. The current network asset value as per prevailing condition is US$2,464 million. The shares of asset value are 67 percent for trunk roads and 33 percent for regional roads. Again the paved roads share is 63 percent while unpaved roads share is 37 percent. Tables 15 and 16 show the data of the Network Asset values for maximum and current values respectively.

Table 15: Network Maximum Asset Values (Million US$)

	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	677	846	232	35	1,790	66
Regional	0	18	105	623	191	937	34
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	695	951	855	226	2,727	100
Percent	0	25	35	31	8	100	

Table 16: Network Current Asset Values (Million US$)

	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	647	789	196	31	1,662	67
Regional	0	17	93	523	168	801	33
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	664	881	719	199	2,464	100
Percent	0	27	36	29	8	100	

Network Indicators

The set of network indicators produced by RONET are shown in Table 17

Table 17: Network Indicators

Monitoring Indicator		Trunk	Regional	District	Feeder	Urban	Overall
Network Length							
Road network length	km	9,728.0	19,271.4	0.0	0.0	0.0	28,999.4
Road network length that is paved	km	4,717.6	466.2	0.0	0.0	0.0	5,183.8
Road network length that is unpaved	km	5,010.4	18,805.2	0.0	0.0	0.0	23,815.6
Road network length that is paved	%	48.5	2.4				17.9
Network Density							
Road network per thousand land area	km/1000 sq km	11.042	21.874	0.000	0.000	0.000	32.916
Road network per thousand total population	km/1000 persons	0.270	0.535	0.000	0.000	0.000	0.806
Road network per thousand rural population	km/1000 persons	0.338	0.669	0.000	0.000	0.000	1.007
Road network per thousand vehicles	km/1000 vehicles	16.000	31.696	0.000	0.000	0.000	47.696
Road network per $ million GDP	km/million $	0.911	1.804	0.000	0.000	0.000	2.715
Network Condition							
Percentage of road network in good and fair condition	%	86.3	73.9				78.0
Percentage of paved roads in good and fair condition	%	94.8	82.4				93.7
Percentage of paved roads with roughness 4 m/km IRI or less	%	94.8	82.4				93.7
Paved roads average roughness weighted by km	IRI, m/km	3.43	4.36				3.51
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.13	3.88				3.18
Percentage of unpaved roads that are all-weather roads	%	68.4	61.7				63.1
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	14.1	22.4				20.7
Percentage of unpaved roads with 300 AADT or more	%	17.0	8.4				10.2
Percentage of paved roads with 300 AADT or less	%	12.4	0.1				0.1
Percentage of paved roads with 10,000 AADT or more	%	0.0	3.0				2.5
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	4,513	1,363	0	0	0	5,876
Annual freight carried over road network	million ton-km	15,265	4,592	0	0	0	19,857
Annual passengers carried over road network	million pass-km	35,855	9,177	0	0	0	45,032
Average network annual average daily traffic	vehicles/day	1,271	194				555
Network Asset							
Current Road asset value	million $	1,662.4	801.5	0.0	0.0	0.0	2,463.9
Current Road asset value as a share of maximum road asset value	%	92.9	85.6				90.4
Current Road asset value as a share of GPD	%	15.6	7.5	0.0	0.0	0.0	23.1

RESULTS – PERFORMANCE ASSESSMENT

The model gives a number of outputs on the network performance in relation to the various budget standards. Selected outputs considered important in Tanzania context are described as follows:

Budget Standards (5 Year Period)

RONET provides various budget scenarios based on eight standards ranging from Very High Standard to Do Nothing as shown in Table 18. The tool can analyze up to a period of 20 years but in this report the first five years have been selected. With this kind of table it is possible to compare with what has been allocated in a financial year. For example in financial year 2006/07 periodic maintenance works was allocated US$20 million. This allocated amount falls between the Very Low Standard and Do Minimum budget.

Table 18: Annual Road Agency Costs Years 1-5 (Annual Costs Years 1-5)

		Annual Costs Years 1-5, M$/year			
Network	Standard	Rehabilitation	Periodic Maint.	Recurrent Maint.	Road Agency
Total Network	Very High Standard	55	44	16	115
	High Standard	48	32	18	97
	Medium Standard	31	34	15	80
	Low Standard	22	42	11	75
	Very Low Standard	3	39	6	48
	Do Minimum	3	0	2	5
	Do Nothing	0	0	0	0
	Custom Standard	31	34	15	80

Network Asset Value

Very High Standard budget of US$115 million per year will increase the current asset value of US$2,464 million to US$2,643 million in the period of five years. Very High Standard budget corresponds to an unconstrained scenario whereby unlimited resources are available to carry rehabilitation, periodic, and recurrent as required over the network. On the other hand a Low Standard budget of US$48 million per year will cause the current asset value to fall from US$2,464 million to US$2,101 million in a five year period. A Medium Standard budget of US$80 million per year will uphold the current asset value at the same level of about US$2,464 million. The Medium Standard budget is therefore considered to be the minimum desired budget. Table 19 provides network asset values in relation to budget standards.

Table 19: Network Asset Value

		Network Asset Value (M$)			
Network	Standard	Current	Year 5	Year 10	Year 15
Total Network	Very High Standard	2,464	2,643	2,678	2,714
	High Standard	2,464	2,589	2,591	2,627
	Medium Standard	2,464	2,477	2,401	2,513
	Low Standard	2,464	2,346	2,269	2,419
	Very Low Standard	2,464	2,101	1,958	1,848
	Do Minimum	2,464	2,101	1,908	1,844
	Do Nothing	2,464	2,088	1,896	1,773
	Custom Standard	2,464	2,477	2,401	2,513

Network Roughness

Very High Standard budget will reduce roughness from the current average of 10.4 to 5.2 in the next five years. This budget will increase roads in very good and good condition while poor roads will be eliminated completely. Low Standard budget will increase the roughness of roads from 10.4 to 17.7, and with this level of budget most roads will fall into poor condition. On the other hand, a Medium Standard budget will keep the network in the same level of roughness of 10.4, and roads will generally be in fair condition. Again, the Medium budget appears to be the minimum desired budget which will not increase roughness and will keep roads in fair condition. Table 20 shows the roughness changes over the years in relation to budget standards.

Table 20: Roughness Weighted by Km

Network	Standard	Roughness by Km (IRI, mm/km)			
		Current	Year 5	Year 10	Year 15
Total Network	Very High Standard	10.4	5.2	5.2	5.0
	High Standard	10.4	6.9	6.9	6.7
	Medium Standard	10.4	10.2	10.3	10.0
	Low Standard	10.4	14.3	14.5	14.1
	Very Low Standard	10.4	17.7	17.9	18.2
	Do Minimum	10.4	19.3	19.6	19.8
	Do Nothing	10.4	21.4	21.6	22.0
	Custom Standard	10.4	10.2	10.3	10.0

Medium Budget Details

The Medium budget of US$80 million per year over a period of five years is composed of US$31 million for rehabilitation, US$34 million for periodic maintenance, and US$15 million for recurrent maintenance (refer to Table 18). It should be emphasized here that the three components of this budget should all be funded concurrently in order to stabilize the network. Of this budget, the trunk roads would require US$47 million while regional roads would require US$33 million. The cost breakdown for rehabilitation, periodic, and recurrent maintenance per year are shown in table 21 to 23 respectively.

Table 21: Rehabilitation Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	5	8	2	1	16	52
Regional	0	0	4	7	5	15	48
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	5	12	9	5	31	100
Percent	0	16	38	29	17	100	

Table 22: Periodic Maintenance Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	9	7	6	0	23	69
Regional	0	0	1	9	0	11	31
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	10	8	16	0	34	100
Percent	0	29	24	47	0	100	

Table 23: Recurrent Maintenance Costs (M$/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	2	3	2	0	8	50
Regional	0	0	0	6	1	7	50
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	2	3	8	1	15	100
Percent	0	12	22	56	10	100	

The corresponding breakdown of the kilometers per year for each network type and works type of the Medium Standard budget over a period of the first five years is summarized in tables 24 to 26.

Table 24: Rehabilitation Works Length (km/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	17	33	829	173	1,051	22
Regional	0	0	16	2,631	1,130	3,777	78
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	17	49	3,460	1,303	4,829	100
Percent	0	0	1	72	27	100	

Table 25: Periodic Maintenance Works Length (km/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	155	265	650	0	1,070	48
Regional	0	5	45	1,094	0	1,144	52
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	161	309	1,744	0	2,214	100
Percent	0	7	14	79	0	100	

Table 26: Recurrent Maintenance Works Length (km/year)

Network	Concrete	Asphalt	S.T.	Gravel	Earth	Total	Percent
Trunk	0	1,934	2,783	4,145	865	9,728	34
Regional	0	59	407	13,153	5,652	19,271	66
District	0	0	0	0	0	0	0
Feeder	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0
Total	0	1,994	3,190	17,298	6,517	28,999	100
Percent	0	7	11	60	22	100	

Conclusion

RONET is quite a good tool in evaluating the network. In Tanzania, through the pilot work on RONET, the country has already obtained quite useful information like network length, road condition, network utilization, roughness changes in relation to budget allocated, and comparison of various budget standards over a five year period .On other hand, this tool will assist very much in providing vital information which is required in the allocation of funds among the network types, in soliciting funds from the government and development partners, in strategic planning in the agency and the transport sector, and in monitoring the performance of the network.

ANNEXES

ANNEX 1: TRAFFIC LEVELS CHARACTERISTICS AND COEFFICIENTS

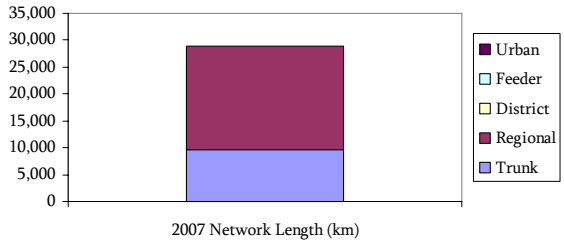
Traffic Levels Characteristics

			Traffic Level	T1	T2	T3	T4	T5	T6	T7	T8	T9
			Average Annual Daily Traffic (AADT)	5	20	65	200	650	2,000	6,500	20,000	65,000
Vehicle	Equivalent Standard Axles	Payload	Passengers	Typical Traffic Composition (%)								
Type	(ESA/vehicle)	(Tons/vehicle)	(persons/vehicle)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Motorcycle	0.00	0.20	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Car Small	0.00	0.32	3	18.0%	14.0%	13.0%	17.0%	17.0%	20.0%	25.0%	32.0%	0.0%
Car Medium	0.00	0.00	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Delivery Vehicle	0.00	0.00	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Four-Wheel Drive	0.01	1.00	3	34.0%	41.0%	38.0%	33.0%	26.0%	20.0%	13.0%	19.0%	0.0%
Truck Light	0.36	3.00	1	20.0%	14.0%	15.0%	14.0%	13.0%	15.0%	14.0%	5.0%	0.0%
Truck Medium	1.70	5.50	1	20.0%	14.0%	14.0%	14.0%	13.0%	11.0%	10.0%	5.0%	0.0%
Truck Heavy	3.30	15.00	1	1.0%	4.0%	2.0%	4.0%	5.0%	6.0%	6.0%	1.0%	0.0%
Truck Articulated	7.10	35.00	1	1.0%	1.0%	2.0%	2.0%	3.0%	4.0%	3.0%	1.0%	0.0%
Bus Light	0.04	1.25	15	0.0%	9.0%	10.0%	11.0%	17.0%	17.0%	22.0%	27.0%	0.0%
Bus Medium	0.00	0.00	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bus Heavy	3.50	3.60	45	6.0%	3.0%	6.0%	5.0%	6.0%	7.0%	7.0%	10.0%	0.0%
			Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
			ESA Loading (M ESA/year)	0.001	0.004	0.017	0.054	0.205	0.713	2.103	4.159	0.000
			Payload/Vehicle (tons/vehicle)	2.81	2.82	2.98	3.19	3.65	4.08	3.66	1.91	0.00
			Passengers/Vehicle (persons/vehicle)	4.68	4.68	6.06	5.74	6.88	7.26	7.92	10.20	0.00

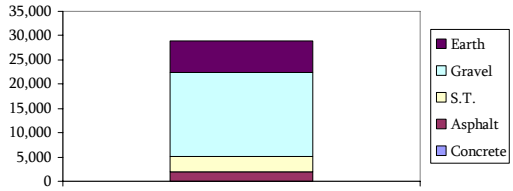
Vehicle Fleet Unit Road User Costs Relationship to Roughness

		Traffic Level	T1	T2	T3	T4	T5	T6	T7	T8	T9
		Average Annual Daily Traffic (AADT)	5	20	65	200	650	2,000	6,500	20,000	65,000
Unit Road User Costs ($/veh-km) = a0 + a1*IRI + a2*IRI^2 + a3*IRI^3	a0 coefficient		0.244721762	0.244721762	0.244721762	0.244721762	0.2447218	0.244721762	0.244642867	0.24572	0.38508
	a1 coefficient		-0.00115626	-0.00115626	-0.00115626	-0.00115626	-0.0011563	-0.00115626	-0.001228916	-0.00214	0.00624
	a2 coefficient		0.001394393	0.001394393	0.001394393	0.001394393	0.0013944	0.001394393	0.0014194 7	0.001657	0.00041
	a3 coefficient		-3.1607E-05	-3.1607E-05	-3.1607E-05	-3.1607E-05	-3.161E-05	-3.1607E-05	-3.23709E-05	-4E-05	-0.00001

ANNEX 2: NETWORK LENGTH

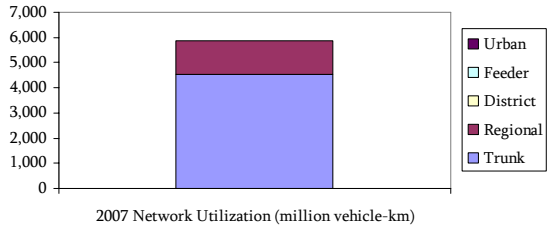


2007 Network Length (km)

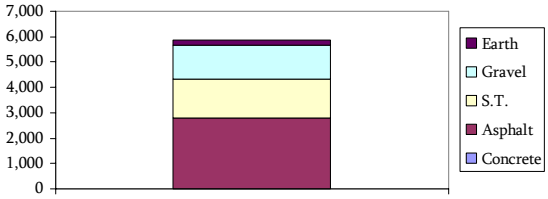


2007 Network Length (km)

ANNEX 3: NETWORK UTILIZATION

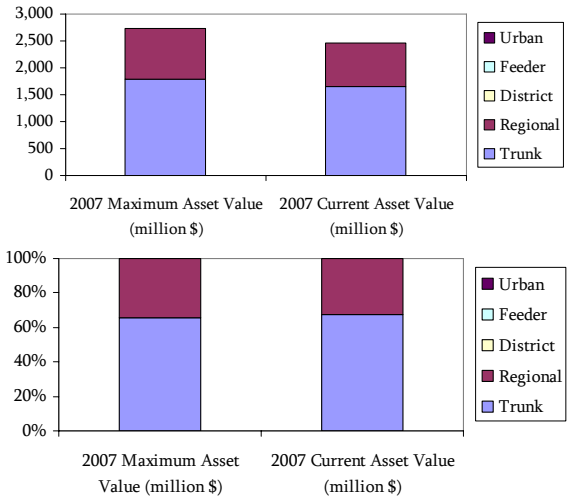


2007 Network Utilization (million vehicle-km)

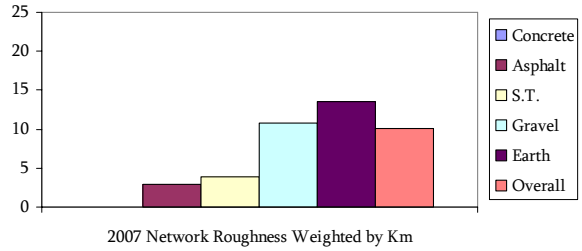


2007 Network Utilization (million vehicle-km)

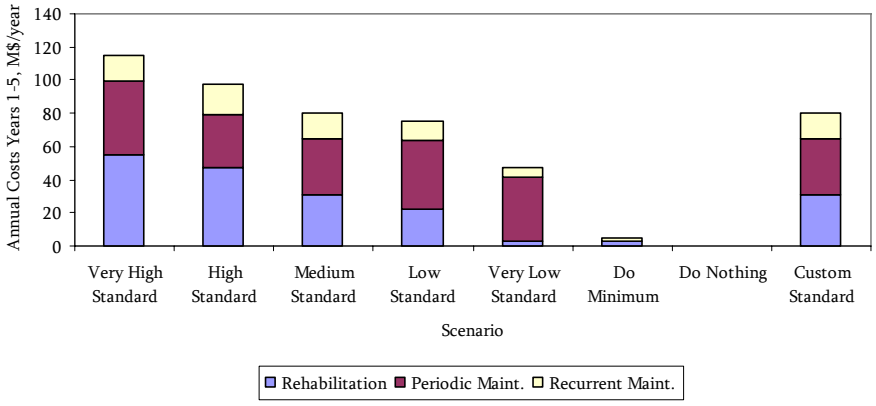
ANNEX 4: NETWORK ASSET VALUES



ANNEX 5: NETWORK ROUGHNESS



ANNEX 6: ANNUAL ROAD AGENCY COSTS



Uganda

David Lyiumbazi

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Uganda Case Study

INTRODUCTION

The RONET Version 1.0 model (2007) is an improvement to the Performance Assessment Model (PAM) of 2003, all developed under the auspices of the Sub-Saharan Africa Transport Policy Program. These models, especially the new RONET model, have been developed to enable decision makers in the road sub-sector to carry out strategic or macro assessments of the sub-sector intended for monitoring the state of the road system, plan the allocation of resources, and assess the consequences of macro policies on the road network.

RONET includes analytical tools designed to evaluate the road network and road sector of a country at a macro level by evaluating a series of representative road classes, which can be characterized, for example, as functions of: (i) functional classification, (ii) surface type, (iii) traffic level, (iv) road condition, (v) terrain, (vi) climate, and (vii) geographical region. RONET has a modular structure allowing the country's road system to be characterized by up to 625 road classes and uses road deterioration models based on the Highway Design and Management Module (HDM-4) relationships.

To improve the country specificity of the outputs from the RONET model, the World Bank's Road User Costs Knowledge System (RUCKS) model to calibrate the RONET coefficients was used to calculate road user costs based on roughness. This requires input to the RUCKS model of country-specific road user costs that can be obtained from recent feasibility studies. The default values in the RONET model broadly reflect African circumstances.

RONET will be enhanced in the future by, for example, adding the following evaluation modules: (i) road user charges evaluation, (ii) life-cycle economic evaluation, (iii) axle loading impacts evaluation, (iv) budget optimization and constrained analysis, and (v) network improvements evaluation.

The results of the assessment done using this model are only indicative and can be used as a first step in the assessment of the road management regime and conditions of the road network. Compared to higher generation models, this model relies on simplified macro level inputs which allow more information to be available to decision makers quickly.

DESCRIPTION OF THE MODELS

RONET Model

The RONET model is a Microsoft Office Excel 2003 workbook tool developed to carry out macro or strategic network analysis mainly in order to:

- Derive current road network statistics and road network performance monitoring indicators for the road sector;
- Evaluate the road network performance under up to eight (8) different rehabilitation and maintenance standards (budget scenarios) determining the consequences to the road agency (funding requirements), the road user and the road infrastructure.

The current road monitoring indicators are derived based on the following inputs of country-specific data:

- Country Name and Year;
- Basic Characteristics:
  - Land area (square kilometers): It is a country's total area, excluding areas under inland bodies of water and some coastal waterways.
  - Total population (million persons): Is the mid-year estimates of all residents regardless of legal status or citizenship.
  - Rural population (million persons): Is the mid-year population of areas defined as rural in each country and reported to the United Nations.
  - GDP ($ Billion): Is the Gross Domestic Product at purchaser prices, that is, the sum of the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.
  - Total vehicle fleet (vehicles): Is the number of road motor vehicles registered at a given date in a country and licensed to use roads open to public traffic.
  - Discount Rate (percent): Is the planning discount rate adopted by the country.
  - Traffic Growth Rate (percent): Is the expected future average annual traffic growth rate in the country.
- Capital Road Works Unit Costs.

The output summary network statistics and network monitoring indicators include the following.

- **Length & Utilization**: Presents the network length and network utilization distribution by network type and road surface type;
- **Asset Value**: Presents the network maximum (replacement) asset value and network current asset value distribution by network type and road surface type;
- **Roughness**: Presents the average network roughness weighted by kilometer and the average network roughness weighted by vehicle-km by network type and road surface type;
- **Network Distribution Charts**: Presents network distribution charts of the network length, utilization, and maximum and current asset value by network type and road surface type.
- **Network Monitoring Indicators**: Presents road network monitoring indicators, e.g.:

  (a) Network Density

  - Road network per thousand land area
  - Road network per thousand total population

- Road network per thousand rural population
- Road network per thousand vehicles
- Road network per $ million GDP

(b) Network Condition

- Percentage of road network in good and fair condition
- Percentage of paved roads in good and fair condition
- Percentage of paved roads with roughness 4 m/km IRI or less
- Paved roads average roughness weighted by kilometer
- Paved roads average roughness weighted by vehicle-km
- Percentage of unpaved roads that are all-weather roads

(c) Network Standards

- Percentage of unpaved roads with 30 AADT or less
- Percentage of unpaved roads with 300 AADT or more
- Percentage of paved roads with 300 AADT or less
- Percentage of paved roads with 10,000 AADT or more

(d) Network Utilization

- Annual motorized vehicle utilization
- Annual freight carried over road network
- Annual passengers carried over road network
- Average network annual average daily traffic

(e) Network Asset

- Current Road asset value
- Current Road asset value as a share of maximum road asset value
- Current Road asset value as a share of GPD

The evaluation of network performance is carried out based on a representative road network matrix. The national road network was divided into 'condition-traffic' category families as surrogate units to the country's or organization's road network. A 'condition-traffic' family contains segments of roads of approximately the same condition index. The road network matrix is comprised of combined homogeneous segments (length of road network for which traffic, road condition, and surface type attributes are constant) into a matrix of representative sections. Each of the representative sections in the matrix represents a large number of real sections (often thousands of kilometers of roads) scattered around the road network, each of which has similar characteristics of traffic, condition, and surface type. Instead of each of the constituent sections being analyzed separately, just the representative section (whose length is the sum of the constituent sections) is analyzed. The user-defined rehabilitation and maintenance standards are applied to the road network matrix to derive Road Agency Costs derived from input capital and recurrent works costs. The input costs for the various standards are financial costs.

RUCKS Model

The RUCKS model is another tool developed by the World Bank designed to compute unit road user costs adopting the Highway Development and Management Model (HDM-4), version 1.3, road user effects equations. The RUCKS model is not used to derive Road User Costs (RUC) for input to RONET, but rather calibration coefficients for calculating RUC.

RONET computes road user costs as a function of road roughness and as such there is a need to define the relationship between unit road user costs and roughness for a particular country. This relationship takes the form of the following cubic polynomial.

Unit Road User Costs ($/vehicle-km) = a0 + a1*IRI + a2*IRI^2 + a3*IRI^3

Where 'Unit Road User Costs' represent the unit road use costs of the vehicle fleet, 'IRI' is the roughness of the road, in IRI, m/km, and a0, a1, a2, and a3 are coefficients of the cubic polynomial.

To derive country-specific coefficients, users have to input country-specific vehicle fleet costs in the Vehicle Fleet datasheet, e.g., economic prices for new vehicle, fuel, and lubricants, as well as characteristics, e.g., annual kilometers driven, working hours, number of passengers, and gross vehicle weight. The required coefficients are available in the 'roughness sensitivity' worksheet.

SPECIFIC RONET INPUTS

This section presents the RONET input data for Uganda PAM. It is based on the most current available data on road condition, traffic, inventory, and vehicle operating cost inputs as well as relevant country statistics from national archives.

Country Data

The basic country statistics as obtained from statistical abstracts is presented in Table 1.

Table 1: Basic Country Statistics for 2007

Attribute	Value
Land area (sq km)	197,097
Total population (million persons)	28.000
Rural population (million persons)	22.40
GDP ($ Billion)	8.502
Total vehicle fleet (vehicles)	278,595
Discount Rate (percent)	12
Traffic Growth Rate (percent)	5

The traffic growth rate of 5 percent was obtained from recent projections of traffic growth by various feasibility studies and more, so is approximately equal to the current GDP growth rate.

Road Network Management

The first basic configuration option is to define the management responsibility for the various road categories in Uganda because the major outputs such as the required resources and other indicators will be distributed by these management types. The management types for the four road categories in Uganda are as indicated in Table 2.

Table 2: Management Types for Road Network

Management Type	Network Type	Terrain Type	Environment Type
Ministry of Works	National Roads	Hilly	Sub-humid, Sub-tropical Hot
Local Governments	District Roads		
LC3	Community Access Roads		
None	Unclassified		
Urban Authorities	Urban Roads		

Unit Costs

The basic country unit costs used in this analysis were based on the most recent returned bid rates for applicable works as well as information from the World Bank's ROad Costs Knowledge System (ROCKS). The input costs comprise capital (Periodic Maintenance, Rehabilitation, and New Construction) and recurrent (Annual Works on Carriageway and Annual Works outside Carriageway) costs.

The input unit costs of the capital works are based on national averages from recently received bids which are also a function of the road category due to different design standards. It is worth noting that for Uganda, the secondary and tertiary road network represents more than 35 percent and 46 percent of the entire national road network respectively. Unless due consideration is made of the capital works unit costs for this part of the national road network, their sheer size can inordinately bias the country's road network asset valuation. For Uganda's case, due to the absence of any historical unit costs for tertiary roads and the fact that most are tracks, only nominal values were input as capital costs.

The recurrent road works unit costs (in US$ per kilometer per year for a two lane road) vary by current road condition and road category. They comprise the sum of the annual road works done on the carriageway (e.g., grading, pothole patching, etc.) and the annual road works done outside the carriageway (e.g., shoulder repairs, grass mowing, etc.). Contrary to best practice, the recurrent unit costs for roads in the poor to very poor category are highest compared to other condition categories. Ideally, roads in the poor to very poor condition categories would require rehabilitation (and not maintenance), thus spending maintenance resources on them would be like throwing "good money after bad money".

Special attention was paid to inputs for Capital Costs because they have a significant impact on the road asset valuations, while the recurrent costs can affect the maintenance costs estimates. The unit costs used for this analysis are provided in Annex 1.

Traffic Characteristics and Levels

Typical traffic levels have been derived from the most recent traffic data available in the Ministry and analyzed to obtain average traffic compositions for the vehicle categories under considerations. For the less trafficked road categories of less than 200 vehicles per day, these compositions were adjusted to reflect less of the heavy vehicle categories such as the articulated and heavy trucks.

The traffic compositions as well as other vehicle characteristics such as Equivalent Standard Axles (ESA) and Payloads for the various vehicle categories are presented in Annex 2. Again, the ESA and payload information was obtained from recent feasibility studies that have used HDM-4.

In order to calibrate RONET for country-specific road user costs, the RUCKS system was used with inputs for vehicle fleets applicable to Uganda as presented in Annex 2.

National Road Network Inventory

The most current road network matrix is summarized in tables 3, 4, 5, and 6:

Table 3: National Road Network Distribution

Road Category / Attribute	National Roads (Primary)	District Roads (Secondary)	Community Access Roads (Tertiary)	Urban Roads
Size (km)	10,820	26,751	35,000	3,579
Percentage	**14**	**35**	**46**	**5**

Table 4: National Road Network Condition Distribution

Road Category / Condition	National Roads (Primary)	District Roads (Secondary)	Community Access Roads (Tertiary)	Urban Roads	Overall percentage
Very Good	657			301	1
Good	1,533			701	3
Fair	6,688	2,809	10,000	901	27
Poor	777	9,577	10,000	670	28
Very Poor	1,165	14,365	15,000	1,006	41

Table 5: National Road Network Distribution by Surface Type

Road Category / Surface Type	National Roads (Primary)	District Roads (Secondary)	Community Access Roads (Tertiary)	Urban Roads	Overall percentage
Asphalt	89				0.12
Surface Treatment	2,588			314	3.81
Gravel	8,143	8,025		1,242	22.86
Earth		18,726	35,000	2,023	73.21

Table 6: National Road Network Distribution by Traffic Levels

Road Category / Traffic Level	National Roads (Primary)	District Roads (Secondary)	Community Access Roads (Tertiary)	Urban Roads	Overall percentage
Traffic I	584	13,108	35,000	31	64
Traffic II	4,312	7,223		1,012	16
Traffic III	2,917	5,484		1,977	14
Traffic IV	2,788	936		559	6
Traffic V	219				0.03

Definition of Standards

The model allows the user to define up to eight road works standards, including one (1) custom standard to be explained later, comprising maintenance and rehabilitation interventions. The standards defined for Uganda for the different surface types are mostly the software default ones and were as follows for the different road surface types:

Surface Treated Roads Capital Works Standards

The works standards for these roads are both scheduled (specified in terms of time interval) and condition responsive (specified in terms of roughness <IRI, m/km> thresholds) to apply recommended road works. The following standards in Table 7 were used:

Table 7: Surface Treated Roads Works Standards

Roughness Range and Required Road Work						
Scenario		IRI<=4.0 Reseal	4.0<IRI<=6.0 Reseal	6.0<IRI<=8.0 Strengthening	8.0<IRI<=10.0 Reconstruction	10<IRI Reconstruction
Code	Standard Name	Time Interval (years)		Roughness Threshold (IRI)		
A	Very High Standard	7	7	6.00	8.00	10.00
B	High Standard	9	9	6.50	8.50	10.50
C	Medium Standard	11	11	7.00	9.00	11.00
D	Low Standard	13	13	7.50	9.50	11.50
E	Very Low Standard	15	15	8.00	10.00	12.00
F	Do Minimum	99	99	8.00	10.00	14.00
G	Do Nothing	99	99	8.00	10.00	25.00

Gravel Roads Capital Works Standards

The capital works standards for these roads are defined in terms of the postponement of required interventions, in this case regraveling, beyond the optimum time as predicted by the gravel loss deterioration equations in the model. The 'Very High Standard' usually has a 'zero' delay, and this delay increases progressively as the standards decrease as shown in Table 8.

Table 8: Regraveling postponement

Scenario		Postponement
Code	Name	(years)
A	Very High Standard	0
B	High Standard	1
C	Medium Standard	2
D	Low Standard	3
E	Very Low Standard	4
F	Do Minimum	5
G	Do Nothing	999

Further to the above, the user also has to specify the average yearly roughness for each of the above standards mainly based on his experience. This roughness will mainly be used in the estimation of Road User Costs. The following assumptions in Table 9 were used in respect of this:

Table 9: Average Yearly Roughness Level (IRI - m/km)

Scenario		Roughness
Code	Name	(IRI)
A	Very High Standard	5
B	High Standard	7
C	Medium Standard	11
D	Low Standard	16
E	Very Low Standard	20
F	Do Minimum	22
G	Do Nothing	25

Earth Roads Capital Works Standards

The definition of standards for earth roads is similar to that for gravel roads and the following standards in tables 10 and 11 were used.

Table 10: Regraveling postponement

Scenario		Interval
Code	Name	Years
A	Very High Standard	2
B	High Standard	4
C	Medium Standard	6
D	Low Standard	8
E	Very Low Standard	10
F	Do Minimum	12
G	Do Nothing	999

Table 11: Average Yearly Roughness (IRI, m/km)

Scenario		Roughness
Code	Name	(IRI)
A	Very High Standard	7
B	High Standard	9
C	Medium Standard	13
D	Low Standard	18
E	Very Low Standard	22
F	Do Minimum	24
G	Do Nothing	25

Recurrent Maintenance Works

The recurrent road works unit costs are defined as the annual carriageway and off-carriageway works implemented by the road agency. These interventions, which are in most cases a function of road condition, should reflect local practices and policies. The input costs for these activities are for the 'Very High Standard', and the model takes account of the lower maintenance by applying 'recurrent cost multipliers'. In this analysis, the default multipliers used are as shown in Table 12.

Table 12: Recurrent Cost Multipliers

Scenario		Surface Type				
Code	Name	Concrete	Asphalt	S.T.	Gravel	Earth
A	Very High Standard	1.00	1.00	1.00	1.00	1.00
B	High Standard	0.90	0.90	0.90	0.90	0.90
C	Medium Standard	0.75	0.75	0.75	0.75	0.75
D	Low Standard	0.50	0.50	0.50	0.50	0.50
E	Very Low Standard	0.25	0.25	0.25	0.25	0.25
F	Do Minimum	0.10	0.10	0.10	0.10	0.10
G	Do Nothing	0.00	0.00	0.00	0.00	0.00

In essence, the use of a lower standard of maintenance would come at a lower cost, hence the application of the above multipliers.

Custom Standard

The design of the model is cognizant of the fact that most countries do not apply a uniform works standards on all road network categories, and this is why a provision was made for a 'custom standard'. This custom standard allows the user to define the 'desirable' mix of standards to be applied to different road categories, taking into account the organization's policy, functional importance, funding available, realities on the ground, etc.

The definition of the custom standard for Uganda as shown in Table 13.

Table 13: Custom Standard for Uganda

Select a Standard per Network Type			
Code	Network Type	Standard Name	Standard No.
R	National Roads	Medium Standard	3
S	District Roads	Low Standard	4
T	Community Access Roads	Do Minimum	6
U	Unclassified	Do Nothing	7
V	Urban Roads	Medium Standard	3

From the foregoing, the Medium Standard was applied to the national (primary) and urban roads, with the Low Standard for district (secondary) roads and Do Minimum for community access (tertiary) roads. The choice of these standards was based on the functional importance of the roads under consideration, and the potential financial requirements of the standards.

RONET OUTPUTS

RONET provides many useful reports under the following themes:

- Length & Utilization
- Asset Value
- Roughness
- Network Distribution Charts
- Network Monitoring Indicators
- Network Performance
- Road Works Distribution
- Road Works Summary

Network Monitoring Indicators

The road network monitoring indicators are presented in Annex 3, but some of the key outcome indicators include:

- Network Density

Monitoring Indicator	Unit	Overall
Road network per thousand land area	km/1000 sq km	386.36
Road network per thousand total population	km/1000 persons	2.720
Road network per thousand rural population	km/1000 persons	3.400
Road network per thousand vehicles	km/1000 vehicles	273.34
Road network per $ million GDP	km/million $	8.96

- Network Condition

Monitoring Indicator	Unit	Overall
Percentage of road network in good and fair condition	percent	31.0
Percentage of paved roads in good and fair condition	percent	88.2
Paved roads average roughness weighted by km	IRI, m/km	5.23
Percentage of unpaved roads that are all-weather roads	percent	25.4

Key information from this table is that less than one-third of the entire national road network is in a maintainable state.

- Network Standards

Monitoring Indicator	Unit	Overall
Percentage of unpaved roads with 300 AADT or more	percent	4.5
Percentage of paved roads with 300 AADT or less	percent	13.5
Percentage of paved roads with 10,000 AADT or more	percent	7.3

From the foregoing, 4.5 percent of the gravel road network is uneconomic to maintain in this state and needs upgrading to bituminous surface treatment.

- Network Utilization

Monitoring Indicator	Unit	Overall
Annual motorized vehicle utilization	million vehicle-km	5,305
Annual freight carried over road network	million ton-km	22,409
Annual passengers carried over road network	million pass-km	30,919
Average network annual average daily traffic	vehicles/day	191

Key subordinate indicators show that 82 percent, 7 percent, 1.2 percent, and 9.9 percent of the total national travel occurs on the national, district, community access, and urban roads respectively. At the same time, 6.2 percent, 64.8 percent, 19.8 percent, and 9.2 percent of the total travel takes place on asphalt, surface treatment, gravel, and earth surface types respectively.

This information can be very handy in making decisions on the allocations of resources from the Road Fund to the various road categories or surface type.

- Network Asset

Monitoring Indicator	Unit	Overall
Current Road asset value	million $	1,856.4
Current Road asset value as a share of maximum/replacement road asset value	percent	76.0
Current Road asset value as a share of GPD	percent	21.8

Subordinate indicators show that the share of the asset value by the national, district, community access, and urban roads is 73 percent, 15 percent, 1 percent, and 10 percent respectively. At the same time, the distribution of the asset value between asphalt, surface treatment, gravel, and earth surface types is 2.6 percent, 56.6 percent, 36.3 percent, and 4.6 percent respectively.

All the above indicators are useful to road organizations for determining policy directions such as increasing the percentage of roads in fair to good condition, reducing the percentage of highly trafficked unpaved roads, etc.

Performance Assessment

Road Agency Requirements

Figure 1 below shows the road agency requirements for the entire road network by applying the alternative eight (8) standards:

Figure 1: Road Agency Costs (Total Costs 1-20 years)

Road Agency Costs (Total Costs Years 1-20)

Network	Standard	Road Agency Costs (M$)	Road Agency Costs (M$/year)	Scenario (%)
Total Network	Very High Standard	2,506	125	100%
	High Standard	2,133	107	85%
	Medium Standard	2,323	116	93%
	Low Standard	1,932	97	77%
	Very Low Standard	1,529	76	61%
	Do Minimum	791	40	32%
	Do Nothing	0	0	0%
	Custom Standard	2,110	105	84%

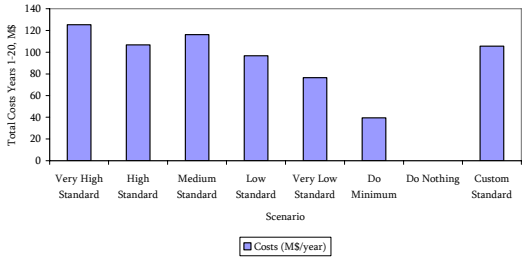
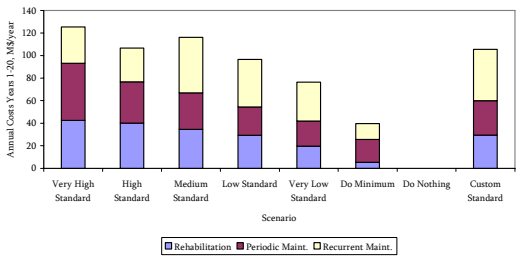


Figure 2: Annual Rehabilitation and Maintenance Requirements

Network	Standard	Annual Costs Years 1-20, M$/year			
		Rehabilitation	Periodic Maint.	Recurrent Maint.	Road Agency
Total Network	Very High Standard	42	51	32	125
	High Standard	40	36	30	107
	Medium Standard	35	32	49	116
	Low Standard	29	25	42	97
	Very Low Standard	20	22	34	76
	Do Minimum	5	20	14	40
	Do Nothing	0	0	0	0
	Custom Standard	29	31	46	105



The breakdown of the above road agency costs into rehabilitation and maintenance costs per year is reflected in Figure 2.

Given that currently the government expends approximately US$55 million per year for maintenance of national, district, and urban roads, the above results in Figure 1 indicate that Uganda can only afford to apply the 'Do Minimum - Very Low Standard'. In fact the current expenditure on maintenance is approximately 50 percent of the desirable needs reflected by 'custom standard' which goes to show the extent of under-funding for road maintenance.

It is worth noting that as long as no additional resources are provided to address the 'rehabilitation' backlog equivalent to around US$20 million per year, the situation concerning poor road conditions and inadequacy of the maintenance budget is expected to become more acute.

Consequences of Various Standards

The consequences of applying the eight (8) alternative rehabilitation and maintenance standards analyzed using RONET are presented below:

Figure 3: Society Costs (Total Costs 1 - 20 years)

Network	Standard	Total Costs Years 1-20, M$		
		Road Agency	Road Users	Society
Total Network	Very High Standard	2,506	54,165	56,671
	High Standard	2,133	55,860	57,993
	Medium Standard	2,323	60,284	62,607
	Low Standard	1,932	67,199	69,131
	Very Low Standard	1,529	76,697	78,226
	Do Minimum	791	79,392	80,183
	Do Nothing	0	82,907	82,907
	Custom Standard	2,110	62,450	64,560

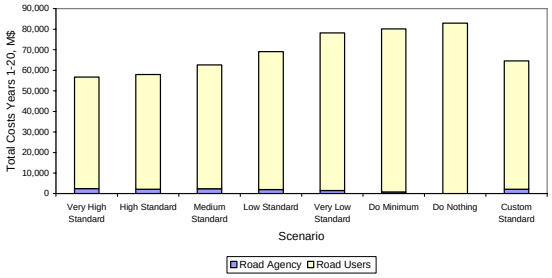


Figure 4: Road User Marginal Costs of Agency Costs Deficit

Costs Comparison with Very High Standard				
Network	Standard Scenario	Total Costs Years 1-20, M$ Agency Deficit	Users Costs Increase	User Costs Increase per Agency Deficit
Total Network	Very High Standard	0	0	0.00
	High Standard	373	1,695	4.54
	Medium Standard	183	6,119	33.40
	Low Standard	574	13,034	22.69
	Very Low Standard	977	22,532	23.07
	Do Minimum	1,715	25,227	14.71
	Do Nothing	2,506	28,743	11.47
	Custom Standard	396	8,285	20.90

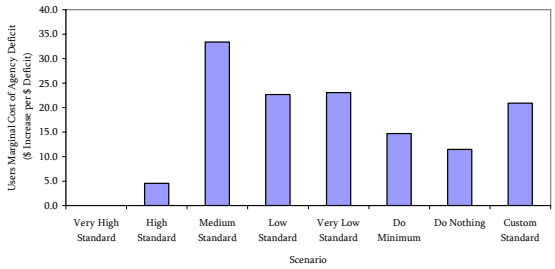
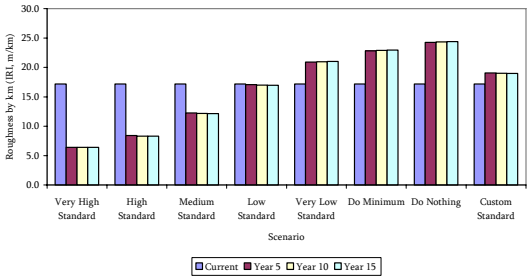


Figure 5: Road Network Roughness weighted by Km

Network	Standard	Roughness by Km (IRI, mm/km)			
		Current	Year 5	Year 10	Year 15
Total Network	Very High Standard	17.2	6.4	6.4	6.4
	High Standard	17.2	8.4	8.3	8.3
	Medium Standard	17.2	12.3	12.2	12.2
	Low Standard	17.2	17.1	17.0	17.0
	Very Low Standard	17.2	20.9	21.0	21.0
	Do Minimum	17.2	22.8	22.9	22.9
	Do Nothing	17.2	24.3	24.3	24.4
	Custom Standard	17.2	19.1	19.0	19.0



From the foregoing and based on the current available funding levels of US$55 million p.a., we can presume that the estimates of the consequences of this inadequate funding (between the 'Very Low Standard' and 'Do Minimum') is as follows:

- Total Society Costs are between US$78.2 and 80.2 billion;
- Road Users are currently spending between US$14.71 – 23.07 for every US$1.00 not provided for the optimum 'Very High Standard';
- The condition of the entire road system will deteriorate further with the current funding levels from the present average IRI of 17.2 to road conditions of 21.0 – 22.9 IRI in 15 years time;
- The rehabilitation backlog is estimated at US$20 million per year, and as long as no special dispensation is made for this requirement, the available maintenance budget will continue to be inadequate as some of it is used to address rehabilitation emergencies. Subsequently, the maintenance and rehabilitation backlog will increase.

BENEFITS OF RONET ANALYSIS

Amongst the benefits of being able to utilize the above model are the following:

- The tool is an Excel spreadsheet that is easy to use and the analysis takes a very short time;
- Decision makers have more information on the network to guide decisions on current status, policy, strategy, funding, etc. with a limited dataset and within a shorter time than previously possible;
- Inputs (especially inventory of road networks) are easily acquired from budget reports while Vehicle Operating and Works Costs are available from recent feasibility studies, policy studies, World Bank ROCKS and RUCKS models, etc.;
- Outputs can be used to support arguments by government or organizations for particular policies or initiatives supported with appropriate information.

Drawbacks

- The summary or aggregate nature of the inputs to the model are susceptible to inaccuracies which can, in turn, distort the validity of outputs;
- Accurate traffic and condition data are not available especially for the secondary and tertiary networks making it necessary to make assumptions;
- The model does not yet carry out optimization of standards for budget of benefit maximization;
- Comprehensive sensitivity analysis has not yet been carried out to determine the impact elasticity of inputs for, say, maintenance standards; RUCKS outputs coefficients (currently based on paved roads); capital and recurrent costs for tertiary roads for which data is not usually available; etc.;
- The model does not yet model the impacts of overloading on network condition and agency requirements which is a very vital piece of information for road managers, etc.

CONCLUSION

The absence of simple operational road management systems to articulate the consequences of road-funding trends to politicians and financiers in a robust manner has often failed the Ministry in winning its argument for more funding or even justifying the adequacy/inadequacy of currently available resources. Complex models such as HDM-4, whereas more accurate, have tended to alienate decision makers because of the complexity of their outputs. The RONET model provides a simple approach to the assessment of road requirements together with the consequences of the various standards.

Whereas insufficient funding for the national road network has been the case for some time since 1994, it was not possible until the introduction of the PAM and now the RONET model to carry out rapid assessments of the impacts of government funding decisions. This model is intended to make it possible for road managers, consultants, and financiers to carry out rapid macro assessments of country or organization networks deriving vital information to guide decision making.

The RONET model is still under development and many more features that are useful to future users will be added in the future. The development of the RONET model is funded by the Sub-Saharan Africa Transport Policy Program (SSATP), which is a collaborative framework set up to improve transport policies and strengthen institutional capacity in the Africa region. The model development supervisor is Olav E. Ellevset, Sr. Transport. Specialist, World Bank, and the author is Rodrigo Archondo-Callao, Highway Engineer, World Bank. The model development is benefiting from contributions and beta testing from Uganda, Ghana, Mozambique, and Tanzania.

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ANNEXES

ANNEX 1: CAPITAL AND RECURRENT ROAD WORKS COSTS

	Two-Lane Unit Costs of Road Works ($/km)					Thickness	Reconstruction Characteristics	
Road Work	National Roads	District Roads	Community Access Roads	Unclassified	Urban Roads	(mm)	Structural No	Roughness (IRI)
Preventive Treatment	5,000	4,000	3,000	3,000	5,000			
Resurfacing (Overlay)	45,000	36,000	27,000	27,000	45,000	50		
Strengthening (Overlay)	130,000	104,000	78,000	78,000	130,000	100		
Reconstruction	230,000	184,000	138,000	138,000	230,000		3	2.0
New Construction	350,000	280,000	210,000	210,000	350,000			
Preventive Treatment	12,500	8,500	5,000	3,000	12,500			
Resurfacing (Overlay)	45,000	25,000	27,000	27,000	45,000	50		
Strengthening (Overlay)	130,000	75,000	78,000	78,000	130,000	100		
Reconstruction	350,000	250,000	138,000	138,000	350,000		3	2.0
New Construction	600,000	400,000	210,000	210,000	600,000			
Preventive Treatment	10,000	7,500	5,000	1,000	10,000			
Resurfacing (Reseal)	25,000	25,000	15,000	15,000	25,000	12		
Strengthening (Overlay)	75,000	75,000	35,000	35,000	75,000	50		
Reconstruction	250,000	250,000	75,000	75,000	250,000		3	4
New Construction	400,000	400,000	125,000	125,000	400,000			
Spot Regravelling	5,000	5,000	2,500	625	5,000			
Regravelling	10,000	10,000	5,000	1,250	10,000	200		
Partial Reconstruction	25,000	25,000	13,000	2,500	25,000			
Full Reconstruction	40,000	40,000	20,000	5,000	40,000			
New Construction	60,000	60,000	30,000	8,750	60,000			
Spot Repairs	1,000	500	125	125	1,000			
Heavy Grading	2,500	1,000	250	250	2,500			
Partial Reconstruction	5,000	2,500	625	625	5,000			
Full Reconstruction	6,500	4,500	1,125	1,125	6,500			
New Construction	10,000	6,000	1,500	1,500	10,000			

	Two-Lane Unit Costs of Road Works ($/km-year)				
Road Work	National Roads	District Roads	Community Access Roads	Unclassified	Urban Roads
Recurrent Maintenance	1,000	750	500	500	1,000
Recurrent Maintenance	1,250	938	625	625	1,250
Recurrent Maintenance	1,500	1,125	750	750	1,500
Recurrent Maintenance	1,750	1,313	875	875	1,750
Recurrent Maintenance	2,000	1,500	1,000	1,000	2,000
Recurrent Maintenance	1,875	750	500	500	1,875
Recurrent Maintenance	1,875	938	625	625	1,875
Recurrent Maintenance	2,500	1,125	750	750	2,500
Recurrent Maintenance	6,250	1,313	875	875	6,250
Recurrent Maintenance	12,500	1,500	1,000	1,000	12,500
Recurrent Maintenance	1,500	1,125	500	100	1,500
Recurrent Maintenance	1,500	1,125	625	100	1,500
Recurrent Maintenance	2,000	1,500	750	100	2,000
Recurrent Maintenance	5,000	3,750	875	100	5,000
Recurrent Maintenance	10,000	7,500	1,000	200	10,000
Recurrent Maintenance	1,500	1,125	563	100	1,500
Recurrent Maintenance	1,500	1,125	563	100	1,500
Recurrent Maintenance	3,500	2,625	1,313	100	3,500
Recurrent Maintenance	4,500	3,375	1,688	100	4,500
Recurrent Maintenance	7,500	5,625	2,813	100	7,500
Recurrent Maintenance	150	113	50	50	150
Recurrent Maintenance	175	131	50	50	175
Recurrent Maintenance	200	150	50	50	200
Recurrent Maintenance	250	188	100	100	250
Recurrent Maintenance	300	225	100	100	300

ANNEX 2: TRAFFIC LEVELS AND CHARACTERISTICS

Traffic Levels Characteristics

				Traffic Level	T1	T2	T3	T4	T5	T6	T7	T8	T9
				Average Annual Daily Traffic (AADT)	5	20	65	200	650	2,000	6,500	20,000	65,000
Vehicle Type	Equivalent Standard Axles (ESA/vehicle)	Payload (Tons/vehicle)	Passengers (persons/vehicle)		Typical Traffic Composition (%)								
					(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Motorcycle	0.00	0.20	0.2		22.9%	22.9%	22.9%	22.9%	22.9%	22.9%	22.9%	22.9%	22.9%
Car Small	0.00	1.45	2		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Car Medium	0.00	1.45	2		19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%	19.4%
Delivery Vehicle	0.00	2.50	7.3		15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Four-Wheel Drive	0.00	2.50	3.8		6.7%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%	6.7%
Truck Light	0.50	4.00	6.6		3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Truck Medium	3.00	10.60	5.4		9.7%	9.7%	9.7%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Truck Heavy	7.00	22.60	0		0.0%	0.0%	0.0%	2.1%	2.1%	2.1%	2.1%	2.1%	2.1%
Truck Articulated	8.50	40.30	0.4		0.0%	0.0%	0.0%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
Bus Light	0.00	2.60	13.8		22.1%	22.1%	22.1%	22.1%	22.1%	22.1%	22.1%	22.1%	22.1%
Bus Medium	0.70	4.80	30		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bus Heavy	2.50	12.20	49		1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
				Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
				ESA Loading (M ESA/year)	0.001	0.002	0.008	0.049	0.160	0.491	1.597	4.913	15.967
				Payload/Vehicle (tons/vehicle)	2.74	2.74	2.74	4.36	4.36	4.36	4.36	4.36	4.36
				Passengers/Vehicle (persons/vehicle)	6.14	6.14	6.14	5.80	5.80	5.80	5.80	5.80	5.80

Vehicle Fleet Unit Road User Costs Relationship to Roughness

		Traffic Level	T1	T2	T3	T4	T5	T6	T7	T8	T9
		Average Annual Daily Traffic (AADT)	5	20	65	200	650	2,000	6,500	20,000	65,000
Unit Road User Costs ($/veh-km) = a0 + a1*IRI + a2*IRI^2 + a3*IRI^3	a0 coefficient		0.29686	0.29686	0.29686	0.29686	0.29686	0.29686	0.29790	0.30856	0.58094
	a1 coefficient		-0.00876	-0.00876	-0.00876	-0.00876	-0.00876	-0.00876	-0.00892	-0.01066	0.00380
	a2 coefficient		0.00232	0.00232	0.00232	0.00232	0.00232	0.00232	0.00236	0.00268	0.00046
	a3 coefficient		-0.00005	-0.00005	-0.00005	-0.00005	-0.00005	-0.00005	-0.00005	-0.00006	-0.00001

ANNEX 3: NETWORK MONITORING INDICATORS

Monitoring Indicator		National Roads	District Roads	mmunity Access Ro	Unclassified	Urban Roads	Overall
Network Length							
Road network length	km	10,820.0	26,751.0	35,000.0	0.0	3,579.0	76,150.0
Road network length that is paved	km	2,677.0	0.0	0.0	0.0	314.0	2,991.0
Road network length that is unpaved	km	8,143.0	26,751.0	35,000.0	0.0	3,265.0	73,159.0
Road network length that is paved	%	24.7	0.0	0.0		8.8	3.9
Network Density							
Road network per thousand land area	km/1000 sq km	54.897	135.725	177.578	0.000	18.159	386.358
Road network per thousand total population	km/1000 persons	0.386	0.955	1.250	0.000	0.128	2.720
Road network per thousand rural population	km/1000 persons	0.483	1.194	1.563	0.000	0.160	3.400
Road network per thousand vehicles	km/1000 vehicles	38.838	96.021	125.630	0.000	12.847	273.336
Road network per $ million GDP	km/million $	1.273	3.146	4.117	0.000	0.421	8.957
Network Condition							
Percentage of road network in good and fair condition	%	82.1	10.5	28.6		53.2	31.0
Percentage of paved roads in good and fair condition	%	88.1				89.2	88.2
Percentage of paved roads with roughness 4 m/km IRI or less	%	26.8				69.1	31.2
Paved roads average roughness weighted by km	IRI, m/km	5.30				4.69	5.23
Paved roads average roughness weighted by vehicle-km	IRI, m/km	5.25				4.68	5.22
Percentage of unpaved roads that are all-weather roads	%	80.1	40.7	0.0		36.4	25.4
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	2.6	70.0	100.0		0.0	73.7
Percentage of unpaved roads with 300 AADT or more	%	29.5	0.0	0.0		28.1	4.5
Percentage of paved roads with 300 AADT or less	%	13.9				9.9	13.5
Percentage of paved roads with 10,000 AADT or more	%	8.2				0.0	7.3
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	4,344	372	64	0	526	5,305
Annual freight carried over road network	million ton-km	18,777	1,223	175	0	2,234	22,409
Annual passengers carried over road network	million pass-km	25,226	2,240	392	0	3,060	30,919
Average network annual average daily traffic	vehicles/day	1,100	38	5		402	191
Network Asset							
Current Road asset value	million $	1,360.2	277.3	26.9	0.0	192.1	1,856.4
Current Road asset value as a share of maximum road asset value	%	86.2	46.7	51.2		87.2	76.0
Current Road asset value as a share of GPD	%	16.0	3.3	0.3	0.0	2.3	21.8

Consolidated Data from All Four Countries

ANNEX 1: CAPITAL ROAD WORKS UNIT COSTS ALL COUNTRIES

Unit Costs used for RONET Calibration for Mozambique, Tanzania, Uganda and Ghana March 2007

Capital Road Works Unit Costs			Ghana								Mozambique							
			Two-Lane Unit Costs of Road Works ($/km)					Thickness	Construction Characteris		Two-Lane Unit Costs of Road Works ($/km)					Thickness	Construction Characteris	
Surface Type	Current Condition	Road Work	Primary	Secondary	Tertiary	Un-Eng.	Urban	(mm)	Structural	Roughness (IF	Primary	Secondary	Tertiary	Vicinal	Urban	(mm)	Structural	Roughness (IF
Concrete	Good Condition	Preventive Treatment	5,000								0	0	0	0	0			
	Fair Condition	Resurfacing (Overlay)	130,000					50			0	0	0	0	0	50		
	Poor Condition	Strengthening (Overlay)	180,000					100			0	0	0	0	0	100		
	Very Poor Condition	Reconstruction	300,000						3	2.0	0	0	0	0	0		3	2.0
	No Road	New Construction	450,000								0	0	0	0	0			
Asphalt Mix	Good Condition	Preventive Treatment	2,500	2,500			3,000				9,500	0	0	0	0			
	Fair Condition	Resurfacing (Overlay)	110,000	110,000			120,000	50			71,500	0	0	0	0	50		
	Poor Condition	Strengthening (Overlay)	170,000	170,000			180,000	80			250,000	0	0	0	0	100		
	Very Poor Condition	Reconstruction	250,000	250,000			300,000		3	2.0	400,000	0	0	0	0		3	2.0
	No Road	New Construction	400,000	400,000			450,000				650,000	0	0	0	0			
Surface Treatment	Good Condition	Preventive Treatment	1,800	1,800	1,000		1,800				3,510	1,600	1,200	1,200	0			
	Fair Condition	Resurfacing (Reseal)	25,000	25,000	22,000		29,000	12			32,500	20,000	18,000	18,000	0	12		
	Poor Condition	Strengthening (Overlay)	60,000	60,000	45,000		60,000	80			107,310	72,000	60,000	60,000	0	80		
	Very Poor Condition	Reconstruction	160,000	160,000	110,000		160,000		2	2.5	300,000	180,000	140,000	140,000	0		2	2.5
	No Road	New Construction	220,000	220,000	180,000		250,000				450,000	400,000	300,000	300,000	0			
Gravel	Good Condition	Spot Regravelling	0	900	900	400	900				3,500	2,400	2,100	1,900	0			
	Fair Condition	Regravelling	0	12,000	12,000	6,600	12,000	150			55,000	45,000	20,000	18,000	0	200		
	Poor Condition	Partial Reconstruction	0	18,000	15,000	10,500	18,000				70,000	55,000	30,000	27,000	0			
	Very Poor Condition	Full Reconstruction	0	28,000	21,000	12,000	28,000				85,000	70,000	45,000	32,000	0			
	No Road	New Construction	0	32,000	25,000	15,000	32,000				110,000	90,000	60,000	40,000	0			
Earth	Good Condition	Spot Repairs			500	500	0				0	150	125	100	0			
	Fair Condition	Heavy Grading			600	600	0				0	300	250	125	0			
	Poor Condition	Partial Reconstruction			750	750	0				0	400	350	200	0			
	Very Poor Condition	Full Reconstruction			950	950	0				0	400	350	200	0			
	No Road	New Construction			1,000	1,000	0				0	400	350	200	0			

Capital Road Works Unit Costs			Uganda							Tanzania							
			Two-Lane Unit Costs of Road Works ($/km)					Thickness	Reconstruction Characteristics		Two-Lane Unit Costs of Road Works ($/km)					Thickness	Reconstruction Characteristics	
Surface Type	Current Condition	Road Work	ational Roa	District Road	unity Acces	Unclassified	Urban Road	(mm)	Structural No.	Roughness (IRI)	Trunk	Regional	District	Feeder	Urban	(mm)	Structural No.	Roughness (IRI)
Concrete	Good Condition	Preventive Treatment	5,000	4,000	3,000	3,000	5,000				5,000	4,231	3,462	3,462	5,000			
	Fair Condition	Resurfacing (Overlay)	45,000	36,000	27,000	27,000	45,000	50			45,000	38,077	31,154	31,154	45,000	50		
	Poor Condition	Strengthening (Overlay)	130,000	104,000	78,000	78,000	130,000	100			130,000	110,000	90,000	90,000	130,000	100		
	Very Poor Condition	Reconstruction	230,000	184,000	138,000	138,000	230,000		3	2.0	230,000	194,615	159,231	159,231	230,000		3	2.0
	No Road	New Construction	350,000	280,000	210,000	210,000	350,000				350,000	296,154	242,308	242,308	350,000			
Asphalt Mix	Good Condition	Preventive Treatment	12,500	8,500	5,000	3,000	12,500				5,000	4,231	3,462	3,462	5,000			
	Fair Condition	Resurfacing (Overlay)	45,000	25,000	27,000	27,000	45,000	50			60,000	50,769	41,538	41,538	60,000	50		
	Poor Condition	Strengthening (Overlay)	130,000	75,000	78,000	78,000	130,000	100			100,000	84,615	69,231	69,231	100,000	100		
	Very Poor Condition	Reconstruction	350,000	250,000	138,000	138,000	350,000		3	2.0	300,000	253,846	207,692	207,692	300,000		3	2.0
	No Road	New Construction	600,000	400,000	210,000	210,000	600,000				350,000	296,154	242,308	242,308	350,000			
Surface Treatment	Good Condition	Preventive Treatment	10,000	7,500	5,000	1,000	10,000				2,000	1,692	1,385	1,385	2,000			
	Fair Condition	Resurfacing (Reseal)	25,000	25,000	15,000	15,000	25,000	12			27,000	22,846	18,692	18,692	27,000	12		
	Poor Condition	Strengthening (Overlay)	75,000	75,000	35,000	35,000	75,000	50			80,000	67,692	55,385	55,385	80,000	80		
	Very Poor Condition	Reconstruction	250,000	250,000	75,000	75,000	250,000		3	4	254,000	214,923	175,846	175,846	254,000		2	2.5
	No Road	New Construction	400,000	400,000	125,000	125,000	400,000				304,000	257,231	210,462	210,462	304,000			
Gravel	Good Condition	Spot Regravelling	5,000	5,000	2,500	625	5,000				3,200	2,708	2,215	2,215	3,200			
	Fair Condition	Regravelling	10,000	10,000	5,000	1,250	10,000	200			10,000	8,462	6,923	6,923	10,000	150		
	Poor Condition	Partial Reconstruction	25,000	25,000	13,000	2,500	25,000				14,000	11,846	9,692	9,692	14,000			
	Very Poor Condition	Full Reconstruction	40,000	40,000	20,000	5,000	40,000				25,000	21,154	17,308	17,308	25,000			
	No Road	New Construction	60,000	60,000	30,000	8,750	60,000				56,000	47,385	38,769	38,769	56,000			
Earth	Good Condition	Spot Repairs	1,000	500	125	125	1,000				150	127	104	104	150			
	Fair Condition	Heavy Grading	2,500	1,000	250	250	2,500				615	521	426	426	615			
	Poor Condition	Partial Reconstruction	5,000	2,500	625	625	5,000				7,500	6,346	5,192	5,192	7,500			
	Very Poor Condition	Full Reconstruction	6,500	4,500	1,125	1,125	6,500				15,000	12,692	10,385	10,385	15,000			
	No Road	New Construction	10,000	6,000	1,500	1,500	10,000				40,000	33,846	27,692	27,692	40,000			

ANNEX 2: RECURRENT MAINTENANCE ROAD WORKS UNIT COSTS ALL COUNTRIES

Recurrent Maintenance Works Unit Costs			Ghana					Mozambique					Tanzania					Uganda				
			Two-Lane Unit Costs of Road Works ($/km-year)					Two-Lane Unit Costs of Road Works ($/km-year)					Two-Lane Unit Costs of Road Works ($/km-year)					Two-Lane Unit Costs of Road Works ($/km-year)				
Surface Type	Road Condition	Road Work	Primary	Secondary	Tertiary	Un-Eng.	Urban	Primary	Secondary	Tertiary	Vicinal	Urban	Trunk	Regional	District	Feeder	Urban	ational Roa	District Roa	unity Acces	Unclassified	Urban Roads
Concrete	Very Good	Recurrent Maintenance	1,000					0	0	0	0	0	1,000	750	500	500	1,000	1,000	750	500	500	1,000
	Good	Recurrent Maintenance	1,250					0	0	0	0	0	1,250	938	625	625	1,250	1,250	938	625	625	1,250
	Fair	Recurrent Maintenance	1,500					0	0	0	0	0	1,500	1,125	750	750	1,500	1,500	1,125	750	750	1,500
	Poor	Recurrent Maintenance	1,750					0	0	0	0	0	1,750	1,313	875	875	1,750	1,750	1,313	875	875	1,750
	Very Poor	Recurrent Maintenance	750					0	0	0	0	0	2,000	1,500	1,000	1,000	2,000	2,000	1,500	1,000	1,000	2,000
Asphalt Mix	Very Good	Recurrent Maintenance	900	800	0	0	900	1,100	880	810	730	0	1,000	750	500	500	1,000	1,875	750	500	500	1,875
	Good	Recurrent Maintenance	1,200	1,100	0	0	1,200	1,200	960	880	800	0	1,250	938	625	625	1,250	1,875	938	625	625	1,875
	Fair	Recurrent Maintenance	1,500	1,450	0	0	1,500	1,300	1,040	950	865	0	1,500	1,125	750	750	1,500	2,500	1,125	750	750	2,500
	Poor	Recurrent Maintenance	1,750	1,600	0	0	1,750	975	780	713	649	0	1,750	1,313	875	875	1,750	6,250	1,313	875	875	6,250
	Very Poor	Recurrent Maintenance	750	700	0	0	750	650	520	475	433	0	2,000	1,500	1,000	1,000	2,000	12,500	1,500	1,000	1,000	12,500
Surface Treatment	Very Good	Recurrent Maintenance	600	500	500	0	600	1,000	880	810	730	0	1,000	750	500	500	1,000	1,500	1,125	500	100	1,500
	Good	Recurrent Maintenance	900	625	625	0	900	1,200	960	880	800	0	1,250	938	625	625	1,250	1,500	1,125	625	100	1,500
	Fair	Recurrent Maintenance	1,200	750	750	0	1,200	1,300	1,040	950	865	0	1,500	1,125	750	750	1,500	2,000	1,500	750	100	2,000
	Poor	Recurrent Maintenance	1,500	875	875	0	1,500	975	780	713	649	0	1,750	1,313	875	875	1,750	5,000	3,750	875	100	5,000
	Very Poor	Recurrent Maintenance	600	375	375	0	600	650	520	475	433	0	2,000	1,500	1,000	1,000	2,000	10,000	7,500	1,000	200	10,000
Gravel	Very Good	Recurrent Maintenance	0	375	250	250	375	1,500	1,200	900	800	0	550	413	275	275	550	1,500	1,125	563	100	1,500
	Good	Recurrent Maintenance	0	470	300	300	470	1,500	1,200	900	800	0	675	506	338	338	675	1,500	1,125	563	100	1,500
	Fair	Recurrent Maintenance	0	580	375	375	580	1,500	1,200	900	800	0	800	600	400	400	800	3,500	2,625	1,313	100	3,500
	Poor	Recurrent Maintenance	0	660	440	440	660	1,125	900	675	600	0	925	694	463	463	925	4,500	3,375	1,688	100	4,500
	Very Poor	Recurrent Maintenance	0	290	200	200	290	750	600	450	400	0	1,050	788	525	525	1,050	7,500	5,625	2,813	100	7,500
Earth	Very Good	Recurrent Maintenance	0	0	40	40	0	0	150	100	75	0	275	188	125	125	275	150	113	50	50	150
	Good	Recurrent Maintenance	0	0	60	60	0	0	150	100	100	0	338	235	157	157	338	175	131	50	50	175
	Fair	Recurrent Maintenance	0	0	80	80	0	0	175	125	125	0	400	281	188	188	400	200	150	50	50	200
	Poor	Recurrent Maintenance	0	0	100	100	0	0	175	125	125	0	463	328	219	219	463	250	188	100	100	250
	Very Poor	Recurrent Maintenance	0	0	40	40	0	0	175	125	125	0	525	375	250	250	525	300	225	100	100	300

ANNEX 3: DEFAULT CAPITAL ROAD WORKS UNIT COSTS RONET VERSION 1.0

Capital Road Works Unit Costs

Surface Type	Current Condition	Road Work	Two-Lane Unit Costs of Road Works ($/km)					Thickness (mm)	Reconstruction Characteristics	
			Primary	Secondary	Tertiary	Unclassified	Urban		Structural No.	Roughness (IRI)
Concrete	Good Condition	Preventive Treatment	5,000	4,000	3,000	3,000	5,000			
	Fair Condition	Resurfacing (Overlay)	45,000	36,000	27,000	27,000	45,000	50		
	Poor Condition	Strengthening (Overlay)	130,000	104,000	78,000	78,000	130,000	100		
	Very Poor Condition	Reconstruction	230,000	184,000	138,000	138,000	230,000		3	2.0
	No Road	New Construction	350,000	280,000	210,000	210,000	350,000			
Asphalt Mix	Good Condition	Preventive Treatment	5,000	4,000	3,000	3,000	5,000			
	Fair Condition	Resurfacing (Overlay)	45,000	36,000	27,000	27,000	45,000	50		
	Poor Condition	Strengthening (Overlay)	130,000	104,000	78,000	78,000	130,000	100		
	Very Poor Condition	Reconstruction	230,000	184,000	138,000	138,000	230,000		3	2.0
	No Road	New Construction	350,000	280,000	210,000	210,000	350,000			
Surface Treatmeant	Good Condition	Preventive Treatment	2,000	1,600	1,200	1,200	2,000			
	Fair Condition	Resurfacing (Reseal)	18,000	14,400	10,800	10,800	18,000	12		
	Poor Condition	Strengthening (Overlay)	90,000	72,000	54,000	54,000	90,000	80		
	Very Poor Condition	Reconstruction	180,000	144,000	108,000	108,000	180,000		2	2.5
	No Road	New Construction	300,000	240,000	180,000	180,000	300,000			
Gravel	Good Condition	Spot Regravelling	3,000	2,400	1,800	1,800	3,000			
	Fair Condition	Regravelling	8,000	6,500	5,000	5,000	8,000	150		
	Poor Condition	Partial Reconstruction	17,500	14,000	10,500	10,500	17,500			
	Very Poor Condition	Full Reconstruction	35,000	28,000	21,000	21,000	35,000			
	No Road	New Construction	60,000	48,000	36,000	36,000	60,000			
Earth	Good Condition	Spot Repairs	200	100	10	10	200			
	Fair Condition	Heavy Grading	800	400	50	50	800			
	Poor Condition	Partial Reconstruction	8,000	4,000	500	500	8,000			
	Very Poor Condition	Full Reconstruction	25,000	12,500	1,500	1,500	25,000			
	No Road	New Construction	40,000	20,000	2,500	2,500	40,000			

ANNEX 4: DEFAULT RECURRENT MAINTENANCE ROAD WORKS UNIT COSTS

Recurrent Maintenance Works Unit Costs

Surface Type	Road Condition	Road Work	Two-Lane Unit Costs of Road Works ($/km-year)				
			Primary	Secondary	Tertiary	Unclassified	Urban
Concrete	Very Good	Recurrent Maintenance	1,000	750	500	500	1,000
	Good	Recurrent Maintenance	1,250	938	625	625	1,250
	Fair	Recurrent Maintenance	1,500	1,125	750	750	1,500
	Poor	Recurrent Maintenance	750	563	375	375	750
	Very Poor	Recurrent Maintenance	750	563	375	375	750
Asphalt Mix	Very Good	Recurrent Maintenance	1,000	750	500	500	1,000
	Good	Recurrent Maintenance	1,250	938	625	625	1,250
	Fair	Recurrent Maintenance	1,500	1,125	750	750	1,500
	Poor	Recurrent Maintenance	750	563	375	375	750
	Very Poor	Recurrent Maintenance	750	563	375	375	750
Surface Treatmeant	Very Good	Recurrent Maintenance	1,000	750	500	500	1,000
	Good	Recurrent Maintenance	1,250	938	625	625	1,250
	Fair	Recurrent Maintenance	1,500	1,125	750	750	1,500
	Poor	Recurrent Maintenance	750	563	375	375	750
	Very Poor	Recurrent Maintenance	750	563	375	375	750
Gravel	Very Good	Recurrent Maintenance	500	375	250	250	500
	Good	Recurrent Maintenance	625	469	313	313	625
	Fair	Recurrent Maintenance	750	563	375	375	750
	Poor	Recurrent Maintenance	375	281	188	188	375
	Very Poor	Recurrent Maintenance	375	281	188	188	375
Earth	Very Good	Recurrent Maintenance	150	150	50	50	150
	Good	Recurrent Maintenance	225	225	75	75	225
	Fair	Recurrent Maintenance	300	300	100	100	300
	Poor	Recurrent Maintenance	150	150	50	50	150
	Very Poor	Recurrent Maintenance	150	150	50	50	150

ANNEX 5: NETWORK MONITORING INDICATORS

Ghana – 2005 Beta-files for All Roads

Network Monitoring Indicators

Monitoring Indicator		Primary	Secondary	Tertiary	Un-Eng.	Urban	Overall
Network Length							
Road network length	km	3,564.3	7,612.6	29,085.9	11,776.0	5,574.4	57,613.2
Road network length that is paved	km	2,204.3	3,157.0	1,255.0	0.0	2,421.5	9,037.8
Road network length that is unpaved	km	1,360.0	4,455.6	27,830.9	11,776.0	3,152.9	48,575.4
Road network length that is paved	%	61.8	41.5	4.3	0.0	43.4	15.7
Network Density							
Road network per thousand land area	km/1000 sq km	14.945	31.919	121.953	49.375	23.373	241.565
Road network per thousand total population	km/1000 persons	0.167	0.357	1.363	0.552	0.261	2.699
Road network per thousand rural population	km/1000 persons	0.297	0.635	2.425	0.982	0.465	4.803
Road network per thousand vehicles	km/1000 vehicles	5.456	11.652	44.521	18.025	8.533	88.187
Road network per $ million GDP	km/million $	0.337	0.720	2.752	1.114	0.527	5.451
Network Condition							
Percentage of road network in good and fair condition	%	82.0	70.0	87.1	0.0	46.2	62.8
Percentage of paved roads in good and fair condition	%	95.3	95.3	93.6		69.9	88.3
Percentage of paved roads with roughness 4 m/km IRI or less	%	55.0	71.4	74.1		45.7	60.9
Paved roads average roughness weighted by km	IRI, m/km	4.36	4.54	4.61		5.52	4.77
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.95	4.40	4.58		5.27	4.62
Percentage of unpaved roads that are all-weather roads	%	60.4	52.0	67.3	0.0	28.0	46.9
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	0.0	0.0	44.9	100.0	0.0	50.0
Percentage of unpaved roads with 300 AADT or more	%	35.7	37.6	0.0	0.0	0.0	4.4
Percentage of paved roads with 300 AADT or less	%	0.0	0.0	11.5		0.0	1.6
Percentage of paved roads with 10,000 AADT or more	%	33.7	0.0	0.0		31.1	16.6
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	8,205	2,622	1,096	54	9,172	21,149
Annual freight carried over road network	million ton-km	24,412	8,035	3,771	212	27,279	63,709
Annual passengers carried over road network	million pass-km	56,426	17,260	5,864	198	63,106	142,853
Average network annual average daily traffic	vehicles/day	6,307	944	103	13	4,508	1,006
Network Asset							
Current Road asset value	million $	609.9	780.5	613.5	0.6	719.1	2,723.6
Current Road asset value as a share of maximum road asset value	%	90.9	89.8	83.3	5.0	82.1	86.1
Current Road asset value as a share of GPD	%	5.8	7.4	5.8	0.0	6.8	25.8

Mozambique 2006 Beta-files for Main Roads excluding Urban Roads

Network Monitoring Indicators

Monitoring Indicator		Primary	Secondary	Tertiary	Vicinal	Urban	Overall
Network Length							
Road network length	km	4,908.8	4,899.6	12,689.3	6,740.2	0.0	29,237.9
Road network length that is paved	km	4,359.8	879.6	458.3	12.2	0.0	5,709.9
Road network length that is unpaved	km	549.0	4,020.0	12,231.0	6,728.0	0.0	23,528.0
Road network length that is paved	%	88.8	18.0	3.6	0.2		19.5
Network Density							
Road network per thousand land area	km/1000 sq km	6.284	6.272	16.245	8.629	0.000	37.430
Road network per thousand total population	km/1000 persons	0.246	0.246	0.637	0.338	0.000	1.468
Road network per thousand rural population	km/1000 persons	0.307	0.307	0.794	0.422	0.000	1.830
Road network per thousand vehicles	km/1000 vehicles	26.158	26.109	67.619	35.917	0.000	155.803
Road network per $ million GDP	km/million $	0.666	0.665	1.722	0.915	0.000	3.968
Network Condition							
Percentage of road network in good and fair condition	%	88.0	78.6	55.9	39.7		61.3
Percentage of paved roads in good and fair condition	%	89.3	78.8	50.5	23.8		84.4
Percentage of paved roads with roughness 4 m/km IRI or less	%	89.3	78.8	50.5	23.8		84.4
Paved roads average roughness weighted by km	IRI, m/km	3.67	4.55	5.49	6.81		3.96
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.79	3.26	4.83	7.85		3.80
Percentage of unpaved roads that are all-weather roads	%	77.6	57.1	44.7	26.8		42.5
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	23.3	18.7	40.2	75.3		46.2
Percentage of unpaved roads with 300 AADT or more	%	6.9	1.6	1.1	0.0		1.0
Percentage of paved roads with 300 AADT or less	%	33.8	71.7	54.8	23.8		0.4
Percentage of paved roads with 10,000 AADT or more	%	0.2	0.0	0.0	0.0		0.1
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	1,928	302	356	88	0	2,673
Annual freight carried over road network	million ton-km	5,786	1,058	1,274	325	0	8,442
Annual passengers carried over road network	million pass-km	13,495	1,988	2,311	513	0	18,308
Average network annual average daily traffic	vehicles/day	1,076	169	77	36		250
Network Asset							
Current Road asset value	million $	1,950.5	472.5	431.2	58.8	0.0	2,913.0
Current Road asset value as a share of maximum road asset value	%	92.9	80.5	74.0	63.7		86.6
Current Road asset value as a share of GPD	%	26.5	6.4	5.9	0.8	0.0	39.5

Tanzania 2007 Beta-files for Main Roads excluding Urban Roads

Network Monitoring Indicators

Monitoring Indicator		Trunk	Regional	District	Feeder	Urban	Overall
Network Length							
Road network length	km	9,728.0	19,271.4	0.0	0.0	0.0	28,999.4
Road network length that is paved	km	4,717.6	466.2	0.0	0.0	0.0	5,183.8
Road network length that is unpaved	km	5,010.4	18,805.2	0.0	0.0	0.0	23,815.6
Road network length that is paved	%	48.5	2.4				17.9
Network Density							
Road network per thousand land area	km/1000 sq km	11.042	21.874	0.000	0.000	0.000	32.916
Road network per thousand total population	km/1000 persons	0.270	0.535	0.000	0.000	0.000	0.806
Road network per thousand rural population	km/1000 persons	0.338	0.669	0.000	0.000	0.000	1.007
Road network per thousand vehicles	km/1000 vehicles	16.000	31.696	0.000	0.000	0.000	47.696
Road network per $ million GDP	km/million $	0.911	1.804	0.000	0.000	0.000	2.715
Network Condition							
Percentage of road network in good and fair condition	%	86.3	73.9				78.0
Percentage of paved roads in good and fair condition	%	94.8	82.4				93.7
Percentage of paved roads with roughness 4 m/km IRI or less	%	94.8	82.4				93.7
Paved roads average roughness weighted by km	IRI, m/km	3.43	4.36				3.51
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.13	3.88				3.18
Percentage of unpaved roads that are all-weather roads	%	68.4	61.7				63.1
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	14.1	22.4				20.7
Percentage of unpaved roads with 300 AADT or more	%	17.0	8.4				10.2
Percentage of paved roads with 300 AADT or less	%	12.4	0.1				0.1
Percentage of paved roads with 10,000 AADT or more	%	0.0	3.0				2.5
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	4,513	1,363	0	0	0	5,876
Annual freight carried over road network	million ton-km	15,265	4,592	0	0	0	19,857
Annual passengers carried over road network	million pass-km	35,855	9,177	0	0	0	45,032
Average network annual average daily traffic	vehicles/day	1,271	194				555
Network Asset							
Current Road asset value	million $	1,662.4	801.5	0.0	0.0	0.0	2,463.9
Current Road asset value as a share of maximum road asset value	%	92.9	85.6				90.4
Current Road asset value as a share of GPD	%	15.6	7.5	0.0	0.0	0.0	23.1

Uganda 2007 Beta-files for All Roads

Network Monitoring Indicators

Monitoring Indicator		National Roads	District Roads	mmunity Access Roa	Unclassified	Urban Roads	Overall
Network Length							
Road network length	km	10,820.0	26,751.0	35,000.0	0.0	3,579.0	76,150.0
Road network length that is paved	km	2,677.0	0.0	0.0	0.0	314.0	2,991.0
Road network length that is unpaved	km	8,143.0	26,751.0	35,000.0	0.0	3,265.0	73,159.0
Road network length that is paved	%	24.7	0.0	0.0		8.8	3.9
Network Density							
Road network per thousand land area	km/1000 sq km	54.897	135.725	177.578	0.000	18.159	386.358
Road network per thousand total population	km/1000 persons	0.386	0.955	1.250	0.000	0.128	2.720
Road network per thousand rural population	km/1000 persons	0.483	1.194	1.563	0.000	0.160	3.400
Road network per thousand vehicles	km/1000 vehicles	38.838	96.021	125.630	0.000	12.847	273.336
Road network per $ million GDP	km/million $	1.273	3.146	4.117	0.000	0.421	8.957
Network Condition							
Percentage of road network in good and fair condition	%	82.1	10.5	28.6		53.2	31.0
Percentage of paved roads in good and fair condition	%	88.1				89.2	88.2
Percentage of paved roads with roughness 4 m/km IRI or less	%	26.8				69.1	31.2
Paved roads average roughness weighted by km	IRI, m/km	5.30				4.69	5.23
Paved roads average roughness weighted by vehicle-km	IRI, m/km	5.25				4.68	5.22
Percentage of unpaved roads that are all-weather roads	%	80.1	40.7	0.0		36.4	25.4
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	2.6	70.0	100.0		0.0	73.7
Percentage of unpaved roads with 300 AADT or more	%	29.5	0.0	0.0		28.1	4.5
Percentage of paved roads with 300 AADT or less	%	13.9				9.9	13.5
Percentage of paved roads with 10,000 AADT or more	%	8.2				0.0	7.3
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	4,344	372	64	0	526	5,305
Annual freight carried over road network	million ton-km	18,777	1,223	175	0	2,234	22,409
Annual passengers carried over road network	million pass-km	25,226	2,240	392	0	3,060	30,919
Average network annual average daily traffic	vehicles/day	1,100	38	5		402	191
Network Asset							
Current Road asset value	million $	1,360.2	277.3	26.9	0.0	192.1	1,856.4
Current Road asset value as a share of maximum road asset value	%	86.2	46.7	51.2		87.2	76.0
Current Road asset value as a share of GPD	%	16.0	3.3	0.3	0.0	2.3	21.8

ANNEX 6: NETWORK MONITORING INDICATORS FOR MAIN ROADS ONLY

Ghana 2005 RONET Version 1.0 Calculations for Main Roads only

Network Monitoring Indicators

Monitoring Indicator		Primary	Secondary	Tertiary	Un-Eng.	Urban	Overall
Network Length							
Road network length	km	3,564	7,613	0	0	0	11,177
Road network length that is unpaved	km	1,360	4,456	0	0	0	5,816
Road network length that is paved	km	2,204	3,157	0	0	0	5,361
Road network length that is paved	%	61.8%	41.5%				48.0%
Network Density							
Road network per thousand land area	km/1000 sq km	14.94	31.92				46.86
Road network per thousand total population	km/1000 persons	0.17	0.36				0.52
Road network per thousand rural population	km/1000 persons	0.30	0.63				0.93
Road network per thousand vehicles	km/1000 vehicles	5.45	11.65				17.11
Road network per $ million GDP	km/million $	0.34	0.72				1.06
Paved road network per thousand land area	km/1000 sq km	5.70	18.68				24.38
Paved road network per thousand total population	km/1000 persons	0.06	0.21				0.27
Paved road network per thousand rural population	km/1000 persons	0.11	0.37				0.48
Paved road network per thousand vehicles	km/1000 vehicles	2.08	6.82				8.90
Paved road network per $ million GDP	km/million $	0.13	0.42				0.55
Network Condition							
Percentage of road network in good and fair condition	%	82.0%	70.0%				73.8%
Percentage of paved road network in good and fair condition	%	95.2%	95.3%				95.3%
Percentage of paved road network with roughness 4 m/km IRI or less	%	54.9%	71.4%				64.6%
Paved roads average roughness weighted by km	IRI, m/km	4.37	4.54				4.47
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.86	4.33				3.94
Percentage of unpaved roads that are all-weather roads	%	60.4%	52.0%				54.0%
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	5.0%	10.0%				8.8%
Percentage of unpaved roads with 300 AADT or more	%	10.0%	0.0%				2.3%
Percentage of paved roads with 300 AADT or less	%	11.0%	42.4%				29.5%
Percentage of paved roads with 10,000 AADT or more	%	10.4%	0.0%				4.3%
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	3,889	974				4,863
Annual freight carried over road network	million ton-km	10,302	2,549				12,851
Annual passengers carried over road network	million pass-km	17,227	3,848				21,074
Average network annual average daily traffic	vehicles/day	2,990	350				1,192
Network Asset							
Current Road asset value	million $	604.0	780.7				1,384.7
Current Road asset value as a share of maximum road asset value	%	90.8%	89.8%				90.2%
Current Road asset value as a share of GPD	%	5.7%	7.4%				13.1%

Mozambique 2006 RONET Version 1.0 Calculations for Main Roads only

Network Monitoring Indicators

Monitoring Indicator		Primary	Secondary	Tertiary	Vicinal	Urban	Overall
Network Length							
Road network length	km	4,909	4,900	0	0	0	9,808
Road network length that is unpaved	km	549	4,020	0	0	0	4,569
Road network length that is paved	km	4,360	880	0	0	0	5,239
Road network length that is paved	%	88.8%	18.0%				53.4%
Network Density							
Road network per thousand land area	km/1000 sq km	6.28	6.27				12.56
Road network per thousand total population	km/1000 persons	0.25	0.25				0.49
Road network per thousand rural population	km/1000 persons	0.31	0.31				0.61
Road network per thousand vehicles	km/1000 vehicles	26.16	26.11				52.27
Road network per $ million GDP	km/million $	0.67	0.66				1.33
Paved road network per thousand land area	km/1000 sq km	0.70	5.15				5.85
Paved road network per thousand total population	km/1000 persons	0.03	0.20				0.23
Paved road network per thousand rural population	km/1000 persons	0.03	0.25				0.29
Paved road network per thousand vehicles	km/1000 vehicles	2.93	21.42				24.35
Paved road network per $ million GDP	km/million $	0.07	0.55				0.62
Network Condition							
Percentage of road network in good and fair condition	%	88.0%	78.6%				83.3%
Percentage of paved road network in good and fair condition	%	89.3%	78.8%				87.5%
Percentage of paved road network with roughness 4 m/km IRI or less	%	59.3%	22.6%				53.1%
Paved roads average roughness weighted by km	IRI, m/km	4.73	5.83				4.91
Paved roads average roughness weighted by vehicle-km	IRI, m/km	4.65	4.40				4.63
Percentage of unpaved roads that are all-weather roads	%	77.6%	57.1%				59.5%
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	23.3%	18.7%				19.2%
Percentage of unpaved roads with 300 AADT or more	%	6.9%	1.6%				2.2%
Percentage of paved roads with 300 AADT or less	%	33.8%	71.7%				40.2%
Percentage of paved roads with 10,000 AADT or more	%	0.2%	0.0%				0.2%
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	1,928	302				2,229
Annual freight carried over road network	million ton-km	5,786	1,058				6,844
Annual passengers carried over road network	million pass-km	13,495	1,988				15,484
Average network annual average daily traffic	vehicles/day	1,076	169				623
Network Asset							
Current Road asset value	million $	1,950.5	472.5				2,423.0
Current Road asset value as a share of maximum road asset value	%	92.9%	80.5%				90.2%
Current Road asset value as a share of GPD	%	26.5%	6.4%				32.9%

Tanzania 2007 RONET Version 1.0 Calculations for Main Roads only

Network Monitoring Indicators

Monitoring Indicator		Trunk	Regional	District	Feeder	Urban	Overall
Network Length							
Road network length	km	9,728	19,271	0	0	0	28,999
Road network length that is unpaved	km	5,010	18,805	0	0	0	23,816
Road network length that is paved	km	4,718	466	0	0	0	5,184
Road network length that is paved	%	48.5%	2.4%				17.9%
Network Density							
Road network per thousand land area	km/1000 sq km	11.04	21.87				32.92
Road network per thousand total population	km/1000 persons	0.27	0.54				0.81
Road network per thousand rural population	km/1000 persons	0.34	0.67				1.01
Road network per thousand vehicles	km/1000 vehicles	16.00	31.70				47.70
Road network per $ million GDP	km/million $	0.91	1.80				2.72
Paved road network per thousand land area	km/1000 sq km	5.69	21.35				27.03
Paved road network per thousand total population	km/1000 persons	0.14	0.52				0.66
Paved road network per thousand rural population	km/1000 persons	0.17	0.65				0.83
Paved road network per thousand vehicles	km/1000 vehicles	8.24	30.93				39.17
Paved road network per $ million GDP	km/million $	0.47	1.76				2.23
Network Condition							
Percentage of road network in good and fair condition	%	86.3%	73.9%				78.0%
Percentage of paved road network in good and fair condition	%	94.8%	82.4%				93.7%
Percentage of paved road network with roughness 4 m/km IRI or less	%	60.7%	33.7%				58.3%
Paved roads average roughness weighted by km	IRI, m/km	4.19	5.48				4.30
Paved roads average roughness weighted by vehicle-km	IRI, m/km	3.60	4.85				3.67
Percentage of unpaved roads that are all-weather roads	%	68.4%	61.7%				63.1%
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	14.1%	22.4%				20.7%
Percentage of unpaved roads with 300 AADT or more	%	17.0%	8.4%				10.2%
Percentage of paved roads with 300 AADT or less	%	12.4%	11.4%				12.3%
Percentage of paved roads with 10,000 AADT or more	%	2.5%	3.0%				2.5%
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	4,513	1,363				5,876
Annual freight carried over road network	million ton-km	15,265	4,592				19,857
Annual passengers carried over road network	million pass-km	35,855	9,177				45,032
Average network annual average daily traffic	vehicles/day	1,271	194				555
Network Asset							
Current Road asset value	million $	1,662.4	801.5				2,463.9
Current Road asset value as a share of maximum road asset value	%	92.9%	85.6%				90.4%
Current Road asset value as a share of GPD	%	15.6%	7.5%				23.1%

Uganda 2007 RONET Version 1.0 Calculations for Main Roads only

Network Monitoring Indicators

Monitoring Indicator		National Roads	District Roads	mmunity Access Ro	Unclassified	Urban Roads	Overall
Network Length							
Road network length	km	10,820	0	0	0	0	10,820
Road network length that is unpaved	km	8,143	0	0	0	0	8,143
Road network length that is paved	km	2,677	0	0	0	0	2,677
Road network length that is paved	%	24.7%					24.7%
Network Density							
Road network per thousand land area	km/1000 sq km	54.90					54.90
Road network per thousand total population	km/1000 persons	0.39					0.39
Road network per thousand rural population	km/1000 persons	0.48					0.48
Road network per thousand vehicles	km/1000 vehicles	38.84					38.84
Road network per $ million GDP	km/million $	1.27					1.27
Paved road network per thousand land area	km/1000 sq km	41.31					41.31
Paved road network per thousand total population	km/1000 persons	0.29					0.29
Paved road network per thousand rural population	km/1000 persons	0.36					0.36
Paved road network per thousand vehicles	km/1000 vehicles	29.23					29.23
Paved road network per $ million GDP	km/million $	0.96					0.96
Network Condition							
Percentage of road network in good and fair condition	%	82.1%					82.1%
Percentage of paved road network in good and fair condition	%	88.1%					88.1%
Percentage of paved road network with roughness 4 m/km IRI or less	%	24.7%					24.7%
Paved roads average roughness weighted by km	IRI, m/km	5.73					5.73
Paved roads average roughness weighted by vehicle-km	IRI, m/km	5.67					5.67
Percentage of unpaved roads that are all-weather roads	%	80.1%					80.1%
Network Standards							
Percentage of unpaved roads with 30 AADT or less	%	2.6%					2.6%
Percentage of unpaved roads with 300 AADT or more	%	29.5%					29.5%
Percentage of paved roads with 300 AADT or less	%	13.9%					13.9%
Percentage of paved roads with 10,000 AADT or more	%	8.2%					8.2%
Network Utilization							
Annual motorized vehicle utilization	million vehicle-km	4,344					4,344
Annual freight carried over road network	million ton-km	18,777					18,777
Annual passengers carried over road network	million pass-km	25,226					25,226
Average network annual average daily traffic	vehicles/day	1,100					1,100
Network Asset							
Current Road asset value	million $	1,360.2					1,360.2
Current Road asset value as a share of maximum road asset value	%	86.2%					86.2%
Current Road asset value as a share of GPD	%	16.0%					16.0%